Ann Arbor, MI USA

# NAPC 2024

## 12th NORTH AMERICAN PALEONTOLOGICAL CONVENTION

University of Michigan 17–21 June 2024

PROGRAM with ABSTRACTS

# 12TH NORTH AMERICAN PALEONTOLOGICAL CONVENTION
# UNIVERSITY OF MICHIGAN 17-21 JUNE 2024

## PROGRAM WITH ABSTRACTS

PROOF

PAPERS ON PALEONTOLOGY — RECENT NUMBERS

29. Evolution of Paleocene and Eocene Phenacodontidae (Mammalia, Condylarthra) *by J. G. M. Thewissen* (1990)

30. Marine Mammals (Cetacea and Sirenia) from the Eocene of Gebel Mokattam and Fayum, Egypt: Stratigraphy, Age, and Paleoenvironments *by Philip D. Gingerich* (1992)

31. Terrestrial Mesonychia to Aquatic Cetacea: Transformation of the Basicranium and Evolution of Hearing in Whales *by Zhexi Luo and Philip D. Gingerich* (1999)

32. Fishes of the Mio-Pliocene Ringold Formation, Washington: Pliocene Capture of the Snake River by the Columbia River *by Gerald R. Smith, Neil Morgan, and Eric Gustafson* (2000)

33. Paleocene-Eocene Stratigraphy and Biotic Change in the Bighorn and Clarks Fork Basins, Wyoming *by Philip D. Gingerich (ed.) and others* (2001)

34. Form, Function, and Anatomy of *Dorudon atrox* (Mammalia, Cetacea): An Archaeocete from the Middle to Late Eocene of Egypt *by Mark D. Uhen* (2003)

35. The Tiffanian Land-Mammal Age (Middle and Late Paleocene) in the Northern Bighorn Basin, Wyoming *by Ross Secord* (2008)

36. Earliest Eocene Mammalian Fauna from the Paleocene-Eocene Thermal Maximum at Sand Creek Divide, Southern Bighorn Basin, Wyoming *by Kenneth D. Rose, Amy E. Chew, Rachel H. Dunn, Mary J. Kraus, Henry C. Fricke, and Shawn P. Zack* (2012)

37. Late Eocene Sea Cows (Mammalia, Sirenia) from Wadi Al Hitan in the Western Desert of Fayum, Egypt *by Iyad S. Zalmout and Philip D. Gingerich* (2012)

38. Skeleton of Late Paleocene *Plesiadapis cookei* (Mammalia, Euarchonta): Life History, Locomotion, and Phylogenetic Relationships *by Doug M. Boyer and Philip D. Gingerich* (2019)

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Museum of Paleontology
The University of Michigan
Ann Arbor, Michigan 48109-1085

12TH NORTH AMERICAN PALEONTOLOGICAL CONVENTION
UNIVERSITY OF MICHIGAN 17-21 JUNE 2024

PROGRAM WITH ABSTRACTS

PROOF

**12th NORTH AMERICAN PALEONTOLOGICAL CONVENTION**

**University of Michigan 17–21 June 2024**

Frontispiece: Designed by Carol Abraczinskas, Scientific/Biological Illustrator at the University of Michigan Museum of Paleontology (UMMP), the NAPC 2024 logo incorporates iconic fossils from Michigan and the Great Lakes region. From left to right, these are:

Skull of the American mastodon *Mammut americanum*. The state fossil of Michigan, mastodons roamed the Great Lakes region until around 10,000 years ago. UMMP houses significant collections of Pleistocene proboscideans that provide clues about how individual animals lived and died, as well as why these species may have gone extinct.

The Devonian tabulate coral *Hexagonaria percarinatum*. It is shown here as a polished example, known colloquially as a "Petoskey stone": Michigan's state gemstone. It is frequently found on northern Michigan beaches, from the Leelanau Peninsula to Harbor Springs, where naturally worn examples show the six-sided, star-shaped pattern of adjacent corallites.

Leaves of the Carboniferous seed fern *Neuropteris schlehani*. A representative of tropical coal-forming peat swamps of North America, fossils of *Neuropteris* can be found near Grand Ledge, Michigan. You might even find an example on an optional NAPC 2024 field trip to this site, which is celebrated for its diversity of plant fossils.

Armor of the giant Devonian placoderm fish *Dunkleosteus terrelli*. The most famous examples of this marine apex predator from the "Age of Fishes" come from rocks in northeastern Ohio, not far from the shores of Lake Erie. Strata of similar age in northern Michigan also yield fossils of *Dunkleosteus*, complementing the diversity of placoderms known from older rocks in the state.

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# 12TH NORTH AMERICAN PALEONTOLOGICAL CONVENTION
# UNIVERSITY OF MICHIGAN 17-21 JUNE 2024

# PROGRAM WITH ABSTRACTS

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**Edited by**

**Jeffrey A. Mantilla Wilson and Matt Friedman**

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UNIVERSITY OF MICHIGAN
PAPERS ON PALEONTOLOGY NO. 39

**2024**

Papers on Paleontology No. 39

Museum of Paleontology
The University of Michigan
Ann Arbor, Michigan 48109-1085

Matt Friedman, Director

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# TABLE OF CONTENTS

Frontispiece ..... ii

Title Page ..... iii

Table of Contents ..... v

**I. North American Paleontological Conventions** ..... 1

**II. Conference Organization** ..... 2

- Organizing committee ..... 2
- Symposia and Coveners ..... 2
- Field Trips and Leaders ..... 4
- Workshops/Embedded Meetings and Organizers ..... 4
- Logistical Support ..... 5
- Sponsors ..... 5

**III. City and Venue Maps** ..... 6

**IV. Welcome to Ann Arbor** ..... 20

**V. Presentation and Social Media Policies** ..... 22

**VI. Code of Conduct and Reporting** ..... 23

- Expected Behaviors ..... 23
- Prohibited Behaviors ..... 23
- Reporting Misconduct: PS RISE at NAPC ..... 23

**VII. Schedule of Events** ..... 25

**VIII. Talk Schedule** ..... 28

**IX. List of Presenters and Titles in Chronological Session Order** ..... 36

**X. Abstracts** ..... 97

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# I

## NORTH AMERICAN PALEONTOLOGICAL CONVENTIONS

1969: Field Museum, Chicago, Illinois
1977: University of Kansas, Lawrence, Kansas
1982: McGill University, Montréal, Québec
1988: University of Colorado, Boulder, Colorado
1992: Field Museum, Chicago, Illinois
1996: Smithsonian Institution, Washington, D.C.
2001: University of California, Berkeley, California
2005: Dalhousie University, Halifax, Nova Scotia
2009: University of Cincinnati, Cincinnati, Ohio
2014: The Florida Museum of Natural History, Gainesville, Florida
2019: University of California, Riverside, California
**2024: University of Michigan, Ann Arbor, Michigan**

## II

# CONFERENCE ORGANIZATION

## ORGANIZING COMMITTEE

Matt Friedman (lead organizer), Catherine Badgley (paleoart chair), Mónica Carvalho (early career chair), David Clark (avocational chair) Laura MacLatchy (workshop chair), Madeline Marshall (social media chair), Hadeel Saad (student chair), Selena Smith (DEI chair), Luke Weaver (field trip chair), Jeff Wilson Mantilla (program chair)

## SYMPOSIA AND CONVENERS

*A Gulf of Knowledge: Interconnecting Paleobiology Research Across the Caribbean* — Lazaro W. Viñola López, Andrew K. Hensley, Brooke Crowley, Siobhán B. Cooke

*A Model System for Evolution and Environmental Change: the Marine Communities of the Neogene Western Atlantic* — Brendan Anderson, Jonathan Hendricks, Bruce Lieberman, Rowan Lockwood, Warren Allmon, Harry Dowsett, Erin Saupe, Luke Strotz

*Answering Big Questions with Small Fossils: High-Resolution Biodiversity Dynamics in Deep Time* — Anieke Brombacher, Huai-Hsuan Huang

*Avocational Clubs as Paleontological Resources* — David Clark, Jennifer Bauer

*Broadening Accessibility in Paleontology through Innovative Community Engagement Practices* — Jeanette Pirlo, Pedro Monarrez, Carmi Thompson

*Conodonts in Time and Space – North American Pander Society Meeting* — D. Jeffrey Over, Nicholas Hogencamp, Steven Rosscoe

*Dawn of Animal Life: Exploring New Advances in Ediacaran Paleobiology* — Philip C. Boan, Prescott Vayda, Princess Aira Buma-at

*Deep Learning in Deep Time: Applications of AI and Automation in Paleontology* — Allison Y. Hsiang, Daniela Schmidt, Anieke Brombacher, Congyu Yu

*Evolutionary Paleobiology: in Honor of Jim Valentine* — Charles Marshall, Seth Finnegan

*Fifty Years in the Himalayan Foothills: Ecosystem Change in the Neogene Siwalik Record of Pakistan* — Catherine Badgley, Michele E. Morgan, Kay Behrensmeyer

*First Principles, Boundless Curiosity - Celebrating the Contributions of Daniel C. Fisher* — Sandy Carlson, Paul Koch

*Fossil Forces: Advances in Biomechanics and Imaging in Paleontology* — Alec Wilken, Casey Holliday

*From Caves to Cenotes: Pleistocene Vertebrate Paleontology of the Yucatán, México, and Belize* — Blaine Schubert, Joaquin Arroyo-Cabrales

*Hominoid Evolution, Environments, and Communities in Eastern Africa* — Susanne Cote, Laura MacLatchy

*Integrated Approaches to Exploring Coupled Biotic, Landscape, and Climate Dynamics* — Tara Smiley, Rebecca Terry, David Fox, Katharine Loughney

*Interconnected Patterns of Natural History: a Tribute to the Career and Contributions of Lance Grande* — Eric Hilton, Matt Friedman

*Lessons Learned and Future Visions for Conservation Paleobiology* — Jonathan Cybulski, Erin Dillon, Broc Kokesh, Lynn Wingard

*Lessons Learned from Phanerozoic Marine Extinctions Applied to Modern Conservation* — Sinjini Sinha, Travis Stone, Claire Williams, Rowan Martindale

*Managing and Engaging with Federal Paleontological Resources in the 21st Century* — Adam Rountrey, Brent Breithaupt, Vincent L. Santucci

*Microbial Biosignatures: from Paleomicrobiology to Astrobiology* — Sarah González Henao, Matthew Schrenk, Jena Johnson

*North American Paleontological Resources 2024* — Danita Brandt

*Paleobiology of Carnivorous Mammals* — John D. Orcutt, Mairin Balisi

*Paleoneurology* — Rodrigo Figueroa, Matteo Fabbri

*Plant-Insect Herbivore Relationships in Deep Time* — L. Alejandro Giraldo

*Progress in Proboscidean Paleontology* — Advait Jukar, William Sanders

*Proxies, Sedimentological Indicators, and Biotic Effects of Oceanic Anoxic Events in the Geological Record* — Brian Huber, Joan M. Bernhard

*Recent Advances in Computational Paleobiology* — William Gearty, Bethany J. Allen, Lewis A. Jones, Erin M. Dillon

*Recent Advances in Virtual Paleobiology* — Russell D. C. Bicknell, Joseph Bevitt

*Reef Paleoecology in Time and Space* — Aaron O'Dea, Rowan Martindale, Katie Cramer

*Stratigraphic Paleobiology: Working with the Nature of the Stratigraphic Record to Answer Paleobiological Questions* — Pedro Monarrez, Annaka Clement, Katharine Loughney

*Systematics and Phylogeny* — Brooke Long-Fox

*The Bighorn Basin: New Frontiers and Inter-Generational Knowledge of a Model System for Studying Terrestrial Ecosystem Evolution* — Luke Weaver, Scott Wing, Vera Korasidis, Ellen Currano

*Traits, Functions, and Systems: Quantifying Paleocommunity Variation, Persistence, and Resilience* — Ashley Dineen, Peter Roopnarine

*Wetland Ecology Through Time* — Sam Neely, Michelle Chrpa

## FIELD TRIPS AND LEADERS

*Behind the Scenes at the University of Michigan's Research Museums Center* — Jennifer Bauer, Adam Rountrey, William Sanders, Andrea Blaser, Aly Baumgartner, Cody Thompson, Randal Singer

*Carboniferous (Mississippian) Fossils of Michigan: the Marshall Formation at the Blue Ridge Esker* — Mike Palescuk, Rodrigo Figueroa

*Carboniferous (Pennsylvanian) Marginal-Marine Fossils and Strata at Grand Ledge, Michigan: Stratigraphical, Educational, and Cultural Significance* — Danita Brandt, Michael Velbel, Peter Voice

*Climatic Change and Cyclic Extinction in Silurian Reefs of the Central United States* — Don Mikulic

*Diving into the Age of Fishes: the Cleveland Shale and the Cleveland Museum of Natural History* — Caitlin Colleary, Robert Carr

*Middle Devonian Marine Fossils of the Michigan Basin: the Silica Formation* — Steve LoDuca, David Thompson

*The Carboniferous Mazon Creek Fossil Site: Collecting at "Worm Hill" and Viewing Non-Worms at the Field Museum* — Victoria McCoy

*The Classic Cincinnatian (Upper Ordovician, Katian) of the Cincinnati Vicinity: Paleoenvironments and Ecology of a Sea without Fish* — Carl Brett, Ian Forsythe, Brenda Hunda

## WORKSHOPS/EMBEDDED MEETINGS AND ORGANIZERS

*An Introduction to Claddis: an R Package for Analyzing Morphological Diversity and Tempo Using (Primarily) Discrete Characters* — Graeme Lloyd

*Analytical Approaches to Networks, Trophic Structure, and Ancient Food Webs* — Carrie Tyler, Peter Roopnarine, Ashley Dineen, Roxanne Banker, Madeline Ess

*Building Custom Ecosystem Models with Biogeochemical Cycles in PALEOtoolkit* — Stuart Daines, Sara Sjosten

*Careers in Science Communications Panel with PBS Eons* — Gabriel Santos

*Creating LGBTQ-mmunities in Paleoscience* — Oliver McLellan, Megan O'Quin, Jill Leonard-Pingel

*Innovative Tools for Research Management in Academia* — Deborah Coyle, Amanda Godbold

*Managing Morphological Character Matrices using MorphoBank* — Brooke Long-Fox

*National Science Foundation Town Hall* — Margaret Frasier

*Open-Source Software for 3D Data* — Anne Kort

*R for Paleobiologists: Getting Started with the Palaeoverse R Package* — Lewis A. Jones, Bethany Allen, William Gearty, Erin Dillon, Christopher Dean

*Save Time, Work Smarter with Zotero* — Nicholas Gardner

*Virtual Paleontology: Hands-On Training with Materialise Mimics* — Sophia Judge, Bradley Tumas

*Vision for a Midwestern Paleontology Center: Exploring Priorities in Research, Participation, and Partnerships* — Tara Selly, James Schiffbauer, Sarah Jacquet, Lydia Tackett, Casey Holliday, Carol Ward

## LOGISTICAL SUPPORT

*Meeting Website and Volume Formatting* — Lindsay Dorosh

*Administrative Support* — Cindy Stauch, Courtney Hooper

*Conference Logo, Maps, and Graphics* — Carol Abraczinskas

*University of Michigan Conference and Event Services* — Mike Hill, Jasmine Pasley, Michael Sydlowski

*On-Site Support, Field Trip Drivers, and Abstract Volume Copy Editing* — Tariq Abdul Kareem, James Andrews, Ava Berger, Jacob Berv, Adriana Brown, Brielle Canares, Kaori Chambers, Michael Cherney, Wyatt Cunningham, Lindsey DeHaan, Rodrigo Figueroa, Daniel Fisher, Fabian Hardy, Cecilia Howard, Sanaa El-Sayed, Matheus Januario, Anne Kort, Theodore Matel, Jeronimo Morales Toledo, Georgia Oppenheim, Rafael Rivero-Vega, Emma Rieb, William Sanders, Ethan Shirley, Donald Swiderski, Miriam Zelditch

## SPONSORS AND IN-KIND SUPPORT

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Botanical Society of America
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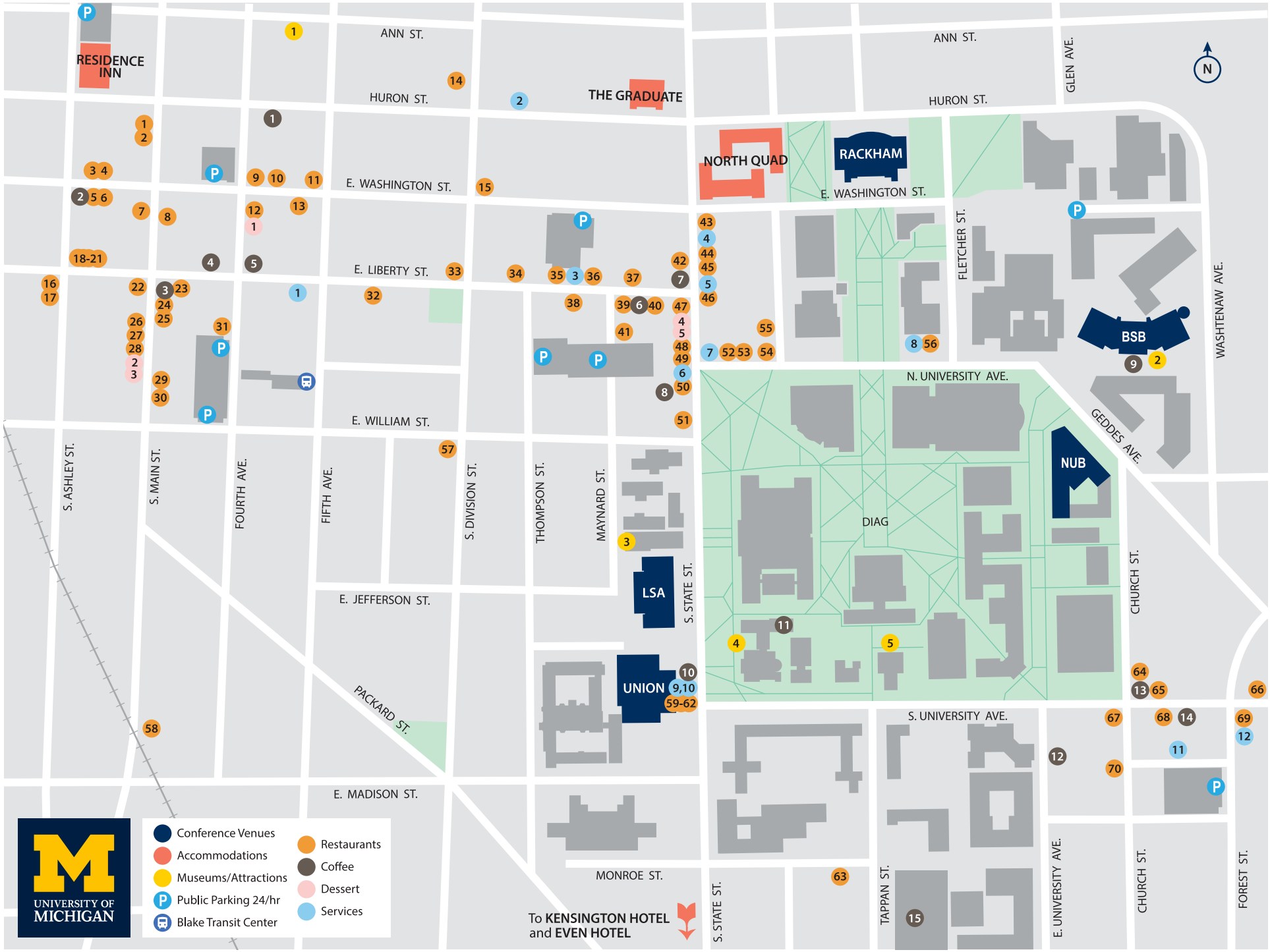
Triebold Paleontology
Taylor & Francis
Treatise on Invertebrate Paleontology
Materialise
PeerJ
CRC Press
Paleontological Research Institution
Black in Natural History Museums
Cincinnati Museum Center
Cleveland Museum of Natural History
Field Museum

# III

# CITY AND VENUE MAPS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ANN ST.
HURON ST.
THE GRADUATE
NORTH QUAD
RACKHAM
E. WASHINGTON ST.
E. LIBERTY ST.
E. WILLIAM ST.
E. JEFFERSON ST.
E. MADISON ST.
PACKARD ST.
MONROE ST.
S. ASHLEY ST.
S. MAIN ST.
FOURTH AVE.
FIFTH AVE.
S. DIVISION ST.
THOMPSON ST.
MAYNARD ST.
S. STATE ST.
LSA
UNION
FLETCHER ST.
N. UNIVERSITY AVE.
DIAG
NUB
BSB
GEDDES AVE.
WASHTENAW AVE.
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CHURCH ST.
S. UNIVERSITY AVE.
TAPPAN ST.
E. UNIVERSITY AVE.
FOREST ST.
N
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*An Ann Arbor Institution

## Restaurants

1 **First Bite** - **$$**
108 S Main St, 369-4765
firstbitefoods.com

2 **Vinology** - **$$$**
110 S Main St, 222-9841
vinologya2.com

3 **Grizzly Peak Brewing Company** - **$$**
120 W Washington St, 741-7325
grizzlypeak.net

4 **Café Zola** - **$$$**
112 W Washington St, 769-2020
cafezola.com

5 **The Earle** - **$$$**
121 W Washington St, 994-0211
theearle.com

6 **Frita Batidos Ann Arbor** - **$$**
117 W Washington St, 761-2882
fritabatidos.com

7 **Regents Field** - **$$$**
204 S Main St, 800-4143
regentsfield.com

8 **The Ravens Club** - **$$**
207 S Main St, 214-0400
theravensclub.com

9 **Haymaker Public House** - **$$**
203 E Washington St, 997-5399
haymakerpublichouse.com

10 **Blue Tractor BBQ & Brewery** - **$$**
207 E Washington St, 222-4095
bluetractor.net

11 **Blue Nile Ethiopian** - **$$**
221 E Washington St, 998-4746
bluenilemi.com

12 **Sottini's Sub Shop** - **$**
205 S 4th Ave, 769-7827
sottinisubs.com

13 **Aventura** - **$$$**
216 E Washington St, 369-3153
aventuraannarbor.com

14 **Ahmo's Gyros & Deli** - **$**
341 E Huron St, 662-4445
ahmos.com

15 **Stray Hen Cafe** - **$$**
403 E Washington St, 929-2590
strayhencafe.com

16 **Fleetwood Diner*** - **$**
300 S Ashley St, 995-5502
orderfleetwooddiner.com

17 **Krazy Jim's Blimpy Burger*** - **$**
304 S Ashley St, 663-4590
blimpyburger.com

18 **Old Town Tavern** - **$$**
122 W Liberty St, 662-9291
oldtownaa.com

19 **The West End Grill** - **$$$$**
120 W Liberty St, 747-6260
westendgrillannarbor.com

20 **Peridot** - **$$$**
118 W Liberty St, 773-3097
peridota2.com

21 **Pacific Rim By Kana** - **$$$**
114 W Liberty St, 662-9303
pacificrimbykana.com

22 **Black Pearl** - **$$$**
302 S Main St, 222-0400
blackpearlannarbor.com

23 **TAQ Taqueria Restaurant & Bar** - **$$**
106 E Liberty St, 369-6922
taqannarbor.com

24 **Shalimar Restaurant** - **$$**
307 S Main St, 663-1500
shalimarrestaurant.com

25 **Jolly Pumpkin Café & Brewery** - **$$**
311 S Main St, 913-2730
annarbor.jollypumpkin.com

26 **Of Rice & Men (ORAM)** - **$$$**
312 S. Main St, 222-0202
oriceandmen.com

27 **Conor O'Neill's Irish Pub** - **$$**
318 S Main, 665-2968
conoroneills.com

28 **The Chop House** - **$$$$**
322 S Main, 669-8826
thechophouserestaurant.com

29 **Real Seafood Company** - **$$$**
341 S Main St, 769-7738
realseafoodcorestaurant.com

30 **Palio** - **$$**
347 S Main St, 930-6156
paliorestaurant.com

31 **Ruth's Chris Steak House** - **$$$$**
314 S 4th Ave, 585-5155
ruthschris.com

32 **Jerusalem Garden** - **$$**
314 E Liberty St, 995-5060
jerusalemgarden.net

33 **Mani Osteria and Bar** - **$$**
341 E Liberty St, 769-6700
maniosteria.com

34 **Tios Mexican Cafe and Tequila Bar** - **$$**
401 E Liberty St, 761-6650
tiosmexicancafe.com

35 **Tomukun Noodle Bar/Korean BBQ** - **$$**
505 E Liberty St Ste 200, 995-8668
noodlebar.tomukun.com

36 **Taste Kitchen** - **$$$$**
521 E Liberty St, 369-4241
tastekitchena2.com

37 **Tropical Smoothie Café** - **$**
607 Liberty St, 585-0266
tropicalsmoothiecafe.com

38 **TK WU** - **$$**
510 E Liberty St, 747-6662
tkwurestaurant.com

39 **Knight's Steakhouse** - **$$$**
600 E Liberty St, 887-6899
knightsrestaurants.com

40 **Slurping Turtle** - **$$**
608 E Liberty St, 887-6868
slurpingturtle.com

41 **Hopcat** - **$$**
311 Maynard St, 436-2875
hopcat.com

42 **Sava's** - **$$**
216 S State St, 623-2233
savasannarbor.com

43 **Buffalo Wild Wings** - **$$**
205 S State St, 997-9143
buffalowildwings.com

44 **Totoro** - **$$**
215 S State #2031, 302-3511
totoroannarbor.com

45 **Taste of India Suvai** - **$$**
217 S State St, 327-6500
tasteofindiasuvai.com

46 **Chipotle Mexican Grill** - **$**
235 S State St, 794-0800
locations.chipotle.com

47 **Potbelly** - **$**
300 S State, 205-7000
potbelly.com

48 **Amer's Delicatessen** - **$$**
314 S State, 761-6000
amersdeli.com

49 **Red Hawk Bar & Grill** - **$$**
316 S State St, 994-4004
redhawkannarbor.com

50 **Noodles and Company** - **$**
320 S State, 327-9041
noodles.com

51 **Ashley's** - **$$**
338 S State St, 996-9191
ashleys.com

52 **Bruegger's Bagels** - **$**
709 N University Ave, 747-8561
brueggers.com

53 **Mama Satto** - **$$**
715 N University Ave, 213-3044

54 **Panera Bread** - **$$**
777 N University, 332-3402
panerabread.com

55 **Jamaican Jerk Pit** - **$$** (take-out only)
314 S Thayer St, 585-5278
jamaicanjerkpit.com

56 **Maizie's Kitchen & Market** - **$**
Michigan League, 911 N University Ave, 936-2224

57 **Namaste Flavours Arbor** - **$$**
400 S Division St, 995-1545
namasteflavoursannarbor.com

58 **Union Rec** - **$$**
545 S Main St, 636-9999
unionrec.com

59 **Mama DeLuca's** - **$**
Michigan Union, 530 S State

60 **Qdoba Mexican Eats** - **$**
Michigan Union, 530 S State, 356-8484
locations.qdoba.com

61 **Panda Express** - **$**
Michigan Union, 530 S State St
pandaexpress.com

62, 66 **Subway** - **$**
Michigan Union, 530 S State St, 994-5900
1315 S University Ave, 761-4160
subway.com

63 **Casa Dominick's*** - **$$**
812 Monroe, 662-5414
casa-dominicks.business.site

64 **Joe's Pizza NYC** - **$**
1107 S University Ave, 619-0032
joespizzanyc.com

65 **Jimmy John's** - **$**
1207 S University Ave, 827-2600
jimmyjohns.com

67 **Good Time Charley's** - **$$**
1140 S University Ave, 668-8411
charleysannarbor.com

68 **Pancheros Mexican Grill** - **$**
1208 S University Ave, 996-9580
pancheros.com

69 **No Thai!** - **$**
1300 S University Ave, 222-8080
nothai.com

70 **Pizza House** - **$$**
618 Church St, 995-5095
pizzahouse.com

## Coffee

1 **Cahoots Cafe** - **$**
206 E Huron St Suite 2, 249-8898
cahootscafe.com

2, 6, 10 **Sweetwaters Coffee & Tea** - **$**
123 W Washington St, 769-2331
604 E Liberty St, 929-2398
Michigan Union 530 S State St, 548-8088
sweetwaterscafe.com

3 **Bitty & Beau's Coffee** - **$**
305 S Main St, 773-3336
bittyandbeauscoffee.com

4 **RoosRoast Liberty** - **$**
117 E Liberty St, 369-2494
roosroast.com

5 **Dunkin'** - **$**
201 E Liberty St
dunkindonuts.com

7, 14, 15 **Starbucks** - **$$**
222 S State St, 623-8067
1214 S University Ave, 994-5437
701 Tappan Ave, 763-8555
starbucks.com

8 **Comet Coffee** - **$$**
16 Nickels Arcade, 222-0579

9 **Darwin's** - **$**
Biological Science Building
1105 N University Ave, 763-1050

11 **UMMA Café** - **$$**
525 S State St, 647-2257
umma.umich.edu/ummacafe

12 **Misfit Society Coffee Club** - **$**
615 E University Ave, 263-2228
misfitsocietycoffee.com

13 **M-36 Coffee Roasters Cafe** - **$**
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## Dessert

1 **Le Bon Macaron** - **$$**
209 S 4th Ave, 997-5501
lebonmacaron.com

2 **La Dolce Vita** - **$$**
322 S Main St, (888) 456-3463
thechophouserestaurant.com/la-dolce-vita/

3 **Milk & Froth Ice Cream** - **$**
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milkandfroth.com

4 **Michigan Creamery** - **$**
302 S State St, 662-1700
michigancreamery.com

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benjerry.com

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11 1214 S University Ste S104, (800) 275-8777
tools.usps.com

**7-Eleven**
2 413 E Huron St, 210-0266
6 318 S State St, 913-2076
12 1300 S University Ave, 997-7008
7-eleven.com

3 **FedEx Office Print & Ship**
505 E Liberty St, 761-4539

4 **CVS**
209 S State St, 769-1804
cvs.com

5 **Target/Target Grocery**
231 S State St, 205-1869
target.com

7 **Walgreens**
317 S State, 352-3623
walgreens.com

**UM Credit Union ATM/PCN ATM**
8 Michigan League Ground Floor,
911 N University Ave, 936-0869
9 Michigan Union Ground Floor,
530 S State St

10 **Blue Market**
Michigan Union Ground Floor,
530 S State St

## Museums/Attractions

1 **Ann Arbor Hands-On Museum and Leslie Science & Nature Center**
220 E Ann St, 995-5439
discoverscienceandnature.org

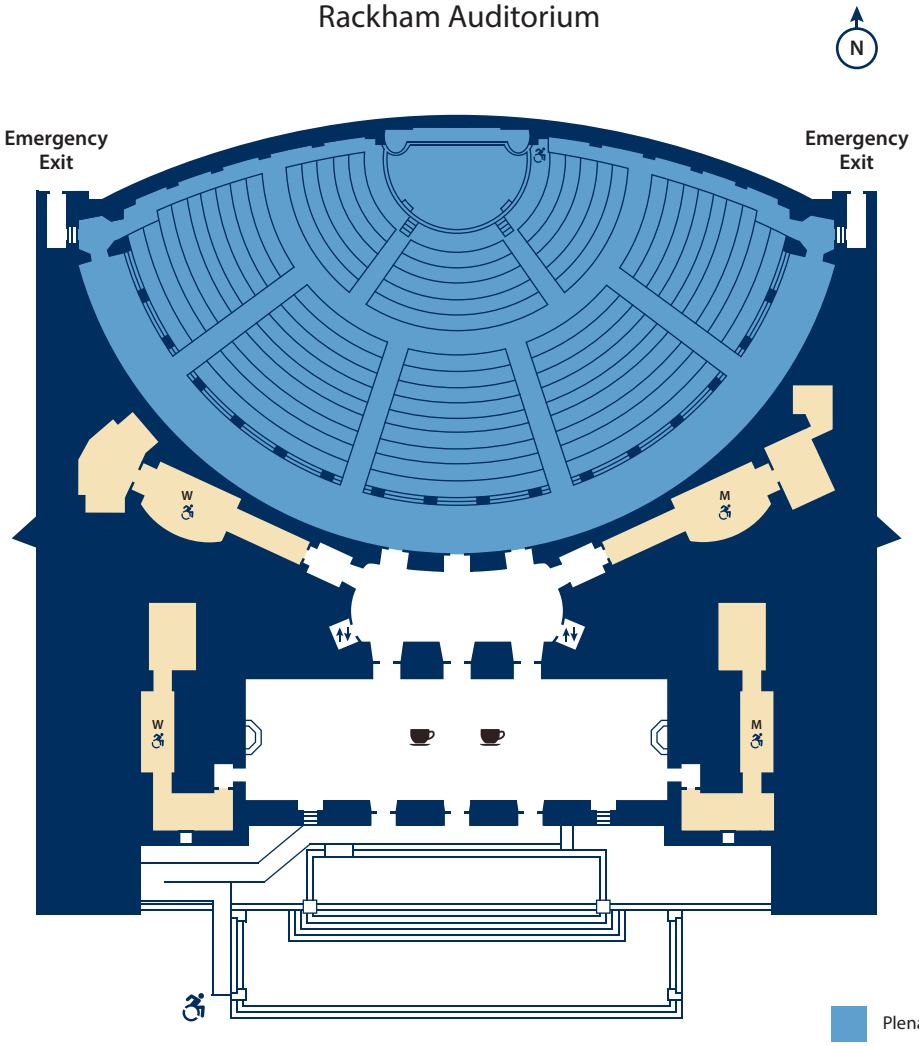
2 **University of Michigan Museum of Natural History/The Museum Store**
1105 N University Ave, 764-0478
ummnh.org

3 **Kelsey Museum of Archaeology**
434 S State St (entrance on Maynard), 764-9304
lsa.umich.edu/Kelsey

4 **University of Michigan Museum of Art**
525 S State St, 764-0395
umma.umich.edu

5 **William L. Clements Library**
909 S University Ave, 764-2347
clements.umich.edu

# Rackham Auditorium




**Main Entrance**
915 E. Washington St.

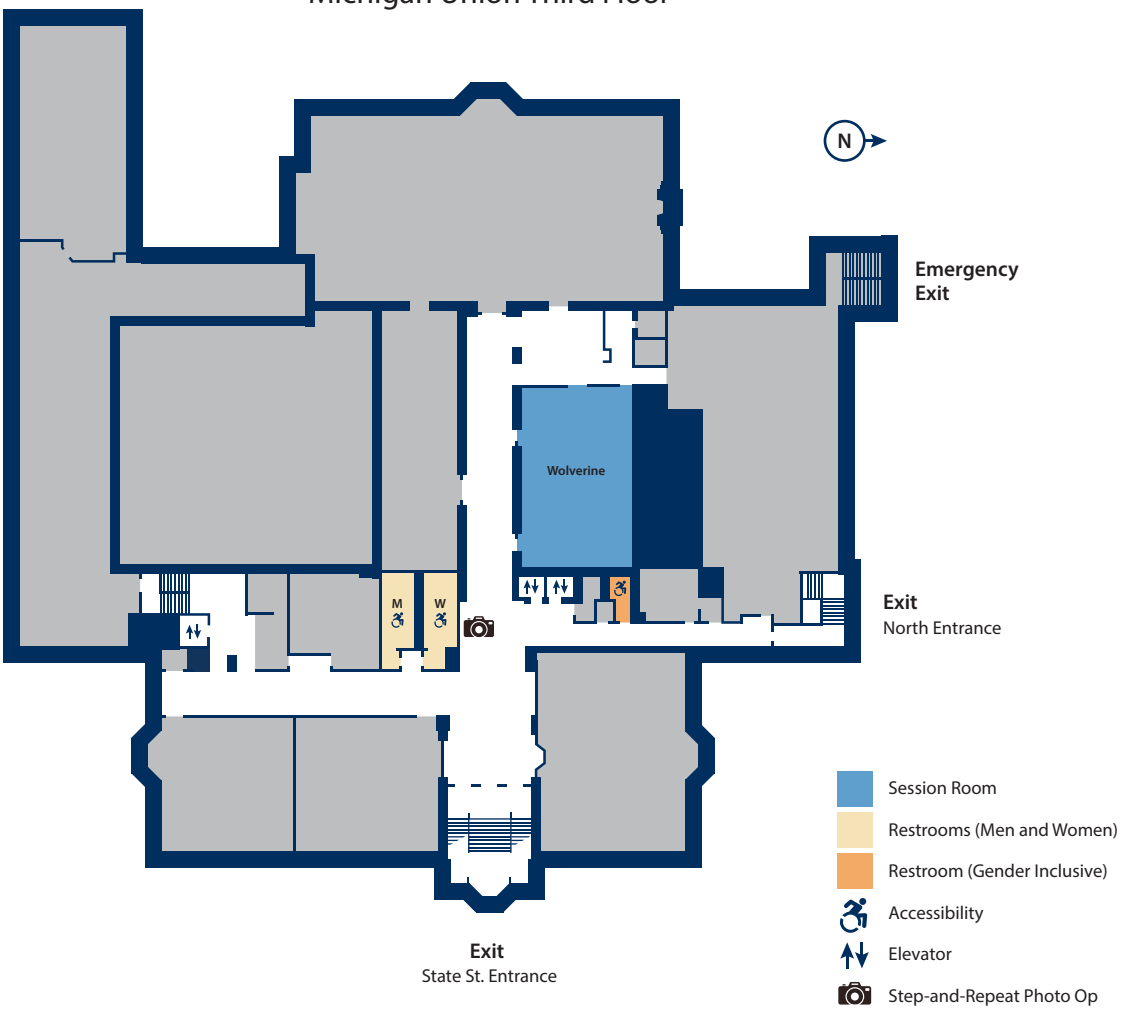
- Plenary Room
- Restrooms (Men and Women)
- Restroom (Gender Inclusive located in the east wing of the building, Floor 3)
- Accessibility
- Elevator
- Coffee/Tea

# Michigan Union Ground Floor

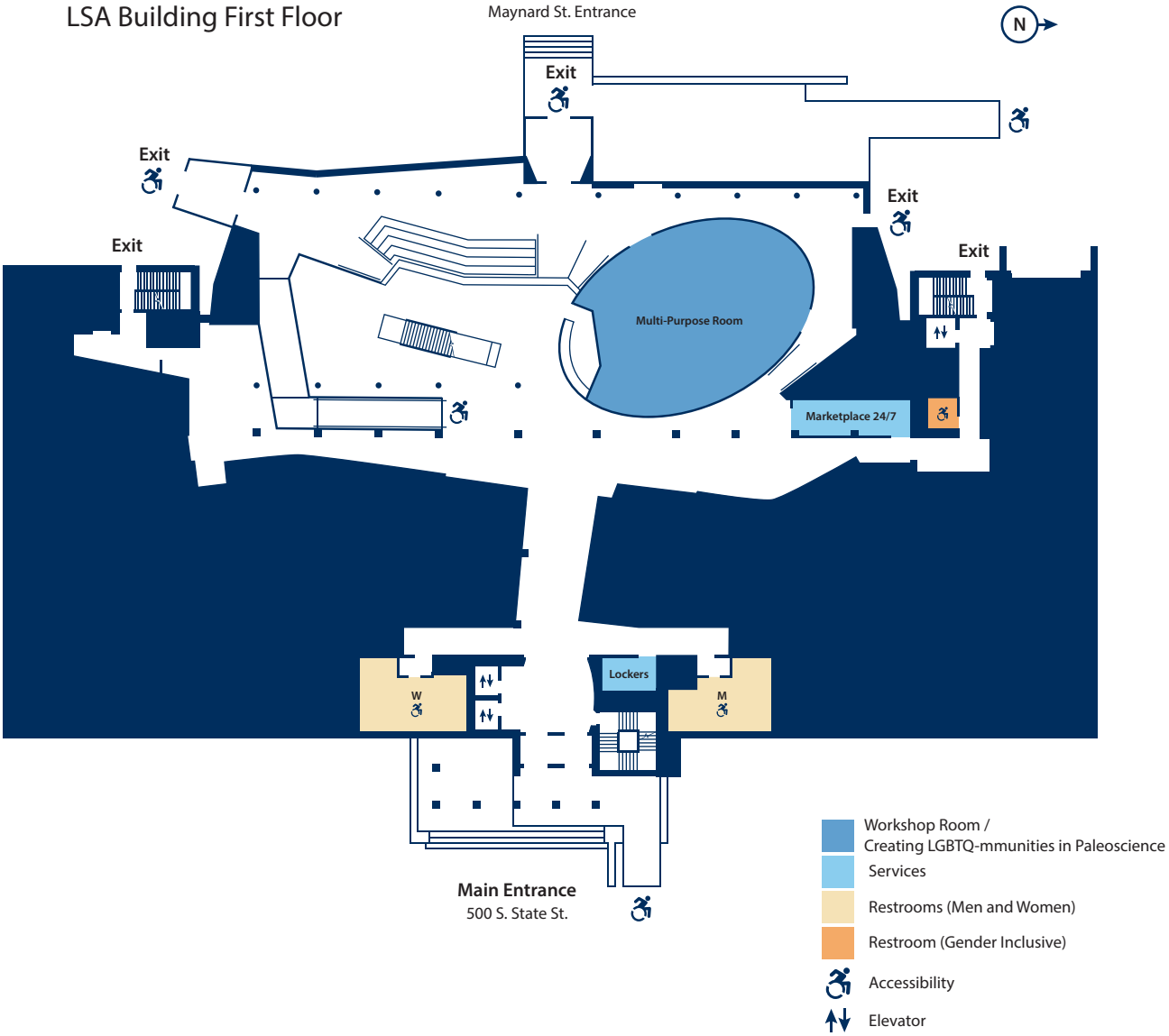
# Michigan Union First Floor

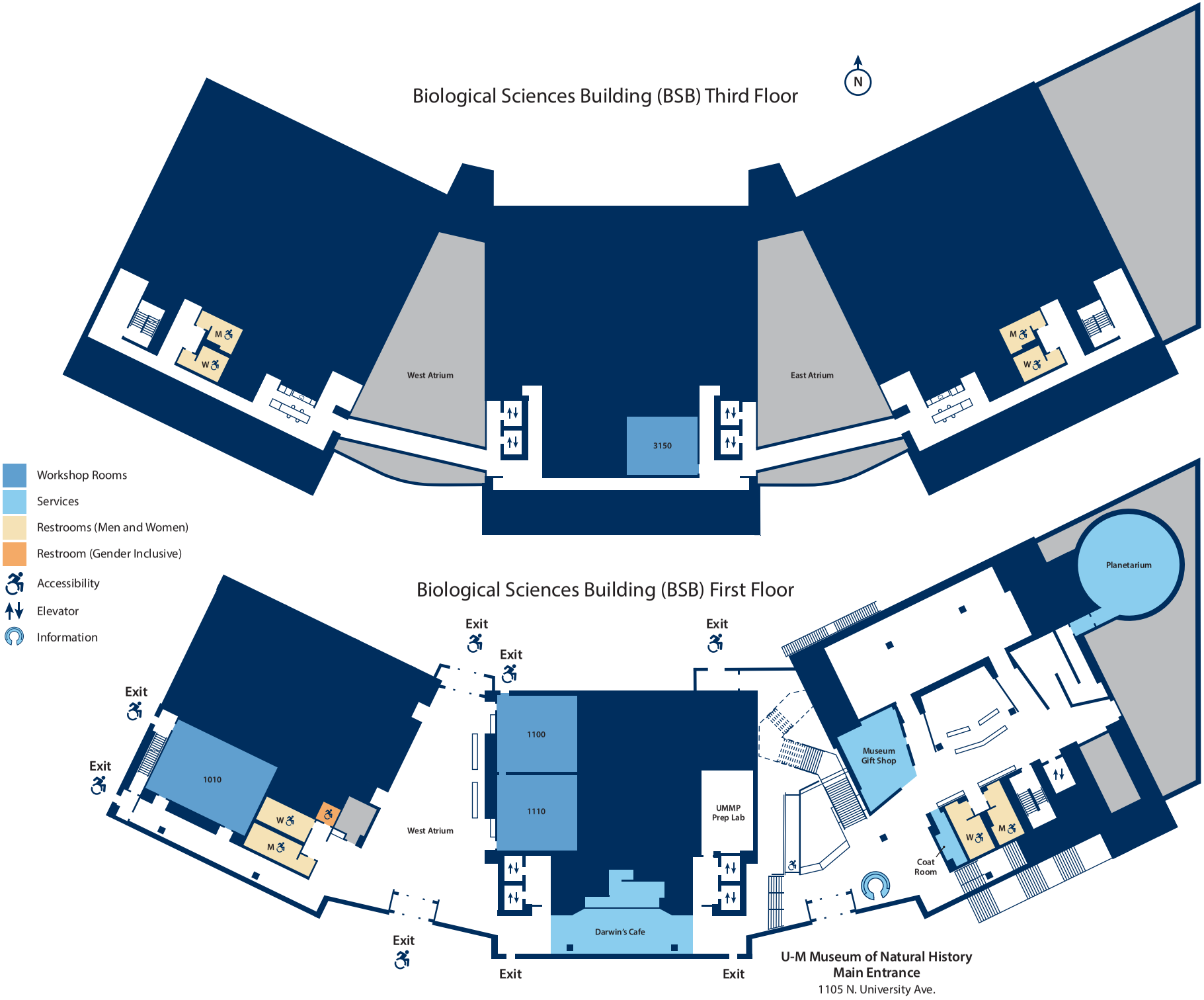
# Michigan Union Second Floor

# Michigan Union Third Floor

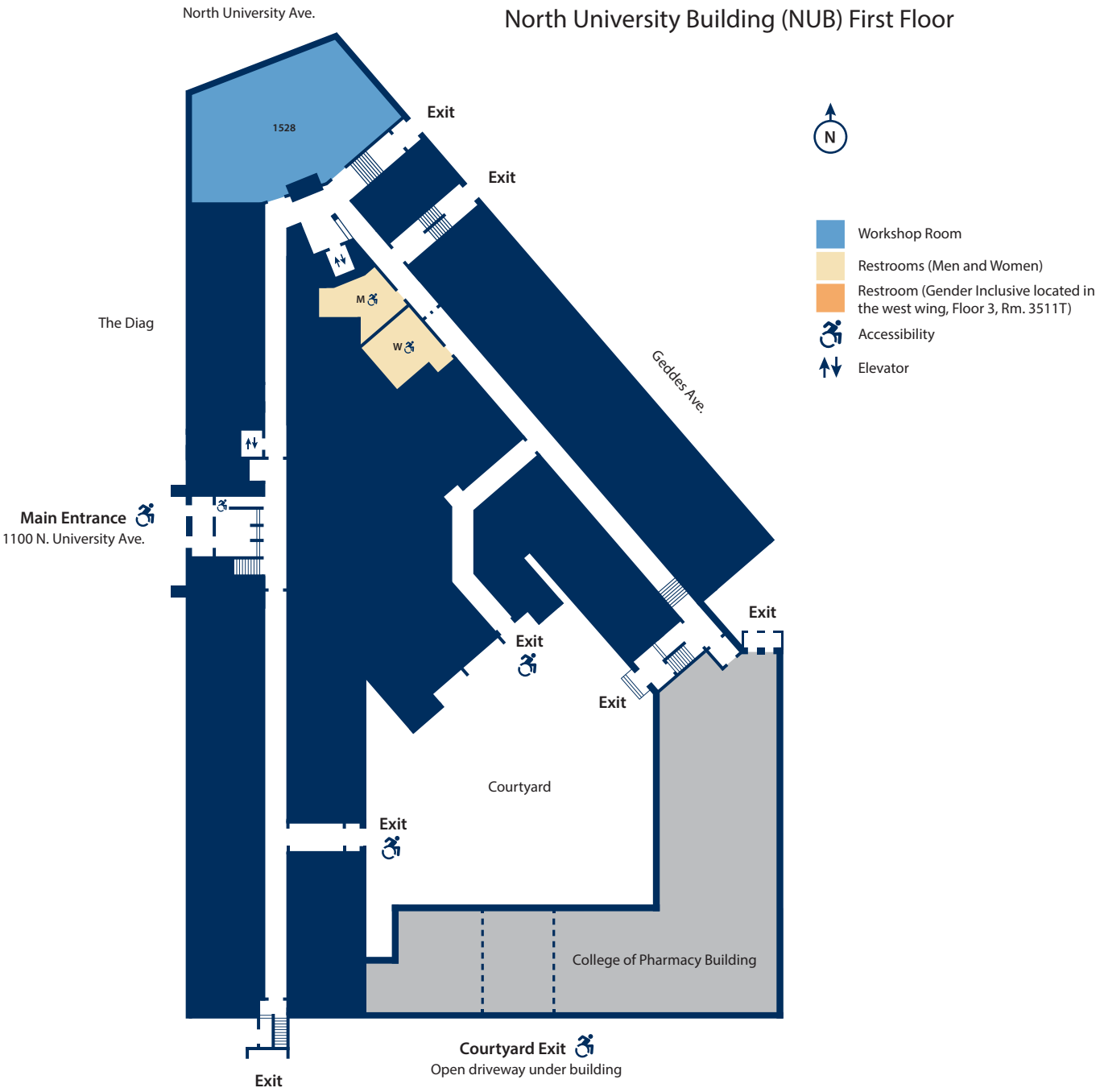


# LSA Building First Floor

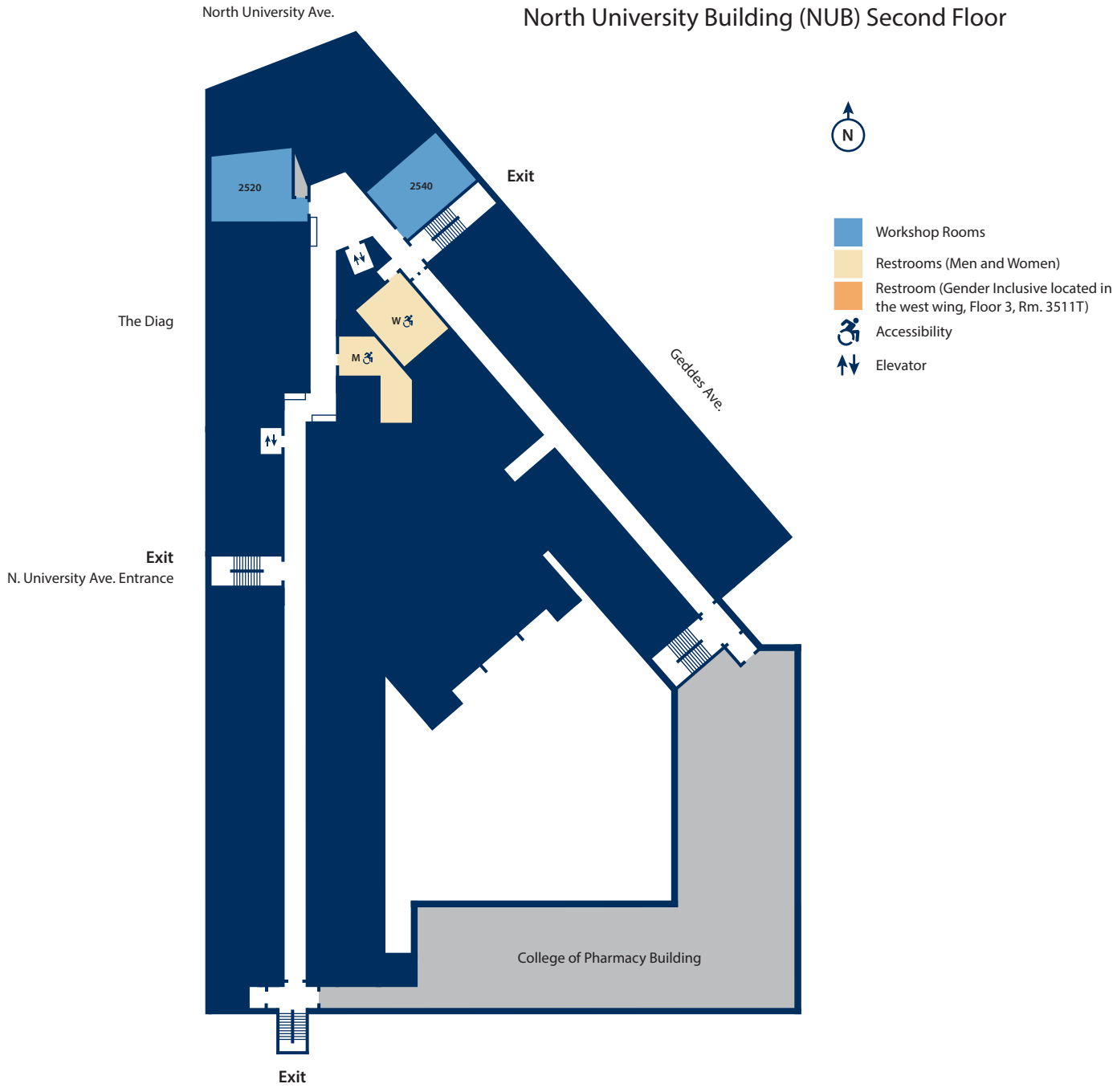



Biological Sciences Building (BSB) Third Floor
N
West Atrium
East Atrium
3150
M
W
Workshop Rooms
Services
Restrooms (Men and Women)
Restroom (Gender Inclusive)
Accessibility
Elevator
Information
Biological Sciences Building (BSB) First Floor
Exit
1010
1100
1110
West Atrium
UMMP Prep Lab
Darwin's Cafe
Museum Gift Shop
Planetarium
Coat Room
U-M Museum of Natural History
Main Entrance
1105 N. University Ave.

# North University Building (NUB) First Floor



# North University Building (NUB) Second Floor



## IV

## WELCOME TO ANN ARBOR AND THE UNIVERSITY OF MICHIGAN

Welcome to the 12th North American Paleontological Convention (NAPC) at the University of Michigan. We're excited that you're able to join us! The first NAPC, held at the Field Museum 55 years ago, marked a break from specialist meetings by bringing together researchers from all areas of paleontology. This inclusive format makes NAPC a fertile setting for developing new research directions and collaborations. With well over 700 delegates and presentation abstracts, we look forward to the novel ideas that will emerge from your time in Ann Arbor!

Paleontology has a long and storied history at the University of Michigan. The first meeting of the Board of Regents in 1837—the year of Michigan statehood—established a Cabinet of Natural History at the young University. The following year, the state legislature enacted the Michigan Geological Survey with a mandate to send duplicate specimens to the cabinet. Douglass Houghton, the first state geologist of Michigan, collected the first fossils added to the cabinet from Isle Royale. Through a combination of field efforts and acquisition of existing collections, paleontological holdings of the University of Michigan continued to grow throughout the 19th and early 20th centuries. The Museum of Paleontology came into being with a separate budget in 1926, and from 1928 made its home in the Alexander G. Ruthven Museums Building. In 2018, the museum moved to two new, state-of-the-art facilities: the Biological Sciences Building and the Research Museums Center. Today, the Museum of Paleontology includes over 30 affiliated students, postdoctoral researchers, staff, and faculty.

The University of Michigan Museum of Paleontology contains an estimated 4 million fossil objects housed in three principal collections: vertebrate paleontology, invertebrate paleontology, and paleobotany. Although the holdings are global in scope, particular strengths include Paleozoic invertebrates of the midwestern United States, Permian and Triassic vertebrates of the southwestern United States, Paleogene mammals of Wyoming, and Pleistocene megafauna of the Great Lakes Region. The roughly 20 million objects now held between the Museum of Paleontology and its sibling units the Museum of Anthropological Archaeology, Museum of Zoology, and Herbarium represent a resource of international significance, and rank as one of the largest university natural history collections in the United States. These research museums collaborate closely with the public-facing Museum of Natural History to share their objects and findings with the University of Michigan community and the public at large.

The University of Michigan predates Michigan statehood, tracing its roots to a network of schools, libraries, and other institutions established in 1817. Ann Arbor has been home to the University of Michigan since 1841, with the school currently enrolling over 52,000 students of whom roughly 18,000 are postgraduates. The grassy, tree-lined "Diag", across State Street from most NAPC events in the Michigan Union, represents the historic core of Central Campus. However, little remains from the earliest days of the university in Ann Arbor, with major growth taking place in the early 20th century and many remaining buildings dating to that time. Today, the university includes a North Campus and South Campus that are home to additional academic programs and athletic facilities, respectively.

Ann Arbor is a quintessential college town, with no shortage of options for delegates looking to spend some time away from NAPC. Several university museums and libraries–all free of charge–are located on Central Campus a short distance from NAPC events: the Kelsey Museum of Archaeology, the University of Michigan Museum of Art, the University of Michigan Museum of Natural History, and the William Clements Library will all be open during the meeting. You can take a quiet moment in the collegiate gothic quadrangles and library of the Law School or stroll in the wooded acres of Nichols Arboretum. Off campus, you can visit the Matthei Botanical Gardens, take a rented canoe or kayak on the Huron River, tube down Argo Cascades, or explore unique shops in Nickels Arcade,

Kerrytown, Main Street, and elsewhere. NAPC coincides with the Ann Arbor Summer Festival, which offers a variety of free outdoor entertainment from concerts to movies to contemporary circus, with many events on Ingalls Mall on Central Campus. You'll also find a wide variety of restaurants, cafes, and watering holes—from no-frills student haunts to fine dining—in Ann Arbor, with many located on State, Liberty, and Main streets west of Central Campus.

We hope you will enjoy your time in Ann Arbor and the University of Michigan!

*Organizing Committee, 12th North American Paleontological Convention*

V

## PRESENTATION AND SOCIAL MEDIA POLICIES

We encourage the discussion of research presented at NAPC. While our default position permits sharing of work outside the meeting, we also recognize that delegates may wish to limit distribution of their results. NAPC adopts the following policies:

- Attendees should be aware of any embargo policies that may pertain to their own work.
- Recording or photographing talks or posters without permission of the presenter is prohibited.
- Sharing recordings or photographs of talks or posters requires permission of the presenter.
- Presenters who do not want their work to be shared beyond the meeting should clearly mark their poster or relevant slide(s). If this indication appears on the title slide, attendees should recognize that no portion of the presentation may be shared.

## VI

# CODE OF CONDUCT AND REPORTING

NAPC adopts the Paleontological Society Code of Conduct. Delegates agreed to abide by the code upon abstract submission and meeting registration. The code applies to all attendees regardless of membership status in the Paleontological Society, and is in effect for all NAPC events on and off the University of Michigan campus. The Paleontological Society Code of Conduct emphasizes the need for dignity, respect, and civil communications. Its policy components include: expected behaviors; prohibited behaviors; reporting misconduct; investigations and enforcement. The Paleontological Society Code of Conduct is available at: https://www.paleosoc.org/non-discrimination-and-code-of-conduct

## EXPECTED BEHAVIORS

- Treat others with dignity and respect
- Communicate with civility
- Give fair and equitable consideration to others without regard to status or identity
- Obey the rules and policies of the meeting venue

## PROHIBITED BEHAVIORS

- Harassment in any form
- Abuse, intimidation, or threats in any form
- Violating previously communicated boundaries
- Recording others without their consent
- Displaying or distributing nude, sexual, bigoted, or other improper images or recordings

## REPORTING MISCONDUCT: PS RISE AT NAPC

PS RISE (Respectful Inclusive Scientific Events) is a mechanism to help support compliance with the code of conduct. There are multiple channels for reporting issues at NAPC:

*Speak to a PS RISE liaison* – Several NAPC delegates serving as PS RISE liaisons will attend NAPC. You can recognize them by their PS RISE pin.

*Visit the PS RISE room* – The Michigan Room in the Michigan Union will act as the PS RISE room during NAPC. It will be open during each day of the meeting from 12:00–1:00 PM and 5:30–6:30 PM, and staffed by at least two representatives.

*Report via NAVEX* – Anonymous reports can be made through the third-party platform Navex, accessible at: https://secure.ethicspoint.com/domain/media/en/gui/57816/index.html You can also scan the QR code below. Instructions for reporting a violation are available at https://www.paleosoc.org/ethics-reporting

SCAN ME

*E-mail the PS Ethics Committee* – You can report your concerns by e-mailing ethics@paleosoc.org.

*Mail the PS Ethics Committee* – Written allegations may be mailed to: Chair of Ethics Committee, The Paleontological Society, 12110 N Pecos St, Westminster, CO 80234.

*In situations requiring immediate intervention: call an on-site PS representative* – Call 970 834 3047 during session hours to contact a representative at the meeting. In the event of emergencies and/or crimes, contact campus security (734 763 1131) or the police (911).

Society members acting in leadership positions, whether for an established term (e.g., elected officials, committee members) or temporarily (e.g., field trip leaders, session organizers) are required to report to the Ethics Committee any incidents involving prohibited behavior that they directly witness or have reported to them to ensure that all parties involved receive appropriate consideration and follow-up.

***Anyone subject to or witnessing behavior that constitutes an immediate or serious threat to public or individual safety or a criminal act should contact the U-M Division of Public Safety and Security (DPSS) or local law enforcement. Those witnessing a potential criminal act should also take actions necessary to maintain their own personal safety.***

***Contact the U-M DPSS at 734 763 1131***
***Contact local emergency services at 911***

## INVESTIGATIONS AND ENFORCEMENT

Investigations will follow standard procedures established by the Paleontological Society and will consider factors in determining an appropriate sanction for violations of the Code of Conduct. The Paleontological Society Sanctions Matrix for violations of the Code of Conduct is available at https://www.paleosoc.org/assets/docs/Paleontological-Society-Conduct-Sanctions-Matrix.pdf

# VII

## SCHEDULE OF EVENTS

| | | |
|---|---|---|
| | **Friday, June 14 – Sunday, June 16** | |
| | *overnight field trip (advance sign-up required)* | |
| 7:30 am (6/14) – 6:30 pm (6/16)* | Climatic Change and Cyclic Extinction in Silurian Reefs of the Central United States | depart from BSB loading dock* |
| | **Sunday, June 16** | |
| 4:00 pm – 7:00 pm | Registration and welcome refreshments (*talk upload for Monday sessions available*) | Union Pendleton |
| | **Monday, June 17** | |
| 7:00 am – 8:00 am | Continental breakfast | Union Rogel, IdeaHub, Opera Lounge |
| 7:30 am – 5:00 pm | Speaker ready room | Union Crofoot |
| 7:30 am – 5:00 pm | Registration | Union 2nd floor foyer |
| 8:00 am – 12:00 pm | Plenary session: Paleontology for All | Rackham Auditorium |
| 12:00 pm – 1:00 pm | Creating LGBTQ-mmunities in Paleoscience | LSA Multipurpose Room |
| 12:00 pm – 1:00 pm, 5:30 pm – 6:30 pm | PS Rise Ethics Room | Union Michigan |
| 1:15 pm – 5:30 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 5:30 pm – 6:15 pm | Monday poster presentations (*posters available from 1:15 pm*) | Union IdeaHub |
| 6:30 pm – 8:30 pm | NSF town hall | Union Rogel |
| | **Tuesday, June 18** | |
| 7:00 am – 8:00 am | Continental breakfast | Union Rogel, IdeaHub, Opera Lounge |
| 8:00 am – 5:00 pm | Speaker ready room | Union Crofoot |
| 8:00 am – 5:00 pm | Registration | Union 2nd floor foyer |
| 8:00 am – 12:00 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 12:00 pm – 1:00 pm | Creating LGBTQ-mmunities in Paleoscience | LSA Multipurpose Room |
| 12:00 pm – 1:00 pm, 5:30 pm – 6:30 pm | PS Rise Ethics Room | Union Michigan |
| 1:15 pm – 5:30 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 5:30 pm – 6:15 pm | Tuesday poster presentations (*posters available from 9:45 am*) | Union IdeaHub |
| 6:15 pm – 8:30 pm | Career Fair sponsored by NSF and the Treatise on Invertebrate Paleontology (*advance sign-up required*) | Union Rogel (*start*) |

| | | |
|---|---|---|
| | **Wednesday, June 19** | |
| 7:00 am – 8:00 am | Continental breakfast | Union Rogel |
| 8:00 am – 5:00 pm | Speaker ready room | Union Crofoot |
| 8:00 am – 5:00 pm | Registration | Union 2nd floor foyer |
| 12:00 pm – 1:00 pm, 5:30 pm – 6:30 pm | PS Rise Ethics Room | Union Michigan |
| 2:00 pm – 3:30 pm | Careers in Science Communications Panel with PBS Eons | Union Rogel |
| 6:00 pm – 7:00 pm | Conservation Paleobiology Network town hall | Union Rogel |
| 7:00 pm | Conservation Paleobiology Network social networking event | The Brown Jug (1204 S University Ave.) |
| | *field trips (advance sign-up required)* | |
| 8:00 am – 12:15 pm | Middle Devonian Marine Fossils of the Michigan Basin: the Silica Formation | depart from Union |
| 8:30 am – 12:00 pm | Behind the Scenes at the University of Michigan's Research Museums Center | depart from Union |
| 9:00 am – 6:40 pm | Carboniferous (Pennsylvanian) Marginal-marine Fossils and Strata at Grand Ledge, Michigan: Stratigraphical, Educational, and Cultural Significance | depart from BSB loading dock* |
| 1:15 pm – 6:15 pm | Carboniferous (Mississippian) Fossils of Michigan: the Marshall Formation at the Blue Ridge Esker | depart from Union |
| 2:00 pm – 5:30 pm | Behind the Scenes at the University of Michigan's Research Museums Center | depart from Union |
| | *workshops (advance sign-up required)* | |
| 8:00 am – 5:15 pm | Analytical Approaches to Networks, Trophic Structure, and Ancient Food Webs | BSB 1100 |
| 8:00 am – 5:15 pm | Innovative Tools for Research Management in Academia | NUB 1528 |
| 8:00 am – 12:00 pm | An Introduction to Claddis: an R Package for Analyzing Morphological Diversity and Tempo Using (Primarily) Discrete Characters | BSB 1110 |
| 8:00 am – 12:00 pm | R for Paleobiologists: Getting Started with the Palaeoverse R Package | BSB 1010 |
| 8:00 am – 12:00 pm | Building Custom Ecosystem Models with Biogeochemical Cycles in PALEOtoolkit | NUB 2540 |
| 8:00 am – 12:00 pm | Vision for a Midwestern Paleontology Center: Exploring Priorities in Research, Participation, and Partnerships | LSA Multipurpose Room |
| 9:00 am – 12:00 pm | Open-Source Software for 3D data | BSB 3150 |
| 1:15 pm – 5:15 pm | Managing Morphological Character Matrices using MorphoBank | BSB 1010 |
| 1:15 pm – 5:15 pm | Save Time, Work Smarter with Zotero: Note Taking, File Management, and Citations All in One Place | NUB 2540 |
| 1:15 pm – 5:15 pm | Virtual Paleontology: Hands-On Training with Materialise Mimics | NUB 2520 |
| | **Thursday, June 20** | |
| 7:00 am – 8:00 am | Continental breakfast | Union Rogel, IdeaHub, Opera Lounge |
| 8:00 am – 5:00 pm | Speaker ready room | Union Crofoot |
| 8:00 am – 5:00 pm | Registration | Union 2nd floor foyer |

| | | |
|---|---|---|
| 8:00 am – 12:00 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 12:00 pm – 1:00 pm | Creating LGBTQ-mmunities in Paleoscience | LSA Multipurpose Room |
| 12:00 pm – 1:00 pm, 5:30 pm – 6:30 pm | PS Rise Ethics Room | Union Michigan |
| 1:15 pm – 5:30 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 5:30 pm – 6:15 pm | Thursday poster presentations (*posters available from 9:45 am*) | Union IdeaHub |
| 6:30 pm – 8:30 pm | Inclusive Paleontology Night sponsored by NSF and Taylor & Francis (*advance sign-up required*) | University of Michigan Museum of Natural History |
| | **Friday, June 21** | |
| 7:00 am – 8:00 am | Continental breakfast | Union Rogel, IdeaHub, Opera Lounge |
| 8:00 am – 12:00 pm | Speaker ready room | Union Crofoot |
| 8:00 am – 12:00 pm | Registration | Union 2nd floor foyer |
| 8:00 am – 12:00 pm | Parallel sessions | Union Rogel, Anderson, Pendleton, Kuenzel, Wolverine, 2210, Pond |
| 12:00 pm – 1:00 pm | Creating LGBTQ-mmunities in Paleoscience | LSA Multipurpose Room |
| 12:00 pm – 1:00 pm, 5:30 pm – 6:30 pm | PS Rise Ethics Room | Union Michigan |
| 1:15 pm – 5:30 pm | Parallel sessions | Union Anderson, Kuenzel, Wolverine, 2210, Pond |
| 1:30 pm – 2:00 pm, 2:30 pm – 3:00 pm, 3:30 pm – 4:00 pm, 4:30 pm – 5:00 pm | Tour of the UMMP fossil prep lab (*walk-up event*) | meet at Darwin's Cafe, BSB 1st floor |
| 1:30 pm – 5:00 pm | Matthaei Botanical Garden field trip (*walk-up event*) | depart from Union |
| 3:30 pm – 4:15 pm | Planetarium show: "Sky Tonight" (*free tickets at registration*) | University of Michigan Museum of Natural History |
| 5:30 pm – 6:15 pm | Friday poster presentations (*posters available from 9:45 am*) | Union IdeaHub |
| 6:30 pm – 8:30 pm | Conference banquet (*ticketed event*) | Union Rogel, Union Pendleton |
| | **Saturday, June 22 – Sunday, June 23** | |
| | *overnight field trips (advance sign-up required)* | |
| 8:00 am (6/22) – 7:00 pm (6/23)* | Diving into the Age of Fishes: the Cleveland Shale and the Cleveland Museum of Natural History | depart from BSB loading dock* |
| 8:00 am (6/22) – 8:30 pm (6/23)* | The Classic Cincinnatian (Upper Ordovician, Katian) of the Cincinnati Vicinity: Paleoenvironments and Ecology of a Sea without Fish | depart from BSB loading dock* |
| 8:00 am (6/22) – 7:00 pm (6/23)* | The Carboniferous Mazon Creek Fossil Site: Collecting at "Worm Hill" and Viewing Non-worms at the Field Museum | depart from BSB loading dock* |

*Please note that depature time refers to when field trip vehicles will leave. Delegates should arrive in advance of the departure time.*

**Accurate as of printing. Defer to correspondence from field trip leaders in the event of changes to schedule or site of departure.*

# VIII

# TALK SCHEDULE

## MONDAY MORNING, JUNE 17, 2024

| TIME | RACKHAM AUDITORIUM<br>*Plenary Session:Paleontology for All* |
|---|---|
| 8:00 | *welcoming remarks* |
| 8:30 | **KILBOURNE** OPENING POEM: "BLINDFOLD WONDER" |
| 8:45 | **BEHRENSMEYER & CSOTONYI** VISUALIZING THE PAST: HOW ARTISTS AND PALEOBIOLOGISTS CREATE SCIENCE-INFORMED RECONSTRUCTIONS OF ANCIENT LIFE |
| 9:15 | **CLARK & BAUER** AN EVER-WIDENING CIRCLE OF FRIENDS |
| 9:45-10:15 | *coffee break* |
| 10:15 | **MONARREZ** LEARNING ABOUT THE FOUNDATIONAL ROLES OF COLONIALISM AND SYSTEMIC RACISM IN PALEONTOLOGY TO CREATE A MORE INCLUSIVE DISCIPLINE |
| 10:45 | **ANTELL** THE TRUTH ABOUT "GLOBAL" DATA, AND THE LIMITS OF THE KNOWABLE |
| 11:15 | **CARVALHO** FOSSILS: ANCIENT KEYS FOR UNDERSTANDING THE BIOLOGY OF A CHANGING PLANET |
| 11:45 | *group photo* |

# TALK SCHEDULE

## MONDAY AFTERNOON, JUNE 17, 2024

| TIME | UNION ROGEL *Bighorn Basin* | UNION ANDERSON *Neogene West. Atlantic* | UNION PENDLETON *Marine Extinctions* | UNION KUENZEL *Taphonomy & Ichnofossils* | UNION WOLVERINE *Oceanic Anoxic Events* | UNION 2210 *Paleoneurology* | UNION POND *Federal Paleo. Resources* |
|---|---|---|---|---|---|---|---|
| 1:15 | GINGERICH | **O'DEA** | BUSH | KIMMIG | BOWSER | *withdrawn* | TWEET |
| 1:30 | VITEK | ***continued*** | AL ASWAD | LUQUE | BERNHARD | ORTEGA-HERNÁNDEZ | BOBER |
| 1:45 | BLOCH | HENDY | MARTINDALE | BRANDT | GLOCK | FIGUEROA | VISAGGI |
| 2:00 | SCHWARTZ | HENDRICKS | STONE | CLEMENTS | ALCORN | GILES | LIGGETT |
| 2:15 | MORSE | CAMPBELL | REDDIN | MCCOY | BURKETT | BALANOFF | BREITHAUPT |
| 2:30 | RIEGLER | CAMPBELL | SINHA | PLAZA-TORRES | WAN | YOHE | RAPP |
| 2:45 | WING | CAMPBELL | GAVIRNENI | *withdrawn* | LI | FABBRI | SCANNELLA |
| 3:00 | | ALLMON | | | | | NAKANO |

| TIME | UNION ROGEL *Bighorn Basin* | UNION ANDERSON *Neogene West. Atlantic* | UNION PENDLETON *Marine Extinctions* | UNION KUENZEL *Taphonomy & Ichnofossils* | UNION WOLVERINE *Oceanic Anoxic Events* | UNION 2210 *Paleoneurology* | UNION POND |
|---|---|---|---|---|---|---|---|
| 3:30 | CURRANO | ANDERSON | SULLIVAN | NEBELSICK | FEARON | ORTEGA-HERNÁNDEZ | |
| 3:45 | KORASIDIS | THOMPSON | JACOBS | JACOBS | JACOBSON | BAZZANA-ADAMS | |
| 4:00 | MILLIGAN | ROJAS ARIZA | MIGUEZ SALAS | NICOL | WANG | LANG | |
| 4:15 | HAVRANEK | GOMES | SCHNEIDER | GAETANO | HUBER | BERTRAND | |
| 4:30 | SNELL | ORNDORFF | WILLIAMS | CHIAPPONE | CHEN | WATANABE | |
| 4:45 | SCHER | THOMAS | | FIORILLO | COHEN | SCOTT | |
| 5:00 | JUD | COLE | | WHITE | MARROQUÍN | BURKE | |
| 5:15 | WEAVER | LOCKWOOD | | | ROSELLI | | |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 3:00–3:30.*

# TALK SCHEDULE

## TUESDAY MORNING, JUNE 18, 2024

| TIME | UNION ROGEL *Valentine Symposium* | UNION ANDERSON *Cenozoic Tetrapods* | UNION PENDLETON *Caves to Cenotes* | UNION KUENZEL *Dawn of Animal Life* | UNION WOLVERINE *Mesozoic Reptiles* | UNION 2210 *Integrative Paleobio.* | UNION POND *Systematics & Phylogeny* |
|---|---|---|---|---|---|---|---|
| 8:00 | ERWIN | SILVIRIA | **CHATTERS** | **TARHAN** | | MCMENAMIN | LLOYD |
| 8:15 | SIMPSON | WRIGHT | ***continued*** | ***continued*** | | SUN | SHEFFIELD |
| 8:30 | WAGNER | SYVERSON | RISSOLO | KAUFMAN | KLIGMAN | BOYER | PÉREZ-PERIS |
| 8:45 | NG | WARD | REINHARDT | SURPRENANT | MELSTROM | FREEMAN PETERS | MONGIARDINO KOCH |
| 9:00 | SOSIAK | STRASSBERG | ARROYO-CABRALES | LIU | WILSON MANTILLA | MA | FAU |
| 9:15 | PATZKOWSKY | MEREGHETTI | SCHUBERT | BOBROVKSY | REGALADO FERNÁNDEZ | NA | YONG |
| 9:30 | STANLEY | AMEEN | SAMUELS | BOAN | RADERMACHER | XU | VILELA-ANDRADE |

| TIME | UNION ROGEL *Valentine Symposium* | UNION ANDERSON *Siwalik Record of Pakistan* | UNION PENDLETON *Caves to Cenotes* | UNION KUENZEL *Dawn of Animal Life* | UNION WOLVERINE *Mesozoic Reptiles* | UNION 2210 *Integrative Paleobio.* | UNION POND *Systematics & Phylogeny* |
|---|---|---|---|---|---|---|---|
| 10:15 | RICHARDS | **RAZA** | MCDONALD | SELLY | BOISVERT | WHITTLE | WANG |
| 10:30 | LOSSO | ***continued*** | CHATTERS | VIXSEBOXSE | BOISVERT | BROCCHINI | ZHANG |
| 10:45 | RIVERO-VEGA | RAYNOLDS | WIDGA | MITCHELL | WILSON MANTILLA | HOWARD | WALTY |
| 11:00 | JORDAN | WILLIS | CRUZ | OSÉS | MAKOVICKY | MACLEOD | DEHAAN |
| 11:15 | SHI | QUADE | OVANDO | MCCANDLESS | NORRIS | WOOLLEY | WATT |
| 11:30 | KLOMPMAKER | KARP | MCDONALD | PEREZ PINEDO | DEAN | FELICE | SON |
| 11:45 | ZHOU | BEHRENSMEYER | *discussion* | | HOLTZ | KNAPP | ABBOTT |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 7:00–8:00, 9:45–10:15.*

# TALK SCHEDULE

## TUESDAY AFTERNOON, JUNE 18, 2024

| TIME | UNION ROGEL *Valentine Symposium* | UNION ANDERSON *Siwalik Record of Pakistan* | UNION PENDLETON *Caribbean Paleobio.* | UNION KUENZEL *Dawn of Animal Life* | UNION WOLVERINE *Virtual Paleobio.* | UNION 2210 *Fishes & Paleoz. Tetrapods* | UNION POND *Systematics & Phylogeny* |
|---|---|---|---|---|---|---|---|
| 1:15 | JABLONSKI | MORGAN | *introductory remarks* | **EVANS** | *withdrawn* | SCHNETZ | PATELLOS |
| 1:30 | EDIE | HEAD | ITURRALDE-VINENT | ***continued*** | *withdrawn* | HARIDY | SALEM |
| 1:45 | YASUHARA | SANDERS | VÉLEZ-JUARBE | XIAO | BEVITT | BRONSON | TORRES |
| 2:00 | HUANG | COTE | ALMONTE | SEGESSENMAN | HEBDON | FLANNERY SUTHER- | GOHAR |
| 2:15 | SINGH | KELLEY | VIÑOLA LOPEZ | BYKOVA | BICKNELL | STACK | DAVIES |
| 2:30 | DOYLE | GILBERT | PEROS | | PATES | WHITNEY | |
| 2:45 | CRESTOHL | PATNAIK | KLUKKERT | | NOLAN | ANGIELCZYK | |

| TIME | UNION ROGEL *Valentine Symposium* | UNION ANDERSON *Siwalik Record of Pakistan* | UNION PENDLETON *Caribbean Paleobio.* | UNION KUENZEL *Microbial Biosignatures* | UNION WOLVERINE *Virtual Paleobio.* | UNION 2210 *Fishes & Paleoz. Tetrapods* | UNION POND *Echinoderms* |
|---|---|---|---|---|---|---|---|
| 3:30 | MARSHALL | FLYNN | HALENAR-PRICE | HAMILTON | HEGNA | MARTINEZ | WATTS |
| 3:45 | SAULSBURY | KIMURA | JACISIN III | SLATER | ZIETLOW | PARDO | SUMRALL |
| 4:00 | RICHARDSON | CASANOVAS-VILAR | MCAFEE | DROSER | REYES | | KEYES |
| 4:15 | SONG | UNO | COOKE | HOWARD | *withdrawn* | | DELINE |
| 4:30 | PETERSEN | JUKAR | HENSLEY | JORN | MAYLE | | GAHN |
| 4:45 | ANTELL | **BADGLEY** | LEFEBVRE | ALIAN | LYNCH | | |
| 5:00 | FINNEGAN | ***continued*** | MYCHAJLIW | | JACQUET | | |
| 5:15 | | | | | PETERMAN | | |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 3:00–3:30.*

# TALK SCHEDULE

## THURSDAY MORNING, JUNE 20, 2024

| TIME | UNION ROGEL *Mollusks* | UNION ANDERSON *Computational Paleobio.* | UNION PENDLETON *Paleocommunities* | UNION KUENZEL *Hominoids* | UNION WOLVERINE *Stratigraphic Paleobio.* | UNION 2210 *N.A. Paleo. Resources* | UNION POND *Grande Symposium* |
|---|---|---|---|---|---|---|---|
| 8:00 | | **COLE** | GILL | ROSSIE | HOLLAND | BRANDT | HILTON |
| 8:15 | | ***continued*** | FRANK | JANSMA | WOOD | KETCHUM | AASE |
| 8:30 | | VARGAS-PARRA | CULLEN | SHERWOOD | LOUGHNEY | CORTEZ | CAPOBIANCO |
| 8:45 | CHATTOPADHYAY | HOPKINS | ROOPNARINE | COSMAN | ORCHARD | DINEEN | IGIELMAN |
| 9:00 | WEINSTEIN | NIKOLIC | MCGUIRE | MACLATCHY | CLEMENT | MAYER | MICKLE |
| 9:15 | CLAPHAM | WRIGHT | SLENKER | ORLIKOFF | KOSNIK | CUNDIFF | GILES |
| 9:30 | WILSON | RHODA | KEMP | MICHEL | KIDWELL | ADRAIN | ATTERBY |

| TIME | UNION ROGEL *Conservation Paleobio.* | UNION ANDERSON *Computational Paleobio.* | UNION PENDLETON *Paleocommunities* | UNION KUENZEL *Hominoids* | UNION WOLVERINE *Stratigraphic Paleobio.* | UNION 2210 *N.A. Paleo. Resources* | UNION POND *Grande Symposium* |
|---|---|---|---|---|---|---|---|
| 10:15 | **DAVIS** | **HOWARD** | SCHAP | BAUMGARTNER | MONARREZ | HOOK | XU |
| 10:30 | ***continued*** | ***continued*** | TERRY | HALL | GALLAGHER | BAUER | DAVID |
| 10:45 | CRAMER | DUNNE | BROMBACHER | MUNYAKA | WESTROP | MILLHOUSE | BROWNSTEIN |
| 11:00 | BARCLAY | JONES | SJOSTEN | COTE | LITTLE | AMATI | FASEY |
| 11:15 | PHAM | WEN | ESS | WINKLER | FORSYTHE | UTRUP | ANDREWS |
| 11:30 | PIER | FLANNERY-SUTHER- | TYLER | MACLATCHY | HERNÁNDEZ GÓMEZ | RHUE | LIU |
| 11:45 | SHIRLEY | YOHLER | BROPHY | HEAD | IRIZARRY | HUNDA | DE PINNA |

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*Coffee and tea available between 7:00–8:00, 9:45–10:15.*

# TALK SCHEDULE

## THURSDAY AFTERNOON, JUNE 20, 2024

| TIME | UNION ROGEL *Conservation Paleobio.* | UNION ANDERSON *Computational Paleobio.* | UNION PENDLETON *Paleocommunities* | UNION KUENZEL *Hominoids* | UNION WOLVERINE *Stratigraphic Paleobio.* | UNION 2210 *N.A. Paleo. Resources* | UNION POND *Grande Symposium* |
|---|---|---|---|---|---|---|---|
| 1:15 | WINGARD | **FURNESS** | BANKER | LUKENS | PIPPENGER | FARRAR | MONTALVO |
| 1:30 | SPANBAUER | ***continued*** | OPAZO MELLA | NORWOOD | HUGHES | GARCIA | YABUMOTO |
| 1:45 | DILLON | GEARTY | TACKETT | OPPENHEIM | SCLAFANI | MIKULIC | CHIDA |
| 2:00 | AUSTIN | BAPST | NOVACK-GOTTSHALL | KINGSTON | MCLAUGHLIN | MCCALL | BEMIS |
| 2:15 | PRUDEN | JONES | STROTZ | UNO | HAYES | CLARY | HILTON |
| 2:30 | DIETL | WANG | THIBODEAUX | WERDELIN | FAN | HENDRICKS | |
| 2:45 | *discussion* | LOUGHNEY | DUTTA | | ZHANG | LÓPEZ CARRANZA | |

| TIME | UNION ROGEL *Conservation Paleobio.* | UNION ANDERSON *Computational Paleobio.* | UNION PENDLETON *Arthropods* | UNION KUENZEL *Insect Herbivory* | UNION WOLVERINE *Conodonts* | UNION 2210 *N.A. Paleo. Resources* | UNION POND |
|---|---|---|---|---|---|---|---|
| 3:30 | KOWALEWSKI | **WIEMANN** | MIKULIC | LABANDEIRA | MILLER | HENDY | |
| 3:45 | KOKESH | ***continued*** | ADRAIN | DEKOSTER | LUBLINER | KARIM | |
| 4:00 | LAKER | COLLINS | LAIRD | LAKERAM | ROSSCOE | JOHNSON | |
| 4:15 | LIYANAGEDARA | *withdrawn* | BEECH | XIAO | HENDERSON | LONG-FOX | |
| 4:30 | TORRES | ROBERTS | DRAGE | CARRILLO-ALBARRAN | HOGANCAMP | SIMPSON | |
| 4:45 | WRIGHT | PETSIOS | MOYSIUK | GIRALDO | OVER | QUIRK | |
| 5:00 | *discussion* | GOSWAMI | | SWAIN | | **RAYMOND** | |
| 5:15 | | | | | | ***continued*** | |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 3:00–3:30.*

# TALK SCHEDULE

## FRIDAY MORNING, JUNE 21, 2024

| TIME | UNION ROGEL *Conservation Paleobio.* | UNION ANDERSON *AI in Paleo.* | UNION PENDLETON *Fisher Symposium* | UNION KUENZEL *Paleobotany* | UNION WOLVERINE *Carnivorous Mammals* | UNION 2210 *Broadening Accessibility* | UNION POND *Avocational Clubs* |
|---|---|---|---|---|---|---|---|
| 8:00 | **FLANTUA** | LESHNO AFRIAT | *introductory remarks* | LODUCA | ORCUTT | PORCELLO | CLARK |
| 8:15 | ***continued*** | HU | LAMSDELL | HUEGELE | MORETTI | INMAN | MCCALL |
| 8:30 | KOOYMAN | HUANG | OCON | BUTRIM | POUST | BOLGER | BISSETT |
| 8:45 | MORLEY | MULQUEENEY | CARLSON | MORALES TOLEDO | RILEY | EL-SAYED | COOPER |
| 9:00 | GIBERT BRET | ANEMONE | PARINS-FUKUCHI | SPAGNUOLO | AMANE | HOPPS | SHOEMAKER |
| 9:15 | SHORT | JARIWALA | LEIGHTON | CORREA-NARVAEZ | LOWERY | THOMPSON | PANKOWSKI |
| 9:30 | *discussion* | *withdrawn* | FOX | TADOUMANT | ROTHSCHILD | FRANCEK | KONIECKI |
| 9:45 | | | BADGLEY | | | | |

| TIME | UNION ROGEL *Conservation Paleobio.* | UNION ANDERSON *AI in Paleo.* | UNION PENDLETON *Fisher Symposium* | UNION KUENZEL *Wetland Ecology* | UNION WOLVERINE *Carnivorous Mammals* | UNION 2210 *Broadening Accessibility* | UNION POND *Avocational Clubs* |
|---|---|---|---|---|---|---|---|
| 10:15 | KUSNERIK | FORCELLATI | PLOTNICK | CHRPA | **KORT** | XU | STOKES |
| 10:30 | CARDEN | RODRIGUEZ | CROWLEY | SCOTT | ***continued*** | SANTOS | WESTGAARD |
| 10:45 | EDELMAN-FURSTEN- | ADAIMÉ | ROUNTREY | JACKSON | LOPEZALLES | LEPORE | KAPLAN |
| 11:00 | SNYDERMAN | ROMERO | CERLING | RAYMOND | POLLY | | SHOEMAKER |
| 11:15 | SMITH | PUNYASENA | CHERNEY | NEELY | EVERETT | WHITE | *discussion* |
| 11:30 | KELLEY | BERV | KOCH | MARTIN | DESANTIS | | *discussion cont.* |
| 11:45 | *discussion* | | SELCER | | MUNSON | | *discussion cont.* |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 7:00–8:00, 9:45–10:15.*

# TALK SCHEDULE

## FRIDAY AFTERNOON, JUNE 21, 2024

| TIME | UNION ROGEL | UNION ANDERSON *Integrated Approaches* | UNION PENDLETON | UNION KUENZEL *Reef Paleoecology* | UNION WOLVERINE *Carnivorous Mammals* | UNION 2210 *Biodiversity Dynamics* | UNION POND *Proboscideans* |
|---|---|---|---|---|---|---|---|
| 1:15 | | WEAVER | | VAYDA | **VALENZUELA-TORO** | TOMASOVYCH | **LISTER** |
| 1:30 | | HARDY | | LI | ***continued*** | ELKIN | ***continued*** |
| 1:45 | | MARDER | | GODBOLD | CHURCHILL | MANOOGIAN | ANINY |
| 2:00 | | DOLBY | | SCHNEIDER | BARRETT | LU | SANDERS |
| 2:15 | | TERRY | | LORD | DOUGHTY | JONES | SAARINEN |
| 2:30 | | WYATT | | KIESSLING | CHRISTISON | JAMSON | WIDGA |
| 2:45 | | PENG | | DIMITRIJEVIC | BALISI | HUNT | HULBERT |
| 3:00 | | | | | | | JUKAR |

| TIME | UNION ROGEL | UNION ANDERSON *Integrated Approaches* | UNION PENDLETON | UNION KUENZEL *Reef Paleoecology* | UNION WOLVERINE *Fossil Forces* | UNION 2210 *Biodiversity Dynamics* | UNION POND *Proboscideans* |
|---|---|---|---|---|---|---|---|
| 3:30 | | WANG | | DUSSEAULT | BYRNE | CERASONI | ARROYO-CABRALES |
| 3:45 | | REID | | O'QUIN | WILKEN | KAHANAMOKU-MEYER | CRUZ |
| 4:00 | | WING | | CHANDROTH | MAGALLANES | BENNETT | LINDSEY |
| 4:15 | | STILES | | **CYBULSKI** | LI | HARRIS | MILLER |
| 4:30 | | HOPKINS | | ***continued*** | DUDGEON | DENG | PARDI |
| 4:45 | | SAMUELS | | ***continued*** | SELLERS | FALK | BUTLER |
| 5:00 | | KELLER | | *discussion* | HOLLIDAY | WILSON | GARAPATI |
| 5:15 | | ZELDITCH | | | | LEDESMA | SHIRLEY |

*Session titles shortened for clarity. Longer, keynote-style talks indicated in bold.*
*Coffee and tea available between 3:00–3:30.*

# IX

# LIST OF PRESENTERS AND TITLES IN CHRONOLOGICAL SESSION ORDER

## MONDAY MORNING, JUNE 17, 2024
## PLENARY SESSION: PALEONTOLOGY FOR ALL
## RACKHAM AUDITORIUM
## MODERATORS: Selena Smith and Matt Friedman

**8:00** *welcoming remarks*

**8:30** **KILBOURNE** OPENING POEM: "BLINDFOLD WONDER"

**8:45** **BEHRENSMEYER & CSOTONYI** VISUALIZING THE PAST: HOW ARTISTS AND PALEOBIOLOGISTS CREATE SCIENCE-INFORMED RECONSTRUCTIONS OF ANCIENT LIFE

**9:15** **CLARK & BAUER** AN EVER-WIDENING CIRCLE OF FRIENDS

**10:15** **MONARREZ** LEARNING ABOUT THE FOUNDATIONAL ROLES OF COLONIALISM AND SYSTEMIC RACISM IN PALEONTOLOGY TO CREATE A MORE INCLUSIVE DISCIPLINE

**10:45** **ANTELL** THE TRUTH ABOUT "GLOBAL" DATA, AND THE LIMITS OF THE KNOWABLE

**11:15** **CARVALHO** FOSSILS: ANCIENT KEYS FOR UNDERSTANDING THE BIOLOGY OF A CHANGING PLANET

**11:45** *group photo*

## MONDAY AFTERNOON, JUNE 17, 2024
## THE BIGHORN BASIN: NEW FRONTIERS AND INTER-GENERATIONAL KNOWLEDGE OF A MODEL SYSTEM FOR STUDYING TERRESTRIAL ECOSYSTEM EVOLUTION
## UNION ROGEL
## MODERATORS: Lucas Weaver and Vera Korasidis

**1:15** **GINGERICH** HISTORY OF THE PALEOCENE–EOCENE TRANSITION IN THE BIGHORN BASIN OF WYOMING

**1:30** **VITEK** SUSTAINED WORK BREAKS NEW GROUND: EVOLUTIONARY RESEARCH FRONTIERS IN THE BIGHORN BASIN

**1:45** **BLOCH** THE BIGHORN BASIN PETM MICROVERTEBRATE PROJECT (PETM-MVP): NEW HIGH-RESOLUTION RECORDS OF VERTEBRATE RESPONSE TO CLIMATE CHANGE ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM

**2:00** **SCHWARTZ** DIETARY CHANGE ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE MESONYCHID *DISSACUS PRAENUNTIUS* THROUGH DENTAL MICROWEAR TEXTURE ANALYSIS

**2:15** **MORSE** A MULTIPROXY APPROACH TO CHARACTERIZING THE ECOLOGY OF THE EARLIEST KNOWN CROWN PRIMATE FROM THE BIGHORN BASIN, WY

**2:30** **RIEGLER** DOCUMENTING LIZARD FAUNAS ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN, WYOMING

**2:45** **WING** MORE SITES, MORE FOSSILS – AN IMPROVED BASIS FOR UNDERSTANDING FLORAL CHANGE DURING THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN

**3:30** **CURRANO** MORE SITES, MORE FOSSILS, PART 2 – AN IMPROVED BASIS FOR UNDERSTANDING INSECT HERBIVORY DURING THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN

**3:45** **KORASIDIS** PALYNOFLORAL CHANGE THROUGH THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN, WYOMING

**4:00** **MILLIGAN** LEAF EPIDERMAL CELLS RECORD THE CANOPY RESPONSE TO CHANGING CLIMATE DURING THE LATE PALEOCENE TO EARLY EOCENE IN THE BIGHORN BASIN, WY

**4:15** **HAVRANEK** CLUMPED ISOTOPE THERMOMETRY RECORD OF THE PALEOCENE EOCENE THERMAL MAXIMUM FROM POLECAT BENCH

**4:30** **SNELL** CLUMPED ISOTOPE THERMOMETRY OF PALEOCENE TO EOCENE HYPERTHERMAL EVENTS IN THE BIGHORN BASIN, WY – EVOLUTION OF A TOOL AND A RECORD

**4:45** **SCHER** *CELTIS* ENDOCARP BOUND ORGANIC MATTER $\Delta^{15}$N: A POTENTIAL PALEOCLIMATE PROXY

**5:00** **JUD** ECOLOGICAL PATTERNS OF THE ANGIOSPERM DIVERSIFICATION IN THE EARLY CRETACEOUS DEPOSITS OF THE CLOVERLY FORMATION

**5:15** **WEAVER** AN EMERGING PERSPECTIVE ON MAMMALIAN EVOLUTION ACROSS THE CRETACEOUS-PALEOGENE BOUNDARY IN THE BIGHORN BASIN (WYOMING, U.S.A)

## MONDAY AFTERNOON, JUNE 17, 2024
## A MODEL SYSTEM FOR EVOLUTION AND ENVIRONMENTAL CHANGE: THE MARINE COMMUNITIES OF THE NEOGENE WESTERN ATLANTIC
## UNION ANDERSON
## MODERATORS: Brendan Anderson and Jonathan Hendricks

**1:15** **O'DEA** EVOLUTION AND ENVIRONMENT OF CARIBBEAN COASTAL ECOSYSTEMS *(30-minute keynote)*

**1:45** **HENDY** KOUROU - A NEW AND HIGHLY DIVERSE PLEISTOCENE FOSSIL RECORD FROM THE EQUATORIAL WESTERN ATLANTIC

**2:00** **HENDRICKS** THE PLIO-PLEISTOCENE PINECREST BEDS: PROBLEMS, PROGRESS, AND POTENTIAL

**2:15** **CAMPBELL** PLIOCENE AND EARLY PLEISTOCENE MOLLUSCAN BIODIVERSITY: ZANCLEAN, PIACENZIAN, AND GELASIAN FAUNAS OF SOUTH CAROLINA AND SOUTHERN NORTH CAROLINA

**2:30** **CAMPBELL** EXTINCTION AND ORIGINATION DYNAMICS IN PLIOCENE AND EARLY PLEISTOCENE MOLLUSCA OF SOUTH CAROLINA AND SOUTHERN NORTH CAROLINA

**2:45** **CAMPBELL** DOUBLING THE DIVERSITY OF THE WACCAMAW FORMATION

**3:00** **ALLMON** THE RISES AND FALLS OF TURRITELLID GASTROPODS DURING THE CENOZOIC IN THE WESTERN ATLANTIC

**3:30** **ANDERSON** MACROEVOLUTIONARY AND MACROECOLOGICAL TRENDS IN TURRITELLIDAE IN THE WESTERN ATLANTIC, NEOGENE-RECENT: INSIGHTS FROM AN ABUNDANT, WELL-STUDIED TAXON

**3:45** **THOMPSON** TROPHIC STRUCTURE CHANGES IN NEOGENE GASTROPODS FROM THE SOUTHWESTERN CARIBBEAN

**4:00** **ROJAS ARIZA** TESTING THE FUNCTIONALITY OF TRAITS: INSIGHTS INTO EXTINCTION SELECTIVITY PATTERNS OF LATE CENOZOIC MOLLUSKS

**4:15** **GOMES** CARBONATE CLUMPED ISOTOPE ($\Delta_{47}$) TEMPERATURE RECONSTRUCTIONS FROM THE PLIO-PLEISTOCENE FLORIDA PLATFORM: ASSESSING MARINE CLIMATE CHANGE AS A POTENTIAL EXTINCTION DRIVER

**4:30** **ORNDORFF** EFFECTS OF CLIMATIC WARMING ON MOLLUSCAN ABUNDANCE AND COMMUNITY STRUCTURE DURING THE MID-PLIOCENE WARM PERIOD

**4:45** **THOMAS** A SHORT-LIVED BURST OF ABERRANT POLYMORPHISM IN PLIOCENE POPULATIONS OF *GLYCYMERIS AMERICANA* (BIVALVIA: ARCOIDA), CONSISTENT WITH EXPRESSION OF A TRANSPOSABLE ELEMENT IN ITS GENOME, ASSOCIATED WITH RAPID ENVIRONMENTAL CHANGE IN THE WESTERN ATLANTIC

**5:00** **COLE** MOLLUSCAN SPECIES COMPOSITION AND EVENNESS ACROSS THE MID-PLIOCENE WARM PERIOD AS RECORDED IN THE YORKTOWN FORMATION (SOUTHEASTERN VIRGINIA)

**5:15** **LOCKWOOD** DECLINES IN BIVALVE BODY SIZE ACROSS THE MID-PLIOCENE WARM PERIOD IN SOUTHEASTERN VIRGINIA: IMPLICATIONS FOR ECONOMICALLY IMPORTANT TAXA?

## MONDAY AFTERNOON, JUNE 17, 2024
## LESSONS LEARNED FROM PHANEROZOIC MARINE EXTINCTIONS APPLIED TO MODERN CONSERVATION
## UNION PENDLETON
## MODERATORS: Sinjini Sinha and Claire Williams

**1:15** **BUSH** LESSONS FROM THE LATE DEVONIAN MASS EXTINCTION IN NEW YORK AND PENNSYLVANIA

**1:30** **AL ASWAD** WHAT CAUSES BIOTIC HOMOGENIZATION?

**1:45** **MARTINDALE** ANACHRONISTIC FACIES (WRINKLE STRUCTURES) IN THE AFTERMATH OF THE PLIENSBACHIAN-TOARCIAN EXTINCTION, MOROCCO

**2:00** **STONE** EARLY JURASSIC REEF COLLAPSE AND RECOVERY: HOW KILL MECHANISMS SHIFTED REEF REGIMES

**2:15** **REDDIN** THERMAL PREFERENCES CORRESPOND TO ESCALATORY REGIONAL SPECIES RESPONSES DURING EARLY JURASSIC CLIMATE CHANGE

**2:30** **SINHA** IMPACT OF THE EARLY JURASSIC EXTINCTION (PLIENSBACHIAN-TOARCIAN STAGES) ON THE FUNCTIONAL DIVERSITY OF MARINE MACROFAUNAL COMMUNITIES

**2:45** **GAVIRNENI** WHOLE-BODY AND MASS-SPECIFIC METABOLIC RATE IN BIVALVES AS PREDICTORS OF EXTINCTION SELECTIVITY DURING HYPERTHERMALS AND BEYOND

**3:30** **SULLIVAN** COMPARING THE TAXONOMIC AND FUNCTIONAL TURNOVERS OF BENTHIC FORAMINIFERA ACROSS THE KPG AND THE EOCENE-OLIGOCENE

**3:45** **JACOBS** THE BENGUELA UPWELLING SYSTEM AS SEEN FROM ITS CRETACEOUS NORTHERN LIMIT

**4:00** **MIGUEZ SALAS** COMPARATIVE ICHNOLOGICAL ANALYSIS OF THE PALEOCENE-EOCENE THERMAL MAXIMUM: GOING FROM SHALLOW TO DEEP MARINE SETTINGS AT THE PYRENEAN BASIN, SPAIN

**4:15** **SCHNEIDER** THE ANATOMY OF A MASS EXTINCTION: COMPARING THE PRESENT WITH THE PAST

**4:30** **WILLIAMS** INTEGRATING FOSSIL DATA IMPROVES PREDICTIONS OF FUTURE HABITAT FOR KEY CARIBBEAN REEF CORALS

## MONDAY AFTERNOON, JUNE 17, 2024
## GENERAL SESSION: TAPHONOMY AND ICHNOFOSSILS
## UNION KUENZEL
## MODERATORS: Madison Gaetano and Javier Luque

**1:15** **KIMMIG** DEATH BECOMES THEM: UNDERSTANDING THE EXCEPTIONAL

**1:30** **LUQUE** THE CHIMAERA BEDS LAGERSTÄTTE: TAPHONOMIC WINDOW FOR BURGESS SHALE-TYPE PRESERVATION OF MARINE INVERTEBRATES STILL OPEN DURING THE CRETACEOUS

**1:45** **BRANDT** MUH-ZON/MAY-ZON: THE MAZON CREEK FAUNA AS A CASE FOR INCLUDING PRONUNCIATION GUIDES IN OUR WRITING

**2:00** **CLEMENTS** A NEW TAPHONOMIC MODEL FOR THE MAZON CREEK LAGERSTÄTTE: UNCOVERING THE IMPACT OF PALAEOGEOGRAPHY ON SOFT TISSUE PRESERVATION

**2:15** **MCCOY** TWO-PHOTON FLUORESCENCE MICROSCOPY PROVIDES EVIDENCE OF SUBERIN PRESERVATION IN FOSSIL BARK OF THE MONKEYHAIR TREE FROM THE EOCENE GEISELTAL FOSSIL LAGERSTÄTTE

**2:30** **PLAZA-TORRES** CRETACEOUS MICROBIAL ACTIVITY PRESERVED IN THE CARBON STABLE ISOTOPE COMPOSITIONS OF HERBIVOROUS DINOSAUR COPROLITES

**2:45** *withdrawn*

**3:30** **NEBELSICK** PRESERVATION POTENTIALS, SKELETAL ARCHITECTURES AND THE SEDIMENTARY RECORD OF NEARSHORE REGULAR ECHINOIDS

**3:45** **JACOBS** LIVE-DEAD COMPARISONS IN TROPICAL REEF SETTINGS RECORD PREDATOR-PREY INTERACTIONS, AND HYDROLOGIC PROCESSES, BUT ARE BIASED BY "PAGURIZATION"

**4:00** **NICOL** ATTACK OF THE CRABS: PREDATION TRACES INDICATING A SUCCESSFUL ATTACK

**4:15** **GAETANO** RODENTS AS TAPHONOMIC AGENTS IN ARCTIC ECOSYSTEMS

**4:30** **CHIAPPONE** FLUVIAL MOBILITY OF HADROSAUROID DINOSAUR SKELETONS: EXPERIMENTALLY TESTING TRANSPORT POTENTIAL IN EXTINCT REPTILES

**4:45** **FIORILLO** A RICH NEW RECORD OF DINOSAUR TRACKS FROM AN UNNAMED CRETACEOUS ROCK UNIT ALONG THE YUKON RIVER IN WEST-CENTRAL ALASKA

**5:00** **WHITE** INTERPRETATION OF EOLIAN ICHNOFOSSILS USING NEOICHNOLOGY OF DESERT ARTHROPODS

## MONDAY AFTERNOON, JUNE 17, 2024
## PROXIES, SEDIMENTOLOGICAL INDICATORS, AND BIOTIC EFFECTS OF OCEANIC ANOXIC EVENTS IN THE GEOLOGICAL RECORD
## UNION WOLVERINE
## MODERATORS: Brian Huber and Joan Bernhard

**1:15** **BOWSER** COPROLITES OF MONOTHALAMIC FORAMINIFERA AND GROMIIDS: STERCOMATA AS MICROFOSSILS IN MICROPALEONTOLOGY

**1:30** **BERNHARD** THE EMERGING PALEO-OXYGEN PROXY MN/CA IN BENTHIC FORAMINIFERA: AN EXPLANATION FOR NON-CONFORMANCE BY KLEPTOPLASTIDIC FORAMINIFERS IN DYSOXIC TO EUXINIC ENVIRONMENTS

**1:45** **GLOCK** PORE CHARACTERISTICS OF CALCAREOUS BENTHIC FORAMINIFERA AS QUANTITATIVE PROXY FOR PAST NITRATE AND OXYGEN CONCENTRATIONS

**2:00** **ALCORN** VERTICAL REORGANIZATION OF THE NORTH PACIFIC OXYGEN MINIMUM ZONE DURING DEGLACIAL WARMING

**2:15** **BURKETT** AN ASSESSMENT OF THE PALEOCENE-EOCENE THERMAL MAXIMUM AND ITS IMPACT ON THE ECOLOGY, GEOCHEMISTRY, AND DENSITY OF BENTHIC FORAMINIFERAL COMMUNITIES ON THE AGULHAS PLATEAU

**2:30** **WAN** COMBINED STABLE O, CA, AND SR ISOTOPE RECORDS REVEAL COCCOLITHOPHORE FEEDBACKS ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM

**2:45** **LI** THE LOCAL/REGIONAL HETEROGENEOUS BENTHIC REDOX RESPONSES TO THE OCEANIC ANOXIC EVENT-2 AS INDICATED BY SEDIMENTARY VANADIUM ISOTOPIC COMPOSITIONS

**3:30** **FEARON** SELECTIVE SURVIVAL OF INFAUNAL DECAPODS OVER THE CENOMANIAN-TURONIAN EXTINCTION (OAE 2)

**3:45** **JACOBSON** HIGH-PRECISION CA ISOTOPE MEASUREMENTS REVEAL POTENTIAL BIOMINERALIZATION CRISES DURING MAJOR CARBON CYCLE PERTURBATIONS

**4:00** **WANG** BIOCALCIFICATION CRISIS INDICATED BY STABLE CA AND SR ISOTOPES DURING OAE1A

**4:15** **HUBER** PURSUIT OF AN EXPLANATION FOR THE PLANKTONIC FORAMINIFERAL MASS EXTINCTION AND CARBON CYCLE PERTURBATION ACROSS OCEANIC ANOXIC EVENT 1B (113 MA)

**4:30** **CHEN** BIOCALCIFICATION STRESS AND FAUNAL TURNOVER AT THE APTIAN-ALBIAN BOUNDARY

**4:45** **COHEN** MICROFOSSIL DIVERSITY AND ABUNDANCE DURING THE LATE DEVONIAN LOWER KELLWASSER EVENT IN THE APPALACHIAN BASIN: IMPLICATIONS FOR EXTINCTION TRIGGERS AND ECOSYSTEM RESPONSE

**5:00** **MARROQUÍN** PROLONGED ANOXIA ACROSS THE TOARCIAN OCEANIC ANOXIC EVENT (T-OAE) WITHIN THE EUROPEAN EPICONTINENTAL SEAWAY

**5:15** **ROSELLI** DISKS AND DYSOXIA: INVESTIGATING POTENTIAL RELATIONSHIPS BETWEEN REDOX CONDITIONS AND SOFT-BODIED PRESERVATION FROM THE MIDDLE DEVONIAN (GIVETIAN) APPALACHIAN BASIN

**MONDAY AFTERNOON, JUNE 17, 2024**
**PALEONEUROLOGY**
**UNION 2210**
**MODERATORS: Rodrigo Tinoco Figueroa and Matteo Fabbri**

**1:15** *withdrawn*

**1:30** **ORTEGA-HERNÁNDEZ** ANATOMY, PRESERVATION AND EVOLUTIONARY SIGNIFICANCE OF THE CENTRAL NERVOUS SYSTEM IN AN ORDOVICIAN TRILOBITE

**1:45** **FIGUEROA** BRAIN OF ALL TRADES: THE NEUROANATOMICAL DIVERSITY OF RAY-FINNED FISHES

**2:00** **GILES** RAY-FINNED FISH NEUROANATOMICAL EVOLUTION REVEALED THROUGH EXCEPTIONAL FOSSIL SOFT TISSUE PRESERVATION

**2:15** **BALANOFF** INTEGRATIVE NEUROANATOMY AND THE ORIGIN OF BIRDS

**2:30** **YOHE** PALEONEUROBIOLOGY OF THE TETRAPOD OLFACTORY BULB INFERRED FROM EXTANT OLFACTORY RECEPTOR REPERTOIRES

**2:45** **FABBRI** THE NERVOUS SYSTEM SHAPES THE SKULL DURING DEVELOPMENT AND EVOLUTION

**3:30** **ORTEGA-HERNÁNDEZ** THE EVOLUTIONARY SIGNIFICANCE AND PRESERVATION OF FOSSILIZED CENTRAL NERVOUS SYSTEMS IN CAMBRIAN METAZOANS

**3:45** **BAZZANA-ADAMS** MORPHOLOGICAL COVARIATION BETWEEN THE INNER EAR, BRAIN, AND BRAINCASE OF THE LEOPARD GECKO (*EUBLEPHARIS*)

**4:00** **LANG** ENDOCRANIAL SHAPE VARIATION IN MADAGASCAR'S SUBFOSSIL LEMURS

**4:15** **BERTRAND** THE VIRTUAL BRAIN ENDOCAST OF *INCAMYS BOLIVIANUS*: INSIGHT FROM THE NEUROSENSORY SYSTEM INTO UNDERSTANDING THE ADAPTIVE RADIATION OF SOUTH AMERICAN RODENTS

**4:30** **WATANABE** ENDOCRANIAL DEVELOPMENT IN NON-AVIAN DINOSAURS REVEALS AN ONTOGENETIC BRAIN TRAJECTORY DISTINCT FROM EXTANT ARCHOSAURS

**4:45** **SCOTT** NEW INFORMATION ON THE BRAIN CAVITY AND INNER EAR OF *PACHYRHINOSAURUS LAKUSTAI* BASED ON CT SCANNING AND 3D VISUALIZATION

**5:00** **BURKE** CAN ENDOCRANIAL FEATURES HELP ELUCIDATE THE EVOLUTIONARY HISTORY OF GAVIALOIDS?

## MONDAY AFTERNOON, JUNE 17, 2024
## MANAGING AND ENGAGING WITH FEDERAL PALEONTOLOGICAL RESOURCES IN THE 21ST CENTURY
## UNION POND
## MODERATORS: Adam Rountrey and Brent Breithaupt

**1:15** **TWEET** THE COLLECTED PALEONTOLOGICAL HERITAGE OF THE NATIONAL PARK SERVICE

**1:30** **BOBER** AN OVERVIEW OF PALEOZOIC PALEOBOTANICAL RESOURCES DOCUMENTED IN NATIONAL PARK SERVICE AREAS

**1:45** **VISAGGI** PALEONTOLOGY IN THE PARKS FELLOWSHIPS: A PROGRESS UPDATE ON THE NATIONAL PARK SERVICE AND PALEONTOLOGICAL SOCIETY COLLABORATIVE PROGRAM

**2:00** **LIGGETT** A NEW TYPE OF RAPTOR: RECREATION AND PERMIT TRACKING ONLINE REPORTING

**2:15** **BREITHAUPT** MANAGEMENT OF PALEONTOLOGICAL RESOURCES USING PHOTOGRAMMETRY IN THE 21ST CENTURY: AN ERA OF ADVANCEMENT

**2:30** **RAPP** STORING RADIOACTIVE FOSSILS SAFELY, A CASE STUDY FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT

**2:45** **SCANNELLA** UNCOVERING, CONSERVING, AND INCREASING ACCESS TO FEDERAL PALEONTOLOGICAL RESOURCES AT MUSEUM OF THE ROCKIES

**3:00** **NAKANO** REBUILDING PARTNERSHIPS FOR THE CARE OF FEDERAL PALEONTOLOGICAL RESOURCES AT THE SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY

## MONDAY POSTERS, JUNE 17, 2024
## UNION IDEA HUB
## PRESENTERS SHOULD ATTEND POSTERS FROM 5:30–6:15

### THE BIGHORN BASIN: NEW FRONTIERS AND INTER-GENERATIONAL KNOWLEDGE OF A MODEL SYSTEM FOR STUDYING TERRESTRIAL ECOSYSTEM EVOLUTION

1 *withdrawn*

2 **FARKE** THE "MESAVERDE" FORMATION (CAMPANIAN) OF THE BIGHORN BASIN, WYOMING, U.S.A.: A KEY TO UNRAVELING LATE CRETACEOUS FAUNAL PROVINCIALITY IN LARAMIDIA?

3 **FLYNN** PRELIMINARY REPORT OF EARLY EOCENE FLORAS FROM THE LOWER SAN JOSE FORMATION, NEW MEXICO, USA

4 **KING** LITTLE BIGFOOT: A PATHOLOGIC ARTICULATED PES OF A SAUROPOD DINOSAUR FROM THE MORRISON FORMATION, BIGHORN BASIN, WY

5 **KRUMENACKER** A POTENTIALLY NEW DRYOMOPRH ORNITHOPOD FROM THE LATE JURASSIC MORRISON FORMATION SIMON QUARRY OF THE BIGHORN BASIN, WYOMING

6 **RAYNOLDS** TWO EPISODES OF DEFORMATION AND SEDIMENTATION IN THE LARAMIDE BIGHORN BASIN, WYOMING

### A MODEL SYSTEM FOR EVOLUTION AND ENVIRONMENTAL CHANGE: THE MARINE COMMUNITIES OF THE NEOGENE WESTERN ATLANTIC

7 **BIONDI** EXAMINING IMPACTS OF THE MID-PLIOCENE WARM PERIOD ON MOLLUSCAN DIVERSITY, RICHNESS, AND ABUNDANCE WITHIN THE YORKTOWN FORMATION (SOUTHEASTERN VIRGINIA)

8 **CAMPBELL** A STRATIGRAPHIC MODEL FOR THE MODEL SYSTEM: IDENTIFYING THE MID-PLIOCENE TRANSGRESSIVE INTERVALS IN THE SOUTHEASTERN US

9 **DAVIS** ISOTOPIC ECOLOGY OF LARGE BARNACLES FROM THE MIDDLE MIOCENE CLIMATIC TRANSITION, CALVERT CLIFFS, MARYLAND: DO BARNACLE PLATES RECORD SIMILAR PALEOCLIMATIC SIGNATURES AND DO BARNACLES HAVE SEASONAL LIGHT AND DARK GROWTH BANDS LIKE MOLLUSKS?

10 **DEL RÍO** EARLY MIOCENE PALEOTEMPERATURES FOR THE HIGH AUSTRAL SW ATLANTIC DERIVED FROM FOSSIL BIVALVES IN PATAGONIA, ARGENTINA

11 **DOWSETT** STRATIGRAPHIC FRAMEWORK FOR THE MID PIACENZIAN WARM PERIOD ON THE U.S. ATLANTIC COASTAL PLAIN

12 **GALE** A GLOBAL COMPARISON OF THE REGIONAL DYNAMICS IN MARINE BIVALVE FUNCTIONAL DIVERSITY UNDER CLIMATE CHANGE IN THE PAST 5 MILLION YEARS.

13 **MCKENZIE** THE SIGNIFICANCE OF ENCRUSTING TAXA AND BORING ICHNOTAXA ON MARINE BIVALVES IN THE MIOCENE, SHALLOW MARINE CALVERT AND CHOPTANK FORMATIONS, CALVERT CLIFFS, MARYLAND

14 **POLI** CHANGES IN ABYSSAL BENTHIC FORAMINIFERAL ASSEMBLAGES IN THE WESTERN NORTH ATLANTIC DURING THE LAST 3 MILLION YEARS (BERMUDA RISE, ODP SITE 1063)

15 **VISAGGI** MARINE MOLLUSCAN COMMUNITIES OF THE PLIO-PLEISTOCENE NASHUA FORMATION FROM MULTIPLE LOCALITIES IN NORTH-CENTRAL FLORIDA

16 **WATERS** DO CHANGES IN SPAWNING SEASON OF *CHIONE* SP. FACTOR INTO SURVIVORSHIP THROUGH THE PLIO-PLEISTOCENE MOLLUSCAN EXTINCTION?

## LESSONS LEARNED FROM PHANEROZOIC MARINE EXTINCTIONS APPLIED TO MODERN CONSERVATION

**17** **HASSELL** CORALLINE ALGAE RESPONSE TO THE PALEOCENE-EOCENE THERMAL MAXIMUM IN NORTH-EASTERN INDIA AND SOUTHERN TIBET

**18** **SHUSTER** UPCYCLING PLASTIC WASTE TO MODEL DANGERS OF THE SIXTH EXTINCTION: VICTIMS OF THE "BIG 5" SEEN THROUGH THE TRASH OF TODAY

## GENERAL SESSION: TAPHONOMY AND ICHNOFOSSILS

**19** **BURNS** PRESERVATION VERSUS CHEMICAL AND BIOLOGICAL DISSOLUTION OF SHELLY CARBONATE AT THE EAST FLOWER GARDEN BRINE SEEP, GULF OF MEXICO

**20** **GUNDERSON** TAPHONOMY OF NAUTILOID CEPHALOPODS FROM THE MIDDLE SILURIAN MASSIE FORMATION OF SOUTHEASTERN INDIANA

**21** **JUSTICE** UNRAVELING THE EFFECTS OF PRESERVATIONAL BIASES ON GASTROPOD DIVERSITY TRENDS FROM THE JURASSIC TO THE PALEOGENE

**22** **KRAPOVICKAS** TRACKWAYS OF A SMALL, QUADRUPEDAL DINOSAUR FROM THE MIDDLE JURASSIC OF PATAGONIA AND ITS IMPLICATIONS FOR LOCOMOTOR EVOLUTION WITHIN ORNITHISCHIA

**24** **MILLER-CAMP** A NEW REPORT ON FLORA AND FAUNA FROM THE MIDDLE PENNSYLVANIAN "STANLEY CEMETARY" LOCALITY IN SOUTHERN INDIANA, A LITTLE-KNOWN LAGGERSTÄTTE FROM A MAZON CREEK-LIKE ENVIRONMENT

**25** **MORRIS** A LIVE-DEAD STUDY OF TAXONOMIC AND FUNCTIONAL DIVERSITY IN GREAT BASIN SMALL MAMMALS

**26** **MUSSO** HYDRODYNAMICS OF NON-UNIFORM, DISARTICULATED CRINOID GRAINS AND THEIR RELEVANCE TO THE MISSISSIPPIAN ROCK RECORD

**27** **POTTER** SCANNING ELECTRON MICROSCOPE INVESTIGATION INTO THE PRESERVATION OF THE "TULLY MONSTER"

**28** **PRZEDWIECKI** MORPHOMETRICS OF CONOSTICHOID BURROWS WITH BIOCLASTIC INFILL FROM THE SILURIAN OF SOUTHERN INDIANA

**29** **SHELBURNE** CHARACTERIZING SOFT TISSUE PRESERVATION IN MAZON CREEK (PALEOZOIC; PENNSYLVANIAN) AMPHIBAMIFORMS (TEMNOSPONDYLI; AMPHIBAMIFORMES)

**30** **TAMEZ** TRILOBITES BURROWING, WALKING, AND FEEDING IN TIDAL FLATS OF THE LATE ORDOVICIAN SEQUATCHIE FORMATION OF GEORGIA, USA

**31** **WHITAKER** A TALE OF TWO LAGERSTÄTTEN: SIMILARITIES AND DIFFERENCES BETWEEN THE SILURIAN ERAMOSA FORMATION AND BRANDON BRIDGE FORMATION OF NORTH AMERICA

**32** **ZHENG** A LATE TONIAN LAGERSTÄTTE: PICKLED VASE-SHAPED MICROFOSSILS FROM THE CHUAR GROUP, GRAND CANYON, USA

## PROXIES, SEDIMENTOLOGICAL INDICATORS, AND BIOTIC EFFECTS OF OCEANIC ANOXIC EVENTS IN THE GEOLOGICAL RECORD

**33** **ASHING-GIWA** THE GOOD, THE BAD, AND THE HYPOXIC: INVESTIGATING THE RESPONSE OF BRACHIOPODS AND BIVALVES TO LOW-OXYGEN CONDITIONS

**34** **BATEMAN** INVESTIGATION OF A UNIQUE END-DEVONIAN EXTINCTION LOCALITY IN WESTERN NEW YORK

**35** **BURKE** REDISTRIBUTION OF MARINE OXYGEN DEFICIENT ZONES DURING THE MID-MIOCENE

**36** **MCCABE** THE END-TRIASSIC ENIGMA: LONG-TERM OXYGEN LOSS AND ENVIRONMENTAL DESTABILIZATION PRECEDED THE END-TRIASSIC MASS EXTINCTION

## PALEONEUROLOGY

**37** **FOSTER** CONTRIBUTIONS TO THE CRANIAL ANATOMY OF THE EARLY TRIASSIC RHYNCHOSAUR *MESOSUCHUS BROWNI* WITH A DISCUSSION OF VOMEROLFACTORY EVOLUTION ACCROSS CROWN ARCHELOSAURIA

## MANAGING AND ENGAGING WITH FEDERAL PALEONTOLOGICAL RESOURCES IN THE 21ST CENTURY

**38** **BONDE** COLLABORATIVE PARTNERSHIPS ENHANCE SCIENTIFIC RESEARCH AND RESOURCE MANAGEMENT IN A NEW NATIONAL PARK SERVICE UNIT: TULE SPRINGS FOSSIL BEDS NATIONAL MONUMENT (TUSK)

**39** **MILLER** NEW TETRAPOD TRACKWAYS IN THE COCONINO SANDSTONE, GRAND CANYON NATIONAL PARK, ARIZONA

**40** **PARRY** A COLLABORATIVE MODEL FOR RECOVERING LOST HISTORIC PALEONTOLOGICAL LOCALITIES AND FOSSIL PROVENIENCE ON FEDERAL LANDS

**41** **PEECOOK** THE GIGANTIC EGG CAME FIRST: A STATE-FEDERAL PARTNERSHIP USING CUTTING-EDGE SCANNING AND 3D PRINTING TECHNOLOGY FOR A MAJOR EXHIBITION

**42** **PULSIPHER** BRINGING THE HERMIT OUT OF HIDING: A REINVESTIGATION OF THE PERMIAN HERMIT FLORA IN GRAND CANYON NATIONAL PARK AFTER NEARLY A CENTURY IN OBSCURITY

**43** **SHELL** VERTEBRATE PALEONTOLOGICAL RESOURCES FROM LOWER CARBONIFEROUS ROCKS OF THE HOOSIER AND SHAWNEE NATIONAL FORESTS (USA: ILLINOIS AND INDIANA)

**44** **VAN VELDHUIZEN** DEVELOPING PROCEDURES FOR THE MIGRATION OF LEGACY PALEONTOLOGICAL LOCALITIES INTO THE BUREAU OF LAND MANAGEMENT'S RECREATION AND PERMIT TRACKING ONLINE REPORTING (RAPTOR) PALEONTOLOGICAL LOCALITIES DATABASE

**TUESDAY MORNING, JUNE 18, 2024**
**UNION ROGEL**
**EVOLUTIONARY PALEOBIOLOGY IN THE 21ST CENTURY: ADVANCING THE LEGACY OF JIM VALENTINE**
**MODERATORS: Charles Marshall and Seth Finnegan**

**8:00** **ERWIN** JIM VALENTINE AND THE EVOLUTION OF BODYPLANS

**8:15** **SIMPSON** THE ORIGIN OF ANIMALS FROM A UNICELLULAR PERSPECTIVE

**8:30** **WAGNER** MACROEVOLUTIONARY MOUSE, PHYLOGENETIC MOUSETRAP: THE BROAD IMPLICATIONS OF EARLY BURSTS

**8:45** **NG** EVOLUTION OF DEVELOPMENT ON MICRO- AND MACROEVOLUTIONARY TIMESCALES IN MURINE RODENTS OF SOUTHWEST AUSTRALIA

**9:00** **SOSIAK** TRAIT-BASED PALEONTOLOGICAL NICHE PREDICTION RECOVERS EXTINCT ECOLOGICAL BREADTH OF THE EARLIEST SPECIALIZED ANT PREDATORS

**9:15** **PATZKOWSKY** VALENTINIAN ECOSPACE, ENVIRONMENTAL AFFINITIES, AND THE ORDOVICIAN RADIATION OF BRACHIOPODS

**9:30** **STANLEY** THE GREAT ORDOVICIAN BIODIVERSIFICATION EVENT HAD NO EXTERNAL CAUSE BUT WAS SIMPLY THE RESULT OF MANY NEW HIGHER TAXA RADIATING AT THEIR INTRINSIC RATES

**10:15** **RICHARDS** A NEW LUOLISHANIID FROM THE EARLY ORDOVICIAN AND THE AUTECOLOGY OF SUSPENSION-FEEDING LOBOPODIANS

**10:30** **LOSSO** TRILOBITES FROM THE WALCOTT-RUST QUARRY (MOHAWKIAN; ORDOVICIAN), NEW YORK: NEW INSIGHTS AFTER 150 YEARS

**10:45** **RIVERO-VEGA** DIVERSIFICATION OF JAW GEOMETRY DURING THE INITIAL RADIATION OF LOBE-FINNED FISHES (OSTEICHTHYES: SARCOPTERYGII)

**11:00** **JORDAN** TRILOBITE CO-OCCURRENCE PATTERNS ACROSS THE DEVONIAN-CARBONIFEROUS BOUNDARY

**11:15** **SHI** DIVERSITY-INDEPENDENT FUSULINID DIVERSIFICATION PATTERN DURING THE LATE PALEOZOIC ICE AGE EXPOSED BY A HIGH-TEMPORAL-RESOLUTION SPECIES RICHNESS ANALYSIS

**11:30** **KLOMPMAKER** WERE DECAPOD CRUSTACEANS IN ALABAMA ADVERSELY AFFECTED BY THE CRETACEOUS-PALEOGENE MASS EXTINCTION?

**11:45** **ZHOU** LOSS AND REBOUND OF MORPHOLOGICAL AND FUNCTIONAL DISPARITY AFTER A NON-SELECTIVE MASS EXTINCTION AT THE K/PG BOUNDARY (FAMILY VENERIDAE, BIVALVIA)

**TUESDAY MORNING, JUNE 18, 2024**
**UNION ANDERSON**
**GENERAL SESSION: CENOZOIC TETRAPODS**
**MODERATORS: Val Syverson and Andrew Weber**

**8:00** **SILVIRIA** AN EXCEPTIONAL MAMMAL LOCALITY FROM THE FIRST ~28 KYRS AFTER THE CRETACEOUS-PALEOGENE MASS EXTINCTION IN NORTHEASTERN MONTANA WITH LANCIAN-ASPECT 'DEAD CLADES WALKING'

**8:15** **WRIGHT** MINING FOR BLANCAN GOLD: THE RICHMOND HILL LOCAL FAUNA OF THE BLACK HILLS, SOUTH DAKOTA

**8:30** **SYVERSON** REVISING AND UPDATING QUATERNARY $^{14}$C CHRONOLOGIES IN THE NEOTOMA PALEOECOLOGY DATABASE FOR COMMUNITY PALEOECOLOGY

**8:45** **WARD** ISOTOPIC EVIDENCE REVEALS LIMITED MOBILITY IN THE SHORT-LEGGED RHINOCEROS *TELEOCERAS MAJOR* AT ASHFALL FOSSIL BEDS, USA

**9:00** **STRASSBERG** LOST DIGGING MODES OF Z: RECONSTRUCTING FOSSORIAL FUNCTION AND EXTINCT DIGGING STRATEGIES IN FOSSIL MAMMALS USING A COMPREHENSIVE MORPHOMETRIC FRAMEWORK

**9:15** **MEREGHETTI** A MAMMOTH DIET: UNDERSTANDING ECOLOGY AND BEHAVIOR OF *MAMMUTHUS PRIMIGENIUS* TO UNDERSTAND CAUSES AND CONSEQUENCES OF ITS EXTINCTION

**9:30** **AMEEN** SYSTEMATICS AND PALEOCLIMATE OF TERRESTRIAL MAMMALIAN FAUNA FROM THE LATE MIOCENE (11.2–3.58 MA) SIWALIK DEPOSITS OF PAKISTAN

**TUESDAY MORNING, JUNE 18, 2024**
**UNION ANDERSON**
**FIFTY YEARS IN THE HIMALAYAN FOOTHILLS: ECOSYSTEM CHANGE IN THE NEOGENE SIWALIK RECORD OF PAKISTAN**
**MODERATORS: Catherine Badgley, Michele E. Morgan, and Kay Behrensmeyer**

**10:15** **RAZA** VERTEBRATE PALEONTOLOGY RESEARCH IN PAKISTAN: HISTORY, PRESENT, AND THE FUTURE *(30-minute keynote)*

**10:45** **RAYNOLDS** TIME ON THE GROUND IN THE HIMALAYAN MOLASSE SEDIMENTS; OBSERVATIONS FROM KHAUR TO KASHMIR

**11:00** **WILLIS** RECONSTRUCTING DEPOSITIONAL PATTERNS OF THE SIWALIK FLUVIAL SYSTEMS, CHINJI AND NAGRI FORMATIONS, POTWAR PLATEAU, PAKISTAN

**11:15** **QUADE** THE SIWALIK GROUP RECORD AND THE EXPANSION OF C4 VEGETATION IN THE MIOCENE

**11:30** **KARP** NEOGENE CLIMATE-FIRE-VEGETATION FEEDBACKS IN THE SIWALIKS AND BEYOND

**11:45** **BEHRENSMEYER** TAPHONOMIC CONTROLS ON THE SIWALIK VERTEBRATE FOSSIL RECORD

**TUESDAY MORNING, JUNE 18, 2024**
**UNION PENDLETON**
**FROM CAVES TO CENOTES: PLEISTOCENE VERTEBRATE PALEONTOLOGY OF THE YUCATAN, MEXICO AND BELIZE**
**MODERATORS: Blaine Schubert and Joaquin Arroyo-Cabrales**

**8:00** **CHATTERS** INTRODUCING THE HOYO NEGRO VERTEBRATE FAUNA, QUINTANA ROO, MÉXICO *(30-minute keynote)*

**8:30** **RISSOLO** RECENT ADVANCES IN VISUAL ANALYTICS AND VIRTUAL ACCESS TO SUBMERGED LATE PLEISTOCENE AND EARLY HOLOCENE FAUNAL DEPOSITS IN THE SUBMERGED CAVES OF THE YUCATAN PENINSULA

**8:45** **REINHARDT** RECONSTRUCTING PAST GROUNDWATER LEVELS IN HOYO NEGRO, SAC ACTUN CAVE SYSTEM, QUINTANA ROO, MEXICO

**9:00** **ARROYO-CABRALES** UNGULATES AND PROBOSCIDEANS FROM CENOTE HOYO NEGRO, QUINTANA ROO, MEXICO

**9:15** **SCHUBERT** EXCEPTIONAL RECORDS OF EXTINCT CARNIVORANS (*ARCTOTHERIUM*, *PROTOCYON*, AND *SMILODON*) FROM SUBMERGED CAVES OF THE YUCATAN PENINSULA, MEXICO

**9:30** **SAMUELS** NEW CARNIVORAN FOSSILS OF THE NATURAL TRAP HOYO NEGRO, FROM A SUBMERGED CAVE IN THE YUCATAN PENINSULA OF MEXICO

**10:15** **MCDONALD** UPDATE ON THE EXTINCT SLOTH *NOHOCHICHAK* AND ITS RELATIONSHIP TO PLEISTOCENE SLOTH DIVERSITY OF THE YUCATAN REGION

**10:30** **CHATTERS** A HIGHLY DIVERSE ASSEMBLAGE OF GIANT GROUND SLOTHS FROM HOYO NEGRO, QUINTANA ROO, MEXICO.

**10:45** **WIDGA** COMBINED MICRO-COMPUTED TOMOGRAPHY AND SERIAL STABLE ISOTOPE ANALYSES OF GROUND SLOTHS FROM CENOTE HOYO NEGRO (QUINTANA ROO, MEXICO)

**11:00** **CRUZ** SMALL VERTEBRATES FROM HOYO NEGRO AND THEIR PALAEOECOLOGICAL IMPORTANCE

**11:15** **OVANDO** VERTEBRATE PALEONTOLOGY OF PLEISTOCENE SITES IN BELIZE

**11:30** **MCDONALD** *EREMOTHERIUM* BONES AND THE CENOTE OF DOOM: ADVENTURES IN UNDERWATER PALEONTOLOGY

**11:45** *discussion*

**TUESDAY MORNING, JUNE 18, 2024**
**UNION KUENZEL**
**DAWN OF ANIMAL LIFE: EXPLORING NEW ADVANCES IN EDIACARAN PALEOBIOLOGY**
**MODERATORS: Princess Aira Buma-at, Prescott Vayda, and Philip Boan**

**8:00** **TARHAN** THE ROLE OF MARINE SILICA CYCLING IN DRIVING THE EXCEPTIONAL FOSSILIZATION OF EARTH'S EARLIEST ANIMAL COMMUNITIES *(30-minute keynote)*

**8:30** **KAUFMAN** THE NEOPROTEROZOIC EMERGENCE AND ENVIRONMENTAL CONSEQUENCES OF BIOMINERALIZED SPONGE GRADE ANIMALS

**8:45** **SURPRENANT** A REVIEW OF THE GLOBAL RECORD OF THE EDIACARAN TUBULAR MORPHOTYPE

**9:00** **LIU** ESTABLISHING THE ENVIRONMENTAL CONTEXT FOR EARTH'S FIRST 'MASS EXTINCTION'

**9:15** **BOBROVKSY** HOW DID THE CREATURES OF THE EDIACARA BIOTA LOOK LIKE?

**9:30** **BOAN** *DICKINSONIA* AND SPRIGGINAMORPH AT NILPENA EDIACARA NATIONAL PARK, SOUTH AUSTRALIA

**10:15** **SELLY** TAXONOMIC REASSESSMENT OF *CLOUDINA*? FROM THE TAYLOR FORMATION, ANTARCTICA

**10:30** **VIXSEBOXSE** AN EXOGENOUS ENZYMATIC CONTROL ON SOFT-TISSUE PRESERVATION IN THE EARLY ANIMAL FOSSIL RECORD

**10:45** **MITCHELL** VARIATIONS IN DENSITY DEPENDENT PROCESSES IN EARLY EDIACARAN COMMUNITIES

**11:00** **OSÉS** SKELETAL ORGANISATION, COMPOSITION AND CONTROLLED BIOMINERALIZATION OF EDIACARAN *CORUMBELLA WERNERI*

**11:15** **MCCANDLESS** PUTTING ALGAE IN EDIACARAN ECOSYSTEMS

**11:30** **PEREZ PINEDO** HYDRODYNAMIC INSIGHTS INTO THE PALAEOBIOLOGY OF THE EDIACARAN RANGEOMORPH *FRACTOFUSUS MISRAI*

**TUESDAY MORNING, JUNE 18, 2024**
**UNION WOLVERINE**
**GENERAL SESSION: MESOZOIC REPTILES**
**MODERATORS: Peter Makovicky and Omar Rafael Regalado Fernández**

**8:30** **KLIGMAN** EXCEPTIONALLY DIVERSE LATE TRIASSIC LEPIDOSAUR ASSEMBLAGE ILLUMINATES SQUAMATE ORIGINS

**8:45** **MELSTROM** DENTAL COMPLEXITY DISPARITY OF LATE TRIASSIC REPTILES APPROACHES THAT OF EXTANT LEPIDOSAURIA

**9:00** **WILSON MANTILLA** A NEW KURMADEMYDINE TURTLE (PLEURODIRA: BOTHREMYDIDAE) FROM THE CRETACEOUS-PALEOGENE INTERTRAPPEANS OF UPPARHATTI (KARNATAKA STATE), INDIA

**9:15** **REGALADO FERNÁNDEZ** FIELD TRIP IN THE MUSEUM: A NEW DINOSAUR BONEBED FROM NIOBRARA COUNTY, WYOMING

**9:30** **RADERMACHER** QUANTIFYING WEAR IN ORNITHOPOD AND CERATOPSIAN DENTAL BATTERIES

**10:15** **BOISVERT** ELEVEN SPECIMENS FROM TEN LOCALES IN EIGHT COLLECTIONS ACROSS THREE STATES, THE DIVERSITY OF KNOWN *HAPLOCANTHOSAURUS* SPECIMENS IN THE MORRISON FORMATION.

**10:30** **BOISVERT** THE OSTEOLOGICAL NEUTRAL POSE OF THE NECK OF AN APATOSAURINE SAUROPOD FROM MILL CANYON (UPPER JURASSIC, MORRISON FORMATION) NEAR MOAB, UTAH.

**10:45** **WILSON MANTILLA** AN EVOLUTIONARY DWARF TITANOSAUR (DINOSAURIA: SAUROPODA) FROM THE UPPER CRETACEOUS (MAASTRICHTIAN) OF AFRO-ARABIA

**11:00** **MAKOVICKY** A NEW, NEARLY COMPLETE SPECIMEN OF *ALNASHETRI CERROPOLICIENSIS* SHEDS LIGHT ON THE COMPLEX EVOLUTIONARY HISTORY OF ALVAREZSAUROIDEA

**11:15** **NORRIS** PROBLEMS AND SOLUTIONS FOR USING CALCIUM ISOTOPE RATIOS OF TEETH AS A PROXY FOR DINOSAUR PALEOECOLOGY

**11:30** **DEAN** OCCUPANCY MODELLING REVEALS SAMPLING BIASES DRIVE THE OBSERVED END-CRETACEOUS DINOSAUR DECLINE

**11:45** **HOLTZ** DINOSAURIAN VS. MAMMALIAN ONTOGENY AND ECOLOGY: THE EFFECT OF A MOTHER'S LOVE ON COMMUNITY STRUCTURE

**TUESDAY MORNING, JUNE 18, 2024**
**UNION 2210**
**GENERAL SESSION: INTEGRATIVE PALEOBIOLOGY**
**MODERATORS: Norman MacLeod and Rowan Whittle**

**8:00** **MCMENAMIN** *PALEODICTYON*, MICROBURROWS, AND THE ORIGIN OF ANIMALS

**8:15** **SUN** SPATIOTEMPORAL DISTRIBUTION AND MORPHOLOGICAL DIVERSITY OF CAMBRIAN ENIGMA *WIWAXIA*: NEW INSIGHTS FROM SOUTH CHINA

**8:30** **BOYER** MORE THAN JUST STROMATOPOROID STORM DEPOSITS: INTERPRETING AN ECOLOGICAL SIGNAL OF *AMPHIPORA* FROM THE GREAT BASIN, U.S.A.

**8:45** **FREEMAN PETERS** SEVEN HABITS OF HIGHLY EFFECTIVE WORMS: HOST TEXTURE PREFERENCE IN DEVONIAN MICROCONCHIDS

**9:00** **MA** REVISITING ORDOVICIAN TEMPERATURE RECORDS

**9:15** **NA** LATITUDINAL GRADIENT CONTROL ON EARLY PALEOZOIC BIODIVERSITY AND ECOSYSTEM FUNCTIONING

**9:30** **XU** COUPLING AND DECOUPLING OF TAXONOMIC AND ECOLOGICAL DIVERSITIES DURING THE LATE PALEOZOIC

**10:15** **WHITTLE** ANTARCTICA'S EARLIEST CENOZOIC GLACIAL COMMUNITIES

**10:30** **BROCCHINI** WHAT WE TALK ABOUT WHEN WE TALK ABOUT COEVOLUTION: REEVALUATING A DOMINANT EXPLANATION FOR THE GEOGRAPHICALLY UNEVEN INTENSITY OF THE LATE QUATERNARY MEGAFAUNAL EXTINCTIONS

**10:45** **HOWARD** A SIMULATION FOR ESTIMATING EXPECTED DIVERSITY OF A CLADE

**11:00** **MACLEOD** DOES DIMENSIONALITY-REDUCTION METHOD MATTER FOR MORPHOLOGICAL DISPARITY (AND OTHER) STUDIES?

**11:15** **WOOLLEY** QUANTIFYING THE REPRESENTATION OF THE SKELETON IN THE FOSSIL RECORD OF BIRDS AND BEYOND: IMPLICATIONS FOR USING INCOMPLETE FOSSILS IN PHYLOGENETIC ANALYSES

**11:30** **FELICE** THE INFLUENCE OF BODY SIZE AND BRAIN SIZE ON DIVERSIFICATION RATES IN BIRDS

**11:45** **KNAPP** TRADE-OFFS AMONG CRANIAL SOFT TISSUES IN AVIAN CRANIAL EVOLUTION

**TUESDAY MORNING, JUNE 18, 2024**
**UNION POND**
**SYSTEMATICS AND PHYLOGENY**
**MODERATORS: Tanya Berardini and Shreya Jariwala**

**8:00** **LLOYD** IS "EQUAL WEIGHT" PARSIMONY A LIE? (AND WHAT HAPPENS IF WE ACTUALLY WEIGHT CHARACTERS EQUALLY IN MAXIMUM PARSIMONY PHYLOGENETIC INFERENCE?)

**8:15** **SHEFFIELD** EXPLORING RATES OF CHANGE AND MODES OF EVOLUTION IN BLASTOZOAN ECHINODERMS

**8:30** **PÉREZ-PERIS** THE ASAPHID TRILOBITE GENERA *TRIGONOCERCA* AND *TRIGONOCERCELLA* FROM THE EARLY ORDOVICIAN OF THE GREAT BASIN, WESTERN USA

**8:45** **MONGIARDINO KOCH** ITERATIVE ORIGINS OF EURYPTERID GIGANTISM WERE DECOUPLED FROM ECOLOGICAL AND ENVIRONMENTAL FACTORS

**9:00** **FAU** PHYLOGENETIC AND TAXONOMIC REVISION OF JURASSIC STARFISHES SUPPORTS A DELAYED ORIGIN OF THE ASTERIIDAE

**9:15** **YONG** NONMINERALIZED "TABULUS" OF THE BASAL CAMBRIAN MEDUSOZOANS *OLIVOOIDES*

**9:30** **VILELA-ANDRADE** POLYPHYLY AND EVOLUTION IN ANAZYGID BRACHIOPODS: A TALE OF MORPHOLOGICAL OVERLAP AND DISPERSAL EVENTS (ATRYPIDA: ANAZYGINAE AND CATAZYGINAE)

**10:15** **WANG** EXCEPTIONAL PRESERVATION OF REPRODUCTIVE ORGANS AND GIANT SPERM IN THE CRETACEOUS OSTRACODS

**10:30** **ZHANG** LATE ORDOVICIAN OSTRACODS OF VALCOUR ISLAND, NEW YORK STATE, U.S.A.

**10:45** **WALTY** DECIPHERING DESMOCERATOIDEA (AMMONOIDEA) TURNOVER RATES DURING CENOMANIAN-TURONIAN OCEAN ANOXIC EVENT 2 USING BAYESIAN AND PARSIMONY-BASED PHYLOGENETIC APPROACHES

**11:00** **DEHAAN** INTEGRATING MOLECULAR PHYLOGENIES AND FOSSILS WITHOUT A MORPHOLOGICAL MATRIX TO INVESTIGATE PATTERNS OF TRAIT EVOLUTION: A CASE STUDY USING CARANGARIA

**11:15** **WATT** EVOLUTIONARY PATTERNS IN THE COMPOSITION OF THE TETRAPOD LOWER JAW

**11:30** **SON** CRANIAL ONTOGENY IN THE EARLY CRETACEOUS CERATOPSIAN DINOSAUR *PSITTACOSAURUS LUJIATUNENSIS*: INTRASPECIFIC VARIATION BY AGE AND TAXONOMIC IMPLICATIONS

**11:45** **ABBOTT** A BOTTOM-UP REVISION OF *LYSTROSAURUS* (THERAPSIDA, DICYNODONTIA) SPECIES IN THE KAROO BASIN, SOUTH AFRICA

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION ROGEL**
**EVOLUTIONARY PALEOBIOLOGY IN THE 21ST CENTURY: ADVANCING THE LEGACY OF JIM VALENTINE**
**MODERATORS: Sarah Losso and Carl Simpson**

**1:15** **JABLONSKI** BIODIVERSITY HOTSPOTS AND LATITUDINAL GRADIENTS: DIFFERENT PATHS FOR LAND AND SEA?

**1:30** **EDIE** GLUTTONS OVER EPICURES? ANALYZING THE ECOLOGICAL STRUCTURE OF THE MARINE BIVALVE LATITUDINAL DIVERSITY GRADIENT

**1:45** **YASUHARA** ECOLOGICAL AND EVOLUTIONARY DEVELOPMENT OF CENOZOIC MARINE LATITUDINAL DIVERSITY GRADIENTS

**2:00** **HUANG** DOES RESOURCE STABILITY THROUGH SYMBIOSIS PROMOTE DIVERSITY?—A COMPARATIVE BIOGEOGRAPHIC PERSPECTIVE

**2:15** **SINGH** SEA SHELLS THROUGH TIME: ABUNDANCE AND DISTRIBUTION OF MARINE SKELETAL BIOMASS ACROSS THE PHANEROZOIC

**2:30** **DOYLE** DIFFERENTIAL EVOLUTIONARY TRENDS OF MARINE BIVALVE BODY SIZE BY HEMISPHERE AND BODY-SIZE CLASSES

**2:45** **CRESTOHL** QUANTIFYING THE IMPACTS OF PRESERVATION ON PALEOBIOLOGICAL PATTERNS: A LITERATURE-BASED SURVEY OF BODY SIZE IN CRETACEOUS AND PALEOGENE GASTROPODS

**3:30** **MARSHALL** FOLLOW THE ENERGY: VIEWING MACROEVOLUTIONARY CHANGE THROUGH THE LENS OF TROPHIC ENERGY FLUXES, THAT IS, THROUGH THE LENS TROPHIC POWER

**3:45** **SAULSBURY** BIOLOGICAL MEANING IN THE RISE AND FALL OF FOSSIL SPECIES

**4:00** **RICHARDSON** BENTHIC FORAMINIFERA CAN PROVIDE A SURROGATE FOR MARINE ECOSYSTEM BIOGEOGRAPHY

**4:15** **SONG** BIAS IN MORPHOLOGICAL DISPARITY STUDIES I: CHARACTERIZATION OF THE PHENOTYPE

**4:30** **PETERSEN** ISOTOPIC SIGNATURES OF PALEOPHYSIOLOGY – A TOOL FOR PALEONTOLOGISTS?

**4:45** **ANTELL** WAVELET ANALYSIS DETERMINES THE SYNCHRONICITY AND PERIODICITY OF ECOLOGICAL AND ENVIRONMENTAL CHANGE IN THE SANTA BARBARA BASIN, CALIFORNIA, THROUGHOUT THE COMMON ERA

**5:00** **FINNEGAN** APPLICATION OF CLUMPED ISOTOPE PALEOTHERMOMETRY TO LATE PLEISTOCENE MARINE TERRACE DEPOSITS SUPPORTS THERMAL NICHE CONSERVATISM IN NORTHEASTERN PACIFIC SHALLOW SUBTIDAL MOLLUSKS

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION ANDERSON**
**FIFTY YEARS IN THE HIMALAYAN FOOTHILLS: ECOSYSTEM CHANGE IN THE NEOGENE SIWALIK RECORD OF PAKISTAN**
**MODERATORS: Catherine Badgley, Michele E. Morgan, and Kay Behrensmeyer**

**1:15** **MORGAN** THE MIDDLE-LATE MIOCENE SIWALIK MAMMAL RECORD AND DYNAMIC PALEOCOMMUNITIES OF THE POTWAR PLATEAU, PAKISTAN

**1:30** **HEAD** REPTILES OF THE SIWALIK GROUP OF PAKISTAN: FAUNAL RESPONSES TO ENVIRONMENTAL CHANGE THROUGH DEEP TIME AND THE ORIGINS OF MODERN SOUTH ASIAN HERPETOFAUNAS

**1:45** **SANDERS** PROBOSCIDEANS OF THE SIWALIKS: A WORLD LIKE NO OTHER

**2:00** **COTE** CHALICOTHERES IN THE MIDDLE SIWALIKS AND BEYOND

**2:15** **KELLEY** PRIMATES IN THE MIOCENE SIWALIK RECORD OF PAKISTAN IN FAUNAL AND PALEOENVIRONMENTAL CONTEXT

**2:30** **GILBERT** NEW INSIGHTS INTO THE DIVERSITY OF THE PRIMATE FAUNA FROM CHINJI-AGED SIWALIK DEPOSITS AND THEIR IMPLICATIONS FOR PRIMATE EVOLUTIONARY HISTORY AND BIOGEOGRAPHY

**2:45** **PATNAIK** NICHE PARTITIONING AMONG MIDDLE MIOCENE SIWALIK PRIMATES FROM RAMNAGAR (J&K), INDIA

**3:30** **FLYNN** THE “SIWALIK” MICROFAUNA

**3:45** **KIMURA** FEEDING-CONTROLLED EXPERIMENTS IN MODERN RODENTS IMPROVE PALEOECOLOGICAL INTERPRETATIONS OF ISOTOPES FROM SIWALIK MOUSE TEETH

**4:00** **CASANOVAS-VILAR** THE EUROPEAN SIWALIKS: THE MIOCENE HIGH-RESOLUTION VERTEBRATE RECORD OF THE VALLÈS-PENEDÈS BASIN (CATALONIA, SPAIN)

**4:15** **UNO** THE SIGNIFICANCE OF THE SIWALIKS IN EVOLUTIONARY, ECOLOGICAL, AND EARTH HISTORY

**4:30** **JUKAR** FOSSILS ACROSS BORDERS IN TIME AND SPACE: THE IMPACT OF THE HARVARD-GSP PROJECT ON THE DEVELOPMENT OF EVOLUTIONARY PALEOECOLOGY IN THE INDIAN SUBCONTINENT

**4:45** **BADGLEY** THE SIWALIK RECORD OF NORTHERN PAKISTAN: HIGHLIGHTS AND SYNTHESIS

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION PENDLETON**
**A GULF OF KNOWLEDGE: INTERCONNECTING PALEOBIOLOGY RESEARCH ACROSS THE CARIBBEAN**
**MODERATORS: Brooke Crowley and Lazaro W. Viñola Lopez**

**1:15** *introductory remarks*

**1:30** **ITURRALDE-VINENT** NEW INSIGHTS INTO CARIBBEAN BIO- AND PALEOGEOGRAPHY DURING THE EOCENE-OLIGOCENE TRANSITION

**1:45** **VÉLEZ-JUARBE** VERTEBRATE PALEONTOLOGY IN PUERTO RICO: PAST, PRESENT AND FUTURE DIRECTIONS

**2:00** **ALMONTE** FOSSIL VERTEBRATES FROM THE LATE QUATERNARY OF HISPANIOLA, ONGOING RESEARCH AND FUTURE PERSPECTIVES

**2:15** **VIÑOLA LOPEZ** A NEW GLIMPSE INTO THE ANCIENT DIVERSITY OF HISPANIOLA: FAUNAL CHANGE AND ASSEMBLY OF MODERN CARIBBEAN BIODIVERSITY

**2:30** **PEROS** PALEOENVIRONMENTAL RECONSTRUCTION OF A SUBAQUATIC CAVE IN WESTERN CUBA CONTAINING EXTINCT SLOTH REMAINS

**2:45** **KLUKKERT** HABITAT SUITABILITY MODEL SUGGESTS CLIMATIC CHANGE DID NOT DRIVE RECENT PRIMATE EXTINCTIONS IN THE CARIBBEAN

**3:30** **HALENAR-PRICE** CRANIAL VARIATION AMONG CARIBBEAN PRIMATES

**3:45** **JACISIN III** ANOLE NEW WORLD: HOW ANOLIS SKULL ELEMENTS HELP CHARACTERIZE THE TEMPO AND MODE OF AN ADAPTIVE RADIATION

**4:00** **MCAFEE** NEW COLLECTIONS, INTRASPECIFIC VARIATION, AND PALEOGEOGRAPHY LEAD TO REVISED TAXONOMY AND SPECIATION OF LATE PLEISTOCENE GROUND SLOTHS (MAMMALIA: PILOSA) IN HISPANIOLA

**4:15** **COOKE** EXPLORING LOCOMOTOR PATTERNS AMONG HISPANIOLA'S EXTINCT RODENTS

**4:30** **HENSLEY** TIME ISN'T ALWAYS A FACTOR: ISOTOPIC EVALUATIONS OF RECENTLY EXTINCT AND THREATENED HISPANIOLAN RODENTS SUGGEST ECOLOGICAL NICHE PARTITIONING AND LITTLE TEMPORAL ISOTOPIC CHANGE PRIOR TO SPECIES LOSS

**4:45** **LEFEBVRE** WE NEED EACH OTHER: BRIDGING PALEONTOLOGY AND ARCHAEOLOGY FOR THE FUTURE OF CARIBBEAN VERTEBRATE DIVERSITY

**5:00** **MYCHAJLIW** CONSERVATION PALEOBIOLOGY IN THE CARIBBEAN: HOW FOSSILS CAN HELP US SAVE THE REGION'S LAST SURVIVING MAMMALS

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION KUENZEL**
**DAWN OF ANIMAL LIFE: EXPLORING NEW ADVANCES IN EDIACARAN PALEOBIOLOGY**
**MODERATORS: Philip C. Boan, Prescott Vayda, and Princess Aira Buma-at**

**1:15** **EVANS** A LOCAL PERSPECTIVE ON GLOBAL TRENDS: EVALUATING RECORDS AT DISTINCT EDIACARAN FOSSIL SITES TO CONSTRAIN EVOLUTIONARY DYNAMICS DURING THE DAWN OF ANIMAL LIFE *(30-minute keynote)*

**1:45** **XIAO** ON THE LATE EDIACARAN "KOTLINIAN CRISIS"

**2:00** **SEGESSENMAN** THE TIDES THAT BIND: CORRELATIONS BETWEEN ROCKS, FOSSILS, AND TRANSGRESSION-REGRESSION CYCLES AT THE DAWN OF ANIMAL LIFE

**2:15** **BYKOVA** SPECIES DIVERSITY OF *DICKINSONIA*

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION KUENZEL**
**MICROBIAL BIOSIGNATURES: FROM PALEOMICROBIOLOGY TO ASTROBIOLOGY**
**MODERATORS: Sarah González Henao and Jena Johnson**

**3:30** **HAMILTON** PHOTOSYNTHESIS IN A PROTEROZOIC OCEAN ANALOG

**3:45** **SLATER** GEOCHEMICAL BIOSIGNATURES OF MICROBIALITES: ANALOGOUS FOR EARLY EARTH AND ASTROBIOLOGY

**4:00** **DROSER** WHEN MATS MATTERED MOST (FOR US!): THE SIGNIFICANCE OF ORGANIC MATS ON THE DISTRIBUTION AND PRESERVATION OF THE EDIACARA BIOTA

**4:15** **HOWARD** REFRAMING THE SEARCH FOR ARCHEAN LIFE

**4:30** **JORN** CAN CRYSTAL ORIENTATION BE USED TO RECOGNIZE MICROBIAL INFLUENCE IN MINERALIZATION? ANALYZING CRETACEOUS CALCAREOUS COPROLITES USING ELECTRON BACKSCATTER DIFFRACTION (EBSD)

**4:45** **ALIAN** MEMORIES IN THE MINERALS: DECIPHERING MICROBIAL BIOSIGNATURES THROUGH MICROSCOPIC CHEMICAL MAPPING

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION WOLVERINE**
**RECENT ADVANCES IN VIRTUAL PALEOBIOLOGY**
**MODERATORS: Russell Bicknell and Joseph Bevitt**

**1:15** *withdrawn*

**1:45** **BEVITT** NEUTRON TOMOGRAPHY – SUBATOMIC PARTICLES MEET FOSSILS WITH GREAT OUTCOMES

**2:00** **HEBDON** USING THEORETICAL MORPHOLOGIES AS A FOUNDATION TO GETTING NOT SO THEORETICAL RESULTS IN FUNCTIONAL PERFORMANCE STUDIES.

**2:15** **BICKNELL** PUSHING THE LIMITS OF ARTHROPOD 3D BIOMECHANICS

**2:30** **PATES** DETERMINING THE LIFE AND FEEDING MODES OF EARLY ARTHROPODS USING COMPUTATIONAL FLUID DYNAMICS

**2:45** **NOLAN** VIRTUAL PALEOBIOLOGY: WALCOTT'S *BROOKSELLA ALTERNATA* AFFINITY RESOLVED THROUGH A COMBINATION OF CLASSIC AND MICRO-CT IMAGING TECHNIQUES

**3:30** **HEGNA** HOW TO EAT WITH A FORK: UNPRECEDENTED POST-ANTENNAL APPENDAGE DIFFERENTIATION IN THE TRILOBITE *ISOTELUS* (ASAPHIDA; ORDOVICIAN)

**3:45** **ZIETLOW** MODERN OSTEOLOGIES REQUIRE MODERN TECHNOLOGIES: MOSASAURS AS MODELS FOR THE CRITICAL IMPORTANCE OF SCAN DATA IN ANATOMICAL DESCRIPTIONS

**4:00** **REYES** AN AGGREGATE OF YOUNG, SKELETALLY IMMATURE AETOSAURS (ARCHOSAURIA: PSEUDOSUCHIA) FROM THE LATE TRIASSIC DOCKUM GROUP (OTISCHALKIAN) OF TEXAS

**4:15** *withdrawn*

**4:30** **MAYLE** THE EYES HAVE IT: OCULAR THERMOREGULATION IN BIRDS AND ITS INVERSE CORRELATION WITH OSTEOARTHRITIS

**4:45** **LYNCH** ENDOCAST MORPHOLOGY DIFFERS SIGNIFICANTLY WITHIN NORTH AMERICAN RIVER OTTERS

**5:00** **JACQUET** TENACIOUS TURDS FROM THE UPPER CRETACEOUS SMOKY HILL MEMBER, NIOBRARA CHALK, KANSAS

**5:15** **PETERMAN** EXPLORING THE STABILIZING POTENTIAL OF AMMONOID CONCH ORNAMENTATION WITH 3D PRINTING, 3D MOTION TRACKING, AND PARTICLE IMAGE VELOCIMETRY

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION 2210**
**GENERAL SESSION: FISHES AND PALEOZOIC TETRAPODS**
**MODERATORS: Allison Bronson and Yara Haridy**

**1:15** **SCHNETZ** DIVERSITY OF FEEDING STRUCTURES IN HETEROSTRACAN FISH

**1:30** **HARIDY** VERTEBRATE TEETH AROSE AS SENSORY ORGANS

**1:45** **BRONSON** NO BONES ABOUT IT: THE DEPOSITIONAL ENVIRONMENT OF THE FAYETTEVILLE SHALE CREATES A TREASURE TROVE OF FOSSIL CARTILAGE

**2:00** **FLANNERY SUTHERLAND** BAYESIAN DIVERSIFICATION RATE ANALYSES IN A SPATIALLY CONTROLLED FRAMEWORK ILLUMINATE THE TIMING OF THE FIRST RADIATION OF RAY-FINNED FISH

**2:15** **STACK** A NEW SPECIES OF *SAURICHTHYS* (ACTINOPTERYGII) FROM THE DOCKUM GROUP OF TEXAS (LATE TRIASSIC, ?EARLY NORIAN) HIGHLIGHTS THE UNEVEN TEMPO OF THE EVOLUTION OF SPECIALIZED JAW MORPHOLOGIES

**2:30** **WHITNEY** THE PALEOHISTOLOGY OF VERTEBRATE WATER-TO-LAND TRANSITIONS: INSIGHTS FROM COMPARATIVE SALAMANDER BONE HISTOLOGY

**2:45** **ANGIELCZYK** NON-MAMMALIAN SYNAPSIDS FROM THE EARLY PERMIAN PEDRA DE FOGO FORMATION (PARNAÍBA BASIN, NORTHEAST BRAZIL) EXPAND OUR KNOWLEDGE OF THE GONDWANAN TROPICAL BIOME

**3:30** **MARTINEZ** QUANTITATIVE ANALYSIS OF IGUANID PALATAL TEETH WITH IMPLICATIONS FOR INFERRING DIETS OF EARLY AMNIOTES

**3:45** **PARDO** VOMERONASAL ADAPTATIONS RESPONSIBLE FOR UNIQUE PALATAL MORPHOLOGY IN ENDOTHIODONT DICYNODONTS (THERAPSIDA, ANOMODONTIA)

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION POND**
**SYSTEMATICS AND PHYLOGENY**
**MODERATORS: Caroline Abbott and Nicolás Mongiardino Koch**

**1:15** **PATELLOS** THE POTENTIAL OF UNASSUMING FOSSILS: ASSESSING THE TAXONOMIC UTILITY OF OSTEODERM MORPHOLOGY IN ARCHOSAURIA

**1:30** **SALEM** A PEIROSAURID CROCODYLIFORM FROM THE UPPER CRETACEOUS (CENOMANIAN) BAHARIYA FORMATION OF THE BAHARIYA OASIS, WESTERN DESERT, EGYPT

**1:45** **TORRES** NEW INSIGHTS INTO THE ORIGIN OF THE GALAPAGOS TORTOISES WITH A TIP-DATED ANALYSIS OF TESTUDINIDAE

**2:00** **GOHAR** A NEW EOCENE PROTOCETID WHALE MATERIAL FROM EGYPT SHEDS NEW LIGHT ON THE EARLY DISPERSAL OF CETACEANS

**2:15** **DAVIES** PUTTING THEORY INTO PRACTICE; EXERCISES AND EXPERIENCES GAINED WHILE USING MODEL-BASED INQUIRY (MBI) AND AMBITIOUS SCIENCE TEACHING (AST) METHODS IN EARTH SCIENCE CLASSES AT A COMMUNITY COLLEGE.

**TUESDAY AFTERNOON, JUNE 18, 2024**
**UNION POND**
**GENERAL SESSION: ECHINODERMS**
**MODERATORS: William Ausich and Bradley Deline**

**3:30** **WATTS** "PSYCHO" ECHINOID SPINES – EVOLUTION THROUGH SPINE MORPHOSPACE IN CROWN GROUP CIDAROID ECHINOIDS

**3:45** **SUMRALL** A LATE MISSISSIPPIAN TURNOVER IN NORTH AMERICAN OPHIUROID FAUNAS

**4:00** **KEYES** THE PARAGARICOCRINIDAE (CRINOIDEA) – A LATE PALEOZOIC DEAD CLADE WALKING

**4:15** **DELINE** ECOLOGICAL STABILITY DURING DEVELOPMENTAL SHIFTS; A CASE STUDY OF PARACRINOIDEA

**4:30** **GAHN** SHIFTING RADIALS AND AN AZIMUTHAL DESCRIPTIVE SYSTEM PROVIDE NEW INSIGHTS INTO PATTERNS OF CRINOID CALYX SYMMETRY AND QUESTIONS OF PLATE HOMOLOGY

## TUESDAY POSTERS, JUNE 18, 2024
## UNION IDEA HUB
## PRESENTERS SHOULD ATTEND POSTERS FROM 5:30–6:15

### EVOLUTIONARY PALEOBIOLOGY IN THE 21ST CENTURY: ADVANCING THE LEGACY OF JIM VALENTINE

*no posters for this session*

### GENERAL SESSION: CENOZOIC TETRAPODS

1 **BECKER** POST-CRANIAL REMAINS FROM A *SUBHYRACODON* BONEBED FROM THE BRULE FORMATION OF NIOBRARA COUNTY, WYOMING, U.S.A

2 **BUTRÓN-XANCOPINCA** TAPHONOMY OF THE POSTCRANIAL SKELETON OF *NANOTRAGULUS* (ARTIODACTYLA: HYPERTRAGULIDAE) FROM AN EARLY OLIGOCENE FAUNA IN SOUTHERN MEXICO

3 **COHEN** THE PETROSAL MORPHOLOGY OF PALEOGENE TYPOTHERIANS AND COMMENTS ON THE DISTRIBUTION OF PETROSAL CHARACTERS AMONG NOTOUNGULATES (MAMMALIA, PAN-PERISSODACTYLA)

4 **DEN OUDEN** THE UTILITY OF LINEAR MORPHOMETRICS AS A TOOL FOR DIETARY INFERENCE IN FOSSIL SHREWS

5 **EHLER** THE LIFE HISTORY OF THE EARLY CAMEL *POEBROTHERIUM* AS INFERRED FROM OSTEOHISTOLOGY

6 **FULGHUM** ASSOCIATED DENTITION AND PETROSAL OF A DRYOLESTOID MAMMAL FROM THE UPPER JURASSIC MORRISON FORMATION, UTAH, U.S.A.

7 **JORDAN** PLEISTOCENE MAMMALS FROM A KARSTIC FISSURE FILL IN PENDER COUNTY, NORTH CAROLINA

8 **MENÉNDEZ** INTEGRATING DATA FROM EXTANT AND EXTINCT SPECIES FOR THE UNDERSTANDING THE EVOLUTIONARY DYNAMICS OF SQUIRREL TOOTH MORPHOLOGY IN RELATION TO DIET

9 **OSWALD** POSSIBLE ADAPTIVE CHELONIVORY IN UINTAN CROCODYLOIDS FROM WESTERN NORTH AMERICA

10 **RUITER** SCREENWASHING FOR VERTEBRATE MICROFOSSILS IN LATE MIDDLE EOCENE STRATA OF THE DUCHESNE RIVER FORMATION, UINTA BASIN, UTAH

11 **STEWART** PALEOECOLOGY AND PALEOENVIRONMENTS OF OLIGO-MIOCENE DESMOSTYLIANS FROM THE STRAIT OF JUAN DE FUCA

12 **STRAUCH** TO FUSE OR NOT TO FUSE: DRIVERS OF SYMPHYSEAL FUSION IN WHALES

13 **WEBER** XENARTHRAN MORPHOLOGICAL DISPARITY AND IMPLICATIONS FOR CINGULATE TAXONOMY

### FIFTY YEARS IN THE HIMALAYAN FOOTHILLS: ECOSYSTEM CHANGE IN THE NEOGENE SIWALIK RECORD OF PAKISTAN

*no posters for this session*

### FROM CAVES TO CENOTES: PLEISTOCENE VERTEBRATE PALEONTOLOGY OF THE YUCATAN, MEXICO AND BELIZE

*no posters for this session*

## A GULF OF KNOWLEDGE: INTERCONNECTING PALEOBIOLOGY RESEARCH ACROSS THE CARIBBEAN

14 **BOVILLE** THE STATE OF QUATERNARY VERTEBRATE PALEONTOLOGY RESEARCH IN THE CARIBBEAN: AREAS OF RIGOR AND OPPORTUNITIES FOR GROWTH

15 **ITURRALDE-VINENT** A NEW TITHONIAN ICHTHYOSAURIAN SKELETON FROM VIÑALES, WESTERN CUBA

16 **ORIHUELA** PLIOCENE-PLEISTOCENE CAPROMYINE RODENTS FROM CUBA: BRIDGING A GAP IN THE CARIBBEAN'S LAND VERTEBRATE PALEONTOLOGICAL RECORD

17 **RIEGLER** FOSSIL SQUAMATES OF PEDERNALES PROVINCE, DOMINICAN REPUBLIC: NOVEL RECORD OF HUMAN-INDUCED EXTINCTION AND EXTIRPATION

## DAWN OF ANIMAL LIFE: EXPLORING NEW ADVANCES IN EDIACARAN PALEOBIOLOGY

18 **BUMA-AT** MORPHOMETRIC AND SPATIAL ANALYSES OF *CHARNIODISCUS* FROM THE EDIACARAN OF NEWFOUNDLAND, CANADA

19 **LIU** CROWN GROUP SPONGES FROM THE NAMA GROUP OF NAMIBIA, AND THE EVOLUTION OF SPICULOGENESIS ACROSS THE EDIACARAN-CAMBRIAN TRANSITION

20 **VIXSEBOXSE** SEAWATER SULFATE AND SEDIMENTARY IRON (OXYHYDR)OXIDE CONCENTRATIONS AS TAPHONOMIC CONSTRAINTS ON SOFT TISSUE PRESERVATION BY PYRITE

## MICROBIAL BIOSIGNATURES: FROM PALEOMICROBIOLOGY TO ASTROBIOLOGY

*no posters for this session*

## GENERAL SESSION: MESOZOIC REPTILES

21 **ABDUL KAREEM** SAUROPOD TAIL CLUBS FROM THE KOTA FORMATION (EARLY TO MIDDLE JURASSIC) OF INDIA AND THEIR IMPLICATIONS FOR EARLY SAUROPOD EVOLUTION

22 **CARTER** PRELIMINARY STATISTICAL STUDY OF LATE TRIASSIC ARCHOSAURIFORM TEETH FROM THE HOMESTEAD SITE, A MICROVERTEBRATE ASSEMBLAGE IN EAST-CENTRAL NEW MEXICO

23 **JACKSON** A NEW BASAL SAUROPODIFORM FROM THE EARLY JURASSIC OF ANTARCTICA

24 **SCOTT** RELATIVELY SIMPLE DENTAL COMPLEXITY SUGGESTS A GENERALIST DIET FOR THE LATE JURASSIC RHYNCHOCEPHALIAN *OPISTHIAS*

## RECENT ADVANCES IN VIRTUAL PALEOBIOLOGY

*no posters for this session*

## GENERAL SESSION: INTEGRATIVE PALEOBIOLOGY

25 **PARSONS** TESTING CHEMICAL-AIDED DISAGGREGATION OF THE SILICA FORMATION'S (MIDDLE DEVONIAN) FOSSILIFEROUS SHALE

26 **SAMUELS-FAIR** SPATIAL DIVISION OF REPRODUCTIVE LABOR IN THE BRYOZOAN *PARASMITTINA AREOLATA* AND IMPLICATIONS FOR INTERPRETING THE CHEILOSTOME FOSSIL RECORD

## GENERAL SESSION: FISHES AND PALEOZOIC TETRAPODS

27 **GARDNER** PALEONTOLOGICAL DISCOVERY IN THE EMSIAN-EIFELIAN (DEVONIAN) NEEDMORE FORMATION IN WEST VIRGINIA: 150 YEARS OF EXPLORATION AND BEYOND

**28** **HOSFIELD** NOVEL INSIGHTS INTO THE EVOLUTION OF ONTOGENY IN LYSTROSAURIDAE (THERAPSIDA, ANOMODONTIA)

**29** **LYONS-WEILER** NEW RECORDS OF THE ACTINOPTERYGIAN *PROGYROLEPIS* FROM THE CARBONIFEROUS-PERMIAN LOWER CUTLER BEDS IN THE BEARS EARS NATIONAL MONUMENT, UTAH

**30** **MERCADO** A FRESH LOOK AT A VERY OLD SPECIMEN: VISUALIZING THE ANATOMY OF *TETRACERATOPS INSIGNIS* (SYNAPSIDA, EUPELYCOSAURIA) WITH μCT

**31** **RAVELOSON** NEW INFORMATION ON THE XENACANTHIFORM SHARK IN THE MALERI FORMATION, UPPER TRIASSIC OF INDIA: PALEOHISTOTLOGICAL APPROACH AND FAUNAL ASSOCIATION INDICATE SOME PALEOBIOLOGICAL AND PALEOECOLOGICAL INSIGHTS.

**32** **ROSE** REASSESSMENT OF THE TAXONOMIC RECORD OF LUNGFISH (SARCOPTERYGII:DIPNOI) IN THE LATE TRIASSIC OF THE UNITED STATES

**33** **SAAD** DESCRIPTION OF A SPADEFISH (ACANTHOMORPHA: EPHIPPIDAE) FROM PAKISTAN AND ITS IMPLICATIONS FOR MARINE FISH BIOGEOGRAPHY IN THE PALEOGENE

**34** **THOMAS** THE IDENTITY OF A HISTORIC MOUNTED DICYNODONT SKELETON AT THE FIELD MUSEUM

## SYSTEMATICS AND PHYLOGENY

**35** **BLEY** ENCRINURID TRILOBITES FROM THE UPPER ORDOVICIAN (KATIAN) OF NORTHEASTERN IOWA

**36** **EK** NOTES ON RARE TRILOBITE TAXA FROM THE SILURIAN ROCKS OF NORTHEASTERN ILLINOIS

**37** **GOODSTADT** ECHO OF THE ANCIENTS: EVOLUTION OF SONG IN THE AVIAN FAMILY CETTIIDAE

**38** **GUENSBURG** REMARKABLE NEW TAXON EXEMPLIFIES EARLY ARM MORPHOLOGY AND PROVIDES ADDITIONAL INSIGHT INTO THE ORIGIN OF CRINOIDS

**39** **KOLATA** CYCLOCYSTOIDS (ECHINODERMATA) FROM THE UPPER ORDOVICIAN (EARLY KATIAN) BRECHIN LAGERSTÄTTE OF ONTARIO, CANADA: IMPLICATIONS FOR CYCLOCYSTOID SYSTEMATICS, ANATOMY, FUNCTIONAL MORPHOLOGY, AND LIFE MODE.

**40** **KRISHER** THE CORALS OF THE DEVONIAN OF NEW YORK: FACILITATING THEIR IDENTIFICATION AND STUDY

**41** **SHANKS** REEVALUATION OF AGNOSTOID ARTHROPOD MORPHOLOGY AND REASSESSMENT OF TRILOBITE AFFINITY USING SILICIFIED SPECIMENS FROM THE GREAT BASIN

**42** **SOCKI** MORPHOLOGICAL, PHYLOGENETIC AND ECOLOGICAL ASSESSMENT OF A NEW SPECIES OF GEOMORPHA FROM THE PAWNEE CREEK FORMATION, CO.

**43** **TYDINGS** A NEW HIGHLY DIVERSE ASSEMBLAGE OF ORGANICALLY PRESERVED VASE-SHAPED MICROFOSSILS

**44** **VELEZ-ROSADO** A LATE CRETACEOUS CROCODYLIAN (*DOLICHOCHAMPSA MINIMA*) PROVIDES INSIGHTS INTO THE EARLY EVOLUTIONARY AND PALEOBIOGEOGRAPHIC HISTORY OF GAVIALINAE

## GENERAL SESSION: ECHINODERMS

**45** **FERRONE** ARCHAEOCIDARID ECHINOID (ECHINODERMATA) MATERIAL FROM THE UPPER PENNSYLVANIAN BARNSDALL FORMATION OF NORTHEASTERN OKLAHOMA: MICROSTRATIGRAPHIC DISTRIBUTION, ENCRUSTATION PATTERNS, AND GRAIN-SIZE EFFECTS

**46** **HAMIDA** THE FOSSILIZED ECHINODERMS IN NORTHERN ALGERIA

**47** **NEWMAN** GLASS HOUSES: POTENTIAL COMMENSALISM BETWEEN A CRINOID AND HEXACTINELLID SPONGE FROM THE UPPER DEVONIAN OF PENNSYLVANIA

**48** **REGISTER** EXPLORING THE MORPHOMETRIC IMPLICATIONS OF THE LOSS OF RESPIRATORY STRUCTURES IN PLEUROCYSTITID ECHINODERMS

**49** **ROBERTS** NEW INFORMATION ON THE UPPER ORDOVICIAN (KATIAN) CRINOID FAUNA FROM SARDINIA, ITALY

**THURSDAY MORNING, JUNE 20, 2024**
**UNION ROGEL**
**GENERAL SESSION: MOLLUSKS**
**MODERATORS: Matthew Clapham**

**8:45** **CHATTOPADHYAY** PARASITIC INTERACTIONS AND THEIR RELATIONSHIP TO ENVIRONMENTAL CHANGE: INSIGHTS FROM THE OLIGO-MIOCENE MARINE MOLLUSCAN ASSEMBLAGES OF WESTERN INDIA

**9:00** **WEINSTEIN** PALEOTEMPERATURE RECONSTRUCTION USING ISOTOPIC ANALYSIS ON LIVE, DEAD, AND FOSSIL GASTROPODS FROM THE WAKULLA RIVER IN FLORIDA

**9:15** **CLAPHAM** ONTOGENY AND CONSTRAINTS IN THE EVOLUTION OF AMMONOID SHELL COILING

**9:30** **WILSON** JAMES PARKINSON: NEGLECTED PALEONTOLOGY PIONEER

**THURSDAY MORNING, JUNE 20, 2024**
**UNION ROGEL**
**LESSONS LEARNED AND FUTURE VISIONS FOR CONSERVATION PALEOBIOLOGY**
**MODERATORS: Jonathan Cybulski and Erin Dillon**

**10:15** **DAVIS** DATA HOMECOMING: THREE ELEMENTS FOR BUILDING TRANSPARENT, REALISTIC, AND MUTUALLY BENEFICIAL INTERDISCIPLINARY COMMUNITIES AND COLLABORATIONS IN CONSERVATION *(30-minute keynote)*

**10:45** **CRAMER** FINDING PATHWAYS FOR INTEGRATING PALEO, ARCHEOLOGICAL, TRADITIONAL ECOLOGICAL KNOWLEDGE, AND HISTORICAL DATA INTO CARIBBEAN CORAL REEF MANAGEMENT

**11:00** **BARCLAY** INDIGENOUS ARCHAEOLOGICAL SITES REVEAL INCREASE IN CLAM SIZES AND CONNECT GEOHISTORICAL DATA TO MARINE CONSERVATION ISSUES IN WESTERN CANADA

**11:15** **PHAM** INCORPORATING LOCAL COMMUNITY PRIORITIES INTO CONSERVATION PALEOBIOLOGY RESEARCH: A CASE STUDY IN VELONDRIAKE, SOUTHWEST MADAGASCAR

**11:30** **PIER** STORYTELLING WITH THE PAST AS A PERSUASIVE TOOL FOR CONSERVATION

**11:45** **SHIRLEY** INVESTIGATING THE IMPACT OF PALEOBIOLOGY OUTREACH ON ATTITUDES ABOUT FOSSILS AND LIVING APE CONSERVATION IN UGANDA

**THURSDAY MORNING, JUNE 20, 2024**
**UNION ANDERSON**
**RECENT ADVANCES IN COMPUTATIONAL PALEOBIOLOGY**
**MODERATORS: William Gearty, Bethany J. Allen, and Lewis A. Jones**

**8:00** **COLE** MACROEVOLUTIONARY CONSEQUENCES OF THE LATE ORDOVICIAN MASS EXTINCTION: A CROSS-CLADE INVESTIGATION OF THE LILLIPUT EFFECT *(30-minute keynote)*

**8:30** **VARGAS-PARRA** PHYLOGENY AND EVOLUTIONARY MODULARITY OF A TRILOBITE FAMILY OVER THE ORDOVICIAN RADIATION

**8:45** **HOPKINS** PERFORMANCE OF MODEL-BASED PREDICTIONS OF BODY SIZE AND BODY PROPORTIONS OF TRILOBITES AT A KEY TRANSITION POINT IN DEVELOPMENT

**9:00** **NIKOLIC** WHAT'S IN THE TRUNK: BIASED TRUNK SHAPE EVOLUTION IN TRILOBITES

**9:15** **WRIGHT** CHARACTER EVOLUTION MODELS MATTER IN PHYLOGENETIC PALEOBIOLOGY: IMPACTS ON TREE TOPOLOGIES, DIVERGENCE TIMES, AND MACROEVOLUTIONARY DYNAMICS

**9:30** **RHODA** MULTIVARIATE FUNCTIONAL ADAPTIVE LANDSCAPES AND HOW WE MAKE THEM

**10:15** **HOWARD** PALEOPHYLOGEOGRAPHIC MODELS: AN R PACKAGE FOR INTEGRATING PALEONTOLOGICAL, NEONTOLOGICAL, AND SPATIAL DATA IN A PHYLOGENETIC COMPARATIVE FRAMEWORK *(30-minute keynote)*

**10:45** **DUNNE** ENVIRONMENTAL CONTROLS ON DINOSAUR DIVERSITY, BIOGEOGRAPHY, AND DIET

**11:00** **JONES** TESTING THE EFFECTS OF COVERAGE-BASED SAMPLING STANDARDIZATION ON FOSSIL TIME SERIES OF MORPHOLOGICAL DISPARITY

**11:15** **WEN** PALEOZOIC EVOLUTION OF THE MARINE LATITUDINAL DIVERSITY GRADIENT REGULATED BY PLATE TECTONICS, CLIMATE CHANGE AND GENUS-SPECIFIC TRAITS

**11:30** **FLANNERY-SUTHERLAND** INTEGRATING BAYESIAN PHYLOGEOGRAPHY WITH LANDSCAPE CONNECTIVITY ANALYSIS REVEALS THE ECOGRAPHY OF THE EARLY ARCHOSAUROMORPH RADIATION

**11:45** **YOHLER** DEVELOPMENT OF AN INVERSE MODELING FRAMEWORK FOR DETERMINING THE DRIVERS OF MASS EXTINCTION EVENTS AND APPLICATION TO THE LATE ORDOVICIAN RECORD OF GRAPTOLITES

**THURSDAY MORNING, JUNE 20, 2024**
**UNION PENDLETON**
**TRAITS, FUNCTIONS, AND SYSTEMS: QUANTIFYING PALEOCOMMUNITY VARIATION, PERSISTENCE, AND RESILIENCE**
**MODERATORS: Peter Roopnarine and Sara Sjosten**

**8:00** **GILL** ARE NOVEL COMMUNITIES ALSO NOVEL ECOSYSTEMS? POLLEN-DERIVED PLANT FUNCTIONAL TRAITS LINK PALEOECOLOGICAL PATTERNS WITH ECOSYSTEM PROCESSES

**8:15** **FRANK** AN ENERGY FLOW MODEL OF EARLY TERRESTRIAL TROPHIC DYNAMICS: EXPLORING THE ROLES OF AQUATIC SUBSIDIES AND DELAYED HERBIVORY EMERGENCE

**8:30** **CULLEN** FUNCTIONAL DIVERSITY AND STRUCTURE OF CRETACEOUS COASTAL PLAIN ECOSYSTEMS

**8:45** **ROOPNARINE** MODELING ECOLOGICAL DYNAMICS ON GEOLOGICAL TIMESCALES: CHANGING COMPOSITION, STRUCTURE AND COMPLEXITY OF LATE CRETACEOUS HELL CREEK COMMUNITIES

**9:00** **MCGUIRE** PLEISTOCENE DISRUPTION OF TRAIT-ENVIRONMENT RELATIONSHIPS INFORMS THE FUTURE CONSERVATION OF AFRICAN MEGAFAUNA

**9:15** **SLENKER** THE EVAPORATION SENSITIVITY OF LARGE-BODIED NORTH AMERICAN MAMMALIAN HERBIVORES

**9:30** **KEMP** DEFAUNATION AND COLONIZATION SHIFT THE FUNCTIONAL DIVERSITY OF CARIBBEAN VERTEBRATE COMMUNITIES: IMPLICATIONS FOR ECOSYSTEM SERVICES AND CONSERVATION IN THE ANTHROPOCENE

**10:15** **SCHAP** USING THE FUNCTIONAL TRAITS OF SMALL MAMMALS TO ESTIMATE PAST ENVIRONMENTS AT NATURAL TRAP CAVE, WYOMING

**10:30** **TERRY** TRACKING TAXONOMIC AND FUNCTIONAL DIVERSITY OF SMALL MAMMALS ACROSS 17,000 YEARS OF CULTURAL AND ENVIRONMENTAL CHANGE AT THE PAISLEY CAVES, OREGON

**10:45** **BROMBACHER** TOWARDS A MULTIVARIATE FRAMEWORK FOR EXTINCTION RISK IN PLANKTONIC FORAMINIFERA

**11:00** **SJOSTEN** MODELLING THE LIFE-ENVIRONMENT INTERFACE IN ANCIENT SHELF SEAS

**11:15** **ESS** CHANGES IN ECOSPACE UTILIZATION ACROSS THE RICHMONDIAN INVASION IN THE CINCINNATIAN ARCH (LATE ORDOVICIAN)

**11:30** **TYLER** CHANGES IN MARINE FOOD WEB STRUCTURE AND THE CONSEQUENCES OF INVASIVE SPECIES DURING THE LATE ORDOVICIAN

**11:45** **BROPHY** PALEOECOLOGICAL DYNAMICS DURING OCEANIC ANOXIC EVENT 2 IN THE CRETACEOUS WESTERN INTERIOR SEAWAY: COMPARISONS BETWEEN HYDROCARBON COLD SEEP AND NON-SEEP COMMUNITIES

**THURSDAY MORNING, JUNE 20, 2024**
**UNION KUENZEL**
**HOMINOID EVOLUTION, ENVIRONMENTS AND COMMUNITIES IN EASTERN AFRICA**
**MODERATORS: Susanne Cote and Laura MacLatchy**

**8:00** **ROSSIE** MIOCENE APES FROM THE LOTHIDOK FORMATION, KENYA

**8:15** **JANSMA** THE PHYLOGENETIC AFFINITIES OF THE EARLY AND MIDDLE MIOCENE SMALL-BODIED CATARRHINES FROM EASTERN AFRICA

**8:30** **SHERWOOD** NEW POSTCRANIAL FOSSILS OF A *PROCONSUL MAJOR* RADIOHUMERAL JOINT FROM THE EARLY MIOCENE SITE COMPLEX NAPAK, UGANDA

**8:45** **COSMAN** POST-CRANIAL TRABECULAR MORPHOLOGY OF THE EARLY MIOCENE HOMINOID *PROCONSUL MAJOR*

**9:00** **MACLATCHY** FROM FOSSILS TO THE FOREST: FRUIT, LEAVES AND HOMINOID LOCOMOTOR EVOLUTION

**9:15** **ORLIKOFF** TERRESTRIAL POSITIONAL BEHAVIOR OF WILD *PONGO PYGMAEUS*: IMPLICATIONS FOR THE ORIGINS OF BIPEDALISM

**9:30** **MICHEL** EVERYTHING OLD IS NEW AGAIN: STRATIGRAPHIC REVISIONS AND SURVEY OF NEARLY 100 YEARS OF WORK ON THE EARLY MIOCENE RUSINGA AND MFANGANO ISLANDS, LAKE VICTORIA, KENYA

**10:15** **BAUMGARTNER** NOT JUST THE GREEN BACKGROUND: THE PAST, PRESENT, AND FUTURE OF PALEOBOTANY OF EAST AFRICAN FOSSIL SITES

**10:30** **HALL** REVISED BIOSTRATIGRAPHIC CONSIDERATIONS OF THE EARLY MIOCENE LOCALITY MFANGANO ISLAND, KENYA: IMPLICATIONS FOR MIOCENE CATARRHINE EVOLUTION AND FAUNAL TURNOVER

**10:45** **MUNYAKA** RECONSTRUCTING THE CLIMATE AND ECOLOGY OF AN EARLY MIOCENE TROPICAL FOREST ON THE FLANKS OF THE TINDERET VOLCANO, NYANZA PROVINCE, WESTERN KENYA

**11:00** **COTE** UPDATE ON A MULTI-PROXY STUDY OF RUMINANT DIETS FROM THE MIOCENE OF EASTERN AFRICA

**11:15** **WINKLER** THE MIDDLE MIOCENE EAST AFRICAN RODENT FAUNAL TRANSITION: EVIDENCE FROM MABOKO ISLAND, KENYA

**11:30** **MACLATCHY** A STRANGE OLD WORLD: PROBOSCIDEAN DIVERSITY AND COEXISTENCE IN THE EARLY MIOCENE OF EASTERN AFRICA

**11:45** **HEAD** SQUAMATE REPTILES FROM THE EARLY MIOCENE OF EQUATORIAL AFRICA INDICATE COMPLEX DISPERSAL BIOGEOGRAPHIC HISTORIES AND WET-FOREST PALEOENVIRONMENTS

**THURSDAY MORNING, JUNE 20, 2024**
**UNION WOLVERINE**
**STRATIGRAPHIC PALEOBIOLOGY: WORKING WITH THE NATURE OF THE STRATIGRAPHIC RECORD TO ANSWER PALEOBIOLOGICAL QUESTIONS**
**MODERATORS: Pedro Monarrez, Annaka Clement, and Katharine Loughney**

**8:00** **HOLLAND** BRIDGING THE GAP: THE DISPARATE EXPRESSIONS OF BIOTIC EVENTS IN NONMARINE, SHALLOW SILICICLASTIC, AND SHALLOW CARBONATE SETTINGS

**8:15** **WOOD** ACCOUNTING FOR BURIAL POTENTIAL IN ESTIMATES OF FOSSIL MAMMAL DIVERSITY

**8:30** **LOUGHNEY** CLIMATE, LANDSCAPE, AND TAPHONOMIC SIGNALS OF FOSSIL ASSEMBLAGES FROM THE MIOCENE BASIN AND RANGE, WESTERN U.S.A.

**8:45** **ORCHARD** POTENTIAL SOURCES OF COMMUNITY COMPOSITION CHANGE IN THE CLOVERLY FORMATION AND SYKES MOUNTAIN FORMATION OF WYOMING, USA

**9:00** **CLEMENT** ORIGIN AND STRATIGRAPHIC CONTEXT OF LOW-DIVERSITY SHELL BEDS: A CASE STUDY FROM LATE TRIASSIC AOTEAROA NEW ZEALAND

**9:15** **KOSNIK** ACCOUNTING FOR DATING UNCERTAINTIES IN TIME-AVERAGING ESTIMATES

**9:30** **KIDWELL** NEW EVIDENCE FOR THE EVOLUTION OF TIME-AVERAGING: HOW TIME IS TANGLED, NOT LOST, IN MARINE RECORDS

**10:15** **MONARREZ** STRATIGRAPHIC CONTROLS ON THE LATE SERPUKHOVIAN (MISSISSIPPIAN, CARBONIFEROUS) MASS EXTINCTION EVENT

**10:30** **GALLAGHER** CHANGES IN BIODIVERSITY AND PALEOECOLOGY OF RHYNCHONELLIFORM BRACHIOPODS ACROSS THE LOWER AND UPPER KELLWASSER EXTINCTION EVENTS (LATE DEVONIAN) AT TIOGA, PENNSYLVANIA, U.S.A.

**10:45** **WESTROP** FORELAND BASIN FORMATION, ENVIRONMENTAL CHANGE AND TRILOBITE DISTRIBUTION, LATE ORDOVICIAN OF EASTERN LAURENTIA

**11:00** **LITTLE** THE RICHMONDIAN INVASION: ECOLOGICAL IMPLICATIONS OF INCUMBENT AND INVADER DISTRIBUTION PATTERNS

**11:15** **FORSYTHE** QUANTIFYING THE PALAEOECOLOGICAL IMPACTS OF THE CLARKSVILLE PHASE OF THE RICHMONDIAN INVASION IN THE NASHVILLE DOME, TN

**11:30** **HERNÁNDEZ GÓMEZ** ECOLOGICAL IMPACTS OF THE RICHMONDIAN INVASION: COMPARING NICHE STABILITY IN NASHVILLE DOME VERSUS THE CINCINNATI ARCH

**11:45** **IRIZARRY** FAUNAL PATTERNS ARE CONTROLLED BY FACIES CHANGES THROUGH THE DRUMIAN ISOTOPE CARBON EXCURSION (DICE) IN SW MONTANA, U.S.A.

**THURSDAY MORNING, JUNE 20, 2024**
**UNION 2210**
**NORTH AMERICAN PALEONTOLOGICAL RESOURCES 2024**
**MODERATORS: Danita Brandt and Brenda Hunda**

**8:00** **BRANDT** NORTH AMERICAN PALEONTOLOGICAL RESOURCES 2024

**8:15** **KETCHUM** NEARLY 150 YEARS OF FOSSIL INVERTEBRATES AT THE AMERICAN MUSEUM OF NATURAL HISTORY

**8:30** **CORTEZ** STATE OF GEOLOGICAL COLLECTIONS AT THE CALIFORNIA ACADEMY OF SCIENCES, SAN FRANCISCO, CALIFORNIA

**8:45** **DINEEN** COLLECTIONS AT THE UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY (UCMP): GROWTH IN THE 21ST CENTURY AND BEYOND

**9:00** **MAYER** DIGITIZING THE FIELD MUSEUM'S FOSSIL INVERTEBRATE COLLECTION USING UNDERGRADUATE INTERNS AND IMLS FUNDED GRANTS

**9:15** **CUNDIFF** PALEONTOLOGY COLLECTIONS AT THE HARVARD MUSEUM OF COMPARATIVE ZOOLOGY

**9:30** **ADRAIN** NORTH AMERICAN PALEONTOLOGICAL RESOURCES: THE UNIVERSITY OF IOWA PALEONTOLOGY REPOSITORY – CHALLENGES OF A GROWING COLLECTION.

**10:15** **HOOK** OVER 100 YEARS OF PALEONTOLOGICAL COLLECTIONS AT THE NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

**10:30** **BAUER** NAVIGATING CHANGE: DESCRIBING 50 YEARS OF ADAPTATIONS IN THE UMMP INVERTEBRATE DIVISION

**10:45** **MILLHOUSE** INCREASING THE ACCESSIBILITY AND DISCOVERABILITY OF THE NATIONAL FOSSIL COLLECTIONS AT THE SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY

**11:00** **AMATI** PERSISTENCE IN PALEONTOLOGY: 188 YEARS OF PALEONTOLOGY AT THE NEW YORK STATE MUSEUM

**11:15** **UTRUP** SPINELESS WONDERS: A HISTORY OF THE INVERTEBRATE PALEONTOLOGY COLLECTIONS AT YALE PEABODY MUSEUM

**11:30** **RHUE** BUILDING AND STEWARDING VERTEBRATE FOSSIL COLLECTIONS HELD IN PUBLIC TRUST: 150 YEARS OF SCIENTIFIC INQUIRY AT THE YALE PEABODY MUSEUM

**11:45** **HUNDA** CINCINNATI MUSEUM CENTER AS A REPOSITORY FOR ORPHANED PALEONTOLOGICAL COLLECTIONS

**THURSDAY MORNING, JUNE 20, 2024**
**UNION POND**
**INTERCONNECTED PATTERNS OF NATURAL HISTORY: A TRIBUTE TO THE CAREER AND CONTRIBUTIONS OF LANCE GRANDE**
**MODERATORS: Eric Hilton and Matt Friedman**

**8:00** **HILTON** AN INTRODUCTION TO THE SYMPOSIUM "INTERCONNECTED PATTERNS OF NATURAL HISTORY: A TRIBUTE TO THE CAREER AND CONTRIBUTIONS OF LANCE GRANDE"

**8:15** **AASE** FOSSIL LAKE (GREEN RIVER FORMATION, EOCENE, YPRESIAN) AT A NEXUS OF COMMERCIAL FOSSIL EXTRACTION, PALEO TOURISM, ACADEMIC RESEARCH AND U.S. GOVERNMENT PRESERVATION

**8:30** **CAPOBIANCO** REVISITING THE USE OF PALEONTOLOGY IN BIOGEOGRAPHY IN THE 21ST CENTURY: THE GREEN RIVER ICHTHYOFAUNA AS A CASE STUDY

**8:45** **IGIELMAN** NEW DATA ON THE LOWER JAWS OF THE FIRST ACTINOPTERYGIANS; IMPLICATIONS FOR THE FIRST RADIATION OF THE EARLIEST RAY-FINNED FISH

**9:00** **MICKLE** LOWER ACTINOPTERYGIAN FISHES FROM THE UPPER PENNSYLVANIAN HAMILTON QUARRY, A KONSERVAT-LAGERSTÄTTE IN SOUTHEASTERN KANSAS, U.S.A.

**9:15** **GILES** ANATOMY AND RELATIONSHIPS OF PARASEMIONOTID ACTINOPTERYGIANS FROM THE EARLY TRIASSIC OF GREENLAND BASED ON CT- AND SYNCHROTRON TOMOGRAPHY

**9:30** **ATTERBY** THE APPLICATION OF CT AND SYNCHROTRON SCANNING TO RESOLVE THE INTERNAL ANATOMY, PHYLOGENY, AND ECOLOGY OF MESOZOIC FOSSIL FISHES

**10:15** **XU** THE ORIGIN AND EARLY EVOLUTION OF GINGLYMODIAN FISHES: FOSSIL EVIDENCE FROM THE MIDDLE TRIASSIC OF CHINA

**10:30** **DAVID** MODERN INSIGHTS REGARDING ANCIENT FISHES

**10:45** **BROWNSTEIN** THE GENOMIC SIGNATURES OF EVOLUTIONARY STASIS

**11:00** **FASEY** THE OLDEST THREE-DIMENSIONALLY PRESERVED ACTINOPTERYGIAN HEARTS? SOFT TISSUE PRESERVATION IN A STEM TELEOST

**11:15** **ANDREWS** MICRO-COMPUTED TOMOGRAPHY REVEALS THE INTERNAL ANATOMY OF PALEOCENE *MAGNIGENA ARABICA* (TELEOSTEI: OSTEOGLOSSOMORPHA: OSTEOGLOSSIDAE)

**11:30** **LIU** FOSSIL RECORDS OF PALEOGENE CATOSTOMIDS AND JIANGHANICHTHYIDS (OSTARIOPHYSI: CYPRINIFORMES) FROM ASIA: REVISION, REMARKS, AND NEW SPECIES

**11:45** **DE PINNA** PHYLOGENY AND EVOLUTION OF SILURIFORMES (TELEOSTEI), WITH A TENTATIVE BIOGEOGRAPHIC SCENARIO AND SPECIAL REFERENCE TO FOSSIL TAXA

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION ROGEL**
**LESSONS LEARNED AND FUTURE VISIONS FOR CONSERVATION PALEOBIOLOGY**
**MODERATORS: Jonathan Cybulski and Lynn Wingard**

**1:15** **WINGARD** APPLICATION OF CONSERVATION PALEOBIOLOGY TO RESOURCE MANAGEMENT: EXAMPLES AND LESSONS LEARNED FROM THE GREATER EVERGLADES ECOSYSTEM RESTORATION

**1:30** **SPANBAUER** BASELINES, BIODIVERSITY, AND BASIN INFILL: USING PALEOLIMNOLOGY TO INFORM MANAGEMENT PRACTICES AND CONSERVATION EFFORTS

**1:45** **DILLON** ALIGNING PALEOBIOLOGICAL RESEARCH WITH CONSERVATION PRIORITIES USING ELASMOBRANCHS AS A MODEL

**2:00** **AUSTIN** A REVIEW OF LATE-QUATERNARY SOUTHERN CALIFORNIA PACKRAT MIDDENS: IMPLICATIONS FOR INTERPRETING THE IMPACT OF PALEOCLIMATE

**2:15** **PRUDEN** BALANCING TRADE-OFFS IN SALIENCY, CREDIBILITY, AND LEGITIMACY IN CONSERVATION PALEOBIOLOGY: A CASE STUDY FROM LONG ISLAND SOUND

**2:30** **DIETL** WHAT DOES "SUCCESS" MEAN IN CONSERVATION PALEOBIOLOGY?

**2:45** *discussion*

**3:30** **KOWALEWSKI** ASSESSING LIVE-DEAD FIDELITY IN MARINE BENTHIC COMMUNITIES

**3:45** **KOKESH** RECENT DECALCIFICATION OF LIVING MOLLUSKS IS NEGATIVELY CORRELATED WITH DEAD SHELL DENSITIES IN PUGET SOUND: AN AGENCY-ACADEMIC COLLABORATION MOTIVATED BY CONCERNS FOR OCEAN ACIDIFICATION

**4:00** **LAKER** EVALUATING LONG-TERM CALVING GROUND VARIABILITY OF CARIBOU (*RANGIFER TARANDUS*) FROM IVVAVIK NATIONAL PARK, YUKON, CANADA

**4:15** **LIYANAGEDARA** LIVE-DEAD FIDELITY OF ECOLOGICAL HEALTH INDICES (AMBI AND M-AMBI) IN BENTHIC MARINE ASSOCIATIONS: A CASE STUDY FROM COASTAL NORTH CAROLINA, USA

**4:30** **TORRES** TAPHONOMY AND TIME-AVERAGING: A COMPARATIVE ANALYSIS OF ECHINOIDS AND MOLLUSKS

**4:45** **WRIGHT** THE TAPHONOMY OF PARASITISM: TWO CASE STUDIES AND A VISION FOR CONSERVATION PALEOBIOLOGY

**5:00** *discussion*

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION ANDERSON**
**RECENT ADVANCES IN COMPUTATIONAL PALEOBIOLOGY**
**MODERATORS: William Gearty, Bethany J. Allen, and Lewis A. Jones**

**1:15** **FURNESS** MODELLING THE MICROBIAL TO METAZOAN TRANSITION *(30-minute keynote)*

**1:45** **GEARTY** THE INTRODUCTION OF LARGE MAMMALS HAS NOT REMEDIED THE ECOLOGICAL IMPACT OF THE LATE PLEISTOCENE EXTINCTIONS

**2:00** **BAPST** PALEOAM – A PACKAGE FOR ABUNDANCE MODELS IN THE FOSSIL RECORD

**2:15** **JONES** MIND THE UNCERTAINTY: GLOBAL PLATE MODEL CHOICE IMPACTS DEEP-TIME PALAEOBIOLOGICAL STUDIES

**2:30** **WANG** QUANTITATIVE ICHNOLOGY: LINKING PALAEOBIOLOGY AND ENVIRONMENTAL CONDITIONS WITH TRACE FOSSIL MORPHOLOGY

**2:45** **LOUGHNEY** PALEOENVIRONMENTAL PROXIES, FACIES DATA, AND RESEARCHER INTERESTS

**3:30** **WIEMANN** COMPUTATIONAL APPROACHES TO CHEMICAL DATA REVEAL THE FIDELITY OF MOLECULAR BIOSIGNATURES THROUGH TIME AND SPACE *(30-minute keynote)*

**4:00** **COLLINS** MEASURING SPIRAL FORM ACROSS MOLLUSCAN CLASSES—AN EMPIRICAL PERSPECTIVE ON THE ‘MUSEUM OF ALL SHELLS’

**4:15** *withdrawn*

**4:30** **ROBERTS** DIVERGENT EVOLUTIONARY HISTORIES OF AXIAL SKELETAL COMPLEXITY BETWEEN REPTILES AND MAMMALS

**4:45** **PETSIOS** MORPHOSPACE OCCUPATION AND BIOMECHANICAL PERFORMANCE OF THE PERIGNATHIC GIRDLE IN JAWED ECHINOIDS

**5:00** **GOSWAMI** SEMILANDMARK AND LANDMARK FREE ANALYSIS OF SYNAPSID SKULL EVOLUTION

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION PENDLETON**
**TRAITS, FUNCTIONS, AND SYSTEMS: QUANTIFYING PALEOCOMMUNITY VARIATION, PERSISTENCE, AND RESILIENCE**
**MODERATORS: Ashley Dineen and Thomas Cullen**

**1:15** **BANKER** COMPARTMENTALIZATION OF PALEOCOMMUNITY TROPHIC NETWORKS DURING THE MESOZOIC MARINE REVOLUTION

**1:30** **OPAZO MELLA** ARE THE FOOD WEB PROPERTIES STABLE THROUGH A MASS EXTINCTION EVENT?

**1:45** **TACKETT** FINE-SCALE FOOD WEB MODELING FOR SHALLOW MARINE ECOSYSTEMS

**2:00** **NOVACK-GOTTSHALL** PERSISTENT ECOLOGICAL DIVERSITY OF MARINE TAXA THROUGH THE HISTORY OF ANIMAL LIFE

**2:15** **STROTZ** COMPETITION AND THE END OF THE LINE: WHAT STEAM LOCOMOTIVES CAN TELL US ABOUT CLADE REPLACEMENT IN THE FOSSIL RECORD

**2:30** **THIBODEAUX** MOLLUSK METABOLIC ENERGY EXPENDITURES FROM SHELL VOLUME AND FUNCTIONAL ECOLOGY INDICATE A PRODUCTIVE POST-IMPACT PALEOCENE SHALLOW MARINE ECOSYSTEM

**2:45** **DUTTA** QUANTITATIVE ECOLOGY OF AN EOCENE GREENHOUSE ANTARCTIC BENTHIC COMMUNITY – LA MESETA FORMATION, SEYMOUR ISLAND

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION PENDLETON**
**GENERAL SESSION ARTHROPODS**
**MODERATORS: Jonathan Adrain and Harriet Drage**

**3:30** **MIKULIC** RESURRECTING THE SILURIAN TRILOBITES OF THE CENTRAL UNITED STATES; NEW LIFE FOR OLD COLLECTIONS

**3:45** **ADRAIN** COORDINATED TURNOVER OF SHALLOW WATER TRILOBITE ASSEMBLAGES ALONG THE EARLY ORDOVICIAN NORTHERN LAURENTIAN MARGIN

**4:00** **LAIRD** TRILOBITE DIVERSITY RESPONSE TO THE END-ORDOVICIAN MASS EXTINCTION: BETWEEN-HABITAT DISSIMILARITY (BETA DIVERSITY) AS A MECHANISM TO MAINTAIN WITHIN-HABITAT RICHNESS (ALPHA DIVERSITY)

**4:15** **BEECH** PARALLEL EVOLUTION AND POSSIBLE FUNCTIONS OF THE HARPIFORM BRIM IN TRILOBITES

**4:30** **DRAGE** DISTINCT CAUSES UNDERLIE DOUBLE-PEAKED TRILOBITE CEPHALON DISPARITY, BUT THIS DISPARITY IS UNRELATED TO EXOSKELETON MOULTING BEHAVIOUR

**4:45** **MOYSIUK** A NEW RADIODONT WITH A SPECIALIZED POSTERIOR TAGMA FROM THE BURGESS SHALE EXEMPLIFIES EARLY PLASTICITY IN ARTHROPOD SEGMENTATION

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION KUENZEL**
**HOMINOID EVOLUTION, ENVIRONMENTS AND COMMUNITIES IN EASTERN AFRICA**
**MODERATORS: Susanne Cote and Laura MacLatchy**

**1:15** **LUKENS** QUANTITATIVE RECONSTRUCTION OF C4 PLANT FRACTIONS IN PALEOSOLS AND MAMMAL DIETS IN THE CENOZOIC RECORD OF EASTERN AFRICA

**1:30** **NORWOOD** REVISITING THE FOSSIL HERBIVORE ENAMEL ISOTOPES FROM LAETOLI, TANZANIA: INSIGHTS INTO THE PALEOECOLOGY OF *AUSTRALOPITHECUS AFARENSIS*

**1:45** **OPPENHEIM** ISOTOPIC NICHE SPACE: ASSESSING A NEW WAY TO LOOK AT HOMININ NICHE DYNAMICS AT HADAR AND WORANSO MILLE

**2:00** **KINGSTON** PALEOECOLOGY OF THE MIDDLE PLEISTOCENE KAPTHURIN FM. CHIMPANZEE (*PAN*) FOSSIL LOCALITY, BARINGO BASIN, KENYA

**2:15** **UNO** NEOGENE ECOSYSTEMS AND MAMMAL DIETS IN EAST AFRICA

**2:30** **WERDELIN** ARIDIFICATION AND FAUNAL ADAPTATIONS IN RESPONSE TO EAST AFRICAN MIOCENE UPLIFT

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION KUENZEL**
**PLANT-INSECT HERBIVORE RELATIONSHIPS IN DEEP TIME**
**MODERATORS: Alejo Giraldo and Anshuman Swain**

**3:30** **LABANDEIRA** MAJOR QUESTIONS ADDRESSING ARTHROPOD AND PATHOGEN HERBIVORY IN DEEP TIME

**3:45** **DEKOSTER** DIVERSITY OF ARTHROPOD HERBIVORE DAMAGE ASSOCIATED WITH THE MIDDLE PENNSYLVANIAN MAZON CREEK FLORA, ILLINOIS, USA

**4:00** **LAKERAM** A TAXONOMIC CLASSIFICATION AND DIVERSITY ASSESSMENTS OF TERRESTRIAL ARTHROPOD COPROLITES IN THE CALHOUN COAL BED FROM PENNSYLVANIAN COAL BALLS

**4:15** **XIAO** HIGHLY DIVERSE INSECT MINES FOUND ON GYMNOSPERMS FROM MIDDLE JURASSIC YANLIAO BIOTA, CHINA

**4:30** **CARRILLO-ALBARRAN** BUGGING BACK IN TIME: THE BOTANICAL TANGO OF LA POPA'S EOCENE (CARROZA FORMATION; NUEVO LEÓN).

**4:45** **GIRALDO** INSECT-FEEDING TRACES FROM EOCENE PATAGONIA REVEAL UNRECOGNIZED EVOLUTIONARY HISTORY OF HERBIVOROUS INSECTS ON AUSTRALIA'S ICONIC *EUCALYPTUS*

**5:00** **SWAIN** EFFECTS OF TEMPERATURE, ARIDITY, AND PLANT STOICHIOMETRY ON INSECT HERBIVORY: LESSONS FROM THE PAST AND THE PRESENT

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION WOLVERINE**
**STRATIGRAPHIC PALEOBIOLOGY: WORKING WITH THE NATURE OF THE STRATIGRAPHIC RECORD TO ANSWER PALEOBIOLOGICAL QUESTIONS**
**MODERATORS: Pedro Monarrez, Annaka Clement, and Katharine Loughney**

**1:15** **PIPPENGER** A COMBINED STRATIGRAPHIC AND ICHNOLOGICAL APPROACH TO RECONSTRUCTING THE EVOLUTION OF THE SEDIMENTARY MIXED LAYER IN THE DEVONIAN OF THE APPALACHIAN BASIN

**1:30** **HUGHES** EVOLUTIONARY TEMPO AND MODE IN STRATIGRAPHIC CONTEXT: DIKELOCEPHALID TRILOBITE EVOLUTION IN THE UPPER MISSISSIPPI VALLEY CAMBRIAN

**1:45** **SCLAFANI** STRATIGRAPHIC PALEOBIOLOGY IN THE LATE SILURIAN AND EARLY DEVONIAN OF CENTRAL NEVADA: PUTTING OLD DATA TO NEW USES

**2:00** **MCLAUGHLIN** FOSSIL POINT OREGON; NEW FOSSILS, OLD FOSSILS REVISITED, AND POSSIBLE CASCADIA TSUNAMI DEPOSITS

**2:15** **HAYES** RECONSTRUCTING HIGH-LATITUDE DEGLACIATION IN THE LATE PALEOZOIC VIA MACHINE LEARNING INFERENCE AND BIOSTRATIGRAPHIC OPTIMIZATION: CANNING BASIN, WESTERN AUSTRALIA

**2:30** **FAN** ONESTRATIGRAPHY: UNVEILING DEEP-TIME EARTH HISTORY THROUGH GLOBAL STRATIGRAPHIC DATA HARMONIZATION

**2:45** **ZHANG** CONSTRUCT A HIGH-RESOLUTION GEOLOGICAL TIMELINE THROUGH THE DEVONIAN TO TRIASSIC

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION WOLVERINE**
**CONODONTS IN TIME AND SPACE – NORTH AMERICAN PANDER SOCIETY MEETING**
**MODERATORS: D. Jeffrey Over and Nicholas Hogencamp**

**3:30** **MILLER** PROBABLE IMPACT ORIGIN OF COINCIDENT EXTINCTIONS AMONG CONODONTS, TRILOBITES, AND BRACHIOPODS, TOP OF SYMPHYSURINID BIOMERE, EARLY ORDOVICIAN, HOUSE RANGE, IBEX AREA, WEST-CENTRAL UTAH

**3:45** **LUBLINER** MIND THE GAP: REVISING THE DESMOINESIAN (MIDDLE PENNSYLVANIAN) VERDIGRIS CONODONT ASSEMBLAGE

**4:00** **ROSSCOE** *GONDOLELLA* SPECIES OF THE UPPER SALESVILLE FORMATION, PALO PINTO COUNTY, TEXAS

**4:15** **HENDERSON** THE DELIVERY OF SHALLOW-WATER CONODONTS INTO DEEPER OFFSHORE SETTINGS: LOWER PERMIAN AND LOWER TRIASSIC CASE STUDIES

**4:30** **HOGANCAMP** AN INTRODUCTION TO THE CONODONT DATA ANALYSIS TOOL (CDAT) FOR VISUALLY ANALYZING RANGE, COUNT, AND DISTRIBUTION DATA

**4:45** **OVER** CONODONT COLOR ALTERATION INDEX REFERENCE SETS: HISTORIC ICONS AND ANITA (EPSTEIN) HARRIS LEGACY

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION 2210**
**NORTH AMERICAN PALEONTOLOGICAL RESOURCES 2024**
**MODERATORS: Lisa Amati and Vanessa Rhue**

**1:15** **FARRAR** HISTORY, SIGNIFICANCE, AND FUTURE DIRECTIONS OF THE INVERTEBRATE PALEONTOLOGY COLLECTION AT THE SAM NOBLE OKLAHOMA MUSEUM OF NATURAL HISTORY

**1:30** **GARCIA** HISTORY AND CURRENT STATUS OF THE LELAND STANFORD JUNIOR UNIVERSITY PALEONTOLOGY COLLECTIONS

**1:45** **MIKULIC** THE FUTURE OF SMALL MUSEUM PALEONTOLOGICAL RESOURCES AND THE WEIS EARTH SCIENCE MUSEUM

**2:00** **MCCALL** THE ELEPHANT IN THE ROOM – THE NON-PROFESSIONAL SIDE OF PALEONTOLOGY

**2:15** **CLARY** U.S. FOSSIL PARKS AS PALEONTOLOGICAL RESOURCES: 21ST CENTURY CHALLENGES FOR PUBLIC FOSSIL COLLECTING AND EDUCATION

**2:30** **HENDRICKS** PRI'S ONLINE RESOURCES FOR LEARNING ABOUT FOSSILS, EVOLUTION, AND EARTH HISTORY

**2:45** **LÓPEZ CARRANZA** THE *TREATISE ON INVERTEBRATE PALEONTOLOGY*: NEW DIGITAL INITIATIVES AND FUTURE-FORWARD VISION

**3:30** **HENDY** DIGITIZATION OF INVERTEBRATE PALEONTOLOGY COLLECTIONS: LOTS OF PROGRESS BUT LOTS OF REMAINING CHALLENGES

**3:45** **KARIM** FOSSIL COLLECTIONS DATA: RESOURCES, STANDARDS, COMMUNITY

**4:00** **JOHNSON** BEST PRACTICES FOR DESIGNING EXPERIMENTS USING 3D DEFOSSILIZED MORPHOLOGIES

**4:15** **LONG-FOX** MORPHOBANK: A PALEONTOLOGICAL RESOURCE FOR COLLABORATIVE RESEARCH AND AN OPEN-ACCESS REPOSITORY FOR MORPHOLOGICAL DATA

**4:30** **SIMPSON** ANALYTICAL PALEOBIOLOGY RELIES ON ACCURATE TAXONOMIC DESCRIPTIONS: AN EMPHASIS ON PALEOBOTANY

**4:45** **QUIRK** A PALEONTOLOGICAL GOLDMINE: EDUCATION AND RESEARCH FUNDING OPPORTUNITIES THROUGH THE NATIONAL SCIENCE FOUNDATION

**5:00** **RAYMOND** WE SHOULD COLLABORATE *(30-minute keynote)*

**THURSDAY AFTERNOON, JUNE 20, 2024**
**UNION POND**
**INTERCONNECTED PATTERNS OF NATURAL HISTORY:**
**A TRIBUTE TO THE CAREER AND CONTRIBUTIONS OF LANCE GRANDE**
**MODERATORS: Sam Giles and Miguel Montalvo**

**1:15** **MONTALVO** REVIEW AND UPDATE OF THE FOSSIL HISTORY OF BILLFISHES (ISTIOPHORIFORMES, XIPHIOIDEI)

**1:30** **YABUMOTO** MESOZOIC AND CENOZOIC ACTINOPTERYGIAN FISHES FROM JAPAN

**1:45** **CHIDA** PLEISTOCENE MARINE FISH FAUNA FROM THE MASUDA FORMATION OF TANEGASHIMA ISLAND, SOUTHWEST JAPAN

**2:00** **BEMIS** ADVENTURES IN TEACHING VERTEBRATE EVOLUTION WITH SOME THOUGHTS ON TRAINING THE NEXT GENERATION OF VERTEBRATE PALEONTOLOGISTS

**2:15** **HILTON** FURTHER NOTES ON MORPHOLOGICAL VARIATION: A HIERARCHICAL CONCEPTUAL FRAMEWORK FOR INTERPRETING EMPIRICAL DATA

## THURSDAY POSTERS, JUNE 20, 2024
## UNION IDEA HUB
## PRESENTERS SHOULD ATTEND POSTERS FROM 5:30–6:15

### GENERAL SESSION: MOLLUSKS

1 **QUIZON** PRELIMINARY INSIGHTS INTO MARINE GASTROPOD PRECIPITATION KINETICS FROM DUAL CLUMPED ISOTOPES (Δ47/Δ48)

2 **SATOUR** BIVALVES FROM THE NEOGENE DEPOSITS OF ALGERIA (SYSTEMATIC & PALEOENVIRONMENTS)

3 **STOWE** BIOTIC RESPONSES TO ENVIRONMENTAL CHANGE IN A RESTRICTED BASIN: A MACROEVOLUTIONARY AND PALEOECOLOGICAL EXAMINATION OF THE LATE NEOGENE SAN JOAQUIN SEAWAY, CALIFORNIA

### RECENT ADVANCES IN COMPUTATIONAL PALEOBIOLOGY

4 **ALI** IMPACT OF A CODING BUG ON PALEOBIOLOGY DATABASE GENUS RICHNESS

5 **ALLEN** RMACROSTRAT: AN R PACKAGE FOR RETRIEVING DATA FROM THE MACROSTRAT GEOLOGICAL DATABASE

6 **CURRANO** PBOT, THE INTEGRATIVE PALEOBOTANY PORTAL: A FREE WORKBENCH FOR PALEOBOTANICAL RESEARCH AND DATA MANAGEMENT

7 **DUMADAG** HIDDEN IN PLAIN SITE: COMPARING DIVERSITY USING SEPKOSKI'S *COMPENDIUM* AND THE PALEOBIOLOGY DATABASE

8 **GEARTY** DEEPTIME: AN R PACKAGE THAT FACILITATES HIGHLY CUSTOMIZABLE VISUALIZATIONS OF DATA OVER LONG TIME PERIODS (AND OTHER THINGS)

9 **JONES** PALAEOVERSE: A COMMUNITY-DRIVEN R PACKAGE TO SUPPORT PALAEOBIOLOGICAL ANALYSIS

### TRAITS, FUNCTIONS, AND SYSTEMS: QUANTIFYING PALEOCOMMUNITY VARIATION, PERSISTENCE, AND RESILIENCE

10 **JANUARIO** INVESTIGATING THE TIMESCALE OF TRAIT RE-STRUCTURATION IN A JURASSIC LAKE

11 **MADURO-SALVARREY** QUANTIFYING ECOSYSTEM STRUCTURE USING BIOVOLUME OF BENTHIC MARINE INVERTEBRATES DURING THE LATE PALEOZOIC ICE AGE

12 **RIZZA** NO TAXONOMIC OR ECOLOGICAL RESPONSE TO GLOBAL CLIMATE EVENTS IN THE LATE MAASTRICHTIAN OWL CREEK FORMATION

### GENERAL SESSION: ARTHROPODS

13 **PANKOWSKI** THE DEVONIAN-CARBONIFEROUS DIVERSITY OF CLAM SHRIMP (CRUSTACEA: BRANCHIOPODA: LAEVICAUDATA, SPINICAUDATA, CYCLESTHERIDA): A PRELIMINARY REPORT

14 **SHILLING** A RE-EVALUATION OF THE SUPPOSED OCCURRENCE OF THE EXTANT NOTOSTRACAN SPECIES, *TRIOPS CANCRIFORMIS*, IN THE TRIASSIC OF VIRGINIA

### HOMINOID EVOLUTION, ENVIRONMENTS AND COMMUNITIES IN EASTERN AFRICA

15 **GOODCHILD** INVESTIGATING THE EFFECT OF HISTORICAL COLLECTION BIASES ON PALEOENVIRONMENTAL INTERPRETATIONS IN EAST TURKANA, KENYA

16 **TWEEDY** EARLY MIOCENE BIOMARKER RECORDS FROM TURKANA PALEONTOLOGICAL SITES

## PLANT-INSECT HERBIVORE RELATIONSHIPS IN DEEP TIME

*no posters for this session*

## STRATIGRAPHIC PALEOBIOLOGY: WORKING WITH THE NATURE OF THE STRATIGRAPHIC RECORD TO ANSWER PALEOBIOLOGICAL QUESTIONS

**17** **CIAMPAGLIO** A PRELIMINARY REPORT OF A LOWER CARBONIFEROUS (MISSISSIPPIAN: TOURNAISIAN) CHONDRICHTHYAN FAUNA FROM THE "BLUE RIDGE ESKER" LOCALITY (MARSHALL FORMATION) OF MICHIGAN, USA

**18** **CLINE** *HESLERODOIDES* (CHONDRICHTHYES: ELASMOBRANCHII: CTENACANTHIFORMES) FROM THE PERMIAN RED EAGLE LIMESTONE OF KANSAS

**19** **OLSON** FOSSILS FROM THE MIDDLE CAMBRIAN OF SOUTHWESTERN MONTANA IN A STRATIGRAPHIC CONTEXT

## CONODONTS IN TIME AND SPACE – NORTH AMERICAN PANDER SOCIETY MEETING

*no posters for this session*

## NORTH AMERICAN PALEONTOLOGICAL RESOURCES 2024

**20** **COOROUGH BURKE** A DOZEN YEARS OF DIGITIZING BRINGS FOSSIL COLLECTIONS INTO THE SEARCHABLE WORLD

**21** **ENGELKE** CURRENT STATUS OF THE PALEONTOLOGICAL COLLECTION AT BELOIT COLLEGE

**22** **HUGHES** NHM UNLOCKED, PREPARING COLLECTIONS TO MOVE

**23** **JOHNSON** THE INDIANA UNIVERSITY PALEONTOLOGY COLLECTION - CURRENT STATUS OF PALEONTOLOGICAL RESOURCES

**24** **MORAN** PALEONTOLOGICAL COLLECTIONS AT THE NORTH CAROLINA MUSEUM OF NATURAL SCIENCES: IMPROVEMENT AND EXPANSION OVER THE LAST DECADE

**25** **MORSE** BETTER NOW THAN NEVER: CATALOGUING A COLLECTION AFTER 188 YEARS

**26** **NARDUCCI** VERTEBRATE PALEONTOLOGY COLLECTIONS AT THE FLORIDA MUSEUM OF NATURAL HISTORY, UNIVERSITY OF FLORIDA

**27** **YACOBUCCI** PALEONTOLOGY AT BOWLING GREEN STATE UNIVERSITY: COLLECTING, RESEARCHING, AND TEACHING ABOUT THE ANCIENT LIFE OF THE GREAT LAKES REGION

**28** **ZHANG** THE FIELD MUSEUM'S 2022 KONECNY FOSSIL INVERTEBRATE COLLECTION DIGITIZATION PROJECT

## INTERCONNECTED PATTERNS OF NATURAL HISTORY: A TRIBUTE TO THE CAREER AND CONTRIBUTIONS OF LANCE GRANDE

**29** **BRITO** THE 'MID' CRETACEOUS FRESHWATER ICHTHYOFAUNA FROM THE NORTHERN GONDWANA: AN UPDATED LOOK

**30** **FRIEDMAN** UNTANGLING THE FIRST ACTINOPTERYGIAN ADAPTIVE RADIATION

**31** **GOTTFRIED** AN UPDATED LOOK AT 'LOWER' ACTINOPTERYGIAN AND COELACANTH RECORDS FROM THE LATE CRETACEOUS OF MADAGASCAR

**FRIDAY MORNING, JUNE 21, 2024**
**UNION ROGEL**
**LESSONS LEARNED AND FUTURE VISIONS FOR CONSERVATION PALEOBIOLOGY**
**MODERATORS: Erin Dillon and Broc Kokesh**

**8:00** **FLANTUA** INTERDISCIPLINARY PERSPECTIVES IN AN ERA OF GLOBAL POLLEN SYNTHESIS

**8:30** **KOOYMAN** USING PALEOBOTANY TO INFORM CONSERVATION OF THE AUSTRALIAN RAINFORESTS

**8:45** **MORLEY** IDENTIFYING A SPRUCE REFUGIUM IN ALASKA, U.S.A. USING MONTE CARLO STATISTICAL METHODS

**9:00** **GIBERT BRET** PLANTS ALWAYS HAVE HIGHER CLIMATE FIDELITY THAN MAMMALS, AND IT GETS WORSE AFTER INDUSTRIALIZATION

**9:15** **SHORT** ADVANCING CONSERVATION PALEOBIOLOGY THROUGH ECOMETRICS: INTEGRATING FUNCTIONAL TRAITS AND ENVIRONMENTS OF PAST, PRESENT, AND FUTURE FAUNAS

**9:30** *discussion*

**10:15** **KUSNERIK** USING LIVE, DEAD, AND FOSSIL GASTROPODS TO ASSESS RESPONSE AND RECOVERY TO LONG- AND SHORT-TERM DISRUPTIONS IN FLORIDA FRESHWATER SPRINGS AND RIVERS

**10:30** **CARDEN** CHANGES IN GROWTH RATES OF TWO SPECIES OF FRESHWATER MUSSELS IN AN OHIO STREAM OVER THE LAST 80 YEARS

**10:45** **EDELMAN-FURSTENBERG** USING THE RECENT PAST TO RECOGNIZE ANTHROPOGENIC INFLUENCE ON THE ISRAELI MEDITERRANEAN SHELF: AGE-BASED STUDY

**11:00** **SNYDERMAN** FROM EXTIRPATION TO EXTINCTION: HOLOCENE RANGE COLLAPSE OF THE GREAT AUK (*PINGUINUS IMPENNIS*)

**11:15** **SMITH** THE THEORETICAL SIDE OF CONSERVATION PALEOBIOLOGY: A PERSPECTIVE FROM THE PALEOSYNTHESIS PROJECT

**11:30** **KELLEY** DEVELOPING PEDAGOGIES TO FOSTER CORE COMPETENCIES FOR THE NEXT GENERATION OF CONSERVATION PALEOBIOLOGISTS: A WORKING GROUP PROGRESS REPORT

**11:45** *discussion*

## FRIDAY MORNING, JUNE 21, 2024
## UNION ANDERSON
## DEEP LEARNING IN DEEP TIME: APPLICATIONS OF AI AND AUTOMATION IN PALEONTOLOGY
## MODERATORS: Allison Hsiang and Meghan Forcellati

**8:00** **LESHNO AFRIAT** TESTING THE BOREAL-TETHYAN SHIFT OF NERINEOIDEAN GASTROPODS: TAXONOMIC CLASSIFICATION USING CONVOLUTIONAL NEURAL NETWORKS

**8:15** **HU** AUTOMATICALLY IDENTIFYING, DETECTING AND MEASURING OSTRACODS WITH DEEP LEARNING

**8:30** **HUANG** MICROFOSSIL AUTOMATIC IDENTIFICATION USING INTEGRATED DEEP-LEARNING MODELS

**8:45** **MULQUEENEY** ADVANCING HIGH-RESOLUTION TRAIT EXTRACTION IN THREE-DIMENSIONAL BIOLOGICAL IMAGES THROUGH DEEP LEARNING

**9:00** **ANEMONE** GEOSPATIAL PALEONTOLOGY: MODELING THE LOCATION OF FOSSIL LOCALITIES USING SATELLITE IMAGERY AND ARTIFICIAL INTELLIGENCE

**9:15** **JARIWALA** UTILIZING ARTIFICIAL INTELLIGENCE FOR EFFICIENT MORPHOLOGICAL DATA INTEGRATION

**10:15** **FORCELLATI** USING MACHINE LEARNING AND PHYLOGENETIC COMPARATIVE METHODS FOR PREDICTING ECOLOGY IN FOSSILS FROM INNER EAR BONY LABYRINTHS OF TOXICOFERANS (SQUAMATA, REPTILIA)

**10:30** **RODRIGUEZ** IDENTIFYING FLORISSANT LEAF FOSSILS TO FAMILY USING DEEP NEURAL NETWORKS

**10:45** **ADAIMÉ** RECONSTRUCTING THE DIVERSITY DYNAMICS OF LATE QUATERNARY EAST AFRICAN GRASSLANDS USING SUPERRESOLUTION IMAGING OF FOSSIL POACEAE POLLEN AND DEEP LEARNING

**11:00** **ROMERO** USING MACHINE LEARNING TO STUDY CHANGES IN THE LATITUDINAL DISTRIBUTION OF TERRESTRIAL PLANTS BETWEEN THE LATE PALEOCENE AND EARLY EOCENE IN NORTH AMERICA

**11:15** **PUNYASENA** DEVELOPMENT OF A HIGH-THROUGHPUT FOSSIL POLLEN ANALYSIS PIPELINE

**11:30** **BERV** 15,000 PASSERINE SKELETONS ILLUMINATE TIME-HETEROGENEOUS PATTERNS OF PHENOTYPIC INTEGRATION

**FRIDAY MORNING, JUNE 21, 2024**
**UNION PENDLETON**
**FIRST PRINCIPLES, BOUNDLESS CURIOSITY –**
**CELEBRATING THE CONTRIBUTIONS OF DANIEL C. FISHER**
**MODERATORS: Sandra Carlson and Paul Koch**

**8:00** *introductory remarks*

**8:15** **LAMSDELL** FOSSIL CHELICERATES AS AN EVOLUTIONARY CASE STUDY INTO MECHANISMS AND DRIVERS OF MORPHOLOGICAL CHANGE

**8:30** **OCON** GROWING UP IN THE GRÈS À VOLTZIA: ONTOGENY IN *LIMULITELLA BRONNI*

**8:45** **CARLSON** TESTING EVOLUTIONARY HYPOTHESES OF THECIDEIDE BRACHIOPOD ORIGINS: HOMOLOGY, HOMOPLASY, AND HETEROCHRONY

**9:00** **PARINS-FUKUCHI** MACROEVOLUTIONARY AND PHYLOGENETIC CONSEQUENCES OF STABLE MORPHOLOGICAL POLYMORPHISM IN THE FOSSIL RECORD

**9:15** **LEIGHTON** HUMAN IMPACTS, RATHER THAN THE LATITUDINAL PREDATION GRADIENT, DRIVE CRAB PREDATION ALONG THE WEST COAST OF NORTH AMERICA

**9:30** **FOX** DENTAL ECOMORPHOLOGY OF MODERN NORTH AMERICAN RODENTS

**9:45** **BADGLEY** THE PUZZLE OF MIOCENE MEGAHERBIVORE RICHNESS

**10:15** **PLOTNICK** NO MORE MONKEYS JUMPING INTO THE BED: FIRST ORDER CONTROLS ON THE FOSSIL RECORD OF PRIMATES

**10:30** **CROWLEY** DIGESTION BY BIRDS OF PREY IMPACTS THE ISOTOPIC COMPOSITION OF CONSUMED PREY: IMPLICATIONS FOR PALEOECOLOGICAL STUDIES

**10:45** **ROUNTREY** "A STRIKING PATTERN OF INCREMENTAL LAMINATION": GROWTH INCREMENTS IN VERTEBRATE TISSUES

**11:00** **CERLING** UNSCRAMBLING THE OMELETTE – ISOTOPE INCORPORATION IN ANIMAL TISSUES AND METHODS FOR INTERPRETING ISOTOPE PROFILES IN TISSUES

**11:15** **CHERNEY** HORMONES PRESERVED IN TUSKS ENHANCE LIFE-HISTORY ANALYSES OF PROBOSCIDEANS PAST AND PRESENT

**11:30** **KOCH** PROTEIN METABOLISM IN EXTANT AND EXTINCT LARGE MAMMALS: DIFFERENCES IN *DE NOVO* AND GUT MICROBE AMINO ACID SYNTHESIS

**11:45** **SELCER** LIFE HISTORIES IN THE HISTORY OF LIFE: A BIOGRAPHICAL APPROACH TO PALEONTOLOGY

**FRIDAY MORNING, JUNE 21, 2024**
**UNION KUENZEL**
**GENERAL SESSION: PALEOBOTANY**
**MODERATORS: Indah Huegele and Edward Spagnuolo**

**8:00** **LODUCA** MORE MICHIGAN MARINE MACROALGAE (SILURIAN, LLANDOVERIAN)

**8:15** **HUEGELE** EVOLUTIONARY MYSTERIES IN THE PLANE TREE (PLATANACEAE) FOSSIL RECORD

**8:30** **BUTRIM** TWO PATHWAYS OF PLANT RECOVERY AFTER THE END-CRETACEOUS MASS EXTINCTION IN THE DENVER BASIN, COLORADO

**8:45** **MORALES TOLEDO** BISEXUAL CLIMBERS OF ARACEAE IN DEEP TIME: A REEXAMINATION OF *ARTHMIOCARPUS HESPERUS* FROM THE LATE CRETACEOUS OF SOUTH DAKOTA

**9:00** **SPAGNUOLO** INTO- OR OUT-OF-INDIA? EARLY EOCENE POLLEN AND MACROFOSSILS FROM THE GHAZIJ FORMATION IN BALOCHISTAN, PAKISTAN TEST LONG-STANDING BIOGEOGRAPHIC HYPOTHESES

**9:15** **CORREA-NARVAEZ** A UNIQUE CARYOPHYLLALEAN FOSSIL AND THE TEMPTATIONS OF THE MODERN FAMILY

**9:30** **TADOUMANT** CLIMATE CHANGE IMPACTS ON ENDEMIC SPECIES IN THE CENTRAL PART OF MOROCCO: *ARGANIA SPINOSA* AS A CASE STUDY

**FRIDAY MORNING, JUNE 21, 2024**
**UNION KUENZEL**
**WETLAND ECOLOGY THROUGH TIME**
**MODERATORS: Michelle Chrpa and Samuel Neely**

**10:15** **CHRPA** MG/CA OF CRINOIDS AND PLANTS IN COAL BALLS FROM THE MID-MOSCOVIAN THROUGH KASIMOVIAN OF THE LATE PALEOZOIC MIDCONTINENT SEAWAY

**10:30** **SCOTT** THE RISE OF ARBORESCENT LYCOPHYTES AS KEYSTONE SPECIES

**10:45** **JACKSON** ALETHOPTERID OR NEUROPTERID? DISTINGUISHING *MYELOXYLON* IN COAL BALLS

**11:00** **RAYMOND** LARGE DEBRIS IN PALEOZOIC AND MODERN PEAT

**11:15** **NEELY** ECOSYSTEM ENGINEERING THROUGH TIME: THE ROLE OF POST-PALEOZOIC DETRITIVORES IN PEATLANDS

**11:30** **MARTIN** TRACES OF ECOLOGICAL RECOVERY IN PALEOCENE FRESHWATER ECOSYSTEMS AT CORRAL BLUFFS (DENVER BASIN), COLORADO

**FRIDAY MORNING, JUNE 21, 2024**
**UNION WOLVERINE**
**PALEOBIOLOGY OF CARNIVOROUS MAMMALS**
**MODERATORS: John D. Orcutt and Mairin Balisi**

**8:00** **ORCUTT** BODY SIZE & *BASSARISCUS*

**8:15** **MORETTI** WILDCAT SKELETONS FROM NATURAL BRIDGE CAVERNS OFFER INSIGHTS INTO THE DIVERSITY OF SMALL FELINES IN THE LATE QUATERNARY OF TEXAS

**8:30** **POUST** A NEW CARNIVORAMORPHAN FROM THE EOCENE FRIARS FORMATION OF SOUTHERN CALIFORNIA

**8:45** **RILEY** FIRST CRANIUM OF THE ENIGMATIC ARCHAIC UNGULATE MAMMAL "*CARCINODON*" IN THE DENVER BASIN, COLORADO, PROMPTS REEVALUATION OF THAT GENUS

**9:00** **AMANE** BASILOSAURIDAE (MAMMALIA, CETACEA) FROM THE SAHARA DESERT OF SOUTHWESTERN MOROCCO

**9:15** **LOWERY** CARNIVORAN BIRTH CERTIFICATES: UTILIZING MULTIPLE VISUALIZATION METHODS TO PINPOINT DENTAL NEONATAL LINES IN NEW TAXA

**9:30** **ROTHSCHILD** CRANIAL CHANNELS AND SUPRA-PARIETAL VASCULAR PLEXUSES: IMPLICATIONS FOR BRAIN THERMOREGULATION IN MAMMALIAN CARNIVORES

**10:15** **KORT** SPEED OR ENDURANCE: WHAT IS THE ECOLOGICAL ADVANTAGE OF CURSORIALITY IN CARNIVORANS? *(30-minute keynote)*

**10:45** **LOPEZALLES** THE SHAPE OF SPEED: THE RELATIONSHIP BETWEEN 3D HUMERUS SHAPE AND MAXIMUM RUNNING SPEED

**11:00** **POLLY** THE ASSEMBLY OF NEW WORLD CAT COMMUNITIES: ECOMETRICS AND NEOGENE LOCOMOTOR TRAIT TURNOVER

**11:15** **EVERETT** MORPHOMETRIC ANALYSIS OF ARCTOID UPPER CARNASSIAL TEETH CORRELATES SHAPE WITH DIET AND PHYLOGENY

**11:30** **DESANTIS** ECOLOGICAL RESONANCE: UNRAVELING THE HUNTING BEHAVIOR AND DIETARY ECOLOGY OF THE AMERICAN LION (*PANTHERA ATROX*), AN INFERRED DEPARTURE FROM AFRICAN LIONS

**11:45** **MUNSON** PREDATOR-PREY DYNAMICS OF DIRE WOLVES AND THEIR PREY IN THE CONTEXT OF CHANGING CLIMATE, LATE PLEISTOCENE-EARLY HOLOCENE, CUTLER HAMMOCK SITE, FLORIDA, U.S.A.

**FRIDAY MORNING, JUNE 21, 2024**
**UNION 2210**
**BROADENING ACCESSIBILITY IN PALEONTOLOGY THROUGH INNOVATIVE COMMUNITY ENGAGEMENT PRACTICES**
**MODERATORS: Jeanette Pirlo and Carmi Thompson**

**8:00** **PORCELLO** HOOKING ELEMENTARY STUDENTS INTO A LOVE OF SCIENCE WITH FOSSILS

**8:15** **INMAN** EVALUATING THE EFFICACY OF INFORMAL EDUCATION THROUGH MUSEUM POP-UP DISPLAYS AT CALIFORNIA STATE UNIVERSITY, STANISLAUS'S VASCHÉ LIBRARY

**8:30** **BOLGER** PALEO PODCASTS: USING PARTICIPATORY NARRATIVE INQUIRY TO EVALUATE STUDENT LEARNING IN A 4-H PALEONTOLOGY SUMMER CAMP

**8:45** **EL-SAYED** ADVANCEMENTS IN EGYPTIAN VERTEBRATE PALEONTOLOGY: MUVP'S CONTRIBUTIONS AND FUTURE PERSPECTIVES

**9:00** **HOPPS** PLACE-BASED FOSSIL KITS FOR ACCESSIBLE PALEONTOLOGICAL EDUCATION

**9:15** **THOMPSON** OTHER STRATIGRAPHIES, OTHER NARRATIVES: EXPLORING POST HUMAN METHODOLOGIES IN PALEOBIOLOGY EDUCATION

**9:30** **FRANCEK** FROM DISCOVERY TO INTERNATIONAL NEWS: A UTILITY AGENCY'S STEWARDSHIP AND PUBLIC OUTREACH OF A CALIFORNIA FOSSIL SITE

**10:15** **XU** EXPLORING STRATEGIES FOR FACILITATING INTERNATIONAL COLLABORATIONS TO ENHANCE PALEONTOLOGICAL RESEARCH

**10:30** **SANTOS** COSPLAY FOR SCIENCE: AN AMBITIOUS CROSSOVER OF POP CULTURE AND SCIENCE EDUCATION

**10:45** **LEPORE** INTERROGATING ABLEISM AND THE PRIVILEGE OF SCIENCE: STUDENT PERCEPTIONS OF ACCESSIBILITY AND DISABILITY IN PALEONTOLOGY COLLEGE CLASSROOMS

**11:15** **WHITE** ADVANCING COMMUNITY COLLEGE EDUCATION AND STUDENT SUCCESS (ACCESS) AT THE UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY: SEVEN YEARS OF EXPANDING ACCESS AND BUILDING NEW PARTNERSHIPS OPPORTUNITIES

**FRIDAY MORNING, JUNE 21, 2024**
**UNION POND**
**AVOCATIONAL CLUBS AS PALEONTOLOGICAL RESOURCES**
**MODERATORS: David Clark and Jennifer Bauer**

**8:00** **CLARK** YOU'VE GOT A FRIEND IN ME – 20 YEARS IN THE FRIENDS OF THE UNIVERSITY OF MICHIGAN MUSEUM OF PALEONTOLOGY

**8:15** **MCCALL** FOSSIL CLUBS – PAST, PRESENT AND FUTURE? THE 10,000 FT VIEW

**8:30** **BISSETT** DISCOVERIES IN THE SILURIAN OF INDIANA: FOUR DECADES OF COLLABORATION BETWEEN AVOCATIONAL AND PROFESSIONAL PALEONTOLOGISTS

**8:45** **COOPER** CONTRIBUTIONS OF AN AVOCATIONAL INVERTEBRATE PALEONTOLOGIST TO RESEARCH COLLECTIONS AND PROFESSIONAL PAPERS

**9:00** **SHOEMAKER** AMATEUR CONTRIBUTIONS TO PALEONTOLOGY: A MIDWESTERNER'S EXPERIENCE

**9:15** **PANKOWSKI** DIGGING ONLINE AND PARTNERING WITH PALEONTOLOGISTS TO DISCOVER NEW SPECIES AND PREHISTORIC BEHAVIOR

**9:30** **KONIECKI** AN AMATEUR'S CONTRIBUTIONS TO PALEONTOLOGY

**10:15** **STOKES** DIGGING FOR TRILOBITES, SCIENCE EDUCATION, AND LONG-TERM SUSTAINABILITY AT PENN DIXIE FOSSIL PARK IN BUFFALO, NY

**10:30** **WESTGAARD** AN INTRODUCTION TO THE HILL ANNEX PALEONTOLOGY PROJECT: A NEW RESEARCH PROGRAM EXAMINING THE CRETACEOUS SYSTEMS OF THE MINNESOTA REGION

**10:45** **KAPLAN** EMPOWERING CLUBS TO ADVISE ON ACADEMIC GRANT PROPOSALS' BROADER IMPACTS SECTIONS: FULFILLING AVOCATIONAL NEEDS WHILE BOOSTING GRANT FUNDING RATES

**11:00** **SHOEMAKER** INSPIRING PUBLIC ENTRY INTO AVOCATIONAL PALEONTOLOGY: IMPEDIMENTS AND INITIATIVES

**11:15** *discussion* (*45 minutes*)

**FRIDAY AFTERNOON, JUNE 21, 2024**
**UNION ANDERSON**
**INTEGRATED APPROACHES TO EXPLORING COUPLED BIOTIC, LANDSCAPE AND CLIMATE DYNAMICS**
**MODERATORS: David Fox and Rebecca Terry**

**1:15** **WEAVER** ON THE ROLE OF TECTONICS IN STIMULATING THE CRETACEOUS DIVERSIFICATION OF MAMMALS

**1:30** **HARDY** QUANTIFYING PRESERVATION OF MODERN RODENT SPECIES IN THE FOSSIL RECORDS OF COLORADO AND ECUADOR

**1:45** **MARDER** THE IMPACT OF MOUNTAIN BUILDING ON BIODIVERSITY OF SMALL TO MEDIUM SIZED TERRESTRIAL MAMMALS IN DEEP TIME

**2:00** **DOLBY** CAPTURING THE NUANCE OF PHYSIOGRAPHIC BARRIERS: AN EXAMPLE FROM RIVERS

**2:15** **TERRY** DIVERSITY UP MOUNTAINS: QUANTIFYING THE ROLE OF CANYON GEOMORPHOLOGY ON ELEVATIONAL DIVERSITY GRADIENTS

**2:30** **WYATT** SPATIAL DIVERSITY AND TRAIT DISPARITY OF MODERN HETEROMYIDAE (RODENTIA) WITH IMPLICATIONS FOR THE RELATIONSHIP BETWEEN DYNAMIC LANDSCAPES AND EVOLUTIONARY HISTORY OVER DEEP TIME

**2:45** **PENG** MODERN BIOLOGICAL DIVERSITY GRADIENTS AND THEIR IMPLICATIONS FOR THE FOSSIL RECORD: A CASE STUDY IN NORTH AMERICAN RODENTS

**3:30** **WANG** BIOGEOGRAPHY AND ISOTOPE ECOLOGY OF EXTANT HERBIVOROUS ARTIODACTYLS, WITH IMPLICATIONS FOR PALEOECOLOGY

**3:45** **REID** BAT GUANO RECORDS OF PAST CLIMATE AND ENVIRONMENT FROM SOUTHWEST VIRGINIA: EXCAVATING THE FORGOTTEN GRASSLANDS OF THE SOUTH

**4:00** **WING** A NEW APPROACH FOR COMPARING PALEOCLIMATE MODEL RESULTS AND FOSSIL PLANT DISTRIBUTIONS

**4:15** **STILES** MID-HIGH LATITUDE FOREST EXPANSIONS ACROSS THE EARLY EOCENE CLIMATIC OPTIMUM IN SOUTH AMERICA: PHYTOLITH RECORDS FROM THE SAN JORGE BASIN OF ARGENTINE PATAGONIA

**4:30** **HOPKINS** HOLARCTIC SMALL MAMMALS SHOW HETEROGENEOUS RESPONSES TO THE SPREAD OF OPEN HABITATS DURING THE MIDDLE AND LATE CENOZOIC

**4:45** **SAMUELS** MAMMAL COMMUNITY EVOLUTION THROUGH THE CENOZOIC OF OREGON WAS DRIVEN BY CLIMATE CHANGES AND GEOLOGIC INFLUENCES

**5:00** **KELLER** CLIMATE CHANGE AND BIODIVERSITY LOSS SHAPE MICROMAMMAL COMMUNITY ECOLOGY OVER THE LAST 22,000 YEARS AT HALL'S CAVE, TEXAS

**5:15** **ZELDITCH** LANDSCAPE, CLIMATE AND ECOLOGY INTERACT TO SHAPE REGIONAL SPECIES ASSEMBLAGES

**FRIDAY AFTERNOON, JUNE 21, 2024**
**UNION KUENZEL**
**REEF PALEOECOLOGY IN TIME AND SPACE**
**MODERATORS: Aaron O'Dea and Katie Cramer**

**1:15** **VAYDA** CAMBRIAN REEFS PROVIDED A FOUNDATION FOR THE CAMBRIAN EXPLOSION: EVIDENCE FROM SMALL SHELLY FOSSIL ASSEMBLAGES FROM YUKON, CANADA

**1:30** **LI** MESOPHOTIC REEFS IN THE SILURIAN: INSIGHTS FROM SOUTH CHINA

**1:45** **GODBOLD** TEMPORAL DYNAMICS OF DEVONIAN REEF COMMUNITIES: INSIGHTS FROM A 3.9 MILLION-YEAR STUDY IN WESTERN AUSTRALIA

**2:00** **SCHNEIDER** TRENDS IN BIOSTROME-OFF BIOSTROME PALEONTOLOGY, SEDIMENTOLOGY, AND DIAGENESIS IN THE WATERWAYS FORMATION (LATE DEVONIAN) FROM ALBERTA, CANADA

**2:15** **LORD** MISSISSIPPIAN (EARLY SERPUKHOVIAN ~331–327 MA) FRAMEWORK REEFS HIDDEN IN THE CAVES OF PIGEON MOUNTAIN IN NORTHWESTERN GEORGIA, U.S.A.

**2:30** **KIESSLING** PHANEROZOIC REEF BUILDING IN RELATION TO CLIMATE CHANGE

**2:45** **DIMITRIJEVIC** CASCADING EFFECTS OF REEF CRISES

**3:30** **DUSSEAULT** NOT ALL TURBIDITY IS EQUAL: THE OCCURRENCE OF DIVERSE PLEISTOCENE REEFS IN A DELTA FRONT SETTING AT THE PALAEO-KAMBANIRU RIVER MOUTH

**3:45** **O'QUIN** UNCOVERING THE PAST: UTILIZING INVERTEBRATE SUB-FOSSIL ASSEMBLAGES FROM BELIZEAN LAGOONAL REEFS TO DETERMINE DRIVERS AND TIMING FOR CARIBBEAN REEF ECOSYSTEM DECLINE

**4:00** **CHANDROTH** ROLE OF REDUNDANCY AND ECOPHENOTYPIC VARIATIONS OF CORALS ON REEF STABILITY

**4:15** **CYBULSKI** NITROGEN STABLE ISOTOPES FROM CORAL FOSSILS CONTEXTUALIZE CLIMATE-ECOLOGY-HUMAN INTERACTIONS THROUGH MILLENNIA *(45-minute keynote)*

**5:00** *discussion*

## FRIDAY AFTERNOON, JUNE 21, 2024
## UNION WOLVERINE
## PALEOBIOLOGY OF CARNIVOROUS MAMMALS
## MODERATORS: John D. Orcutt and Mairin Balisi

**1:15** **VALENZUELA-TORO** DIVING THROUGH SHALLOW AND DEEP TIME: UNRAVELING THE (PALEO) ECOLOGY AND ECOMORPHOLOGY OF MARINE CARNIVOROUS MAMMALS *(30-minute keynote)*

**1:45** **CHURCHILL** DISPARITY IN CRANIAL TELESCOPING IN WHALES (ARTIODACTYLA: CETACEA) THROUGH TIME

**2:00** **BARRETT** MOSAIC EVOLUTION UNDERLIES FELIFORM MORPHOLOGICAL DISPARITY

**2:15** **DOUGHTY** FUNCTIONAL GROUP RICHNESS OF NORTH AMERICAN LARGE MAMMALIAN PREDATORS AND HERBIVORES WERE POSITIVELY CORRELATED OVER THE CENOZOIC

**2:30** **CHRISTISON** EARLY (WASATCHIAN) AND LATE EOCENE (CHADRONIAN) CREODONT AND CARNIVORAMORPHAN NICHE OCCUPATION IN NORTH AMERICA

**2:45** **BALISI** A WORLD OF SMALLER ANIMALS: ECOMORPHOLOGICAL AND BIOGEOCHEMICAL SHIFTS IN MESOCARNIVORES FOLLOWING THE PLEISTOCENE MEGAFAUNAL EXTINCTIONS

## FRIDAY AFTERNOON, JUNE 21, 2024
## UNION WOLVERINE
## FOSSIL FORCES: ADVANCES IN BIOMECHANICS AND IMAGING IN PALEONTOLOGY
## MODERATORS: Alec Wilken and Casey Holliday

**3:30** **BYRNE** INTEGRATING VERTEBRAL MORPHOLOGY AND HISTOLOGIC CORRELATES TO ELUCIDATE DIVERGING PATTERNS OF CARDIOPULMONARY SYSTEM EVOLUTION IN TERRESTRIAL VS SECONDARILY AQUATIC ARCHOSAURS

**3:45** **WILKEN** BONE DISTRIBUTION, LOAD PATHS, AND A NEW FRAMEWORK OF MANDIBLE FUNCTION FOR RECONSTRUCTING OF MAMMALIAN JAW EVOLUTION

**4:00** **MAGALLANES** FUNCTIONAL MORPHOLOGY OF ASYMMETRICAL ROOTS IN THE LOWER MOLARS OF JURASSIC DRYOLESTOIDEAN MAMMALS AND THEIR BIOMECHANICAL IMPLICATIONS

**4:15** **LI** KINEMATIC MOBILITY AND MODULARITY OF ANCESTRAL MAMMALIAN HYOID

**4:30** **DUDGEON** DISPARATE FEEDING MECHANICS BETWEEN A CONTEMPORANEOUS LAMBEOSAURINE AND HADROSAURINE (ORNITHOPODA: HADROSAURIDAE) SUPPORT THE POTENTIAL FOR NICHE PARTITIONING

**4:45** **SELLERS** THE ORIENTATION OF THE QUADRATE BONE COEVOLVED WITH JOINT REACTION FORCE DURING CROCODILE EVOLUTION

**5:00** **HOLLIDAY** AVIAN CRANIAL KINESIS IS THE RESULT OF INCREASED ENCEPHALIZATION DURING THE ORIGIN OF BIRDS

**FRIDAY AFTERNOON, JUNE 21, 2024**
**UNION 2210**
**ANSWERING BIG QUESTIONS WITH SMALL FOSSILS:**
**HIGH-RESOLUTION BIODIVERSITY DYNAMICS IN DEEP TIME**
**MODERATORS: Anieke Brombacher and Huai-Hsuan M. Huang**

**1:15** **TOMASOVYCH** FUNCTIONAL FORM OF SPECIES-TIME RELATIONSHIP IS NOT POWER-LAW IN MOST LONG TIMESERIES

**1:30** **ELKIN** AN ONTOGENETIC MORPHOMETRIC APPROACH TO RECONSTRUCTING THE LATE CRETACEOUS PHYLOGENY OF BISERIAL PLANKTONIC FORAMINIFERA

**1:45** **MANOOGIAN** DID THE DECCAN VOLCANIC EVENT CAUSE BIOTIC STRESS AND EXTINCTIONS OF LATEST CRETACEOUS PLANKTONIC FORAMINIFERA?

**2:00** **LU** SEPARATING THE PLANKTONIC AND BENTHIC FORAMINIFERAL RESPONSE TO ENVIRONMENTAL CHANGES ACROSS THE EOCENE-OLIGOCENE TRANSITION

**2:15** **JONES** ARE COMMUNITY TRAIT CHANGES A RESULT FROM ENVIRONMENTAL DRIVERS OR SHIFTS IN SPECIES COMPOSITION?

**2:30** **JAMSON** INVESTIGATING THE RESPONSES OF DEEP SEA SEDIMENTS TO CENOZOIC PALEOCLIMATE AND PALEOCEANOGRAPHIC EVENTS USING DATA SYNTHESIS AND THE EODP PROJECT

**2:45** **HUNT** USING STATE SPACE MODELS TO UNDERSTAND THE EVOLUTION OF MORPHOLOGY IN THE LAKE DIATOM *STEPHANODISCUS YELLOWSTONENSIS* OVER THE PAST 14,000 YEARS

**3:30** **CERASONI** PALAEOECOLOGY AND *G. DORYSSUS* EVOLUTION IN A MIOCENE DIATOMITE PALEOLAKE WITHIN THE TRUCKEE FORMATION, HAZEN, NEVADA

**3:45** **KAHANAMOKU-MEYER** HIGH-THROUGHPUT PHENOTYPING REVEALS A 19TH-CENTURY DECLINE IN CLONAL REPRODUCTION OF BENTHIC FORAMINIFERA IN THE SANTA BARBARA BASIN, CALIFORNIA

**4:00** **BENNETT** REEF-LECTING ON THE CAMBRIAN: TAXONOMIC REVISION AND LATERAL DISTRIBUTIONS OF SMALL SHELLY FAUNAS FROM REEF-ADJACENT FACIES OF THE UPPER HARKLESS FORMATION, NEVADA

**4:15** **HARRIS** REDEFINING AND CONTEXTUALZING PALEOZOIC ECHINODERM DIVERSITY DYNAMICS

**4:30** **DENG** DO NOVEL FUNCTIONS DRIVE DIVERSIFICATION IN CENOZOIC ANOMALODESMATA (BIVALVIA)?

**4:45** **FALK** MICRO- AND MACROFOSSIL REMAINS OF VERTEBRATES FROM THE GIVETIAN BOYLE FORMATION (MIDDLE DEVONIAN) OF EASTERN KENTUCKY, USA

**5:00** **WILSON** INTEGRATING MICROVERTEBRATE FOSSILS AND MOLECULAR PHYLOGENIES TO BETTER UNDERSTAND THE DIVERSITY DYNAMICS OF FRESHWATER FISH ACROSS THE K/PG MASS EXTINCTION EVENT

**5:15** **LEDESMA** CHANGES IN A CENTRAL TEXAS LIZARD COMMUNITY IN RESPONSE TO SHIFTING VEGETATION AND CLIMATE OVER THE LAST 16,000 YEARS

**FRIDAY AFTERNOON, JUNE 21, 2024**
**UNION POND**
**PROGRESS IN PROBOSCIDEAN PALEONTOLOGY**
**MODERATORS: Advait Jukar and William Sanders**

**1:15** **LISTER** THE EVOLUTION OF MAMMOTHS: MORPHOLOGY MEETS DNA *(30-minute keynote)*

**1:45** **ANINY** DISCOVERY OF BARYTHERIUM REMAINS (MAMMALIA: PROBOSCIDEA) FROM THE MIDDLE EOCENE OF MOROCCO: IMPLICATIONS FOR MORPHOLOGY, PHYLOGENY AND PALEOGEOGRAPHY

**2:00** **SANDERS** WINNERS AND LOSERS IN AFRO-ARABIAN PROBOSCIDEAN EVOLUTION

**2:15** **SAARINEN** EVOLUTION OF PROBOSCIDEAN DENTAL FUNCTIONAL TRAITS – HOW ARE THEY RELATED TO VEGETATION AND CLIMATE?

**2:30** **WIDGA** WE THOUGHT WE KNEW YOU: EVOLVING PERSPECTIVES ON THE ORIGINS, BIOGEOGRAPHY, AND MORPHOLOGY OF THE AMERICAN MASTODON, *MAMMUT AMERICANUM*

**2:45** **HULBERT** PROBOSCIDEA (MAMMUTIDAE AND GOMPHOTHERIIDAE) FROM THE LATE MIOCENE MONTBROOK LOCALITY, FLORIDA, USA: TAPHONOMY, PALEOBIOLOGY, AND PHYLOGENETIC IMPLICATIONS

**3:00** **JUKAR** THE IDENTITY OF AMEBELODONTIDS FROM MIXSON'S BONE BED AND ITS BIOGEOGRAPHIC IMPLICATIONS

**3:30** **ARROYO-CABRALES** MEXICAN CONTRIBUTIONS ON KNOWLEDGE ON THE BIOLOGY OF PLEISTOCENE COLUMBIAN MAMMOTH (*MAMMUTHUS COLUMBI*)

**3:45** **CRUZ** THE MAMMOTHS AT THE AIRPORT IN MEXICO CITY AFTER EXCAVATIONS

**4:00** **LINDSEY** WHAT'S THE DEAL WITH PROBOSCIDEANS AT RANCHO LA BREA?

**4:15** **MILLER** GAPS IN THE FOSSIL RECORD PROVIDE NEW INSIGHT INTO MAMMOTH EXTINCTION DYNAMICS

**4:30** **PARDI** WHAT IS THE FUNCTIONAL EQUIVALENT OF A MAMMOTH?

**4:45** **BUTLER** PATHOLOGY PREVALENCE IN PROBOSCIDEAN POPULATIONS AS A PALEOENVIRONMENTAL PROXY

**5:00** **GARAPATI** EARLY-LIFE ENDOCRINOLOGY IN MODERN AND PREHISTORIC PROBOSCIDEANS REVEALED THROUGH STEROID ANALYSES OF HAIR AND DENTIN

**5:15** **SHIRLEY** MAMMOTH TUSK CT-DERIVED REPRODUCTIVE LIFE HISTORIES FROM EASTERN SIBERIA AND THE CONSERVATION BIOLOGY OF ELEPHANTS

## FRIDAY POSTERS, JUNE 21, 2024
## UNION IDEA HUB
## PRESENTERS SHOULD ATTEND POSTERS FROM 5:30–6:15

### LESSONS LEARNED AND FUTURE VISIONS FOR CONSERVATION PALEOBIOLOGY

1 **BRUCE** ECOMETRIC MODEL FOR BODY MASS AND TEMPERATURE WITHIN GLOBAL TERRESTRIAL CARNIVORAN COMMUNITIES

2 **DEPAOLIS** MICROPLASTICS IN VIRGINIA'S EASTERN SHORE: ESTABLISHING A BASELINE FOR FUTURE CONSERVATION PRACTICES

3 **GÓMEZ** RECONSTRUCTING SPATIAL VARIATION IN SHARK COMMUNITIES ACROSS THE ISTHMUS OF PANAMÁ USING FOSSIL DERMAL DENTICLES

5 **LONG-FOX** GEOMETRIC MORPHOMETRICS AS A TOOL FOR CONSERVATION PALEOBIOLOGY: DETECTING ENVIRONMENTAL CHANGE USING LIVE-DEAD COMPARISONS OF LUCINID BIVALVE SHELL SHAPES AND SIZE

6 **MASCHLER** DIETARY GENERALISM OF PLEISTOCENE COYOTES FROM THE MCKITTRICK AND RANCHO LA BREA ASPHALT SEEPS, SOUTHERN CALIFORNIA, USA

7 **SANDERS** LIVE-DEAD DATA FROM BENTHIC MARINE SURVEYS OF THE EASTERN GULF OF MEXICO REVEAL POSSIBLE RANGE CONTRACTION IN AN IUCN RED LIST CONE SNAIL

8 **SONI** LESSONS FROM THE PAST: INSIGHTS FROM LATE PLEISTOCENE MARINE INVASIONS INTO SOUTHERN CALIFORNIA

9 **SPANO** WHERE THE WILD THINGS WERE: AN ONLINE, INTERACTIVE, AND ACCESSIBLE ATLAS OF ANIMAL LOSSES FROM THE PLEISTOCENE TO TODAY

10 **SUH** FOSSIL BOBCATS: A LENS TOWARD UNDERSTANDING RESILIENCE TO ANTHROPOGENIC CHANGE

11 **WANG** FOSSILS OF AN ENDANGERED, ENDEMIC, GIANT DIPTEROCARP TREE UNLOCK A HISTORICAL PORTAL INTO BORNEO'S VANISHING RAINFORESTS

12 **WITTMER** HISTORY OF INTERLOCKING THREATS USING JOINT BIOSTRATIGRAPHY OF MOLLUSKS AND OSTRACODES: SPECIES INVASION AND CULTURAL EUTROPHICATION IN THE WESTERN FINGER LAKES OF NEW YORK

13 **YU** DETANGLING EQUATORIAL INDIAN OCEAN OXYGENATION, VENTILATION, AND DIAGENESIS WITH BULK AND FORAMINIFERA SHELL-BOUND D15N ACROSS THE LAST TWO GLACIAL TERMINATIONS

### GENERAL SESSION: PALEOBOTANY

14 **BAGHAI-RIDING** PALYNOLOGY OF A LATE CRETACEOUS VERTEBRATE SITE IN NORTHEASTERN MISSISSIPPI, U.S.A. – IMPLICATIONS FOR FLORISTICS, BIOSTRATIGRAPHY AND CLIMATE

15 **CONTRERAS** RECONSTRUCTING THE COASTAL VEGETATION OF CENOMANIAN SOUTHWESTERN APPALACHIA: AN INTEGRATED STUDY OF PLANT FOSSILS AND SEDIMENTS OF THE LEWISVILLE FORMATION (WOODBINE GROUP), DALLAS-FORT WORTH TEXAS, U.S.A.

16 **HOLIAN** DINOSAURS PERISHED BUT FERNS FLOURISHED: RESILIENT FLORA DURING THE CRETACEOUS-PALEOGENE MASS EXTINCTION

17 **WHITE** DOCUMENTING THE EARLY CONIACIAN *PEDIASTRUM* ACME BIO-EVENT IN A THIRD SECTION FROM THE NUMANHA FORMATION, YOLA BASIN, NIGERIA

**WETLAND ECOLOGY THROUGH TIME**

18 **BEDDOW** ASSESSING GEOCHEMISTRY OF CARBONIFEROUS COAL BALLS ALONG THE EQUATOR

**INTEGRATED APPROACHES TO EXPLORING COUPLED BIOTIC, LANDSCAPE AND CLIMATE DYNAMICS**

19 **LAVIN** REVEALING PATTERN AND PROCESS OF EAST AFRICAN RODENT DIVERSITY

**FIRST PRINCIPLES, BOUNDLESS CURIOSITY – CELEBRATING THE CONTRIBUTIONS OF DANIEL C. FISHER**

*no posters for this session*

**DEEP LEARNING IN DEEP TIME: APPLICATIONS OF AI AND AUTOMATION IN PALEONTOLOGY**

20 **AL-ZAYADI** APPLICATION OF MACHINE LEARNING AND ECOLOGICAL NICHE MODELING IN THE PREDICTION OF NEANDERTHAL SETTLEMENTS IN PREHISTORIC AUSTRIA

21 **MATE** THROUGH THE SIEVE AND THE ACID BATH: SAMPLE PREPARATION AND TAPHONOMIC BIASES OF SMALL SHELLY FAUNAS FROM THE CAMBRIAN (SERIES 2: STAGE 3) OF SOUTH AUSTRALIA

**REEF PALEOECOLOGY IN TIME AND SPACE**

22 **CORDIE** BIODIVERSITY OF WESTERN LAURENTIA DURING THE MIAOLINGIAN AND FURONGIAN (LATE CAMBRIAN): A CASE FOR UNIQUE REGIONAL CONDITIONS THAT REDUCE MUD MOUND FORMATION

23 **HEAD** EXTINCTION RECOVERY AND ECOLOGICAL IMPLICATIONS OF MISSISSIPPIAN SOLITARY AND COLONIAL RUGOSE CORALS IN NORTH AMERICA

24 **HOPPS** PALEOECOLOGY OF CRINOID COMMUNITY FROM THE GLEN DEAN FORMATION OF KENTUCKY

25 **MARTINDALE** "REEF SURVIVOR": A NEW BOARD GAME DESIGNED TO TEACH COLLEGE AND UNIVERSITY UNDERGRADUATE STUDENTS ABOUT REEF ECOLOGY, EVOLUTION, AND EXTINCTION

26 **SAAD** INVENTORY OF EAR STONES: DATABASE OF OTOLITHS THROUGHOUT THE CENOZOIC

27 **ZONNEVELD** THE SIGNIFICANCE OF ENCRUSTING TAXA AND BORING ICHNOTAXA ON MARINE FOSSILS IN FORAMINIFERAL BIOSTROMES IN THE LATE EOCENE (PRIABONIAN) LOWER PAGAT MEMBER, TANJUNG FORMATION, IN THE ASEM ASEM BASIN, SOUTH KALIMANTAN, INDONESIA

**PALEOBIOLOGY OF CARNIVOROUS MAMMALS**

28 **FAMOSO** NEW MATERIAL OF THE HEDGEHOG *AMPHECHINUS* (ERINACEIDAE, EULIPOTYPHLA) FROM THE OLIGOCENE OF THE PACIFIC NORTHWEST, U.S.A.

29 **HAN** DIETARY ECOMORPHOLOGY OF DIRE WOLVES FROM THE MCKITTRICK ASPHALT SEEPS, SOUTHERN CALIFORNIA, U.S.A.

30 **PLOTNIKOV** THE LATE PLEISTOCENE FOSSILS OF THE WOLF (*CANIS* SP.)

31 **TANG** ECOMORPHOLOGICAL COMPARISON OF FOSSIL COYOTES AT THE MCKITTRICK AND RANCHO LA BREA ASPHALT SEEPS USING TWO-DIMENSIONAL GEOMETRIC MORPHOMETRICS OF THE LOWER JAW

**FOSSIL FORCES: ADVANCES IN BIOMECHANICS AND IMAGING IN PALEONTOLOGY**

**32** **BALL** EXPLORING THE EVOLUTION AND ECOLOGY OF GEOMORPH RODENTS USING BITE FORCE ANALYSIS AND GIS

**33** **KAFFLER** INFLUENCE OF LOCOMOTOR BIOMECHANICS ON MORPHOLOGICAL AND PHENOTYPIC DIVERSIFICATION IN CARNIVORAMORPHA (MAMMALIA)

**34** **SULLIVAN** LOCOMOTOR MODULES AND THE EVOLUTION OF FLIGHT IN BIRDS, BATS AND PTEROSAURS

**BROADENING ACCESSIBILITY IN PALEONTOLOGY THROUGH INNOVATIVE COMMUNITY ENGAGEMENT PRACTICES**

**35** **DRAGE** OPAL: OPEN PALAEONTOLOGY – A COMMUNITY-DRIVEN DIAMOND OPEN ACCESS JOURNAL WITH PREREGISTRATION

**36** **GARDNER** DIGGING FOSSILS #LIKEAGIRL: BROADENING PUBLIC ENGAGEMENT WITH PALEONTOLOGY THROUGH DEDICATED SCOUTING FUN PATCH

**37** **LAM** TIME SCAVENGERS: EDUCATING AND SUPPORTING THE PUBLIC AND FUTURE EARTH STEWARDS

**ANSWERING BIG QUESTIONS WITH SMALL FOSSILS: HIGH-RESOLUTION BIODIVERSITY DYNAMICS IN DEEP TIME**

**38** **BRUNOIR** INSIGHTS INTO LATE ORDOVICIAN PALEOECOLOGY FROM SPONGE FOSSILS

**39** **KANNICHANKANDY** DECODING CALCIUM COMPENSATION DEPTH VARIATIONS AT EOCENE-OLIGOCENE CLIMATE TRANSITION: AN OUTLOOK FROM IODP HOLE 1218 A

**40** **KEARNS** INVESTIGATING THE TIMING AND SPATIAL VARIATION OF PLANKTIC ECOSYSTEM RECOVERY FOLLOWING THE END-CRETACEOUS MASS EXTINCTION EVENT

**41** **LEVENTHAL** THE EMERGENCE OF POLYMORPHISM IN A CHEILOSTOME BRYOZOAN

**42** **VIEIRA RIBEIRO** TRACKING THE IMPACT OF THE K/PG ON PELAGIC SHARK DIVERSITY USING DERMAL DENTICLES

**AVOCATIONAL CLUBS AS PALEONTOLOGICAL RESOURCES**

**43** **COOPER** DISCUSSIONS OF A PRIVATE PREPARATION LABORATORY DEDICATED TO INVERTEBRATE PALEONTOLOGY

**44** **HARTSHORN** ANOTHER DECADE OF SCIENTIFIC CONTRIBUTIONS FROM THE CINCINNATI DRY DREDGERS: 2014–2024

**PROGRESS IN PROBOSCIDEAN PALEONTOLOGY**

**45** **YARD** RE-EVALUATION OF THE *MAMMUTHUS COLUMBI* ASSEMBLAGE AT WACO MAMMOTH NATIONAL MONUMENT (WACO, TEXAS, U.S.A.)

# X

# ABSTRACTS

## FOSSIL LAKE (GREEN RIVER FORMATION, EOCENE, YPRESIAN) AT A NEXUS OF COMMERCIAL FOSSIL EXTRACTION, PALEO TOURISM, ACADEMIC RESEARCH AND U.S. GOVERNMENT PRESERVATION

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Paleontology in the Green River Formation, comprised of three Eocene lakes in Utah, Colorado, and Wyoming, had its beginnings with industrial discoveries and commercial fossil collecting. In the Fossil Lake deposits of southwest Wyoming, the abundance of fossils in laminated micrite has garnered much scientific interest while availability of private land has fostered commercial fossil collecting. In 1972 the U.S. Congress established Fossil Butte National Monument, a unit of the National Park Service, creating an area focused on conservation and interpretation surrounded by lands managed by the Bureau of Land Management on which the fossils are preserved for scientific inquiry. Occasionally, universities had research quarries in Fossil Lake deposits which were short lived, ironically due to the exceedingly abundant fossils dominated by the fishes *Knightia eocaena* and *Diplomystus dentatus* which rapidly filled museum cabinets before more interesting fishes, birds, reptiles, insects, or mammals were found. The paucity of academic quarry operations has not slowed scientific investigation, which has increased dramatically in the past 30 years coincident with increased commercial activity. Commercial operations on the whole welcome institutions into their fossil quarries for academic field trips and research projects. The longest running partnership between an academic institution and private fossil quarry ran from the 1980s to 2022. Commercial operations result in scientifically important specimens going to museums and into private collections, which on one occasion resulted in the loss of the holotype for *Boavus idelmani*, a snake. Loss of holotypes is not unique to private collections. Institutions have lost holotypes during normal operations, catastrophes, and armed conflicts. Over time, privately held and scientifically interesting specimens come to institutions from the private collector while living and more commonly when the owner dies, and the collection is dispersed. Paleo tourism has potential to disperse specimens into small private collections where the importance of a specimen has a reduced likelihood of being recognized as important when the owner is no longer interested or dies. Through encouragement by private quarry operators, paleo tourists frequently provide scientifically interesting specimens to institutions. To date, evidence shows the nexus of commercial fossil collecting, paleo tourism, academic research and federal conservation and interpretation creates synergy, expanding our scientific understanding of ancient Fossil Lake. Less easily measured, but no less important, this nexus provides opportunities for the public to form their own intellectual, emotional, and physical connections to the meanings and values found in the stories told by the exquisite fossils of ancient Fossil Lake.

## A BOTTOM-UP REVISION OF *LYSTROSAURUS* (THERAPSIDA, DICYNODONTIA) SPECIES IN THE KAROO BASIN, SOUTH AFRICA

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*Lystrosaurus* is among the most iconic survivors of the End Permian Mass Extinction (EPME) due to its broad geographic distribution and abundance during the extinction event. Thousands of *Lystrosaurus* specimens have been collected over the past century and a half, sampling across taxonomy, ontogeny, and taphonomy. Its fossil record is especially rich in the Karoo Basin, South Africa, where it has used to investigate a variety of questions related to biostratigraphy, biogeography, paleoecology, and life history in the context of the EPME. However, this work is complicated by unresolved issues in Lystrosaurus taxonomy. Over 27 species were named in the Karoo Basin alone, largely based on deformation mode, ontogeny, and locality. Today, four species are recognized: *L. curvatus*, *L. maccaigi*, *L. declivis*, and *L. murrayi*, yet they also suffer from bias due to deformation and ontogenetic stage. Here we present a new bottom-up approach to remedy issues of *Lystrosaurus* taxonomy. We surface scanned *Lystrosaurus* crania, sampling across ontogeny, taphonomic

states, and recognized species. We then scored 10 discrete characters, taken from our own observations and prior work on cranial variation in *Lystrosaurus*, for 75 specimens. To quantify taphonomic effects, we scored deformation severity and mode, preservation style, and preparation quality on a numerical scale, and scored three discrete characters that are commonly used to diagnose species, but also highly subject to deformation. We used basal skull length and lines of arrested growth (when available) as additional measures of ontogenetic stage. We ordinated the data using non-metric multidimensional scaling (NMDS) to visualize taphonomic, ontogenetic, and taxonomic groupings among specimens. Our results highlight the need for taxonomic revision in Karoo *Lystrosaurus*. There is relatively low variation between specimens attributed to *L. declivis* and *L. murrayi*, indicating that these taxa may be synonyms. Both species appear to represent differing ontogenetic, deformation, and preservation modes of one, potentially sexually dimorphic morphospecies with few large, or "adult" specimens represented. Without added information, such as body size, *L. curvatus* specimens group with juveniles of the other three species because *L. curvatus* lacks features that change over ontogeny in other species. *Lystrosaurus maccaigi* adults are the most distinctive group, due to their apomorphic character states. Large *L. maccaigi* skulls are often the most deformed, likely due to their size, but the discrete characters they share make them easy to identify. We plan to extend this work by using ontogenetic sequence analysis and additional specimens and characters to further refine our understanding of ontogenetic and taxonomic variation in *Lystrosaurus*. A robust, easily-used alpha taxonomy of *Lystrosaurus* is needed to fully realize the taxon's potential contribution to research on the terrestrial EPME.

## SAUROPOD TAIL CLUBS FROM THE KOTA FORMATION (EARLY TO MIDDLE JURASSIC) OF INDIA AND THEIR IMPLICATIONS FOR EARLY SAUROPOD EVOLUTION

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The Early to Middle Jurassic Kota Formation of India has yielded abundant yet disarticulated skeletal remains attributed to the basally diverging sauropod dinosaur *Kotasaurus yamanpalliensis*. The hypodigm of *Kotasaurus* includes four ellipsoidal elements that we identify as tail clubs, based on morphological similarities to enlarged distal caudal elements attributed to two basal sauropods from China: *Shunosaurus lii*, for which a fully articulated tail series was recovered, and *Omeisaurus tianfuensis*. Detailed comparison of the Chinese and Indian tail clubs suggests that they are variably composed of up to three individual elements that fuse in adulthood. Computed tomography of the Indian tail clubs reveals their internal structure, which shows incremental growth lines as well as other features whose origin and function remain unknown. The Indian and Chinese tail clubs share a similar temporal range (Early to Middle Jurassic) and taxonomic position outside of Neosauropoda, which raises the question of whether sauropod tail clubs evolved once, multiple times, or were gained and then lost within basally diverging members of Sauropoda. We present a coding strategy to reflect the morphological constituents of sauropod tail clubs known to date.

Funding source: Scott Turner Award

## RECONSTRUCTING THE DIVERSITY DYNAMICS OF LATE QUATERNARY EAST AFRICAN GRASSLANDS USING SUPERRESOLUTION IMAGING OF FOSSIL POACEAE POLLEN AND DEEP LEARNING

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Grass pollen identification has traditionally been limited to the family level due to the qualitative nature of palynological identifications. We used convolutional neural networks (CNNs) to enhance the classification of grass pollen by analyzing optical superresolution micrographs. Our method employs a semi-supervised learning approach, integrating both modern and unlabeled fossil data during training, thus improving the network's capability to generalize feature recognition in fossil pollen specimens. Our dataset includes 60 modern Poaceae species, which are difficult to differentiate with conventional methods. Our models successfully discriminated among these species by focusing on grain morphology and surface ornamentation. Additionally, we were able to train models that distinguished between $C_3$ and $C_4$ grasses based solely on morphological data, revealing that pollen morphology holds more significant biologically meaningful features than previously recognized. We next applied our trained models to fossil pollen images from a 25,000-year sediment core from Lake Rutundu, Mt Kenya. Our goal was to study grass species diversity changes and correlate these shifts with environmental factors such as atmospheric $CO_2$ levels, inferred paleotemperatures, paleoprecipitation, and charcoal

abundance (a proxy for fire history). Our approach quantified grass diversity by focusing on morphotypic variability, rather than species identification, by calculating Shannon entropy from the probability density function of specimens' CNN-learned features for each core depth. We further refined our analysis by grouping specimens into distinct morphotypes using k-means clustering, selecting the optimal number of clusters that resulted in biodiversity values that best aligned with our initial estimates. Our findings indicate strong correlation between shifts in grass diversity and climatic variables, with multivariate analyses showing significant effects of both temperature and fire activity on pollen abundance data. This suggests changes in the Quaternary environment significantly impacted grass species diversity. Additionally, predicted $C_3$ *versus* $C_4$ abundances suggest a gradual increase in $C_4$ grass species, correlated with rising temperatures. Our methods constitute a novel approach to assessing past biodiversity of grass communities and their responses to environmental changes. By using quantitative tools and machine-learned morphological features in palynology, we can analyze pollen assemblages and their responses to paleoenvironmental shifts, even without species-level identifications.

## COORDINATED TURNOVER OF SHALLOW WATER TRILOBITE ASSEMBLAGES ALONG THE EARLY ORDOVICIAN NORTHERN LAURENTIAN MARGIN

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The Ordovician northern Laurentian margin (part of present day western North America) preserves one of the richest Lower Ordovician shallow water fossil records known from anywhere in the world. Of particular note is that the faunas typically feature pervasive secondary silicification, and such horizons with exquisitely preserved fossil trilobites occur on a meter scale throughout most of the Lower Ordovician. The systematics of these trilobite faunas are by now more or less fully worked out on the basis of new field sampling, though only partially published. They feature dozens of new genera and hundreds of new species, along with revision of the taxa originaly described by Lehi Hintze and Rube Ross more than 70 years ago (now known to represent only a small fraction of the preserved diversity). All classic stratigraphic sections and multiple new sections of the Pogonip Group in western Utah and eastern Nevada and the Garden City formation in northern Utah and southeastern Idaho were re-measured, logged, and all identified silicified horizons were sampled. Combining the new taxonomic work with the detailed stratigraphic context provides an unparalleled regional dataset of stratigraphic species distributions. As a result, a new, highly resolved, species level, biostratigraphic zonation has been developed that is applicable along the margin from southern Nevada to the Canadian Rocky Mountains in Alberta. The stratigraphic distributions of species are strongly patterned: first appearance data (FADs) and last appearance data (LADs) tend to be strongly clustered, so that a particular set of species occurs in essential stasis through a meter- or decimeter-scale stratigraphic interval then is abruptly replaced by an almost entirely new set of species (mostly of the same genera). This phenomenon occurs without interruption throughout the Lower Ordovician rocks regionally. There are temporal variations in sampling intensity, but no data from anywhere in the interval suggest sustained, gradual species turnover: the pattern is of dozens of distinct assemblages, each almost wholly replacing its predecessor, with only a small number of species ranging through, if any. This pattern of lockstep coordinated turnover is unlikely to be mainly biological (though evolutionary rates appear to have been extremely high). Rather, it seems most likely to reflect sequence stratigraphic control of stratigraphic species distributions, a hypothesis that will be tested in a forthcoming phase of new field-based sequence stratigraphic investigation. If confirmed, one of the richest, densest, and most stratigraphically resolved shallow water fossil records in the world may suggest that fossil marine species ranges are heavily influenced, and their LADs and FADs essentially controlled, by stratigraphic architecture.

## NORTH AMERICAN PALEONTOLOGICAL RESOURCES: THE UNIVERSITY OF IOWA PALEONTOLOGY REPOSITORY—CHALLENGES OF A GROWING COLLECTION.

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The University of Iowa Paleontology Repository (UIPR; acronym SUI), created by an 1858 Act of Iowa Legislature, is a valuable research resource with exceptional collections, a hub for student training, and a community engagement tool. The collections contain over two million fossils, worldwide in scope, representing nearly all geologic ages. U. S. Midwest marine invertebrate paleontology collections comprise the bulk of the UIPR, justifying its ranking as the 9th most significant invertebrate paleontology collection in North America in terms of combined size and specialty in the CONARIP Report of 1977. Since then, the UIPR has continued to receive significant bulk collections of this focal material, and substantial microfossil collections, almost doubling the number of specimens. The collection of invertebrate paleontology type specimens has increased fourfold as researchers across the U. S. continuously and steadily deposit research material (encouraged by requirements of many grant funding agencies). Collections are being digitized and catalogued using Specify. Participation in professional societies, e.g., the Society for the Preservation of Natural

History Collections, ensures that standards and best practices in collection management are implemented. With a staff of just one full-time professional collections manager, the curatorial assistance of student interns is critical. The UIPR is a training hub for paleontological collections management in partnership with the UI Museum Studies Undergraduate Certificate Program, with an average of seven students (high school through graduate) per semester contributing a total of more than 1200 work hours a year. The UIPR is supported by the Department of Earth and Environmental Sciences, College of Liberal Arts and Sciences, and a small endowment for curation materials. Interns are funded through UI scholarships or external funding. Large-scale projects rely on grant funding, usually from the National Science Foundation. A solid history, active collections, student engagement and experiential learning, and low running costs provide a research facility that is exceptional value for money! Collections are not without challenges, however. Increasing the number of researchers using the collections through visits and loans is vital as these are important metrics for administrators. Space is an ever-looming issue requiring improved storage, adherence to the UIPR's Scope of Collections, and assessment and transfer of selected material to other institutions. The number of orphan collections and bulk transfers acquired from other institutions and amateur paleontologists puts a strain on resources and looks to increase in the future. Synergies with other entities are beneficial, such as the Iowa Geological Survey (data-sharing) and MAPS, the Mid-America Paleontology Society (expert volunteers and collection documentation outreach). Strategic planning is required to prevent overload and unmanageable backlog.

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## WHAT CAUSES BIOTIC HOMOGENIZATION?

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Substantial increases in the taxonomic similarity of marine communities across the globe occurred after the end-Permian mass extinction. In prior work, we demonstrated that the increase in similarity is consistent with predictions based on organisms tracking physiologically viable habitat in the aftermath of extinction and does not require a component of ecological release. However, the complexity of ecological interactions prevents us from ruling out an ecological component to the end-Permian case and, further, makes testing such expectations against models difficult in general. To overcome this challenge, and to better test the extent to which changes in taxonomic similarity across distance result from physiological habitat tracking in response to environmental change versus ecological release following taxonomic losses, we compare changes in taxonomic similarity across numerous pairs of adjacent stages in the geological past to determine if global compositional similarity was affected by a combination of differing levels of long-term environmental change (increasing, decreasing or absent temperature and oxygen availability) and extinction intensity (background versus mass extinction). Examining these scenarios will reveal whether increase in global community homogeneity is explained by physiology, ecology, or both.

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## APPLICATION OF MACHINE LEARNING AND ECOLOGICAL NICHE MODELING IN THE PREDICTION OF NEANDERTHAL SETTLEMENTS IN PREHISTORIC AUSTRIA

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Central Europe is an excellent area for studying prehistoric hominin population dynamics, as this region holds some of the earliest evidence for the presence of modern humans in Europe and a late persistence of Neanderthal populations. Despite having high resolution paleoclimatic records, many horizons remain underexplored. This project aims to integrate machine learning (ML) techniques into classical ecological niche modelling (ENM) to identify sites within Austria that may have been well suited and attractive to Neanderthal occupation. ENM is a method used routinely in extant ecological research for the prediction of the distribution of species through time using environmental data. By integrating ML into these methods this study will avoid limitations due to low observer count, a consistent problem faced in archaeology. We will use ML to analyze existing site data including paleoclimate estimates, topography and hydrology to generate high resolution predictions of which locations were most likely to be inhabited by Neanderthal populations. In doing so, this study applies an innovative combination of ML and ENM to improve the field of archaeological site discovery.

## VERTICAL REORGANIZATION OF THE NORTH PACIFIC OXYGEN MINIMUM ZONE DURING DEGLACIAL WARMING

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Climate change is currently driving the expansion of oxygen minimum zones (OMZs), areas of the ocean with consistently low levels of oxygen (<0.5 mL $L^{-1}$ or 22 µmol $kg^{-1}$). OMZ expansion/contraction is driven by changes in productivity, consequent respiration, and water mass ventilation with implications for ecosystem function and biogeochemical cycling. However, significant uncertainties exist in how OMZs respond to climatic change on longer timescales. Foraminifera are valuable paleoceanographic tools with well-defined ecological niches and preserved calcium carbonate shells. Here, OMZ structure and drivers of change (productivity and water source) in the Eastern Tropical North Pacific (ETNP) through the most recent period of rapid warming (~20.5–10.5 ka) are investigated using planktic foraminiferal assemblages, ventilation ages, and multispecies oxygen and carbon isotopes. Evidence from core MAZ1-E04 (22°54.29'N, 106°54.59'W; 1463 m depth) from the Mexican Margin shows the OMZ intensified into the Holocene relative to the Last Glacial Maximum (LGM), but with dynamic reorganization during the deglaciation. At this site, subpolar planktic foraminifera dominated until a dramatic drop ~13 ka where transitional foraminifera became the most abundant through the Holocene. Productivity-affiliated *Globigerinita glutinata* had peak relative abundance during early deglaciation and from ~12 ka into the early Holocene. Ventilation ages record relatively old bottom waters during the LGM and Holocene indicating input from less ventilated intermediate depth water. Multispecies oxygen isotopes from foraminifera at multiple depth habitats (*Globigerinoides ruber*, *Neogloboquadrina dutertrei*, *Globorotaloides hexagonus*, and *Uvigerina* sp.) indicate abrupt shallowing of the OMZ ~14 ka with continued expansion into the thermocline ~12 ka and through the early Holocene. Using these approaches, we demonstrate that this site likely experienced higher productivity and poorly ventilated bottom waters during both the LGM and Holocene. Conversely, early deglaciation was associated with well-ventilated bottom waters and lower productivity. We hypothesize that the ETNP OMZ contracted during early deglaciation before expanding again into deeper waters in the Holocene due to increased surface productivity alongside the input of older intermediate waters.

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## IMPACT OF A CODING BUG ON PALEOBIOLOGY DATABASE GENUS RICHNESS

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Since its inception, a little-known coding bug has existed in the source code of the Paleobiology Database (PBDB). The error occurs when multiple versions of the same name have been entered independently, and subsequently (but algorithmically incorrectly) joined. These occur most often when a name is reranked or corrected as a misspelling. For example, the eurypterid *Adelophthalmus* currently exists in the PBDB in three versions, as *Adelophthalmus*, *Adelophthalmus (Eurypterus)*, and *Eurypterus (Adelophthalmus)*. Only the latter one correctly points to *Adelophthalmus*, but the second version is maintained as a separate name in the PBDB namespace, even though the opinion to link them has been entered correctly. Because the coding bug can cause the same taxon to occur in two or more versions, it can unintentionally inflate the number of apparent taxa in data downloads. The impact of this bug is unknown. Here, we evaluate its impact on genus richness trends by comparing PBDB downloads on the public data portal to the beta (training) portal, where a test version of a bug patch has been released since Spring 2023. The impact is minor but widespread. The bug has inflated apparent genus richness by 325 genera, but this amounts to only 0.38% of the approximately 85,000 PBDB genera across all life. All but 21 of these duplications occur in animals, with the remainder in plants. The impact is magnified if tallying subgenera, inflating their number by 216 subgenera (or nearly 5% of subgenera). As a result of these relatively small numbers, there is minimal impact on resulting diversity curves. Raw and corrected range-through genus richness trends are highly correlated. However, for small clades and lower taxonomic ranks—and especially those where the historical usage of subgenera has been common practice—the impact can be significant. Our goal with this study is to alert PBDB users to the coding bug and to encourage users to vet their downloads carefully to remove improper duplications.

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## MEMORIES IN THE MINERALS: DECIPHERING MICROBIAL BIOSIGNATURES THROUGH MICROSCOPIC CHEMICAL MAPPING

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Over millions of years, Earth has undergone multiple physical and chemical changes that have contributed to the appearance of life, which in turn has also contributed to its continued evolution. The exact prebiotic processes leading to life and its

continued evolution remain only inferred from the geological and fossil record where macrofauna demonstrate physical taxonomic differences, however microbes remain even more mysterious as Earth's first inhabitants with much more scant and controversial preservations in the fossil record. Due to the microscopic scale microorganisms live within, the effects and traces concurrent with those microbial residents are also on much smaller scales that require higher resolution analysis for their discernment. Using the Lost City hydrothermal vent field as an analog environment for an ancient Earth where hydrothermalism was much more prevalent, we preserved, mapped and analyzed the microbe-environment interface to produce a high-resolution map of the relationship between mineralogy, quantitative elemental characteristics and microbial community structure, coupled with genomic data to identify subtle differences in the mineral microenvironment missed by low-resolution bulk analysis. Combined with historical and modern observations of the geochemical dynamics underpinning the formation of Lost City vents, we identify deviations in elemental composition within the mineral matrix from what is expected in purely abiotic processes. These deviations correspond in many instances to the metabolic activities of the resident microbes, pointing to a potential signature for microbe-mineral interactions preserved in the mineral matrix and potentially in a preserved ancient rock record from similar extinct environments. This represents a significant step in characterizing the Earth's ancient microbial history in terms of its co-evolution with both the environment and any feedback effects from its activity. Using analog sites such as Lost City produces a potentially rich dataset to test and validate hypotheses as they relate to the evolution of Earth's environment and planetary bodies of similar age and environmental history where the potential for biogenesis in the past would have been high.

## RMACROSTRAT: AN R PACKAGE FOR RETRIEVING DATA FROM THE MACROSTRAT GEOLOGICAL DATABASE

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The geological record is the only source of empirical data about the evolution of Earth and the life it has hosted. Macrostrat (https://macrostrat.org) is a global database containing information regarding rock ages, types, geographic extent, and much more, both at Earth's surface and in sections underneath it. At present, it contains over 2.5 million geologic map polygons, spanning over 35,000 rock units. Whilst a hugely valuable resource to the geological and palaeontological communities, at present the underlying data can only be accessed directly through Macrostrat's application programming interface (API), limiting the number of potential users. Removing accessibility barriers to the data hosted by Macrostrat is therefore required for its broader use. Here we present a new R package, rmacrostrat, which interacts with the Macrostrat API, allowing users to browse and access data contained in the Macrostrat database within the R programming environment. We also provide a vignette which explains how to use the package and provides examples of how the data contained in the Macrostrat database could be further analyzed. Making these data more easily accessible provides the research community with an efficient, reproducible pipeline for accessing global geological data. We hope that this will promote a suite of novel studies by providing the tools to test longstanding hypotheses in the Biological and Earth Sciences.

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## THE RISES AND FALLS OF TURRITELLID GASTROPODS DURING THE CENOZOIC IN THE WESTERN ATLANTIC

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Turritellid gastropods are among the most diverse, abundant, and frequently-occurring marine macrofossil groups of the past 100+ million years worldwide. From their apparent origin in central Tethys in the late Jurassic they spread across most of the world's oceans by the Late Cretaceous. They suffered substantial extinction at the K-Pg but diversified quickly thereafter, and they were present on every continent during the Paleogene. The record of their diversity, abundance, and morphology during the Cenozoic has become clearer due to recent studies of body size, molecular phylogenetic analysis, and systematic treatments of Paleogene, Miocene, and Plio-Pleistocene fossils from the Western Atlantic region (southeastern North America, the Caribbean, Central America, and northern South America). A database (still a work in progress) of more than 230 described species from this region shows turritellid diversity of more than 20 species in the Paleocene, a low of fewer than 10 in the early Eocene, a peak of more than 80 in the Miocene, a decline to around 20 in the Pliocene, and a decline to only 4 species in the central Western Atlantic today. Diversity within single formations shows a slightly different pattern, with highs of 11–16 species in the Late Miocene of Colombia and 18 species in the Late Pliocene Pinecrest Sand of Florida. Overall abundance has also declined, with turritellid-dominated assemblages common across the region throughout the Cenozoic, but limited today to only small areas of northern Venezuela. Higher taxonomic assignments of fossil and Recent turritellids and their phylogenetic relationships are still poorly known (and are likely to remain

so for many species), but recent molecular data and systematic work on fossil turritellids indicate that several clades (e.g., *Torcula*) persisted in the region throughout the Cenozoic, while other groups which became significant likely appeared in the Miocene, including *Vermicularia* and *Caviturritella*. A common pattern in all of this change is correlation with likely patterns of primary productivity. Hyperdiverse assemblages and high regional diversity of turritellids appear to occur at times and places of high productivity, frequently in association with upwelling or significant terrestrial runoff, and patterns of extinction (temporal and geographic) correlate with declines in productivity.

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## FOSSIL VERTEBRATES FROM THE LATE QUATERNARY OF HISPANIOLA, ONGOING RESEARCH AND FUTURE PERSPECTIVES

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Hispaniola, the second largest islands on the Caribbean, have one of the highest diversities of terrestrial vertebrates in the region today. This diversity was much richer during the late Quaternary before the arrival of humans, which unleashed several waves of extinctions and extirpations events that affected vertebrates, especially terrestrial mammals. Nowadays, only one a native rodent and an eulipotyphlan "insectivores" survive, both of which are threatened by extinction. In the late Pleistocene-early Holocene, the island was home of several species that are extinct today including two primate, ten rodents, six sloths, four eulipotyphlan "insectivores", six birds, and five reptiles. However, new studies based on specimens collected during recent field work in flooded caves of the east of the island, dry sinkholes in the south, and historical collections from the west are revealing local as well as island scale biodiversity patters. This work has also led to the discovery of several new species of vertebrates, including a primate, two rodents, an eulipotyphlan, as well as several lizards and birds suggesting that we are still far from understanding the biodiversity lost suffered on the island. At the same time we highlight the potential that these collections have to further understand biogeographical patterns within Hispaniola, reconstruct ecosystems and the ecology of extinct species, understand phylogenetic relationships between living and extinct taxa.

## BASILOSAURIDAE (MAMMALIA, CETACEA) FROM THE SAHARA DESERT OF SOUTHWESTERN MOROCCO

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The Sahara Desert in southwestern Morocco is becoming an area as important as Egypt's Wadi Al Hitan, the northern margin of Tethys (present-day Ukraine, western Russia, and Germany), and the southeastern United States of America in terms of richness of Eocene archaeocete remains. In the Moroccan Sahara, protocetid whales are known in localities from the middle and upper Eocene (Bartonian of the Aridal Formation in the Guéran Depression and Lutetian-Bartonian of the same Formation in the El Breij Depression), while basilosaurids are known from rich material from these localities as well as from the Priabonian Samlat Formation southwest of Ad-Dakhla. Unfortunately, there are not many complete skeletons, which rarely makes it possible to directly associate the skull and postcranial bones of the numerous species present in each locality. However, the multivariate analysis of the lumbar vertebrae of basilosaurid species, and the phenetic analysis by a distance method of mixed tympanic bullae of basilosaurid and protocetid species, make it possible to discuss and reassess the taxonomic determination of the different species present in these localities and to compare them with each other and with the forms of Egypt, Central Europe and America. The phylogenetic position of all the Paleogene species present in the Moroccan Sahara compared to other Paleogene cetaceans was determined using a cladistic analysis.

## PERSISTENCE IN PALEONTOLOGY: 188 YEARS OF PALEONTOLOGY AT THE NEW YORK STATE MUSEUM

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The oldest and largest State Museum in the United States is the New York State Museum. It was founded as the New York Geological and Natural History Survey in 1836 which is when the Paleontology Collection was established. A continuous line of paleontologists, including James Hall, John Mason Clarke, and Winifred Goldring have overseen the collection since that time. Our holdings range in age from the Vendian through the Cretaceous and consist of invertebrate fossils including microfossils and ichnofossils, fossil fish, and fossil plants. A

second, separate collection houses the Pleistocene vertebrates. We estimate that the Paleontology Collection contains about 750,000 specimens. Type and figured specimens (over 23,000) and Exhibit specimens (almost 14,000) are recorded using a traditional catalogue in which each specimen has a unique identifying number. Most of the remainder of the collection is catalogued using the locality-register system, but the quality of the data associated with these specimens varies greatly. Additionally, and unfortunately, the data we do have are mostly not digital. Not only is this inefficient, it prevents us from sharing our considerable resources with scientists, educators, artists, and the citizens of New York. Every museum must strive to maintain the physical integrity of its collections. However, we must also create a traditional catalogue for the majority of the collection and digitize our data to ensure long-term preservation and to increase public access. With a collection of this size, one of our biggest challenges is our staffing level. Like other museums, we would benefit from having additional team members and their knowledge. While we have outlined a clear path forward, we struggle, like many institutions, with the limitations and challenges listed above. We are optimistic that Paleontology at the New York State Museum has a bright future. To continue our important work, our small staff takes advantage of volunteer and student intern programs, which also serves our public by providing educational and outreach opportunities. Additionally, we make every effort to keep the collection in the public eye by featuring unique and/or interesting specimens on social media and we take every opportunity to participate in meetings and present lectures to interested groups. Finally, the Paleontology Department works to ensure that there will be a next generation of scientists and people who value science through educational outreach.

## SYSTEMATICS AND PALEOCLIMATE OF TERRESTRIAL MAMMALIAN FAUNA FROM THE LATE MIOCENE (11.2–3.58 MA) SIWALIK DEPOSITS OF PAKISTAN

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The Siwaliks represent one of the best exposed and richest fluvial fossil deposits available in the world. Numerous mammalian lineages have been reported and presented to the world from the 18th century. Majority of these lineages have been retrieved from the Late Miocene Siwalik deposits including perissodactyls, artiodactyls (most abundant), carnivores, proboscideans, rodents (rarest). The current study describes 14 mammalian fossil remnants collected from Hasnot and Khokhar Zer localities of Dhok Pathan and Nagri Formations of the Late Miocene, Punjab, Pakistan, respectively. These fossil remnants belong to four orders viz. Perissodactyla, Artiodactyla, Proboscidea and Carnivora. The order Proboscidea is represented by a tusk fragment that lack enamel and has its oval cross section and allocated to Choerolophodon corrugatus. An isolated lower canine and an upper third premolar is designated to the genus *Machairodus*. The canine is small with crenulated anterior and posterior edges while upper premolar has typical machairodont morphology with broad crown and having anterior and posterior accessory conules. The order Perissodactyla is represented by a single species, *Brachypotherium perimense*, with two isolated upper premolars. Both premolars are brachyodont, large sized, and tend to have flattened buccal walls. The order Artiodactyls is represented by *Tragoportax*, *Selenoportax*, and *Miotragocerus* (family Bovidae) having six fossil specimens; *Propotamochoerus hysudricus* and *Hippopotamodon sivalense* (family Suidae), and *Merycopotamus dissimilis* (family Anthracotheriidae). The presence of machairodont specimens is a great find because this family is extremely rare in the Siwaliks and these specimens will add more morphological data to our existing knowledge. Dental morphologies and the existence of different taxa during the Late Miocene of the Siwaliks indicate grassland ecosystem with semi-arid paleoclimate.

## MACROEVOLUTIONARY AND MACROECOLOGICAL TRENDS IN TURRITELLIDAE IN THE WESTERN ATLANTIC, NEOGENE–RECENT: INSIGHTS FROM AN ABUNDANT, WELL-STUDIED TAXON

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Turritellid evolution represents a microcosm of large-scale patterns of molluscan evolution during the Cenozoic observed across the region. Additionally, isotopic studies of fast-growing turritellids and other gastropods have been important for documenting changing environment including the history of nutrient conditions associated with upwelling and different patterns of seasonal rainfall distribution across the region. These studies have included data from Colombia, Florida, Panama and Venezuela, documenting paleoenvironmental conditions that were substantially different than modern oceanographic conditions. Aside from being substantially impacted by extinction and showing declines in abundance along with other suspension feeding taxa, turritellids also exhibited 1) a shift towards hard substrate and biogenic substrate associated taxa; 2) a shift away from planktotrophy as a larval feeding mode; and 3) a loss of large species in association with the decline of high productivity environments. While soft-substrate-associated turritellids declined in both diversity and ecological significance, the reef and hardground associated turritellid genus *Vermicularia* continued to diversify, and

*Vermicularia* now represent half of all turritellid species in the western Atlantic, and the majority of turritellid species in Florida. Larval mode within turritellids shifted towards increased lecithotrophy, independently in deeply divergent lineages when comparing modern taxa, fossil assemblages, and modern eastern Pacific species. The decline of the generally large-bodied taxon *Caviturritella* in the western Atlantic, including both the extirpation of *Caviturritella* from Florida and the extinction of the largest ever turritellid gastropod, *Caviturritella abrupta*, mirrors observed losses of many large-bodied taxa and declines in body size observed in other lineages, especially bivalves.

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## MICRO-COMPUTED TOMOGRAPHY REVEALS THE INTERNAL ANATOMY OF PALEOCENE †*MAGNIGENA ARABICA* (TELEOSTEI: OSTEOGLOSSOMORPHA: OSTEOGLOSSIDAE)

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Osteoglossids are an iconic clade of freshwater fishes. Modern species occupy South America, Africa, Australia, and Southeast Asia. Fossils show osteoglossids once had a broader geographic distribution, with several species from the northern hemisphere, including examples from marine deposits. These marine taxa seem restricted to the early Cenozoic, but they are poorly known in comparison with their freshwater contemporaries. One example is †*Magnigena arabica*, represented by a single articulated skull specimen from the Thanetian-age Umm Himar formation of Saudi Arabia. †*Magnigena* has been described from external anatomy, but application of micro-computed tomography (µCT) provides additional details and revises some existing interpretations. µCT reveals anatomical details of the basihyal and associated toothplate, ceratohyals, urohyal, hyomandibulae, endopterygoids, neurocranium, and an anterior portion of the pectoral girdle. Features of note with a limited distribution among fossil and living osteoglossids include: an anterior process of the hyomandibula contacting the endopterygoid, an elongate opercular process of the hyomandibula, posteriorly-placed fangs of the parasphenoid, and paired fangs along the posterolateral margin of the basihyal. Utilizing this newfound information, we place †*Magnigena arabica* in a phylogenetic framework among fossil and living osteoglossids.

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## GEOSPATIAL PALEONTOLOGY: MODELING THE LOCATION OF FOSSIL LOCALITIES USING SATELLITE IMAGERY AND ARTIFICIAL INTELLIGENCE

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While finding vertebrate fossils in remote field locations relies on expert knowledge of the geology and topography of an area, as well as long hours of ground-surveying, an element of chance or good luck often plays a role in successful field seasons. Over the past decade, a growing number of paleontological researchers have begun to use satellite imagery and machine learning algorithms to reduce the role of serendipity in locating productive vertebrate fossil localities. Our lab has developed and successfully field-tested several different algorithms that yield predictive models for locating productive localities in Paleogene deposits in Wyoming and Utah. Our approach, which we refer to as Geospatial Paleontology, seeks to characterize spectral signatures of known fossil localities derived from classification of satellite imagery, and to then train machine learning algorithms to identify similar spectral signatures throughout the research area. Our approach is general enough to be used in other paleontological contexts regardless of location, geology, or time period. In addition, it has led us to develop new work flows for field surveying that effectively reduce the spatial extent of the areas we seek to survey by orders of magnitude, and that can be rigorously tested. In this paper we discuss two of these models. The first utilizes a supervised classification of land covers based on individual pixels in medium resolution Landsat 7 ETM+ imagery of the Great Divide Basin (GDB) in southwestern Wyoming. A simple artificial neural network (ANN) model was trained to identify five different landcover classes throughout the entire GDB (e.g., forest, wetland, scrubland), one of which was previously identified localities, based on 6 bands of EM radiation spanning the visible and infra-red spectrum. The resulting confusion matrix indicated that the model successfully identified Localities (User's Accuracy 99% and Producer's Accuracy 79%), and correctly classified 84% of pixels for all classes. Our second model attempts to overcome the limitations of the previous model by using high resolution imagery and classifying multi-pixel geographic objects based on homogenous, adjacent pixels. Using an approach known as Geographic Object-Based Image Analysis (GEOBIA), we segmented high resolution Quickbird imagery from the GDB into image objects. The segmented image yielded a classification rule set that identified image objects whose statistical parameters most closely resembled those of an extremely productive fossil-bearing sandstone locality (CM 4026). To test the model predictions, 26 high-priority locations (each with a 100m buffer zone) were exhaustively searched in the field: 18 yielded vertebrate fossils. Overall, our model yielded a 74% correct classification rate with a Cohen's

Kappa statistic of 39% (over random chance). Both models support the use and further development of geospatially informed predictive models in vertebrate paleontology.

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## NON-MAMMALIAN SYNAPSIDS FROM THE EARLY PERMIAN PEDRA DE FOGO FORMATION (PARNAÍBA BASIN, NORTHEAST BRAZIL) EXPAND OUR KNOWLEDGE OF THE GONDWANAN TROPICAL BIOME

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Historically, the paleotropics of Euramerica have provided nearly our entire picture of Permo-Carboniferous terrestrial tetrapod evolution. Despite its richness, the geographic sampling bias inherent in this record obscures important questions, such as the timing and geographic location of the origin of therapsids. The Cisuralian (early Permian) Pedra de Fogo Formation (PDF) of Brazil provides a unique window into the Gondwanan tropical to subtropical terrestrial biota of this time. The PDF is thought to represent a semi-arid to arid coastal to continental sabkha, but evidence from the paleobotanic record suggests that conditions in proximity to bodies of water could be relatively humid and stable. The PDF has produced a rich aquatic vertebrate assemblage, including chondrichthyans, actinopterygians, sarcopterygians, and temnospondyls, but the terrestrial tetrapod assemblage reported to date is limited to acleistorhinid and captorhinid reptiles. Here we report the first two specimens of Synapsida from the PDF. One specimen is a natural mold of the cranial face of a posterior dorsal or anterior caudal vertebra. Its large size (estimated presacral length more than 1.2 m), amphicoelous centrum, and narrow neural arch with closely set, dorsolaterally-angled anterior zygapophyses allow its identification as synapsid, but a more specific assignment is not possible. The second specimen is a natural mold of the medial surface of a partial maxilla. The large caniniform tooth, presence of a supracaniniform buttress lacking a dorsal process, and pronounced ventral convexity of the element permit its identification as a member of Sphenacodontia, but the straight, dagger-like caniniform is unique within the clade. Phylogenetic analysis of the maxilla corroborates its sphenacodontian affinities. In addition to expanding the phylogenetic diversity of the PDF tetrapod assemblage, the specimens add a new size class (very large terrestrial amniote) and ecological guild (medium-size terrestrial faunivore) to the PDF terrestrial fauna. These new finds hint at the presence of a complex terrestrial ecosystem alongside large, persistent bodies of water capable of supporting aquatic predators such as the very large temnospondyl *Prionosuchus*. They are consistent with wetter local conditions, including the existence of wetlands within the Parnaíba Basin during the deposition of the PDF. When combined with paleobotanic data, the biogeographic picture that emerges is of a broadly-distributed biome spanning the northern and southern tropical and subtropical regions of Pangaea during the Cisuralian. However, within this biome, local environmental variation and dispersal barriers likely facilitated the emergence of distinct low-level taxa in different areas, as indicated by unique combinations of faunal components in the PDF relative to roughly coeval Euramerican assemblages.

## DISCOVERY OF BARYTHERIUM REMAINS (MAMMALIA: PROBOSCIDEA) FROM THE MIDDLE EOCENE OF MOROCCO: IMPLICATIONS FOR MORPHOLOGY, PHYLOGENY AND PALEOGEOGRAPHY.

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Since its discovery in the Fayum at the beginning of the XXth century, the extinct proboscidean *Barytherium* has remained elusive and enigmatic, found only in a handful of north African localities. Recent discovery of *Barytherium* remains in the Middle Eocene epoch of Morocco expands our knowledge of this taxon, anatomically, but also geographically and phylogenetically. This discovery comes from the Aridal Formation in the sabkha of El Breij, which lies roughly 150 kilometers southeast of the coastal city of Boujdour. The formation is in the Tarfaya-Laâyoune-Dakhla Basin, which parallels the Atlantic coast and represents the nearshore portion of Morocco's Atlantic passive margin. The Aridal Formation at El Breij is divided into three lithostratigraphic units, and the basal unit, with a thickness of seven to eight meters, is an alternation of indurated whitish marls forming platy structures and sandy marls. Three intervals within the basal unit are coarse-grained marly sands rich in vertebrate fossils. These levels are separated by persistent yellowish sandstones. *Barytherium* comes from the lower interval of the basal unit. These new remains consist in isolated dental and postcranial elements that most likely belonged to a single individual. They

include, notably, elements previously unknown for this taxon, such a complete axis, and they also display characteristics not observed in previously known *Barytherium* specimens. This material is housed in the paleontological collections of the Department of Geology, Faculty of Sciences Aïn Chock, Hassan II University, Casablanca. Comparative analyses with contemporary faunal assemblages, notably those from the localities of Fayûm and Dor El Talha, confirm the temporal placement of the species and contribute to a refined understanding of the dispersal and diversification patterns of proboscideans across Africa. The discovery also underscores the importance of the Moroccan Sahara's fossil record for unraveling the early evolutionary history of mammals. It adds a new dimension to our understanding of prehistoric life in North Africa. This study not only enriches the fossil record of early proboscideans but also reinforces the Sahara Desert as a critical site for paleontological research, offering profound implications for the biogeographical and evolutionary studies of ancient mammals.

## WAVELET ANALYSIS DETERMINES THE SYNCHRONICITY AND PERIODICITY OF ECOLOGICAL AND ENVIRONMENTAL CHANGE IN THE SANTA BARBARA BASIN, CALIFORNIA, THROUGHOUT THE COMMON ERA

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Modern ecology and paleoecology both aim to explain interactions between life and Earth systems but make observations at incongruent temporal scales. Ecology studies typically span no more than years or decades, while paleontology routinely examines taxa over millions of years. There is a dearth of data for intermediate temporal scales of centuries to millennia, which limits ability to predict ecosystem shifts over the coming centuries—the scale over which species will go extinct or adapt to anthropogenic climate change. The high-sedimentation Santa Barbara Basin (SBB), between mainland California and the Channel Islands, is a rare system where it is possible to resolve ecological and environmental changes at intermediate timescales undocumented elsewhere. Sediment varves accumulate annually, enabling chronological correlations and calibrations; moreover, productive surface waters maintain anoxic bottom-water conditions, which prevent bioturbation and time-averaging. A long history of sediment core collection has generated a wealth of published time series for biotic and abiotic variables from the basin. The current work integrates these disparate paleo-environmental proxies and microfossil records into holistic analyses of ecosystem change, over timescales that span impactful regional climate anomalies and European settler land-use changes. Data cover the past 2,000 years at decadal resolution and the past 250 years at near-annual resolution. Applying wavelet analysis, this study aims to quantify how synchronous population dynamics have been between trophic levels, between biotic and abiotic variables, and between intervals of environmental perturbation and background change. Wavelet analysis is a more flexible alternative to Fourier transform or spectral analysis, capable of estimating the strength and period length/frequency of any cycle(s) present at each point in a time series, as well as the correlations and lags in periodicity between series. Results suggest each biotic and abiotic variable exhibits characteristic periodicities, from 8–128 years, which are variably stable through time. Short-scale synchronicity between biotic and abiotic series emerged at ~1500 and ~1850 CE, coincident with the Little Ice Age and cattle ranching destruction of onshore vegetation structure. Major environmental perturbations might force a lockstep, high-frequency (5-30 year period) concurrence between species and environmental correlates. Ultimately, it is possible to incorporate modern live-catch data and deeper-time sediment core data into this study framework. Reanalysis at telescoping temporal scales from months to ten–thousands of years would encompass environmental change ranging in magnitude from seasonal variation to stadial–interstadial cycles. Such an approach offers an avenue to quantify how causal relations in marine ecosystems may emerge or weaken with temporal scale, which may help reconcile and unify results between ecology and paleoecology.

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## MEXICAN CONTRIBUTIONS ON KNOWLEDGE ON THE BIOLOGY OF PLEISTOCENE COLUMBIAN MAMMOTH (*MAMMUTHUS COLUMBI*)

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Columbian mammoth (Proboscidea, Elephantidae, *Mammuthus columbi*) was the largest Pleistocene mammal in North and Central America, which inhabited the current territories of northern Canada, throughout U.S.A., Mexico, and apparently isolated records from Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica. In Mexico, their remains are one of the most abundant findings in Pleistocene deposits (more than 300 known localities), mostly because their enormous size turn them exceptional, including large-size populations in the Mexican Plateau (San Luis Potosí), and the Transvolcanic Belt (Basin of Mexico) Mexico. This large-sample size has

allowed to estimate its geographic and ecological distribution, and undertaking detailed studies on feeding habits, migration patterns, and habitat general characteristics, using micro and mesowear and stable and radiogenic isotopes; recent results showed that the study species was a generalist in its diet, and occupied migratory routes from over 100 km. Also, the availability of dental material has allowed enamel and dentine sampling for paleogenomics studies, and dating assays.

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## UNGULATES AND PROBOSCIDEANS FROM CENOTE HOYO NEGRO, QUINTANA ROO, MEXICO

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Much of the early prehistory of the Americas lies underwater along its coastlines and in the submerged caves and cenotes of Florida and the Yucatan region. Hoyo Negro (HN), near Tulum, Quintana Roo, has provided an amazing collection of Late Pleistocene bone of vertebrates, particularly medium and large mammals, including the largest terrestrial mammals from the Yucatan Peninsula, the gomphotheres (Proboscidea, Gomphotheriidae), as well as another megamammal, tapir (Perissodactyla, Tapiridae), and a medium-sized mammal, the peccary (Artiodactyla, Tayassuidae). These mammals are spread over the cave floor and walls, as well as the nearby tunnels; those of the proboscideans and tapirs are well known from here and other cenotes and submerged caves of the Peninsula. At least five of six individual proboscideans have been more precisely identified, based primarily on their molars and tusks. They are initially assigned to the genus *Cuvieronius* sp., which was previously known from dry and submerged caves located elsewhere on the Peninsula. Three of the HN individuals consist of largely complete, if scattered, skeletons, while others are represented by only few bones and/or teeth each. A radiocarbon date was obtained on one individual at around 35,000 years cal BP and another at around 20,000 cal BP. It is noteworthy that gomphotheres seem to have excluded other proboscideans, like mammoths or mastodons, from spreading over the Peninsula, either by excluding competition or because of inhabiting different environments. Regarding tapirs, the HN specimens consist of at least two individuals assigned to Tapirus sp. in the pit and five in connecting tunnels. While the most likely taxon is the Mesoamerican tapir Tapirus bairdii, morphological features are currently being assessed to confirm or negate this hypothesis. Finally, peccary skulls from HN are assigned to the collared peccary *Dicotyles tajacu*, and although a new taxon was described from another nearby cenote, subsequent research rejected that hypothesis and assigned it to the collared peccary. Radiocarbon dates on specimens of these two ungulate taxa tentatively range between 36,000 and 30,000 cal BP. The presence of these animals in this locality is important considering the large size of some, including the large proboscideans, since they must have walked through the upper dry cave passages for quite a distance before encountering the Hoyo Negro pit in total darkness. We hypothesize that fresh water in the pit was the primary attraction for these mammals.

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## THE GOOD, THE BAD, AND THE HYPOXIC: INVESTIGATING THE RESPONSE OF BRACHIOPODS AND BIVALVES TO LOW-OXYGEN CONDITIONS

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The end-Permian mass extinction resulted in the greatest animal biodiversity loss in the history of life, across both the terrestrial and marine spheres. Lingulid brachiopods exhibited remarkably high abundance in the wake of this catastrophe, resulting in their establishment as a 'disaster' taxon. However, there has been limited physiological work to explain the mechanism(s) responsible for this observation. The exact kill mechanisms of the extinction—potentially including warming, reduced food availability, hypercapnia, deoxygenation, and sulfide poisoning—have been hotly debated. One or more of these may have played a role in lingulid brachiopods' relative success. Here, we use respirometry experiments on lingulid brachiopods (*Glottidia pyramidata*) and bivalves (*Mercenaria campechiensis*) from the Gulf of Mexico to compare the synergistic impacts of ocean warming and hypoxia on marine invertebrates. To determine if and how inarticulate brachiopods and bivalves differentially respond to low $O_2$

levels and high temperatures, we measured the absolute $pO_2$ tolerance ($P_{crit}$) and the temperature sensitivity of $P_{crit}$ of each species. This measurement was done by performing respirometry experiments at three temperature controls: 16, 22, and 26°C. We found that lingulids are more sensitive to higher temperatures, but less sensitive to hypoxia than bivalves. This finding aligns with results from earlier work, which suggested that bivalves tolerate high temperatures better than brachiopods, but have lower tolerance for hypoxia. Based on previously collected data (Marquez et al., in prep), articulate brachiopods (*Terebratalia transversa*) are more sensitive to hypoxia and temperature than both inarticulates and bivalves. These results could explain lingulids' comparatively high abundance in Lower Triassic strata with geochemical and sedimentary indicators of low-oxygen conditions.

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## THE APPLICATION OF CT AND SYNCHROTRON SCANNING TO RESOLVE THE INTERNAL ANATOMY, PHYLOGENY, AND ECOLOGY OF MESOZOIC FOSSIL FISHES

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Neopterygians are an immensely diverse assemblage of ray-finned fishes which encompass over 36,000 living species, divided into teleosts and holosteans. These two groups are extremely taxonomically imbalanced: Holostei comprise just eight species, while Teleostei contains the remaining 99.8% of neopterygian diversity, accounting for over half of all living vertebrates. However, despite their overwhelming modern success, taxa outside of the living teleost radiation—stem teleosts—remain poorly understood. The teleost stem includes an abundance of charismatic Mesozoic fossil groups underpinned by centuries of study, such as pholidophorids, aspidorhynchids and pachycormids. But efforts to understand their interrelationships have been limited by two critical areas of uncertainty: the internal anatomy of well-preserved specimens is rarely described and there are multiple conflicting hypotheses of their phylogenetic arrangement. Ultimately, fossil teleost fishes lack a solid phylogenetic foundation, which has undermined attempts to investigate patterns of diversification on the stem. Here, we present a series of remarkably preserved specimens described using high resolution CT and synchrotron scanning. This includes a new, three-dimensionally preserved specimen of *Dorsetichthys bechei*—a herring-like fish from Early Jurassic Lyme Regis closely related to pholidophorids. Via CT scanning, we have uncovered previously unknown aspects of this key taxon, including its endocast, gill skeleton, and a protrusible jaw, hinting at potential filter-feeding behaviour. We also describe the endocast of *Richmondichthys* (Aspidorhynchidae) for the first, and identify a new genus (Ionoscopidae), following the taxonomic reassignment of misidentified "*Aspidorhynchus*" braincases from the Great Oolite Group (Bathonian) Northamptonshire, UK. Finally, we present an exceptionally preserved *Pachycormus* (Pachycormidae) from the Strawberry Bank Lagerstätte (Toarcian) Somerset, UK. This extraordinary specimen preserves a partially ossified braincase, elaborate gill skeleton and evidence of soft tissue preservation. The anatomical insight obtained in this project has informed a markedly strengthened phylogeny of the teleost stem, and associated groups within Neopterygii. This sets in motion future macroevolutionary studies and allowing us to better understand the origins of this exceptionally vast and important vertebrate group.

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## A REVIEW OF LATE-QUATERNARY SOUTHERN CALIFORNIA PACKRAT MIDDENS: IMPLICATIONS FOR INTERPRETING THE IMPACT OF PALEOCLIMATE

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Documenting how ecosystems responded to climate change in the past can inform models for the future relevant to conservation decision-making. Packrat middens, or giant nests consisting of gathered plant material made by rodents of the genus *Neotoma*, represent one of the best data sources for understanding how plant communities change over time. These middens provide important data for paleoecologists, as packrats collect plant remains from a broad swath of taxa within a 50 ft radius of their nest. In arid regions, these nests, or middens, get preserved by the packrats' viscous urine, and can be preserved for thousands of years, giving insight into past distributions of plants and small vertebrates. Using data from the USGS Packrat Database, we analyzed records of 40 common plant taxa from over 200 middens in Southern California (SoCal) across the past 35,000 years. These data comprise periods of significant climate changes, spanning the pre-glacial, Last Glacial Maximum, terminal Pleistocene

and Holocene. Using the literature of SoCal sediment cores and oxygen 18 curves, we have been able to compare plant distribution changes with climatic events, giving insight into how climate change has previously affected floral changes in elevation and geographic range. Furthermore, we examined records from three biogeographic provinces: the Sierra Nevada; Mojave Desert; and Sonoran Desert, identifying changes in plant distributions that correspond with periods of climate change. These species-specific distribution patterns are detailed and compared against modern distributional data obtained through community science initiatives. Additionally, with input from paleobotanists and practitioners from The Nature Conservancy, we focused on 10 focal taxa to connect this research to modern conservation. These data on past plant distributions can be useful for scientists and practitioners looking to predict impacts of modern climate change on floral communities.

## THE SIWALIK RECORD OF NORTHERN PAKISTAN: HIGHLIGHTS AND SYNTHESIS

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The continental fossil record has exceptional long sequences that are the basis for evaluating ecosystem dynamics and their driving forces. The Siwalik sequence of South Asia is one such example, deposited in a foreland basin created by the collision of Indian and Eurasian tectonic plates. In the Potwar Plateau of northern Pakistan, the Siwalik sequence is about 5000 m thick and spans 18–1 Ma. Alluvial sediments representing river-channel and floodplain deposits correspond to mountain-sourced large river systems and foothill-source smaller rivers. Vegetation and associated climatic information is recorded in stable isotopes and biomarkers in paleosols, as well in stable isotopes of mammal teeth. Molluscs, fishes, crocodilians, turtles, lizards, snakes, birds, and mammals are preserved throughout the sequence. We evaluated the diversity dynamics of mammalian faunas over well-sampled portions of this sequence. Mammalian faunas had exceptionally high species richness (116 species, excluding bats) at their peak and included up to 18 contemporaneous megaherbivores (>800 kg). Origination and extinction of mammal lineages occurred throughout the sequence with peaks of origination occurring early in the sequence and peaks of extinction later in the sequence. The major changes over time in species richness, taxonomic composition, and ecological structure occurred in two phases. The first was a rapid increase in richness from 14.7–13.1 Ma, beginning with the cooling interval at the end of the warm Miocene Climatic Optimum. The second phase began around 10.0 Ma and continued through 6.0 Ma. Environmental changes included a decline in coniferous trees and increase in deciduous trees along with expansion of fire-prone grasslands. During this phase, mammalian faunas declined in species richness, with frugivorous and browsing species disappearing first as seasonality of moisture increased. Mixed feeders and grazers persisted through this transition. These patterns indicate a strong role for environmental forcing as a significant influence on faunal change. Additional likely influences were the ecosystem engineering effects of megaherbivores and predation by diverse terrestrial and aquatic faunivores. These Miocene faunas have no modern counterparts and thus offer unique insights about faunal responses to environmental changes of the past.

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## THE PUZZLE OF MIOCENE MEGAHERBIVORE RICHNESS

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Megaherbivores are broadly herbivorous terrestrial mammals that weigh >800 kg as adults. (Some definitions use 1000 kg as the weight threshold.) Present-day ecosystems contain few megaherbivore species, with four or five co-occurring at most. When present, megaherbivores have strong impacts on their ecosystems—through trampling of vegetation, creating openings in forest canopies, reducing fuel loads for fire, and redistributing nutrients and dispersing seeds over long distances. The continental Neogene fossil record, in contrast, contains many sequences with 10 or more contemporaneous megaherbivore species. For example, the Miocene Siwalik record of northern Pakistan preserves up to 18 contemporaneous megaherbivores from three clades (Proboscidea, Artiodactyla, Perissodactyla). What kind of ecosystem can support such high richness of megaherbivores? Three plausible ecological processes could have interacted to support high megaherbivore richness. (1) Nutrient redistribution by large mammals is estimated to have been more than ten times greater before the late Quaternary megafaunal extinction than it is today. This process could have enhanced ecosystem productivity over large areas, thereby supporting high richness of mammals of all sizes. (2) High primary productivity, stimulated in part by nutrient redistribution, in three dimensions would provide the resource base for a large biomass of terrestrial consumers. This production would include aquatic vegetation, ground-level herbs, grasses, and shrubs, and tree canopies. Most

Miocene megaherbivores were browsers and co-occurred with diverse medium-sized ungulates and arboreal species. (3) High Miocene faunivore richness included many species of mammalian predators (creodonts and carnivores) across the size spectrum. Some of these predators were much larger than their modern relatives and could have preyed upon juvenile megaherbivores and, in groups, upon adults. Case studies from the fossil records of South Asia, East Africa, and North America provide glimpses into how these processes would have interacted to promote high megaherbivore richness.

## PALYNOLOGY OF A LATE CRETACEOUS VERTEBRATE SITE IN NORTHEASTERN MISSISSIPPI, U.S.A. – IMPLICATIONS FOR FLORISTICS, BIOSTRATIGRAPHY AND CLIMATE

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We report here on a palynological assemblage recovered from an early Campanian vertebrate fossil site (Tolar-Stevens Dinosaur Site (TSDS)) near Booneville, Mississippi, first reported in 2014. The TSDS, from the lower Coffee Formation (calcareous nannofossil zone CC-19), consisting of interlaminated carbonaceous clays, silts, and fine-grained sands along with teredinid-bored lignitized logs, is interpreted as a tidal flat in the intertidal zone. The faunal assemblage includes a partial skeleton of an adult hadrosaur found within a thin shell bed of disarticulated *Trigonia* sp. This ornithopod fossil, the most complete dinosaur found in Mississippi to date, was found with the dentary of a very young hadrosaur, suggesting that this assemblage may have included a nesting site. The fauna also includes a crocodilian, a toxochelyid sea turtle, the teleost fish *Enchodus*, and sharks such as *Squalicorax* and *Scapanorhynchus*. A very well-preserved palynoflora was extracted from matrix associated with the dinosaur bones. Based on an approximately 200-grain count, angiosperms comprise almost half (47%) of the assemblage, spores about 28%, and gymnosperms about 10%. Algal cysts also make up a significant component of the assemblage (~ 12%). Dinoflagellates are present but rare, indicating sporadic marine incursions, perhaps from storm surges. Among the angiosperms, species of Normapolles (= Fagales) are prominent, especially *Plicapollis rusticus*, *Complexiopollis abditus*, and *Osculapollis aequalis*. Other typical Late Cretaceous angiosperms include species of *Holkopollenites*, *Tschudypollis*, *Liliacidites* and *Echimonocolpites* (most representing eudicots or monocots of uncertain affinity). Almost all of the gymnosperm pollen represents members of the Pinaceae, with a minor component of Cupressaceae (*Inaperturopollenites dubius*). Spores are varied and represent Anemiaceae, Polypodiaceae, Gleicheniaceae, Sphagnaceae, and Lycopodiaceae, as well as other unknown families. Algal cysts point to a strong fresh-water influence. A refined biostratigraphic age for the TSDS can be proposed based on correlations with palynofloral assemblages in comparable units in Tennessee. The co-occurrence of *Holkopollenites propinquus* with a LAD in the earliest mid-Campanian and *Osculapollis* aequalis with a FAD in the late early Campanian places it in the upper half of the Hp palynozone of Christopher & Prowell, close to the early-middle Campanian boundary. The abundance of Normapolles forms, and angiosperms in general, point to a warm and semiarid climate, but the abundance and diversity of ferns and bryophytes, as well as algal cysts, indicate that much of the local vegetation near the site of deposition was more hydrophilic. This research was supported by a Bryce-Griffis grant to N.L. Baghai-Riding.

## INTEGRATIVE NEUROANATOMY AND THE ORIGIN OF BIRDS

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The evolution of flight is a rare event in vertebrate history, and one that demands functional integration across multiple anatomical/physiological systems. The neuroanatomical basis for such integration and the role that brain evolution assumes in behavioral transformations remains poorly understood. Avian powered flight is especially conducive to study because it occurs in a group whose extant diversity is abundant, easily sampled, and tied to a stem lineage rich in well-preserved fossils. This combination permits experimental data to be integrated with broad-based, macroevolutionary patterns to better understand the demands of powered flying on structural complexes that originated for terrestrial locomotion. I use patterns derived from in-vivo positron emission tomography (PET) analysis to assess brain activity of flying birds and interpret these results within a macroevolutionary context shaped by non-avian dinosaurs. Although neural activity is generally conserved from rest to flight, we found significant increases in the cerebellum as a whole and the optic flow pathways. A derived cerebellar capability likely arose at the base of maniraptoran dinosaurs, where volumetric expansion and possible folding directly preceded paravian flight. These data represent an important step toward establishing how the brain of modern birds supports their unique behavioral repertoire and provide novel insights into the neurobiology that first allowed these bird-like dinosaurs to achieve powered flight.

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## A WORLD OF SMALLER ANIMALS: ECOMORPHOLOGICAL AND BIOGEOCHEMICAL SHIFTS IN MESOCARNIVORES FOLLOWING THE PLEISTOCENE MEGAFAUNAL EXTINCTIONS

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Large mammalian carnivores were common for millions of years until the Pleistocene megafaunal extinctions, the consequence of intersecting large-scale disturbances: climatic warming and drying, increased human pressure on herbivores, and unprecedented fire activity. These intersecting impacts altered the landscape, effecting a sudden transition toward a world of smaller animals. "Mesocarnivores"—small to medium-sized mammalian carnivores—survived the megafaunal extinctions and now comprise most carnivore biodiversity, especially in urban communities. Here, I evaluate ecological change, quantified using morphological and biogeochemical techniques, in five mesocarnivore species through the last 55,000 years in southern California, U.S.A.. These species are the American badger (*Taxidea taxus*), bobcat (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), and long-tailed weasel (*Mustela frenata*), all of which continue to live in the area today. These species are preserved as late-Pleistocene to Holocene fossils at the Rancho La Brea (RLB) asphalt seeps in Los Angeles, CA, and furthermore as historic (<100 years old) specimens from the same region at the Natural History Museum of Los Angeles County. Radiocarbon dates show that bobcats, grey foxes, and striped skunks at RLB tend to precede the Last Glacial Maximum (LGM), while most badgers date to the latest Pleistocene. No sampled specimens date to the LGM itself, likely an effect of low sample size or taphonomy. In multiple ecomorphological traits, RLB specimens differ significantly from historic representatives: fossil mesocarnivores tended to be larger, exhibiting a greater degree of carnivory-adapted morphology that may have granted competitive advantage against now-extinct megafaunal predators. Species-specific differences in postcranial morphology correspond to shifts in locomotor ability, potentially a response to environmental change such as aridification. Further, stable isotope analyses of carbon and nitrogen show widening of the mesocarnivore niche from Pleistocene to historic times: while $\delta^{13}C$ and $\delta^{15}N$ of Pleistocene mesocarnivores is contained largely between values for coyotes and megaherbivores, the isotopic range of historic specimens nearly encompasses Pleistocene ranges from coyotes to megaherbivores, demonstrating mesocarnivore release following megafaunal extinction. All species except the weasel show higher and more variable $\delta^{13}C$ toward modern-day than pre-LGM, likely recording vegetational shifts. Temporal differences in $\delta^{15}N$ are less significant but suggest shifts in either meat consumption or baseline nitrogen availability: hypotheses to be evaluated in future work. Altogether, this multi-proxy study provides complementary metrics for diet and resource use, illuminating the roots of today's mesocarnivore fauna in the last Ice Age and highlighting their potential responses to continuing anthropogenic change.

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## EXPLORING THE EVOLUTION AND ECOLOGY OF GEOMORPH RODENTS USING BITE FORCE ANALYSIS AND GIS

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Bite force is associated with a variety of behavioral and ecological factors including locomotion, diet, reproductive ecology, and size. Geomorph rodents, the clade comprising pocket gophers (Geomyidae) as well as kangaroo rats and their relatives (Heteromyidae), are an ideal study system to explore bite force over evolutionary timescales due to their ecological, morphological, and taxonomic diversity. In this study, we estimated the bite force of 65 extant and 52 fossil geomorph species using two measurements of the lower incisor and the lengths of the crania or toothrows for 899 specimens. Locomotion and body size were found to have the greatest impact on bite force. We used an ancestral character state reconstruction and a phylogenetic ridge regression to map the evolution of bite force and analyze rates of evolution and phenotypic change from the Oligocene to the present. We find that bite force evolution in Geomorpha follows an early-burst model likely attributable to ecological diversification 30 Ma. The common ancestor of all geomorph rodents displays an intermediate bite force. Heteromyids show decreased bite forces compared to that common ancestor. That decrease coincides with a significant change in evolutionary rate, potentially reflecting a trade-off between bite force and cranial evolution, particularly hypertrophied auditory bullae. A modest increase in bite force is seen within Geomyidae, with some species having higher bite forces than others. These interspecific differences are associated with differences in burrowing strategy; chisel-tooth digging gophers having higher bite forces than scratch-digging gophers. This enables us to make locomotory inferences for 11 species of extinct entoptychine gophers. The presence of chisel-tooth digging and scratch-digging *Thomomys* gophers has previously been attributed to spatial differences in aridity and its effects on soil hardness. Our preliminary spatial analyses of extant pocket gopher species ranges and digging mode suggests that aridity may indeed act as an environmental filter across the entire family. Chisel-tooth digging gopher species are restricted to the more arid Basin and Range, Rocky Mountains, and

Great Plains regions. These results hint at a new approach to reconstructing paleoenvironments using small mammal paleoecomorphology. This approach could be used for several extant and extinct burrowing rodent lineages to offer a more complete picture of the evolution of burrowing modes and their association with aridification.

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## COMPARTMENTALIZATION OF PALEOCOMMUNITY TROPHIC NETWORKS DURING THE MESOZOIC MARINE REVOLUTION

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Recent work investigating trophic network structure has shown that food webs representing real ecosystems contain more modules than would be expected by chance. Modules, or compartments, are subsets of species that interact more often with each other than other species in the community. Moreover, it has been suggested that the presence and arrangement of modules is an important determinant of ecosystem stability. Here we evaluate module structure in four previously reconstructed trophic metanetworks spanning the Mesozoic Marine Revolution (MMR), a period of immense ecological change in marine ecosystems wherein taxa systematically diversified into novel, more energetically intensive lifestyles. Modularity and module structure were investigated using metanetworks, i.e., networks of guild trophic interactions, that represent shallow marine communities of the western Tethys during the Anisian, Carnian, Bathonian, and Aptian stages. As has been observed in empirical food web networks of modern ecosystems, we consistently recover multiple modules in all four Mesozoic communities. Interestingly, the number of modules recovered in each community was not the same; while the Anisian, Carnian, and Aptian all had four modules, the Bathonian had only three. Module one is dominated by suspension feeders, deposit feeders, and grazers, with predatory roles occupied by durophagous reptiles, fishes, and crustaceans. Module two contains a mixture of suspension feeders, grazers, omnivores, and deposit feeders, and the primary predator guilds are benthic gastropods. Module three is composed of predatory guilds of ammonites, nautiloids, fishes, and reptiles of varying sizes. Finally, Module four, contains only three guilds, photosymbiotic suspension feeders, omnivorous planktonic zooplankton, and benthic attached stationary carnivores (hydrozoans), though this module also contains a guild of detrivore-suspension feeders in the Anisian only. Notably, the guild of benthic attached stationary carnivores are entirely absent from the Bathonian. The other two guilds found in Module four in the Anisian, Carnian, and Aptian (photosymbiotic suspension feeders and omnivorous planktonic zooplankton) are members of Module one in the Bathonian network. Overall, results show that modules are consistent features of trophic network structure, even while new consumer-prey interactions were being created amongst the ecological diversification that occurred during the MMR. Additionally, module structure varies depending on what functions are represented in the community. This work shows that minor changes in guild diversity has profound implications for the flow of energy pathways in trophic networks, consistent with previous studies. These results have important implications for how we understand systems and select species targets in conservation using a network-based systems perspective of ecosystem assembly and stability.

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## PALEOAM—A PACKAGE FOR ABUNDANCE MODELS IN THE FOSSIL RECORD

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Community paleoecologists often use abundance information from multiple species in the fossil record to reconstruct biotic gradients and environmental change. In particular, faunal indices and transfer functions are utilized as proxies of temperature, marine productivity, oxygen availability, precipitation, soil quality, water quality, and many other important variables. But just how sensitive are such measures to the effects of time-averaging and reworking? We might easily predict how a single taxon's relative abundance would be affected by the effect of time-averaging on the community composition, but multivariate measures that utilize the entire paleo-community may behave in unexpected ways. We present a software package for R, named paleoAM, which uses density-based models of species abundance along reconstructed gradients to simulate samples of fossil taxa, which can then be used to assess the effect of modifying the sedimentary history. We expect this package will be of particular use for paleontologists working with detailed fossil records and who seek to narrow down the possible time-scales of rapid or brief changes in those paleo-communities. We demonstrate the package using a record of graptolite community succession through the Katian-Hirnantian boundary from Sheets et al. (2016; PNAS).

# INDIGENOUS ARCHAEOLOGICAL SITES REVEAL INCREASE IN CLAM SIZES AND CONNECT GEOHISTORICAL DATA TO MARINE CONSERVATION ISSUES IN WESTERN CANADA

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Shellfisheries worldwide are increasingly important socioeconomic resources threatened by human-induced pressures including climate change, pollution, and overharvesting. Improved sustainable management of these fisheries is therefore vital economically and for food security. However, shellfish population assessments and management are often hampered by a lack of long-term records, particularly compared to finfisheries. Geohistorical records are an unutilized resource for fishery management that can complement and support Indigenous knowledge, extend fishery records, and/or provide missing data to understand long-term fishery population health and inform current management policies. Here, we examine the current population health of socioeconomically important shellfishes (crabs and clams) by comparing modern and archaeological shell material. Clam shells (*Saxidomus gigantea* and *Leukoma staminea*) were collected from three sites in Barkley Sound (Vancouver Island, BC, Canada), with archaeological material collected from shell middens and modern empty shells collected from nearby beaches. Whole valves were measured (dorsal length) and examined for crab predation traces (a proxy for crab abundance). In contrast to other studies, we found a significant increase in the size of modern clams (approx. 20% for *L. staminea* and 9% for *S. gigantea*), while crab populations remained consistent through time (based on generalized linear models of clam size and presence/absence of crab predation scars, respectively). Larger modern clams are likely a result of the release in human harvesting pressure due to the displacement of the Tseshaht people from their traditional territories in the early–mid 20$^{th}$ century, while the effects of ancient and modern crab fishing have not resulted in any long-term population changes yet, likely due to low localized fishing pressure through time. Our results differ from other west coast shellfish studies that include geohistorical data, highlighting the importance of geographic variation in human history and activities, such as European colonization, industrialization (e.g., logging and urbanization), and harvesting pressure on natural ecosystems and populations. We suggest that integrating archaeological data and Indigenous knowledge/histories is a valuable, yet often overlooked component of conservation palaeobiology and modern ecological studies that can aid in the conservation and sustainable management of fisheries. The implementation of geohistorical shellfish data in fisheries management and conservation is all but new in Canada and elsewhere. Increased interdisciplinary collaboration between conservation palaeobiologists, archaeologists, and both historical and modern ecologists, as well as the local communities most impacted by ongoing changes to fishery populations and the different land and fisheries governing bodies, is therefore an ongoing, but worthwhile challenge.

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**WITHDRAWN**

## MOSAIC EVOLUTION UNDERLIES FELIFORM MORPHOLOGICAL DISPARITY

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Constraint is a fundamental concept in evolutionary theory. Morphology and ecology both are limited by functional, historical, and developmental factors to a subset of the theoretical range species could occupy. Cat-like carnivorans (Feliformia) offer a unique opportunity to investigate phenotypic constraint, as several feliform clades are purported to be limited to generalized ecomorphological roles, while other clades have extremely specialized durophagous (bone-crushing) and sabertooth morphology. We investigated the evolutionary history of feliforms by constructing a total-evidence Bayesian phylogeny and assessing rates of morphological evolution and disparity with discrete characters. Results show a mosaic pattern exists in the degree of morphological disparity per anatomical region and ecology. Generalists have the greatest dental disparity, while hypercarnivores have the least dental disparity but highest cranial and mandibular disparity (excluding dentition). Patterns further differ in the correlation between these anatomical regions and ecology. Hypercarnivores possess a stronger (Mantel r = 0.69) connection between dentition and skull regions than generalists (Mantel r = 0.40), while postcranial correlations between skull or dentition regions are insignificantly different for each ecology. However, high disparity is not necessarily associated with high rates of evolution, but instead with ecological radiations, particularly at the Eocene origin of the earliest feliform clades. We reveal that relationships between specialization and disparity are not as simple as past research has concluded. Instead, morphological disparity results from an anatomical mosaic of evolution, where different ecologies correlate with unique patterns/combinations of disparity per anatomical partition. The constraint on the dentition of hypercarnivores to process and subdue their prey likely facilitates the diversity of skull shapes (many-to-one mapping) seen with this ecology (e.g. sabertooth, durophagous and soft-flesh specialists), while non-hypercarnivores display broad dental variation for an equally broad diet, but can do so with limited skull variation, i.e. one-to-many mapping. Thus, while constraint seems to exist among feliforms, it may be better viewed as a fruitful channel to the disparity of morphology it generates in associated anatomical regions.

## INVESTIGATION OF A UNIQUE END-DEVONIAN EXTINCTION LOCALITY IN WESTERN NEW YORK

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The Frasnian-Fammenian boundary corresponds to the boundary between the black, organic-rich Dunkirk Shale and the underlying blue-gray Hanover Shale at the Dunkirk beach of Western New York. Historically, the black shales at the Dunkirk beach have yielded woody plant remains (including a flattened tree trunk about two feet in diameter) as well as large, disarticulated placoderm bones–but the exact horizon of origin was never recorded. The upper part of the Hanover Shale contains a 'Dunkirk Shale-like' bed less than a meter below the contact. This black shale contains lenticular pyrite patches, fish bones, macroscopic coalified Devonian plant material—only woody material, no leaves. SEM analysis of the plant material excavated from the Hanover black shale show that the coalified material contains aligned pockets of pyrite framboids and euhedral gypsum crystals. The pyrite framboid alignment may reflect relict biological structure, while the gypsum is authigenic–formed from a diagenetic interaction between calcium carbonate and the pyrite. The paleoenvironment fluctuated from oxic, marine environment in much of the Hanover Shale (indicated by bioturbation) to

anoxic marine basin in the finely laminated, hydrocarbon-rich black shales. The assemblage is interpreted as a transported assemblage as the locality is thought to have been some distance from the paleoshoreline. The event(s) causing the input of plant material into the basin–and its potential connection to the Frasnian-Fammenian extinction event—remains a question for further research.

## NAVIGATING CHANGE: DESCRIBING 50 YEARS OF ADAPTATIONS IN THE UMMP INVERTEBRATE DIVISION

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The University of Michigan Museum of Paleontology (UMMP) Invertebrate Division houses approximately 3 million specimens. This large collection has physically moved several times over the past two decades and has undergone significant changes regarding the space, material, personnel, and computerization over the past 50 years since the CONARIP report was published. Of the 3 million specimens, ~69,000 are in the database, ~18,000 are type and figured specimens, with ~14,000 primary types and ~2,200 holotypes. Many UMMP specimens come from localities no longer accessible due to development, abandonment and/or flooding of quarries, restriction by private landowners, and more strict collection laws on public and private lands. Specimen and related data were migrated into Specify circa 2016 and the data are continually being curated within the database. A critical change in management style occurred with the move to a newly renovated collection facility, where all the natural history research museums are housed. This has increased collaboration between and across museum collection professionals. This presentation will provide current updates in basic statistics drawn from data in the CONARIP report and compared to today. Additionally, I will contribute more anecdotal updates regarding absorbing smaller collections, evolving policy and procedure, and increasing access to the UMMP Invertebrate Division.

## NOT JUST THE GREEN BACKGROUND: THE PAST, PRESENT, AND FUTURE OF PALEOBOTANY OF EAST AFRICAN FOSSIL SITES

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Being non-motile photoautotrophs means that plants are intrinsically tied to their environment, allowing paleobotanists to use the patterns of relationships between modern plants and their environments to reconstruct the ancient world. When trying to understand drivers of evolution, context is everything. Plants are the context. During the last century, the study of fossil plants from East African localities has shifted from incidental observations to systematic paleobotanical collections. As such, our understanding of the paleoclimate and paleoenvironment of East Africa from the Oligocene onward has shifted from a vision of a "pan-African" lowland forest giving way to expanding grasslands, to a mosaic of open- and closed-canopy environments shifting with changes in paleoprecipitation. In addition to estimating paleotemperature and paleoprecipitation, fossil leaves allow paleobotanists to reconstruct more aspects of the ancient environment, from $pCO_2$ to canopy cover to leaf lifespan, among others. Historically, these proxy methods have been based on "global" models. However, the global calibration datasets have consistently excluded African floras, raising the question of how "global" these proxies truly are. Preliminary results have shown that the addition of even a few African floras into calibration datasets leads to improvements in accuracy when estimating temperature and precipitation. The development of Africa-specific models is a logical next step. By understanding the history of paleobotanical inquiry in East Africa, we can explore new paths going forward to more fully understand the world in which our ancestors evolved.

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## MORPHOLOGICAL COVARIATION BETWEEN THE INNER EAR, BRAIN, AND BRAINCASE OF THE LEOPARD GECKO (*EUBLEPHARIS* )

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The neuroanatomy of living tetrapods is widely varied, with mammals, birds, non-avian reptiles, and amphibians each exhibiting highly unique, and independently specialized, sensory capabilities. A dramatic example is that of the semicircular canals (SCC) of the inner ear, which display a remarkable degree of variability in nearly every aspect of their morphology, including the relative heights and lengths of the individual canals, the degree of circularity, and the size and prominence of the primary sensory structures. Because the SCC provide critical information for balance and navigation, their morphology has historically been thought to be strongly linked to the widely varied locomotor behaviours exhibited by tetrapods. Many attempts have been made to identify functionally significant patterns in the variation seen in canal morphology but detected relationships are difficult to reproduce. The potential influence of phylogenetic history on neuroanatomy is often acknowledged but little attention

has been given to the role of covariation between the inner ear and its surrounding structures, including the brain and braincase. Using contrast enhanced computed tomography and geometric morphometrics, we evaluate the degree of morphological covariation between the inner ear, brain, braincase, and overall skull shape in a sample of 29 leopard geckos (*Eublepharis*), providing novel information regarding the influences on SCC morphology and on our ability to draw functional inferences from the canal systems of extinct animals. The brain and braincase are hypothesized to be the most strongly influential on inner ear morphology, with skull shape showing a reduced effect due to potential independence of different skull regions. Preliminary results indicate a potential association between SCC shape and braincase height, but no association with centroid size, endocranial width, or the length or width of the braincase, suggesting that the covariation between braincase and canal morphology is not solely attributable to allometric effects. If no other significant patterns of covariation are found, this may suggest that inner ear morphology is influenced more by functional demands or by the phylogenetic history of the organism in question; in contrast, the presence of significant covariation between SCC shape and overall braincase and brain morphology, beyond simple linear dimensions, will indicate that discussions and interpretations of inner ear morphology must occur within the context of their surroundings (i.e., in reference to the morphologies of the brain and braincase), to avoid erroneous claims of functional significance.

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## POST-CRANIAL REMAINS FROM A *SUBHYRACODON* BONEBED FROM THE BRULE FORMATION OF NIOBRARA COUNTY, WYOMING, U.S.A.

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*Subhyracodon* is an extinct genus of hornless rhinoceroses in the family Rhinocerotidae. They once thrived in North America, including Wyoming, where they are preserved in the Brule Formation. Roughly 33 to 30 million years old, the Brule Formation comprises 300 meters of terrestrial sedimentary rocks, suggesting the presence of streams overflowing the banks and depositing mud, silt, and sand. Fossils from a *Subhyracodon* bonebed in the Brule Formation of Niobrara County, Wyoming, are in the collections of the Raymond M. Alf Museum of Paleontology in Claremont, California, U.S.A.; the goal of this study is to reconstruct the taphonomy of this deposit based on 378 post-cranial specimens. To do so, we calculated commonly used taphonomic abundance metrics: Number of Identified Specimens (NISP), Minimum Number of Elements (MNE), and Minimum Number of Individuals (MNI). The most abundant long bones were the humerus (NISP = 27, MNE = 20), femur (NISP = 25, MNE = 17), and tibia (NISP = 18, MNE = 18). The left humerus produces a minimum number of 11 individuals. Sorting specimens into juveniles and adults, with juvenile status determined using unfused epiphyses, we find at least four juveniles based on the femur and tibia and at least nine adults based on the humerus. Though sample sizes are low, this adult-juvenile ratio differs from ratios in modern rhinos, where adult males are typically solitary and each gestation normally yields only one calf, generating a ratio of 1:1 rather than the 2.25:1 in our bonebed. Given our adult-juvenile ratio, and assuming that specimens were not simply lost, we infer two possibilities: either male and female adults cohabitating with juveniles, or predation or scavenging of juveniles. The latter scenario appears more likely because forelimb elements—which are more easily disarticulated from the axial skeleton—number half as many as hindlimb elements, although sample sizes are too small to be conclusive. While reconstructing this bonebed is complicated due to the lack of stratigraphic and other metadata, other sites in the Brule Formation offer insight into the rich ecosystem that underlies the bonebed. For instance, the Big Pig Dig in the Badlands of South Dakota abundantly preserves *Subhyracodon* with other herbivores like the entelodont *Archaeotherium*, the deer-like *Leptomeryx*, and the early horse *Mesohippus*; predators include the amphicyonid *Daphoenus* and the nimravids *Dinictis* and *Nimravus*, all of which could have preyed on *Subhyracodon* juveniles. Our next steps include measuring post-cranial elements to estimate body size and investigate sexual dimorphism; as well, the bonebed's cranial remains have yet to be studied. While rhinos have long disappeared from North America and today are endangered globally, extinct rhinos like *Subhyracodon* illuminate the ecological importance of what were once plentiful animals that undoubtedly shaped the landscape.

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## ASSESSING GEOCHEMISTRY OF CARBONIFEROUS COAL BALLS ALONG THE EQUATOR

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Coal balls are the diagenetically altered remains of plants living in Carboniferous (~300 Ma) swamps. Sections of the peat swamp are permineralized with calcium carbonate and can preserve cellular level detail of plant material. These peat swamps were localized to areas along the equator including North America, Europe, and China. How these coal balls formed and why they are restricted to the Late Carboniferous and Early Permian is still poorly understood. Previous work on coal balls have analyzed their carbon, oxygen, and strontium isotopes in hopes to understand this formation process. No one has yet compared coal ball geochemistry in all areas where coal balls have been found. This study compares the chemistry of coal ball samples from different North American and European localities. Using carbon, oxygen, strontium and trace element analysis, we compare the different conditions under which these coal balls formed.

## PARALLEL EVOLUTION AND POSSIBLE FUNCTIONS OF THE HARPIFORM BRIM IN TRILOBITES

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In the fossil record, paleontologists will sometimes encounter distinct taxa with remarkably similar morphologies. We naturally may wish to draw a connection between two such taxa, but to understand the true nature and significance of such a connection, we need to ask ourselves *why* these two taxa share a similar morphology. Morphology is controlled by a number of interacting factors, including phylogenetic tradition, bioecological adaptation, and morphogenetic fabrication. These factors can in turn produce various evolutionary patterns leading to morphological similarity, such as stasis, convergence, and parallelism. Using two groups of brimmed trilobites—Harpetida and Trinucleioidea—we demonstrate how these patterns can be discerned in the fossil record through phylogenetic methods. In particular, we show that harpiform brims arose in Harpetida and Trinucleioidea through a process of parallel evolution. To understand why these distantly related trilobites followed parallel evolutionary paths, we seek to constrain the possible ecological functions of the harpiform brim. We begin by testing the idea that the brim was a kind of 'snowshoe' that prevented the trilobites from sinking into soft sediments. This is one of the oldest hypotheses regarding the function of the harpiform brim, but our calculations indicate that it is implausible. Finally, we debut a new multidimensional morphospace that captures variation in the size and shape of the harpiform brim. We have populated this morphospace with 3D models developed from images of well-preserved harpiform fossils and modified to show regular variation only in our previously defined brim shape variables. These models will allow us to test additional hypotheses about the function of the harpiform brim—beginning with the idea that it may have acted as a sediment plough—by relating brim shape to performance and then plotting the morphologies of real harpiform trilobites within the resulting performance space.

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## TAPHONOMIC CONTROLS ON THE SIWALIK VERTEBRATE FOSSIL RECORD

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The Siwalik sequence offers an unprecedented opportunity to document the depositional context and taphonomy of vertebrate fossils over millions of years in the sub-Himalayan foreland basin. Locality-based studies through four formations (Kamilial, Chinji, Nagri, Dhok Pathan) provide the foundation for assessing how physical and biological processes affected the fossil samples and what we can say about the original biota. Most of the Siwalik vertebrate record consists of fragmentary remains collected from outcrop surfaces at well-defined localities. Excavations and systematic biostratigraphic surveys provide information on patterns of preservation not reliably recorded by traditional collecting methods. A limited number of unusual fossil concentrations (e.g., associated skeletal remains, burrows, and mass-death assemblages) contribute additional taphonomic data. Parallel datasets for macro- and micro-vertebrate records represent different collecting strategies and preservation processes, offering complementary taphonomic and faunal data for reconstructing Siwalik paleocommunities. Vertebrate preservation occurred in four fluvial environments—major channel, floodplain channel, crevasse splay and floodplain. Formation-scale changes in fossil preservation were controlled by shifting channel versus floodplain environments and increasing sediment accumulation rates over time. Presence, absence, and abundance of vertebrate taxa correlate with depositional environment as well as body size, affecting biostratigraphic ranges and other occurrence-based faunal data. Taphonomic and microstratigraphic analyses of the Potwar Siwalik record show: 1) fluvial environments in the four successive formations provide similar but locally variable samples of vertebrate faunas; 2) the finest level of spatio-temporal

resolution for localities is <10 km$^2$ and 100's–1000's of years, and combining records over ~100 kyr duration also samples faunas from areas of 100's of km$^2$; 3) species of intermediate size (50–250 kg, including equids after 10.8 Ma) had the highest probability of preservation in all depositional environments; 4) the diversity of large and mega-mammals likely approached their original Miocene biodiversity, based on combined samples from different environments. At the largest scale, tectonic forces driving foreland basin subsidence and the rise of the Himalayas preserved the Siwalik sediments. At intermediate scale, climate interacted with tectonics to create river systems and a vast, biologically productive alluvial plain. At the locality scale, ecological and depositional processes accumulated and preserved skeletal remains representing different ecological settings. Taphonomic controls on Siwalik fossil preservation were variable and non-random, but with careful documentation and analysis provide strong support for a high-fidelity record of Miocene paleocommunity structure and faunal change.

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## ADVENTURES IN TEACHING VERTEBRATE EVOLUTION WITH SOME THOUGHTS ON TRAINING THE NEXT GENERATION OF VERTEBRATE PALEONTOLOGISTS

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I met Lance Grande when we were graduate students more than 40 years ago. Both of us studied fossil and living fishes and drew strength and inspiration from the community of phylogenetic systematists then working on grand problems in fish evolution. Our first collaborative project on fossil and living paddlefishes confirmed something that guided all of our subsequent work: to understand fossils, we needed more detailed and specific knowledge about extant taxa than we could find in the literature so we always started out by studying the anatomy of extant taxa. We flagged wholly extinct clades with the dagger symbol (†) to remind everyone that we will always know less about an extinct clade than an extant one. Among the many happy memories from our work together are those related to the third edition of Functional Anatomy of the Vertebrates (FAOV3), published in 2001. We passed the chapters and art back and forth to improve them, usually by overnight mail in those days, and Lance prepared one of the best glossaries ever published for vertebrate biologists. FAOV3 treats each of the ten organ system of vertebrates as a chapter, a common approach in textbooks for comparative anatomy and vertebrate evolution throughout the 20th century. But there are some other approaches to organizing such books, notably the regional anatomical approach used by Goodrich in Studies on the Structure and Evolution of Vertebrates and the phylogenetic approach used in the 11 editions of Vertebrate Life. Having worked as an author, art designer, and illustrator on both FAOV3 and Vertebrate Life 11e, and having taught vertebrate anatomy and evolution in many different ways during the last 50 years, I will discuss some differences between the organ system and phylogenetic approaches and why these differences matter when we think about how to train the next generation of vertebrate paleontologists.

Funding source: Tontogany Creek Fund

## REEF-LECTING ON THE CAMBRIAN: TAXONOMIC REVISION AND LATERAL DISTRIBUTIONS OF SMALL SHELLY FAUNAS FROM REEF-ADJACENT FACIES OF THE UPPER HARKLESS FORMATION, NEVADA

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Cambrian archaeocyathid reef systems represent the earliest metazoan-dominated topographically complex bioconstructions in the rock record and provide valuable insights into community composition with respect to the major framework builders and their small shelly fossil (SSF) inhabitants. This study focuses on lower Cambrian (Series 2, Stage 4) SSF assemblages from the Harkless Formation in southern Esmeralda County, Nevada, as a comprehensive systematic and quantitative analysis of these communities is currently lacking. This study investigates changes in SSF richness and diversity in relation to proximity to biohermal facies based on lithology and composition of SSF assemblages. Combining petrographic and quantitative analyses with a systematic review of the SSFs reveals a low diversity, but abundant assemblage. Trends in diversity and richness of species show no consistent patterns in distance from the reef across the measured 2 sections. However, lithology serves as a major control in determining SSF biofacies, with select fauna exhibiting evidence of additional taphonomic controls. More research is needed to understand spatial relationships and biodiversity across these ancient carbonate archaeocyathid reefs and platforms to determine key factors in maintaining biodiversity hotspots.

## THE EMERGING PALEO-OXYGEN PROXY MN/CA IN BENTHIC FORAMINIFERA: AN EXPLANATION FOR NON-CONFORMANCE BY KLEPTOPLASTIDIC FORAMINIFERS IN DYSOXIC TO EUXINIC ENVIRONMENTS

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A universally accepted, well-established proxy for past oxygen concentration in aqueous settings (marine, freshwater) is not presently available. One emerging marine paleo-$O_2$ proxy is Mn/Ca in calcium carbonate of benthic foraminiferal tests (shells). This proxy, based on redox-sensitive trace element entrainment into biogenic calcium carbonate, has gained considerable acceptance but calibrations across oxygen regimes and assessments using varied taxa continue. While testing this proxy in different benthic foraminiferal species, we noted that some species exhibited expected Mn/Ca values in low-oxygen waters (e.g., *Bulimina marginata* in Gullmar Fjord) while the Mn/Ca of kleptoplastidic foraminiferal species did not. Kleptoplasty, known in certain foraminifera, ciliates, sea slugs, and a flatworm, occurs when a host sequesters, or "steals", chloroplasts made by a different type of organism. In all known cases of benthic foraminiferal kleptoplasty, the chloroplast source is diatoms. Kleptoplasty should not be confused with symbiosis involving entire algal cells. At least one kleptoplastidic foraminifer is known to have multiple anaerobic pathways to support their dominance in anoxic to euxinic sediments. Cases of benthic foraminiferal kleptoplasty continue to be discovered, especially when cytoplasm stains such as Rose Bengal are not used. We present here a possible biological influence, based on gene expression, for the unanticipated Mn/Ca records of kleptoplastidic benthic foraminifera. Metatranscriptome analysis reveals that kleptoplastidic *Nonionella stella* populations inhabiting the euxinic laminated seafloor sediments of the Santa Barbara Basin (California, U.S.A.) express genes that can oxidize Mn. Intriguingly, a non-kleptoplastidic species, *Bolivina argentea*, lacks such genetic potential. The kleptoplastidic *N. stella* may oxidize Mn, therefore decreasing the concentration of Mn(II) in their microhabitat, causing lower than expected availability of Mn in their milieu. This would result in a lower than predicted Mn/Ca value in their carbonate. Other foraminifers that do not have these genes are anticipated to perform as expected for this proxy. In sum, it is plausible that co-occurring foraminiferal taxa leave different proxy values in the record due to differential foraminifer-induced trace-metal microhabitat regimes. Many kleptoplastidic species have test ornamentation or features such as apertural teeth, jagged toothplate, and/or umbilical pustules that hypothetically assist with chloroplast acquisition. Thus, if a benthic foraminifer species has much lower than expected Mn/Ca values, an explanation could be their ability to oxidize Mn, so their tests should be examined for characters associated with kleptoplasty. Studies dedicated to Mn incorporation into kleptoplastidic foraminifers, in addition to their gene expression and test morphology/ ornamentation, are warranted.

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## THE VIRTUAL BRAIN ENDOCAST OF *INCAMYS BOLIVIANUS*: INSIGHT FROM THE NEUROSENSORY SYSTEM INTO UNDERSTANDING THE ADAPTIVE RADIATION OF SOUTH AMERICAN RODENTS

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Caviomorph rodents are endemic to South America and are one of the most adaptively diverse radiations, including four superfamilies, 11 families and close to 250 extant species. Their ancestors immigrated from Africa, probably during the Eocene via one or more crossings of the South Atlantic. The fossil record of caviomorphs is relatively rich and fossils have been recovered from Argentina, Peru, Chile, Bolivia, and Brazil. Although their origin and diversification have been intensively studied, questions still remain about where, when and how the group radiated. One area of continuing debate relates to the evolution of their neurosensory system. Modern caviomorphs exhibit a rich diversity of brain shape and size. In the last couple of years, ~60 virtual brain endocasts for extant caviomorph rodents, and 3 for fossils, have been published of which the oldest is dated to the early Miocene. Here, we used X-ray computed tomography scanning to reconstruct the oldest virtual brain endocast for a caviomorph rodent, belonging to the late Oligocene stem chinchillid *Incamys bolivianus* (Salla-Luribay Basin, Bolivia, ca. 27.5–26.2 Ma). We also provide new hypotheses regarding the ancestral brain anatomy and size of Chinchillidae and Caviomorpha more broadly. The ancestor of caviomorph rodents probably had a lissencephalic brain or at most had a few sulci, and an exposed midbrain. By the Late Oligocene, caviomorphs exhibit an expansion of the temporal lobe of the cerebrum, and had independently reached a relative neocortical size similar to that of contemporaneous squirrels from North America. Relative to the inferred ancestral condition, *Incamys* exhibits an expanded neocortex, but nonetheless has exposed caudal colliculi (part of the midbrain which have roles in audition and vocalization processing). We interpret this unique morphology as evidence for enhanced auditory acuity, vocalization processing and potentially group-living in *Incamys*, presaging behaviours observed in modern members of the Chinchillidae family, which also exhibit enlarged caudal colliculi. *Incamys bolivianus* was probably less agile than modern chinchillids based on its smaller petrosal lobules, but these structures were not as reduced as in slow arboreal porcupines. Current neurosensory data are compatible with a ground-dwelling lifestyle and a slower locomotion than modern chinchillids.

Considering the broader context of relative brain size of South American mammals for which endocasts are known (i.e., Caviomorpha, Xenarthra, Notoungulata, Primates and Liptoterna), there is no evidence of systematic brain size increase from the Oligocene to the Pleistocene; however, our sample is limited and unevenly distributed taxonomically and temporally. Ultimately, *Incamys* provides crucial insight into the evolution of the caviomorph brain and demonstrates that we still have much to explore about how these small mammals achieved one the most impressive adaptive radiations of the Cenozoic.

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## 15,000 PASSERINE SKELETONS ILLUMINATE TIME-HETEROGENEOUS PATTERNS OF PHENOTYPIC INTEGRATION

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Computer vision is poised to revolutionize our ability to generate and analyze phenotypic data. We developed and applied a new AI pipeline leveraging U-Net and Mask R-CNN approaches to measure thousands of voucher skeleton specimens. Our approach is trained to identify and generate linear measurements of the legs, torso, wings, hand, and skull with low error (RMSE ~0.89 mm). We further develop approaches using multivariate phylogenetic models to impute missing data with similarly low error rates, leading to datasets that are 100% complete at the specimen level across the entire UMMZ collection. These new data, which currently comprise Passerine songbirds, present exciting opportunities to investigate the evolution of allometric scaling and integration across this hyper-diverse avian order (comprising ~6,500 species). Here, we present an overview of this dataset and showcase the potential of leveraging specimen metadata (e.g. sex, mass) to analyze nuanced macroevolutionary patterns. We investigate how broad-scale patterns of skeletal integration co-vary with important biotic and abiotic factors, including life history and climate parameters, and find numerous discrete shifts across the songbird phylogeny. We show that the origins of several avian families are associated with shifts in patterns of skeletal integration and how these patterns may differ across males and females. The 'skelevision' system is flexible and can accommodate the training of new features and provides the ability to extract information about shape and 3D geometry. We expect to extend our 'imageomics' approaches to enable high-dimensional phenotyping of entire museum collections within a few years.

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## NEUTRON TOMOGRAPHY—SUBATOMIC PARTICLES MEET FOSSILS WITH GREAT OUTCOMES

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X-ray radiography and micro-tomography (CT) are critical tools employed in the characterisation of fossils through detailed surface, and internal renderings for taxonomic, ontogenetic and bone histology. Neutron tomography is a complementary method to traditional CT that uses neutrons, subatomic particles generated by a nuclear reactor or spallation neutron source, as the penetrating radiation. Neutrons provide an alternative contrast relative to X-rays due to the differing material interactions. While X-rays interact with and are attenuated by the electrons surrounding each atom, neutrons interact with and are scattered by atomic nuclei. The result is a set of material attenuations that are not correlated with those of X-rays. Museums and affiliated researchers have historically been hesitant to employ or authorise the use of neutron tomography (NT) in paleontology. This is due primarily to concerns regarding the potential for long-term induced radioactivity, the unclear benefit of neutrons tomography over X-ray CT, and limited accessibility and logistics involved with accessing international neutron facilities. Over the last 10 years, the research community has increasingly engaged with our neutron imaging facility DINGO at the Australian Nuclear Science and Technology Organisation (ANSTO), first through exploratory studies on low-value, low-significance test specimens, before rapidly transitioning to challenging (X-ray opaque), holotypes and other high-impact specimens. The primary reason for this change is the realisation that neutrons can penetrate through iron pyrite and have high-sensitivity to variation in hydrogen atom concentration. This talk draws from the extraordinary outcomes of the diverse merit-based user community to summarise the benefits and challenges of employing neutrons over X-rays, and traces the development of a world-leading program of paleontology

research using the DINGO. Highlights include the first evidence that crocodiles ate dinosaurs, the world's oldest-known fossil heart, neurosensory diversity in early reptiles, and discovery of new dinosaur and pterosaur species. These and other examples will further demonstrate the challenges, lessons learned and future direction for neutron imaging in paleontology.

Funding source: This work has been supported by numerous merit-access grants to the Australian Centre for Neutron Scattering and the Australian Synchrotron.

## PUSHING THE LIMITS OF ARTHROPOD 3D BIOMECHANICS

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Analyzing predation in the fossil record using modern paleobiological tools has advanced to a position where an array of methodologies can be used to address complex questions. One area that has seen rapid development has been the use of 3D engineering methods—such as finite element analysis (FEA)—to model how anatomical structures implicated in prey capture functioned. This allows biomechanical limits to be examined. Commonly FEA has been the realm of vertebrate palaeontologists. However, in the last half-decade, there has been a noticeable shift towards using FEA to explore possible arthropod predators. This emerging framework reflects the on-going examination of exceptionally preserved fossils and the investigation of potential modern analogues to contextualize extinct animals. The state-of-the-art for 3D arthropod biomechanics will be considered, focusing on proposed extinct arthropod predators. Building on this, innovations in modelling predation by extinct and modern decapod crustaceans will be presented, highlighting the importance of using 3D preserved fossils to more thoroughly understand extinct predators.

## EXAMINING IMPACTS OF THE MID-PLIOCENE WARM PERIOD ON MOLLUSCAN DIVERSITY, RICHNESS, AND ABUNDANCE WITHIN THE YORKTOWN FORMATION (SOUTHEASTERN VIRGINIA)

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Valuable insights into the ecological and evolutionary responses of biodiversity to specific environmental changes can be gained by examining the marine fossil record. During the Mid-Pliocene Warm Period (MPWP), a period characterized by significant climate fluctuations, global temperatures rose by approximately 3°C over ~300,000 years. This study aims to investigate the potential impact of prolonged global warming and ocean acidification on marine molluscan diversity, utilizing the MPWP as a model for future scenarios. Focusing on the Sunken Meadow, Rushmere, and Moore House Members of the Yorktown Formation in southeastern Virginia, we examined changes in molluscan diversity and richness. Bulk samples were collected from field sites within this region and from museum collections, which yielded specimens from all three members. Approximately 2,500 molluscan specimens were meticulously processed through sieving, sorting, identification, and counting. Species were identified and revised taxonomically using available resources such as monographs, the Neogene Atlas of Ancient Life, and the World Register of Marine Species. To acquire the minimum number of individuals, bivalves were counted based on identifiable hinges with the total number divided by two, and gastropods were counted based on apex or aperture with the higher count recorded. Various statistical analyses, including rarefaction analyses and diversity indices, including the Shannon-Weiner index, were employed to assess taxonomic richness, diversity, and abundance. Our analysis revealed a statistically significant increase in diversity and richness at the genus level across the MPWP. Analysis also revealed diversity increased at the species level. These initial findings suggest a potential introduction of new species to molluscan communities and changes in the abundance of rare and common species during this period. Understanding how modern mollusks respond to future global warming scenarios can be enhanced by observing how molluscan diversity fluctuates during warming intervals throughout the fossil record.

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## DISCOVERIES IN THE SILURIAN OF INDIANA: FOUR DECADES OF COLLABORATION BETWEEN AVOCATIONAL AND PROFESSIONAL PALEONTOLOGISTS

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In 1979, amateur collectors from the Dry Dredgers fossil club discovered a huge assemblage of echinoderms in Silurian Massie Shale (formerly Osgood Shale) in the New Point Stone commercial limestone quarry near Napoleon, Indiana. The discovery was shared with Harrell Strimple (University of Iowa). We led him on field trips to the quarry, and donated hundreds of echinoderm samples for study and publication.

Thus began over four decades of collaboration between avocational and professional paleontologists at this locality. In our frequent collecting trips to the quarry every year, we have not only saved thousands of echinoderms from destruction by the quarrying operation, but also made other discoveries and observations. The new specimens and findings have led to several additional studies done in collaboration with Professors Carlton Brett (University of Cincinnati), James Thomka (SUNY Plattsburg), and Sarah Sheffield (University of South Florida). Examples of these new studies follow: discovery of a large grouping of cystoid holdfasts on hard ground; discovery and quantitative analysis of parasitic borings on echinoderm tests; collection of echinoderm columnals for estimation of echinoderm population numbers; donation of rare juvenile cystoid specimens for study of changes with growth; depositional studies based on collected cystoid specimens; identification of anemone trace (*Conostichus*) fossils from the Massie Shale; evaluation of encrustation of echinoderms and cephalopods; study of rare *Holocystites* anal pyramids and oral cover plates. Over the years, many oral presentations, posters, graduate theses, and peer-reviewed publications have arisen from the collaborations. And in a time when access to commercial quarries is problematic due to liability concerns, the close relationship that the avocational collectors have nurtured with the quarry personnel has allowed collection and study to proceed unhindered for over forty years. That has led to other professional collaborations: Brassfield Limestone conodont studies with Dr. Mark Kleffner (Ohio State University at Lima); brachiopod studies by Texas A&M University (Dr. Ethan Grossman); field trip stops for professional paleontologists; field trips by local university geology classes. We are willing to share our collected specimens and our knowledge of the quarry and the Massie Shale for further serious studies.

## ENCRINURID TRILOBITES FROM THE UPPER ORDOVICIAN (KATIAN) OF NORTHEASTERN IOWA

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Named in 1870 by Charles White after the Little Maquoketa River in Dubuque County Iowa, The Upper Ordovician (upper Katian) Maquoketa Formation of northeastern Iowa contains a rich trilobite fauna, including many species that have been widely cited in the modern literature. Predominantly composed of dolomitic shale and argillaceous dolomite, the Maquoketa formation was initially treated as the Maquoketa Group with 3 divisions by Savage (1901). Further work by Ladd (1929) treated the group as a formation, and the divisions as the Elgin Limestone, Clermont Shale, Fort Atkinson Limestone, and Brainard Shale members. Initial trilobite sampling in 1910 and 1912 by Arthur Slocom revealed 12 previously undescribed species, which were described in his 1913 monograph. Most have not been revised in the modern era and for many the only photographs available are those published in the original monograph. One family, Encrinuridae Angelin, 1854 (Order Phacopida; Suborder Cheirurina), is represented among these. Encrinuridae includes the subfamilies Cybelinae, Encrinurinae, Coronocephalinae, Dindymeninae, and Staurocephalinae. The two species described in Slocom's monograph are the cybeline *Cybeloides iowensis* Slocom, 1913 and the encrinurine *Encrinuroides pernodosus* (Slocom, 1913). *Cybeloides iowensis* is the type species of the diverse and widely distributed *Cybeloides*, which includes 15 formally named species from various areas of Laurentia, Avalonia, central Mongolia, and Siberia. *Encrinuroides pernodosus* has rarely been mentioned in the literature. For both species, Slocom's tiny illustrations are the only ones ever published. These species are revised based on new images of the type specimens housed in the Field Museum of Natural History, along with new, well documented, and previously unstudied collections made by vocational paleontologists Calvin Leverson and Arthur Gerk that were donated to the University of Iowa Paleontology Repository. These collections include multiple well preserved, fully articulated specimens. In addition to new material of *C. iowensis* and *E. pernodosus*, the Leverson and Gerk collections contain an undescribed encrinurine species, which will also be formally described. In combination, this work will transform taxa known only from small, 111-year-old photographs to fully documented species with images of multiple examples of nearly all exoskeletal elements. New knowledge of *C. iowensis* assists in the development of a hypothesis of relationship for the genus based on maximum parsimony. *Encrinuroides pernodosus* is currently assigned to a sprawling para- or polyphyletic taxon of convenience, presently containing 46 formally named species. Thorough documentation of its morphology and new parsimony analysis will help to revise the phylogenetic structure and relationships of subsets of these species, making progress toward disentangling what is at present an uninformative jumble.

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## THE BIGHORN BASIN PETM MICROVERTEBRATE PROJECT (PETM-MVP): NEW HIGH-RESOLUTION RECORDS OF VERTEBRATE RESPONSE TO CLIMATE CHANGE ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM

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The Paleocene-Eocene Thermal Maximum (PETM) was an interval of rapid carbon release (millennial scale) and global warming (~5 °C) ~56 million years ago that altered terrestrial ecology and permits testing of hypotheses related to modern biotic responses to future climate change. Despite intensive study, basic patterns such as the timing of species first and last appearances and temporal ranges are limited by stratigraphic resolution and sampling that is often biased towards recovery of larger taxa. Two decades of intensive fieldwork, including substantial screen washing for microvertebrates, in sections spanning the PETM in the Bighorn Basin, WY, has yielded >29,000 mammal fossils from 1,751 localities tied into a high-resolution stratigraphic framework. Many of the recovered fossils are microvertebrates (teeth and postcrania of small mammals <1,200 g, squamates, fish, birds, and amphibians), that shed light on a cryptic yet meaningful portion of the fauna often overlooked by traditional surface collecting methods. While the PETM is often characterized as a single interval, we recognize three distinct phases as recorded by paleosols, fossil plants, and isotopes: a sudden 'onset' with prominent negative carbon isotope excursion associated with warmer climate; a sustained 'body' of hot, seasonally dry climate lasting ~100 kyr; and a more gradual 'recovery' when climate shifted back to cooler, wetter conditions. At least 20 mammal taxa did not survive past the latest Paleocene and at least 11 additional taxa were extirpated during the PETM, including not only the well-known larger phenacodontids *Copecion brachypternus* and *Ectocion osbornianus*, but several smaller taxa such as the multituberculate *Neoliotomus*, several plesiadapiform primates (*Ignacius graybullianus*, *Phenacolemur pagei*, and *Tinimomys graybulliensis*), and the stem rodent *Alagomys*. In contrast, the multituberculate *Ectypodus* and plesiadapiform *Phenacolemur praecox* range through the PETM, with the former being among the most abundant animals recovered. Several taxa previously described from only a few, limited stratigraphic levels are documented in our sections from more than a dozen distinct levels throughout all phases of the PETM, including the plesiadapiform *Niptomomys*, the eulipotyphlan *Macrocranion junnei*, and the apheliscine *Haplomylus zalmouti*, previously thought to be constrained to the earliest onset and recovery. The fauna of the PETM recovery is particularly diverse, with many taxa otherwise restricted to the PETM such as the equid *Sifrhippus sandrae* and the primate *Teilhardina brandti* found alongside the reappearance of extirpated taxa such as *C. brachypternus* and *E. obornianus*. While the details of these occurrence data and associated shifts in abundances, taxonomic richness, and evenness are still being unraveled, the current evidence demonstrates that mammal communities were compositionally distinct across the changing environments before, during, and after the PETM.

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## *DICKINSONIA* AND SPRIGGINAMORPH AT NILPENA EDIACARA NATIONAL PARK, SOUTH AUSTRALIA

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Interspecific relationships, such as competition or parasitism, have been reported from the fossil record, but positive relationships, such as mutualism, commensalism, and facilitation are more difficult to constrain. At Nilpena Ediacara National Park (NENP), South Australia unique preservation has enabled the excavation of over 40 fossiliferous beds of the Ediacara Member of the Rawnsley Quartzite. These *in situ* cast/molds of Ediacara organisms allow resolution of ecological-scale processes and provide an unusually good opportunity to test possible interspecific interactions. Using bivariate spatial point pattern analysis, we demonstrate that sprigginamorphs-mm-scale fossils with a morphology consistent with, but distinct from *Spriggina* - are spatially attracted to *Dickinsonia*. Additionally, clusters of sprigginamorphs show preferential orientation toward a shared direction, commonly aligning with nearby *Dickinsonia*. One hypothesis that could explain this relationships is that sprigginamorphs somehow benefitted from the mat-grazing feeding ecology of *Dickinsonia*. This represents the earliest example of interspecific attraction in the fossil record, highlighting the complex nature of the earliest animal ecosystems in the Ediacaran.

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## AN OVERVIEW OF PALEOZOIC PALEOBOTANICAL RESOURCES DOCUMENTED IN NATIONAL PARK SERVICE AREAS

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An inventory of paleobotanical resources from throughout National Park Service administered lands is being coordinated through a partnership program known as the Paleontology in the Parks Fellowship, which is jointly sponsored by the National Park Service (NPS) and Paleontological Society (PS). Four mentors and four students from different institutions have been conducting literature reviews to document fossil plants at parks nationwide in collaboration with the NPS and PS. Fossil plants have been documented in at least 202 different NPS areas. The project team divided its study of fossil plants by geologic era. The Paleozoic Era includes 36 different parks containing paleobotanical resources. These fossils represent a range of paleobotanical remains that include algae, palynomorphs, root traces, and body fossils of land plants. The most significant NPS Paleozoic paleoflora are found in Grand Canyon National Park, Big South Fork National River and Recreation Area, New River Gorge National Park and Preserve, Upper Delaware Scenic & Recreational River, and Yukon-Charley Rivers National Preserve. The most productive Paleozoic periods for paleobotanical resources in NPS areas are the Devonian and the Permian. Forty-five Paleozoic paleobotanical species have been named from specimens collected in NPS units. The inventory has included an extensive literature review of existing published, gray literature, and non-published sources of information regarding fossil plants preserved within these parks. A comprehensive manuscript will be developed to report on the Paleozoic paleobotanical resources within NPS parks, which is intended to support both science and resource management involving NPS fossil plants. This report will build on Cenozoic and Mesozoic NPS paleobotanical resource inventories to establish a comprehensive record of plant life through geologic time preserved in the nation's public lands.

Funding source: This would not have been possible without the support of the National Park Service and the Paleontological Society.

## HOW DID THE CREATURES OF THE EDIACARA BIOTA LOOK LIKE?

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The Ediacara biota existed ~575 to 538 million years ago, just before the main radiation of animals during the Cambrian explosion, and might hold clues to the earliest evolution of animals on our planet. However, a crucial step in understanding the paleobiology of these organisms is to recognize the effects of taphonomy on the final morphology of the fossils. For a long time, it has been suggested that the Ediacara biota was preserved due to early cementation of sediment on just one side of the organisms, creating a "death mask" of the outside of the creatures. However, analysis of fossils in the Ediacaran deposits of the White Sea area, which uniquely were altered by neither weathering nor metamorphism, showed that such cementation never occurred. Instead, Ediacaran macroorganisms were preserved due to a prolonged preservation of organic matter in anoxic sediments; at the surfaces between sedimentary layers, the fluid behavior of unconsolidated sediments with lower rheological properties provided continuous support to rheologically stronger lithologies, which preserved the impressions of the Ediacara biota. These impressions, however, seem to be left by the most degradation-resistant tissues of the organisms, soft organic "skeletons", and may have little to do with how the organisms looked like. Studying uniquely preserved fossil specimens and the patterns of sediment flow during the degradation of soft tissues can help us figure out where the "skeletons" were located within the organisms and reconstruct some missing aspects of paleobiology of Ediacaran creatures.

Funding source: The study is funded by the Branco Weiss Fellowship.

## THE OSTEOLOGICAL NEUTRAL POSE OF THE NECK OF AN APATOSAURINE SAUROPOD FROM MILL CANYON (UPPER JURASSIC, MORRISON FORMATION) NEAR MOAB, UTAH.

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Sauropods, the largest of all dinosaurs, are renowned for their extraordinarily long necks. There are two major neck pose hypotheses: the S-shaped (bird-like) and the straight horizontal (cow-like) poses. Both hypotheses were developed primarily using virtual rigs of cervical vertebrae, but these models are hampered by taphonomic distortion and possible difficulties with accurately articulating vertebrae using virtual models. A new sauropod specimen with an exceptionally preserved, almost complete, and minimally distorted, set of cervical vertebrae (C2–C15) provides an unrivaled opportunity to determine the ONP using cervical vertebrae 2–13 (14 & 15 are not yet prepared). The specimen, BYU 18531, is a large apatosaurine with a 2-m-wide pelvis and 1.7-m-long femur. The specimen was collected from the Brushy Basin Member of the Morrison Formation at Mill Canyon, near Moab, Utah. The cervical vertebrae of this specimen were rendered in 3D using photogrammetry (C2–C13) while (C14–C15) are still being rendered from CT scans. These models were used

to determine the osteological neutral pose (ONP), where the zygapophyses and centra of the neck are maximally overlapped. The resultant model indicates that most of the neck curved strongly ventrally, forming half a parabola while the neck near the skull (C2–C4) arches gently dorsally. This pose places the head close to ground level, depending on the slope of the dorsal vertebral series. This model argues against the previously proposed models (S-shaped and straight horizontal), both of which put the head at near-shoulder height, far from the body. When cervical vertebrae 14 and 15 are prepared, the ONP will be further developed, along with the range of motion of the neck in both sagittal and lateral positions. Our virtual neck model was tested for accuracy by comparing it to a physical model consisting of scaled, 3D-printed vertebrae and articulating them in the ONP. In the sagittal plane, virtual and physical models are nearly identical, indicating virtual methods are essentially as accurate as physical models and far easier to create. The best interpretation for the osteological neutral position from this individual is a ventrally curved neck. Other positions, tried virtually and physically, led to inconsistencies in intervertebral space, with some vertebral centra becoming dislocated. The osteological range of motion is being tested and this research will help with determining this animal's feeding envelope. Studies of the neck posture and feeding envelope of multiple sauropod taxa from a single biota will provide insights into how so many large-bodied animals could live in the same environment.

## ELEVEN SPECIMENS FROM TEN LOCALES IN EIGHT COLLECTIONS ACROSS THREE STATES, THE DIVERSITY OF KNOWN *HAPLOCANTHOSAURUS* SPECIMENS IN THE MORRISON FORMATION.

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*Haplocanthosaurus* has often been described as an enigmatic sauropod due to its unstable phylogenetic position and small number of specimens. However, this genus is not as rare as once thought, with specimens known from all three major members of the Morrison Formation (Tidwell, Salt Wash, and Brushy Basin). Specimens are known from Wyoming, Colorado, and Utah, making it a mostly central-northwestern Morrison Formation genus, but within that area, it is both spatially and temporarily widespread. We quantify the number of *Haplocanthosaurus* specimens known from the literature and in collections. Our investigation identified eleven *Haplocanthosaurus* across at least three species in eight public collections. We consider the following specimens as belonging to *Haplocanthosaurus*: Holotype CM 572, and CM 879, both from the Marsh-Felch Quarry and housed at the Carnegie Museum; CMNH 10380 from the Cleveland Delfs Quarry housed at the Cleveland Museum of Natural History; USNM 4275 from the Canon City Quarry 1 housed at the National Museum of Natural History; FHPR 1106 from Williams Slow Eagle Quarry housed at the Utah Field House of Natural History State Park Museum; MWC 8028 from the Gordon-Bramson Brothers Quarry housed at the Museum of Western Colorado's Dinosaur Journey; CMNH 10725 from the Oil Creek Quarry housed at the Cleveland Museum of Natural History; BYU 9194, 11506, 12865,17530-1,17689 from the Dry Mesa Dinosaur Quarry housed at the BYU Museum of Paleontology; SMM P 90.37.10 from the Poison Creek Quarry housed at the Science Museum of Minnesota; CM 36034 from the Red Fork Powder River Quarry B housed at the Carnegie Museum; and an uncatalogued BLM field specimen from near the Brachiosaur Gulch Quarry in Utah. Herein we assign a tibia (CM 2043) to the holotype of CM 572. CM 2043 was found in the Marsh-Felch Quarry with the holotype specimen. Also, this tibia is short and robust, possessing a greatly expanded distal end which is characteristic of *Haplocanthosaurus*. Of historical note, USNM 4275, assigned to *Morosaurus* by Marsh in 1896, was found before the CM 572 specimen. The existence of eleven specimens across three states indicates *Haplocanthosaurus* was widely dispersed and more common than traditionally thought. The only more common Morrison Formation sauropods are *Diplodocus*, *Apatosaurus*, and *Camarasaurus*. The majority of the *Haplocanthosaurus* material consists of caudal and dorsal vertebrae, plus tibiae, which allow cross-species comparisons, indicating at least three species are present. MWC 8028 may become the holotype of a new species of *Haplocanthosaurus* due to unique characters including deeply biconcave caudal centra and tall, reclined sacral neural spines. Among the known specimens of *Haplocanthosaurus*, differences in secondary laminar construction and centra subtleties exceed individual variation, but not genus-level differentiation.

## PALEO PODCASTS: USING PARTICIPATORY NARRATIVE INQUIRY TO EVALUATE STUDENT LEARNING IN A 4-H PALEONTOLOGY SUMMER CAMP

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Podcasting provides great potential not only for science communication but also as an educational tool. Paleo Podcasts focused on the design, implementation, and assessment of a paleontology lesson for a Florida 4-H summer camp with the goal of increasing content knowledge, science literacy, and

STEM career interest. University science communicators in the University of Florida's Department of Agricultural Education and Communication and a paleontologist from the Florida Museum of Natural History designed and led the 4-H summer camp of youth (ages 10–15) through stations of dinosaur, vertebrate, and invertebrate fossils and a final station of the applications of paleontology to conservation to showcase the diversity of paleontology. To assess student learning and attitudes toward paleontology, we used arts-based research methods in the form of narrative inquiry and youth co-creation of the Paleo Podcast. In pairs, campers were guided through how to create podcasts and interview their partner about paleontology concepts they learned and narrate what they think a day in the life of a paleontologist is like. The conversational framework allowed students to formulate and articulate their own thoughts, providing a more participatory and active approach to learning. The arts-based research method of narrative inquiry will be used to code the data for emergent themes to gain rich insight into the youths' learning of paleontology concepts and perceptions of careers. Through the narrative coding process, portions of their participant created audio will be created around emergent themes to produce the Paleo Podcast as the final result. Such themes could include fossils, science communication, and youths' relationship with science. Through our description of the camp and its outcomes, we will illustrate the potential of how podcasts can be used in non-formal learning as an educational tool to promote active learning and as a novel arts-based research method that studies learners' experiences through personal reflection. We will also demonstrate the potential of youth science communication outreach through podcasting. This research was in partnership with The Streaming Science Project and funded by the Paleontological Society.

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## COLLABORATIVE PARTNERSHIPS ENHANCE SCIENTIFIC RESEARCH AND RESOURCE MANAGEMENT IN A NEW NATIONAL PARK SERVICE UNIT: TULE SPRINGS FOSSIL BEDS NATIONAL MONUMENT (TUSK)

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Tule Springs Fossil Beds National Monument was established in December 2014. As a new fossil park with a small staff and fixed funding, the monument is limited in the amount of new scientific research able to be conducted. A solution to this has been found through the leveraging of deep-rooted and collaborative partnerships with other federal, private, and public organizations, such as the U.S. Geological Survey (USGS), Cogstone Resource Management, Inc, and the Protectors of Tule Springs. The national monument has been able to facilitate an extraordinary amount of new research and studies utilizing their partners' common interests and expertise to assist the park's paleontological resource management needs. The work of USGS has been essential to mapping the sedimentology and exposures of the fossiliferous Late Pleistocene Las Vegas Formation and its numerous subunits that are widely exposed across the monument. Cogstone's on-going research of the Late Pleistocene Rancholabrean fossils has enlightened the National Park Service and the scientific community of the unique and diverse Tule Springs Local Fauna. The Protectors of Tule Springs assist in providing site stewardship management to paleontological sites in situ, as well as leading tours and programming to interpret the geology and paleontology of the monument. These collaborations have established a mutualistic partnership for this new National Park Service unit to support USGS and Cogstone endeavors in wetland paleohydrology of the Southwest and the Tule Springs fossil record. At the same time, the USGS has worked out the stratigraphy, environmental conditions, and numerical ages that Tule Springs Fossil Beds National Monument managers can use as a framework to place fossils into through the Late Pleistocene. The resulting work of these four organizations has provided a holistic story of large to small scale climatic fluctuations and megafaunal response over the last 100,000 years in the Mojave Desert and has allowed that story to be shared with the public.

## THE STATE OF QUATERNARY VERTEBRATE PALEONTOLOGY RESEARCH IN THE CARIBBEAN: AREAS OF RIGOR AND OPPORTUNITIES FOR GROWTH

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Paleontological research has flourished in the Caribbean for well over 150 years, providing deep insight into the biogeography, extinction and diversification dynamics, and ecological processes of a globally significant insular biodiversity hotspot. These data not only prove pivotal in contextualizing modern-day patterns of biodiversity, but they can also play a role in safeguarding Caribbean biotas from future global changes that disproportionately impact insular systems. As Caribbean paleontology continues to grow, it is important to take a step back and evaluate where our knowledge is deepest, as well as areas of opportunity for future growth and discovery. Through an extensive literature search that centers Quaternary vertebrate paleontology, we compile a database of over 250 publications with the goal of characterizing the state of Caribbean vertebrate paleontology research. We note a broad geographic distribution of paleontological sites across all three island groups, though the main islands of the Greater Antilles and select islands of the Bahamas and Lesser

Antilles dominate the literature. Additionally, there is great disparity in terms of taxonomic representation, with mammals being the most well-represented vertebrate group, whereas descriptions of herpetofauna, particularly amphibians, are much rarer. Many studies lack clarity about the excavation methods employed, making it difficult to determine if disparities in taxonomic diversity are due to methodological biases, taphonomic processes, or a combination of factors. We delve into the paleobiology of several sites distributed across the region to explore the availability of ancillary data such as abiotic climate proxies, radiocarbon dates, and non-vertebrate fossils that could be useful for interpreting past vertebrate diversity. We also examine patterns of authorship and specimen accession to evaluate who has opportunity and access to Caribbean vertebrate fossil specimens. Based on our review we identify areas of opportunity for future research and collaboration within the Caribbean paleontology community.

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## COPROLITES OF MONOTHALAMIC FORAMINIFERA AND GROMIIDS: STERCOMATA AS MICROFOSSILS IN MICROPALEONTOLOGY

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Monothalamic foraminifera (e.g., *Bathysiphon* spp.) and gromiids inhabit most marine oxygenated and hypoxic sediments. They are poorly represented in the fossil record, although *Bathysiphon* has a record back to 485 Ma. Certain monothalamids and all gromiids contain "stercomata," which are micrometer-scale, cytoplasmic aggregates of undigested waste (e.g., clay particles, diatom frustules, sponge spicules). The discovery of fossil stercomata—the unicellular equivalent of metazoan coprolites—in specimens of Ordovician *Bathysiphon*, prompted our taphonomic investigation of stercomata obtained from live and experimentally-decayed specimens of gromiids from McMurdo Station, Antarctica. Despite 20 yr incubation in bacterized seawater, stercomata retained all the structural features of those seen in live specimens. Stercomata resist disaggregation by sonication, overnight incubation in sodium hypochlorite or boiling in hydrogen peroxide, and ashing for 24 hr at 500°C. Sonication in surfactant/detergent solutions (Triton X-100, NP-40, Quaternary O) also failed to disrupt stercomata. The structural integrity of stercomata seems imparted by refractory organic matter that serves as a binding agent, which may provide isotopic signatures of past oceanic conditions at the time of death. In the geological record, fossil stercomata may be useful taxonomic markers, e.g., to distinguish monothalamids and gromiids from other organic-walled taxa.

## MORE THAN JUST STROMATOPOROID STORM DEPOSITS: INTERPRETING AN ECOLOGICAL SIGNAL OF *AMPHIPORA* FROM THE GREAT BASIN, U.S.A.

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During the Frasnian, stromatoporoid dominated reef communities reached their maximum diversity and geographic extent before becoming extinct at the end of the Devonian. The genus *Amphipora*, recognizable by its distinct dendroid form, was abundant globally occurring a range of environments and may be volumetrically the most abundant form preserved from Devonian shelf settings. This study evaluates 18 stratigraphically distinct, densely packed *Amphipora*-rich beds across five localities in Utah and Nevada, U.S.A. in order to characterize range of variability. Previous accounts of these deposits reported that they are current aligned and preserve a biofabric consistent with transport. Data including stem orientation, density packing of stems, and width of individual stems were measured to test if these deposits preserve an original ecological signal. There is no strong preferential orientation of stems and common stem orientation that is not parallel to bedding supports that these assemblages were not transported extensively. Density data, to describe degree of close packing, were collected using the ribbon method in the field and within densely packed assemblages ranged from 8.5 to 394 individual stems per meter. Variation in the biofabric associated with density was only rarely associated with distinct sedimentary signal of storm events, suggesting that variation in density and fabric could be recording an original ecological signal. Sizes of individual stems were variable, but averages ranged from 1.5 to 4.18 mm and is not correlative with density. Although these deposits are not preserved *in situ*, the unevenness in the size and packing of these deposits likely represents variability within the original community rather than a signal of post mortem reworking and deposition.

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## NORTH AMERICAN PALEONTOLOGICAL RESOURCES 2024

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In the late 1970s, The Paleontological Society (PS) convened the *ad hoc* Committee On North American Resources in Invertebrate Paleontology (CONARIP) to assess the status of materials available for paleontological research. The effort was framed in terms of regarding fossil collections as national resources. CONARIP identified 24 "major" fossil collections, 108 smaller, "specialized" collections, and ~200 teaching collections. CONARIP also counted as paleontological resources 44 in-house print publications and 30 "classic" library collections. In the ensuing half-century, the paleontological resources landscape has undergone seismic shifts. Half of CONARIP's "major" fossils collections persist whereas transfer and consolidation of collections and closure impacted other institutional resources, large and small, private, public, and government-sponsored. About 50% of the listed in-house publications have folded; one made the transition to online. CONARIP did not include a census of paleontological human resources, but subsequent study points to the specimen-based paleontologist as an endangered species, which, with concurrent pressure in justifying the physical space needed to house specimens, endangers the existence of paleontological collections. Neither did CONARIP discuss the health of the discipline's professional societies, sources and levels of funding available to specimen-based researchers and for collections maintenance or contributions from avocational organizations. The intervening 48 years have seen gains in the diversity of paleontological human resources and technological innovations that would have been unimaginable to the authors of the 1977 study. Any update of the 1977 report will reflect a fundamental shift in the justification for preserving specimen collections, from using fossils as essential data for resource exploration, to a broader emphasis including the importance of fossils as the primary data for research into and education about the history of life. In light of shrinking resources for maintaining specimen collections it would behoove academic, government, private, and avocational stakeholders to coordinate their efforts toward the shared goal of preserving these irreplaceable national resources.

## MUH-ZON/MAY-ZON: THE MAZON CREEK FAUNA AS A CASE FOR INCLUDING PRONUNCIATION GUIDES IN OUR WRITING

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NAPC 2024 takes place one coal basin east of former coal strip-mining pits famous among geoscientists and avocational collectors for its millions of fossil-bearing ironstone concretions, including the enigmatic *Tullymonstrum*, state fossil of Illinois. The assemblage is referred to as the Mazon Creek Fauna, named for the small river that runs through the area. Locals pronounce the name of the river and town "muh-ZON", yet most geoscience professionals pronounce the name of the fauna "MAY-zon". What is the "correct" pronunciation of a place name? Noah Webster said the true pronunciation is that which prevails in and near the place. The county seat of Eaton County, Michigan, [Charlotte] is "shar-LOTT" to Michiganders, but the largest city in North Carolina is "SHAR-let" to its citizens. The Grundy County, Illinois, Historical Society is unequivocal in its explanation that the name "Mazon" has its origins in an Algonquin word for "nettle", plants that grew abundantly in the area, and is pronounced "muh-ZON". Our journals generally do not include pronunciation guidelines for place names, peoples' names or discipline-specific jargon. In the absence of the reader's knowledge of local pronunciation, it is a small step from a word on a printed page becoming mis-pronounced in an oral presentation. Like a virus, once the variant is "airborne" it can spread to those in within earshot, who then become vectors and spread the non-local pronunciation through the system. Non-local pronunciations are the linguistic equivalent of an invasive species: once they have gained a hold, they may propagate unchecked. As with invasive species, eradication of non-local pronunciation is informed by understanding the origin of the variant and untangling the path through which it propagated. The explanation for the "muh-ZON/MAY-zon" disparity is straightforward. Most English place names are pronounced with the word stress on the first syllable (YORK-shire, BRIGH-ton, OX-ford); unaware of regional exceptions, Anglophilic non-locals likely default to this convention. What is less clear is how the non-local pronunciation became the paleontological community's default, as early professional researchers, primarily from the Field Museum in Chicago, 70 miles east of Mazon, worked closely with local collectors. An informal census of professional and avocational paleontologists who live in northern Illinois revealed that the 'local' pronunciation of Mazon may be more accurately described as "hyperlocal", that is, 'pertaining to a town, village, single postcode or other small, geographically defined community'. The number of hyperlocal paleontologists, that is, professionals who were born and raised in the "Mazon zone" so far has been insufficient to shift use of the prevailing non-local pronunciation. We acknowledge and honor the peoples, identity, culture, traditions, and history of a place by using its proper name and pronunciation.

## MANAGEMENT OF PALEONTOLOGICAL RESOURCES USING PHOTOGRAMMETRY IN THE 21ST CENTURY: AN ERA OF ADVANCEMENT

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Photogrammetry has been in use for over 150 years for the collection of 3D imagery and data. However, it was not until the late 1990s that photogrammetry became integrated into paleontological resource management and ichnological documentation in North America. Over the past 25 years, tracksites located on Bureau of Land Management (BLM) lands have been managed for public visitation (e.g., left exposed, developed, and interpreted). Premier vertebrate tracksites such as the Jurassic Red Gulch Dinosaur Tracksite (RGDT) in Wyoming and the Cretaceous Mill Canyon Dinosaur Tracksite (MCDT) in Utah made excellent laboratories for the testing of various platforms for image collection (e.g., handheld, tripods, monopods, tethered blimps, Uncrewed Aerial Systems). Included in the development of photogrammetric ichnology were partner sites such as the Cretaceous tracksite at Dinosaur Ridge in Colorado and the Jurassic Twentymile Wash Dinosaur Tracksite (TWDT) in Utah. Episodic photogrammetric documentation of these sites has captured imagery, which produces high-quality 3D datasets with submillimeter resolution. When coaligned into the same coordinate space, direct visual and quantitative analysis of tracks and overall site impacts and degradation may be conducted over time. Thus, assisting in assessing, monitoring, and quantifying the effects of natural weathering and human degradation of the track surfaces. These localities (among the most extensively and intensively documented dinosaur tracksites in the world) preserve the unique community dynamics of ancient ecosystems, as well as showcasing the use of photogrammetry for in situ paleontological resources management. "First Alert Digital Documentation" (photogrammetric image capture shortly after sites are exposed) provides baseline data for condition assessment and future monitoring. In 2024, impacts of reclaiming the Community Pit #1 on an early Permian ichnolagerstätte in the Robeldo Mountains Formation outside Prehistoric Trackways National Monument in southern New Mexico were assessed and monitored using photogrammetry as the red beds were uncovered. Photogrammetry used in managing paleontological resources can generate qualitative products like 3D models, as well as highly detailed point clouds and digital surface models for quantitative analysis. Advancements in digital imagery and structure-from-motion photogrammetric software have revolutionized photogrammetry, making it possible to image a wide range of objects with consumer digital cameras. These advancements have made photogrammetry more accessible to field personnel, while becoming a commonly used, best practice technique in the noninvasive, 3D digital collection of in situ paleontological resources. Photogrammetry is a powerful tool, which allows land managers to protect paleontological resources using scientific principles and expertise and make scientific-based management decisions to preserve invaluable parts of America's Natural Heritage.

## THE 'MID' CRETACEOUS FRESHWATER ICHTHYOFAUNA FROM THE NORTHERN GONDWANA: AN UPDATED LOOK

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Freshwater fossil deposits from the Mesozoic of Gondwana, although rare, play a fundamental role for better understanding historical biogeographical patterns of diversification in continental taxa. In this way, the Late Cretaceous (Cenomanian, ~100–95 million years), Douira Formation, Kem Kem Group of Morocco, Africa, provides one of the richest fish fauna of Gondwanian origin. The recent discovery of a coeval similar ichthyofauna in northeastern Brazil (Açu Formation of the Potiguar Basin and Alcântara Formation of the São Luis Basin) casts doubt on the Cenomanian age of these formations, as well as sheds light on some evolutionary events that occurred during the early phase of the break-up of western Gondwana. These northern Gondwanian fauna were absent from localities farther south (e.g., Sanfranciscana and Bauru basins in southeastern Brazil) in the Late Cretaceous, indicating they were part of a northern paleoenvironmental complex.

## WHAT WE TALK ABOUT WHEN WE TALK ABOUT COEVOLUTION: REEVALUATING A DOMINANT EXPLANATION FOR THE GEOGRAPHICALLY UNEVEN INTENSITY OF THE LATE QUATERNARY MEGAFAUNAL EXTINCTIONS

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The cause of the global late Quaternary extinction (LQE), in which roughly half of terrestrial mammal species weighing over 45 kg went extinct, has been hotly debated for decades. This event, characterized by its unusual size-selectivity and geographically uneven intensity, has defied easy explanation, with climate change and human hunting (overkill) emerging as the two predominant and best supported causal hypotheses. Increasingly, analyses of the global evidence have come to support human expansion, not climate change, as the primary cause of the LQE. However, while prodigious amounts of scholarly effort have been devoted to understanding why many megafaunal species went extinct, there has been relatively little investigation into why some survived, and why those survivors are disproportionately found in Africa and Tropical Asia. Proponents of the overkill hypothesis have usually cited coevolution of African megafauna with hominins to explain

the geographic unevenness in the intensity of the LQE. This argument postulates that greater duration of exposure to hominin hunters gave African megafauna time to evolve adaptive traits, while the naïve megafauna in the rest of the world were unable to evade human hunters as they expanded across the globe in the late Quaternary. We review the overkill literature and reconstruct the intellectual history of the coevolution hypothesis. We find that, although routinely referenced as an established explanation, coevolution between African megafauna and hominins has almost never been directly investigated as an explanation of better survival outcomes in Africa during the LQE, and that there is not a strong empirical basis from which to conclude that the coevolution hypothesis is the best explanation for the relatively mild LQE in Africa. We additionally find that the coevolution hypothesis relies on bold arguments and implicit assumptions that have rarely or never been stated explicitly in the literature. We conclude that although the global megafaunal extinction of the Late Quaternary is best explained by human impacts, there is not sufficient evidence to indicate that the lower intensity of the extinction in Africa is due to a coevolutionary dynamic. We suggest that the persistence and widespread acceptance of this largely unsupported hypothesis can be attributed in part to the history of highly polarized debate around the LQE.

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## TOWARDS A MULTIVARIATE FRAMEWORK FOR EXTINCTION RISK IN PLANKTONIC FORAMINIFERA

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How predictable is extinction? Geographic range-size contractions, decreasing abundance and changes in species morphology have all separately been proposed as early warning signals for population decline. However, how these ecological facets interact is less clear. Abundance and body size together have been shown to be a better predictor of marine megafauna decline than either parameter alone, and high abundance can in some cases buffer the higher extinction risk of smaller geographic ranges. These results suggest that a reliance on single ecological facets biases estimates of extinction risk. To improve predictability of extinction, multiple early warning signals need to be combined into a multivariate framework. The fossil record is the only direct source of ‘natural‘ extinction dynamics, yet its notorious incompleteness inhibits our ability to accurately determine population extinction risk through time and space. Marine microfossils are the exception to this rule: their large population size, global distribution and excellent preservation potential allow for multivariate trait analyses. Sample collection and specimen identification is a time-consuming process that limits the size of a dataset that can be generated by individual researchers, but museum collections provide unique opportunities to generate large, global datasets required for extinction dynamics through time and across space. Here, we use the CLIMAP and PRISM foraminifera assemblage slide collections to compare morphology, biogeographic range size, abundance, and phylogenetic relatedness between suvivors, and species that became extinct since the mid-Pliocene warm period. Our results will provide the first clade-wide multivariate framework of extinction and shed new light on the complex interplay of the internal and external factors driving extinction.

## NO BONES ABOUT IT: THE DEPOSITIONAL ENVIRONMENT OF THE FAYETTEVILLE SHALE CREATES A TREASURE TROVE OF FOSSIL CARTILAGE

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The Upper Mississippian (Middle Chesterian) Fayetteville Shale has been studied by invertebrate paleontologists and paleobotanists for many decades, resulting in vast collections of phosphatic concretions. Fossils described from the formation mainly include permineralized plants and cephalopods. Upon donation to the American Museum of Natural History, dozens of these nodules were split open or CT-scanned, revealing a diversity of vertebrates previously unknown from these deposits, including several species new to science. Unusually for the time period, very few of these fossils are bony fishes, and instead the formation preserves three-dimensional fossil cartilage. We provide a brief overview of this recently described vertebrate diversity and use X-ray fluorescence and diffraction to test previous theories of Fayetteville Shale paleoecology and depositional environment, explaining this preferential cartilage preservation and the relative absence of bone and shell.

## PALEOECOLOGICAL DYNAMICS DURING OCEANIC ANOXIC EVENT 2 IN THE CRETACEOUS WESTERN INTERIOR SEAWAY: COMPARISONS BETWEEN HYDROCARBON COLD SEEP AND NON-SEEP COMMUNITIES

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Methane emissions at cold seeps enhance benthic habitat heterogeneity, increase chemosynthetic production, and can sustain oasis-type ecosystems in the offshore realm. Seeps also have a long Phanerozoic fossil record, and some have suggested that seep biota may have been buffered from perturbations affecting photosynthetic-based food webs throughout geologic time; however, few have directly tested this at the community-level scale. The North American Western Interior Seaway (WIS) was the site of widespread yet periodic seep activity throughout the Late Cretaceous. Cenomanian-Turonian (C-T) age seep deposits from the Tropic Shale Formation are coeval with Oceanic Anoxic Event 2 (OAE2; ~94 Ma), a globally recognized event associated with a severe disruption to the global carbon cycle and biotic turnover. WIS strata preserve a near continuous record of OAE2, and the paleontology of this interval has been documented across the basin. However, the response of seep communities has not been adequately investigated. Here, we address the following: (1) how did seep and non-seep paleocommunity structure change in response to variations in paleoenvironmental conditions throughout OAE2?; and (2) how do changes in seep dynamics affect the habitability of seeps, and how did this govern the distribution of fauna? We reconstruct seep paleocommunity structure using macroinvertebrate abundance, richness, and taxonomic and functional diversity metrics from a seep-bearing Tropic Shale locality in Kane County, Utah. The same analyses were applied to macroinvertebrate occurrence data obtained from the Paleobiology Database (PBDB) from correlative non-seep localities in UT, AZ, and CO, allowing us to compare seep and non-seep community responses to OAE2 across the basin. Seep carbonate concretions were analyzed morphologically and petrographically to interpret seepage style and diagenetic history. Paleocommunities appear similar across all localities during the earlier stages of OAE2, though faunal abundance and richness is highest in UT seep and non-seep sites. During peak OAE2, the proportion and diversity of infauna declines across non-seep localities, while seep carbonates remain fossiliferous. The spatial distribution of seep biota appears to also be governed by carbonate morphology, which we interpret to be related to seepage style and local geochemical gradients. Large carbonate masses produced during intense seepage may have extended into more oxygenated waters, possibly providing suitable habitat for diverse epifauna. These carbonates also contain abundant ammonites and fish debris, suggesting chemosynthetic primary production impacted the overlying water column. Further investigation of faunal community structure and function within seep influenced ecosystems may shed insight into the spectrum of processes driving species' distribution and survivorship during environmental crises.

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## THE GENOMIC SIGNATURES OF EVOLUTIONARY STASIS

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Evolutionary stasis characterizes lineages that seldom speciate and exhibit little phenotypic change over long stretches of geological time. Although lineages that appear to exhibit evolutionary stasis are often called living fossils, no single mechanism is thought responsible for their slow rates of morphological evolution and low species diversity. Some analyses of molecular evolutionary rates in a handful of living fossil lineages have indicated they exhibit slow rates of genomic change. Here, we investigate mechanisms of evolutionary stasis using a dataset of 1,105 exons for 481 vertebrate species. We demonstrate that two ancient clades of ray-finned fishes classically called living fossils, gars and sturgeons, exhibit the lowest rates of molecular substitution in protein coding genes among all jawed vertebrates. Comparably low rates of evolution are observed at four-fold degenerate sites in gars and sturgeons, implying a mechanism of stasis decoupled from selection that we speculate is linked to a highly effective DNA repair apparatus. We show that two gar species last sharing common ancestry over 100 million years ago naturally produce morphologically intermediate and fertile hybrids. This makes gars the oldest naturally hybridizing divergence among eukaryotes and supports a theoretical prediction that slow rates of nucleotide substitution across the genome slows the accumulation of genetic incompatibilities, enabling hybridization across deeply divergent lineages and perhaps slowing the rate of speciation. Our results help establish molecular stasis as a barrier to speciation and phenotypic innovation and provide a mechanism to explain the low species diversity in living fossil lineages.

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## ECOMETRIC MODEL FOR BODY MASS AND TEMPERATURE WITHIN GLOBAL TERRESTRIAL CARNIVORAN COMMUNITIES

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Functional traits determine the suitability of an individual organism to its environment and are consequently closely tied to the environmental conditions inhabited by organismal communities. Ecometric models are powerful tools that utilize these functional trait-environment relationships to study community responses to environmental change across spatial and temporal scales. Body mass is a functional trait that is negatively, nonlinearly correlated with mean annual temperature in terrestrial mammals, yet it has not been studied using an ecometric model. Order Carnivora is uniquely important for understanding environmental change due to its trophic level and ecological diversity. Small carnivorans (<22 kg) have been suggested to be more sensitive to environmental change than large carnivorans, but it is unknown if this pattern is seen at the community level. Here, we present a preliminary ecometric model for global modern carnivoran communities utilizing the trait-environment relationship of body mass and mean annual temperature, and we demonstrate the utility of the model for paleoenvironmental interpretations. We used a 50 km point grid to assemble communities from species lists gathered from overlapping IUCN range maps and sampling associated temperatures from WorldClim. At each point, we generated a community average body mass value using data obtained from the macroecological database of mammalian body mass. We binned communities in a 25x25 matrix based on community averaged mean and standard deviation of body mass and used a maximum likelihood approach to produce estimated temperature values. Five Quaternary fossil sites were assessed with the body mass ecometric model to produce paleotemperature estimates and demonstrate the utility of ecometric models in understanding faunal responses to climate. Results from this study will contribute to understanding the importance of carnivoran communities for estimating environmental change, including the hypothesis that small carnivorans are more sensitive to environmental change. Moreover, ecometric modeling of body mass advances ecometric methods and provides a new tool for understanding faunal change through time.

## INSIGHTS INTO LATE ORDOVICIAN PALEOECOLOGY FROM SPONGE FOSSILS

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The Late Ordovician mass extinction (485–444 Ma), the inaugural event of the Big Five extinctions, is commonly attributed to abrupt glaciation. Despite ongoing debates about the specific drivers of this glaciation, numerous hypotheses converge on increased weathering and sedimentation leading to CO2 drawdown and subsequent cooling, which rely on geochemical signals and sedimentary proxies and offer a broad understanding of environmental dynamics. However, during this extinction event, marked by an 85% loss in species diversity, a more precise understanding of environmental conditions is crucial for interpreting exact mechanisms of loss. Interestingly, while overall species diversity declined at the end Ordovician, sponge fauna thrived in diversity and abundance. Sponges, representing one of the most ancient animal clades, exhibit a unique characteristic: extreme phenotypic plasticity in adults. This adaptability, influenced by factors such as water movement and light, allows them to change their body plan to suit their environment. For this reason, sponge fossils can serve as a valuable proxy for environmental conditions, including sedimentation, nutrient availability, and temperature. We hypothesize that the morphology of Ordovician sponge fossils can offer unique insights into changing paleoenvironmental conditions during the late Ordovician. Our research focuses on five locations along the western continental margin of Laurentia from 458 to 444 Ma. We propose a systematic examination of Ordovician sponge fossils through fieldwork, morphofunctional analysis, and environmental correlations. Preliminary findings indicate intriguing patterns, suggesting potential ecological adaptations of Ordovician sponges to specific paleoenvironmental niches based on various characteristics like height and shape. Integration of environmental data, such as sediment type, depth, and associated fauna, will be crucial in exploring correlations with sponge morphology. Statistical analyses, including correlation coefficients and regression models, will rigorously test these relationships . Additionally, temporal dynamics within the Ordovician sequence will be examined, revealing variations in sponge diversity and morphology across different strata. This project aims to contribute not only to our understanding of local sponge biodiversity but also to broader discussions on the paleoecology of Ordovician marine ecosystems in western North America. By synthesizing

taxonomic, ecological, and temporal dimensions, our research provides a nuanced perspective on the paleobiology of sponges during this critical period in Earth's history.

Funding source: Paleontological Society

## MORPHOMETRIC AND SPATIAL ANALYSES OF *CHARNIODISCUS* FROM THE EDIACARAN OF NEWFOUNDLAND, CANADA

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Ediacaran macrofossils (580–539 Ma) reveal critical insight into the evolution of life and include representatives of the earliest-known complex animals. In this study, we focus on *Charniodiscus*—a group of upright, sessile frondose organisms that are exceptionally well-preserved under volcanic ash deposits in Newfoundland, Canada and Charnwood Forest, UK. They are relatively understudied and are morphologically simpler than the iconic rangeomorphs, and so provide a perfect test case for the development of new quantitative techniques. One of the largest *in situ* census populations of *Charniodiscus* occurs within the Main E Surface community in the UNESCO Mistaken Point Ecological Reserve. With over 120 specimens, this population provides an opportunity to explore physical variation across different specimens, as well as the spatial distributions of those variations. To do this, a photogrammetric map of E Surface was generated, and a 3D surface mesh was created by combining LiDAR (mean resolution of 1mm) with 0.05 mm laser-line probe data. Then, the branching architecture of 116 well-preserved *Charniodiscus* specimens was marked up on Inkscape. Quantified morphological traits included the disc width, frond length, frond-to-stem angle, number of primary branches, average primary branch angle and branch lengths. Multivariate cluster techniques were used to identify different morphotaxa groups present within the *Charniodiscus* specimens on the surface, and to constrain the key morphological traits that defined them. Subsequently, random labelling analyses were used to investigate how the spatial patterns of specific characteristics varied across the population, and to identify the spatial patterns of the different morphogroups identified. Traits that show distinctive spatial patterns and defined morphogroups are likely to be more ecologically and therefore evolutionarily important than those which vary randomly within the population. Therefore, this novel approach is the first step in elucidating which morphological traits—or combinations of traits—are the key drivers of ecological dynamics in the Ediacaran.

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## CAN ENDOCRANIAL FEATURES HELP ELUCIDATE THE EVOLUTIONARY HISTORY OF GAVIALOIDS?

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Historically, the interrelationships of the extant crocodylians *Gavialis gangeticus* and *Tomistoma schlegelii* have been disputed. Whereas analyses based on molecular data indicate a sister taxon relationship between the two species, morphological datasets typically place *Gavialis* as the outgroup to all other extant crocodylians. Recent morphological-based phylogenetic analyses have begun to resolve this discrepancy; however, several stratigraphically old fossil taxa (including 'thoracosaurs') are recovered as closer to *Gavialis* than to *Tomistoma*. This results in anomalously early divergence times when compared with estimates based on molecular data. One way to attempt to resolve this could be to evaluate neuroanatomical data, which has not been incorporated into phylogenetic analyses. For example, the endocast, nasal cavity and inner ear in the Early Miocene gavialoid '*Tomistoma*' *dowsoni* reflects an intermediate morphology between both extant species, with their morphologies appearing to be primarily influenced by ecology. However, the evaluation of more fossil gavialoids is needed to test if the morphology of neuroanatomical features can be interpreted as ecological or phylogenetic signals. We reconstructed the neuroanatomy of 16 gavialoids and discuss two exemplar features herein. Some 'thoracosaurs', such as the late Paleocene species *Eosuchus lerichei*, possess concave depressions on the internal surface of the prefrontals and lacrimals, where the paranasal sinus expands. In extant marine reptiles, these concave depressions are osteological correlates for salt glands. These depressions have also been noted and interpreted as such in several early diverging marine crocodyliforms. These depressions in *E. lerichei* might therefore be interpreted in the same way, which would be consistent with proposals that this species was capable of transoceanic dispersal. If other 'thoracosaurs' have this feature, it might therefore be a plesiomorphic gavialoid feature that was lost in a more phylogenetically nested clade that includes *Gavialis* and *Tomistoma*. The nasopharyngeal duct is also significantly expanded in 'thoracosaurs', including the middle Eocene species '*Tomistoma*' *cairense*, and the early Paleocene species *Thoracosaurus scanicus*. In these species, the duct is approximately the same

mediolateral width as that of the cerebrum. In *Gavialis*, the nasopharyngeal duct width is approximately half that of the cerebrum; however, the duct is instead characterised by a pterygoid bulla. As the pterygoid bulla of *Gavialis* connects to the nasopharyngeal duct medially, this expansion in 'thoracosaurs' could be an early form of the bulla. Previously, the stratigraphically earliest known species interpreted to have a bulla was the late Eocene gavialoid *Eogavialis africanum*. Thus, the expansion of the duct seen in 'thoracosaurs', could be interpreted as a phylogenetic signal, with the pterygoid bulla expanding throughout gavialoid evolution.

## REDISTRIBUTION OF MARINE OXYGEN DEFICIENT ZONES DURING THE MID-MIOCENE

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The distribution of dissolved oxygen in the world's oceans has broad implications for biogeochemical cycling and the distribution of marine organisms. It has generally been predicted that marine oxygen deficient zones will increase in size and intensity as global temperatures rise. However, recent data from the Pacific Ocean during the mid-Miocene has suggested that ODZs might have actually shrunk during a greenhouse interval known as the Miocene Climatic Optimum (14.5-17ma). Here, we present new results from the foraminiferal iodine-to-calcium paleoredox proxy to contribute to reconstructions of Pacific and Atlantic dissolved oxygen and iodate distributions during the mid-Miocene. We also used the cGENIE model framework to simulate the distribution of dissolved oxygen throughout the world's oceans. Our results indicate a redistribution and not necessarily a decline in ODZ conditions during the MCO. Further analysis of cGENIE simulations implicates the configuration of continents during the Miocene as a primary driver of the smaller Pacific ODZ during this period.

## AN ASSESSMENT OF THE PALEOCENE-EOCENE THERMAL MAXIMUM AND ITS IMPACT ON THE ECOLOGY, GEOCHEMISTRY, AND DENSITY OF BENTHIC FORAMINIFERAL COMMUNITIES ON THE AGULHAS PLATEAU

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A new deep-sea record of the Paleocene-Eocene Thermal Maximum (PETM) was recently recovered at International Ocean Discovery Program (IODP) Site U1580 on the Agulhas Plateau, southwest Indian Ocean. We examined benthic foraminifera in a composite splice of two parallel drillcores spanning the Paleocene/Eocene boundary recovered at Site U1580. The splice was constructed using high-resolution X-ray fluorescence (XRF) core scanning data and bulk carbonate stable isotope stratigraphy, and initial cyclostratigraphic analysis of these datasets indicates nearly continuous sedimentation through the PETM. However, single-specimen planktic foraminiferal stable isotope analysis also reveals mixing (reworking) of foraminifera over 10s of centimeters. Benthic foraminifera species were identified to the species level in 19 samples in the Site U1580 PETM sequence and the assemblages show significant variability. Throughout the PETM study interval, benthic foraminifera abundances remain relatively high (average of 14 individuals/g sediment) and calcareous taxa dominate. A decrease in foraminiferal diversity and an increase in total abundance coincide with the PETM carbon isotope excursion (CIE). During crises, opportunistic taxa have been shown to increase in populations which is likely to be the case here with population increases observed in Buliminids, *Melonis affinis*, and *Nuttallides truempyi*. Since *Nuttallides truempyi* is present in sufficient abundance throughout the event, foraminiferal calcite can be used for reliable bottom water reconstructions. An analysis of MicroCT images is also being used to assess changes in morphology and calcification during PETM. Using MicroCT, calcite thickness and distribution can be determined within and between individuals. Stable isotope analysis will then be performed on the same benthic foraminifera analyzed in MicroCT in order to compare calcification and dissolution patterns with pH, productivity, and temperature data. These measurements will also be used to study foraminiferal geochemistry, sediment mixing, and dissolution to determine how dissolution occurs in benthic ecosystems and how it affects reconstructions using foraminiferal calcite geochemistry.

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## PRESERVATION VERSUS CHEMICAL AND BIOLOGICAL DISSOLUTION OF SHELLY CARBONATE AT THE EAST FLOWER GARDEN BRINE SEEP, GULF OF MEXICO

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In deep disphotic marine environments, carbonate shells can be destroyed by chemical dissolution and diagenesis as well as by micro- and macro-bioerosion, leaving little, if any, potential fossil record. However, in the disphotic zone, there are places where preservation is enhanced. We investigated bivalve carbonate preservation at the East Flower Gardens (EFG) in the Gulf of Mexico (27º54‘N, 93º34‘W). Here, a brine seep was created by a salt diapir that rose forming a high bank, then interacting with the seafloor creating brine seeps. Our seep is located on the edge of the bank where the brine runs off the bank into an outlet stream. The brine pool is anoxic, has a salinity ~200 ppt, and has H2S levels of 2,200 µM. To test if the unusual chemistry of the brine seep has an impact on fossilization, mesh bags filled with fresh bivalve shells (*Arctica islandica*, *Codakia orbicularis*, *Argopecten purpuratus*) were placed in the brine pool and stream. The brine is sulfur-rich and as it flows off the bank, it mixes in the stream with normal salinity seawater which decreases its salinity. To document carbonate preservation and loss, we examined the bivalves after 12 years on site. Using a Scanning Electron Microscope, ~1 cm section of shell was impregnated with epoxy and was examined in cross-section. Ten random photos of the shell’s interior edge were taken, and point counted for the presence of microboring as well as documenting if dissolution was present or absent. We found very few borings and limited dissolution on the shells where the salinity was highest (in the brine pool), representing an excellent opportunity for Laggerstätte preservation. In the brine stream, the density of microbial borings in the shells increased with distance from the brine pool as salinity and sulfide became increasingly diluted. In the brine stream closest to the brine pool, the mixing of sulfidic brine produced sulfuric acid and led to purely chemical dissolution of the shell. Because of the chemistry of the sulfidic anoxic brine, typical microbial borers such as fungi and photosynthetic algae seem unable to inhabit shells in the brine or the high sulfidic mixing zones in the stream. However, the microbial borers become the primary bioeroders as salinity drops closer to normal seawater levels (~35 ppt). Therefore, we find a potentially recognizable signature for ancient brine seep environments where excellent preservation is surrounded by an absence of shelly carbonate. Progressing away from the Laggerstätte we would find an increasing presence of carbonate that would be micro-bioeroded.

## LESSONS FROM THE LATE DEVONIAN MASS EXTINCTION IN NEW YORK AND PENNSYLVANIA

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Ocean anoxia and global cooling are frequently discussed as proximal kill mechanisms for the Late Devonian (Frasnian-Famennian) mass extinction. Both pulses of the extinction (the Lower and Upper Kellwasser Events) are recorded in the Upper Devonian strata of New York and Pennsylvania. The outcrop belt exposes a wide range of facies from deeper-water shales in the west to shallow-marine and eventually terrestrial sediments in the east, permitting a study of faunal changes along an offshore-onshore gradient. Our studies of these extinctions have so far focused on brachiopods in the shallow-marine “Chemung” facies; we have tabulated close to 30,000 brachiopod specimens in approximately 400 bulk samples that span both extinction pulses. The selectivity of extinction during the Lower Kellwasser Event is consistent with cooling as a proximal extinction kill mechanism, strengthening the evidence that climate change is often an important mass extinction killer. Somewhat unusually, the Lower Kellwasser Event was more severe than the Upper Kellwasser Event. We suggest that extinctions might have proceeded faster in this region because the Appalachian Basin was partially isolated, limiting species’ ability to migrate to refugia as the climate changed. At a higher taxonomic level, the composition of the fauna changed considerably during this time interval with the extirpation of atrypids and strophomenids and an increase in the diversity and relative abundance of productids. However, brachiopod species that survived the Lower Kellwasser Event exhibited niche conservatism rather than evolving new habitat preferences during the environmental and ecological perturbations. Skeletobionts living on brachiopod shells did not suffer any apparent extinctions, and their ecological distributions shifted only in minor ways. In total, our studies suggest that some aspects of ecology changed greatly through these events, while other aspects remained relatively stable.

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## PATHOLOGY PREVALENCE IN PROBOSCIDEAN POPULATIONS AS A PALEOENVIRONMENTAL PROXY

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The physical condition of animal populations is inextricably tied to environmental health. Unfavorable conditions such as drought, contaminated water, or extreme temperatures

increase pathology rates, and ultimately mortality rates, within affected populations. Because population health is connected to environmental health, the pathology rates within a fossil population may serve as a proxy for paleoenvironmental conditions. We assessed the osteological condition of a syndepositional population of juvenile and adult female *Mammuthus columbi* from Waco Mammoth National Monument (WMNM) to better understand environmental conditions of central Texas 66.8±5 ka. Individuals were coded as having typical pathologies (related to normal behaviors and/or aging), acute pathologies (rare and/or debilitating), or no discernible pathologies. The individuals at the site are in varying degrees of completeness, and two individuals may be synonymized in the future. For this reason, we calculated rates that included these individuals and rates with one or both synonymized. Based on this assessment, we calculated an overall pathology rate of 47–59% for the WMNM population. We then compared the WMNM pathology rate to both living and fossil proboscidean populations. Pathology rates in comparison assemblages were notably lower than at WMNM and were 12–15% among 33 *M. primigenius* individuals from Sevsk, Russia (Late Pleistocene); 6% among 47 *Notiomastodon platensis* individuals from Águas de Araxá, Brazil (Late Pleistocene); 22% among captive *Loxodonta africana* individuals in Association of Zoos and Aquariums (AZA)-accredited institutions (modern); and 28% among captive *Elephas maximus* individuals in AZA-accredited institutions (modern). Previous taphonomic and geochemical analyses suggest prolonged drought conditions at WMNM, and we interpret the comparatively high rate of pathologies to be the result of the environmental stressors associated with drought. Thus, paleopathologies in proboscideans appears to be a potentially useful paleoecological signal that can complement other methods of paleoecological and paleoenvironmental reconstruction. Pathology prevalence has potential to be a powerful tool for reconstructing paleoecological trends, but it will only be possible if more workers report the frequency of pathology in the populations they study.

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## TWO PATHWAYS OF PLANT RECOVERY AFTER THE END-CRETACEOUS MASS EXTINCTION IN THE DENVER BASIN, COLORADO

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The fossil flora of the Denver Basin, Colorado, preserves the story of two distinct pathways of floral recovery in the aftermath of the end-Cretaceous mass extinction (66 Ma). Along the western margin of the basin, plant species richness and leaf morphological diversity rebounded to pre-extinction levels within 200,000 years of the mass extinction event. In the basin center however, it took over 1,000,000 years for plant localities to return to pre-extinction levels of diversity. This difference in pace of recovery presents an opportunity to understand some of the nuances of how plants respond to mass extinction by enabling controlled comparisons between distinct, but geographically, climatically, and to an extent, taxonomically proximal pathways of floral recovery. To ultimately trace both pathways from the mass extinction event through "full recovery," we start by defining their end states and identifying the floral components that must necessarily come together by the culmination of the recovery process. Using leaf architectural characters, we describe the morphospecies present at three well-sampled Denver Basin localities from 1.5 to 2.2 Myrs after the mass extinction. From the western margin of the basin, the Plum Creek Parkway (63.8 Ma; DMNH 3613, 3618, 3620) and Chopping at the Gap (64.3 Ma; DMNH 2687) localities represent a part of the basin in which plant richness and morphological diversity had been stably recovered for at least 1.5 Myrs. From the basin center, the Cold Coyote Canyon locality (64.5 Ma; DMNH 2359) contains the area's earliest known flora to reach pre-extinction levels of species richness. We describe the morphological diversity of the morphospecies present at each locality, estimate paleoclimate using fossil leaf physiognomic methods, and identify crossover morphospecies that are present at multiple localities. Combined, we establish two anchor-points for tracing the progression of these distinct floral recovery pathways back through time until the point where they diverged, soon after the Chicxulub bolide impact set off the end-Cretaceous mass extinction event.

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## TAPHONOMY OF THE POSTCRANIAL SKELETON OF *NANOTRAGULUS* (ARTIODACTYLA: HYPERTRAGULIDAE) FROM AN EARLY OLIGOCENE FAUNA IN SOUTHERN MEXICO

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Postcranial skeleton remains of the basal ruminant *Nanotragulus* have been collected over the years from early Oligocene fluviolacustrine sediments that make up

the Iniyoo Local Fauna that crop out in the surroundings of Santiago Yolomécatl, Oaxaca, Mexico. U-Pb zircon dating of a sandstone bed that overlies the fossiliferous beds dated the fauna at a maximum of 30.6 Ma, and is considered the southernmost land mammalian assemblage of early Arikareean age in North America. In situ preservation of the elements is considered excellent, although most were found disarticulated, only a few bones were fragmented or incomplete. This, along with the slight abrasion and few V-shaped transportation lines on the surface of the bones suggest that flood stages existed where the remains were dispersed and transported short distances by low-energy hydraulic flows. Regular sedimentary contributions with periods of cessation caused some specimens to experience exposure to weathering and root marks on their surface indicating the growth of vegetation during periods of stability. Calcite replacement in the majority of the elements also indicates droughts and floods under a subhumid climate, allowing fissures to appear on the bone surface due to contractions caused by the loss of water and humidity. Other elements showed both signs of having been digested and gnawed by rodents before their final burial. Overall taphonomic analysis allows us to infer that *Nanotragulus* postcranial elements were autochthonous to the area and must have died close to their final depositions.

## SPECIES DIVERSITY OF *DICKINSONIA*

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*Dickinsonia* is an iconic organism of the Ediacara-like biota. Since its first discovery in 1947 by Reg C. Sprigg from South Australia it is still stimulating active research. The phylogenetic affinity of this taxon is still unknown, but based on biomarker research animal affinity was proposed. Overall, nine species of *Dickinsonia* were described. However, in many cases, when first identified only a handful of specimens were used. Now, after almost 80 years of research, the scientific community has accumulated enough material which allow the use of statistical methods to help with the taxonomy of this genera. Specimens of *Dickinsonia* are found in Australia, the White Sea area, the Ural Mountains, and China. Recent attempts at the classification of this genera resulted in a proposal of a decrease of species diversity into two species, *D. costata* and *D. tenuis*. However, this effort was made only using specimens from Australia. Here, we present our results from statistical analysis of *Dickinsonia* specimens from Australia, the White Sea, and the Ural Mountains. So far only one partial specimen has been reported from China, thus we did not include it in our study. Metric data on *Dickinsonia* populations from three locations were assembled and a cluster analysis using the PCA method was performed. At least three morphospecies (costata, tenuis and the Ural population) were statistically separated on our database. Previously, it was suggested that the Ural material could be classified as *D. minima* (originally described on Australian material), but after studying the type material of *D. minima* it became clear that such an identification is impossible, since they differ from each other in morphometric parameters.It is interesting to note that the Ural and Australian populations do not overlap in the PCA space, while representatives of the White Sea specimens of *Dickinsonia* were found in all three clusters during clustering analysis. It is peculiar that the White Sea specimens fall into all three clusters while Australian and Ural specimens do not intersect in the PCA space. Taking into account the difference in sedimentary environments between the Ediacara sandstones (Australia) and the Konovalovka Member (Middle Urals), as well as the wide range of sedimentological environments in the White Sea, it can be hypothesized that environmental conditions could influence the morphology of this taxon.

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## INTEGRATING VERTEBRAL MORPHOLOGY AND HISTOLOGIC CORRELATES TO ELUCIDATE DIVERGING PATTERNS OF CARDIOPULMONARY SYSTEM EVOLUTION IN TERRESTRIAL VS SECONDARILY AQUATIC ARCHOSAURS

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The evolutionary origins of the crocodylian-style hepatic piston and avian-style air sac pulmonary systems are enigmatic due to the rarity of soft-tissue preservation in fossils. However, archosaur lung embryology suggests a homologous origin of air sac-like pulmonary structures. Additionally, there is increasing evidence that the ability to sustain higher systemic blood pressures and higher aerobic capacity may have been ancestral for Archosauria. Here, we ask: Are there reliable fossilizable indicators of cardiopulmonary evolution? And do they reveal divergent patterns in terrestrial versus secondarily aquatic archosaur lineages near the Triassic avian and crocodylian split? We present a combined study that uses:

1) vasculo-lacunar histometrics and phylogeny to accurately retrodict red blood cell (RBC) sizes in 20 extinct and 20 extant tetrapods via phylogenetic eigenvector mapping, along with 2) macroscopic (fossae, laminae, foramina) vertebral features in over 230 extinct and extant archosaurs, and 3) microscopic (pneumosteum) thin sections in 21 extant archosaurs to assist in hypothesizing the presence of pulmonary diverticula connecting with the axial skeleton. Assessing states in Triassic taxa will clarify whether pseudosuchians always lacked these features or lost them secondarily in or leading to Crocodylomorpha. Our results show external pneumaticity associated with the invasion of pulmonary diverticula, and the corresponding histologic signature, is lost when secondarily adapting to an aquatic environment. Increases in RBC size also occur in semi-aquatic crocodylians, suggesting slower O2 uptake kinetics. Because early-diverging pseudosuchians exhibited specialized vertebral morphology more similar to early avemetatarsalians than to extant crocodylians, this suggests that the resulting divergence in pulmonary style found in extant archosaurs is likely a result of secondary adaptation to an aquatic lifestyle in crocodylians.

Funding source: USC Department of Earth Sciences, Geological Society of America, NHMLAC

## A STRATIGRAPHIC MODEL FOR THE MODEL SYSTEM: IDENTIFYING THE MID-PLIOCENE TRANSGRESSIVE INTERVALS IN THE SOUTHEASTERN US

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Despite the passive margin setting, local tectonic activity and the vagaries of erosion create a patchwork of Plio-Pleistocene units and outcrops across the coastal plains of Virginia and the Carolinas. Tectonic adjustments result from factors such as the subduction of the Farallon plate under North America, changing weights of glaciers and sediment, upwarps and downwarps associated with arches and embayments, rebound from delamination of the plate base, and structural instability from the Chesapeake Bay impact. Some sections preserve multiple unconformities. The diversity of mollusks in most outcrops, notably the diagenetically resistant scallops, allows biostratigraphic correlation and recognition of multiple transgressive intervals. The oldest Pliocene units are the Zone 1/Sunken Meadow Member Yorktown Formation and the Wabasso beds with *Chesapecten jeffersonius*. Next in age are the very local *Paraleptopecten olgensis* bed north of the Cape Fear arch and the lower Goose Creek Limestone to the south. The *P. olgensis* bed falls between the Zone 1 and Zone 2 Yorktown, and has the ancestral lower rib count form of *C. madisonius*. These units are capped by an unconformity. The Raysor Marl overlies the lower Goose Creek Limestone. Faunally, the Raysor matches the upper Goose Creek Limestone and the type Rushmere Member of lower zone 2 Yorktown, including the last occurrence of *Chesapecten septenarius* and *Sphenolithus*, a nannofossil extinct at 3.5 million years, and medium rib count *C. madisonius*. *Chesapecten septenarius* occurs near the stratotype of the Moore House Member, suggesting that it may be age equivalent to the Rushmere stratotype. The Bear Bluff Formation stratotype is upper Goose Creek Limestone and neither lithologically nor stratigraphically like the upper Pliocene to lower Pleistocene beds commonly assigned to that unit. The lower "Duplin Formation", found near Florence to Darlington, SC, and the middle Zone 2 Yorktown retain some older faunal elements such as high-variability *Glycymeris* forms, which die out before the stratotype Duplin Formation and uppermost Yorktown. Highest rib count *C. madisonius* begins here. The high diversity and high stratigraphic location supports identification of the stratotype Duplin as the mid-Piacenzian temperature peak. They are followed by major extinctions, including *Ecphora* and *Chesapecten*. A depauperate end-Pliocene fauna is found in the Chowan River Formation, with patchy equivalent beds to the south commonly labeled "Bear Bluff". (Some "Bear Bluff" faunas are lower Pleistocene Waccamaw Formation.) Although the Morgarts Beach, Rushmere, and Moore House Members are available stratigraphic names within Zone 2 Yorktown, in current use they do not correspond to parts of a single transgressive pulse, but rather to low, medium, and high energy facies variation across multiple transgressions. Identification of the age units present at a particular locality requires careful examination of the fauna.

## PLIOCENE AND EARLY PLEISTOCENE MOLLUSCAN BIODIVERSITY: ZANCLEAN, PIACENZIAN, AND GELASIAN FAUNAS OF SOUTH CAROLINA AND SOUTHERN NORTH CAROLINA

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We document the biodiversity of Pliocene and Early Pleistocene mollusks of North and South Carolina from the Neuse River in North Carolina south to Georgia. The Atlantic Coastal Plain in the study area contains a complex sequence of marine sediments dating from the Zanclean lower Pliocene through the Gelasian early Pleistocene. From oldest to youngest, the units are the Wabasso Formation, Lower Goose Creek Limestone, the Upper Goose Creek Limestone and Raysor Marl as lateral facies, the Darlington beds, Natural Well stratotype Duplin,

the beds at Elizabethtown, North Carolina, and the lower and upper Waccamaw Formation. Most of these units in outcrop are framed by unconformities. Faunal documentation was drawn from literature sources and museum online databases, but principally from previously unpublished personal and museum collections. The marine mollusks of the Carolinas are remarkably diverse with 728 Piacenzian taxa here documented. Adding the Gelasian faunas brings the total to 1616 species. Only the Natural Well, North Carolina site, and its strict equivalents appear to represent the mid-Piacenzian Warm Period, with 525 documented molluscan species. Documented species richness for the Wabasso Formation was 2, for Lower Goose Creek Limestone-111, the Upper Goose Creek Limestone-164, Raysor Marl-375, the Darlington beds-357, stratotype Natural Well Duplin-525, the beds at Elizabethtown-161, the lower Waccamaw-1155, and upper Waccamaw-693 mollusk species. Combining the Waccamaw faunas yields 1251 mollusk species, some 60 percent being 0.75 to 10 mm in adult size range (T. Campbell, 2023). The increase in species richness in the Waccamaw should not be seen as a surge in speciation. Prior to 2016 the documented Waccamaw fauna was about 650 species. Access to sites near Old Dock, North Carolina enabled intensive collection, pushing the rarefaction curves toward a maximum. Sampling a site with extensive Upper Waccamaw outcrop allowed the first major survey of that unit. Similar focus on Natural Well-equivalent and the Darlington beds, when and if exposures become available, should yield similar numbers. The other units generally show partial to complete leaching of aragonite and so have much less preservation of the smaller species. The Wabasso also is only known to outcrop on the bottom of the Savannah River and so has very limited sampling.

## EXTINCTION AND ORIGINATION DYNAMICS IN PLIOCENE AND EARLY PLEISTOCENE MOLLUSCA OF SOUTH CAROLINA AND SOUTHERN NORTH CAROLINA

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The Pliocene and Early Pleistocene marine strata of North and South Carolina from the Neuse River in North Carolina south to Georgia contain varied molluscan faunas dating from the Zanclean Lower Pliocene through the Gelasian Early Pleistocene. Long-standing debates about the patterns of diversification and extinction emphasize different assessments of how the fossil diversity compares with the Recent. These faunal patterns take on increased significance in light of global warming. Neogene warm intervals provide models of future climates and climate-related extinction, but correct correlation and good chronological resolution are critical to accurate interpretation of the past patterns. Although the distinctions have often been overlooked in the past, at least eight distinct chronostratigraphic faunas can be recognized in this time interval. A dataset of 1616 molluscan species was analyzed at the species level and genus level for the first appearance datum, last appearance datum, and how many species were unique to that stratigraphic unit. The dataset noted which species survive to the Recent. Although the patterns are also affected by taphonomy and sampling biases, in general there is increasing diversity through the lower Pliocene, with a peak in beds correlating to the stratotype Duplin Formation. This corresponds to the mid-Pliocene temperature maximum, and is followed by 41% species-level (9.6% genus-level) extinction in the subsequent cooling. Diversity increases again to the lower Pleistocene Waccamaw Formation. Although not a globally warm interval, the strengthening of the Gulf Stream due to closing of the Isthmus of Panama produced locally warm conditions. The upper Waccamaw Formation is followed by a 68% species-level extinction (8.6% genus-level). During the subsequent 1.8 million years of colder and highly variable climate, the fauna has not shown much recovery in diversity, although some more tropical species have invaded the area during interglacials. Regional endemics have especially high extinction rates; the modern fauna of the Carolinas has extremely low endemism. Surviving taxa are more eurythermal.

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## DOUBLING THE DIVERSITY OF THE WACCAMAW FORMATION

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The Waccamaw Formation is a Gelasian (2.4–1.9 MYA) muddy shell sand composed of two informal faunal units and present in patches between the Cape Fear Arch and Georgetown, South Carolina. It has a diverse molluscan fauna, not yet monographed. Previous studies document about 650 species of mollusks which can be precisely recognized. This study has included examination of some museum collections, surface collecting, and extensive bulk sampling. The known molluscan diversity has been increased to about 1250 species, comparable to the diversity of a similar area and depth range in the northern Caribbean today. This includes 54 families not previously reported from the formation, about 350 undescribed species (including ones reported in previous studies on the Waccamaw), and about 46 undescribed genera

(7 of them noted as undescribed in prior studies on other faunas). Micro-mollusks are especially diverse, with the median maximum size of species present being about 7.5 mm. "Skeneidae", Epitoniidae, "Vitrinellidae", Eulimidae, marginelliforms, Conoidea, "Lower Heterobranchia," Cephalaspidea, Pyramidelloidea, Galeommatoidea, and Anomalodesmata have all increased in documented diversity by a factor of over 2.4. Contrasting with this diversity, the constituents of the fauna more closely resemble those in the recent of South Carolina than the recent northern Caribbean. The level of sampling required to achieve this documentation is quite high—a total of about 2000 kg of bulk samples have been collected and analyzed; another 400 are in progress. Similarly intense study of other non-leached deposits in the Carolinian upper Zanclean, Piacenzian, and Gelasian would likely produce comparable documented diversities.

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## REVISITING THE USE OF PALEONTOLOGY IN BIOGEOGRAPHY IN THE 21ST CENTURY: THE GREEN RIVER ICHTHYOFAUNA AS A CASE STUDY

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40 years ago, Lance Grande outlined in a seminal work the potential contributions of paleontological data to systematics and historical biogeography, using the Green River Formation ichthyofauna as a case study. Since then, enormous progress in analytical paleobiology, phylogenetics, and comparative methods has highlighted the crucial role of fossils for macroevolutionary inference. Yet, the use of fossils in biogeographic analyses remains somewhat limited to this day, despite the development of complex models that are able to accommodate—among others—changing connectivities between geographic areas and environmental shifts over time. Here, I revisit the biogeographic affinities of Green River teleosts in a Bayesian phylogenetic framework, by applying likelihood-based biogeographic models to tip-dated phylogenies of several fish clades with fossil representatives found in the Green River Formation. These analyses confirm a strong affinity between western North American and eastern Asian freshwater biotas during the early Paleogene, as previously hypothesized, suggesting some level of geographic connectivity between these areas at that time. On the contrary, the Australian affinities of the Green River biota, rather than reflecting an early connection between Asia and Australia in an Australasian biogeographic region, result exclusively from the dispersal of marine-adapted osteoglossid bonytongues in the earliest Cenozoic, followed by the independent reinvasion of freshwater systems in separate landmasses. Using the example of the Green River ichthyofauna, I point out the importance and potential of including paleontological data in phylogeny-based biogeographic analyses, as well as the current limitations of this approach.

## CHANGES IN GROWTH RATES OF TWO SPECIES OF FRESHWATER MUSSELS IN AN OHIO STREAM OVER THE LAST 80 YEARS

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Native freshwater mussels (Family: Unionidae) in North America have been in decline for decades and the Asian clam (*C. fluminea*) is considered a possible culprit in these declines, possibly due to food competition. However, in part due to the challenges with survey funding and methods (such as locating and identifying mussels) and national declines in population sizes, there have been few opportunities to test for changes in growth among mussels following *C. fluminea* arrival. Using historically collected museum specimens, we investigated variation in annual growth of two mussel species (*Eurynia dilatata*, *Ptychobranchus fasciolaris*) through time. We hypothesized that *C. fluminea* reduced food availability for mussels, resulting in growth reduction after the arrival of *C. fluminea*. We tested our hypotheses using mussel shells collected in Big Darby Creek (Ohio), which contains a high freshwater mussel diversity and was colonized by *C. fluminea* in ~1987. Big Darby Creek has not experienced major changes in temperature, precipitation, or nitrogen and phosphorous loading concurrent with the arrival of *C. fluminea*. We evaluated individuals collected from 1982 to 2015 (representing individuals alive between 1935 and 2015) to evaluate mussels that lived before, shortly after, and over twenty years following the invasion. We thin-sectioned 36 ($n_{Eurynia}$ = 19, $n_{Ptychobranchus}$ = 17) shells, identified annual growth rings, and measured annual growth increments for each year of each individual's life using light microscopy and cellLens software. We used linear regression and an analysis of variance (ANOVA) to evaluate changes in age-specific growth before, during, and after *C. fluminea* arrival. We found that *Ptychobranchus fasciolaris* had no changes in age-specific body size and growth across the time series. Age-specific body size of *Eurynia dilatata* increased through time, but only for growth during the first five years of life. However, the start of this change predated the arrival of *C. fluminea*. These results suggest that changes in mussel growth over the eight decades have been variable and species specific. Our project also demonstrates the utility of historical shells in museum collections for evaluating shifts in mussel biology through time.

Funding source: Geological Society of America American Malacological Society

## TESTING EVOLUTIONARY HYPOTHESES OF THECIDEIDE BRACHIOPOD ORIGINS: HOMOLOGY, HOMOPLASY, AND HETEROCHRONY

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Thecideide brachiopods are curiously different from most other brachiopods: very tiny body size; short lifespans; live today in mostly cryptic, tropical habitats; first appear in the Upper Triassic. They are widely considered to be paedomorphic—most likely progenetic. However, their evolutionary origins are still unclear, despite considerable efforts to determine their ancestry among brachiopods. Proposing any hypothesis of heterochrony requires evidence of organism size and shape change over ontogeny and phylogeny; testing an assertion of progenesis requires data from multiple sources. Ideally, all data sources should indicate the same patterns of phylogenetic relationship, but in practice they often do not: character convergence, developmental changes in timing and rate, preservational biases, etc. can produce unexpected results. Which source(s) of comparative data—morphology, stratigraphy, or genetics—are the most trustworthy to test hypotheses of heterochrony? How do results from different methods of phylogenetic analysis compare? Early workers claimed that thecideides were derived strophomenates because of morphological similarity in their shell form and lophophore supports, despite a large gap in their stratigraphic ranges and differences in shell microstructure. Most recent conventional wisdom argues for descent from either punctate or impunctate spire-bearing brachiopods because spiralia are present in the putative earliest extinct thecideide (Thecospira), despite all later thecideides having brachial ridges supporting a ptycholophe lophophore. Based on single gene analyses (18S rDNA), thecideides may be most closely related to terebratulides, in apparent conflict with most morphological data. Recent transcriptomic evidence from a single taxon (Pajaudina) places them as sister to the long-looped Terebratellidina, within all terebratulides. These hypotheses conflict with one another—which is more easily rejected? We coded seven thecideide species for 100 morphological characters and added them to a newly constructed matrix with representatives from all major groups of rhynchonellate (neoarticulate) brachiopods (74 extant and extinct genera). Most surprisingly, and in conflict with historical assertions based largely on single characters and relative stratigraphic position, our preliminary analyses of morphological data, both parsimony and Bayesian analyses, place thecideides as emerging from the terebratulides, in agreement with the transcriptomic results. Fossilized birth-death process models will soon be completed to compare with earlier stratocladistic methods that endeavored to incorporate relative stratigraphic position into analyses of morphology. Focusing on single characters assumed to have particular significance in determining ancestry can be misleading—and has been so for well over a century. Long-held, entrenched assumptions are best tested with multiple sources of ever-newer and more robust data and methods.

Funding source: National Science Foundation

## BUGGING BACK IN TIME: THE BOTANICAL TANGO OF LA POPA'S EOCENE (CARROZA FORMATION; NUEVO LEÓN).

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Angiosperms are the most diverse group of vascular plants in current terrestrial ecosystems. Their appearance and diversification represent a determining evolutionary event in establishing modern terrestrial ecosystems related to their interactions with animals, including herbivory. In Mexico, studies of plant-insect interactions through fossil records are limited to the Paleozoic in the center of Mexico. However, a recent re-examination of angiosperm fossils from the locality La Popa has shown a high diversity of plant-insect interactions. Therefore, the locality can provide critical data to understand the dynamics of vegetation turnovers during the Cenozoic, expanding the latitudinal bias for this region. La Popa is in the northwest of Mexico in Nuevo Leon. It is part of the La Carroza Fm., is the youngest unit of the Difunta Group, dated based on ostreids to the middle Eocene. Eocene is an interval characterized by environmental changes, including increased temperature and $CO_2$ levels, known as the Paleocene-Eocene Thermal Maximum (PETM). The preliminary observations of the La Popa association show a high diversity of plant-insect interactions, which confirms the presence of complex ecosystemic relationships between plants and insects in the communities of the Eocene in La Popa. Around 1600 samples of leaves and fruit fossils of La Popa were collected for more than ten years and are kept in the collection of the

Paleobotany Laboratory of the Institute of Geology, UNAM. For the identification of interactions in La Popa, we follow the Functional Feeding Group-Damage Type (FFGs-DT) system of Labandeira et al. (2007), which categorizes interactions into three hierarchical levels: feeding class, which is based on how an insect uses its mouthparts about its host plant, FFGs, which defines the feeding style and DT which defines certain groups of damages that share similar size, shape, position, and plant response tissue. Although there is a protocol for the study of fossil interactions, the guidance and support of a specialist in the area are essential, especially for the numerical analysis of fossil material, including the calculation of the richness and rarefaction of DTs and FFGs as well as comparisons with other floras using rarefaction analysis, because until now plant-insect associations with statistical analysis have not been reported in Mexico.

## PRELIMINARY STATISTICAL STUDY OF LATE TRIASSIC ARCHOSAURIFORM TEETH FROM THE HOMESTEAD SITE, A MICROVERTEBRATE ASSEMBLAGE IN EAST-CENTRAL NEW MEXICO

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During the Triassic, archosaurs underwent dramatic diversification and, while their modern-day representatives have either simplified (crocodilians) or even lost (birds) their dentition, Triassic archosauriformes exhibit great dental diversity. Taxonomically assessing this diversity is difficult due to the isolated or fragmentary nature of fossil teeth. The Homestead (HS) site, in the Upper Triassic Garita Creek Fm of east-central New Mexico, yields thousands of teeth, bones, scales, and coprolites, most of microvertebrate (<1 cm) size. This is a relatively rare Revueltian (Norian) age microvertebrate site with the potential to illuminate patterns of Triassic archosaurifrom evolution. Past, largely qualitative, studies have shown that teeth are some of the most diagnostic specimens from these microvertebrate sites, but as specimens get smaller (<2 mm) identifications get more tenuous. Morphotypes based on qualitative observations may not account for, or be able to discriminate among, convergence or ontogenetic, positional, or other sources of variation. Simple linear measurements and other statistical analyses, often used on Cretaceous dinosaur teeth, also show insufficient separation. Non-metric Multidimensional Scaling (nMDS) analysis uses descriptive characters (e.g., binary traits) to create a table of quantitative data; attempting to show the pairwise dissimilarity between objects in a low-dimensional space. A striking feature of the HS microvertebrate assemblage is the large number of relatively low-crowned archosauriform teeth (crown height < 1.5x crown length). Our preliminary nMDS analysis (n = 25 teeth) identifies two clusters of short-crowned teeth. Cluster one (morphotype A) includes particularly short teeth, some with crown height shorter than basal length. These teeth are laterally compressed with a unique taper where the mesial/distal carina meets the root, and one of the most prominent traits is the presence of vertical ridges on the labial face. Another feature characteristic of morphotype A is an offset of the mesial carina, which affects the mesio-distal long axis. Cluster two (morphotype B) has denticles of most specimens being parallel to the basal surface and possessing a smoother labio-lingual surface. The most characteristic feature of this morphotype is the sudden change in angle in labio-lingual view at a single point along the mesial edge, the subtlety of this point varies across specimens, but basal to this point there are few, if any, denticles. These analyses also allow for more rigorous comparison to broadly contemporaneous microvertebrate assemblages, such as the Owl Rock Formation (Member) from northeastern Arizona, yielding superficially similar low-crowned teeth. We tentatively assign the Owl Rock specimens to morphotype A. In addition to incorporating more specimens, we plan to add more characters to further discriminate among tooth morphotypes.

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## THE EUROPEAN SIWALIKS: THE MIOCENE HIGH-RESOLUTION VERTEBRATE RECORD OF THE VALLÈS-PENEDÈS BASIN (CATALONIA, SPAIN)

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The multidisciplinary research carried out in the impressive Miocene Siwaliks vertebrate record has been taken as a model for the study of similarly long and continuous continental records elsewhere. Our team started applying an analogous approach to the Miocene record of the Vallès-Penedès Basin (Catalonia, Spain) about ten years ago in the framework of successive research projects that include comparisons with the Siwaliks as one of their main goals. The Vallès-Penedès is a paradigmatic area for the study of Miocene terrestrial vertebrate faunas of Europe. Thanks to systematic surveys and excavations since the 1940s, it is one of the most densely sampled Miocene basins worldwide. Its fossil record covers almost the entire Miocene and includes both large and small vertebrates, as well as some fossil plant sites. During the last decades, improvement in the taxonomic knowledge of the Miocene vertebrate faunas from this basin

has been complemented by detailed magnetostratigraphic and biostratigraphic studies, which enable high-resolution analysis of paleobiodiversity dynamics. The Vallès-Penedès terrestrial vertebrate record includes about 100 sites and more than 80,000 specimens (recorded as for January 2024), which are compiled in an online database using an ad hoc software which also can automatically compute species and specimen counts per taxon for a given site or time interval. Additional functionality to calculate paleobiodiversity metrics will soon be implemented. The quality of the Vallès-Penedès record is uneven, but it is excellent for key intervals including: the Mid-Miocene Climatic Optimum (~17–15 Ma); the middle/late Miocene transition (~12.5–11 Ma); and the so-called Vallesian Crisis (~10–8.5 Ma). The latter is a major turnover event in the European Miocene that implied the abrupt disappearance of most of the taxa adapted to warm and humid forested environments, such as hominoid and pliopithecoid primates, and their replacement by taxa better adapted to more open and drier habitats. However, our more refined paleobiodiversity analyses have shown that, at least for micromammals, this turnover event was likely protracted and merely appears as abrupt due to sampling biases. Simultaneously, new proxies for paleoenvironmental and paleoclimatic reconstruction are being applied, including mammal dental ecometrics, stable isotope analyses of tooth enamel of large and small mammals, as well as palynology and the study of plant remains. Future work will provide the first paleobiodiversity analyses involving multiple vertebrate groups and start comparing paleobiodiversity and ecosystem dynamics with those of the Siwaliks.

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## PALAEOECOLOGY AND *G. DORYSSUS* EVOLUTION IN A MIOCENE DIATOMITE PALEOLAKE WITHIN THE TRUCKEE FORMATION, HAZEN, NEVADA

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Commercial mining near Hazen, northern Nevada, exposed Miocene (ca. 10.3 Ma), lacustrine, varved diatomite deposits of the Truckee Formation. These extensively studied deposits are a productive source of stickleback fish fossils (*Gasterosteous doryssus*) spanning over 100,000 continuous years of accumulation. Here we present preliminary palaeoecological analyses of the lacustrine and terrestrial near-shore paleoenvironments covering over 24,500 years. Analysis of botanical microfossils (diatoms and phytoliths) and stable isotopes extracted from the diatomite matrix reveal patterns in paleoecology demonstrating fluctuating changes in water level, temperature, salinity, terrestrial biome, and lacustrine communities. The data also reveal possible environmental correlations with stickleback evolution and extinction.

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## UNSCRAMBLING THE OMELETTE—ISOTOPE INCORPORATION IN ANIMAL TISSUES AND METHODS FOR INTERPRETING ISOTOPE PROFILES IN TISSUES

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Some 25 years ago Dan Fisher with Dave Fox suggested that primary isotope inputs could be modified during processes such as maturation of enamel. Subsequent work on modern mammals shows that isotope incorporation can be affected by multiple metabolic pools that can have isotope turnover half-lives of up to 0.5 years, and that maturation of enamel varies from months in small mammals such as rodents to years for large mammals such as elephants or hippos. Therefore, seasonal or other dietary inputs have the potential to be attenuated in such a way that affects the amplitude, structure, and timing of apparent events as recorded by stable isotopes. We show examples different turnover half-lives for different isotopes in the same tissue, and different maturation parameters for different mammals. For the turnover processes involving metabolism, tissues record the previous diet or migration history and forward modeling can deconvolve such processes. Maturation processes result in diet histories being recorded in the post-initial-formation period and inverse modeling is a successful approach to determining the likely diet or migration history. In some cases, both processes are recorded in the isotope record and so both the "previous" and the "post-formational" histories complicate the interpretation of a time sequence of data. With sufficient understanding of the processes that complicate the isotope record, it is possible to reconstruct diet or migration histories that otherwise would give incomplete or false narratives concerning diet, physiological stress, or migration.

## ROLE OF REDUNDANCY AND ECOPHENOTYPIC VARIATIONS OF CORALS ON REEF STABILITY

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Scleractinian corals are capable of ecophenotypic variation, which positively impacts their survival. Today, we observe drastic changes in environmental conditions, and it is predicted that if the current rate of change continues, most reefs will perish. Here we analyze differences among adaptability of coral species from a functional perspective. We hypothesize that coral species that show ecophenotypic variation of growth forms would have a wider environmental niche and thus adapt to future climate changes better than the species that do not. Additionally, multiple corals species have similar morphologies thus similar functional roles potentially leading to functional redundancy. Functional redundancy is said to help in filling the ecological space, i.e., if one species that performs the same ecosystem function is lost, then others that belong to the same functional group could maintain ecosystem functioning. To test this hypothesis, ecoregions within the Caribbean province were set as the calibration area. Species occurrence data across ecoregions were extracted from GBIF (Global Biodiversity Information Facility) and AGRRA (Atlantic and Gulf Rapid Reef Assessment). A total of 56 species were identified. We categorized species into morpho-functional groups based on their growth forms. Environmental variables necessary for prediction were extracted from BIO-ORACLE and we used parameters such as light availability, pH, temperature, nutrient availability, dissolved oxygen, and current velocity. We compared differences among species suitability distributions of selected species for the present and future climatic scenarios. We used R 4.3.0 to run the maxtent algorithm with different calibration settings to create the candidates for species distribution models. For our pilot study, we compared the areas of acroporid species (branching morpho-functional group) and 7 species within the massive+encrusting group. We compared the distribution for 4 future climate change scenarios (RCP2.6, RCP4.5, RCP6.0, RCP8.5), and in each case, we saw a drop in area of suitability from the present day. To assess the potential of ecophenotypic variation, we compared the E-space (Environmental space) of massive+encrusting group with massive group, and the former was found to have a larger volume of E-space. We then compared the differences in the geographical area for 4 coral species within the massive morpho-functional group to test for functional redundancy. Though the morphology was similar, the distribution range is different for each species within the same morpho-functional group. However, there is a significant overlap between the Environmental space (E space) of the species within the massive morpho-functional group, indicating their similarity in ecology. Thus, our results not only indicate that there would be a reduction in suitable areas for most species but also that functional redundancy might not be providing an insurance effect as previously thought.

## A HIGHLY DIVERSE ASSEMBLAGE OF GIANT GROUND SLOTHS FROM HOYO NEGRO, QUINTANA ROO, MEXICO.

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Explorers documenting the labyrinthine cave systems near the east coast of the Yucatan Peninsula, Mexico, often encounter remains of mammalian megafauna, among which the most surprising and abundant is a remarkable diversity of the gravigrade Pilosa. Currently, five genera of giant ground sloths representing the Megalonychidae (3), Nothrotheriidae (1) and Mylodontidae (1) are known from those systems while a sixth, the Megatheridae has been found in northern Belize. The nothrothere, *Nothrotheriops shastensis* and the megalonychid *Xibalbaonyx* are the taxa most often encountered in the now-submerged cave passages of Quintana Roo and elsewhere in the Yucatan. Most of the cave finds are isolated individuals, but multiple members of most of these genera have been found in Outland Cave, which includes the immense natural trap, Hoyo Negro. Representatives of four genera from three families have been found, including multiple individuals (2 each) of *Nothrotheriops shastensis*, *Xibalbaonyx* cf. *oviceps*, and *Nohochichak xibalbahkah* on the floor of the great pit and one each of *Nothrotheriops* and an as-yet-undescribed new genus of mylodont in the connecting tunnels. All but the two *Xibalbaonyx*, which are more weathered and/or dispersed, are represented by articulated or closely associated complete skeletons. Healed traumas are common. One animal of each genus exhibits healed trauma around the head or shoulder, suggestive of either attack by predators or possibly the result of violent competition between males for mating opportunities that characterizes modern tree sloths. Radiocarbon dates on at least one member of each genus place the animals in the late Rancholabrean, but they fall into a distinct chronological sequence. *Xibalbaonyx* is the earliest, followed by *Nohochichak*, then the mylodont, and finally *Nothrotheriops*. If we consider the habitat preferences attributed to the different families the megalonychids, a group generally labeled browsers, the first pair would appear to represent a sequence of forested habitats with *Xibalbaonyx* occupying the older forest type. Mylodonts, most often characterized as grazers, might represent a grassland or savannah ecosystem, followed by the more arid-adapted *Nothrotheriops* in a desert-like environment. This sequence is not inconsistent with the vegetation history of the nearby Peten region. As we sample and date more specimens of a wider range of taxa from the region's submerged caves and establish a chronology of mammalian communities, the interspecific relationships among the myriad species of Yucatan sloths and their relationship to the changes in the region's paleoecology will become clearer.

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## INTRODUCING THE HOYO NEGRO VERTEBRATE FAUNA, QUINTANA ROO, MÉXICO

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Over the last 30 years, recreational divers exploring the extensive submerged cave systems of the eastern Yucatan Peninsula have discovered a trove of Pleistocene vertebrate remains. The most spectacular among these finds is the natural trap of Hoyo Negro (HN), in Outland Cave of the Sac Actun system. This site has been under investigation since 2007 by an international team of scientists using state-of-the-art visualization and recovery methods, working under the auspices of the Subdireccion Arqueologia Subacuatica, Instituto Nacional de Antropologia e Historia, Mexico. Formed at the confluence of three large tunnel systems, HN is a bell-shaped, 64-meter-diameter collapse chamber that plunges from 12 to 50 meters below sea level (mbsl). Below 39 mbsl, the walls and floor of HN are littered with mammal bones, most in remarkable condition, although lacking proteins and DNA. Animals are widely enough scattered on the floors of the pit and passages that individual animals can be isolated. At least 59 individual mammals of 19 genera are recognized, exclusive of mice and bats, including the extinct *Cuvieronius*, *Arctotherium*, *Protocyon*, *Smilodon*, and four genera of giant ground sloth. These comprise most of the collection, which also includes the near-complete skeleton of a late adolescent human female. This is the Hoyo Negro vertebrate fauna. Taphonomic analyses, which addressed patterns of bone breakage, weathering, patination, and anatomical distributions of individual skeletons, indicate all larger mammals fell into and decomposed in water when a shallow pool occupied the floor below 39 mbsl. Although the pool was often empty, bone distributions reveal that no animal fell in while the site was under that condition; it was almost certainly the quest for water that drew the animals to their deaths. The history of water levels in the Caribbean Sea, in part established through studies of HN sediment, limits the age of the fauna between 70 and 10 ka. Radiocarbon and uranium-thorium dating of bones and enclosing calcite, the former used with consideration of a local reservoir effect, narrow the age of recovered fossils to between ~40 and 11 ka. Three chronological groupings of taxa are tentatively recognizable, beginning with occupants of a forested environment, followed by denizens of more open habitats in the full glacial through deglaciation, and finally an impoverished community after megafaunal extinctions and return of the tropical forest. Hoyo Negro is a spectacular locality, unique in many ways. Ongoing research has revealed two new genera/species of giant ground sloth, *Nohochichak xibalbahkah* and a yet-to-be-revealed mylodont, the first record of the South American carnivorans *Arctotherium wingei* and *Protocyon troglodytes* north of the Isthmus of Panama, the best-preserved specimens of *A. wingei*, the first complete cranium of *Smilodon fatalis* from Mexico, and the most complete of the earliest human skeletons of the Western Hemisphere.

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## PARASITIC INTERACTIONS AND THEIR RELATIONSHIP TO ENVIRONMENTAL CHANGE: INSIGHTS FROM THE OLIGO-MIOCENE MARINE MOLLUSCAN ASSEMBLAGES OF WESTERN INDIA

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Antagonistic biotic interactions, such as predation and parasitism, played a crucial role in evolution in deep time. Unlike other such interactions, parasitism remains poorly understood in deep time. The record of parasitism in the fossil record is far from complete and is primarily dominated by the records of non-marine deposits. Bivalve mollusks are ubiquitous in the marine ecosystem, have an excellent fossil record, and often preserve traces of interactions with their parasites. Even though many parasites do not leave body fossil records, they induce characteristic malformations in the shells of their bivalve hosts. The host-parasite dynamics in fossilized ecosystems can be evaluated using such characteristic traces. In recent marine ecosystems, extant parasites have been known to respond to changing temperatures and salinity of the ocean. It is yet to be established if the host-parasite dynamics also responded to changes in the physical environment in deep time. The Oligo-Miocene shallow marine deposits of the Kutch Basin witnessed changes in the climate and tectonic setting. Using the bivalve assemblages from chronostratigraphically constrained Oligo-Miocene strata, we evaluated the evolution of host-parasite interactions through a period of 9 Ma. Five major types of parasitic traces, including Entobia, Caulostrepsis, Maeandropolydora, Clionoides, and indeterminate Polychaete traces, are present in the assemblage. The polychaete trace is the most dominant, accounting for more than half of all traces, followed by Entobia. These interactions are host-specific. Only four families—Ostreidae, Pectinidae, Gryphaeidae, and Anomiidae—of sixteen bivalve families record such infestation. Except for the family Anomiidae, the infested

individuals are significantly smaller than the uninfested ones, implying a reduction in host fitness due to infestation. The evenness of the host community shows a negative correlation with that of the community from the shellbeds. We see a change in infestation frequency from the reefal community of the late Oligocene to the siliciclastic-dominated shallow marine environment of the early Miocene. A combination of temperature and salinity explains the infestation patterns; higher infestation frequency is observed in younger shellbeds of the Miocene, where the inferred salinity was higher than the other shellbeds. A better understanding of the role of the physical environment on host-parasite interaction is critical to evaluate their dynamics in the past and provide insight for future prediction of parasitic interaction in the changing oceans of modern times.

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## BIOCALCIFICATION STRESS AND FAUNAL TURNOVER AT THE APTIAN-ALBIAN BOUNDARY

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The Early Cretaceous Aptian-Albian boundary interval (AABI) witnessed a diverse array of evolutionary and environmental disruptions, including Oceanic Anoxic Event 1b (OAE1b) and a major extinction of planktic foraminifera. These events played out against a backdrop of large-scale climatic and tectonic reorganization. Rapid global warming began a long-term transition that would give rise to the mid-Cretaceous greenhouse, while emerging ocean gateways due to the breakup of Gondwana began to reshape global circulation. The most complete record of the AABI has been preserved at Deep Sea Drilling (DSDP) Site 511 (Falkland Plateau, South Atlantic). High-resolution studies of planktic foraminiferal assemblages at Site 511 have provided evidence for major morphological turnovers across the AABI. Late Aptian assemblages mostly comprise large and heavily-calcified tests, while earliest Albian assemblages are almost exclusively composed of minute and thin-walled individuals. These changes coincide with the disappearance of 70–80% of Aptian planktic species. Such extinctions have been globally documented at other deep-sea sites and continental localities. Geochemical analyses have had limited success in resolving the causes of this planktic foraminiferal extinction. Stable carbon isotope measurements show significant carbon cycle perturbations associated with OAE1b—in particular, a negative $\delta^{13}C$ excursion at the stage boundary attributed to volcanic $CO_2$ degassing. Meanwhile, stable oxygen isotope measurements at the boundary yield negative $\delta^{18}O$ values that imply unrealistically warm temperatures, complicating interpretations of geochemical data. Stable calcium isotope measurements of carbonates offer a novel tool for evaluating past environmental changes, including potential biocalcification stress. Only a few studies have examined foraminiferal $\delta^{44/40}Ca$ values, which appear sensitive to ocean acidification via biological compensation. Dramatic shifts in the abundance and morphology of planktic foraminifera across the AABI suggest that the $\delta^{44/40}Ca$ proxy may aid in understanding the drivers and consequences of evolutionary changes during this interval and their association with OAE1b. We present high-precision $\delta^{44/40}Ca$ TIMS measurements of Aptian-Albian planktic and benthic foraminifera from DSDP Site 511. These records are paired with a preliminary $\delta^{44/40}Ca$ record of AABI bulk carbonates from Site 511—together comprising the first calcium isotope records for this interval. These measurements will be used to test the hypothesis of biocalcification stress in response to ocean acidification and a shoaled CCD during the AABI. Such findings could further advance the AABI and OAE1b as ancient analogs for modern global warming and ocean acidification.

## HORMONES PRESERVED IN TUSKS ENHANCE LIFE-HISTORY ANALYSES OF PROBOSCIDEANS PAST AND PRESENT

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Steroid hormones incorporated in proboscidean tusks provide accurate chronological records of systemic endocrine activity that give insights into individual life histories. Previously, fine-scale serial samples of tusk dentin analyzed using liquid chromatography with tandem mass spectrometry (LC-MS/MS) revealed annual surges in testosterone associated with musth in a modern African elephant (*Loxodona africana*) as well as a Siberian woolly mammoth (*Mammuthus primigenius*) that lived 35,000 years ago. Subsequent tests focusing on other specimens and steroids demonstrate the potential for these analyses to have far-reaching applications. Our experiments consistently detect testosterone, progesterone, and androstenedione in modern elephant tusks and permafrost

woolly mammoth tusks from the late Pleistocene of Siberia. In addition to revealing episodes of musth in adult males, these steroid data support a hormone-based approach to determining an individual's sex from dental specimens. Furthermore, pilot analyses of tusks from captive elephants with known calving histories suggest that pregnancies could be recorded in dentin-associated steroids. Other steroids, including cortisol, cortisone, estradiol, and aldosterone, can be detected in some dentin samples, and their quantification may be enhanced with further instrumental optimizations, identification of metabolites more abundant in dentin, and steroid derivatizations. Recent analyses have shown that certain steroids can even be recovered from mid-latitude mastodon (*Mammut americanum*) tusks preserved in late Pleistocene pond sediments. This discovery may lead to an expansion of the scope of applications for dentin-associated steroid measurements from pristinely preserved permafrost mammoth remains to remains preserved in less favorable, temperate conditions. Hormone analyses of woolly mammoth and American mastodon tusks show promise for enhancing proboscidean life-history inferences in support of efforts to evaluate the dynamic relationships between life-history patterns, environmental stress, and hunting by humans. The methods could also be used to track changes in historic elephant populations, providing insights that would inform conservation efforts. Our results demonstrate the potential utility of both modern and ancient dentin for wide-ranging studies of hormones in paleontology, zoology, ecology, and wildlife conservation to investigate ontogenetic development, reproduction, behavior, and stress in extant and extinct mammals.

## FLUVIAL MOBILITY OF HADROSAUROID DINOSAUR SKELETONS: EXPERIMENTALLY TESTING TRANSPORT POTENTIAL IN EXTINCT REPTILES

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The fossil record is our primary window into understanding extinct ecosystems, and understanding the taphonomic processes that shape it is integral to interpreting the record of extinct life. Bones preserved in fluvial environments make up a major part of the terrestrial vertebrate fossil record, and unsteady state flows (flooding, crevasse splays, debris flows) are often invoked as drivers of mobility and burial of skeletal elements. Actualistic experiments have explored the fluvial taphonomy of mammal skeletons, but other terrestrial vertebrates, especially extinct clades, have only been sparingly studied. Because of this, some researchers have raised concerns that the morphologies of non-mammalian bones would result in different hydrodynamic properties and mobility patterns. Being known from extensive remains throughout the Cretaceous and across the globe, hadrosauroid dinosaurs make an ideal group for this kind of taphonomic study. Here we investigate the mobility of postcranial bone models of the hadrosauroid, *Eolambia caroljonesa*, and articulated and disarticulated skull elements of *Edmontosaurus regalis*, using 3D-printed bones weighted to maximum and minimum densities feasible for disarticulated bones in a large-scale flume setup. We find that under unsteady state flow conditions at two discharge levels, our bone models sort into statistically significant transport groups based on transport distance. These groups are broadly similar to Voorhies Groups in sheep, although the modes of mobility and groups certain elements sort into, such as the ilium, ischium, and pubis, is variable due to differing morphologies from the sheep skeletal elements we tested under the same conditions. While distance-based groups were evident among the more extremely weighted hadrosauroid bones, such groupings were less clear among the more continuously distributed sheep bones. Voorhies Groups were originally constructed from qualitative observations on the order and mode of bone movement rather than transport distance or exact competent velocity. In the quantitative context of our study, it was not possible to match the sheep skeleton to the originally established Voorhies Groups in a statistically significant and non-arbitrary manner due to their somewhat continuous distribution of transport distances. We also find that both shape and mass were significantly correlated with transport distance by both the model hadrosaur postcrania and the sheep bones, which is suggestive that travel distance in absence of other obstacles relies on both of these characteristics. We additionally observe modes of possible burial via scouring and redeposition of sediment on the downstream side of bones, which together with bedform movement could work to fully bury skeletons even over relatively short timescales.

## PLEISTOCENE MARINE FISH FAUNA FROM THE MASUDA FORMATION OF TANEGASHIMA ISLAND, SOUTHWEST JAPAN

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In 1929, two fossil fishes were found in Sumiyoshi, Tanegashima Island of Kagoshima Prefecture, Japan. These two fishes were described as new species, *Clupea tanegashimaensis* and *Percichthys chibei*, although the former was later reassigned to a different genus *Clupanodon*, which currently is found only in Southeast Asia. Later, in the summer of 1988 and 1989, many fossil specimens were excavated from

the Sumiyoshi area where the first two fishes were collected. The fossil assemblage contains various taxa including plants, invertebrates, and vertebrates, such as amphibians, mammals, and many fishes. Here, we provide an overview of the fish fauna from this locality. The fossil assemblage was recovered from the Katanoyama Member of the Masuda Formation, which consists of shallow marine deposits of lower Pleistocene age (ca. 1.3 Ma.). Based on the fossil assemblage, the depositional environment is considered to have been an inland bay where the incurrent water from the river made the area brackish. Currently, more than 20 species of fishes have been recognized, including clupeiforms, anguilliforms, osmeriforms, beloniforms, mugiliforms, perciforms, gobiiforms, pleuronectiforms, and tetraodontiforms. *Cupanodon tanegashimaensis* and gobiiforms are abundant. We have identified several specimens to be possible undescribed species possessing unique characters that are not seen in their extant relatives. For example, tetraodontid specimens are assigned to the genus *Takifugu*, but the morphology of the caudal skeleton is unique compared to the extant species of *Takifugu*. Also, we identify osmeriform specimens as the genus *Plecoglossus*, which contains only one living species with several subspecies. The fossil specimen differs from extant *Plecoglossus* in having a distinct caudal skeleton. Lastly, we classify nearly a hundred gobiiform specimens into several groups and recognize some similarities and differences from extant species. The fossil fish assemblage of Tanegashima Island expands our knowledge of the origin and transition of the current ichthyofauna of Japan and the Northwest Pacific Ocean since the early Pleistocene.

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## EARLY (WASATCHIAN) AND LATE EOCENE (CHADRONIAN) CREODONT AND CARNIVORAMORPHAN NICHE OCCUPATION IN NORTH AMERICA

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Today, the Carnivora comprise the only group of carnivorous mammals in North America. However, during the Paleogene (66–23.03 million years ago [mya]) the carnivorous mammal niche was also occupied by Oxyaenida and Hyaenodontida (a polyphyletic group referred to as "creodonts") as well as extinct members of the Carnivoramorpha (Miacoidea and Viverravidae; Mesonychia is not considered here). "Creodonts" emerged during the Paleocene and comprised the dominant clade of carnivorous mammals. They, however, underwent a steady decline in diversity from the late early Eocene (~50 mya) until their North American extinction during the Oligocene; by the beginning of the Oligocene, only a single genus (*Hyaenodon*) remained. Carnivoramorphans, however, diversified, during the mid to late Eocene. The near simultaneous decline of the creodonts and diversification of carnivoramorphans suggests that biotic interactions (i.e., resource competition) may have been played a role. To test this hypothesis, we use a community ecology approach, comparing carnivoramorphan and creodont niche occupation between the early and late Eocene at the locality scale. To assess niche occupation, we scored body mass (a measure of prey focus mass), relative carnassial blade length (a measure of degree of carnivory), and foot posture (a measure of locomotor behavior) for cooccurring species at two early Eocene (Wasatchian) and two late Eocene (Chadronian) localities. We find that Wasatchian taxa clustered together in morphospace (i.e., they show similar degrees of carnivory and similar locomotor behavior), occupying a range of body masses. The oxyaenids occupied the largest body size niche, overlapping little with the carnivoramorphans and hyaenodontids. By the Chadronian, taxa were more distributed in morphospace and the morphospace emptied by the extinction of the Oxyaenids was occupied by both carnivoramorphans and hyaenodontids. The pattern of change from the early to late Eocene is most consistent with enhanced extinction risk among the oxyaenids relating to factors unrelated to competition with carnivoramorphans. While biotic interactions may have played out from the late Eocene through early Oligocene, we do not find evidence that creodont extinctions during the early through late Eocene were likely to have been driven by competitive interactions. Investigations of niche occupation on larger spatiotemporal scales in a community ecology context may further clarify the drivers of creodont extinction in North America and globally.

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## MG/CA OF CRINOIDS AND PLANTS IN COAL BALLS FROM THE MID-MOSCOVIAN THROUGH KASIMOVIAN OF THE LATE PALEOZOIC MIDCONTINENT SEAWAY

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Coal balls are carbonate concretions in coal that preserve Late Paleozoic plants in cellular detail. Despite their importance to paleobotany and paleoecology, the salinity of coal ball

swamps remains controversial. Late Pennsylvanian coal balls from four North American localities (Dalton coal, Midland Basin; Rich Hill coal and Cliffland coal, Midcontinent Basin; Calhoun coal, Illinois Basin) contain crinoid fossils and peat permineralized by high-Mg calcite (HMC). The presence of early HMC cement in coal balls suggests a marine origin for these concretions. Seawater has more Mg than freshwater, and HMC seldom forms in freshwater depositional settings. However early HMC cement in coal balls has also been interpreted as freshwater microbial carbonate. Crinoids in coal balls lived in shallow marine communities close to the coast and were transported into the swamp by storms. They provide direct evidence of the Mg/Ca ratio of seawater adjacent to coal-ball swamps, because crinoids are marine organisms, and the Mg/Ca ratio of crinoid skeletons reflects the Mg/Ca ratio of the seawater they lived in. To test whether coal-ball crinoids preserve their original Mg/Ca values, we compared Mg/Ca values of well-preserved crinoids in coal balls with the Mg/Ca values of crinoids from nearby marine facies of the same age. Both marine and coal-ball crinoids contain similar amounts of Mg: coal-ball crinoids average 123.6 Mg/Ca mmol/mol, within the range of crinoids from the North American midcontinent-shelf marine facies (107.8–141.8 Mg/Ca mmol/mol). Crinoids in coal balls reflect the Mg content of epicontinental seawater adjacent to the swamp, they also provide information about the salinity of pore water in the swamp during coal-ball formation. Experimental studies show that abiotically-precipitated HMC has higher Mg/Ca than echinoderm skeletons grown in seawater with the same Mg/Ca ratio. If coal balls formed in marine pore-water, they should have early HMC cement with higher Mg/Ca values than crinoids from the same coal balls. To test this hypothesis, we compared the Mg/Ca of crinoids in coal balls with the Mg/Ca of early HMC cement in plant fossils from the same coal balls, and with the Mg/Ca of early HMC in plant-only coal balls from the same deposit. We tested plant-crinoid and plant-only coal balls separately because plant-crinoid coal balls typically occur at the top of the coal, and may have formed in different pore water than plant-only coal balls. The earliest widespread calcite cement in coal balls from all four localities is HMC that has Mg/Ca than crinoids from the same deposit, as well as high Sr/Ca and Na/Ca values, indicating formation from marine or brackish pore water. Second-generation cement in these coal balls is low-Mg calcite (LMC) with low Na/Ca values, suggesting freshwater diagenesis and cementation followed the formation of marine HMC. Coal balls from all four localities likely formed in the marine-freshwater mixing zone.

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## DISPARITY IN CRANIAL TELESCOPING IN WHALES (ARTIODACTYLA: CETACEA) THROUGH TIME

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Whales have some of the most bizarre skulls in Mammalia, much of which is a result of a process called cranial telescoping. Cranial telescoping describes the overlapping and compression of cranial bones, associated with the posterior movement of the external nares. At least two modes of cranial telescoping are evident in whales: Prograde telescoping, dominant in baleen whales (mysticetes), where posterior elements of the skull shift anteriorly, and retrograde telescoping, dominant in toothed whales (odontocetes), where anterior elements of the skull shift posteriorly. Although morphometric variation in cranial shape related to cranial telescoping has been documented in whales, few studies have tried to assess specifically how disparity in cranial telescoping has shifted over time and between the two major living suborders of whale. To address these questions, I assembled a cladistic matrix of morphological characters, pruned from previous phylogenetic analyses, that relate directly or indirectly to cranial telescoping. This character matrix consists of 97 characters coded for 205 taxa, including 24 archaeocetes, 77 mysticetes, and 104 odontocetes, spanning the evolutionary history of whales. I then converted this character matrix into a distance matrix and performed principal component analysis as well as calculated three disparity metrics: mean pairwise distance, sum of ranges, and sum of variances. The PCA identified three major clusters of whales within the morphospace: ancestral archaeocete whales and stem mysticetes, crown mysticetes, and odontocetes. Archaeocete and stem mysticetes broadly overlap, although aetiocetids and eomysticetids occupy a separate but adjacent region of the morphospace. Within odontocetes, the early diverging xenorophids, simocetids, and agorophiids occupy a region of the morphospace between crown Odontoceti and archaeocetes; the only crown odontocete to occupy this region is the bizarre walrus-dolphin *Odobenocetops*. By examining the morphospace over time, we can observe it significantly increase in size during the Oligocene, with odontocetes and mysticetes becoming more divergent from one another over time over the course of the Neogene. Disparity metrics show sharp increases in disparity in the late Eocene and early Oligocene for all whales. After this point, Odontocetes exhibit higher disparity than mysticetes, with disparity relatively constant through the rest of the Cenozoic. Retrograde cranial telescoping is linked to echolocation, and the importance of echolocation may have accelerated the evolution of cranial telescoping and constrained its further modification. Mysticetes show lower disparity related to cranial telescoping over the Cenozoic, with a second major increase in disparity in the Late Miocene. This change in disparity occurs at the same time mysticetes greatly increase body size, both trends likely driven by increases in coastal upwelling and productivity.

## A PRELIMINARY REPORT OF A LOWER CARBONIFEROUS (MISSISSIPPIAN: TOURNAISIAN) CHONDRICHTHYAN FAUNA FROM THE "BLUE RIDGE ESKER" LOCALITY (MARSHALL FORMATION) OF MICHIGAN, U.S.A.

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The "Blue Ridge Esker" deposit in Michigan's Lower Peninsula is a Pleistocene glacial deposit apparently created by glacial meltwater during the Last Glacial Maximum. Within this esker are boulders that were plucked by the glacier from an outcrop of the lower Marshall Formation, a Lower Carboniferous marine sandstone, to the north. From the literature on the Marshall Sandstone, a diverse invertebrate fauna is known, whereas vertebrate fossils have been reported but have gone largely undescribed. Despite this, cobbles and boulders at the Blue Ridge Esker locality preserve a diverse assemblage of marine vertebrates, with many of the teeth and skeletal elements preserved as impressions in matrix. The vertebrate fauna of this locale includes apex predators such as *Saivodus striatus* (Chondrichthyes: Elasmobranchii), as well as durophagous chondrichthyans such as *Deltodus*, and an unknown psammodontiform. This assemblage demonstrates marine fishes migrated into the Michigan Basin in or before the Silurian Period and existed long after the End Devonian Extinction event, which appeared to truncate the biostratigraphic ranges of all previously known vertebrate taxa. While this fauna is typical of the lower Carboniferous marine realm, many of these animals are more often recovered from marine shales and carbonates than sandstone. It is possible that a population dense, but stratigraphically brief, assemblage of nautiloid and ammonoid cephalopods, bivalves, and brachiopods (all recovered alongside vertebrate fossils) formed a large enough component of the local food web to allow vertebrates to persist in the Michigan Basin at this time.

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## ONTOGENY AND CONSTRAINTS IN THE EVOLUTION OF AMMONOID SHELL COILING

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The coiled shell of ammonoid cephalopods has a first-order influence on hydrodynamic interactions with the environment, with implications for the biology and ecology of the organism. Over their 350 million-year history, ammonoids evolved a wide range of coiling morphologies; however, the variety of planispiral forms was greatest in the Paleozoic and greatly reduced in the Jurassic and Cretaceous. This reduction in disparity occurred because depressed forms with large whorl width rarely evolved in the Jurassic or Cretaceous. However, why those forms rarely evolved is more puzzling, and the roles of functional, constructional, and developmental constraints are unclear. To investigate the contribution of developmental constraints, I examined ontogenetic shape trends from digitized ammonoid whorl sections. Disparity is lower among Jurassic–Cretaceous ammonites at all size classes, from post-hatchlings at diameters of only a few millimeters to adult sizes, despite pronounced shifts in ecology and function during growth. Planispiral ammonoids exhibited strong preferential shape change during ontogeny, almost always towards more compressed shells with slightly greater whorl overlap. As a result, adult shell shape is strongly constrained by the range of available juvenile forms. Jurassic–Cretaceous ammonites lacked juvenile shells with large whorl widths, and the rare depressed adult forms evolved through an atypical ontogenetic pathway. This suggests that developmental constraints at the earliest ontogenetic stages played an important role in disparity of shell coiling in planispiral ammonoids.

## YOU'VE GOT A FRIEND IN ME—20 YEARS IN THE FRIENDS OF THE UNIVERSITY OF MICHIGAN MUSEUM OF PALEONTOLOGY

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The Friends of the University of Michigan Museum of Paleontology ("The Friends") is an active group passionate about paleontology, focused on charitable, educational and scientific work. "The Friends" is a 501(c)(3) non-profit volunteer organization chartered to support the University of Michigan Museum of Paleontology (UMMP). Founded in 1971 by Dr. Robert Kesling (former UMMP curator and director), Ruth Chilman, and Jean Wright, these three individuals laid the foundation of collaboration between professional and avocational paleontologists in Michigan. During my twenty years as a member and officer of "The Friends," the professional and avocational members have been tremendous mentors. After my first "Friends" field trip to Alpena, Michigan, John and Mike Topor (2011 Strimple Award winners) encouraged me to donate my first scientifically important fossil find for research—the second known specimen of Devonian cystoid, *Lipsanocystites oblatus*. The Topor brothers and Joe Koniecki (2022 Strimple Award winner) are experienced fossil preparators and advised me with the design of my fossil preparation room. They have also shared best practices and

techniques for fossil preparation and curation. My passion for paleontology continued to develop and there were multiple opportunities to collaborate with professional paleontologists. My professional career as an engineer allowed me access to a Scanning Electron Microscope (SEM) which was used to image pyritized *Triarthrus eatoni* trilobite eggs to support Dr. Thomas Hegna's 2016 paper. My proudest moment as an avocational paleontologist was discovering a new species of crinoid. Dr. William Ausich described the specimen and honored me with the name *Jovacrinus clarki*. Since there is only one known specimen, Dr. Jen Bauer shared a 3D scan so a printed *J. clarki* can be in my collection. Over the years as new members have joined "The Friends," my role has evolved from mentee to mentor. "The Friends" continue to embrace the legacy of Kesling, Chilman and Wright, fostering the next generation of professional and avocational paleontologists.

## US FOSSIL PARKS AS PALEONTOLOGICAL RESOURCES: 21ST CENTURY CHALLENGES FOR PUBLIC FOSSIL COLLECTING AND EDUCATION

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Fossil parks provide unique venues within the United States where, for a small fee, visitors may collect and retain a small number of personal fossils while also learning about important geological constructs such as geological time, biodiversity, evolution, and climate change. These sites bridge informal collecting locales and protected geoheritage areas while promoting sustainable collecting; at sites where visitors may uncover scientifically important specimens, fossil parks enact protective measures to ensure that these specimens are available to future researchers. When effectively implemented, fossil park experiences result in meaningful learning, promotion of public stewardship, and visitor awareness of critical issues facing the planet. Therefore, fossil parks contribute to the United States' paleontological resources primarily through public education: increased visitor understanding can create public stakeholders for US fossil resources and promote citizen science. However, challenges exist for both fossil parks' sustainable public collecting opportunities and educational outreach. Fossil parks vary not only in the fossil types and geological age of their strata, but also in their size, park administration, funding sources, and visitors' opportunities to learn. Often, the site's funding and its continuity are not guaranteed, and a fossil park's science education content may not align with local religious groups' ideologies and/or political views. A published inventory of fossil park sites may contribute to public awareness, geotourism, and a viable future for these unique public collecting and educational venues.

## ORIGIN AND STRATIGRAPHIC CONTEXT OF LOW-DIVERSITY SHELL BEDS: A CASE STUDY FROM LATE TRIASSIC AOTEAROA NEW ZEALAND

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Shell lag deposits are common components of transgressive marine systems, and the internal structure and context of thick shell beds can reveal the dynamics of condensational sedimentation regimes. Here these principles are applied to the Norian-age shell beds of the Murihiku Supergroup from Aotearoa New Zealand and aid in the distinction of larger stratigraphic patterns across Norian deposits in the North and South Islands. Both the North and South Islands of New Zealand contain extensive Norian deposits; however, measurable outcrops are rare making sequence stratigraphic interpretation challenging. In light of this, the more easily found dense shell beds of the Murihiku Supergroup provide a potential window into the broader depositional systems of the basin. In both the North and South Islands two distinct intervals of shell bed accumulation are interpreted from observed outcroppings, each formed by a single, fairly endemic, bivalve genus. The lower Otamitan (New Zealand Stage) shell beds are dominated by *Manticula* with a very fine silty sandstone matrix and, where visible, first appear with a sharp base overlying siltstone deposits. Otamitan-age shell beds become interbedded with less to non-fossiliferous fine sandstone beds up section, potentially indicating a change from a more starved shelf to dynamic bypassing, and eventually give way to interbedded sand and siltstones with fewer fossiliferous beds. The upper Warepan shell beds are composed almost entirely of monotid bivalves with a very fine to fine sandstone matrix and sharply overlie the Otamitan-age interbedded sand- and siltstone beds. Monotid bivalves are very thin-shelled, yet exhibit little damage in the shell beds, with most shells disarticulated but often whole indicating the likely influence of gentle winnowing and *in situ* reworking of sediments to produce these dense shell beds. Warepan shell beds follow a similar depositional pattern to the Otamitan shell beds where they become interbedded and ultimately disappear up-section. Both the thickness of the Warepan shell bed interval as well as the total thickness of Warepan deposits varies significantly across the North and South Islands, but where the Otamitan–Warepan contact is present the abrupt appearance of Warepan monotid shell beds is consistent. Shell bed occurrences in the context of surrounding sedimentary units can provide clues toward the placement of major sequence stratigraphic surfaces, which has important implications for interpreting the diversity dynamics in a region. The identification of two distinct periods of significant sedimentary condensation allows for the identification of a probable sequence boundary at the contact of the Otamitan strata and overlying Warepan shell beds, and clarifies the abrupt nature of the monotid take-over in New Zealand.

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## A NEW TAPHONOMIC MODEL FOR THE MAZON CREEK LAGERSTÄTTE: UNCOVERING THE IMPACT OF PALAEOGEOGRAPHY ON SOFT TISSUE PRESERVATION

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Understanding the preservation of soft-tissues is vital for accurately reconstructing ancient organisms. 'Exceptional preservation' of soft tissues is rare, and restricted to specific short-lived depositional regimes (Konservat-Lagerstätten), which are vital 'windows' into the geological past. Over the last three decades, taphonomists have designed investigations, often using decay experiments, to elucidate the timing and patterns of preservation in Lagerstätten, allowing bespoke taphonomic models to be created. However, despite considerable advances in the field, unifying taphonomic models for Lagerstätten are challenging, especially because, even within a taxon, variations in preservation can make each fossil appear to have a unique taphonomic trajectory. The Carboniferous Mazon Creek Lagerstätte (Illinois, U.S.A.) is one such fossil bed, where a diverse assortment of late Carboniferous marine and terrestrial animal fossils, including polychaetes, polyplacophorans, lampreys, fish, sharks, amphibians, and reptiles, have been described, preserved within siderite concretions (iron carbonate). Both recalcitrant (e.g., bone, teeth) and soft-tissues (e.g., integument, organs, and pigments) are reported to preserve, yet the mode of preservation is poorly understood and there is considerable variation in intra-taxon preservational fidelity. Here, we present the first taphonomic investigation designed to elucidate the controls on exceptional preservation in siderite concretions, utilising museum collections, fieldwork, geochemical analyses (SEM-EDX and XRF), and decay experiments. Our results demonstrate key patterns in preservation across taxa, and we present a general model for concretionary siderite preservation. We also quantify, for the first time, that the variation in preservation of soft-tissues within a single taxon in the Mazon Creek Lagerstätte is controlled by the interaction between decay and palaeogeography, particularly proximity to the palaeo-coastline. Our results demonstrate that palaeogeography is an undervalued environmental control on soft tissue preservation and has important implications for future investigations of Konservat-Lagerstätten.

## *HESLERODOIDES* (CHONDRICHTHYES: ELASMOBRANCHII: CTENACANTHIFORMES) FROM THE PERMIAN RED EAGLE LIMESTONE OF KANSAS

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The Red Eagle Formation is a marine sequence of limestones and shales. The formation's members define the Carboniferous-Permian boundary in the American Mid-Continent, and from the Bennett Shale Member (Permian: Asselian), a tooth apparently belonging to the order Ctenacanthiformes was recovered near Manhattan, Kansas. Diagnostic features of this tooth match specimens referred to the species *Heslerodoides triangularis*, which has previously been described from the Carboniferous of Russia, Brazil, and Belgium. This is the farthest known westward occurrence of this genus, the first ever occurrence of *Heslerodoides* from the northwest hemisphere, and from the North American continent. This fossil was found in a vertebrate assemblage containing microfossils of other piscivorous vertebrates such as *Glikmanius myachkovensis*, *Stethacanthus sp.*, *Denaea sp.* and an unknown predatory palaeonisciform (Actinopterygii). This new occurrence illustrates that, despite radical climate change at the end of the Carboniferous, many marine vertebrate communities were able to maintain high species richness in several habitats. The occurrence of this genus in the United States is reminiscent of the distributions of other small-bodied predators from this time, such as *G. myachkovensis* and *Heslerodus divergens* which are known only from Eurasia and North America. While this may suggest that an unknown mechanism of marine shark dispersal existed around the Carboniferous-Permian boundary, the fact that *Heslerodoides* is also known from Brazil may instead imply that many small sharks from this time had either pantropical or cosmopolitan distributions in the Panthanlassic and Paleoiapetus Oceans. Further investigation into the paleobiogeography of *Heslerodoides* and other small sharks from this time may shed light on the dispersal patterns of a number of marine vertebrates and generate more information about the ecosystems that supported them.

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## THE PETROSAL MORPHOLOGY OF PALEOGENE TYPOTHERIANS AND COMMENTS ON THE DISTRIBUTION OF PETROSAL CHARACTERS AMONG NOTOUNGULATES (MAMMALIA, PAN-PERISSODACTYLA)

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Our understanding of the cranial morphology of notoungulates (Mammalia, Pan-Perissodactyla) is biased, as most information currently available was taken from Neogene species and morphologically and functionally specialized taxa, with obvious limitations imposed to recent phylogenies. The petrosal (the bony element that houses organs of hearing and balance) is important for mammalian phylogenetics, since nerves and vessels that pass through it and muscles attached on its surface are associated with marks and structures easily recognizable as morphological characters. Here we present new information on the petrosal of *Griphotherion*, *Colbertia*, and *Dolichostylodon*, all typotherian notoungulates recorded in Eocene beds of northwestern Argentina. These three taxa show some well-known petrosal features commonly found in representatives of the order, such as the blade-like medial flange, extended epitympanic wing, and bean-shaped and well-differentiated promontorium. However, they also are unique in each case (e.g., smooth and wide crista petrosa in *Griphotherium*, greatly extended epitympanic wing in *Dolichostylodon*, large epitympanic recess in *Colbertia*). These observations reinforce the utility of the petrosal as a phylogenetically important element, with possible diagnostic features at least on a generic level, as observed in other eutherian groups, such as cingulates (Xenarthra). Moreover, the inclusion of these observed traits in a phylogenetic analysis allowed reconsidering the state of certain characters within the order. The expanded medial flange, reduction of the pars mastoidea, and lateral position of the tensor tympani fossa were not recovered as unequivocal synapomorphies, as did some previous studies. In turn, a superficial subarquate fossa and a stapedial fossa coalescent with the postpromontorial tympanic sinus resulted as synapomorphies for most taxa within Toxodontia. Finally, a curved promontorium is a synapomorphy for most of the Typhotheria, and the deep position of the transverse crest within the internal acoustic meatus was recovered as a synapomorphy for Astrapotheria and Notoungulata. This analysis was affected by the lack of information on the ear region of Henricosborniidae, where its members are considered as having plesiomorphic features relative to most other notoungulates. Hence, we emphasize the necessity to further study the cranial morphology of the available specimens of these forms (e.g., *Simpsonotus*). The phylogenetic position of *Griphotherion* in the present analysis supports an affiliation with the early radiation of the Typotheria-Hegetotheria lineage, established by previous studies. In turn, observations for *Dolichostylodon* and the cerebellar side of *Colbertia* represent novel additions to the morphological data base of those taxa. It is evident that, as our knowledge of the petrosal in Paleogene forms increases, certain patterns and ideas regarding phylogenetic hypotheses on notoungulates might radically change.

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## MICROFOSSIL DIVERSITY AND ABUNDANCE DURING THE LATE DEVONIAN LOWER KELLWASSER EVENT IN THE APPALACHIAN BASIN: IMPLICATIONS FOR EXTINCTION TRIGGERS AND ECOSYSTEM RESPONSE

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The Late Devonian mass extinction is the only "Big Five" mass extinction with a yet-unknown cause. In the Appalachian Basin, the most significant extinction pulse is during the Late Frasnian Lower Kellwasser Event. Here, we compile and synthesize microfossil data from five Lower Kellwasser sites in the Appalachian Basin including absolute and relative abundance and category-level diversity and evenness. We compare these results with those from macrofossil data and interpret them in light of proxies including TOC, redox-sensitive trace metal concentrations, and organic carbon isotopes. Major observations of this synthesis include the following. (1) We observe no significant difference in overall microfossil richness, diversity, or evenness between beds representing the extinction interval and those before and after the extinction. This stands in contrast to the brachiopod record for some of these same strata, which shows a 55% diversity loss (Pier et al. 2021). (2) We observe higher microfossil absolute abundance in beds from within the extinction interval as compared to those before and after, as well as higher abundance in nearshore sections. (3) We observe higher richness, diversity, and evenness in nearshore sections as compared to deep-water sections. Our data showing lower microfossil diversity and abundance in deeper water settings, coupled with redox proxies that show increased anoxia in these sections, supports the idea that anoxia and dysoxia played a role in ecosystem stress in the Lower Kellwasser Event in the Appalachian Basin. However, our finding that microfossil diversity metrics are invariable between extinction and non-extinction beds complicates this narrative and suggests that proximity to terrestrial weathering sources, rather than low oxygen, may be the most significant variable influencing microfossil diversity in the Appalachian Basin and indicates that the extinction was largely a benthic affair. In addition, our finding that microfossil abundance is higher in extinction beds supports hypotheses that some components of the microfossil assemblage may represent bloom or disaster taxa. These analyses provide a critical window into ecological and environmental dynamics in the surface ocean during the Lower Kellwasser Event in the Appalachian Basin.

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## MOLLUSCAN SPECIES COMPOSITION AND EVENNESS ACROSS THE MID-PLIOCENE WARM PERIOD AS RECORDED IN THE YORKTOWN FORMATION (SOUTHEASTERN VIRGINIA)

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The mid-Pliocene Warm Period (MPWP) was an interval of global climate change that spanned 300 ky and was marked by a rise in temperature of 3 °C. The purpose of this study was to assess how molluscan taxonomic composition and evenness were affected by the increase and subsequent decrease in temperature that occurred during this time. Ultimately, this study will be used to gain insight into how the MPWP can serve as an analogue for current global climate change. To assess this, samples from three members of the Yorktown Formation in southeastern Virginia were compiled from both museum material and bulk samples collected from field sites in Virginia. After sieving and sorting, molluscan specimens were identified to the lowest taxonomic level possible. This was achieved using published literature including monographs and the World Register of Marine Species. Bivalve abundance was quantified by halving the total number of bivalve hinges. For gastropods, the maximum number of apices and apertures was recorded to determine abundance. To assess changes in taxonomic composition across the warming interval, species and genus lists were compared from the Sunken Meadow to the Rushmere Member. Comparison of taxonomic lists across the Rushmere to the Moore House Members highlighted changes across the subsequent cooling period. We identified a handful of species (e.g., *Costaglycymeris mixoni*, *Modiolus pulchellus*, etc.) and one genus (*Placopecten*), which were extirpated locally, as well as other taxa that shifted biogeographically into the region as a result of warming. A number of first occurrences of species (e.g., *Carditamera arata*, etc.) and genera (e.g., *Abra*, *Cancellaria*, etc.) in southeastern Virginia seem to coincide with the end of the MPWP. Evenness was quantified using multiple indices, which recorded an increase in species evenness across both the warming and cooling intervals.

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## MACROEVOLUTIONARY CONSEQUENCES OF THE LATE ORDOVICIAN MASS EXTINCTION: A CROSS-CLADE INVESTIGATION OF THE LILLIPUT EFFECT

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The reduction of organismal body size following extinction events, known as the "Lilliput Effect," is a prevalent macroevolutionary phenomenon in many groups of organisms throughout the history of life. However, the ubiquity of this pattern across clades or extinction events remains unclear. In addition, it has proven challenging to differentiate between the proposed mechanism(s) responsible for driving patterns of body size decrease, which include selective extinction of large taxa, selective origination of smaller post-extinction taxa, and/or within-lineage dwarfing. To address these open questions surrounding the Lilliput Effect, we assembled a global body size database of Middle Ordovician to Middle Silurian marine invertebrates to analyze patterns of body size change across the Late Ordovician mass extinction. This body size database represents most major groups of solitary, skeletonized marine invertebrates, including bivalves, trilobites, strophomenid brachiopods, orthid brachiopods, crinoids, and rugose corals. Data are based primarily on museum collections and published literature and include multiple measurements per taxon within a time series to permit investigation of within-lineage body size trends and better differentiate between potential causal mechanisms of the body size change over time. Analyses were conducted using mean body size, which captures the overall size of individuals within a taxon, as well as maximum body size, which bypasses accidental inclusion of any sub-adult specimens and may be more appropriate for clades with indeterminate growth, like trilobites. On a global scale, we find evidence for the Lilliput Effect over the Late Ordovician mass extinction in three of the six groups investigated. In all cases, significant decreases in body size are concentrated over the first pulse of the extinction (Katian–Hirnantian) but not the second pulse (Hirnantian–Llandovery). Within some groups, the magnitude and/or significance of body size decrease appears to vary between paleocontinents, suggesting environmental factors associated with the Late Ordovician mass extinction played a major role in generating this pattern. In addition, we conducted a series of analyses to (1) investigate whether the Late Ordovician mass extinction resulted in a shift in the evolutionary mode of body size, and (2) evaluate support for the different mechanisms potentially driving the Lilliput Effect. Results indicate that the Lilliput Effect is a common, but not ubiquitous, phenomenon over the Late Ordovician mass extinction and help to further elucidate the long-term, macroevolutionary consequences of this extinction-related phenomenon.

## MEASURING SPIRAL FORM ACROSS MOLLUSCAN CLASSES—AN EMPIRICAL PERSPECTIVE ON THE 'MUSEUM OF ALL SHELLS'

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Molluscs are an incredibly rich study system for the evolutionary biologist, providing a 500-million-year record of morphology that reflects aspects of the animal's ecological function and growth patterns. Mollusc fossils are also often found together in great abundance, making it feasible to tease apart patterns of population-level change, effects of ecological factors, and faunal dynamics through time. The substantial morphological variety explored by molluscs presents a difficult analytical problem: how do we quantify their disparity across the phylum? Even within families, enough morphological breadth exists that comparing all species is sometimes impossible with the kinds of point-based homologies that geometric morphometric methods have successfully used in vertebrate groups. No landmarks exist that are shared across all molluscs. Few landmarks exist that are universal even within a single class. One thing that all shelled molluscs do hold in common is that their shells describe, to a greater or lesser extent, a spiral as they grow. As Raup showed in his seminal 1966 paper, simple alterations to a theoretical model of spiral growth produce forms consistent with gastropods, bivalves, monoplacophorans, cephalopods and scaphopods. Theoretical models have produced many fruitful lines of enquiry into molluscan form, addressing questions of morphogenesis and growth patterns in particular, but empirical morphospaces have lagged behind for most taxa, largely due to the difficulties of measuring spirals from 2D images or using calipers. Following on from the development of an empirical morphospace for regularly-coiling gastropods, this talk will discuss and illustrate ways of expanding empirical measurement of spiral form to accommodate less-regularly coiled gastropods, bivalves, and other molluscan forms, and assess how close we are to the true 'Museum of All Shells' and to analyses of morphological evolution for molluscs that truly encompass the impressive breadth and variety of the shell-bearing members of that phylum. We will show that empirically-derived morphospaces of coiling challenge the pure-logarithmic assumptions underlying more classical theoretical morphospaces, perhaps explaining why their application to helicospiral forms has lagged compared to applications for planispiral forms. Using empirical measures to tune purely theoretical approaches will lead to improvements in how we examine and understand the evolution of molluscan shell morphology.

## RECONSTRUCTING THE COASTAL VEGETATION OF CENOMANIAN SOUTHWESTERN APPALACHIA: AN INTEGRATED STUDY OF PLANT FOSSILS AND SEDIMENTS OF THE LEWISVILLE FORMATION (WOODBINE GROUP), DALLAS-FORT WORTH TEXAS, U.S.A.

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The Cretaceous rise of flowering plants marked a critical, transformative period for terrestrial landscapes, ultimately leading to modern vegetation types and ecosystems. However, key Cretaceous time intervals and localities remain poorly studied, leaving our understanding of the ecological transformation of landscapes incomplete. The Cenomanian Woodbine Group (Lewisville Formation), deposited along the southwestern Appalachian coast provides opportunities for interdisciplinary approaches to paleoecology through palynological, meso- and macrofloral, and sedimentological studies of approximately 13 m exposed near Lake Grapevine, Tarrant County, Texas. Combined sedimentological and fossil evidence indicate deposition in a shallow-marine to continental-terrestrial setting. Palynological samples from the lower half of the stratigraphic succession mostly have compositions dominated by conifer pollen and fern spores; samples from the upper part of the succession have a higher diversity of conifers, ferns, and angiosperms. These upper strata contain abundant plant fossils of all types in highly organic drapes within tidal channels and in organic muds of tidal flats and lagoons. Mats of compressed foliage in the tidal drapes, all with well-preserved cuticles, contain mostly angiosperms. Charcoalified woods from drapes include both conifers and angiosperms. Similarly, angiosperms are most abundant in fine-grained laminated mudstones, with much lower abundance of conifers and ferns. Overall, fossil data are consistent with conifer-fern swamp forests on the coastal plain. However, abundant and diverse angiosperms suggest that some coastal areas rich in angiosperms may not be well represented in the palynological record, and ecological heterogeneity is likely represented differently across sample types. Abundant charcoal indicates significant wildfires. The Lake Grapevine fossil plant record refines our understanding of Western Interior Seaway coastal vegetation during the middle of the Cenomanian. Combining this dataset with ongoing work on the diverse vertebrate record in these same deposits allows for refinement of the complex ecosystems of the time.

## EXPLORING LOCOMOTOR PATTERNS AMONG HISPANIOLA'S EXTINCT RODENTS

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Hispaniola once had over ten endemic rodents, but today only one remains, *Plagiodontia aedium*, a largely arboreal species weighing ca. 1000g, which genomic analyses place in Echimyidae. Extinct taxa were morphologically diverse and ranged in mass from ca. 400 g (*Brotomys voratus*) to nearly 5,000 g (*P. ipnaeum*). Isotopic work suggests dietary niche differentiation, but beyond this, little is known about the functional morphology and ecology of extinct species. This lack of data impedes our understanding of how species divided niche space and the factors that may have affected extinction risk. Locomotor pattern is a vital aspect of ecological niche. We performed locomotor reconstructions for four extinct Hispaniolan species (*Br. voratus, Hexolobodon phenax*, *P. ipnaeum*, *Rhizoplagiodontia lemkei*) as well as four extinct Cuban species (*Boromys torrei*, *Boromys offella*, *Geocapromys columbianus*, *Macrocapromys acevedo*). The modern comparative sample included extant Caribbean species, *P. aedium*, *Geocapromys brownii*, *Capromys pilorides*, *Mesocapromys nanus*, *Mesocapromys auritus*, *Mesocapromys angelcabrerai*, *Mesocapromys melanurus*, *Mysateles prehensilis*, *Geocapromys ingrahami* and 73 South American mainland taxa engaging in a variety of locomotor patterns including terrestrial, cursorial, arboreal, scansorial, fossorial, semiaquatic, and saxicolous (living on and among rocks). We collected 21 linear measures on the humerus, femur, and tibia and calculated 13 functionally relevant indices. Species averages were used for extinct taxa as complete skeletons were not available. *R. lemkei* had a femur available and *M. acevedo* had a femur and humerus available so these taxa were analyzed using a partitioned dataset. Principal component analysis was used to explore variation in indices among locomotor groups. In a PCA including indices from all bones, PC1 separated terrestrial, cursorial, and saxicolous species from arboreal, scansorial, fossorial, and semiaquatic species. Loadings indicate PC1 is associated with relative width of the humeral epicondyle (a proxy for attachment area for forearm flexors) and femoral trochanter height (a proxy for gluteal muscle attachment area). There was substantial overlap on PC2 among all taxa. PC3 separated fossorial species from all other groups; loadings indicate an association with hindlimb robusticity and length of the humeral deltoid tuberosity. All Caribbean taxa clustered within the space occupied by arboreal, scansorial, and semiaquatic species. This includes the extant terrestrial/saxicolous *G. brownii*, potentially indicating an "arboreal stamp" remains on postcranial anatomy despite moving into new ecological niches. When only echimyids are included in the analysis, extinct and extant Caribbean taxa fall within their own morphospace. This may indicate that Caribbean taxa have locomotor niches unrepresented by their mainland relatives.

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## CONTRIBUTIONS OF AN AVOCATIONAL INVERTEBRATE PALEONTOLOGIST TO RESEARCH COLLECTIONS AND PROFESSIONAL PAPERS

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Throughout history the contributions of avocational paleontologists have made a significant impact on research and collections in paleontology. For this presentation, I will discuss the different donations and other activities as an avocational paleontologist I have made in the last 45 years and their impact on research and scientific collections. Many of these specimens have led to professional publications and added rare and valuable specimens to institutional collections.

## DISCUSSIONS OF A PRIVATE PREPARATION LABORATORY DEDICATED TO INVERTEBRATE PALEONTOLOGY

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This poster highlights the efforts of a private laboratory dedicated to the preparation of invertebrate fossils. Although the majority of work has involved private collections, several key projects have included extraordinary specimens at the Cincinnati Museum Center and Houston Museum of Natural History.

## A DOZEN YEARS OF DIGITIZING TO BRINGS FOSSIL COLLECTIONS INTO THE SEARCHABLE WORLD

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Over the past twelve years, the Institute of Museum and Library Services has supported three collaborative digitization projects to move paper-based records of fossil collections to

digital format. The first project was a collaboration between the Milwaukee Public Museum (MPM) and The Field Museum of Natural History (FMNH) to digitize the Silurian fossils of the upper Midwest. The second project, digitizing Ordovician fossils in the collections, continued the MPM-FMNH partnership and added the University of Wisconsin-Milwaukee's Greene Gallery (UWM) to the project. The current and active project is digitizing the Devonian collections at MPM and FMNH. These projects brought outside resources to museum collections and encouraged communication within and between institutions. The work also brought standardized vocabulary to biodiversity, audiovisual, and geographic information. Digitizing the Silurian Reefs of the Midwest (2012–2015) created a consolidated online database with geographic, stratigraphic, and systematic data along with select locality and specimen photographs of the world's most extensive Silurian collections from the upper Midwest (mid-continent). Over 31,000 fossil records were converted to digital format and over 12,000 specimen and label images were produced. As a public-facing outreach, the 1990s-era MPM Virtual Silurian Reef website was updated, and a searchable database was added. Digitizing the Ordovician: from biodiversification to extinction in three collections, began in 2017 and ended in 2021. The three Ordovician fossils collections, MPM, FMNH, and UWM, document the radiation of animal life that gave rise to the Paleozoic fauna following the Cambrian explosion. The grant began as a three-year project and was altered by pandemic shutdowns and limited access to our collections. After time extensions and adaptations for COVID restrictions, the project was completed and converted over 60,000 records and produced over 35,000 specimen and label images. In addition, the Virtual Silurian Reef website was expanded to include the Ordovician records with narratives to accompany them. The three-year Devonian Digitization Project is a work in progress with FMNH and MPM partnering to convert over 37,000 records to digital format. The museums expect to image over 26,000 specimens and labels for the project. The Virtual Silurian Reef website will be expanded with the addition of Virtual Devonian Sea (VDS). And include the new data in the searchable database.

## BIODIVERSITY OF WESTERN LAURENTIA DURING THE MIAOLINGIAN AND FURONGIAN (LATE CAMBRIAN): A CASE FOR UNIQUE REGIONAL CONDITIONS THAT REDUCE MUD MOUND FORMATION

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During the early Cambrian, our planet experienced an "explosion" of originations that gave rise to many of the modern phyla we know today. Subsequently, in the early Ordovician, those phyla diversified into thousands of new species. The intervening late Cambrian, however, is often overlooked because of its perceived lower diversity and lack of major radiation events. This view has gradually changed as new data suggest the Cambrian and Ordovician radiations may have been one protracted event and additional fossil data from the Gondwanan paleocontinent suggests a more robust fossil record during the late Cambrian than previously known. However, the fossil record of Laurentia is less well documented to see if these patterns are globally uniform. The goal of this study is therefore to investigate the fossil record of the latest Cambrian into the Ordovician in the western basin and range region to (1) determine biodiversity and (2) explore potential sedimentological and geochemical causes for its reduction, if any. Our primary field sites were in northern Utah outside of Logan in the St. Charles Formation of the late Cambrian and the Garden City Formation of the early Ordovician. Both are mixed siliciclastic-carbonate, shallow marine environments. Additional field sites from the Antelope Valley region of Nevada and descriptions from the primary literature were also considered. What is presented here is an initial description of findings and exploration of hypotheses. Additional geochemical and sedimentological testing are still needed to confirm these results. With that said, from field observations we suggest that diversity in the St. Charles Formation was higher than initially expected indicating that, like studies of late Cambrian deposits in Gondwana, Laurentia may be more diverse than previously expected. However, the distribution of the highest diversity periods appears to be limited to mud mound bearing intervals in the earliest Ordovician of the Garden City Formation. These mud mounds are only found in low sedimentation intervals, a pattern repeated across distinct parasequences. Taken together, we propose that biodiversity is in part controlled by mud mound abundance which is overall depreciated during the late Cambrian prior to the early Ordovician. The reason for this could be due to multiple causes such as low accommodation space, deep water anoxia, high temperatures, ocean acidification, or others not yet explored. We present a model based on these conditions that could explain the combination of factors that affect regional diversity of the late Cambrian in Laurentia. In particular, lack of accommodation space restricting shelf availability combined with deep water anoxia reduced the conduits for repopulation of shallow marine ecosystems.

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## A UNIQUE CARYOPHYLLALEAN FOSSIL AND THE TEMPTATIONS OF THE MODERN FAMILY

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We consider a new angiosperm genus based on recognized attached foliage, flowers, and fruits from the Eocene Parachute Creek Member of the Green River Formation in eastern and western Colorado. MacGinitie previously assigned the isolated fossil leaves to Araliaceae as *Oreopanax elongatum*; the in-situ fossils reveal traits for leaves, flowering buds and fruits which do not fit the Araliaceae family.The leaves are shortly petiolate, entire-margined and elongate-lanceolate; the leaves have thick midveins, pinnate, brochidodromous venation, and a fine higher-order mesh. In the axil of the leaf, a paniculate inflorescences emerges. Although blossoming flowers are not present, we observe globose-ovoid flowers buds, a bisexual flower with ca. 5 parianth parts, 5-lobed stigma and ca. 12 stamens with short filaments and elongate anthers. The hypanthium, stigma (apical) and stamens persist into the fruiting stage. The berry fruit has numerous curved seeds. Using the newly described suite of characters, we consider Caryophyllales the best fitting order but find few strong affinities to any one family within the order. Paleobotanists often face a temptation to place Cenozoic fossils into modern families; we consider this an unrealitic expectation, especially with increasing geologic age. Here we make the case to assign a fossil to an extant order, but refrain on assignment to an extant family. Lastly, we discuss the possibility and criteria for establishing a new (fossil) family.

## STATE OF GEOLOGICAL COLLECTIONS AT THE CALIFORNIA ACADEMY OF SCIENCES, SAN FRANCISCO, CALIFORNIA

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The Geology collections at the California Academy of Sciences (CAS) includes plant, vertebrate and invertebrate fossils, microfossils, the world's third largest diatom collection, as well as rock hand-samples, minerals and meteorites, with an estimated 5–6 million specimens currently being preserved on site at Golden Gate Park in San Francisco, California. The geological collections are held in the CAS Department of Invertebrate Zoology and Geology (IZG), and the original Department of Geology has been around since the Academy's inception in 1853. Since then, the Academy and its collections have overcome many challenges including several earthquakes, a fire, and four separate building moves. The most notable challenge was the 1906 San Francisco Earthquake where the museum and its collections were destroyed during the earthquake and its aftermath. A then Curator, and ammonite paleontologist, Francis Marion Anderson, was able to recover some of the geological specimens from the rubble which, coupled with collections from the 1905–1906 Galapagos Expedition, acted as seeds to the rebuilding of the collection. Its unique positioning with invertebrate zoology in a single department unites the two disciplines which allows for richer studies in taxonomic relationships between extinct and extant invertebrate communities. Collections growth is driven by field collecting, exchanges with peer institutions, and over the past several decades the acquisition of several large collections, including part of the former Stanford University collections, the surviving portion of the Chevron microfossil collection, and the Union Oil of California microfossil collection. Recent years have brought the collections up to date and collections staff have participated in TCN's and institution wide initiatives to digitize the collection in an effort to increase accessibility. Here we present the current state of collections as well as its past and future projects as we continue to expand our knowledge and learn new ways to utilize paleontological collections.

## POST-CRANIAL TRABECULAR MORPHOLOGY OF THE EARLY MIOCENE HOMINOID PROCONSUL MAJOR

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Bones are a crucial source of data from the fossil record because bone size and shape reflect both heredity and developmental plasticity. The amount and distribution of trabecular bone in particular has been shown to be predictive of interspecific differences in locomotor patterns in primates. However, the use of trabecular bone variables to infer loading environment in extinct taxa is rarely feasible because excellent fossil preservation is required. This study uses trabecular bone properties to reconstruct the functional use of a distal humerus from the Early Miocene hominoid species, *Proconsul major*. The extent to which this species used arboreal vs. terrestrial substrates during locomotion is unknown, however a body mass estimate of 80 kg suggests *P. major*'s use of arboreal substrates may have been limited. This project aims to reconstruct elbow function in *P. major* and add to our understanding of the locomotor evolution of basal hominoids. A distal humerus (UMP NAPCC 06'1432) of *P. major* was scanned with a micro-Computed Tomography (µCT) at the University of Texas Computed Tomography laboratory. µCT scans from humerii in eleven comparative species of extant primates were gathered using an X-Tek HMXST225. Scans were optimized for each specimen to ensure the highest resolution possible while accounting for size variation across species. Bone analysis was conducted in Dragonfly (Version 2022.2: ORS, Montreal). The capitulum of the humerus was chosen as the region of interest due to preservation and its importance in bearing variable loads during pronation and

supination across taxa according to locomotor patterns. The region of interest was segmented, and the Dragonfly bone wizard was used to remove user bias in the cortical-trabecular boundary. Secondly, a specific bone to background then cortical bone to trabecular bone machine learning model was created for the fossil to extract trabecular data. Trabecular properties such as degree of anisotropy and bone volume fraction (BV/TV) were collected. Species were grouped into locomotor categories that included the proportion of arboreal locomotor usage. There was substantial overlap in degree of anisotropy and BV/TV across modern locomotor groups. However, there was limited overlap in BV/TV or degree of anisotropy between *P. major* and brachiators, arboreal suspensors, and leaping arboreal quadrupeds (e.g., *Presbytis rubicunda*). Rather, the *P. major* values fell within the range of variation for species who use more mixed terrestrial and arboreal quadrupedal locomotion such as *Gorilla gorilla* and *Macaca fascicularis*. Thus, *P. major* may have had a component of terrestrial locomotion in its positional repertoire. This study represents the first usage of trabecular analysis in a Miocene hominoid, and provides further insight into a species with limited and fragmented post-cranial material. Future analysis of the complementary proximal radius from *P. major* will allow for further locomotor reconstruction.

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## UPDATE ON A MULTI-PROXY STUDY OF RUMINANT DIETS FROM THE MIOCENE OF EASTERN AFRICA

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Ruminants are one of the first Laurasiatherian immigrant groups to become well established in Africa. The oldest ruminants appear ~21 Ma, with subsequent waves of immigration and in-situ evolution throughout the remainder of the Cenozoic. Today, they form one of the more diverse and abundant groups of medium-large mammals in most African ecosystems and engage in varied dietary habits. The origins of this diversity are not well understood. Ruminants have been particularly successful in adapting to open grassland environments. Open grasslands are present by the Late Miocene and recent research suggests that grasses, including C4 grasses, existed back through the Early Miocene. We ask: (1) what dietary diversity exists amongst Miocene ruminants? (2) Are any Miocene ruminants practicing mixed feeding or grazing? A multi-proxy approach to dietary reconstruction has the benefit of providing complimentary data, since different proxies reflect different periods of time in an animal's life and vary in the degree to which signals are time averaged. Multi-proxy studies can provide a more detailed and nuanced reconstruction of diet than a single proxy alone. Therefore, we measured hypsodonty, mesowear, microwear (two distinct methodologies), and carbon and oxygen enamel isotopes for as many teeth as possible, prioritizing getting multiple proxies for single individuals or even from a single tooth. Our sample spans the Early and Middle Miocene of Kenya, and Early Miocene of Uganda. We included both Tragulidae and Pecora in our sample. The pecoran sample includes stem pecorans of unclear affinities (e.g., *Walangania*) as well as early representatives of giraffoids (including Climacoceratidae), giraffids, and bovids; bovids are sampled for the Middle Miocene only. Our results to date indicate that: (1) *Walangania* and all tragulids show a broadly similar and browse-based diet throughout the Early Miocene. There is some evidence for a small amount of C4 in the diet and for niche partitioning between sympatric tragulid species at Rusinga. (2) There is a sharp increase in hypsodonty in the Middle Miocene, with the introduction of bovids; these Eurasian immigrants to the region are hypsodont when they arrive. In contrast, mesowear and microwear scores, as well as stable carbon isotopes, strongly suggest that these bovids are not grazing and there is only scant evidence for mixed feeding. Ultimately, their dietary signals are not distinct from brachydont giraffoids found at the same sites. (3) Both microwear methodologies produced similar results. Overall, there is little evidence that grasses played an important role in ruminant diets prior to ~13 Ma, but both tragulids and pecorans may have eaten them in small amounts. Seasonality may play an important role in the early adoption of grass into the diet. Enamel isotope analysis is ongoing and will hopefully provide greater insights.

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## CHALICOTHERES IN THE MIDDLE SIWALIKS AND BEYOND

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Chalicotheriidae, a clawed family of Perissodactyla that includes the subfamilies Chalicotheriinae and Schizotheriinae, first appear in South Asia in the Oligocene and persist into the Plio-Pleistocene. Members of the Chalicotheriinae occur in the well-calibrated and highly fossiliferous Middle Siwaliks sequence but are rare, as is typically the case elsewhere. In the

past, Siwalik Chalicotheriinae have been assigned to a single species, originally known as *Chalicotherium salinum.* Today, the generic name *Chalicotherium* has been restricted, and several species formerly attributed to *Chalicotherium* are now placed in the genus *Anisodon*. Here we address three main questions regarding the Middle Siwalik chalicotheriine: (1) the proper generic attribution for this taxon; (2) how it might be related to both earlier and subsequent Chalicotheriinae in South Asia; and (3) whether the material includes more than one species. We re-analyzed all available material of the Siwalik chalicothere from the Harvard-Geological Survey of Pakistan collections housed at Harvard University, in addition to older collections from the Yale Peabody Museum, American Museum of Natural History, and Natural History Museum, London. The material is restricted to mandibles, maxillae, isolated teeth, and unassociated elements of the manus and pes, which are extremely distinctive in chalicotheriines. We photographed and measured the material and coded the Siwalik chalicothere dental material for characters from recent phylogenetic analyses of the Chalicotheriinae. Our results confirm that the Siwalik chalicothere should be placed in the genus *Anisodon*. The presence of a wide postfosette and mesiodistally oriented metastyle on M3, lack of a retromolar space, and expanded mandibular angle resemble *Anisodon* and not *Chalicotherium. A. salinus* is a relatively basal member of the anisodontin clade, lacking the brevirostry seen in derived members. Chalicotheriinae also appear in the early Oligocene of South Asia, represented by the poorly known species "*Chalicotherium*" *pilgrimi*, which is likely close to the ancestor of all later chalicotheriines, including both the European and African branches. *Nestoritherium sivalense* from the Plio-Pleistocene Upper Siwaliks is an unlikely descendant of *A. salinus,* showing far more advanced anisodontin characteristics. While we document some morphological variation within the *A. salinus* sample (e.g., postcranial elements, upper premolar morphology), there is no obvious stratigraphic or geographic patterning to this variation. For now, all Middle Siwalik chalicotheriine material is retained in *A. salinus.* Our examination of chalicothere material from South Asia demonstrates that the subfamily Schizotheriinae is sporadically present in Neogene deposits up to 10 Ma. The latest schizotheriine in this region is a single lower molar referable to cf. *Ancylotherium*, which had not previously been documented from the Middle Siwaliks or this faunal province.

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## FINDING PATHWAYS FOR INTEGRATING PALEO, ARCHEOLOGICAL, TRADITIONAL ECOLOGICAL KNOWLEDGE, AND HISTORICAL DATA INTO CARIBBEAN CORAL REEF MANAGEMENT

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Paleoecological, archaeological, traditional ecological knowledge, and historical data ("historical data") can inform coral reef management by providing accurate ecological baselines and by pinpointing the timing, magnitude, and drivers of ecosystem declines. However, these data are rarely incorporated into policy and management frameworks for reefs. We formed a Conservation Paleobiology Network-supported working group composed of paleontologists, historical ecologists, ecologists, fisheries scientists, and reef conservation practitioners from management agencies, academia, and environmental nonprofits to develop pathways for incorporating long-term ecological data into decision-making, focusing on the Caribbean region. This working group honed in on the application of long-term data to two pressing management issues for Caribbean coral reefs, which together address the most urgent local human drivers of ecosystem change: fishing and land-based pollution. In this talk, I will outline the major findings of this working group's efforts, including obstacles that currently hinder the integration of historical data into Caribbean coral reef policy and management, instances where these data have been considered in management decisions, and additional actions that hold promise for further bridging the gap between conservation paleobiology and conservation of coral reefs.

Funding source: Conservation Paleobiology Network, National Science Foundation

## QUANTIFYING THE IMPACTS OF PRESERVATION ON PALEOBIOLOGICAL PATTERNS: A LITERATURE-BASED SURVEY OF BODY SIZE IN CRETACEOUS AND PALEOGENE GASTROPODS

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With a series of seminal papers beginning in the late 1960s, Jim Valentine helped kick off the modern study of biodiversity history in the fossil record. More than fifty

years later, paleobiologists continue to debate methods for paleobiodiversity reconstruction, the effects of biases on the measurement of diversity, and the geological and biological drivers of diversity change. For example, the diversification of mollusks in the Mesozoic and Cenozoic was one of the key radiations in the history of marine life (and one in which Jim was greatly interested), but questions have lingered about the effects of preservational biases on the apparent magnitude of the event. Specifically, the radiation coincides with an increase in the frequency of unlithified sedimentary deposits and in the quality of preservation of aragonitic fossils, trends that could magnify the appearance of diversification by improving fossil recovery. Given that lithification and aragonite dissolution are expected to preferentially affect the recovery of small fossils, we explore the relationship between preservational quality and body size in Cretaceous and Paleogene gastropods. We measured shell size for over 7000 species occurrences illustrated in over 200 published sources; the literature-based approach allows broad geographic and taxonomic sampling. Three aspects of preservational quality were assessed using semi-quantitative metrics: overall shell completeness, surface pristineness, and degree of lithification. Average preservational quality increased through the study interval, as did the proportional representation of small shells, suggesting that taphonomic biases may indeed have altered observed biodiversity trends (to some degree) by obscuring small taxa. Specifically, shells smaller than 10-13 mm (geometric mean of length and width) become underrepresented as preservational quality declines. Interestingly, small fossils are particularly common in the Danian (a possible example of the Lilliput Effect following the Cretaceous-Paleogene extinction), but only in well-preserved material. Importantly, we find that our lithification and pristineness metrics both have a predictable, systematic relationship with body size; an improvement by one unit in either metric is associated with a decrease in mean size of about 20%. The simple, predictable relationship between preservation and body size distribution suggests that there may be a simple, predictable relationship between preservation and biodiversity measurement bias in gastropods during this time interval. Going forward, we hope that this approach will contribute to a nuanced analysis of the effects of diagenetic biases on observed patterns of gastropod diversification.

## DIGESTION BY BIRDS OF PREY IMPACTS THE ISOTOPIC COMPOSITION OF CONSUMED PREY: IMPLICATIONS FOR PALEOECOLOGICAL STUDIES

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We conducted a semi-controlled feeding study with Rhett, a red-tailed hawk (*Buteo jamaicensis*), and Caspian, a Eurasian eagle owl (*Bubo bubo*) from the Cincinnati Zoo. We compared the isotopic composition of bone collagen, bone bioapatite, fur, and muscle from murine rodents fed to the birds before digestion, bone and fur recovered from regurgitated pellets, and raptor fecal matter for 11 days. We analyzed carbon, oxygen (O), and strontium (Sr) isotopes for bone bioapatite; and C, N, and Sr isotopes for feces. Feces had significantly lower C and Sr isotopes than rodent tissues for both Rhett and Caspian, but trends for N isotopes were starkly different for the two birds. Fecal N isotopes were higher than rodent tissues for Caspian, and lower than rodent tissues for Rhett. Following digestion, there were no changes in C isotope values for rodent fur, N isotopes for either bone or fur, or O isotopes for bone bioapatite. However, C isotopes for rodent collagen decreased by ca. 1.5‰, and C isotopes in bioapatite increased by ca. 0.5–1‰ after digestion for both birds. Strontium isotopes for undigested rodent bioapatite were also significantly higher than digested bioapatite (by ca. 0.0013) for both birds. To our knowledge, this is the first investigation of the isotopic influence of digestion for birds of prey. Fecal stable isotope analysis is widely used to monitor foraging ecology of mammals, but little attention has been paid to birds. The contrasting trends in N isotopes for Caspian and Rhett are unexpected, and may reflect differences in digestive physiology between owls and red-tailed hawks. Analyzing remains from consumed and regurgitated prey could be a non-invasive approach for evaluating dietary intake and habitat preference for predatory birds. Accumulated prey remains (e.g., from owl roosts) are also widely recognized as archives of climate and environmental conditions. However, researchers should be aware of the influence of digestion on both C and Sr isotope values in bone. While small, these could impact data interpretations if unaccounted for. The shifts in C isotopes are particularly important as these could shrink the estimated spacing between collagen and bioapatite by as much as 2.5‰.

## THE MAMMOTHS AT THE AIRPORT IN MEXICO CITY AFTER EXCAVATIONS

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During the construction of the Felipe Angeles International Airport (AIFA), realized between 2019–2022, in Santa Lucia, State of Mexico, more than 50,000 fossil specimens were

collected, including the remains of at least 500 mammoths with different age classes. This is the largest Quaternary fossil locality ever discovered, and offers a phenomenal opportunity to investigate the biology and paleoecology of proboscideans at the end of the Pleistocene. Archaeologists from Mexico's National Institute of Anthropology and History (INAH) have been excavating and studying Santa Lucia-AIFA fossils through two paleontological projects, Prehistory and paleoenvironment of the Northwest Basin of Mexico and Paleoenvironmental and paleoclimatic reconstruction of AIFA paleontological site using small fossil vertebrates. These studies have identified three depositional events with mammoths' remains occurring between ?24,000 to 11,700 years BP. Small fossil vertebrates, but not megafauna, are founded in layers older than ?24,000 years BP. The proboscidean material found in AIFA is comparable with the Mammoth Site in Hot Springs, South Dakota, U.S.A., because present similar age, a large number of mammoth specimens, the absence of human interaction, and a lacustrine deposit. Stable isotope analyses on mammoth molars from Santa Lucia-AIFA suggest that these animals were mixed feeders of C3/C4 plants. The remains of flamingos in these deposits suggest warmer and more humid climatic conditions when mammoths were present. Other Quaternary sites near Santa Lucia-AIFA include similar taxonomic compositions and stratigraphic characteristics. The Quinametzin Paleontological Research Center (CIPAQ, Centro de Investigacion Paleontologica Quinametzin) is currently leading taphonomic and paleopathological studies focused on the megafaunal bones, and paleoenvironmental reconstructions with small vertebrates. Much work remains to be done including dating of material, obtaining 3D images accessible to researchers, and multidisciplinary collaborations.

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## SMALL VERTEBRATES FROM HOYO NEGRO AND THEIR PALAEOECOLOGICAL IMPORTANCE

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Hoyo Negro is a paleontological site located in the Sac Actun cave system of Quintana Roo, Mexico, in the Yucatan Peninsula. This natural trap pit is very important because the remains of a 15–16 year old woman named Naia, dated in 12,000–13,000 years BP, were recovered. Hoyo Negro presents a wide variety of extinct mammals including the bear *Arctotherium wingei*, canid *Protocyon troglodytes*, sabertooth cat *Smilodon fatalis*, gomphothere *Cuvieronius*, and a variety of giant ground sloths, including the new species *Nohochichak xibalbahkah*. Small fossil vertebrates are also present in Hoyo Negro and includes boids (*Boa* sp.), opossum (*Didelphis* sp.), hairy porcupine (*Coendou mexicanus*), fruit bat (*Artibeus* sp.), and stripe-headed round-eared bat (*Tonatia* sp.). The microvertebrate assemblage is interesting because they are all currently present in the Hoyo Negro area, except the stripe-headed round-eared bat which is currently located 400 km south of Hoyo Negro site. This range shift towards the north of the Yucatan Peninsula has been found also for the skunk (*Mephitis macroura*), the wolf (*Canis lupus*), and the spiny iguana (*Ctenosaura* subgenus *Loganisaura*) in Loltun Cave, a paleontological site found at the same latitude as Hoyo Negro. The distribution changes of the bat *Tonatia* could be caused by changes in the vegetation structure or isotherm displacement recorded during the Late Pleistocene or Early Holocene in the Yucatan Peninsula. It is necessary to expand the study of small fossil vertebrates from Hoyo Negro because the microvertebrates can give paleoecological information about the environment in the past when the megafauna and ancient humans inhabited the Yucatan area.

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## FUNCTIONAL DIVERSITY AND STRUCTURE OF CRETACEOUS COASTAL PLAIN ECOSYSTEMS

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Latitudinal and altitudinal differences in faunal composition in the Cretaceous of North America have become important for the study of faunal turnover in greenhouse climate systems. The composition and diversity of taxa recovered in this region are strongly tied to their distance from paleoshoreline, and may be relevant to predicting biological responses to modern climate-mediated sea level changes. However, the functional diversity and community dynamics in these systems remain poorly characterized at finer scales. In this study, we use a high-resolution record (60 sites, >75,000 specimens) to examine functional diversity among vertebrate communities in a coastal plain ecosystem during a 3-million-year interval of climatic change and sea level fluctuations. We find that

functional richness is highest during more marine-influenced intervals of higher sea level, and lower during more terrestrial communities associated with lower sea level. Conversely, we see functional disparity, evenness, and divergence highest during periods of greater terrestrial exposure. This suggests that while communities under higher sea level may have a larger total number of ecologies represented, the relative distributions of taxa may indicate that the more terrestrial communities were as functionally complex, with more even distributions of differing ecologies and energy among taxa, and that nearshore epeiric marine systems in this Cretaceous greenhouse climate were comparatively simple when compared to the greater niche-partitioning present among adjacent terrestrial communities.

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## PALEONTOLOGY COLLECTIONS AT THE HARVARD MUSEUM OF COMPARATIVE ZOOLOGY

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The Invertebrate Paleontology collection at the Harvard Museum of Comparative Zoology (MCZ) was one of the 24 "major" collections identified by the 1977 Committee On North American Resources in Invertebrate Paleontology (CONARIP) report. It remains one of the major collections today having had significant improvements made to collection storage, digitization, and staffing over the past five decades. In addition, the MCZ houses fossil insect and vertebrate paleontology collections that were not part of the 1977 report. These collections are significant in their own right and have seen similar improvements with the passing decades. The MCZ Entomology fossil collection is one of the largest and most historically important paleoentomology collections in the world, thanks to the work of Prof. Frank Morton Carpenter. A recent NSF-funded project, led by Prof. Brian Farrell and Dr. Ricardo Pérez-de la Fuente facilitated digitization and rehousing of all 40,000 specimens in the MCZ Entomology fossil collection. The MCZ Vertebrate Paleontology collection contains the best material for study of the transition from reptiles to mammals between 225 and 248 million years ago. It also has the distinction of being home to the two foremost authorities on vertebrate paleontology of the 20th century—George Gaylord Simpson and Alfred Sherwood Romer. Over the past decade, staffing increases and a major collection move have greatly improved the physical storage and digitization of the collection. This talk will serve as a status update on the MCZ's paleontology collections, focusing on the priorities and strategies that have allowed these collections to persist and thrive with time.

## PBOT, THE INTEGRATIVE PALEOBOTANY PORTAL: A FREE WORKBENCH FOR PALEOBOTANICAL RESEARCH AND DATA MANAGEMENT

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Fossil plants represent the best record for understanding ancient terrestrial environments because of the fundamental role vegetation plays in food webs, atmospheric cycling, and nutrient cycling dynamics. Yet paleobotanical data remain severely underrepresented in major research databases. This gap exists because paleobotanists commonly use morphologically-based, informal taxonomies (morphotypes) in addition to the traditional Linnaean classifications that these databases require. In 2020, our group received EarthCube funding to address these problems by creating PBot, The Integrative Paleobotany Portal, a free online software for fossil plant data management, analysis, and exploration (https://pbot.paleobiodb.org). PBot bridges the plant taxonomy gap and provides the first open-access, online data-management infrastructure that can accommodate both morphotypes and formal taxonomies, and that uses standardized descriptions to facilitate comparison of plant taxa among regions, time periods, or research groups. PBot works with and complements existing databases (the Paleobiology Database, iDigBio, Plant Fossil Names) to enhance the utility and accessibility of paleobotanical data, allowing paleobotanists to more easily share data and fulfill NSF (or other funding agency) data management plans. A graph database was chosen for PBot because its network structure is easily understood by paleontologists, as it mirrors common biological concepts such as food webs. Additionally, graph databases naturally lend themselves to similarity analyses, allowing for more powerful search functionality and facilitating morphotype comparisons. Using the *PBot Workbench*, registered users can 1) create novel, dynamic character schemas for describing plant fossils; 2) enter and compare descriptions of specimens for informally and formally named plant taxa; and 3) propose synonymies and comment on PBot contents via an integrated community forum to stimulate productive scientific discourse. Data can be entered as public, or as private data that can be shared amongst designated users, thus allowing PBot to be

used from inception to completion of a project and facilitating collaboration on in-progress research. The *PBot Explore* portal allows anyone to browse and view all public data that has been entered into PBot. With widespread use, PBot has the potential to bring paleobotany's "dark data" to light and allow plants to be meaningfully included in synthetic studies of ancient climate, weathering and biogeochemical cycles, paleoecology, biodiversity, and evolutionary science.

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## MORE SITES, MORE FOSSILS, PART 2—AN IMPROVED BASIS FOR UNDERSTANDING INSECT HERBIVORY DURING THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN

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The Bighorn Basin paleobotanical record has proven integral to understanding how insect herbivory responds to climate change over geologic time scales. Well-preserved fossil leaves show the scars of insect feeding events, which can be categorized into damage morphotypes (DTs) as described in the *Guide to Insect (and Other) Damage Types on Compressed Plant Fossils* by Labandeira et al. A sequence of nine Bighorn Basin sites that span six million years of the late Paleocene and early Eocene, including one site within the Paleocene-Eocene Thermal Maximum (PETM), previously demonstrated an extremely strong correlation between damage richness (sample standardized number of DTs observed on a flora) and reconstructed mean annual temperature (MAT), as well as a significant, albeit weaker correlation between damage frequency (proportion of leaves with herbivory damage) and MAT. This relationship is likely to be at least partially driven by the abundance of plants with nitrogen-rich leaves (here, legumes and Alnus), which also increases with MAT. Legumes are diverse and abundant at Hubble Bubble, the first PETM site examined for insect folivory damage, and this site displays a uniquely high percent leaf area damaged, nearly twice as high as reported anywhere else in the fossil record. In the years since the initial Bighorn Basin herbivory work was completed, we have discovered seven additional paleofloral sites from the body of the carbon isotope excursion (CIE) and five sites from the CIE recovery. We are currently identifying all dicot leaves from these sites and scoring them for herbivory damage, as well as reconstructing paleoclimate and depositional setting. These additional PETM data will help us to tease apart the influences of climate and nitrogen availability on insect herbivory.

## NITROGEN STABLE ISOTOPES FROM CORAL FOSSILS CONTEXTUALIZE CLIMATE-ECOLOGY-HUMAN INTERACTIONS THROUGH MILLENNIA

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Scleractinian corals have been the dominant reef builders in the tropics for millions of years, creating the most biodiverse marine habitats on Earth. Corals owe much of this reef-building success to their symbiosis with photosynthetic algae, which gives them the ability to assimilate otherwise limiting nutrients such as nitrogen (N). However, coral reefs are severely threatened by numerous anthropogenic stressors, such as climate change and eutrophication, causing instability in this symbiosis with negative impacts to reefs globally. Tracing the causes of reef degradation requires investigating interactions among humans, reefs, and climate over thousands of years to contextualize modern-day anthropogenic impacts. Stable isotope analysis of the organic N preserved within coral skeletons provides a powerful method for understanding nutrient cycling over geologic time. When coupled with other proxies (i.e., additional elements) and ecological methods, N isotope values can be harnessed to better understand the complex interactions of corals with their environment. Here, we use two case studies from reefs in the tropical Western and Eastern Pacific to highlight the potential of this multi-disciplinary framework for investigating coral dynamics over millennia. In reefs of the Greater Bay Area in the Western Pacific, we documented a decrease in coral cover and biodiversity linked with poor water quality caused by local and recent nutrient runoff. Increased concentrations of anthropogenic nutrients completely altered the marine N cycle, which had previously been controlled by monsoonal rains and deep-ocean sources for the last 5,000 years. In contrast, on Panamanian reefs of the Eastern Pacific, we would have expected a variable N record punctuated by well-documented local climatic and ecological perturbations. However, N isotopes consistently decline over 5,000 years, revealing a nutrient system controlled by broader regional/global climate patterns and ocean currents rather than by local forces. In these case studies, we weave together patterns of N cycling and climate dynamics for each region, coral physiology (e.g., coral nutrient assimilation and resource partitioning), historical ecology (e.g., human interactions and changes in coral community composition through time), and conservation biology to develop a more holistic view of coral ecological trajectories through time. The climate-ecology-

human framework discussed here can be expanded to other biogenic reefs and improve the utility of paleo-archives to inform the ecological consequences of future environmental change.

Funding source: Smithsonian, STRI Tupper Fellowship, Max Planck Insitute for Chemistry

## MODERN INSIGHTS REGARDING ANCIENT FISHES

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Extant members of ancient lineages of non-teleost ray-finned fishes provide valuable insights into ecology, evolution, and conservation. Holosteans (i.e., gars and bowfins) in particular have served as model organisms for evolutionary developmental biology, conservation of biodiversity, revised management of fisheries, and even justifying the concept of "living fossils." This presentation will synthesize examples of the role of holosteans across disciplines in the past 20 years, including the influence of Lance Grande on our understanding of these unique, and often enigmatic fishes.

## PUTTING THEORY INTO PRACTICE; EXERCISES AND EXPERIENCES GAINED WHILE USING MODEL-BASED INQUIRY (MBI) AND AMBITIOUS SCIENCE TEACHING (AST) METHODS IN EARTH SCIENCE CLASSES AT A COMMUNITY COLLEGE.

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In 2021–2022, the Advancing Community College Education and Student Success (ACCESS) program at the UC Museum of Paleontology (UCMP) initiated a Professional Learning Community (PLC) composed of UCMP graduate students and community college instructors from across the country. The goal was to design new Earth science course materials that integrated Model-Based Inquiry (MBI) and Ambitious Science Teaching (AST) practices and align with the 2021 Vision and Change in the Geosciences framework. AST centers student learning around evidence-based discovery and problem-solving drawing from relevant phenomena, and this phenomena-based learning approach has been shown to more equitably engage students of diverse backgrounds. The use of phenomena and explanatory modeling activities aligns with evidence that learning should be contextualized, and that students should apply what they know to construct scientific explanations. PLC participants were introduced to these instructional practices while experiencing lessons as adult learners, and then worked collaboratively over a year to develop lessons using these practices that could be integrated into their courses. The products and classroom experiences that resulted from this collaboration are presented, with the goal of fostering discussion in adopting Model-Based Inquiry (MBI) and Ambitious Science Teaching (AST) methods to Earth science instruction.

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## ISOTOPIC ECOLOGY OF LARGE BARNACLES FROM THE MIDDLE MIOCENE CLIMATIC TRANSITION, CALVERT CLIFFS, MARYLAND: DO BARNACLE PLATES RECORD SIMILAR PALEOCLIMATIC SIGNATURES AND DO BARNACLES HAVE SEASONAL LIGHT AND DARK GROWTH BANDS LIKE MOLLUSKS?

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Barnacles build a hard calcite shell used in stable isotopic analyses to document modern and fossil whale migrations. In shelf environments, barnacles are also common encrusters of hard substrates and shelled invertebrates like mollusks. Because of their sessile lifestyle, barnacle calcite could capture water mass characteristics for marine shelves, such as water temperature and productivity, and reveal physiological features like growth and age. Here, we test whether individual plates from the same barnacle record similar paleoclimatic snapshots; if they do, then all plates are useful for isotopic analysis. We also discovered the presence of light and dark growth bands so we tested whether they formed seasonally, like similar bands in mollusks. Further, we examined the age of the barnacles, the season they started to grow, and the water temperatures they lived in. Our work is part of a larger project to determine if shelf barnacles and scallops provide a record of environmental conditions during the Middle Miocene Climatic Optimum (MMCO) and the Middle Miocene Climatic Transition (MMCT), a time when the East Antarctic Ice Sheet was growing, cooling the Earth just after the MMCO when climate was much warmer than today. We drilled three different plates (rostral, rostral marginal, and radius) along a growth transect for two *Balanus concavus* (Balanidae) living on the same scallop, *Chesapecten nefrens*, from Shattuck Zone 17, Middle Miocene, Calvert Cliffs, Maryland. Based on a previous scallop analysis, these barnacles are representative of the MMCT. We expected both barnacles and all of their plates to exhibit seasonality in $\delta^{18}O$ and $\delta^{13}C$ and be statistically indistinguishable from each other. We also expected that light and dark growth bands represented different seasons. Results revealed that the barnacles started growing in the fall and lived for ~3 years. The rostral and

rostral marginal plates were statistically indistinguishable from each other, but the radius was significantly different because it grew only in the winter, when productivity was the highest. The stable isotopes of the light and dark bands were not statistically distinguishable; however, for $\delta^{13}C$, the dark bands occurred more frequently during the seasonal extremes. In summary, radii plates should not be used for isotopic analysis in balanid barnacles, while dark bands could be influenced by nutrient uptake and the hottest or coolest temperatures. $\delta^{18}O$ revealed seasonal climatic flux during the MMCT in the western mid-Atlantic shelf region, yielding ~ 10 °C temperature change between summer and winter; higher productivity occurred during winter. While we found that fossil barnacles are model organisms to study physiologic responses to climatic-driven water mass characteristics on continental shelves, only some plates are better than others for such analyses.

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## DATA HOMECOMING: THREE ELEMENTS FOR BUILDING TRANSPARENT, REALISTIC, AND MUTUALLY BENEFICIAL INTERDISCIPLINARY COMMUNITIES AND COLLABORATIONS IN CONSERVATION.

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Conservation Paleobiology and ecology have complex histories of justice, equity, participation, and ownership. The Bahamas as a research location and a community of people are diverse and relatively accessible to North American and Global North researchers. This accessibility has led to significant research effort distributed across the islands of the Bahamas. However, equity has not grown in pace with effort. The Conservation Paleobiology Network Working Group, "Restoring Ecosystems Lost in Conservation" (RELIC: Bahamas) during its establishment has sought to balance the goals of academic research with equally important work towards equity. This presentation will highlight social obstacles of equity, accessibility, and vulnerability; and logistic obstacles of geography, timing and capacity. We will share the group methodology and three key elements for building transparent, realistic, and mutually beneficial interdisciplinary communities and collaborations in conservation. The talk will culminate in practical guidance for working in Bahamian and other vulnerable scientific communities and share our ongoing efforts to develop capacity and long-term relationships at the University of the Bahamas.

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## PHYLOGENY AND EVOLUTION OF SILURIFORMES (TELEOSTEI), WITH A TENTATIVE BIOGEOGRAPHIC SCENARIO AND SPECIAL REFERENCE TO FOSSIL TAXA

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Knowledge about phylogenetic relationships among Siluriformes has undergone significant progress over the past 20 years, in major part due to the availability of molecular data. Although the picture is still controversial in several important aspects, there is much higher-level information that seems solid on the basis of multiple analyses and sources of data. Catfishes have the widest geographic distribution of any ostariophysans, with a presence on all continents and the only ones on Australia, New Guinea, Madagascar and Antarctica. Although enticing, their global biogeographic history has been considered as intractable because of the lack of clear transcontinental tracks. Herein I present a scenario that attempts to accommodate current notions of catfish phylogeny with their geography, in particular with the fragmentation history of Gondwana. In contrast with some other Gondwanan clades (e.g., osteoglossomorphs, Dipnoi, Cichlidae), catfishes indeed do not follow a traditional Gondwanan-split template. It is proposed that their vast distribution today is explained by distributional expansions associated with early stages of continental breakup and the opening of new intercontinental waterways, coinciding with the invasion of lowland and estuarine habitats by specific lineages. Early stages of continental mass separation were therefore a factor of dispersion (as opposed to dispersal), rather than isolation. Intercontinental-level vicariance only came into play later, with the spread of continental margins into actual ocean basins. Catfish fossils are potentially an important source of data in this scenario, especially in demonstrating past marine occurrences and distributions. The relevance of the fossil record for understanding the phylogeny and evolution of the Siluriformes is reviewed. Especial attention is dedicated to the North American family Hypsidoridae, the best-known catfish fossil at the moment and one which has greatly benefitted from research by L. Grande. Hypsidorids are generally considered as the sister group to all non-diplomystid siluriforms, a hypothesis revisited in a number of subsequent studies. The evidence for the position of hypsidorids is reviewed in light of more recent discoveries on catfish characters and relationships, and on key fossils such as *Bachmannia* and *Kooiichthys*.

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## OCCUPANCY MODELLING REVEALS SAMPLING BIASES DRIVE THE OBSERVED END-CRETACEOUS DINOSAUR DECLINE

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Whether non-avian dinosaurs were already in decline prior to the Cretaceous/Paleogene mass extinction 66 Ma has been the subject of intense debate. Recent work showed that habitability for North American dinosaurs remained stable throughout the latest Cretaceous (Campanian–Maastrichtian [83–66 Ma]), but has not conclusively shown that dinosaurs remained widespread during this interval or that sampling bias is the cause for the observed pattern. Occupancy modelling, a technique commonly applied in ecology and conservation, provides a novel avenue to directly evaluate both of these issues. By distinguishing between true (taxon absent) and false (taxon present, but not observed) absences, occupancy modelling produces independent and simultaneous probability estimates for both occupancy and detection. These can then be compared against 'naïve' occupancy produced without modelling to establish whether observed occupancy patterns are genuine or a result of poor detection of fauna. Herein, we use two varieties of multi-season occupancy models, along with a suite of modern environmental and palaeoclimatic modelling covariates, to evaluate trends in occupancy and detection within three groups of dinosaurs (Tyrannosauridae, Ceratopsidae and Hadrosauridae) during the latest Cretaceous of North America. Whereas a literal reading of the fossil record shows declines in occupancy for Hadrosauridae and Tyrannosauridae up to the Cretaceous/Paleogene boundary, occupancy modelling reveals stable to increasing occupancy for these groups within the Maastrichtian, but reduced probability of detection. This conclusively demonstrates that sampling bias is the direct cause of the apparent latest Cretaceous decline. Additionally, whereas outcrop area, rainfall, and land use are shown to significantly impact detection probability, heterogeneity across sites is the largest driver across all groups, suggesting site-level variation in preservation potential controls the observed dinosaurian fossil record. We show that occupancy modelling provides a novel approach in palaeobiology for evaluating the robustness of biodiversity trends in the face of fossil record bias.

## INTEGRATING MOLECULAR PHYLOGENIES AND FOSSILS WITHOUT A MORPHOLOGICAL MATRIX TO INVESTIGATE PATTERNS OF TRAIT EVOLUTION: A CASE STUDY USING CARANGARIA

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Investigating the tempo and mode of trait evolution through geologic time is a central focus among evolutionary biologists and is often approached using a time-calibrated phylogeny and a matching phenotypic dataset of extant species. However, there is a growing body of literature highlighting the importance of including paleontological data when modeling trait evolution because of the unique data captured by fossils. In particular, incorporation of paleontological evidence can change or strengthen macroevolutionary inferences. Currently, only a few exemplar clades with well-described fossils and an available morphological matrix of extinct and extant taxa can be subjected to a combined phylogenetic analysis in a total-evidence framework to provide the comparative foundation for such work. Here we test a variety of ways of inserting fossils into a molecular phylogeny without a morphological matrix using Carangaria (flatfishes, billfishes, and jacks) as a model system. We fit models of continuous trait evolution to trees of living species only and those with fossils inserted to test the impact on inferences of mode of phenotypic evolution from (1) inserting fossils into a phylogeny generally and (2) contrasting approaches to fossil insertion. A model of diffusive evolution was repeatedly favored for phylogenies with inserted fossils, regardless of how those fossils were inserted. Significantly, exclusion of fossils reduces statistical support for the model. Morphological matrices are critical when resolving the precise interrelationships among fossil and extant taxa, but other approaches using approximate phylogenetic placements of fossil taxa might still have value in macroevolutionary analysis.

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## DIVERSITY OF ARTHROPOD HERBIVORE DAMAGE ASSOCIATED WITH THE MIDDLE PENNSYLVANIAN MAZON CREEK FLORA, ILLINOIS, U.S.A.

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During the Pennsylvanian Subperiod, terrestrial food webs were reshaped by the expansion of plant-arthropod interactions resembling those observed in modern ecosystems. The Middle Pennsylvanian Mazon Creek Lagerstätte was deposited during this important interval and is well-known for its exceptional preservation of plant and animal fossils. Despite the abundance of well-preserved fossil insects from Mazon Creek, including known herbivorous clades, only limited evidence of arthropod herbivory has been reported, such as margin feeding damage type 12 (Scott and Taylor, 1983), suggesting that arthropod feeding damage associated with the Mazon Creek flora is low-diversity and rare. However, these estimations of damage frequency are based on only 100 specimens of a single pteridosperm genus, Macroneuropteris. The high diversity of the Mazon Creek flora, as well as the abundant specimens housed in multiple museum collections, present a valuable opportunity to examine ecological interactions in equatorial Euramerican wetlands during the Pennsylvanian Subperiod. In this preliminary study, we examined over 1800 Mazon Creek pteridosperm (*Alethopteris*, *Cyclopteris*, *Diplazites*, *Eusphenopteris*, *Odontopteris*, *Neuropteris*, *Macroneuropteris*), fern (*Diplazites*), and sphenopsid (*Calamophyllites*) fossils for evidence of arthropod herbivory and other damage, assigning them to standardized damage types (DTs). Close examination of the fossil flora, aided with high-resolution photography and scanning electron microscopy, indicates that while herbivore damage diversity is fairly low at Mazon Creek, it is more diverse than previously recognized. In addition to previously reported margin feeding (DT12), we found evidence of three additional margin-feeding DTs (DTs 13, 14, and 15). We also observed additional damage types from the piercing and sucking (DT 46), and oviposition (DTs 72, 100, 101) functional feeding groups. Some damage on Mazon Creek leaves can also be attributed to factors other than insect damage, including infection by a pathogen (possibly fungi; DTs 75, 97, 130, and 232), abiotic processes, and post-depositional processes. These preliminary results indicate that detailed surveys of a broader range of genera from the Mazon Creek flora provide a more complete view of plant-insect interactions and pathogenic attack in the Middle Pennsylvanian wetland ecosystem. As we broaden our survey of Mazon Creek plant species, we expect to find additional plant-arthropod associations.

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## EARLY MIOCENE PALEOTEMPERATURES FOR THE HIGH AUSTRAL SW ATLANTIC DERIVED FROM FOSSIL BIVALVES IN PATAGONIA, ARGENTINA

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The Miocene is receiving increased attention because estimated $pCO_2$ is comparable to that forecast over the next century and proxy data suggest very warm conditions. While sea surface temperatures (SSTs) in the tropics and northern latitudes are reasonably well constrained, few data exist from the southern hemisphere and high south Atlantic. Here, we present oxygen isotope data from fossil bivalves preserved in the Monte León Formation, at the southernmost tip of South America, and explore their implications for Miocene paleoclimate. The Monte León Formation is exposed between the mouth of the Santa Cruz River (49°59'S–68°33'W) south to Las Cuevas–Monte Observación (50°22'S–68°55'W) (Austral Basin; Santa Cruz Province) and records high Austral shallow marine deposition during the early Miocene, ca.19.27–17.69 Ma (Burdigalian), just before the onset of the Miocene Climatic Optimum. We examined three lithostratigraphic sections and collected well-preserved fossil bivalves from six stratigraphic horizons. Sedimentology and paleoecology indicate deposition under fully marine conditions in inner shelf to lower tidal environments, aside from the uppermost horizon where there is evidence for brackish and deltaic conditions. The taxa of interest are *Cucullaea alta* Sowerby, *Retrotapes striatollamellata* Ihering, *Austrocallista iheringii* (Cossmann) and *Glycymerita cuevensis* (Ihering). We collected time-integrated (bulk) samples from multiple individuals in each horizon and sequentially microsampled one specimen from four of the horizons, then use their stable oxygen isotope data to reveal season of growth, constrain seasonal range in SSTs, and estimate mean annual SST over the interval. Preliminary paleotemperatures increase upsection from an annual average around 15 °C to around 17.5 °C. Seasonal range increases upsection from ~4 °C to ~7 °C. Seasonally-resolved data show that *Cucullaea* grows more in the winter-spring months, *Glycymerita* in the summer, and *Retrotapes* and *Austrocallista* grow year-round. Isotope data from the uppermost horizon are both lower and more seasonal, consistent with inferred brackish conditions and suggesting artificially warm paleotemperatures. Nevertheless, calculated values ranging between 15 and 23 °C are consistent over more than five years of growth, and growth is comparatively rapid and uninterrupted over the warm/brackish season, unlike what might result from salinity

stress. Clumped isotope paleotemperatures could help to resolve uncertainty over seawater isotope values and provide better constraints on oxygen-isotope-derived temperatures. Our seasonally resolved paleotemperatures are consistent with limited early Miocene proxy data from high southern latitudes and reinforce the warm conditions at high latitudes that have been difficult to capture with climate models. SSTs substantially warmer than those in the study area today (6–10 °C), despite only moderately elevated estimated $pCO_2$, merit further attention.

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## ECOLOGICAL STABILITY DURING DEVELOPMENTAL SHIFTS; A CASE STUDY OF PARACRINOIDEA

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Shifts in developmental patterns have been hypothesized as both a mechanism for changing ecological function resulting in expanding niche occupation and diversification as well as constraining disparity thus limiting future evolutionary potential. Therefore, the relationship between development, functional morphology, ecology, and diversification dynamics is complicated. Echinoderms are a model system to study the result of developmental changes. Paedomorphic shifts in the oral system are well documented in many groups of Paleozoic echinoderms resulting in dramatic changes in body plan symmetry and thecal architecture. In addition, many of these shifts have been linked to novel ecological modes (e.g., pleurocystitid rhombiferans) within echinoderms. This pattern can be observed in Paracrinoidea, a small monophyletic group of Late Ordovician Laurentian stalked echinoderms. Recent phylogenetic analyses indicate steady developmental changes in the oral system reducing the number of ambulacra and changing overall body symmetry within the clade. Basal paracrinoids exhibit stereotypical pentameral symmetry with globular theca, whereas derived taxa exhibit distinctive bilateral symmetry and laterally flattened body plans. To explore how the change in body shape paired with ambulacral reduction altered function, we constructed four 3d models of paracrinoids (including *Columbocystis*, *Implicaticystis*, *Canadocystis*, and *Platycystites*) and examined their feeding ecology and hydrodynamics using computational fluid dynamics. Despite paedomorphic shifts resulting in change in the number of ambulacra, morphology of feeding appendages, oral symmetry, and thecal shape the hydrodynamics and feeding ecology remained consistent. All of the forms reduced fluid flow through the feeding appendages and created recirculating currents to effectively feed above and below the theca. This pattern results from shifts in thecal forms in concert with changes in feeding morphology thus remaining in a consistent position within the ecosystem as effective lower tier filter feeders. Thus, large shifts in developmental processes need to be considered holistically and can result in little ecological or functional change despite large changes in overall morphologic form.

## THE UTILITY OF LINEAR MORPHOMETRICS AS A TOOL FOR DIETARY INFERENCE IN FOSSIL SHREWS

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Linear morphometrics have been used extensively to infer the ecology of fossil organisms, including locomotory mode and dietary preference. While this technique has been applied to many groups of mammals, there are some which have not yet been thoroughly explored, like shrews of the family Soricidae. Some recent work has used linear morphometrics to explore locomotory mode in shrews, but much less has been done in the exploration of their dietary ecology. Though often considered to have a homogenous insectivorous diet, direct dietary observation suggests shrew dietary diversity is substantial and underappreciated. Many species appear to have distinct preferences for prey of specific hardness, while others include notable amounts of plant, fungus, or vertebrate material into their diets. Dietary diversity of this nature is well established to have influenced the morphology of the skull in other mammal clades, so similar patterns are hypothesized to be detectable in shrews. Here, we examine the link between known diet and morphological disparity in extant shrews using linear morphometrics and use that framework to infer dietary ecology in fossil taxa. A series of 42 linear measurements were gathered that characterize elements of the shrew dentition, mandible, and cranium which should reflect dietary specializations. The extant taxa included over 20 species (> 100 individuals) and represents a phylogenetically diverse sample with documented dietary information. Taxa were classified using two distinct schemes: 1) based on the hardness of the most abundant documented prey items (hard, intermediate, and soft bodied feeders), and 2): functional morphology of their dentition (slicing, crushing, and mixed processing). In addition to this sample of extant species, three fossil taxa from the Early Pliocene Gray Fossil Site (GFS) of eastern Tennessee were also characterized: "*Blarinella*," *Crusafontina*, and *Tregosorex*. These three taxa show considerable morphological differences between them

and thus were expected to provide an exceptional test of this modern framework′s ability to infer diet in fossil shrews. The results of a principal component analysis reveal substantial morphological variation among studied taxa and suggest that while phylogenetic history has influenced the dental morphology of shrews, dietary and functional differences are evident within clades. Within this context, soft feeders having generally more elongate shearing surfaces and reduced grinding areas compared to hard or mixed feeders. A discriminant function analysis found the studied metrics can differentiate extant shrews with different diets (63.2 % correct classification) and was able to classify the GFS shrews as soft and intermediate feeders. Findings from this study supports the utility of linear morphometrics as a tool for dietary inference in fossil shrews and other "insectivorous" mammals more broadly.

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## DO NOVEL FUNCTIONS DRIVE DIVERSIFICATION IN CENOZOIC ANOMALODESMATA (BIVALVIA)?

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Today the most taxonomically diverse bivalve clade is Imparidentia (Imparis). 300 million years ago, however, Anomalodesmata (Anomalos), Imparidentia's sister clade, was dominant among marine bivalves while Imparidentia was of minor importance. As Anomalos consistently cooccur with Imparis in fossil assemblages, these apparently reciprocal patterns resemble the classic double-wedge pattern at first glance and raise the question of whether Imparis competitively replaced Anomalos. New analyses of range-through occurrence data of Anomalos and Imparis unveil a more complex three-phase pattern in which diversity and diversification rates switched from favoring Anomalos in the Paleozoic, to favoring Imparis in the Mesozoic, to the two groups having identical diversification rates in the Cenozoic, when they diversified in parallel. Given these results, I test for within-clade and between-clade interactions as a mechanism underlying the apparent negative interactions between the sister clades. I first calculated diversification rates using boundary-crossing diversity in each ~5-million-year interval, then correlated them between Anomalos and Imparis. Negative interactions do appear to exist in the Mesozoic: Anomalo extinction rates and Impari origination rates in 5-million-year intervals positively correlate with each other, so that Imparis diversified at a rate more than twice that of Anomalos. In the Cenozoic, however, Anomalos reached a net diversification rate 4 times higher than in the Mesozoic, similar to that of Cenozoic Imparis, suggesting an evasion of negative interactions. To test whether the negative interactions arose from ecological overlap between the two clades, I focused on the subset of Anomalos that adopted modes of life distinctive different from those of Imparis: these "anomalous Anomalos" (borers, carnivores, etc.) should show an evolutionary advantage relative to "Impari-like Anomalo" lineages (infaunal soft-sedimentary suspension-feeders) in terms of taxonomic diversity, genus duration or ages, or diversification rates. I found that, notwithstanding their exploitation of novel food sources or substrata, the anomalous Anomalo lineages do not show significant evolutionary advantage relative to the Impari-like Anomalo lineages. This rules out functional partitioning as the mechanism for Anomalos to escape negative interactions with Imparis in the Cenozoic, and is inconsistent with the evolutionary dynamics instead simply reflecting clade interactions among Anomalo genera. These results direct us to the next step: testing for geographical partitioning by bathymetry and latitude as the mechanism for escape from the negative interactions in the Cenozoic, with anomalos diversifying at high latitudes and in the deep sea, and the Imparis most prolific in tropical shallow waters.

## MICROPLASTICS IN VIRGINIA'S EASTERN SHORE: ESTABLISHING A BASELINE FOR FUTURE CONSERVATION PRACTICES

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Microplastics (plastics smaller than 5 mm) have been accumulating in onshore and offshore sediment sinks since the rise of plastic production and use in the early 1950s. Prior studies have focused largely on the effects of microplastic pollution in deep marine ecosystems and documented the harm that plastics and microplastics cause to marine fauna. Intertidal ecosystems (i.e., salt marshes, estuaries, etc.) are a particularly significant sink for microplastics since sediment can be sourced from both marine and freshwater environments. Despite their occurrence in coastal waters and sediments, microplastics are not included in coastal ecosystem health assessments to prepare for future conservation efforts. In coastal estuaries, microplastic concentrations can increase due to urbanization and land use, with shorebirds and invertebrates accumulating macro and microplastics. How can we properly establish the health of coastal ecosystems so that we can best predict (and mitigate) how microplastics will affect these environments with time? Here, we establish foundational questions to understand how to best measure the effects of microplastic occurrence in a coastal marsh of Accomack County, Virginia, bordering the eastern Chesapeake Bay. Our preliminary data demonstrates that from the top 6 cm of sediment, 75–80% of the particles recovered were plastic, with an average

concentration of 4.83 particles per cm. Common polymers recovered were polypropylene (44%) and polyethylene (31%). We present future directions for this research, including the comparison of microplastic concentrations between bay and ocean coastal marsh sediments, using primary producers (i.e., diatoms) to assess past and present marsh health, and establishing interdisciplinary methods that incorporate a holistic approach to conserving long-term ecosystem health. Microplastics represent an emerging pollutant that will become more pervasive with time due to population growth and demand, therefore we must establish methods to properly assess the past and present health of these ecosystems so that we can appropriately conserve them as microplastic accumulation accelerates.

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## ECOLOGICAL RESONANCE: UNRAVELING THE HUNTING BEHAVIOR AND DIETARY ECOLOGY OF THE AMERICAN LION (*PANTHERA ATROX*), AN INFERRED DEPARTURE FROM AFRICAN LIONS

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The American lion (*Panthera atrox*), a formidable Pleistocene hypercarnivore, ranks among the largest felids to have roamed the Earth. Although genetic analyses have established its close phylogenetic relationship with the European cave lion (*Panthera spelaea*) and African lions (*Panthera leo*), morphological studies have suggested a greater resemblance to the extant jaguar (*Panthera onca*). Inferences regarding the dietary ecology and behavior of the American lion often rely on comparisons with its most closely related living relatives. In this study, we employ Dental Microwear Texture Analysis (DMTA) to explore the dietary behavior of the American lions from Rancho La Brea and beyond (i.e., Alaska, California, Florida) and broaden the scope of the baseline comparative data to include a diverse array of big cats not previously examined via DMTA (i.e., modern leopards, tigers, and jaguars). Complexity values of *Panthera atrox* are significantly lower than African lions, jaguars (*Panthera onca*), the mountain lion (*Puma concolor*), and all hyenas examined (i.e., the spotted hyena, *Crocuta crocuta*; the striped hyena, *Hyaena hyaena*; and the brown hyena, *Parahyaena brunnea*), indicative of a diet of softer foods in the former. *Panthera atrox* complexity values are indistinguishable from the tiger (*Panthera tigris*), leopard (*Panthera pardus*), and cheetah (*Acinonyx jubatus*); these extant cats are typically solitary and do not engage in significant carcass sharing, bone processing, or scavenging behavior—primarily eating the flesh from carcasses they acquire themselves. Similarly, *Panthera atrox* has textural fill volume values significantly lower than African lions, mountain lions, and all hyenas examined; further evidence of soft-food consumption. High anisotropy values are indicative of the consumption of tough foods; *Panthera atrox* has the highest anisotropy values as compared to all extant and extinct cats and has significant greater mean values that cheetahs, African lions, and all hyenas. Contrary to expectations based on phylogenetic relationships, our findings challenge the notion that the American lion exhibited dietary behavior similar to extant African lions. Instead, our DMTA results reveal a striking ecological convergence most similar to modern leopards, tigers, and jaguars. This study highlights the importance of considering ecological factors in addition to genetic relationships when reconstructing the behavior and dietary preferences of extinct species, shedding new light on the ecological adaptations of *Panthera atrox* during the Pleistocene. Further work is needed to determine when these ecological adaptations occurred and the drivers responsible for their ecological similarity to solitary big cats.

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## WHAT DOES "SUCCESS" MEAN IN CONSERVATION PALEOBIOLOGY?

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Traditionally, impact in conservation paleobiology—and the conservation sciences more broadly—has been framed as successfully influencing policy and/or practice. However, this framing does not capture the full diversity of impacts. In this presentation, I argue for a broader conception of "success" in conservation paleobiology that recognizes that achieving the ultimate goal of a co-production process (i.e., practitioner-relevant research that is accessible, shared, and used) can take time and is often affected by multiple factors outside of a researcher's control (e.g., shifting agency priorities). Providing timely results that are considered, but not necessarily acted upon, achieving desired programmatic outcomes (e.g., boundary objects such as decision-support tools, models, and reports for use by practitioners), helping set priorities to direct future research funding opportunities, and the sustainability and continued use of knowledge produced can all be considered as forms of success in conservation paleobiology research. In addition, not every outcome of the co-production process is readily evidenced. Co-production processes often result in intangible outcomes, such as mutual learning, development of practitioners' capacity to use paleontological data, trust building, expanded networks, and personal growth. Moving

beyond a narrow conception of success is crucial for guiding future efforts to assess conservation paleobiology's impact.

## ALIGNING PALEOBIOLOGICAL RESEARCH WITH CONSERVATION PRIORITIES USING ELASMOBRANCHS AS A MODEL

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Humans have dramatically transformed ecosystems over the previous millennia and are potentially causing a mass extinction event comparable to the others that shaped the history of life. However, only a fraction of these human impacts has been directly recorded, limiting conservation actions. Conservation paleobiology leverages geohistorical records to offer a long-term perspective on biodiversity change in the face of anthropogenic stressors. Nevertheless, the field's on-the-ground contributions to conservation outcomes are still developing. Here, we present an overview of directions in which paleobiological research could progress to aid conservation in the coming decades using elasmobranchs (sharks, rays, and skates)—a highly threatened group with a rich fossil record—as a model. These research directions are guided by areas of overlap between an expert-led list of current elasmobranch conservation priorities and available fossil and historical records. Four research topics emerged for which paleobiological research could address open questions in elasmobranch science and conservation: 1) baselines, 2) ecological roles, 3) threats, and 4) conservation priorities. Increasingly rich datasets and novel analytical frameworks present exciting opportunities to apply the elasmobranch fossil record to conservation practice, which could be extended to other clades. Given the synthetic nature of these topics, we encourage interdisciplinary collaboration across timescales and with conservation practitioners to produce more actionable conservation paleobiology research.

## CASCADING EFFECTS OF REEF CRISES

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Metazoan reefs have endured numerous crises throughout the Phanerozoic when reef carbonate production collapsed in geologically short times. Some crises led to a complete turnover in the reef-building consortium, whereas there was little change across other crises, and there is no obvious correspondence between crisis intensity and turnover. For example, Middle Triassic reefs had very similar reef builders at the genus level as Late Permian reefs, despite the biggest Phanerozoic mass extinction happening in between. The extent to which these crises induced substantial changes in reef community composition remains uncertain, and it is unknown whether reef crises caused cascading effects on reef dwellers. Here we used a global compilation of reef-related occurrences from the Paleobiology Database combined with a rigorous novel community detection framework to identify novel reef communities across the Phanerozoic for reef builders as well as reef dwellers. Using a genus-level taxonomic resolution and stage-level stratigraphic resolution, we identified four novelty events among reef builders and four novelty events among reef dwellers. The novelty events match in one case—after the end-Triassic reef crisis and mass extinction. Outside of novelty events, the novelness of reef-building and reef-dwelling communities is tightly correlated ($R = 0.44$, $p < 0.0001$). Our findings underscore the intricate relationship between reef builders and reef dwellers and render cascading effects plausible. Our study draws attention to the risk of losing many more species than just corals when coral reefs vanish.

## COLLECTIONS AT THE UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY (UCMP): GROWTH IN THE 21ST CENTURY AND BEYOND

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Established in 1921 by a gift from Annie M. Alexander, the University of California Museum of Paleontology's (UCMP) mission is to investigate and promote the understanding of the history of life and the diversity of the Earth's biota through research and education. Fundamental to this mission is stewardship of UCMP's rich collections, which date back to the original Geological Survey of California in 1864. UCMP has continued to enrich our state's fossil record and grown to include collections from every continent and five oceans. These include vertebrate, invertebrate, paleobotanical, and microfossil specimens, consisting of at least 15 million fossils, hence earning its identification as a "major" collection in the CONARIP Report of 1977. From the 1970s, the collection continued to grow principally from the research activities of faculty, staff, and students. However, beginning in 1990 and continuing to the present, transfers of collections have resulted in dramatic growth. Some of these were "orphaned" by institutions, most notably collections from the US Geological Survey (USGS) at Menlo Park (itself a "major" collection in the 1977 report), San Francisco State University (SFSU), UC-Los Angeles (microfossil and vertebrate), UC-Riverside

(vertebrate), Stanford (microfossil types), and both Texaco and Arco (microfossils and core samples). Other major collections came from retiring faculty at other institutions (notably, a coral collection from Cal Stevens at San Jose State, paleobotanical collections from Daniel Axelrod and James Doyle of UC-Davis, and fossil fish from Michael Bell of Stony Brook U). These are also joined by significant new collections arising from California's active mitigation industry. Taken together, the last twenty years has seen a shift in growth from that of primarily internal research by UCMP affiliates, to the addition of mitigation projects, external researcher's collections, as well as repository requests from land management agencies. Several of the orphan collections have been supported by NSF grants and recent mitigation projects have supported curation, but most have not, making it challenging to make these collections available. Despite such growth, in the 47 years since the original CONARIP Report, budget cuts have resulted in the loss of all of UCMP's preparator positions and cut the number of collection staff in half. However, UCMP continues to host researchers from around the world as well as produce cutting-edge paleontological research. Our in-house journal established in 1967, PaleoBios, transitioned to open access and publishes several issues a year; it remains one of the few museum-run publications to still operate on the West Coast. After over 100 years of paleontological research, UCMP perseveres in its stewardship role and to work towards increasing the integration and accessibility of our collections and associated data for both research and educational purposes.

## CAPTURING THE NUANCE OF PHYSIOGRAPHIC BARRIERS: AN EXAMPLE FROM RIVERS

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It has long been proposed that rivers act as barriers, limiting gene flow and structuring populations of species that cannot, or at low frequency, traverse the channel. While this hypothesis has been thoroughly tested, evidence has been variable and widely contradicting among studies. That variability of outcomes could be a concern, but such variability could also reflect the nature of the system—that is, under some conditions rivers act as barriers, under some conditions they do not, and based on trait characteristics some organisms are more readily affected than others. The question becomes, how can we measure those conditions? In an attempt to answer this question, we used published genomic data for organisms whose range spans a river channel and paired them with publicly available data on river attributes (discharge, seasonality of discharge, and river width) for locations where the genomic data was taken. In total we measured river-associated differentiation (as cross-river pairwise Fst) on 27 genomic datasets of lizards, snakes, birds, trees, an herb, and a mouse that collectively spanned 24 different river segments across the contiguous United States. We used directed acyclic graphs to articulate direct and indirect relationships of river variables, geographic distance, and dispersal ability on population differentiation. We varied complexity of graph structures and quantified graph paths using structural equation modeling (in total, 38 models). In summary, we found that discharge has a positive direct effect on population differentiation but it is negated by its indirect effects on other river attributes (e.g., width). Low dispersing species were more affected by river width than high dispersers as expected but surprisingly, that relationship was consistently negative. This means that narrower rivers associated with higher population differentiation. While surprising, we interpret this to be a function of two phenomena that both have empirical support: 1) narrow channels occur more at higher elevation where incision is deeper and potential dispersal-dampening topography is greater, and 2) river meanders and avulsions increase river width and occur more in low-lying areas and can facilitate dispersal. Seasonality was consistently important, but more work is needed to interpret this effect. Overall, we find graph structures may be a helpful tool to capture the nuance and internal complexities of physiographic features; here they suggest more work is needed to disentangle the effects of topographic setting and river attributes.

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## FUNCTIONAL GROUP RICHNESS OF NORTH AMERICAN LARGE MAMMALIAN PREDATORS AND HERBIVORES WERE POSITIVELY CORRELATED OVER THE CENOZOIC

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Species richness of extant large mammalian predators and their large herbivore prey is positively correlated at regional and continental scales; a relationship that increases in strength with increasing predator size. Predator richness has been observed to roughly track that of their presumed large herbivore prey over much of the Cenozoic (Uintan to Holocene). However, the scope and character of this pattern has never been fully explored to determine if the predator guild was evolving in response to changes in herbivore guild richness. To test for correlated evolution, we characterized the richness of the predator and herbivore guilds at the continental scale using body mass and predator diet (e.g., hypercarnivore, mesocarnivores, and hypocarnivores) to evaluate whether the predator guild evolved in response to changes in the body mass distribution of species richness within the herbivore

guild. Linear measurements of the cheek tooth row were compiled from the literature and our own measurements of museum specimens. Large herbivore (n = 1087 species) body masses were estimated using the lengths and widths of the upper and lower cheek teeth whereas predator (n = 400 species) body masses were estimated based on the length of the lower carnassial (m1). Both guilds were subsequently partitioned into ecologically informed size categories. We observed significant positive correlations between lion-size (>100 kg) predators and antelope- (25–150 kg) and rhino-size (>500 kg) herbivores when the whole predator guild was considered. The significant correlations between antelope- and horse-size (150–500 kg) herbivores and lion-size predators increased in strength when the predator guild was restricted to just hypercarnivores. Finally, we observed significant positive correlations between wild-cat-size (1–7kg) mesocarnivores and javelina- (5–25 kg) to horse-size herbivores. We suggest that these correlations between smaller predators and the presence of relatively large prey might represent a response to increased carcass availability due to large hypercarnivores.

Funding source: Herbivore dental measurements were collected using NSF funding (NSF EAR-1252123).

## STRATIGRAPHIC FRAMEWORK FOR THE MID PIACENZIAN WARM PERIOD ON THE U.S. ATLANTIC COASTAL PLAIN

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Global reconstructions of Pliocene environmental conditions provide insights into how the climate system operates under elevated temperatures and atmospheric $CO_2$ levels. Most previous work focused on the Late Pliocene interval known as the mid Piacenzian Warm Period (mPWP), originally identified and reconstructed by the U.S. Geological Survey Pliocene Research, Interpretation and Synoptic Mapping Project (PRISM). These reconstructions have been used both as boundary conditions for paleoclimate modeling experiments, and for comparison to simulated past and future conditions. The US Atlantic Coastal Plain preserves a record of these Pliocene paleoenvironments from Virginia to Florida. Here we evaluate the large-scale stratigraphic framework of Pliocene units from Virginia to Georgia with a primary focus on planktic foraminiferal assemblages and other fossil groups providing biochronologic control. We correlate the mPWP to a transgression following a major global sea level event (Marine isotope Stage M2; MIS M2). Where preserved, Early Pliocene units (Sunken Meadow Member or Zone 1 of the Yorktown Formation in SE Virginia and part of North Carolina, and the Wabasso beds of the Hawthorn Group, South Carolina-Georgia) rest unconformably on Eocene, Oligocene or Miocene sediments. The later regression associated with MIS M2 (~3.33 Ma) removed part (in places all) of the earlier Pliocene sediments. The subsequent transgression associated with the MIS M2–MIS M1 transition deposited Zone 2 Yorktown (Rushmere, Morgarts Beach and Moore House Members) in southeastern Virginia and North Carolina, north of the Neuse River, and Duplin and Raysor Formations in southern North Carolina, South Carolina and Georgia, parts of which represent the mPWP. The Early Pleistocene Chowan River (Virginia and North Carolina) and Bear Bluff (South Carolina) Formations rest unconformably on these Pliocene units.

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## DIFFERENTIAL EVOLUTIONARY TRENDS OF MARINE BIVALVE BODY SIZE BY HEMISPHERE AND BODY-SIZE CLASSES

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The shapes of trait distributions and their changes through time are informative about many aspects of a clade's evolutionary history, and can therefore shed light on broad evolutionary trends and possible controls on those trends. For all marine bivalve genera with at least ten extant species and a known fossil record (n = 160), I analyzed how (a) the shapes of body-size distributions and (b) the evolutionary trajectories of these genera (determined by comparing the body size of their first known fossil member of each genus to the body-size distribution of the modern species in that genus) differed by size class and biogeographic region. The skewness and median of body-size distributions consisting of the maximum size of each extant species within each genus were analyzed by size class, which was determined by dividing the median of each distribution into equal tertiles. Following this, body sizes for the oldest known fossil occurrences of each genus—largely restricted to the Mesozoic and Cenozoic, with the median age falling in the Eocene—were calculated from dimensions or images found in the literature. The sizes of these oldest fossil occurrences were then tested against the body-size distribution of their extant congenerics to determine, in concert with the skewness of the modern body-size distribution, whether genera showed stasis, passive trends, or driven trends in body size, sensu McShea, analyzed by size class and hemisphere. Small-bodied genera were much

more likely to have symmetric body-size distributions (37 of the 53 small genera), while medium- and large-bodied genera sport left-skewed (45 of the 108 genera) and symmetric (56 of the 108 genera) body-size distributions with near equal frequency. Though evidence for stasis, passive, driven trends in body-size evolution was found across size classes and for genera with peaks in species richness in both the Northern and Southern Hemisphere, there are some indications that driven trends may be more common in small-bodied genera, while passive trends may be more common in medium- and large-bodied genera. These contrasts in body-size evolution may indicate that selective pressures through time are, on a broad level, fundamentally different for small bivalves than for medium and large ones, with conditions allowing for more exploration of extremes in larger genera.

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## OPAL: OPEN PALAEONTOLOGY—A COMMUNITY-DRIVEN DIAMOND OPEN ACCESS JOURNAL WITH PREREGISTRATION

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We are establishing a new diamond open access journal, OPal: Open Palaeontology. OPal's scope will cover all aspects of palaeontological research and the journal will have a flexible publishing model with a range of publication types, preprinting, and transparent peer review. The founding principles of OPal directly address concerns that the current academic publishing landscape is systemically unfit for purpose, dominated by a few large publishing houses that extract substantial profit from public resources for little return value, remove copyright from authors, and hinder innovation. Traditional publishing models bake-in gatekeeping practices controlling who and what is published; single-blind peer review has long been suggested to suppress original thought, be biased against marginalised groups, and be ineffective at improving the quality of flawed work. There is also increasing recognition of a reproducibility crisis in science, partly driven by pressure to publish novel work in high-impact journals. The result is systemic inaccessibility, opacity, and lack of accountability—all supported by the academic publishing system. But all is not lost: there is a wealth of established and emerging good practice across the academic publishing landscape, and OPal will draw on these across its publishing model. OPal's ethos is rooted in financial accessibility, transparency, and accountability in academic research. OPal's model draws on established and emerging good practice from across the academic publishing landscape, including diamond open access to mitigate financial inaccessibility, interactive and transparent peer review procedures, and research preregistration integrated with article publication. We also propose a flexible approach to publishing research at various stages of intellectual development and in different formats. We hope that OPal will help transform our understanding of how palaeontological research can be rigorously assessed and published. Here, we put out an open call for those interested in working with us on this new journal. In particular, we seek people interested in working on the OPal editorial board to manage journal editorial processes and those wishing to act as handling editors. We particularly encourage early-career researchers, those working in non-academic positions, and people working outside Europe and North America to get in touch!

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## DISTINCT CAUSES UNDERLIE DOUBLE-PEAKED TRILOBITE CEPHALON DISPARITY, BUT THIS DISPARITY IS UNRELATED TO EXOSKELETON MOULTING BEHAVIOUR

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Trilobites had strongly biomineralised exoskeletons with a diversity of morphological adaptations to different niches across the Palaeozoic. The group was extremely influential on the development of Palaeozoic ecosystems, having a global range and being found in vast abundance in varied marine environments. Correspondingly, there is a long history of research on their functional adaptations, diversity, and disparity, which we are increasingly able to develop using expanded datasets and technological advancements. We used a global dataset of c. 1000 trilobite cephalon outline curves (including 387 specimens resampled from Suárez and Esteve, 2021) to create an expansive morphospace exploring the full extent of trilobite cephalon outline morphometric disparity. We then used these data to analyse the differences in morphospace occupation across the Palaeozoic and between taxonomic orders. Elliptical Fourier transformation visualised as a Principal Components Analysis suggests significant differences in morphospace occupation and disparities for order and geological Period groups. Cephalic outline disparity increases from the Cambrian to Ordovician, apparently as a result of radiations to new niches. This is followed by morphospace occupation constriction to the Silurian, a second disparity peak in the Devonian caused by within-niche diversification, and a further constriction following the Devonian. The latter decline was likely the result of a high number of species going extinct, notably forms at the extremes

of occupied morphospace. The post-Devonian survivors and trilobites that originated after the end-Devonian mass extinctions are constrained towards the centre of the morphospace. Kmeans clustering analyses support this constriction in natural grouping through the Palaeozoic. However, analyses interrogating the predictiveness of cephalon outline morphometry suggest that order and geological Period assignment cannot be robustly predicted for an unknown trilobite, except for Harpida and the Cambrian and Ordovician Periods. Analyses of morphological disparity can also be used to explore key trilobite behaviours, such as exoskeleton moulting. Like all euarthropods, trilobites moulted their exoskeletons repeatedly throughout their lives to grow and develop, but were uniquely variable in the behaviours involved, partly because of their cephalon morphological disparity. However, analyses using this dataset suggest cephalic shape had little overall impact on moulting behaviour, with the behavioural groups almost entirely nested in morphospace. Further, cephalon morphometry cannot be used to predict moulting behaviour from this dataset. Perhaps trilobites demonstrated high phenotypic plasticity in moulting that cannot be explained by individual variables or evolutionary drivers such as morphometry.

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## WHEN MATS MATTERED MOST (FOR US!): THE SIGNIFICANCE OF ORGANIC MATS ON THE DISTRIBUTION AND PRESERVATION OF THE EDIACARA BIOTA

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In the absence of complex, bioturbating organisms, the Precambrian seafloor was covered by widespread organic matgrounds readily identified in the geologic record as distinct macroscopic sedimentary structures, features such as "microbially induced sedimentary structures" (MISS). The Ediacaran stratigraphic record is further characterized by textured organic surfaces (TOS) which consist of organosedimentary textures recording the presence of not only benthic microbial aggregates but also densely packed communities of macroscopic and multicellular eukaryotic organisms. At Nilpena Ediacara National Park, South Australia, a combination of preservation and exposure of the Ediacara Member has uniquely facilitated the excavation and reconstruction of discrete and fossiliferous bedding planes representing, in total, approximately 350 square meters of Ediacaran seafloor. These excavations have permitted the spatially broad and stratigraphically detailed reconstruction of snapshots of the ecology, habitat and fossilization of Ediacara communities. In particular, excavation of fossiliferous beds with varying degrees of mat development provides the opportunity to test relationships between mat type, mat maturity and Ediacara Biota community structure as excavated beds vary in the taxonomic composition, density and body size distribution of fossil assemblages; type and extent of TOS; and thickness, lateral extent and sedimentary structures. There is a wide range of mat types. However, mat maturity, rather than the mat type itself, more strongly influenced the distribution of taxa and the development of Ediacara macroorganism communities. Using a ranked mat maturity index, we find that density of macroscopic body fossils and genus diversity correlate with mat maturity, evenness however, does not. We additionally find that the sessile taxa *Obamus* and *Coronacollina* are restricted to surfaces with mature mats while all other Ediacaran macrobiota show no connection to occurrence and mat maturity. The exceptional record of mat surfaces preserved in the Flinders Ranges area demonstrates that, in addition to the apparent ecological role played by mat surfaces in Ediacaran communities, they were also likely a significant component of the Ediacara Member biomass and were integral to community function. Furthermore, the organically-stabilized substrate also shaped the sedimentologic and stratigraphic expression of Ediacaran siliciclastic sedimentary successions, providing search images for signatures of past life in the rock record on Earth and other planets.

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## DISPARATE FEEDING MECHANICS BETWEEN A CONTEMPORANEOUS LAMBEOSAURINE AND HADROSAURINE (ORNITHOPODA: HADROSAURIDAE) SUPPORT THE POTENTIAL FOR NICHE PARTITIONING

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Lambeosaurines, a lineage of duck-billed herbivorous dinosaurs, exhibit extreme modifications to the facial skeleton, where the premaxillae, nasals, and prefrontals are modified to form prominent supracranial crests that develop early in ontogeny. The crests are hypothesized to have facilitated intraspecific communication via sound production and sociosexual visual display. Oddly, these crests are extensions of the premaxillae and nasals onto the skull roof, where stress from feeding is usually dissipated in amniotes. Their sister group, the hadrosaurines, exhibits the plesiomorphic condition, lacking hollow crests and having proportionately longer skulls. It has been suggested that these differences in skull shape

may have forced lambeosaurines to feed on softer vegetation than hadrosaurines, but it is unknown exactly how these differences in skull shape affected feeding mechanics through ontogeny and between crested and non-crested forms. To test for differences in feeding mechanics, we used finite element analysis (FEA) to describe the distribution of stress in the skull of the hadrosaurine *Gryposaurus notabilis* and an ontogenetic series of the contemporaneous lambeosaurine *Corythosaurus casuarius* during simulated feeding. A subadult *Gryposaurus*, and four *Corythosaurus* (two juvenile, one subadult, and one adult) were CT scanned and segmented to generate 3D models of the skull and lower jaws for manipulation. The models were then retrodeformed to repair missing or damaged areas. Jaw muscles were reconstructed to calculate maximum muscle input forces, and restraints were placed on the anterior aspect of the premaxillae and jaw joints to simulate biting vegetation. The reconstructed models were then subjected to FEA to map the distribution of stress throughout the skulls during biting, with the bone and dental batteries modeled as separate materials. We found *Gryposaurus* has significantly greater muscle forces than similarly sized *Corythosaurus* due to relatively larger temporal chambers. *Gryposaurus* exhibits concentrated stress in the snout and braincase, as it typical for amniotes more broadly. Crestless juvenile *Corythosaurus* transfer stress primarily through the lateral processes of the premaxillae, whereas the crested subadult and adult dissipate less stress through the premaxillae, instead concentrating it in the facial skeleton and temporal region. The greater muscle contractile forces in *Gryposaurus* suggests that this taxon may be better able to process tough foods, and *Corythosaurus* may therefore have had a more limited diet breadth. Additionally, the ontogenetic changes observed in *Corythosaurus* suggest that the expansion of the premaxillae and nasals to form the crest altered the distribution of stress in the skull during feeding. This work suggests the potential for an evolutionary trade-off between feeding efficiency and the development of bizarre cranial structures in lambeosaurine evolution.

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## HIDDEN IN PLAIN SITE: COMPARING DIVERSITY USING SEPKOSKI'S *COMPENDIUM* AND THE PALEOBIOLOGY DATABASE

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When the Paleobiology Database (PBDB) was created in 1998, it was seeded with approximately 36,000 genus names from Sepkoski's (1999) *Compendium of Fossil Marine Animal Genera*. These original *Compendium* ranges are visible in the genus summary view pages of the PBDB. However, because the PBDB uses fossil occurrences to determine stratigraphic ranges, this means that any *Compendium* genus not tied to a collection will lack a usable stratigraphic range. In other words, it is possible that many fossil marine genera are virtually ignored when using the PBDB to run diversity and other analyses using downloaded data. The extent of this invisibility is unknown. Here, we compare the stratigraphic ranges for genera in the *Compendium* to those in the PBDB to identify the magnitude of this missing data and its impact on understanding trends in marine diversity. We demonstrate that only approximately 70% of genera in the *Compendium* have stratigraphic ranges in the PBDB, with protists and bryozoans having poorer coverage and brachiopods slightly better ones. For *Compendium* genera with PBDB ranges, the reported ranges are highly congruent in both data sets, although PBDB FADs begin slightly earlier and LADs end slightly later than in the *Compendium*. The PBDB includes more than 17,000 additional marine genera that were not included in the *Compendium*. Many of these were named after Sepkoski's passing, or in previously understudied or poorly fossilized taxa that have been more formally investigated in recent decades (e.g., subjects of recent *Treatise* volumes). New genera are especially concentrated in the Permian and Triassic, reflecting the increasing focus on these intervals in past decades. The cumulative effect of these differences can result in important differences in apparent diversity through time. When PBDB and *Compendium* ranges are combined, apparent range-through diversity typically increases, sometimes by large magnitudes, although this impact varies significantly by taxonomic group and time interval. Paleontologists interested in analyzing marine genus diversity should be aware of these "invisible" data and consider choosing appropriate methods to incorporate them into their analyses.

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## ENVIRONMENTAL CONTROLS ON DINOSAUR DIVERSITY, BIOGEOGRAPHY, AND DIET

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Dinosaurs were dominant members of terrestrial ecosystems throughout the Mesozoic, yet only recently are studies beginning to illuminate the key role of global environmental conditions in controlling dinosaur biodiversity, global distribution, and macroevolution. Specifically, the integration of analytical techniques from computational paleobiology with general circulation (paleoclimate) models have allowed long-standing hypotheses to be interrogated in much greater depth than ever before, as well as facilitate the generation of new hypotheses. Over half of all dinosaur species were herbivorous and relied on primary production and surrounding vegetation for food sources. In turn, some of these herbivorous forms became the largest terrestrial animals to have existed, the titanosaurian sauropods. Our previous work has revealed the tight link between sauropod biogeographic patterns and climatic conditions, and provided evidence for an important evolutionary shift from cooler to warmer climatic niches during the evolutionary origins of Sauropoda. Building on this, we investigated the influence of environmental conditions on patterns of herbivorous dinosaur diversity during the Jurassic–Cretaceous. For this, we used comprehensive fossil occurrence data originating in the Paleobiology Database and paleoclimate data from general circulation models, as well as information from deep-time vegetation models. Our results demonstrate a link between climatic conditions and sauropod diversity in the Jurassic, suggesting that climate played a key role in the origins of sauropod gigantism and the evolution of herbivory in this group. We found no significant relationship between the diversity of herbivorous dinosaur groups and proxies for food availability (namely, primary productivity, vegetation cover and biomass), which challenges the long-standing hypothesis that gigantism was facilitated by the increasing availability of high quality vegetation. Further analyses, including those using phylogenetic comparative approaches, suggest niche partitioning between different herbivorous groups. In particular, herbivorous theropods and 'traditional' herbivorous dinosaurs (e.g., thyreophorans) occupy different paleoclimatic niche space, indicating that climatic changes influenced evolutionary innovations related to dinosaur diet and feeding behaviours. Ongoing work applying geometric morphometrics to the skulls of these herbivorous groups aims to further reveal the drivers behind this ecological pattern. Overall, our work examining the influence of environmental conditions on dinosaur diversity, biogeography, and diet is showcasing the immense power of computational tools and how they are offering increasingly deeper insights into key evolutionary innovations.

## NOT ALL TURBIDITY IS EQUAL: THE OCCURRENCE OF DIVERSE PLEISTOCENE REEFS IN A DELTA FRONT SETTING AT THE PALAEO-KAMBANIRU RIVER MOUTH

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Turbid near-shore environments are likely to become more prominent as sea levels rise, storms become more frequent, and coastal development intensifies. Despite posing challenges for corals, these turbid water settings are likely to play a crucial role as 'refugia' environments. They shield sensitive reef faunas from solar radiation during increasingly abundant hyperthermal events. Examining coral reefs in the rock record provides insights into how reefs have responded to changes in sunlight exposure (irradiance)—a key environmental control for the symbiotic microbes which support coral health by providing a fixed carbon source. Reduced irradiance can result from a greater quantity of suspended sediment owing to processes such as year-round low-volume flow of water with high suspended load, compounded by episodic high-volume flow events and periodic intense wave action. The Kambaniru River, the largest on the island of Sumba, East Nusa Tenggara, Indonesia, has hosted deltaic reefs from the middle Pleistocene through the Holocene. The Palaeo-Kambaniru River Delta experienced high-energy, episodic flow during monsoon seasons, resulting in the formation of moderate-sized patch reefs in a broad embayment. The river was sourced in the southern highlands comprising Cenozoic volcaniclastic bedrock. As is the case with the modern Kambaniru system, rainfall was highly episodic and much higher in the distal highlands than in the northern carbonate platform that the Palaeo-Kambaniru incised through. Consequently, although the river transported significant suspended sediment, they were characterized by very low proportions of dissolved plant tannins, similar to the modern Kambaniru River. This is significant because tannins would have resulted in acidic water conditions, severely constraining the occurrence and diversity of reefs. Initial exploration of Pleistocene coral diversity at the Palaeo-Kambaniru River mouth reveals a diverse deltaic reef dominated by both branching and massive corals such as *Favites* sp., cf. *Goniopora* sp., *Goniastrea* sp., cf. *Leptoria* sp., cf. *Platygyra* sp., *Porites* sp., *Tubipora* sp., and *Acropora* spp. The latter is not typically resistant to significant turbidity, but its fast growth rate when compared to massive coral species, and aptitude for quick recovery after disturbances, contributes to its presence in these environments. Although turbidity from siliciclastic input poses challenges to reef faunas, the episodic nature of sediment input and low-vegetation landscape in the Kambaniru embayment likely influenced reef development. Assessing the exact nature of the turbidity is essential for understanding reef survival and adaptation. We posit that under adverse climatic conditions, some reef faunas may survive because of turbidity due to high siliciclastic input rather than despite it.

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## QUANTITATIVE ECOLOGY OF AN EOCENE GREENHOUSE ANTARCTIC BENTHIC COMMUNITY - LA MESETA FORMATION, SEYMOUR ISLAND

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Modern Antarctic benthic (seafloor) communities are unique compared to the rest of the world. Durophagous predators are uncommon and the ecosystems are dominated by sessile suspension feeding epifaunal organisms. Understanding how these communities evolved is vital to predict their response to anthropogenic environmental change. Recent documentation of Cretaceous and Cenozoic stalked crinoid distribution and the presence of shell-crushing decapods in the Miocene complicates prevailing theories that late Eocene cooling extensively restructured Southern Ocean benthos. In this project, we will conduct the first quantitative ecological analysis of a fossil-rich Eocene greenhouse marine assemblage from Seymour Island, Antarctica to provide new evolutionary insights. Through extensive upcoming fieldwork and examination of museum collections, we will amass large quantitative datasets which will be used for understanding community ecology, and will be linked to palaeoclimatic data from stable isotope analyses ($\delta^{18}O$ and $\delta^{13}C$). We will re-evaluate assumptions about benthic community transitions from the Eocene onwards. In addition, we aim to refine how taphonomy and preservation affect our interpretations of ancient Antarctic community structure. Broader impacts include advancing transferrable quantitative methodologies for analyzing paleocommunities globally. Our novel analyses will provide unparalleled quantitative ecological insights into Antarctica's ancient greenhouse world and inform scenarios of projected biotic change in this region under future climate regimes.

## USING THE RECENT PAST TO RECOGNIZE ANTHROPOGENIC INFLUENCE ON THE ISRAELI MEDITERRANEAN SHELF: AGE-BASED STUDY

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The Israeli shelf situated at the southeastern part of the Mediterranean is ideally positioned for high-resolution studies of historic extent. Both natural and anthropogenic trends over the last centuries, namely the distinct cooling of the Little Ice Age (LIA), the opening of the Suez Canal that connected the Mediterranean to the Indian Ocean, the damming of the Nile River, and coastal development have had a strong impact on the biota. However, information on the past ~150 years of globally-growing human influence and data relevant to understanding the cause-effect relationship of human activity in the region are scarce due to limited detailed sedimentary records that are also age-based. The goal of this study was to track major natural and human-driven changes recorded in the eastern Mediterranean by investigating a high-resolution well-dated sediment core. In particular, the focus was on the controlling factors governing the faunal and sediment composition of the area and on how they relate to known, recent, historic events. Detailed sampling, 210Pb sediment dating and macrobenthos analyses were combined to better understand the rate and extend of human activity on shaping current seafloor patterns, but especially the past ~150 years of anthropogenic influence in the eastern Mediterranean. We used mollusk shells from large-volume box cores (penetrating 50 cm of sediment), from 60m water depth, to evaluate the (paleo)ecological history. Mollusks are sensitive recorders of seafloor conditions and their skeletal death assemblages naturally preserve historic environmental conditions of the recent past. Thus, they can serve as a baseline for understanding the current ecological status of marine environments. Our core recorded a sedimentation rate of 0.32 cm/y. Sediment coarsening and decreasing total organic levels characterize the period after the LIA, whereas the damming of the Nile (1960's) and the decrease in river input of clayey material, created a further coarsening superimposed on the existing coarsening trend. Over 6000 gastropod and bivalve individuals were examined, yielding 92 species of which 8 were alien. The gastropods demonstrate a change from dominance of the indigenous carnivore Tritia varicose, before the opening of the Suez Canal in 1869, to dominance of the alien Varicopeza pauxilla that comprises 83% of the gastropod assemblage today. The bivalve assemblage demonstrate a change in feeding mode over time, characterized by disappearance of deposit feeders, associated with the damming of the Nile River and the subsequent nutrient depletion. Variations in relative abundance and community structure of the molluscan assemblages captured the long-term changes the eastern Mediterranean is undergoing. Identifying long-term patterns were crucial in correctly understanding the present ecological state. This entails added background studies that are time consuming and may become an obstacle for conservation practice.

## GLUTTONS OVER EPICURES? ANALYZING THE ECOLOGICAL STRUCTURE OF THE MARINE BIVALVE LATITUDINAL DIVERSITY GRADIENT.

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One potential driver of the latitudinal diversity gradient is the differential accommodation of taxa within modes of life, and Jim Valentine once proposed (in Edie et al. 2018, PNAS) that higher latitudes favor biotas with "a few gluttons over many epicures." Thus, compared to temperate and polar latitudes, the relatively stable climates and environments of the tropics may support greater specialization on resources. Using a global database of modern marine bivalve species occurrences and ecological functions, we find that all functional groups are present in the tropics, forming the global richness peak. Functional specialization is specific to tropical latitudes—no functional groups are endemic to extratropical latitudes. Species richness within functional groups also peaks in the tropics (for 40 of the 44 groups), making each of the above patterns consistent with the tropics accommodating greater taxonomic and functional diversity via the stability of the underlying resource base compared to higher latitudes. It follows that the most speciose functional groups in the tropics tend to maintain their high rank order in temperate and even polar latitudes (with the strong decline in species richness of photosymbiotic groups as an exception). The functional richness of the Antarctic biota is about half that of the Arctic biota, but it is a strict, nested subset of those functions. Assuming equilibrial dynamics on macroecological timescales (perhaps reasonable given the persistence of latitudinal diversity gradients over geologic time), these patterns suggest that the decline in functional richness with latitude reflects an attenuation in resource availability and stability rather than any turnover or rebalancing. Valentine's predictions on latitudinal gradients in evolutionary and ecological incumbency are partially reflected in these patterns: higher latitude genera tend to be geologically older than their lower latitude counterparts—but species-poor and -rich functional groups in the tropics have similar genus ages, suggesting the former are not necessarily recent evolutionary experiments. Morphological disparity within these coarse functional groups might proxy finer degrees of functional specialization, so that the richest functional groups in the tropics have the highest variety of shell forms. This appears to be true, although functional groups in the tropics also have among the lowest morphological distances between taxa, suggesting a 'packing' of many, morphological similar taxa, which tends to thin towards higher latitudes. Taken together, the current latitudinal gradients in taxonomic, functional, and morphological diversity are consistent with a diminution in the variety, abundance, and stability of bivalve resources towards higher latitudes, perhaps supporting Jim Valentine's ideas that those biotas harbor a few, mostly generalist taxa.

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## THE LIFE HISTORY OF THE EARLY CAMEL *POEBROTHERIUM* AS INFERRED FROM OSTEOHISTOLOGY

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The White River Formation of Wyoming houses an incredibly rich fossil record from the late Eocene through early Oligocene. It preserves a period of climatic shifts and tectonic activity that imposed environmental pressures on the fauna that lived there, especially for large-bodied mammals. Among the White River Formation mammalian taxa, *Poebrotherium*, the diminutive North American camel, serves as a particularly useful species to better understand the environmental pressures experienced by mammals during this time. As an outgroup member of the Camelinae, *Poebrotherium* represented many of their ancestral characteristics. *Poebrotherium*'s herbivorous diet was reliant on available vegetation, making it susceptible to any changes in the local environment. Any fluctuations in diet would therefore be reflected in its bone microstructure, thus giving *Poebrotherium*'s biology the potential to reveal how climate, geography, and life history played a role in the evolution of Camelidae. In the summer of 2023, our field team recovered an articulated forelimb of *Poebrotherium* from the White River Formation of South-Eastern Wyoming. Here, we report on the paleohistology of the humerus, providing insight into the growth and life history of this early camel. The histology of *Poebrotherium* reveals that juvenile members of the species exemplified a high growth rate based on the presence of fibrolamellar bone and abundant vasculature. These histological features are consistent within the mid-cortex, indicating that *Poebrotherium* grew rapidly into adolescence. Regular lines of arrested growth (LAGs) are present throughout the cortex of *Poebrotherium*. The regularity of these LAGs indicate seasonal cessation of growth that mirrors cyclical environmental changes. The rapid growth apparent in juvenile-to-adolescent bone, slows considerably towards the periosteum as evident by the increased contribution of lamellar bone and a significant decrease in vasculature. The periosteal surface lacks vasculature all together, indicating that the humerus has essentially reached skeletal maturity. Overall, these findings show that *Poebrotherium*'s rapid growth into sub-adulthood was impacted by seasonality, potentially linked to the subtropical to semi-arid/temperate climatic shift that occurred during this time. Further, the presence of LAGs shows that, even at rapid growth rates, it took multiple seasons for these animals to reach skeletal maturity. Lastly, this study suggests that the ancestral rapid growth rates for Camelidae might have allowed for extant camels to reach the large sizes seen today.

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## NOTES ON RARE TRILOBITE TAXA FROM THE SILURIAN ROCKS OF NORTHEASTERN ILLINOIS

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Most of the common Silurian trilobites of the *Gravicalymene celebra* association, found in the upper beds of the Romeo member of the Joliet Dolomite and lower Sugar Run Dolomite (Sheinwoodian), are well known through extensive collecting and study for over one hundred years. However, rare taxa, which are only represented by a few skeletal elements, have not been fully described and are poorly understood. Recent collecting of the Romeo member and the Sugar Run Dolomite along the Des Plaines River Valley near Lemont, Illinois has revealed new information about the systematics, preservation, or stratigraphic position for several of these rare taxa. *Trochurus (Atyzela) welleri*, *Arctinurus thompsoni*, *Ceratocephala* cf. *goniata*, and *Dalmanites illinoiensis* are found through the transition of the Joliet Dolomite into the Sugar Run, which has not been documented before.

## ADVANCEMENTS IN EGYPTIAN VERTEBRATE PALEONTOLOGY: MUVP'S CONTRIBUTIONS AND FUTURE PERSPECTIVES

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Mansoura University Vertebrate Paleontology center (MUVP) was established in 2010 as Egypt's inaugural vertebrate paleontology program and has since become one of the most significant research endeavors in the Middle East. Despite Egypt's rich history of fossil discoveries, prior to MUVP's inception, paleontological investigations were predominantly led by international scientists. MUVP is committed to educating the next generation of Egyptian vertebrate paleontologists, expanding awareness of the nation's paleontological resources for public outreach and training, and undertaking study of Egypt's fossil vertebrates. MUVP's active field projects in Egypt have resulted in the discovery of new dinosaurs, archaic whales, and many other significant fossils. These discoveries not only advance knowledge of Africa's prehistory but also contribute to the increasing popularity of paleontology in the Middle East. Recently, MUVP's future prospects have been significantly enhanced following the acquisition of new instruments that have enabled the digitization of fossils and introduced myriad student training opportunities. We have also selected passionate pre-university students and provided them with training, aiming to cultivate their scientific abilities. Yet another critical aspect of MUVP's work is its public outreach, which plays a key role in helping communicate new discoveries via social media posts presented free of jargon in Arabic. MUVP has played a pivotal role in the development of various cultural and educational projects in Egypt. This includes its involvement in establishing the Open Air Museum in the Jebel Qatrani area, the Fossil and Climate Change Museum located within the World Heritage Site of Wadi El-Hitan, and the Fayum Cultural Heritage House situated in the Fayum Depression. Moreover, MUVP has initiated several programs designed to actively involve local communities in the study of vertebrate paleontology in Egypt. These initiatives, such as "Explore with Us," "Young Egyptian Paleontologists," and "Women in Paleontology," are geared towards fostering greater societal engagement with the field of vertebrate paleontology. These activities have enhanced public engagement with science and provided a model that other Middle Eastern institutions may seek to emulate.

Funding source: Mansoura University and Science and Technology Development Fund

## AN ONTOGENETIC MORPHOMETRIC APPROACH TO RECONSTRUCTING THE LATE CRETACEOUS PHYLOGENY OF BISERIAL PLANKTONIC FORAMINIFERA

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Planktonic foraminifera are one of the most widely used of all microfossil groups for biostratigraphy in the Cenozoic and Cretaceous because of their widespread distribution, rapid evolution, high preservation potential, and abundance in pelagic and hemipelagic sediments. Studies of biserial planktonic foraminifera have demonstrated that they underwent a relatively rapid evolution during the Late Cretaceous, yet their potential in biostratigraphy has been unrealized because of taxonomic ambiguities. In particular, there has been a dramatic increase in the number of new genera

and species published during the past 18 years. Prior to 2007, four Late Cretaceous biserial genera were widely recognized, but within the following seven years, 12 new genera were defined, five of which are monospecific. Those recently proposed classification schemes were based on inferences from qualitative morphologic observations and inferred directional evolutionary trends rather than stratophenetic observations of quantified taxonomic differences. We apply an ontogenetic morphometric approach combined with measurements of morphologic features observed from test exteriors to reconstruct the phylogeny of Late Cretaceous biserial planktonic foraminifera. Our study includes analysis of holotypes, paratypes, and well-preserved species populations from multiple biogeographic realms. Because the chamber growth of biserial planktonic foraminifera occurs entirely along a single plane, the entire ontogenetic growth history can be measured from two-dimensional microcomputed tomography (μ-CT) images. Our measurements of the ontogenetic growth series utilize an R package for automated trait measurements from μ-CT scans. Multivariate analyses of the measurement data will provide a more reliable basis for species and genus-level groupings, leading to a more natural classification scheme and more reliable species age-range determinations.

## CURRENT STATUS OF THE PALEONTOLOGICAL COLLECTION AT BELOIT COLLEGE

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The paleontological collection at Beloit College was established in the late 1800's and by the turn of the century contained more than 50,000 fossil specimens from across the world. Through the years the collection has been relocated multiple times among campus buildings, funding was not available to maintain a dedicated curator, and the collection was ultimately neglected and in some cases discarded when the campus shifted its focus to wartime efforts during the 1940's. Since then, additional private collections have been donated to Beloit College, curation efforts have resumed albeit sporadically and with limited funding, and a number of educational displays have been constructed on campus. Although only a small portion of the original 19th-century collection exists, the current paleontological collection at Beloit College contains a number of historically and scientifically valuable specimens. According to our current records, the collection includes material collected by T.C. Chamberlin, the Beane Crinoid Collection (~200 slabs with articulated crinoid assemblages and >350 individual crinoid specimens), a collection of La Brea Tar Pit fossils (>1400 vertebrate bones), the Coe College collection of Midwest Paleozoic invertebrate fossils (>500 taxa), the J.J. Rivers Collection of Cenozoic marine invertebrates (>800 taxa), and various other collections for a total specimen count approximating 5,000. However, not all specimens in the collection are currently cataloged, and records include a combination of original identification cards, historical ledgers, and original correspondence from donors and collectors with varying amounts of information. A curation and digitization effort led by undergraduate students for hourly wages or course credit is currently underway. The ultimate goal of these curation efforts is to enhance accessibility of this collection for both teaching and research. Students are working on entering all available information on each specimen into a spreadsheet and flagging specimens with limited to no scientific value for possible deaccession. During student curation of the collection, it has become clear that many specimens do not have accession numbers, are stored in old and brittle boxes, are identified incorrectly, and in some cases even permanently altered and destroyed from improper collections etiquette (pyrite disease). Current and future curation includes integration of all records (identification cards, ledgers, and correspondence) into a museum collection software database, adding new identification cards to each specimen with all available information, re-boxing specimens as needed, photographing all specimens, and creating a web interface for students and external users.

## JIM VALENTINE AND THE EVOLUTION OF BODYPLANS

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The origin and evolution of animal architectures was a project to which Jim Valentine returned throughout his career, from papers in the early 1970s to 2018, as well as his encyclopedic 2004 book *On the Origin of Phyla* and a later book on the Ediacaran-Cambrian radiation. Jim's enduring fascination reflected the nexus of several concderns: Jim rightly considered the appearance of bodyplans a principal challenge for any theory of evolution and particularly for the unique status of macroevolution within evolutionary theory. Moreover, since any resolution to the origin of bodyplans necessarily involved puzzling out the relative contributions of ecology, development and changes in the physical environment (although Jim acknowledged but wrote less about the latter) it played to Jim's intellectual strengths in broad-ranging synthesis across biology and geology. Yet Jim's views of this problem themselves changed, an evolution that reflected not just his growth as a paleontologist, but also changing views at the intersection of paleontology, evolution and development. Jim's 1970s papers grew out of his interest in hierarchies and his documentation of Phanerozoic diversity patterns, particularly the early establishment of phyla and classes of marine invertebrates. He recognized

this early burst of maximal disparity (as it would later be called), but initially described this in terms of Simpsonian adaptive zones. By 1975, however, he and Cathy Campbell employed Roy Britten and Eric Davidson's early models of animal gene regulatory networks to consider possible roles of genetic and developmental novelty. Thus, this early work established this continuing question of roles of development and ecology. Later work expanded on these themes utilizing the refined documentation of Cambrian fossils, molecular clocks and Jim's pioneering estimates of the number of cell types as a metric of organismal complexity. Yet some of this later work shows tension between his ingrained love of Darwin and natural selection and growing challenges from macroevolution, from the phylogenetic revolution and from the deluge of new insights from comparative evo-devo. Today we have a far more richly resolved temporal, phylogenetic, ecological and developmental framework for interrogating the problems of the Ediacaran-Cambrian Radiation, yet are still confronting many of the same questions Jim established in the 1970s.

## CHANGES IN ECOSPACE UTILIZATION ACROSS THE RICHMONDIAN INVASION IN THE CINCINNATIAN ARCH (LATE ORDOVICIAN)

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Invasions are becoming more common as modern sea temperatures rise and biogeographical barriers break down. The fossil record provides a record of biotic interactions and can be used to understand the impacts of biotic invasion on ecosystem structure and functioning over evolutionary timescales. During the Late Ordovician (Katian), deglaciation caused small shallow epicontinental seas that were previously isolated to combine, facilitating the coordinated invasion of over 80 genera through larval dispersal in several pulses throughout the Richmondian. Here we examine 1,309 species from benthic marine communities of the Cincinnati Arch (USA) to quantify the effects of non-native species on functional space. Species were grouped by three common functional traits readily identifiable in fossil taxa: living habit, tiering above the substrate, and feeding mode. Changes in functional structure were quantified across six 3rd order stratigraphic sequences. During the two sequences before the arrival of invaders (C2 & C3) we observe stability in species richness (413 species in C2 and 412 species in C3), as well as functional richness (16 functional groups in C2 and 17 functional groups in C3). Functional redundancy (FR) is also consistent with values of 25.8 and 24.2 in C2 and C3 respectively. However, once invading taxa start becoming established in the region in pulses beginning in C4 through to C6, we see oscillation as the ecosystem adjusts to changes in species composition. Species richness fluctuates during this interval, while the number of functional groups remains relatively consistent from 16-15. However, despite similarities in the number of species and functional groups, functional redundancy (FR), the average number of species per functional group, fluctuates. During the early establishment phase in C4 the FR drops to 16.4. There is then a small increase in FR during C5 (23.5), followed by a decline to 15.4 during C6 (i.e., the sequence known as the main phase of the invasion). During these repeated influxes, invaders were likely occupying existing functional space upon arrival and then may have outcompeted and replaced incumbents during establishment and integration, or adapted better to the changing conditions. Once invaders become integrated in C7, species richness increases to 412 species, functional richness to 14, and FR increases to 29.4. Overall, increased species richness did not correspond to an increase in the number of functions (rho = 0.75, p = 0.63). These results are consistent with previous work documenting niche packing as a result of the invasion and suggest that this led to community-wide structural changes, which has important implications for predicting the long-term effects of modern invasions.

## A LOCAL PERSPECTIVE ON GLOBAL TRENDS: EVALUATING RECORDS AT DISTINCT EDIACARAN FOSSIL SITES TO CONSTRAIN EVOLUTIONARY DYNAMICS DURING THE DAWN OF ANIMAL LIFE

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Studies of the Ediacara Biota represent the premier dataset for understanding the early evolution and diversification of animals. Concentrated efforts since the turn of the century greatly enhance our knowledge of life during this interval, from studies of individual organisms to community interactions to the broad-scale spatial and temporal distribution of these commonly enigmatic soft-bodied macrofauna. Significantly, global patterns of diversity, disparity and ecological structure support radiations and extinctions within the Ediacaran Biota of similar magnitude to those observed during major biotic turnover events of the Phanerozoic. Hypotheses have been proposed regarding the mechanism(s) responsible for such change, but these have proved difficult to disentangle. Critically, total taxonomic richness and the number of discrete localities that yield abundant and diverse Ediacaran taxa are relatively low compared with the subsequent fossil record. Consideration of three regions in which the Ediacara Biota is documented—South Australia, the Great Basin, and Northwest Canada—

suggests that each preserves a unique record influenced by a distinct combination of factors. Global trends are necessarily constructed from local studies, so it is imperative to understand these varied controls to interpret any biotic signals. Such consideration reveals promising avenues for future research testing hypothesized changes among the Ediacara Biota, which will undoubtedly shed new light on the dynamics responsible for the appearance and proliferation of animals.

Funding source: Paleontologic Society, Boucot Grant

## MORPHOMETRIC ANALYSIS OF ARCTOID UPPER CARNASSIAL TEETH CORRELATES SHAPE WITH DIET AND PHYLOGENY

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Carnivoran mammals primitively have an enlarged upper fourth premolar (P4) "carnassial" that produces a shearing bite. Several clades within Arctoidea have highly modified P4 morphologies, which hypothetically correlate with distinct diets. This study uses extant arctoids to establish correlation between P4 shape and diet category, then incorporates extinct taxa to infer their diet. 2D landmark morphometric analysis is used to quantify and compare tooth shape. Facultative or obligate terrestrial carnivores with plesiomorphic carnassial teeth are unsurprisingly found to consistently cluster together. Pan-pinnipeds, skunks, and river otters form a larger cluster with unclear eco-functional implications. Most ursoids and omnivorous musteloids are broadly distributed in the remaining morphospace. From these shape data, ANOVA and canonical phylogenetic ordination have found weak correlations with diet and phylogeny, respectively. With some refinement, this method may be a viable non-destructive way to infer diet among extinct carnivorans.

## THE NERVOUS SYSTEM SHAPES THE SKULL DURING DEVELOPMENT AND EVOLUTION

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With more than thirty apomorphies characterizing their phenotype, the evolutionary history and phylogenetic placement of modern birds have been an evolutionary conundrum for centuries. It was only through the recent discovery of exceptional fossils and innovation in molecular techniques that birds could be confidently identified as archosaurs and modern representatives of non-avian dinosaurs. Although major progress has been made on the tempo and mode of evolution of skeletal, sensorial, nervous and muscular systems, their integration, potential co-evolution, and the mechanisms underpinning their morphological change across evolutionary transitions remain unclear. Using an evo-devo approach, I focused on the evolutionary and developmental integration of the brain and skull across the dinosaur-bird transition with the goal of tracking changes between these two systems and how they influence each other. The application of three-dimensional imaging techniques, such as CT-scan, allowed to build an evolutionary comparative framework composed of pivotal taxa encompassing the evolution and diversity of Reptilia (including fossil and modern species). After segmentation of the braincase and brain (endocast for fossils), the use of 3D landmarks and morphometrics revealed a pattern of co-evolution between these two systems, with a sudden transitional shift in coincidence with the appearance of avialans. Moreover, a one-to-one morphological correlation is recovered between regions of the brain (forebrain and midbrain) on the one hand, and their adjacent skeletal element (frontal and parietal) on the other. In order to verify if the brain has a primacy on skull morphology and how this influence the resulting phenotype, CLARITY and immunofluorescence were applied to developmental series of six model and non-model reptilian taxa (gecko, snake, alligator, tinamou, quail, and zebrafinch). The brain drives skull formation in development. The first mesenchymal condensations forming the neurocranium appear once the brain already underwent the three-vesicle stage. Early ossifications of the dermatocranium appear only later in development. A conserved pattern of ossification (order of appearance of ossification centers) is found among reptiles. However, timing of full ossification of the braincase is different among the investigated taxa. In particular, the positive allometric growth of the brain in birds delays ossification of the skull roof, leading to its unique, "paedomorphic" morphology in the adult phenotype.

## MICRO- AND MACROFOSSIL REMAINS OF VERTEBRATES FROM THE GIVETIAN BOYLE FORMATION (MIDDLE DEVONIAN) OF EASTERN KENTUCKY, U.S.A.

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Vertebrate fossil remains are a rarity in Kentucky. Some vertebrate remains have been reported from the Carboniferous of the various areas within Kentucky, including chondrichthyans from Mammoth Cave National Park. Other vertebrate remains include fish and tetrapods from the Carboniferous from the Illinois basin of Kentucky, and conodonts and fish from eastern-central Kentucky in the Appalachian basin. Minimal amounts of work, however, have been done on the faunal diversity of the Middle Devonian Boyle Formation of central-eastern Kentucky. A survey of material from a relatively new road cut north of Irvine, KY

has revealed both macroscopic portions of bone attributed to placoderm armor, possible fin material, and a lungfish tooth plate. Microfossils, including conodonts, scales tentatively attributed to *Ohiolepis*, placoderm scales, possible acanthodian and jawless fish scales have also been discovered. In addition, the algal spore *Tasmanites*, have also been found, which may have interesting implications for paleoenvironmental interpretations for this area in the Givetian. This relative wealth of microfossils from a relatively understudied and (presumed) depauperate ecosystem suggests that the margin of the Appalachin basin in eastern Kentucky had a higher diversity of vertebrate fauna than previously suggested. The bonebed locality sampled thus far is significantly shortened compared to other sections of Boyle Formation available, it has been correlated with additional outcrops in the area of eastern Kentucky and has been formally divided into the Kiddville and Beechwood Members (following Brett et al., 2018). The bonebed under study can be found in the lowest part of the Kiddville Member, just above the contact with the Estill Shale. There have been other bonebeds reported from the Boyle Formation in the area around Irvine; however, they have not been explored yet in the current study, primarily due to the COVID-19 pandemic. Future study should make use of additional outcrops in the area. Given the lack of faunal sampling in this area, and the fact that the lowest part of the New Albany Shale is also considered Givetian in this portion of the Appalachian Basin, the diversity and richness of these fossils may have paleoecological implications for the leadup to the Frasnian-Famennian event and the extent and severity of the Late Devonian Mass Extinction.

## NEW MATERIAL OF THE HEDGEHOG *AMPHECHINUS* (ERINACEIDAE, EULIPOTYPHLA) FROM THE OLIGOCENE OF THE PACIFIC NORTHWEST, U.S.A.

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Oligocene hedgehog material is poorly known west of the Rocky Mountains in the United States, with only isolated teeth or partial jaws identified. These specimens cannot be confidently identified to the species level. To better understand Oligocene hedgehog ecology in what is now known as the western United States, additional fieldwork was necessary to recover new material. A nearly complete hedgehog skull with two dentaries (JODA 18944) was recovered from the JDNM-269, Rudio Creek 4 locality on Bureau of Land Management-administered land in 2019. The site includes exposures of the Kimberly Member of the John Day Formation between the Tin Roof Tuff (25.33 Ma) and the Haystack Valley Member Tuff (23.79 Ma). The specimen was found in a concretion and was misidentified as a gopher skull until further preparation was completed (fall 2022). The site is known for a high density of concretions with gopher skulls and jaws with damage to the base of the skulls contained within, suggesting the site may contain the remnants of a bird-of-prey roost. Mechanical preparation with an airscribe uncovered both the completeness of the specimen and its delicate nature. However, the diagnostic features in the dentition could not be safely exposed using mechanical means, so, JODA 18944 was scanned using microtomography (voxel size = 33.861 µm) to nondestructively reveal these structures, and the scan was segmented to produce a 3D model for further analysis. These 3D images reveled hidden morphology and allowed for measurements of features and structures to be made. The following characteristics were identified on JODA 18944: the i1 terminates below p4 and the P4 is under the orbit; the m3 has a single root with a length of 0.9 mm, is rounded, and pointing posteriorly; the mental foramen is anterior to the p4; the p4 talonid is the same width as the trigonid. These characters suggest a genus-level diagnoses of *Amphechinus*, though the exact affinities are still to be determined. This complete skull and two associated jaws allows for a better understanding of morphology of this taxon. The only other specimen from this genus to be recovered in this region is an isolated tooth, making JODA 18944 the most complete hedgehog specimen known from this region and the first know from this locality.

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## ONESTRATIGRAPHY: UNVEILING DEEP-TIME EARTH HISTORY THROUGH GLOBAL STRATIGRAPHIC DATA HARMONIZATION

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The Deep-time Digital Earth (DDE) is a prominent Big Science Program recognized by the International Union of Geological Sciences (IUGS), with the primary objective of establishing a platform that links geoscience informatics initiatives to the FAIR (Findable, Accessible, Interoperable, and Reusable) principles. This groundbreaking ten-year initiative aims to synchronize global deep-time geodata encompassing diverse spheres of the Earth, including the biosphere, lithosphere, and hydrosphere. The overall goal is to catalyze data-driven discoveries in our understanding of Earth's deep-time history. As a component within the DDE framework, OneStratigraphy was conceived in early 2019 to harmonize global stratigraphic data. Currently, the OneStratigraphy database contains 1,727,035 fossil occurrences derived from 19,420 sections/

drill cores. This extensive dataset, spanning major continents and oceans, is derived from literature, stratigraphic reports, or unpublished work, following consistent standards to ensure data quality. The integration of various tools into the OneStratigraphy system, such as TS Creator for stratigraphic visualization and PaleoGIS and GPlates for paleogeographic visualization, enhances its capabilities. It also supports quantitative stratigraphic methods such as Graphic Correlation, Constrained Optimization (CONOP), and Horizon Annealing. As a result, the ever-increasing amount of data coupled with powerful analysis tools makes OneStratigraphy an invaluable resource for innovative studies, including the development of refined geologic time scales, the exploration of high-resolution evolutionary histories of life, and investigations into the biotic/abiotic factors that influence the evolution and distribution of life.

## THE "MESAVERDE" FORMATION (CAMPANIAN) OF THE BIGHORN BASIN, WYOMING, U.S.A.: A KEY TO UNRAVELING LATE CRETACEOUS FAUNAL PROVINCIALITY IN LARAMIDIA?

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Studies of faunal provinciality in Campanian-aged vertebrate assemblages from Laramidia often lament a sampling gap between "northern" formations (Alberta, Saskatchewan, Montana) and "southern" ones (Utah, New Mexico, Texas, Coahuila). The "Mesaverde" Formation, exposed in the Wind River and Bighorn basins of Wyoming, bridges this critical geographic divide. Historically, the most detailed work in the "Mesaverde" Formation has focused on fossil mammals and chondricthyans, which represent only one piece of the paleoecological puzzle, and other aspects of the assemblage remain comparatively understudied. Ongoing fieldwork by the Alf Museum has focused on better sampling the vertebrate fossils of the formation, through identifying new localities and collecting previously known ones across the Bighorn Basin. In the eastern outcrop belt ("Case localities"), most sites are within a horizon traditionally correlated with the Teapot Sandstone, yielding an unusual mix of marine, freshwater, and terrestrial taxa. Notably, champsosaurs are incredibly rare at all of the sampled localities in the Bighorn Basin, more similar to the frequency in southern rather than northern assemblages of the Western Interior Basin. Although previously unreported, lissamphibians (including frogs and salamanders) are surprisingly abundant. Ecologically, this mixture of freshwater and marine taxa (including lamniform sharks) is similar to some assemblages reported in the Foremost Formation of Alberta and the Judith River Formation of Montana, although the lithological associations may differ. Additional work is needed to investigate temporal and latitudinal variation. Work in the Oregon Basin area, approximately 100 km to the northwest of the Case sites, has identified a more inland assemblage from multiple levels within the "Mesaverde" Formation, including at least three vertebrate microfossil localities. The chondrichthyan assemblage lacks definitively marine taxa. Hadrosaurids represent by far the most common non-avian dinosaurs (as seen in penecontemporaneous formations), and small theropods are also somewhat common. Troodontids have not yet been identified, which is consistent with early late and middle Campanian deposits elsewhere in the Western Interior Basin. Turtles include abundant trionychids, baenids, and solemydids. Work in the "Mesaverde" Formation of the Bighorn Basin is still in its early stages, with a current focus on standardized sampling techniques and identification of taxa using contemporary taxonomy and apomorphy-based identifications. Additionally, efforts are underway to characterize abundances of taxa, to facilitate more in-depth paleoecological comparisons with other formations.

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## HISTORY, SIGNIFICANCE, AND FUTURE DIRECTIONS OF THE INVERTEBRATE PALEONTOLOGY COLLECTION AT THE SAM NOBLE OKLAHOMA MUSEUM OF NATURAL HISTORY

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The Sam Noble Oklahoma Museum of Natural History is located in Norman, Oklahoma and specializes in twelve natural and cultural history collections. The museum was originally established at the University of Oklahoma in 1899 by the Territorial Legislature with a focus on zoological, botanical, and geological specimens. The Invertebrate Paleontology collection was started from the personal collections of Charles N. Gould, who was teaching geology at the time. The museum hired the first curator of invertebrate paleontology in 1912 and continued to incorporate the collections of the curators into the museum. For decades, the collections of the museum were spread out between many different buildings on campus, including the vertebrate paleontology collection housed in the old ROTC stables. In 2000, the museum opened its doors to a new building that holds all 12 collections, lab spaces, and exhibit halls. Although the Sam Noble Museum houses >1 million fossil invertebrate specimens, it was not included in the original 1977 Committee on North American Resources in Invertebrate Paleontology (CONARIP) survey. Here, we would like to present the status and strengths of our collections as the official state museum of Oklahoma. The invertebrate paleontology collection has many strengths,

especially in Paleozoic echinoderms and brachiopods. For example, the Sam Noble houses one of the largest collections of paracrinoids and other enigmatic early echinoderms in the world. We also have a significant graptolite collection from Charles E. Decker, invertebrate paleontology curator from 1916–1943, which includes extensive material from the Ordovician-Silurian of Oklahoma. Recent donations from Charles E. Mitchell have expanded our graptolite collection with additional taxonomically and biostratigraphically significant Ordovician-Silurian material. Other unexplored strengths of our collection are the collections of T.W. Amsden, which span multiple geologic periods and focus on mass extinction boundary intervals worldwide. A collection of recent, major interest to external researchers is our BP-Amoco collection of global macroinvertebrate faunas. The Amoco Petroleum Company operated from Tulsa, Oklahoma and made significant collections in both paleontology and biostratigraphy in the 1960s and 1970s. The portion of the collection that was donated to the Sam Noble consists of approximately 200,000 macroinvertebrate specimens that have yet to be catalogued, with strengths in the Paleozoic of the south-central United States and many undescribed specimens from remote areas of Alaska. These collections include several localities now within National Park land, which has sparked the interest of the National Park Service regarding potential collaborative opportunities for improvement and digital databasing of the collection. We would love to open our doors to researchers interested in any portion of our collection and look forward to collaborating with you all!

## THE OLDEST THREE-DIMENSIONALLY PRESERVED ACTINOPTERYGIAN HEARTS? SOFT TISSUE PRESERVATION IN A STEM TELEOST

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Teleostei account for almost all extant actinopterygian diversity and over half of all extant vertebrate diversity. Extant teleosts are distinguished in part by soft tissue characters, such as a reduction in the number of valves and the hydrostatic dominance of the bulbus arteriosus over the conus arteriosus in the outflow duct of the heart. There is relatively little published data on soft tissue anatomy in fossil actinopterygian taxa, due both to the rarity of this style of fossil preservation and a poor understanding of how three-dimensional preservation of vertebrate soft tissue occurs. Consequently, there is a significant gap in knowledge regarding the acquisition of key soft tissue characters in early actinopterygian evolution. Here we present μCT and synchrotron tomography data of exceptional three-dimensionally preserved specimens of the stem teleost *Pachycormus macropterus* from the Toarcian (Jurassic) Strawberry Bank Lagerstätte of southwest England, with a focus on the pectoral region. Tomographic data indicates substantial soft tissue preservation, including in the orbit, body wall musculature and between the pectoral regions, indicating the presence of a fossilised heart. DiceCT data of a phylogenetically broad sample of extant Actinopterygii were used to aid anatomical interpretation and build up a comparative dataset of soft tissue anatomy in ray-finned fishes. The fossil specimens are sufficiently well preserved to reveal phylogenetically important characters, including the relative sizes of the bulbus and conus arteriosus, and putative outflow valves. *Pachycormus macropterus* represents the oldest and most phylogenetically basal three-dimensionally preserved actinopterygian hearts, with implications for the sequence of character acquisition during the evolution of the teleost heart. This further supports that Strawberry Bank, long recognised as a source of fossil soft tissue, may be fertile site for future descriptive work on fossil vertebrate soft tissue anatomy.

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## PHYLOGENETIC AND TAXONOMIC REVISION OF JURASSIC STARFISHES SUPPORTS A DELAYED ORIGIN OF THE ASTERIIDAE

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The superorder Forcipulatacea encompasses approximately 400 extant species. Over the past century, the systematics of Forcipulatacea have undergone multiple revisions by various authors, with some considering numerous families such as Asteriidae, Zoroasteridae, Pedicellasteridae, Pycnopodiidae, Labidiasteridae, and Neomorphasteridae, while others recognized only two families (i.e., Asteriidae and Zoroasteridae). Recent molecular analyses have shown the artificial nature of some of these groupings. Notably, four well-supported clades (Zorocallida, Brisingida, Stichasteridae, and Asteriidae) emerged from a synthesis of morphological and

molecular evidence. The majority of extinct forcipulatacean species have been placed in modern families, especially the within the Asteriidae, and are in need of reappraisal. In light of the recent advancement of the forcipulatacean phylogeny, this study comprehensively reassesses six well-preserved Jurassic forcipulatacean taxa, including the earliest crown-group members from the Hettangian and the description of two new genera. Through extensive morphological observations, encompassing details of the abactinal skeleton, ossicle spination, and pedicellariae, we derived over a hundred phylogenetic characters. Subsequently conducting the most exhaustive phylogenetic analysis based on morphological data for this group. Additionally, a tip-dating analysis was performed to assess the timing of the origination of the Asteriidae. To refine time calibration for the Forcipulatacea, seven extinct species were added to the tip-dating analysis. These include two recently reappraised species from the Jurassic, and five species from the Cretaceous and Miocene. Contrary to prior assumptions, our results indicate that none of the Jurassic taxa belong to Asteriidae or any other modern families, and instead, represent stem-forcipulatids. Furthermore, the tip-dating analysis suggests that Asteriidae likely originated in the late Cretaceous. Our findings highlight a greater early diversity within the Forcipulatacea than previously presumed, challenging existing perceptions of the evolutionary history of this significant clade.

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## SELECTIVE SURVIVAL OF INFAUNAL DECAPODS OVER THE CENOMANIAN-TURONIAN EXTINCTION (OAE 2)

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The Cenomanian-Turonian ocean anoxic event (OAE 2) was a period of abrupt warming associated with a mass extinction and a release of $CO_2$ into the atmosphere. Rising ocean temperatures are thought to have created severe bottom water anoxia. Environmental conditions during the Triassic-Jurassic OAE have been shown to create selective evolutionary pressures in molluscs based on their life habit. This project uses the Paleobiology Database to assess changes in life habit in decapods over OAE 2. I hypothesize that organisms with infaunal life habit will have adaptations that help them survive climate-based mass extinctions, particularly those driven by widespread basin anoxia. Burrows and other structures with limited water flow also tend to be anoxic. Thus, I hypothesize that burrow-dwelling infaunal decapods will have adaptations that allow them to cope with anoxic water more effectively, and will have lower rates of extinction in OAE 2 compared with semi-infaunal and epifaunal decapods. We compiled a record of Cretaceous and Paleogene decapods from the primary literature using the Paleobiology Database. Then we assigned life habit on the family level as epifaunal, infaunal, or semi-infaunal. We calculated the mean boundary-crosser extinction rate and mean counts, using maximum likelihood estimation to assess error. Preliminary data indicates a low level of extinction throughout the late Cretaceous and Paleogene in infaunal decapods, as well as an equivalent percentage extinction in epifaunal and semi-infaunal decapods through OAE2, with semi-infaunal percentage extinction rates outpacing epifaunal rates toward the end of the Cretaceous. We expect preservational sampling bias will be the largest concern. Infaunal decapods such as *Callianassidae* tend to have weakly mineralized skeletons, and many are only known from their first cheliped. The cheliped does not change much over evolutionary time, so researchers are more likely to lump infaunal decapods into the same genera, which then persist longer that the average semi- or epifaunal genus. This makes the rate of extinction in infaunal decapods seem lower than it may truly be.

## THE INFLUENCE OF BODY SIZE AND BRAIN SIZE ON DIVERSIFICATION RATES IN BIRDS

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Across vertebrate clades, both body size and relative brain size have frequently been investigated as potential divers of diversification patterns. Body size is correlated with nearly every aspect of physiology and life history and is thus thought to influence speciation and extinction rates via its interaction with reproductive rates and dispersal rates, among other traits. Large relative brain sizes are hypothesized to reduce the rate of extinction by allowing organisms to cope with extrinsic threats like habitat loss. Although there have been many attempts to investigate how organismal traits influence speciation and extinction rates in birds, few of these have incorporated the essential information provided by the fossil record. Here, we use a dataset of 9993 extant and 323 extinct species to investigate how body size influences speciation, extinction, and fossilization rates across the entire history of this clade. We use a subset of these species (2084 extant, 32 extinct) to model how diversification rates are influenced by relative brain size. We achieved this using advanced quantitative trait-dependent speciation and extinction models (QuaSSE) in a Bayesian framework in which we jointly model phenotypic evolution and diversification rates. We demonstrate that diversification rates in birds are indeed body size-dependent,

with diversification rates decreasing as body size increases. The highest diversification rates are found in lineages with body mass less than 50 grams, which includes include many songbird clades, as well as Apodiformes (hummingbirds and swifts), Piciformes (woodpeckers), some members of Charadriiformes (e.g., plovers, buttonquails) and Psittaculidae (e.g., pygmy parrots). We also recover robust support for a bias toward increases in body size through time. We propose that these patterns describe an evolutionary ratchet, with avian lineages tending to evolve toward larger body size classes that are characterized by higher extinction risk. Our models of brain size-dependent diversification support the hypothesis that large relative brain size reduces extinction rates. However, we do not find evidence that speciation rates are influenced by relative brain size. Together, these results support the hypothesis that the acquisition of large brain size primarily influences diversification by making such lineages more resistant to extinction rather than by acting as a key innovation that fosters rapid speciation. Finally, excluding fossils from the dataset results in completely different estimates of speciation and extinction rates, emphasizing the important influence of evidence from extinct taxa in reconstructing diversification patterns.

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## ARCHAEOCIDARID ECHINOID (ECHINODERMATA) MATERIAL FROM THE UPPER PENNSYLVANIAN BARNSDALL FORMATION OF NORTHEASTERN OKLAHOMA: MICROSTRATIGRAPHIC DISTRIBUTION, ENCRUSTATION PATTERNS, AND GRAIN-SIZE EFFECTS

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Regular echinoids (Phylum Echinodermata, Class Echinoidea) are rare within Paleozoic marine ecosystems, owing to their rapid post-mortem disarticulation into isolated ossicles and the consequent lack of attention paid to fragmentary material that cannot be identified to low taxonomic levels. Hence, much remains unknown about echinoid diversity and biogeography through the Paleozoic, complicating recognition of the major paleoenvironmental, paleoecological, and preservational controls over their distribution. Improved knowledge of echinoid evolutionary history thus requires increased documentation of Paleozoic material. The present study describes a new occurrence of archaeocidaroid echinoids from the Upper Pennsylvanian (Kasimovian; Missourian) Barnsdall Formation of Washington County, northeastern Oklahoma. Specimens were recovered via disaggregation of poorly lithified mudstones comprising the Copan crinoid Lagerstätte interval. Specimens consist entirely of isolated ossicles (n = 341), namely spines (n = 182) and interambulacral test plates (n = 159). Given the absence of articulated material, the material cannot be identified below family level (Archaeocidaridae) but probably represent one or more species of *Archaeocidaris*. Approximately 27% of both spines and test plates are encrusted, overwhelmingly by thin, vermiform tubes, making this the second report of encrustation of echinoid material in the Paleozoic. Encrustation most likely occurred post-mortem. Echinoid ossicle abundance varies from 4.6 to 23.5 ossicles/kg between samples (mean: 11.9 ossicles/kg) and shows no discernable relationship to crinoid abundance throughout the microstratigraphy of the Copan crinoid Lagerstatte interval. Interestingly, some samples display strong grain-size effects, with spines concentrated in gravel-sized (>2 mm) fractions and test plates concentrated in coarse sand-sized (1–2 mm) fractions. This has implications for sieve sizes that are best for maximizing echinoid specimen yield. Collectively, this new occurrence provides new data on Paleozoic echinoid distribution and preservation, and suggests promise for improving the record of Paleozoic echinoids via targeting of Pennsylvanian mudrock units.

## BRAIN OF ALL TRADES: THE NEUROANATOMICAL DIVERSITY OF RAY-FINNED FISHES

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Actinopterygians, or ray-finned fishes, are a hyperdiverse clade in extant settings both in terms of species and ecomorphological diversity. However, most of the known morphological variation in this clade is related to osteology and external appearance (e.g., body shape, color), while variation in internal soft-tissue morphology remains relatively unknown on a broad scale. Given their range of ecomorphologies it is expected that ray-finned fishes would exhibit a high neuroanatomical diversity. This neuroanatomical diversity has sparked interest from comparative morphologists and neuroanatomists, but most in-depth descriptions of ray-finned fish brains have focused only on a handful of lineages that remain a poor representation of the phylogenetic diversity of the clade. In this work I compile information from the literature plus a novel dataset of high resolution scans (µCT and dice-CT) coupled with comparative approaches and geometric morphometrics of ray-finned fish brains in order to better understand neuroanatomical variation in respect to time, phylogenetic relationship and ecology, as well as physical constraints to brain size and morphology, such as endocast

morphology and skull geometry. Preliminary results indicate that variation in brain morphology relates to both phylogenetic position and ecomorphology of the sampled taxa. Despite being much more diverse then previously thought, endocasts seem to be a poor predictor of brain morphology and size, but the role of spatial constraints to brain morphology remain obscure. Thus, my results highlight the importance of in-depth study of ray-finned fish neuroanatomical variation across phylogeny and ecomorphology. A better understanding of what factors shapes ray-finned fish neuroanatomical diversity will shed light on patterns of vertebrate brain evolution across time and space.

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## APPLICATION OF CLUMPED ISOTOPE PALEOTHERMOMETRY TO LATE PLEISTOCENE MARINE TERRACE DEPOSITS SUPPORTS THERMAL NICHE CONSERVATISM IN NORTHEASTERN PACIFIC SHALLOW SUBTIDAL MOLLUSKS

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Pleistocene marine terraces along the California coast preserve mollusk assemblages that have been studied for over 150 years. This record has been especially important for documenting geographic range shifts of species in response to climate changes, and early application of oxygen isotope paleothermometry found broad consistency between paleotemperature estimates based on $d^{18}O$ of mollusk shells and paleotemperature estimates based on the modern-day geographic distributions of co-occurring species. However, further progress in understanding this record has been inhibited by persistent uncertainties concerning (1) the formation ages of individual terraces and (2) the relative contributions of temperature and salinity variations to variation in $d^{18}O$ values. Here we report new paleotemperature estimates for well-dated California terrace assemblages from clumped isotope paleothermometry, which is independent of salinity. We analyzed 6 recent and 26 fossil shells of the intertidal to subtidal gastropod *Callianax biplicata*, which is ubiquitous in both modern and ancient mollusk assemblages in southern California. Modern shells from 3 sites yield mean growth temperature estimates well within observed local annual temperature ranges. Fossil shells from nearby terraces yield temperatures that are indistinguishable from modern for the last full interglacial ~125,000 years ago (Marine Isotope Stage 5e) and on average ~2.5°C cooler than modern for the Marine Isotope Stage 5a interglacial ~80,000 years ago. Seawater $d^{18}O$ values calculated from clumped isotope temperature estimates and shell $d^{18}O$ values are generally indistinguishable from modern seawater $d^{18}O$ values in the Southern California Bight. We use these seawater $d^{18}O$ values to extend our dataset by estimating paleotemperatures from more than 1,000 bulk $d^{18}O$ measurements of 54 additional *C. biplicata* individuals. Our results confirm that isotopic paleotemperature estimates and paleotemperature estimates based on the modern-day geographic distributions of co-occurring species are generally consistent across multiple sites representing multiple Pleistocene interglacials. These findings bolster evidence that the thermal tolerance ranges of marine species are generally stable on ~100,000-year timescales.

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## A RICH NEW RECORD OF DINOSAUR TRACKS FROM AN UNNAMED CRETACEOUS ROCK UNIT ALONG THE YUKON RIVER IN WEST-CENTRAL ALASKA

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We report on a rich, new record of dinosaur tracks from Cretaceous rocks exposed along the Yukon River of west-central Alaska. In August 2023, we undertook an investigation of unnamed middle Cretaceous sedimentary rocks in the Yukon-Koyukuk Basin that may be as much as 8000 m thick. Our survey covered approximately 120 river miles and we recorded 93 new occurrences of dinosaur tracks in an area where none had been documented previously. The age of these rocks is approximately 100–90 Ma. Ten stratigraphic sections were measured which display primarily fluvial-delta plain facies. Main fluvial channels, up to 18 m thick, consist of well-developed fining-upward successions of medium- to fine-grained, trough cross-bedded, and ripple cross-laminated sandstones. Lag deposits at the base of these channels often contain log impressions, cobbles, clay, and siderite rip-up clasts. Large-scale lateral accretion surfaces are visible in larger exposures. Main channels may be single-story or multi-story and are interpreted as meandering river deposits. Smaller channels, consisting of lenticular, fine- to very-fine, trough

cross-bedded sandstones up to 2 m thick, represent crevasse or distributary channels. Thin tabular, fine- to very-fine-grained sandstones interbedded with siltstone, mudstone, and shale represent vegetated floodplains. Tabular, trough cross-bedded, and laminar, fining upward sandstones less than 1 m thick are interpreted as sheet flood deposits. Sandstones are typically bioturbated and moderately rooted with plant leaf impressions and woody stems at the base. Interbedded, fine-grained sandstones, siltstones, and mudstones are interpreted as distal floodplain deposits. Root traces are pervasive throughout floodplain mudstones and crevasse splays. Organic fragments on thin sandstones, plant detritus, and leaf impressions are common. Thin coals or coaly shales represent peat swamps, and thick mudstone deposits represent small ponds or lakes. Small coarsening-upward successions of interbedded tabular sandstone and mudstone probably represent crevasse deltas and/or crevasse splays into interdistributary bays. The broad ichnotaxonomic groups represented in our survey are non-avialan theropods, at least three examples of avialan theropods, hadrosauroids, and nodosaurids. Of these ichnotaxa, the most encountered track type was tridactyl with rounded, broad digits, tracks attributable to young to adult hadrosauroids, a frequency pattern like that found in a roughly correlative study several hundred kilometers north in the Nanushuk Formation of North Slope, Alaska. Also of note is this work documents the first occurrence of a crane-like bird in this region. Our study not only provides new insights into a biologically productive ancient, high-latitude, terrestrial ecosystem, but also demonstrates the need for additional high-latitude studies to expand our knowledge of ancient biodiversity in the Cretaceous Arctic.

Funding source: Funding provided by Friends of Alaska Paleontology at ISEM at SMU.

## BAYESIAN DIVERSIFICATION RATE ANALYSES IN A SPATIALLY CONTROLLED FRAMEWORK ILLUMINATE THE TIMING OF THE FIRST RADIATION OF RAY-FINNED FISH

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Ray-finned fish (Actinopterygii) first became diverse components of vertebrate ecosystems in association with end-Devonian Hangenberg extinction event. The timing of their initial diversification remains contentious, however. The phylogenetic relationships of early fossil actinopterygian lineages suggest that they had already begun to diversify in the latest Devonian, with multiple cryptic lineages surviving through the Hangenburg event, but this is based on a fraction of all known early actinopterygian taxa. Conversely, subsampling analyses of their total fossil occurrence record indicates rapid diversification in the earliest Carboniferous, but the reliability of this view is undermined by issues of spatiotemporally and taxonomically uneven sampling which plague the fossil record more generally. To overcome these problems, we analyse a taxonomically comprehensive occurrence database of all known early actinopterygians in a spatially explicit framework, using analytical tools rooted in the birth-death process that underpin phylogenetic diversification rate analyses, but without the requirement of a resolved tree. We obtain diversification rate estimates for early actinopterygians which are compatible with both their total fossil record and the statistical requirements of their underlying, yet incompletely known phylogeny. We use these results to determine the stratigraphic relationship between the Hangenberg event and the first explosive radiation of actinopterygians which set the foundations for their subsequent evolutionary success.

## INTEGRATING BAYESIAN PHYLOGEOGRAPHY WITH LANDSCAPE CONNECTIVITY ANALYSIS REVEALS THE ECOGRAPHY OF THE EARLY ARCHOSAUROMORPH RADIATION

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The fossil record is incomplete through time and across space, resulting in a biased and limited view of the spatial distributions of clades throughout their evolutionary history. Phylogeographic estimates of clade origins go some way towards alleviating the gaps in the fossil record, but the intervening space separating ancestors and descendants is rarely considered despite offering a potentially rich source of data on the environmental tolerances and spatial distributions necessitated by their biogeographic histories. Improved palaeogeographic and earth-system modelling provides the high-resolution landscape and climate reconstructions needed for these investigations, but computational tools tailored for landscape ecology in deep time are lacking. I address this issue with a novel landscape connectivity analysis framework implemented in the R programming environment, TARDIS (Terrains And Routes of Dispersal In Spacetime). To demonstrate its utility, I infer the geographic origins of archosauromorph reptiles in the Late Permian to Early Triassic using Bayesian phylogeographic ancestral state estimates, then use TARDIS to reconstruct ancestral dispersal routes as least cost pathways through geological time and across geographic space. These pathways provide information on the unseen spatial distribution of basal archosauromorphs while climatic conditions along their lengths reveal their early environmental breadth, which far outstrips their fossil record at face value and even exceeds the bounds of ancestral state estimates.

## INTERDISCIPLINARY PERSPECTIVES IN AN ERA OF GLOBAL POLLEN SYNTHESIS

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The proliferation of open-access paleoecological databases marks a new era of interdisciplinary research, offering unprecedented opportunities to explore biodiversity patterns and their drivers over vast temporal and spatial scales. Fossil pollen analysis specifically can serve as a cornerstone for understanding vegetation dynamics, plant biodiversity shifts, and the impacts of anthropogenic change on ecosystems. With new workflows and R-packages being developed, an unprecedented number of pollen-based datasets from across the globe can now easily be sourced and analysed by researchers from all fields and locations. However, we still need to confront the risk of 'interdisciplinary isolation' where researchers use the same data but continue to work separately with discipline-centered approaches. Such isolation can hamper a much-needed collaboration between pollen-based paleoecology and other disciplines tapping into global paleoecological databases. In this talk, I will address bridges for interdisciplinary research by acknowledging and tackling the challenges of large-scale pollen syntheses ('macroecological paleoecology') and interdisciplinary teams, while showing the need for cross-discipline-friendly guidelines, and proposing actionable steps towards a collaborative, open science framework. By fostering interdisciplinary dialogues and embracing open-access principles, the future of conservation paleobiology lays open for innovative, integrative approaches to safeguarding our planet's biodiversity heritage.

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## PRELIMINARY REPORT OF EARLY EOCENE FLORAS FROM THE LOWER SAN JOSE FORMATION, NEW MEXICO, U.S.A.

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The early Eocene was marked by a globally warm climate as well as a series of hyperthermal events caused by global carbon cycle perturbations. The best known terrestrial record of these early Eocene hyperthermal events—the Paleocene Eocene Thermal Maximum (PETM) and Eocene Thermal Maximum 2 (ETM2)—and the early Eocene Climatic Optimum (EECO) is from the Bighorn Basin in north-central Wyoming. There the hyperthermal events are linked to intensified fluctuations in precipitation and possible opening of vegetation. During the PETM, mesic temperate plant taxa were temporarily extirpated and replaced by a thermophilic, dry-adapted flora dominated by possibly nitrogen fixing legumes (Fabaceae). Some of these plants reappeared during ETM2 and the EECO in the Bighorn Basin. The biogeographic origins of the hyperthermal plants are poorly known and weak age constraints on Paleogene floras from southern North America has inhibited our understanding of floral biogeographic patterns during this important time interval. The San Juan Basin, located in northwestern New Mexico and southwestern Colorado, preserves a succession of extensive but understudied early Eocene terrestrial deposits making it an ideal place to study early Eocene floras from southern North America and investigate latitudinal differences in floral composition and diversity. The lower San José formation consists of over 300 m of fossiliferous fluvial deposits temporally constrained to the first ~4.0 million years of the Eocene (approximately 56.0 to 52.0 Ma) via magnetostratigraphy (i.e., magnetochrons C24r–C23r) and mammalian biostratigraphy (i.e., early Wasatchian North American Land Mammal Age). Here we present a preliminary report of the fossil macro- and microfloras from the lower San José Formation. Fossil macro- and microfloras were collected from the lower San José Formation from three sampling localities: Arroyo Chuijillia and Arroyo San Ysidro in the southeastern San Juan Basin and Santos Peak in the basin center. Fossil macrofloras are dominated by dicotyledonous angiosperms with monocotyledonous angiosperms, pteridophytes, and *Ginkgo* as accessory taxa. Importantly, legume foliage and reproductive organs are common within the macroflora, as well as other taxa restricted to hyperthermal events in the Bighorn Basin; these taxa are found outside of hyperthermal events in the San Juan Basin. The fossil palynofloras recovered, for the first time from the San José Formation, are also dominated by angiosperm pollen. This preliminary floral record from the San Juan Basin provides evidence that the southern Rocky Mountains were a source for some plants known only from the hyperthermal events in the Bighorn Basin and for substantial latitudinal differences in floral community composition during the early Eocene.

## THE "SIWALIK" MICROFAUNA

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What was the Siwalik microfauna? This question implies dimensionality in time. It assumes that assemblages of the later Tertiary Siwaliks sampled the small mammal community of the Indian Subcontinent, and that the community had a beginning and showed little change through time. These assumptions are simplistic but involve complex answers. First, the roots of the Siwalik microfauna extend deeper in time than that captured on the Potwar Plateau of Pakistan where its basal 18 Ma fauna is unabashedly "Siwalik." We find that Siwalik small mammal taxa are encountered to the southwest in the earliest Miocene (23 Ma) of the Zinda Pir Dome. Yet earlier (Oligocene) assemblages differ greatly in dominance by archaic rodents (including a rare, primitive muroid and an aberrant squirrel). Earliest Miocene microsites record a shrew and a bat. Treeshrews are also known, and fragmentary specimens attest to their much earlier presence. Hedgehogs appear ~19 Ma and came to be abundant in middle Miocene age assemblages. By 23 Ma, Siwalik assemblages were dominated by advanced rodents: derived muroids, squirrels, and gundis (*Sayimys*). The muroids were precursors to hamsters, gerbils, and true mice on the one hand, and to living root rats on the other. There were other rodent elements, but these are the main players in successive communities. Siwalik assemblages saw considerable changes in the middle and late Miocene. Most notable was evolution among muroids. The earlier Miocene community was rich in members of the hamster and gerbil clades. Siwalik small mammal ecology supported high rodent diversity at this time. One muroid lineage of abundant species in the successive genera *Potwarmus* and *Antemus* displayed only moderately novel morphology. The successor to *Antemus* showed new cusp linkage and development of shearing blades. This muroid was immediately successful, accounting for about a third of all small mammals. One million years later at 11.6 Ma murines accounted for over half of all small mammal individuals; success coincided with gerbil and hamster extinction. This began the tremendous splitting radiation of true mice. In contrast, gundis sustained anagenic evolution over millions of years. Root rats were successful, climbing in abundance to one third of small mammal individuals encountered in the late Miocene. Their number included members of the living fully subterranean bamboo rat tribe. Shortly after 10 Ma, bamboo rats invaded a subterranean habitus to exploit underground food sources and avoid the heat of surface fire. True mice had successfully competed with and replaced gerbils and hamsters; bamboo rats illustrate evolution in response to an abiotic challenge. The Siwalik microfauna, in place at the debut of the Miocene, was not static, but evolved opportunistically.

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## USING MACHINE LEARNING AND PHYLOGENETIC COMPARATIVE METHODS FOR PREDICTING ECOLOGY IN FOSSILS FROM INNER EAR BONY LABYRINTHS OF TOXICOFERANS (SQUAMATA, REPTILIA)

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How can we reconstruct behavior of extinct species of which we only have fossils remains? Pioneering investigations in lizards and snakes have attempted to use inner ear shape and size data to identify whether extinct fossil species, particularly early-diverging snakes, were most likely fossorial or aquatic. This research has, however, failed to both 1) sample broadly across Toxicofera, a lineage including snakes and their closest lizard relatives which contains several independently-derived limbless, aquatic, and fossorial species and 2) test whether training models on inner ear data of lizards and snakes can be used to accurately discriminate whether lizards or snakes are fossorial or aquatic. By greatly extending the sampling of inner ear morphology in proposed sister groups to snakes, and by applying validation-test dataset partitions, which prevent overfitting to the validated data, we make more general and robust interpretations of trends in this structure's shape and size. We apply both geometric morphometric (N = 110 individuals, 77 unique species) and conventional morphometric (N = 97 individuals, 67 unique species) sampling techniques to micro-computed tomographic scans of extant and fossil squamate inner ears to better understand how ecological, phylogenetic, and allometric variables relate to toxicoferan inner ear morphology. We then use supervised machine learning to determine whether fossorial or aquatic habits can be predicted from inner ear morphology using our dataset. Finally, we use phylogenetic comparative methods to test the hypothesis that inner ear shape relates to spatial constraints in the skull imposed by potentially adaptive modifications related to inner ear and neurocranial allometry in fossorial taxa. We find neither inner ear shape nor size strongly predict nor associate with these different habits in toxicoferans, but that cochlear morphology may be more associated with these unique lifestyles than vestibular.

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## QUANTIFYING THE PALAEOECOLOGICAL IMPACTS OF THE CLARKSVILLE PHASE OF THE RICHMONDIAN INVASION IN THE NASHVILLE DOME, TN

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The Richmondian Invasion (RI) was a Late Ordovician biotic immigration event that has been well studied in the Jessamine Dome where its first major pulse (the Clarksville Phase) occurs in the Waynesville Formation. A suite of taxa (e.g., the coral Grewingkia canadensis; brachiopods Eochonetes clarksvillensis and Strophomena planumbona) entered the basin as a part of the Clarksville Phase. However, it has long been known that this suite of taxa spread to the Nashville Dome of Tennessee as well. The "Arnheim" Formation of the Nashville Dome has historically been correlated with the Arnheim Fm of the Jessamine Dome despite hosting two markedly different macrofaunal assemblages. As a result of this correlation, it has been posited that the invasion was not synchronous between regions and occurred earlier in the Nashville area. This study employs integrated stratigraphy (litho-, bio-, and chemostratigraphy (C-isotopes), as well as sequence stratigraphy) to reassess this correlation. Results indicate that the "Arnheim" Formation of the Nashville Dome represents both the Arnheim Formation (approximate lower half) and part of the Waynesville Formation, of the Jessamine Dome. Moreover, the overlying "Sequatchie Formation," which is variably truncated beneath the lower limestones of the Fernvale Formation appears to record the upper Waynesville or Blanchester Member. The upper or Waynesville-equivalent portion of the Tennessee "Arnheim" Formation is characterized by the abrupt appearance, within part of a single 6th order cycle (<20,000 kyr ) of many of the same taxa that entered the Jessamine Dome in the Clarksville Phase and records the southern expression of the first pulse of the RI. This revised correlation indicates that this faunal immigration was in fact synchronous between regions. Thus, the widespread and geologically abrupt appearance of this faunal cohort suggests a eustatic/climatic driver and is attributed to a glacioeustatic transgression and/or warming that altered current and larval dispersal patterns as well as permitting viability of warmer water taxa. A preliminary faunal dataset collected from the "Arnheim," and overlying Sequatchie Formations was analyzed from a synecological perspective using cluster analysis, guild analysis, rarefaction, and detrended correspondence analysis. The results demonstrate that the Clarksville Phase is clearly abrupt and had similar patterns and ecological impacts.

Funding source: ODNR Ohio Rocks Research Grant Dry Dredgers Paleontological Research Award

## CONTRIBUTIONS TO THE CRANIAL ANATOMY OF THE EARLY TRIASSIC RHYNCHOSAUR *MESOSUCHUS BROWNI* WITH A DISCUSSION OF VOMEROLFACTORY EVOLUTION ACCROSS CROWN ARCHELOSAURIA

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*Mesosuchus browni* Watson 1912 is a pan-archosaur represented by a small series of specimens collected from Early Triassic sediments of the Karoo Basin, South Africa. Known specimens are housed in the Iziko South African Museum in Cape Town and include an exceptionally preserved skull (SAM 6536) that Robert Broom considered one of the finest specimens known to vertebrate paleontology. A detailed description of *Mesosuchus* skeletal anatomy using a traditional approach was published, and that was followed by a microCT study targeting the SAM 6536 braincase. Here, we build on these efforts by extending the benefits of advanced imaging to the remainder of SAM 6536. Justification for these efforts is drawn from the heuristic potential of the specimen as reflected in its overall preservation, the striking resolution of the resultant CT images, and the strategic phylogenetic position in which *Mesosuchus* is commonly recovered. As an early-diverging rhynchosaur, *Mesosuchus* is critical for polarizing characters and testing evolutionary and phylogenetic hypotheses, both within Rhynchosauria and along the phylogenetic backbone that produced crown Archosauria. Internal details of the anterior hard palate and cranial roof reveal a number of intriguing morphologies whose phylogenetic and evolutionary implications are not yet clear. Most notably, these regions preserve several interesting osteological features that support the hypothesis that *Mesosuchus* possessed a fully functioning vomeronasal system. These features include a previously undescribed and deeply sculpted septomaxilla, a nasolacrimal duct that empties into close proximity to a potential vomeronasal organ, and deeply concave impressions on the skull roof formed by expanded olfactory regions of the brain. We review the transformation of vomerolfaction-related cranial anatomy within crown Archelosauria and use the resultant distribution to map patterns of vomerolfactory evolution. The developmental truncation of the vomeronasal system in both crown Testudinata and crown Archosauria correlates with a simplification of the anterior bony palate, including the loss of the septomaxilla. This complex story of neurosensory evolution suggests a level of developmental modularity between the soft tissues of the vomeronasal system and the bony framework of the skull, and provides an opportunity for the integration of paleontological, developmental, and genomic data.

## DENTAL ECOMORPHOLOGY OF MODERN NORTH AMERICAN RODENTS

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The species richness and ecological composition of modern North American rodent assemblages in terms of distributions of body size and diet category have strong quantitative relationships to continental climatic and topographic gradients, suggesting that fossil rodent assemblages could be used for quantitative paleoenvironmental reconstructions. Estimating body mass for fossil rodents from teeth is straightforward, but rodents are extremely diverse taxonomically and ecologically and have a wide range of dental morphologies, which complicates quantitative assignment of diet type to fossil rodents. We developed methods to quantify rodent tooth shape and assign diet type using the 3D shape of lower cheek tooth rows for 148 extant North American rodent species assigned to six a priori diet categories (frugivory, omnivory, granivory, folivory, invertivory, and rootivory). Using microCT-derived dental models to characterize ecomorphology, we collected >500 variables including linear measures, GIS-based topographic variables, published and novel 3D methods, and variations thereof. Several individual measures statistically distinguished species in at least one a priori diet category from those in other categories. Using stepwise variable selection, the best discriminant function model included 36 dental variables and correctly assigned 88.5% of species to a priori dietary category based on jackknife cross-validation. Most misclassifications were to omnivory or to categories associated with species' seasonal fallback foods (including those yielded a 98.7% classification rate). Given correlations among the variables and potential model overdetermination, we prefer a six-variable model (84.5% a priori and 95.3% acceptable classification rates) using ecologically interpretable variables: enamel to crown ratio (ECR), occlusal convexity (OCC), volumetric relief index (vRFI), Dirichlet normal energy (DNE), m2 proportion, and stenodonty index (SNI). Our results demonstrate that morphologically distinct teeth of rodent species with similar diets share underlying shape characteristics, providing a means to assign diet type quantitatively to extinct rodents and suggesting a generalizable new dental ecomorphology toolkit for mammalian paleoecology.

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## FROM DISCOVERY TO INTERNATIONAL NEWS: A UTILITY AGENCY'S STEWARDSHIP AND PUBLIC OUTREACH OF A CALIFORNIA FOSSIL SITE

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In 2020 a previously unknown Late Miocene fossil locality was discovered by a public utility ranger while on patrol in the northern Sierra Nevada foothills. Dubbed the "Miocene Zoo," this site contains significant vertebrate and botanical remains which include camelids, proboscideans, horses, rhinoceros, tapirs, tortoise, canines, rodents, fish, birds, and hundreds of fossilized logs. This site has become the subject of intensive study by a multidisciplinary team of researchers. For site security the land manager, East Bay Municipal Utility District (EBMUD) and research partners initially refrained from making a public announcement about the discovery. However, extensive public outreach and educational efforts have been made to engage communities near the site about California's rich fossil history. EBMUD's public affairs department crafted a media and education announcement strategy which became public 10 months following the discovery. This program, with a global reach, has been translated into 17 languages and includes an interactive web-based educational 'story map' built on Esri arcGIS platform. There is public access of the fossil collection on exhibit at Gateway Science Museum (CSU Chico) and EBMUD's traveling exhibit for regional schools and museums. Lectures and public education events are conducted by rangers and researchers. Colleagues in the study have participated in television coverage of the discovery including a European documentary series. Field studies by undergraduate & graduate students as well as ranger-led earth science field programs for local high schools are underway. Management of a fossil site is a unique challenge for a water agency and has shown to provide new opportunities for scientific research, public engagement and educational programs.

Funding source: East Bay Municipal Utility District

## AN ENERGY FLOW MODEL OF EARLY TERRESTRIAL TROPHIC DYNAMICS: EXPLORING THE ROLES OF AQUATIC SUBSIDIES AND DELAYED HERBIVORY EMERGENCE

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Understanding early terrestrial ecosystems is important for tracing how modern terrestrial ecosystem structure arose, and more generally for addressing how ecological systems

develop complexity through deep time. Terrestrial trophic structures are built around the primary productivity generated by land plants and its accessibility to consumers. In today's world, herbivorous animals play a significant role as primary consumers. However, the Paleozoic records of terrestrial arthropods and plant damage suggest that herbivory was extremely limited before the Pennsylvanian, with animals supported directly or indirectly by decomposing vegetation. This raises questions of how detritivory-based communities would have functioned, and whether the emergence of widespread herbivory significantly impacted the availability of energy for supporting higher trophic levels and larger animals on land. Additionally, there is the potentially important but generally overlooked role of adjacent aquatic communities in subsiding terrestrial consumers with energy and nutrients. To investigate the potential interplay of detritivory, herbivory, and aquatic subsidies in early terrestrial ecosystems, we introduce a simple numerical energy flow model that simulates the effects of these factors on the stability and energy balance of a trophic system. Initial results are consistent with herbivores playing an important role in making energy accessible to other animals, with their presence disproportionately boosting the biomass of both energy-limited carnivores and predation-controlled detritivores. Herbivores also increase overall primary productivity by continuously suppressing standing vegetative biomass below the system's carrying capacity. Subsidies of aquatic detritus into the system increase terrestrial consumer biomass with diminishing returns at higher trophic levels, whereas subsidies of aquatic animals, depending on input intensity, can either boost the biomass of terrestrial consumers or destabilize the system due to over-predation of animal consumers by well-subsidized terrestrial carnivores. While further exploration of model parameter space is necessary to assess the generality of observed system behaviors, these results suggest that the relative abundance of predatory arthropods observed in Silurian and Devonian terrestrial faunas may reflect an early dominance of aquatic subsidies and could have played a role in suppressing proliferation of early herbivores.

## SEVEN HABITS OF HIGHLY EFFECTIVE WORMS: HOST TEXTURE PREFERENCE IN DEVONIAN MICROCONCHIDS

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Sclerobionts are encrusting organisms which have skeletonized hard parts; they can encrust onto abiotic or biotic substrate. They are frequently studied in the fossil record as they preserve in situ, and often form fairly complete communities on their hosting substrate. Whole community studies of brachiopod hosted sclerobionts are numerous, but fewer studies are done on the preferences and ecology of specific taxa within the sclerobiont community. Our research focuses on the common sclerobiont group Microconchida. Microconchids are likely the fossilized tests of serpulid worms; they are coiled and bear some resemblance to the modern epibiont *Spirorbis*. They are found in sclerobiont assemblages as far back as the Ordovician. Because microconchids are solitary organisms, they might face challenges from the topography of their substrate which larger or colonial sclerobionts might not, and subsequently might preferentially be found on host substrates with certain textures. To test this, we selected brachiopods from three different Devonian basins in the U.S.A. (Hamilton Group, New York (N = 144); Traverse Group, Michigan (N = 313), and Lime Creek Formation, Iowa (N = 213)). We sorted the host brachiopods into three groups, based on the texture of their valve surfaces. Group one was brachiopods with strong texture creating features, such as pronounced plicae. Group two was brachiopods with medium textural features, such as finer plicae or costae. Group three was brachiopods with weak textural features, such as very fine costae or a smooth surface. The number of microconchids encrusting both dorsal and ventral valves were counted. The percent of the encrusted valves which had at least one microconchid was calculated for both regional groups and texture groups. A Fisher's exact test was used to test for differences in the frequency of microconchid encrusted valves between region and textural categories. Microconchids had a very similar encrustation frequency between regions. Brachiopod hosts with weak textures were significantly less likely to be encrusted by microconchids than hosts with non-weak textural features ($p < 0.001$). No difference was observed between microconchid encrustation on hosts with strong vs. medium textures. Although larger individuals are occasionally found, most Devonian microconchids are only a few millimeters in diameter. It is possible that host brachiopod plicae or costae could help to shelter small and larval microconchids, giving them a greater chance of survival than they would have had on host brachiopods without. These data span three basins which would have had variable environmental conditions. The fact that preference for textured brachiopod hosts is stronger than any encrustation trends observed between basins suggests that this is a generalisable result that can be applied to microconchids in a variety of environments in the Devonian.

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## UNTANGLING THE FIRST ACTINOPTERYGIAN ADAPTIVE RADIATION

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Actinopterygians or ray-finned fishes are the principal vertebrate group in modern aquatic ecosystems, where they display a bewildering variety of form and function. This has not always been the case. The actinopterygian fossil record shows a marked change centered on the transition between the Devonian and Carboniferous. Before this time, actinopterygians were comparatively minor components of aquatic vertebrate faunas. After the boundary, ray-fins represent a greater proportion of taxa in both freshwater and marine settings, and display striking innovations in body geometry, dentition, and skull shape. This dramatic change has been interpreted as an adaptive radiation following the Devonian/Carboniferous extinction, possibly fueled by the clearing of occupied ecological roles. However, two linked and persistent gaps in our understanding obscure a more refined macroevolutionary perspective on this key episode of actinopterygian history. First, most actinopterygians of latest Devonian and early Carboniferous age are known in limited detail, with available information limited to external morphology of dermal bones and scales. Second, evolutionary relationships among early ray-fins remain highly contentious, in part due to a lack of comprehensive anatomical data for most taxa. Computed tomography (CT) scanning of both three-dimensionally preserved and—perhaps surprisingly—flattened material of early actinopterygians can yield substantial new osteological information. Additionally, these provide additional raw material for downstream phylogenetic and macroevolutionary analyses. We have undertaken a systematic CT survey of Devonian and Carboniferous actinopterygians, focusing mostly on the cranial region, with a particular emphasis on structures related to feeding (i.e., jaws and teeth). Work to date has exposed substantial—and unexpected—patterns of variation in dental and jaw morphology among otherwise anatomically similar taxa. Additional cranial character data has allowed us to propose a new hypothesis of early ray-finned fish interrelationships that implies that many lineages persisted across the Devonian/Carboniferous boundary. Uniting information about jaws and teeth with revised phylogenies in a quantitative comparative framework will permit a critical test of whether the Devonian/Carboniferous boundary is associated with shifts in the dynamics of phenotypic evolution predicted by models of adaptive radiation.

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## ASSOCIATED DENTITION AND PETROSAL OF A DRYOLESTOID MAMMAL FROM THE UPPER JURASSIC MORRISON FORMATION, UTAH, U.S.A.

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Vertebrate fossils from the Late Jurassic Morrison Formation are fundamental to our understanding of the evolution of Mesozoic terrestrial biotas, and the Morrison has yielded one of the most diverse records of Late Jurassic mammals and their kin. However, a majority of mammals from the Morrison are solely represented by isolated teeth and incomplete jaws, which are not informative for the evolution of the mammalian skull and other skeletal elements. Recent excavations at the Cisco Mammal Quarry (CMQ)—a Tithonian locality from the Morrison Formation of eastern Utah—have yielded many well-preserved mammal specimens, including associated skull elements and partial skeletons. These new fossils offer an exciting opportunity to explore questions of early mammalian evolution with greater clarity. Here we report a mammal specimen from CMQ that preserves a petrosal and associated teeth that can be identified as a possible "paurodontid" dryolestoid. This fossil is notable because "paurodontid" mammals are so far known only by disassociated and incomplete dentitions. The dentition of the specimen consists of three partial upper molars and a single complete upper molar which we interpret as the M5. The petrosal is dorsoventrally compressed, but preserves many features such as the fenestra vestibuli, fenestra cochleae, foramen ovale, and the stylomastoid notch. On the endocranial aspect, it preserves the subarcuate fossa and the internal acoustic meatus. Segmentation of microcomputed tomography (μCT) scans of the teeth reveal features that resemble those of the "Paurodontidae," and in particular, *Euthlastus*, known from the Morrison Formation at Como Bluff. Further comparative analysis is necessary for a more conclusive generic assignment of this specimen. Digital reconstruction of the petrosal and inner ear endocast is ongoing, but has thus far yielded promising information related to the promontorium and the cochlea. Notably, preliminary analysis of the inner ear endocast has revealed a partially preserved cochlear canal with primary and secondary bony lamina impressions. Characters from the dentition and the ear region are particularly useful for mammalian systematics; as potentially the first known "paurodontid" petrosal from the Morrison, this specimen offers valuable insight into the early evolution of the mammalian inner ear and may ultimately improve the resolution of a group positioned close to the root of Theria, the clade containing most living mammals.

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## MODELLING THE MICROBIAL TO METAZOAN TRANSITION

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During the Ediacaran (635–538.8 Ma), the fossil record records a unique evolutionary shift from microbial-dominated ecosystems to ecosystems dominated by large, multicellular metazoans. However, these first metazoan ecosystems were very different from modern ecosystems, or even the ecosystems of the Cambrian (538.8–485.4 Ma). Various modern ecological features such as motility, predation, and bioturbation were absent from these ecosystems, and evolved over the course of the Ediacaran, culminating with the radiation of recognisably modern body plans and ecologies in the Cambrian. Consequently, while a wide range of taxa are known from these early ecosystems, the ecological functioning of these ecosystems is not well understood. We tackle this problem using biomass-explicit ecological network models, where nodes in the network represent ecologically distinct groups of organisms, and edges (i.e., connections between nodes) are modelled as pairs of Lotka-Volterra equations, describing nodes' effects on one another. These models allow for the assessment of the biological plausibility of different sets of potential inter-species interactions and species biomasses, and can identify potential responses of ecosystems to changes in biotic and abiotic conditions. Our parameter-space analysis indicates that the stability of early metazoan ecosystems may have been facilitated in part by high concentrations of detrital organic carbon in the Ediacaran oceans. Furthermore, while growth in ecosystem complexity in the latest Ediacaran and earliest Cambrian results in an increase in the number of both stabilising and destabilising feedback loops and, therefore, an increase in the range of possible stability values, the net result of this growth in complexity trends, at least initially, towards destabilisation of the networks. Consistent with this observation, incorporation of late Ediacaran (548 Ma) tube-boring predators into the networks results in the loss of the previously most stable areas of parameter space in Cloudina reef networks. Similarly, an increase in predator biomass in the earliest Cambrian (Fortunian; 538.8–528 Ma) networks results in progressive decline in stability. Further analysis is required to determine the role of organism-environment feedbacks, such as ecosystem engineering, on the earliest ecosystems, and to determine at what stage growth in ecosystem complexity results in net stabilisation of Cambrian ecosystems due to portfolio effects. Our next-generation ecological network models provide an ideal tool for this further analysis.

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## RODENTS AS TAPHONOMIC AGENTS IN ARCTIC ECOSYSTEMS

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How much do rodents drive the recycling of minerals sequestered within bone and the loss of bones from landscape surfaces? Rodents gnaw fresh and weathered bone to supplement dietary fats and minerals (Ca and P), and to help grind down their ever-growing incisors. In light of these multiple benefits, assemblages of bones are likely to record relatively frequent rodent gnawing. However, an initial evaluation of bone recovered from the Coastal Plain of Alaska found very few occurrences of rodent gnawing (<3% of available bones), despite abundant rodent populations, indicating that bone resources can be largely unnecessary for local rodent communities. Has the reliance of rodents on bone been overestimated, or is there variation in resource need based on rodent community composition and region-specific nutrient dynamics? Here, we evaluate the extent to which rodents modify bone resources on an Arctic landscape, comparing rodent modification of bones laying on the Porcupine Caribou Herd's Alaskan mating grounds versus their calving grounds. While the PCH range is home to abundant populations of rodents, calving grounds along the tundra-rich Coastal Plain and mating grounds situated within southern boreal forests have distinct rodent communities. There are greater abundances of porcupine and red squirrels (*Erethizon dorsatum*, *Tamiasciurus hudsonicus*) on the mating grounds and greater dominance of lemmings (*Dicrostonyx groenlandicus*, *Lemmus trimucronatus*) on the calving grounds, with voles and ground squirrels occurring in both regions (*Microtus* spp., *Urocitellus parryii*). To evaluate rodent modification, we surveyed the PCH mating and calving grounds using standardized antler surveys, which recovered 1,352 shed antlers. We then compared the frequency and intensity of rodent gnawing on antlers between the two regions. Finally, we measured the furrows left on antlers by rodents and compared them to incisor widths of locally occurring rodent species. We found that antlers located on mating grounds are much more frequently modified by rodents (50%) than those on calving grounds (<3%). Additionally, antlers laying on the mating grounds were more intensely modified than those on the calving grounds, where rodent gnawing removes less overall bone. Rodents are important drivers of bone recycling on the PCH mating grounds, though contribute only minimally to bone recycling on the calving ground deposits. On the mating grounds, furrow sets generated by rodents are also larger than found on the calving grounds, consistent with porcupines being important contributors to bone loss within the boreal forests (mating grounds). For bones laying on landscape

surfaces, rodents can act as prominent taphonomic agents. While there are likely important and unevaluated nuances in habitat and nutrient availability that impact the dominance of rodents as bone recyclers, the species composition of the rodent community likely plays an important role.

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## SHIFTING RADIALS AND AN AZIMUTHAL DESCRIPTIVE SYSTEM PROVIDE NEW INSIGHTS INTO PATTERNS OF CRINOID CALYX SYMMETRY AND QUESTIONS OF PLATE HOMOLOGY

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Since the late 19th century, interpretation of crinoid calyx plates has been rooted in the ontogeny of highly derived comatulids, a radial-interradial (R-I) descriptive system, the assumption that plates are positionally fixed, and that infrabasals represent "accessory" pieces sometimes inserted between calyx and stem. Collectively, this has led to a prevailing opinion that the proximal circlets of monocyclic clades (e.g., disparids and monobathrids) are homologous with the midcup of dicyclics, a lens through which crinoid homology and evolutionary morphology have been viewed since the 1870s. Prior to this, the standard model homologized the cup-base circlet (pelvis) throughout Crinoidea. Given recent work demonstrating radial plates can shift into interradial positions, and that infrabasals are as fundamental as basals in early isocrinid larvae, there is cause to reconsider long-standing morphological questions from the perspective of basal, not infrabasal loss, among Paleozoic monocyclics. In early (doliolaria-cystidean) stages of skeletogenesis, calyx plates remain unfused and may shift positions. For example, in many cladids, the C radial is pushed over the BC basal, and in others, all radials and corresponding ambulacra may be interradially repositioned. However, such plate shifts are often subtle—neither radial nor interradial—demonstrating a limitation in the R-I dichotomy. An azimuthal system for plotting ray positions reveals informative subtleties in calyx symmetry and demonstrates the "Law of Wachsmuth and Springer" (LWS) strictly fails except in cases of perfect pentamerism. This is especially apparent among taxa with radial circlets disrupted by anal plates. However, a model of shifting radials, and constancy of stem-pelvis orientation, explains the general symmetry differences between dicyclic and monocyclic crinoids summarized by the LWS, in addition to other morphological patterns. Among disparids, clockwise rotation of radials into an interradial position, with C shifting into CD, explains the convergence of the right-posterior arm and anitaxis. Moreover, inferradials are explained as midcup plates over which the radials have shifted. Interpreting the pelvis of many monobathrids as comprised of infrabasals provides a simpler explanation for cup base circlets with less than five plates than does the current system. For example, in the 3-plate Periechocrinacea, the problematic suture in the posterior interray may be explained as the boundary between fused B+C and D+E infrabasals with a hypertrophied A infrabasal on the anterior side. Despite providing simple explanations for many problems of crinoid plate homology, the "shifting radial" model requires further consideration, especially with respect to posterior plating, nerves, and the chambered organ. Regardless, given that the foundational assumptions of the current system of plate homology have been upended, we should entertain alternatives.

## A GLOBAL COMPARISON OF THE REGIONAL DYNAMICS IN MARINE BIVALVE FUNCTIONAL DIVERSITY UNDER CLIMATE CHANGE IN THE PAST 5 MILLION YEARS

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Shallow marine bivalves are taxonomically and functionally diverse, occurring from pole to pole across all major coastlines of the world. They underpin many ecosystem services (e.g., reef building) and are a key indicator for ecosystem health. Throughout the Cenozoic, the group has been impacted by pulses of extinction coincident with rapid climatic changes. Of particular interest is the extinction associated with the Pliocene-Pleistocene transition into an icehouse climate, being the most recent period in which past $CO_2$ and temperature reached modern levels. The magnitude of this extinction is spatially variable along the latitudinal gradient, presumably more pronounced in high-latitude regions which experienced greater changes in average sea-surface temperatures. Evidence suggests that bivalve functional groups are more resistant to extinction than taxonomic groups, however we have limited evidence for how functional groups were impacted spatially during the Plio-Pleistocene event. The loss of a functional group within a region may have greater ecological consequences than the loss of a species. Here, we assign genus-level functional traits (mobility, substrate, diet, and fixation) to bivalve occurrence data across 11 regions globally, across tropical to cold temperate settings, from collections and published literature. We present new preliminary data on how functional diversity in bivalves is distributed spatially, and how the different functional groups have been impacted by climate change as measured by extinction since the Pliocene.

## CHANGES IN BIODIVERSITY AND PALEOECOLOGY OF RHYNCHONELLIFORM BRACHIOPODS ACROSS THE LOWER AND UPPER KELLWASSER EXTINCTION EVENTS (LATE DEVONIAN) AT TIOGA, PENNSYLVANIA, U.S.A.

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The Late Devonian (Frasnian-Famennian) mass extinction event occurred in two pulses, the Lower Kellwasser and Upper Kellwasser events. Upper Devonian strata of Tioga, Pennsylvania preserve shallow-marine facies of the Appalachian Foreland Basin at two outcrops. One outcrop crosses the Pipe Creek Formation (temporally equivalent to the Lower Kellwasser) and includes rocks of the upper Frasnian, below the F-F boundary, whereas the other outcrop encompasses rocks of the lowermost Famennian, just above the F-F boundary. We use rhynchonelliform brachiopod fossil abundance counts from bulk samples to analyze changes in fossil assemblages, including faunal turnover and shifts in relative abundances of taxa. With non-metric multidimensional scaling (nMDS), we reconstruct paleoecological gradients both before and after each extinction event. We also examine sample-level species richness (alpha diversity) to assess changes in diversity relative to an onshore-offshore paleoenvironmental gradient and through time. Using updated facies analyses, we track relationships between facies and alpha diversity as well as onshore-offshore gradient positioning. These analyses help reveal how Late Devonian environmental perturbations affected the brachiopod faunal assemblage structure in this region. Studying such changes within a shallow-marine ecosystem during this past mass extinction event may improve our understanding of potential effects of anthropogenic climate change on modern-day ecosystems.

## EARLY-LIFE ENDOCRINOLOGY IN MODERN AND PREHISTORIC PROBOSCIDEANS REVEALED THROUGH STEROID ANALYSES OF HAIR AND DENTIN

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Steroid hormones incorporated into growing tissues provide a record for investigating endocrine state and functioning over extended periods. Analyses of hormones in hair, baleen, bone, and teeth have yielded important revelations in medical, biological, and archaeological studies. Recent steroid analyses of woolly mammoth (*Mammuthus primigenius*) tooth dentin samples revealed that like living African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*), woolly mammoth males experienced musth, a periodic physiological condition associated with heightened aggression and sexual activity. Reconstructions of temporal patterns in testosterone and other common androgen levels pave the way for further efforts to interpret steroid data from tusk growth records, and one unexplored avenue of future research is neonatal endocrinology of proboscideans. We measured steroid hormones in tail hair from a juvenile elephant and tusk dentin from juvenile mammoths to test whether or not male proboscideans undergo "minipuberty," a stage of gonad development indicative of future fertility in infant male humans and other primates that is associated with a short-term spike in testosterone. If so, testosterone measurements from juvenile mammoth tusks may be useful for determining an individual's sex in individuals too young to exhibit overt sexually dimorphic anatomy. We also measured dehydroepiandrosterone sulfate (DHEAS) in a juvenile mammoth tusk with an apparent neonatal line marking the time of birth. In human fetuses, DHEAS is elevated due to adrenal activity triggered by the placental release of corticotropin-releasing hormone and then declines by nearly 80% following parturition. If true for proboscideans as well, DHEAS could provide an independent test of proposed neonatal lines that mark the timing of birth in tusk growth records. Fine-scale serial sampling of hair and tusk dentin paired with steroid analysis using liquid chromatography with tandem mass spectrometry (LC-MS/MS) produced detailed records of endocrine activity in proboscideans' first years of life. Our results characterize androgen patterns that provide a framework for interpreting growth records contained in juvenile tusks. This study demonstrates some of the ways hormone data might enhance the reconstruction of juvenile life histories of woolly mammoths, thus advancing the potential applications of the burgeoning field of paleoendocrinology.

## HISTORY AND CURRENT STATUS OF THE LELAND STANFORD JUNIOR UNIVERSITY PALEONTOLOGY COLLECTIONS

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By the mid-twentieth century, the paleontology collection at Leland Stanford Junior University (LSJU) was regarded as being among the largest and most important in North America, with particular strengths in invertebrate paleontology and micropaleontology. Transitions in staffing and a lack of

adequate storage space resulted in the divestment of the majority of the collection in the late 1970's and 1980's. During this time, approximately 200,000 specimens, including 10,000 type specimens and important stratigraphic collections, were transferred to other institutions, namely the California Academy of Sciences (CAS). The first wave of transfers to CAS was in progress when the Committee on North American Resources in Invertebrate Paleontology released their 1977 report. As a result, details regarding the composition of the transferred collections were likely missed, and information about the collections that remained at LSJU were absent from the report. Here, we characterize the collections that were transferred to other institutions as well as the collections that remained and continued to grow. Finally, we will report on newly launched efforts to modernize and steward LSJU's invaluable research and teaching collection.

## DIGGING FOSSILS #LIKEAGIRL: BROADENING PUBLIC ENGAGEMENT WITH PALEONTOLOGY THROUGH DEDICATED SCOUTING FUN PATCH

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Gender disparity in science and technology fields is a well-documented issue. Although progress has been made in recent decades, underrepresentation of women in science is still a pervasive problem—particularly in the geological sciences. With career aspirations largely formed by age 13, it is imperative that elementary- and middle school- aged girls be provided with a variety of avenues to explore, and feel supported within, STEM fields. The Girl Scouts of the U.S.A. organization made a pledge in 2017 to reduce the gender gap by bringing millions of girls into the STEM pipeline, and while many STEM-related badges have been added over recent years, none pertain directly to earth science or paleontology. By excluding these subjects from badge activities, the Girl Scouts institution is failing to utilize the power of paleontology as a gateway science. In an effort to address this issue and to help broaden community access to and public engagement with paleontology, the University of Kansas Natural History Museum worked with the Girl Scout Council of Northeast Kansas and Northwest Missouri to create a paleontology-themed fun patch for scouts called "I Dig Fossils." To earn the patch, scouts: (1) learn about the history of life on earth through a museum gallery program; (2) perform inquiry-based activities exploring paleobotany, invertebrate paleontology, and vertebrate paleontology; and (3) discover careers in paleontology and related sciences, featuring highlights of scientists from underrepresented groups (especially women). An optional field component examining cyclothem deposits and associated invertebrate fossils from the Pennsylvanian of eastern Kansas is also available to further learning. The fun patch debuted in Fall 2022 at a National Fossil Day museum event, where 65 scouts earned the patch. Since then, numerous scout troops/groups have earned the patch during You-Schedule-It sessions and relevant museum public events, such our popular annual Women in Science celebration. Through development of the patch program, we have learned valuable lessons about engaging with under-resourced community organizations. Finally, based upon participant feedback, we have made changes to facilitation which reflect the importance of girl-led programming.

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## PALEONTOLOGICAL DISCOVERY IN THE EMSIAN-EIFELIAN (DEVONIAN) NEEDMORE FORMATION IN WEST VIRGINIA: 150 YEARS OF EXPLORATION AND BEYOND

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The Emsian-Eifelian (Devonian) Needmore Formation spans the central Appalachian states of Maryland, Pennsylvania, Virginia, and West Virginia. The Needmore has been studied for nearly 150 years. It correlates to the Esopus, Schoharie, and Onondaga formations in New York and the Huntersville Chert in West Virginia, Virginia, Pennsylvania, and Maryland. Here, we report new occurrences of invertebrate and vertebrate fossils from a locality in the West Virginia Potomac Highlands region. The locality consists of olive gray to yellow, slightly calcareous shaly limestones, and likely forms part of the upper Emsian Hares Valley Member. The particular horizon from which these fossils were recovered consists of argillaceous limestones. The site is often frequented by hobbyist collectors who target trilobites, but new intriguing specimens have come to light as well. These include multiple sponge species that have potential to illuminate the diversity and ecology of sponges that may have contributed to the formation of local cherts. An apparent chelicerate mesosoma was also recovered, which is totally unprecedented in this unit. Historically, the Needmore's arthropod fauna was restricted to a diverse trilobite assemblage. Recent work has increased the species richness of Needmore trilobites, and this new arthropod expands our

understanding of the unit's arthropod biodiversity into other clades. Finally, we report placoderm bones from this site, which constitute the first definitive vertebrate remains in the Needmore of West Virginia and possibly the first identifiable such remains in the Needmore as a whole. The reasons so few vertebrates have been found in the region are not discussed in the literature, but the Needmore reflects an offshore facies of a sea which spanned northward as far as southeastern Canada. The better-explored shallower water zones of this sea in New York and Ohio have ample evidence for fossil fishes, especially in the Onondaga and Columbus Limestones. Geographic isolation and difficult terrain have restricted past studies in this region. However, it is clear the West Virginia Needmore holds scientifically important surprises for those willing to explore. Furthermore, this locality is adjacent to the proclamation boundary of the George Washington and Jefferson National Forests. Exploration of such localities for additional outcrops within National Forest boundaries may result in further recovery of significant paleontological resources. Many outcrops of the Needmore within the state are protected from destruction related to development as they occur on federal lands and are farther removed from urban areas than similar outcrops elsewhere. The Needmore Formation has enormous potential for future research that is unhindered by urban expansion, and promotable by land management agencies in terms of its geo-heritage and paleontological resources.

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## WHOLE-BODY AND MASS-SPECIFIC METABOLIC RATE IN BIVALVES AS PREDICTORS OF EXTINCTION SELECTIVITY DURING HYPERTHERMALS AND BEYOND

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As organismal metabolic rates are intertwined with environmental temperature and oxygen consumption, it stands to reason that they may be useful as a predictor of extinction risk during intervals of rapid climate warming in Earth's history. However, metabolism can and has been quantified in multiple different ways, and the resulting patterns differ in the context of investigating extinction risk. Here, we estimate resting (basal) metabolic rates of bivalve genera using measures of body size and estimates of paleotemperature in order to assess the degree to which metabolic rate determines survival both during and outside of periods of rapid climate warming, or 'hyperthermals.' In the past, whole-body basal metabolic rate, the total metabolic rate of an individual organism, has been the preferred metric, but we argue that mass-specific metabolic rate, as the standardized metabolic demands of one gram of tissue, may also be a source of useful information relating to trends in survival and extinction. Accounting for the effects of geographic range size, we find an overall pattern of preferential extinction of bivalves with lower total calorific needs, largely determined by their body size, which is congruent with the postulated ramping up of ecosystem energetics over the Meso-Cenozoic. Additionally, higher metabolic rates calculated per gram of tissue, largely determined by ambient environmental temperature, consistently increase the probability of extinction during hyperthermals relative to baseline conditions, particularly within the tropics. These results in tandem with previously documented patterns of extinction selectivity based on relative activity levels, including motility and feeding styles, paint a more complete picture of the role of metabolic activity during climate-driven extinctions. Standardized by mass, per-gram metabolic rate may represent a useful metric through which can be predicted the effects of anthropogenic climate change on modern marine faunas.

## THE INTRODUCTION OF LARGE MAMMALS HAS NOT REMEDIED THE ECOLOGICAL IMPACT OF THE LATE PLEISTOCENE EXTINCTIONS

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The fossil record lends itself to the study of the taxonomic and functional impacts of large-scale extinctions; however, it is much harder to infer the ecological repercussions of and recovery from such events. The Late Pleistocene extinctions, relative to other extinction events, are notable both because 1) they are recent enough to infer ecological interactions through behavioral and biochemical lines of evidence and 2) they were strongly size-selective and targeted almost exclusively large-bodied animals. Therefore, these extinctions provide a unique case study to investigate the ecological effects of and recovery from a highly selective loss of taxonomic and functional biodiversity. We used trophic guild and dietary information, informed by previously published stable isotope data, along with previously published body size data to build an ecological metanetwork of the mammal community represented within the Hall's Cave system in Texas before the extinctions, after the extinctions, and in the modern. We simulated a set of realized food webs and calculated a suite

of network topology metrics to identify how the biological network dynamics have shifted over time. Most notably, we found that the connectance and coherence of the community both increased as the network size decreased across the extinction. This suggests that the removal of unique herbivores and carnivores, combined with the reduction of redundancy and the increase in ecological interdependence, may have caused a more stable, yet also more susceptible, ecological system. Furthermore, we found that the mammal community has yet to recover to these pre-extinction states, despite the introduction of several large mammals. These results indicate that extinctions, particularly those which are highly functionally selective, can have dramatic long-term ecological impacts from which communities may never recover.

## DEEPTIME: AN R PACKAGE THAT FACILITATES HIGHLY CUSTOMIZABLE VISUALIZATIONS OF DATA OVER LONG TIME PERIODS (AND OTHER THINGS)

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Data visualization is a key component of any scientific data analysis workflow and is vital for the summarization and dissemination of complex ideas and results. One common hurdle across the earth sciences, evolutionary biology, ecology, and other scientific fields remains the effective and reproducible visualization of data over long time periods. Here I present a new R package, called *deeptime*, that provides easy-to-use functions to facilitate such visualizations, among other things. The package includes functionality to add various geological timescales to many different types of plots, visualize biological disparity through time and across phylogenies, and plot occurrence data through time. By leveraging the existing frameworks of the *ggplot2* R package and the wider *tidyverse* R package ecosystem, *deeptime* allows for these visualizations to be highly customizable. Further miscellaneous functionality includes custom scales and coordinate systems to be used with *ggplot2* and tools to assemble plots into multi-panel publication-quality figures. The open-source and constantly evolving package is accompanied by exhaustive documentation about the myriad of options available to users and several tutorials demonstrating the available functionality. My hope is that *deeptime* will reduce the amount of time and experience needed to make reproducible and professional data visualizations, giving scientists more time to ensure that these visualizations are more accessible and engaging.

## PLANTS ALWAYS HAVE HIGHER CLIMATE FIDELITY THAN MAMMALS, AND IT GETS WORSE AFTER INDUSTRIALIZATION

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Globally, ongoing climate change has triggered massive range shifts toward higher latitudes or elevations. In fact, climate tracking in response to global warming has been detected in approximately 50% of observed species (*IPBES report*) and may nevertheless not be enough to protect most of these species from extinction as the anthropogenic climate change could outpace their dispersal ability. However, the fact that today, half of observed species do not seem to track climate illustrates that the relationship between climate and species distributions is more complex than expected. Furthermore, modern data are temporally restricted to a couple of decades when climate change, niche displacement, and dispersal are long-term events and processes. In consequence, the use of paleontological data may be crucial to understand how species and communities have responded and could respond to the past and ongoing climate change. To do so, we collected all Holocene (from 11,700 bp to present) occurrences from the best sampled mammalian species and plant genera, and we reconstructed their climatic niches by associating each of their occurrences, based on site age, with a mean precipitation and mean temperature value. We then estimated the individual capacity of taxa to track climate by measuring the temporal stability or climate fidelity of their reconstructed climatic niches. To decipher the effect of taxonomic (i.e., plants vs mammals) and functional groups (e.g., large vs small mammals) on climate fidelity, and create a more realistic view of community change in the light of climate change and growing anthropic impact, we have reconstructed the joint history of North American plants and mammals' climate niches since 11,700 BP. We found that since the last deglaciation, plants have higher climate fidelity than mammals and that the arrival of Europeans and the industrialization of North America has profoundly changed the climatic niches of mammals, while only slightly modifying plants' climatic niches. These divergent histories illustrate how North American plants are not relying on mammal-mediated dispersal to cope with climate change. We showed that since the 16th century, mammalian communities in vast part of the Great Lakes region and temperate plains have lost their largest mammals under the pressure of urbanization and industrialized crops, while facilitating specific small mammals. The impact of anthropization has not spared the forests of North America, whose communities exhibit trajectories identical to those of cities and fields. Finally, mountains and grasslands acted as refugia for the mammals with the highest climate fidelity: the largest ones.

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## NEW INSIGHTS INTO THE DIVERSITY OF THE PRIMATE FAUNA FROM CHINJI-AGED SIWALIK DEPOSITS AND THEIR IMPLICATIONS FOR PRIMATE EVOLUTIONARY HISTORY AND BIOGEOGRAPHY

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For over 180 years, fossil primates have been rare, but highly notable components of the Siwalik fauna. Throughout the Siwalik sequence, primate assemblages change through time, capturing snapshots of the evolutionary history and biogeography of several major primate clades. In the oldest Siwalik deposits (i.e., the Kamlial Formation and equivalent-aged sites), recorded primates include a stem catarrhine (*Dionysopithecus* sp.), three sivaladapids, and two lorisid species. Historically, the biggest change in the succeeding Chinji Formation and similar-aged sites such as Ramnagar is the appearance of the well-studied hominid *Sivapithecus*, alongside the continued presence of sivaladapids and lorisids (and possibly stem catarrhines). Over the past 14 years, fieldwork in the Lower Siwaliks surrounding Ramnagar, India, has documented new primate specimens from Chinji Formation-aged deposits (~14–11.4 Ma). In addition to previously recognized taxa at the Chinji-level (*Sivapithecus*, *Sivaladapis*, and a large lorisid), we have recently described two new primates: a sivaladapid (*Ramadapis sahnii*) and a lesser ape, *Kapi ramnagarensis*. Not only do these new species increase known primate diversity during this time interval, but they also likely document important evolutionary trends in the diversification and biogeography of their respective groups. In particular, the new sivaladapid attests to the taxonomic expansion and overall success of this group during the Middle Miocene, as well as further documents their apparently folivorous dietary adaptations. The newly recognized co-occurrence of both lesser and great apes in Chinji-aged deposits (combined with their apparent absence prior to this time) suggests that these groups were part of the same biogeographic dispersal event into South Asia after the Mid-Miocene climatic optimum (MMCO). Thus, the proposed environmental changes after the MMCO that allowed great apes such as *Sivapithecus* to migrate and radiate into Asia also likely allowed lesser apes to migrate and radiate as well. More broadly, the addition of new primate taxa, and also the recovery of novel micromammals, suggests that there are still new mammalian taxa to discover in the Siwalik faunas, even after almost 200 years of research.

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## RAY-FINNED FISH NEUROANATOMICAL EVOLUTION REVEALED THROUGH EXCEPTIONAL FOSSIL SOFT TISSUE PRESERVATION

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Many of the characters that define Actinopterygii (ray-finned fishes) and the living lineages contained within it relate to the brain, including unique features such as an everted telencephalon. As soft-tissue preservation, especially of the neural tissues, is exceptionally rare in fossils, so understanding how and when these innovations evolved is challenging. Instead, brain morphology is typically inferred based on endocasts, infillings of the endocranial cavity that housed the brain and associated soft-tissue structures. Recent work has led to the discovery of a three-dimensionally preserved fossil ray-finned fish brain from the upper Carboniferous (~319 million years) of the UK, suggesting that this type of exceptional preservation might be more common than previously thought. Here we use micro-CT- and synchrotron-based tomography to report exceptional cranial and neuroanatomical soft tissue preservation in ray-finned fishes spanning the Carboniferous to Triassic of North America, South America, and the UK. As well as apparently pristine three-dimensional structures, some soft tissues differ in preservation state, suggesting that a range of taphonomic windows and decay states are being sampled. Crucially, the taxa in which soft tissue is preserved appear to be spread across early actinopterygian phylogeny, branching both inside and outside of the living radiation. Thus, these exceptional fossils offer a unique window into brain anatomy in the earliest ray-finned fishes. As such, they provide tools to

clarify when key neuroanatomical features evolved, and which of the features seen in living taxa represent specialisations rather than primitive features.

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## ANATOMY AND RELATIONSHIPS OF PARASEMIONOTID ACTINOPTERYGIANS FROM THE EARLY TRIASSIC OF GREENLAND BASED ON CT- AND SYNCHROTRON TOMOGRAPHY

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Parasemionotids are an assemblage of marine Early Triassic ray-finned fishes of uncertain monophyly that have long confounded palaeoichthyologists. Despite—or perhaps because of—being known from a multitude of articulated specimens, including acid-prepared and mouldic endoskeletal elements such as the braincase and palate, their phylogenetic relationships are unresolved. Affinities have been proposed with both halecomorphs (crown holosteans) due to e.g., a double jaw joint, as well as the neopterygian stem due to e.g., large clavicles and a broad preoperculum, with conflicting signals from aross the skeleton. Endocast anatomy does not provide clear evidence for a close affinity with either extant neopterygian lineage. Most parasemiontid taxa are typically excluded from formal phylogenetic analyses due to uncertainty over their monophyly and taxonomic status, but the Early Triassic *Watsonulus eugnathoides* is commonly used to calibrate the crown neopterygian node in timescaaled studies, highlighting the importance of accurately interpreting the affinities of parasemionotids. Here we use CT- and synchrotron-based computed tomography of three-dimensional, articulated parasemionotids from Greenland to reveal new anatomical details of the jaws, palate and gill skeleton. There is substantial anatomical variation in the braincase between these two specimens and with those described in the literature, for example in the robustness of the lateral commissure, the development of the vestibular fontanelle, and the condition of the dorsal aorta. We are able to reconstruct a complete gill basket for the first time. Elongate, hook-like anterior processes on the hypobranchials form almost a complete circle, and short epibranchial processes are present on the epibranchials. The first infrapharyngobranchial articulates on the ventral face of the braincase, as in early fossil teleosts and most generalised early actinopterygians, rather than with a notch on the parasphenoid, as occurs in *Amia* and *Lepisosteus* and had been inferred for parasemionotids. We also find elaborate, stalked, branching gill rakers spread across the dorsal and ventral elements of the branchial skeleton, with implications for the likely ecology of these taxa. Out new data reaffirm that thorough, ideally CT-aided redescription and detailed taxonomic revision of parasemionotids is needed in order to confidently resolve their status and position (or positions) in early neopterygian phylogeny.

## ARE NOVEL COMMUNITIES ALSO NOVEL ECOSYSTEMS? POLLEN-DERIVED PLANT FUNCTIONAL TRAITS LINK PALEOECOLOGICAL PATTERNS WITH ECOSYSTEM PROCESSES

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Novel plant communities emerge as a result of individualistic shifts in species' ranges and abundances in response to changing climates, biotic interactions, disturbance regimes, or human activity. Such assemblages pose a challenge to researchers and managers, in part because it is unclear to what extent novel associations will maintain ecosystem function relative to a baseline of interest. The very nature of such communities makes predictions difficult when relying on contemporary observations alone, but the well-documented no-analog plant associations from late Quaternary North American paleorecords provide a useful model system. These late-glacial novel communities were geographically widespread during the last deglaciation, and are thought to have been driven by a combination of more seasonal-than-present climates and the extinction of Pleistocene megaherbivores. To test whether these novel associations also exhibited novel ecosystem function, we reconstructed vegetation dissimilarity, climate dissimilarity, and community trait dissimilarity from present across the last 21,000 years, to test whether late-glacial no-analog plant associations exhibited altered function, calculated by community-weighted seed weight, maximum height, and specific leaf area derived from pollen assemblages. We found that even as community dissimilarity increased as no-analog communities emerged, functional dissimilarity remained low due to functional replacement. Our results suggest that the regional species pool has evolved for an optimal set of traits that may have emerged much earlier in the Cenozoic.

## HISTORY OF THE PALEOCENE–EOCENE TRANSITION IN THE BIGHORN BASIN OF WYOMING

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The Paleocene was first named by Wilhelm-Philipp Schimper in 1874 for an interval of geological time with a flora distinct from those of the preceding Cretaceous and succeeding Eocene.

Vertebrate and invertebrate paleontologists were skeptical, but in 1911 William Sinclair and Walter Granger discovered a new vertebrate fauna in Rough Gulch on the southwest side of McCullough Peaks in the Bighorn Basin. Their geological map of 1912 showed Wasatch strata overlying Laramie and Fort Union, with the latter designated 'Palaeocene.' Additional field work led Granger (1914) to distinguish a 'Clark Fork' fauna yielding the reptile *Champsosaurus* but lacking mammalian Artiodactyla, Perissodactyla, and Primates ('APP' taxa). Glenn Jepsen, a student of Sinclair, wrote his 1930 doctoral dissertation on Paleocene mammals of the northern Bighorn Basin—and then spent his entire career working on Paleocene faunas there. The Clark Fork fauna was the basis for a Clarkforkian land-mammal age codified in the Horace Wood et al. report of 1941. I spent the summer of 1967, my first as a summer field assistant, helping Jepsen test Roger Wood's claim, newly published, that "it is not possible … to differentiate a Clark Fork fauna from those of under- and overlying strata." The issue was definitively settled in 1980 by my first Ph.D. student, Kenneth Rose, who analyzed new University of Michigan collections to show that the Clarkforkian was worthy of recognition as a land-mammal age. Later, attempting to clarify the Paleocene-Eocene boundary, we found a new 'dwarfed' Wa-0 fauna near the base of the Wasatchian that included the oldest APP taxa. And we found a slightly older Wa-M fauna with the distinctive mammal *Meniscotherium* sandwiched between Clarkforkian and Wa-0 strata. Isotope stratigraphy by Paul Koch et al. (1992) showed that the Wa-0 interval fell within a light carbon isotope excursion (CIE) tied to a similar excursion in a South Atlantic marine core—thus the Paleocene-Eocene Thermal Maximum (PETM) greenhouse warming event was global. The PETM is the largest of a series of late Paleocene and early Eocene hyperthermals that enable wide correlation of marine and continental strata. Lithologically, the Bighorn Basin PETM starts and ends with prominent purple beds (Purple-0 through Purple-4). Faunally, the PETM includes distinct (1) latest Clarkforkian; (2) Wa-M; (3) Wa-0; and finally (4) a Wa-R recovery fauna—overlying typical Clarkforkian and underlying succeeding Wasatchian faunas. Florally, Scott Wing and colleagues have shown that the PETM has plants typical of Paleocene and Eocene floras found 1000 km farther south. The PETM interval was the time of appearance of many modern orders of mammals (APP etc.), and its onset marks the beginning of the Eocene epoch.

## INSECT-FEEDING TRACES FROM EOCENE PATAGONIA REVEAL UNRECOGNIZED EVOLUTIONARY HISTORY OF HERBIVOROUS INSECTS ON AUSTRALIA'S ICONIC *EUCALYPTUS*

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Plants and their insect herbivores represent the bulk of terrestrial (non-microbial) biodiversity, accounting for over 50% of all described species. Understanding how insect herbivore communities assemble on plant host lineages through evolutionary time is key to comprehend the source of this great biodiversity. However, direct fossil evidence of long-term associations originated in deep time and persisting to the modern day on the same host lineage is scarce. Here, we tested whether insect herbivore assemblages tracked the speciose genus *Eucalyptus* (Myrtaceae) for 52 Ma by comparing the insect herbivore damage on 284 fossil *Eucalyptus frenguelliana* leaves from the Laguna del Hunco fossil rainforest locality in Argentinean Patagonia with that of 36 extant, rainforest-associated *Eucalyptus* species. In the fossil material—which represents the oldest macrofossil evidence of the genus—we identified a diverse suite of 29 damage types, including twelve types of external feeding associations, two of piercing-and-sucking marks, five of galls, and ten of mines that, to the best of our knowledge, represent the highest richness of mines reported for a single plant host in the fossil record. Nearly identical suites of insect herbivore damage were observed in extant *Eucalyptus* herbarium specimens (>10,000 sheets reviewed), suggesting that the associated insect herbivore assemblages tracked and radiated on multiple species of their host genus through time and space. Our literature survey showed that although hundreds of insect herbivore species are associated with *Eucalyptus* hosts, most of the extant analogs for the herbivore damage seen in the fossils are made by still-unknown culprits, pointing to previously unrecognized biodiversity and evolutionary history of herbivorous insects on Australia's iconic *Eucalyptus*. The undescribed insect culprits can be sought at the surviving locations where the herbarium vouchers were collected.

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## PORE CHARACTERISTICS OF CALCAREOUS BENTHIC FORAMINIFERA AS QUANTITATIVE PROXY FOR PAST NITRATE AND OXYGEN CONCENTRATIONS

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Recently, different characteristics of pores in shells of benthic foraminifera (i.e., total porosity, pore density and pore size) received more attention as possible paleo proxies for past redox conditions. The total porosity (percentage of surface area covered with pores) and pore density (number of pores/surface area) of several calcareous benthic foraminifera species increase significantly with decreasing availability of electron acceptors. Most likely, the pores are critical for the uptake of electron acceptors and foraminifera, therefore, increase their porosity to optimize the uptake when electron acceptors are depleted. Several species of foraminifera from $O_2$-depleted environments are able to respire nitrate via denitrification. The pore density of denitrifying foraminifera can thus be used as a quantitative nitrate proxy. Nevertheless, not all species of foraminifera are able to denitrify. Consequently, the porosity and pore density of non-denitrifying epifaunal species can be valuable quantitative $O_2$ proxies. Here, we will present examples of deglacial nitrate and $O_2$ paleo-reconstructions from different $O_2$-depleted locations around the Pacific. These reconstructions are based on pore density records of the denitrifying species *Bolivina spissa* and *Bolivina subadvena* and the non-denitrifying epifaunal species *Planulina limbata*. Automated image analysis based on deep learning has been used to efficiently generate large datasets that include the total porosity, pore density and average size of the pores. A deglacial $O_2$ reconstruction at the Peruvian oxygen minimum zone (OMZ) reveals that the Peruvian OMZ was similar in extent but a bit weaker than today. The deglacial nitrate records from intermediate waters around the Pacific show a strong regional variability. For example, intermediate-depth nitrate concentrations at the Peruvian OMZ and the Gulf of California are lower today compared to the Last Glacial Maximum (LGM), possibly due to increased denitrification due to positive feedbacks for ocean deoxygenation in these regions via the recycling of phosphate and iron in $O_2$-depleted sediments. In contrast, bottom water nitrate in intermediate waters of the Mexican Margin is elevated today in comparison to the LGM, which is possibly related to a shift in the depth of the OMZ. Finally, a case study at the seasonally hypoxic Bedford Basin identified a facultative denitrifying species, *Stainforthia fusiformis*, which adapts its pore density to $O_2$ rather than nitrate availability. Preliminary results of this study also indicate that *S. fusiformis* possibly determines the pore density to the bottom water conditions during the time of chamber formation. Subsequently, this species might still be able to adapt the size of its pores "dynamically" after chamber formation, depending on the microenvironment it experiences within the pore water.

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## TEMPORAL DYNAMICS OF DEVONIAN REEF COMMUNITIES: INSIGHTS FROM A 3.9 MILLION-YEAR STUDY IN WESTERN AUSTRALIA

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The decline in living coral cover is occurring as a result of both global climate change and local human impacts. The ongoing transformation of coral reefs necessitates proactive intervention, demanding a profound comprehension of the mechanisms regulating community assembly and maintaining biodiversity in these ecosystems. This study aims to assess the community persistence of Devonian reef communities over 75 sea-level fluctuation cycles spanning approximately 3.9 million years. Abundance data were gathered for in-situ coral and calcareous sponge taxa along 164 transects across two field localities within the Canning Basin, Western Australia. The Bray-Curtis dissimilarity index was employed to measure the dissimilarity in taxonomic composition among transects. Reef communities exhibited remarkable persistence for around 1 million years before undergoing a shift in community structure. Three distinct community types were identified, each differing in the diversity and composition of coral assemblages. We found that reef communities maintain remarkable persistence over time scales of thousands to hundreds of thousands of years. However, over extended time scales spanning millions of years, reef communities exhibit increased variability, likely reflecting significant changes in Earth-surface systems during the Devonian, such as fluctuations in global sea-surface temperatures and sea-level. By establishing baseline community composition dynamics in systems unaffected by human influence, this study deepens our understanding of naturally occurring phase shifts. Recognizing the factors contributing to the past persistence of community assembly across multiple scales provides important information for the conservation of coral reef ecosystems amid ongoing environmental changes.

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## A NEW EOCENE PROTOCETID WHALE MATERIAL FROM EGYPT SHEDS NEW LIGHT ON THE EARLY DISPERSAL OF CETACEANS

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Protocetids are semiaquatic whales predominant in the middle Eocene of Africa, Asia, North America, and South America, serving as a key point in understanding the evolutionary transition of cetaceans from terrestrial to fully aquatic habitats. The Fayum Depression in Egypt holds great significance for protocetids, producing some of the most basal protocetids (e.g., *Phiomicetus*) from the Lutetian of Wadi El-Rayan, as well as the latest-surviving protocetids (e.g., *Aegicetus*) from the Priabonian of Wadi El-Hitan. Here, we present a newly discovered protocetid specimen (MWH-113-1) from the Lutetian of the Midawara Formation in the Wadi El-Rayan area of the Fayum Depression, Egypt. MWH-113-1 comprises nearly complete mandibles, exhibiting morphological traits consistent with other protocetids and, notably, sharing similarities with the North American protocetid *Georgiacetus*, including a mandibular symphysis terminating at the level of the diastema between $P_2$ and $P_3$, a straight ventral margin of the mandible lacking any indentation or notch beneath the molars, molars with well-developed and thick labial and lingual cingula, and lower cheek teeth bearing small, blunt accessory cusps (homologous with the larger accessory cusps of later basilosaurids). The anterior teeth ($I_1$–$P_1$) are single-rooted and single-cusped, contrasting with the double-rooted and double-cusped posterior teeth ($P_2$–$M_3$). The anterior teeth exhibit long diastemata, whereas a very short diastema is observed between $P_3$ and $P_4$, with $P_4$–$M_3$ forming a closed series. Comparison with other protocetids suggests that MWH-113-1 represents a medium-sized protocetid, similar in size to *Georgiacetus*, larger than *Maiacetus* and *Phiomicetus* but smaller than *Pappocetus*. These anatomies, aligning the new specimen closely with *Georgiacetus*, suggest multiple colonization events during early cetacean dispersal to the New World. The discovery of MWH-113-1 provides valuable insights into the evolutionary history and paleobiogeography of protocetids, offering a better understanding of the early stages of cetacean dispersal and evolution during the middle Eocene.

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## CARBONATE CLUMPED ISOTOPE ($\Delta_{47}$) TEMPERATURE RECONSTRUCTIONS FROM THE PLIO-PLEISTOCENE FLORIDA PLATFORM: ASSESSING MARINE CLIMATE CHANGE AS A POTENTIAL EXTINCTION DRIVER

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The densely fossiliferous shell beds of southern Florida have played a critical role in characterizing the precise magnitude and pacing of a Plio-Pleistocene faunal turnover event observed more broadly across the western Atlantic. Although cooling water temperatures have long been invoked as a potential driver of this turnover event, the marine temperature history of the Plio-Pleistocene Florida Platform remains poorly quantified. In particular, prior paleotemperature and seasonality estimates based on $d^{18}O_{carb}$-thermometry yield ambiguous results due to poor constraints on $d^{18}O_{water}$ values in this unique platform environment. In this project, we apply high-resolution $\Delta_{47}$-sclerochronology to fossil bivalves to produce the first quantitative estimates of (i) mean water temperatures, (ii) seasonal extreme temperatures, and (iii) mean $d^{18}O_{water}$ values in each of the major Plio-Pleistocene formational units of southern Florida. Here, we present $\Delta_{47}$-derived temperature and $d^{18}O_{water}$ reconstructions from the Pinecrest Beds of the Tamiami Fm. (Late Pliocene), the Caloosahatchee Fm. (Early Pleistocene), the Bermont Fm. (Middle Pleistocene), and the Fort Thompson Fm. (Late Pleistocene), documenting changes in temperature seasonality across the extinction interval. Our formation-level temperature and seasonality estimates are used to evaluate hypotheses of marine climate change as an extinction driver. Reconstructed $d^{18}O_{water}$ profiles indicate subannual-scale and formation-to-formation variability in past $d^{18}O_{water}$ compositions, demonstrating the utility of $\Delta_{47}$-thermometry in this unique geologic setting to unambiguously constrain past water temperatures. Additionally, reconstructed $d^{18}O_{water}$ compositions enable a re-evaluation of prior $d^{18}O_{carb}$-based temperature estimates from the Plio-Pleistocene Florida Platform, strengthening the community-wide effort to quantify marine climate seasonality within these remarkable fossil beds.

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## RECONSTRUCTING SPATIAL VARIATION IN SHARK COMMUNITIES ACROSS THE ISTHMUS OF PANAMÁ USING FOSSIL DERMAL DENTICLES

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Sharks are important keystone species in marine ecosystems. As apex and meso predators, they are fundamental to maintaining equilibrium and ensuring the sustainability of oceanic food webs. Panamá is home to significant shark biodiversity, yet little information exists about their ecology and local conservation status. Our understanding of shark

communities and abundance in the region is preceded by industrial fishing, so population trends without anthropogenic influence are unknown. Consequently, a longer-term perspective is needed to reconstruct variation in shark populations, understand the severity of human activities on shark diversity, and better focus conservation efforts. Here, we use fossil shark scale (dermal denticle) accumulations in coral reef sediments to survey spatial variation in sub-recent shark communities along the Pacific (Gulfs of Panamá and Chiriquí) and Caribbean (Bocas del Toro) coasts of Panamá, which are characterized by different oceanographic conditions and levels of human impact. Using a purpose-built reference collection, we classify denticles into functional morphotypes and measure ecologically-relevant traits to 1) catalog the morphological diversity of denticles at each site and 2) measure the relative abundances of different denticle morphologies. We then contrast these denticle assemblage data with available ecological and fisheries records of modern shark communities in each region to pinpoint relevant changes. We outline the taxonomic, paleoecological, and life-history information that can be inferred from fossil denticle assemblages and discuss the implications for targeted shark conservation efforts. This project highlights historical variation of shark populations across the Isthmus of Panamá and can become a powerful tool to identify overlooked vulnerable regions.

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## INVESTIGATING THE EFFECT OF HISTORICAL COLLECTION BIASES ON PALEOENVIRONMENTAL INTERPRETATIONS IN EAST TURKANA, KENYA

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To better understand the evolutionary pressures driving hominin evolution, it is imperative to contextualize the environments they inhabited. Yet, collecting efforts have historically been biased towards certain taxa which may skew faunal-based reconstructions of local paleoenvironments. Area 123 in the Bura Hasuma region of the Koobi Fora Formation in northern Kenya provides an ideal case study for understanding the influence of collection biases on paleoenvironmental reconstructions. It has yielded numerous significant hominin fossils, including the well-preserved cranium of *Homo habilis* (KNM-ER 1813), and a diverse mammalian community. We combined historic fossil collections in the Turkana Public Database with additional faunal surveys from recent field seasons to assess the structure of the mammal community. We compared our recent collections to historical collections, and found a high abundance of Cercopithecidae in the historical collections (31%), in comparison to 5% of the modern assemblage. The community composition, in terms of the relative abundance of mammalian families, differed significantly between modern and historic collections. Some taxa, like bovids, occur at similar frequencies, while rare groups, like felids, may be more abundant in the historical sample due to its larger sample size. The higher relative abundance of suids and cercopithecids in the historic sample is most likely the result of collecting efforts that favored the collection of these taxa for biochronological utility. Thus it seems the relative abundance of mammal families in the Turkana Public Database reflects significant sampling biases associated with historic collection interests. Therefore it is important to consider such biases when interpreting paleoenvironmental conditions.

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## ECHO OF THE ANCIENTS: EVOLUTION OF SONG IN THE AVIAN FAMILY CETTIIDAE

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The vocalizations produced by now extinct vertebrates have been a topic of debate for many years. While it is true that we can never know with absolute certainty as to what now extinct species may have sounded like, advancements in the study of acoustics can provide tantalizing clues. For just as the mutations of genes lead to the gradual evolution of organisms, vocalizations too progress from an ancestor to its offspring, changed, but retaining the bulk of its ancestral sound. Thus, just as phylogenetics can help piece together the ancestry of modern species, the study of vocalizations, and how they change, can provide further clues as to the evolutionary history of many organisms. For this project we focused on the Cettiidae in particular. A family of primarily small, insectivorous, Asiatic and Austronesian, mountain birds, which have been the subject of acoustic analysis in the past. However, these

past analyses were small in scope, and until this point an in-depth review of the songs of the entire family had yet to be undertaken. During this study, the songs of all 29 Cettiidae species were examined through the usage of acoustic analysis software, with specific factors such as bandwidth, frequency, and strophe duration being statistically recorded. In total 286 individuals and over 800 strophes were analyzed, with the collected data being displayed in various PCA plots. These PCA graphs were then compared to both a dated phylogenetic tree specifically created for this study, and a Mahalanobis distance vs. genetic distance plot, created using the acoustic data as well as Cytochrome b genetic data. Based on these plots, several notable trends could be observed. In many instances, large scale conservation of song characteristics occurred within closely related clades. However, some clades which experienced little genetic diversity experienced rapid and extreme divergence within their vocalizations. Overall, evidence of convergence of vocal traits was scant within this study, with each clade producing statistically distinct vocalizations. Strong statistical divergence between island and continental species was also noted, conferring with previous research which found island species affected by a completely sperate set of selection pressures when compared to those on the continent. Lastly, a visual analysis of every species song, mapped on the dated phylogenetic tree, suggested that two distinct linages of simple and complex songs could be traced back approximately 10 million years. This allows for speculation as to the songs of now long extinct Cettiidae species as far back as the Miocene.

## SEMILANDMARK AND LANDMARK FREE ANALYSIS OF SYNAPSID SKULL EVOLUTION

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It is well appreciated that the shapes of distantly related taxa are difficult to compare meaningfully using geometric morphometric approaches due to the problem of identifying unambiguously homologous landmarks in disparate morphologies. As a result, analyses spanning classes or infraclasses of vertebrates necessarily reduce landmarks to a handful of points that capture a minority of the variation present in organismal anatomy. Numerous landmark-free approaches exist, but these are often excessively computationally demanding and, to date, have primarily been applied within closely related taxa, particularly in intraspecific comparisons. Our recent work has applied dense sliding semilandmark analysis extensively to diverse vertebrate clades, but this approach is highly manual and struggles with increasing disparity of morphologies. More recently, we have demonstrated deterministic atlas analysis to be a powerful approach that captures similar variation as high-density semilandmarks. Here we present comprehensive 3D analyses of skull shape spanning living and extinct synapsids, comprising 322 placentals, 83 marsupials, 4 monotremes, and 13 non-mammalian synapsids and stem mammalians, and spanning nearly 300 million years of evolutionary history. Using a combination of surface and micro-CT scans, we applied both sliding semilandmark and landmark-free approaches to demonstrate their strengths and weaknesses and suggest a path forward for homology-informed landmark free analysis. Our sliding semilandmark analysis applied a common set of 66 landmarks and 69 semilandmark curves, for a total of 754 landmarks and semilandmarks. For our landmark-free approach, we tested different kernel values that produced a range of 50 to 2000 control points. Extracting the phylogenetic and kernel PCs, respectively, that capture the full variation of the dataset, in combination with recently published phylogenetic frameworks, we fit a range of evolutionary models to this dataset to identify clade-specific patterns, including testing for differences in rates of evolution based on traits including diet, locomotion, and geography, all of which influence evolutionary rate. We further applied a newly described climatic OU model, where evolutionary rate tracks an extrinsic factor, specifically temperature in this study. Our results demonstrate that this model is well supported in some groups, but that interaction with climate is strongly dependent on diet and habitat with, for example open habitat species more closely tracking shifts in global temperature. In sum, landmark free approaches are orders of magnitude faster to apply than manual landmarking and produce comparable results in macroevolutionary analysis, thereby greatly increasing the potential scale of high-resolution multivariate studies of morphology.

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## AN UPDATED LOOK AT 'LOWER' ACTINOPTERYGIAN AND COELACANTH RECORDS FROM THE LATE CRETACEOUS OF MADAGASCAR

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Ongoing research on the highly diverse Late Cretaceous vertebrate record from the Mahajanga Basin of Madagascar continues to refine our understanding of late Mesozoic Gondwanan faunal dynamics. We report here on the records to date of two 'lower' actinopterygian groups –polypterids and amiids – and, within sarcopterygians, mawsoniid coelacanths. The polypterid material is from the Maevarano Formation (Maastrichtian) and includes an opercle, centra, and 18 very small ganoid scales, all ca. 1 cm or less in length. The amiid material consists of four vertebral centra from the Ankazomihaboka beds (Santonian/Coniacian) – these are morphologically distinctive, with an excavated concavity along the ventrolateral margin of the laterally extended centra. This closely matches what has been considered to be a diagnostic feature of the amiid genus Melvius from the Late Cretaceous of the western USA. The largest of these centra measures 3.8 cm at its greatest lateral extent. The coelacanth material, all from the Ankazomihaboka, includes a distinctive leaf-shaped median extrascapular element (1.5 cm in length) that permits assignment to the Cretaceous mawsoniid genus Axelrodichthys, otherwise known from sites in northern Africa and Brazil. The Ankazomihaboka material also includes ca. two dozen pieces of dermal bone with a distinctive ornament of subparallel elongate pits, linear grooves, and thin ridges of bone, very similar to the ornament seen on Axelrodichthys as well as on Mawsonia from the same family. Taken together, these records comprise the first record, fossil or extant, of polypterids and amiids on Madagascar, and the geologically youngest fossil record of coelacanths from the island (living coelacanths have been caught along the west coast of Madagascar). The records suggest an African signal in these components of the Malagasy Late Cretaceous fish fauna, given that all three groups are represented in the Cretaceous of northern Africa. The most surprising of these occurrences relates to the fossil amiid centra that look essentially identical to the western North American Late Cretaceous genus Melvius – convergence or an unexpected Late Cretaceous biotic connection?

## REMARKABLE NEW TAXON EXEMPLIFIES EARLY ARM MORPHOLOGY AND PROVIDES ADDITIONAL INSIGHT INTO THE ORIGIN OF CRINOIDS

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Early Ordovician (Tremadocian-Floian) strata of the western United States have yielded many new crinoids after decades of recent field work. These specimens demonstrate a significant, previously unknown, initial radiation of the Crinoidea and much unexpected morphology. The slow pace of studying the new taxa has been the result, in part, of difficult, time-consuming preparation. Here, we report an unusual new crinoid from the late Floian Wah Wah Formation, Utah. The shallow, monocyclic cup is sharply demarcated from the tegmen. Five atomous arms extend perpendicularly to the cup axis, generating a strongly pentameral crown. Interradial plate fields separate ambulacra and brachials. These plate fields extend continuously from the tegmen to nearly the arm tips. Brachials make up a relatively small portion of arm height. Ambulacra have laterally exposed pore-bearing biserial floor plates and hinged primary cover plates extending directly from the peristome. An isolated arm of an apparently similar taxon from the mid Floian Garden City Formation, Idaho, showing the proximal interradial plate field, makes up about 70% of arm height; ambulacra comprise another 25%, and only 5% is formed of brachials. This new crinoid exhibits ancestral and derived morphology. The cup resembles a disparid or simplified monobathrid camerate typical of the later Paleozoic. In contrast, the arms closely parallel those of protocrinoids and basal camerates, cladids, and disparids. Closest resemblance is with the stem cladid Apektocrinus. Collectively, this morphology is unlike that of any blastozoan but most similar to that of edrioasterids (traditionally placed within the Edrioasteroidea), a taxon whose origin extends back to the Early Cambrian. Character analysis suggests these similarities are synapomorphies, consistent with the hypothesis that crinoids share nearer common ancestry with edrioasterids than blastozoans. No basic difference exists between the ambulacral systems of edrioasterids and the earliest crinoids. Unlike edrioasterids, somatocoel-bearing arms, a key crinoid apomorphy, extend ambulacra outward from the primary thecal cavity. The new crinoid reported above represents a plesiomorphic morphology predating the more derived condition in which arm support is provided by brachials alone.

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## TAPHONOMY OF NAUTILOID CEPHALOPODS FROM THE MIDDLE SILURIAN MASSIE FORMATION OF SOUTHEASTERN INDIANA

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Nautiloid cephalopods are a moderately abundant but under-studied faunal component of the middle Silurian (Wenlock: Sheinwoodian) Massie Formation of southeastern Indiana. The mudstone lithofacies of the Massie Formation as exposed at the New Point quarry near Napoleon, northern Ripley County, has yielded a large collection of specimens, a

sample of which (N = 300) was studied to assess taphonomic patterns. The cephalopod fauna is of low diversity, consisting of *Dawsonoceras annulatum* (70%), indeterminate orthoconic forms (22%), and *Michelinoceras* (8%). Specimens consist of incomplete phragmocones infilled with well-lithified gray biomicrite; 70.7% of specimens contain at least some original shell material, with the remaining 29.3% of the collection preserved as internal molds. 68.3% of specimens display one hemisphere characterized by heavily degraded, missing, or "planed off" shell material (traditionally interpreted as the upward-facing side that was subjected to weathering prior to burial), with most of the others impossible to assess due to embedment in matrix. Semi-quantitative indices were developed to describe the relative extents of encrustation (EI), bioerosion (BI), and corrasion (CI), with 0 indicating a pristine surface and 3 indicating a severely encrusted/bioeroded/corraded surface. In total, 55% of all specimens (63.6% of non-moldic specimens) are encrusted to some extent, with microconchid tentaculitoid mollusks (26.7%) and trepostome bryozoans (39.3%) representing the most common encrusters. However, encrustation was relatively light, with a mean EI of 0.45 for the entire collection and mean EI of 0.82 for encrusted specimens. Bioerosion structures consist exclusively of the ichnogenus *Ropalonaria* and occur in 27% of specimens (36.4% of non-moldic specimens). As with encrustation, bioerosion was not intense, with a mean BI value of 0.19 for all specimens and 0.26 for non-moldic specimens. Corrasion values displayed a mean value of 2.22 for all specimens and a mean value of 1.91 for non-moldic specimens. Collectively, these data suggest a paleoenvironmental setting characterized by a slow background sedimentation rate, in which cephalopod shells or upper portions of partially buried shells were exposed on the seafloor for a limited amount of time following death and prior to final burial.

## CRANIAL VARIATION AMONG CARIBBEAN PRIMATES

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Extant South American primates are a diverse group with deep evolutionary roots. When they arrived on the continent almost 40 million years ago from Africa, their rapid adaptive radiation produced a multitude of forms that make both phylogenetic and functional interpretations complicated. Many of the fossil taxa exhibit combinations of traits not seen in the extant animals. Nowhere is this more true than on the islands of the Greater Antilles, which were inhabited by endemic primates for at least 15 million years. Four genera have been named so far based on craniodental and postcranial remains: *Paralouatta* from Cuba, *Xenothrix* from Jamaica, and *Antillothrix* and *Insulacebus* from Hispaniola. While ancient DNA studies have linked *Xenothrix* to extant *Callicebus* (sensu lato), questions remain about whether the Caribbean taxa represent a monophyletic radiation, the number and timing of island colonization events, and to which mainland species they are most closely related. Here, three-dimensional geometric morphometric techniques are used to quantify cranial morphology of the fossils and compare them to extant taxa. The *Xenothrix* cranial remains are the most fragmentary of those that exist (*Insulacebus* is so far represented only by teeth and potentially some postcrania), but the palate and lower face are still informative. While the rounded toothrow and lack of a diastema between the lateral incisor and canine are features shared with extant titi monkeys, the lack of inferiorly extended zygomatic bones and a narrowed palate cause the fossil not to overlap with *Callicebus* (sensu lato) in shape space. The 2.1.3.2 dental formula (shared with some of the more recently discovered specimens of *Antillothrix*) could also affect the shape of the *Xenothrix* palate and, therefore, the interpretation of morphological characters used in previous phylogenetic analyses. *Paralouatta* and *Antillothrix* have small endocranial volumes relative to their overall cranial size, which may have important implications for interpreting their cranial morphology. When the endocranial volumes of specimens of the extant genera are artificially reduced, their cranial shape changes in ways that make them look similar to *Alouatta*. This suggests that some of the similarities in cranial shape between *Paralouatta* and howler monkeys, like the steeply angled occipital, are due to shared small brain size rather than a phylogenetic linkage. *Antillothrix* is now represented by seven nearly complete crania. This relatively large sample allows for an investigation of intraspecific morphological variation, a rare situation in paleontology. The craniodental variation that exists within *Antillothrix* is at a relatively low level suggestive of a sexually monomorphic taxon with small canines—as in extant titi monkeys.

## REVISED BIOSTRATIGRAPHIC CONSIDERATIONS OF THE EARLY MIOCENE LOCALITY MFANGANO ISLAND, KENYA: IMPLICATIONS FOR MIOCENE CATARRHINE EVOLUTION AND FAUNAL TURNOVER

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Early Miocene deposits on Mfangano Island, Kenya, have produced more than 1600 fossils important for understanding early Neogene mammalian evolution in Africa. These specimens derive from deposits as old as ~19.81 Ma, which falls within a period of rapid faunal turnover in eastern Africa. However, exact provenance data for many specimens in the historic collections are lacking, making it difficult to place fossils in relative stratigraphic position. Historic and recent fossil assemblages were re-analyzed and compared to other contemporaneous eastern African assemblages to better situate the Mfangano communities within the broader context of Early Miocene mammal evolution. Historically, the Mfangano fauna as a whole was thought to be either intermediate between the younger Hiwegi and the older Tinderet biostratigraphic reference faunas or essentially indistinguishable from the younger Hiwegi reference fauna. Our results support the former conclusion. Basic species-level presence/absence data suggest that Mfangano's entire faunal assemblage is most like the Hiwegi fauna. However, the Mfangano fauna differs from Hiwegi assemblages, but is strikingly similar to older Tinderet assemblages, in the proportions of identifiable rodent specimens (specifically *Diamantomys*/*Paraphiomys* ratio). Furthermore, the Mfangano mammalian assemblage lacks the pecoran taxa *Canthumeryx* and *Propalaeoryx*, but includes the ochotonid *Kenyalagomys* and suid *Kenyasus*, four genera that are characteristic of the younger Hiwegi fauna. When the analysis is restricted to only Mfangano specimens with exact provenance, all found in the Makira Beds, our results support the hypothesis that the Mfangano fauna as a whole is derived from at least two distinct temporal units. The fauna found in the lowest stratigraphic sections of the Makira Beds is most similar to the older Tinderet fauna and lacks all taxa specifically characteristic of the younger Hiwegi fauna. Interestingly, the only hominoid fossil recorded from this unit is morphologically more similar to the Tinderet ape *Proconsul* than it is to *Ekembo*, known from the younger Hiwegi fauna from Rusinga Island. The younger Mfangano fauna occupies an intermediate position between the Tinderet and Hiwegi reference faunas. Specifically, the presence of *Ekembo*, *Kenyalagomys*, and *Kenyasus* plus the absence of large pecoran taxa supports the intermediate biostratigraphic position of this younger assemblage. Overall, our results corroborate the hypothesis that Mfangano fossils represent an interval of time between Tinderet and Hiwegi biostratigraphic reference faunas, recording evidence of a period of rapid faunal turnover. Further, this study demonstrates the importance of continued fossil collection, accompanied by detailed provenance data, to inform our understanding of this faunal turnover event in the Early Miocene of eastern Africa.

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## THE FOSSILIZED ECHINODERMS IN NORTHERN ALGERIA

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Initially, our intention was to conduct a comprehensive revision of all fossilized echinoderms in North Africa. However, a purely morphological study would offer only secondary insights into the descriptions of some rare types of echinoderms. In an effort to unveil the richness of fossilized echinoderms present in our region, we embarked on a project that, admittedly, is subject to certain imperfections given the current state of our knowledge of North African geology. Echinoderms first appear in the Paleozoic, specifically at the end of the Ordovician period, but their diversity remains limited. However, in the Silurian period, an adaptive radiation coincides with a significant increase in diversity, including the development of irregular forms. In Mesozoic formations, echinoderms become more abundant and serve as valuable stratigraphic markers (e.g., *Clypeus* and *Micraster* genera). There exists a discernible relationship between the shape of echinoderms and their respective environmental habitats. In this study, we will explore the distinctions that set African echinoderms apart from those found on other continents and attempt to catalog the rarest varieties.

## PHOTOSYNTHESIS IN A PROTEROZOIC OCEAN ANALOG

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The ability to harvest light and fuel cellular processes through phototrophy is arguably the most important biological innovation to date. Phototrophs are prevalent on Earth today on land and in the world's oceans. However, long before plants and algae, microbial phototrophs evolved simple forms of phototrophy that eventually gave rise to oxygenic photosynthesis. In oxygenic photosynthesis, two reaction centers work in concert to split water, producing oxygen as a by-product. Despite the prevalence of phototrophs on Earth today and the key role this metabolism played in the evolution of complex life, there are many outstanding questions about the first forms of phototrophy and the emergence of oxygenic photosynthesis billions of years ago. Here I will discuss an emerging model cyanobacterium—*Leptolyngbya* sp. strain *hensonii*—that performs anoxygenic photosynthesis. Using strain hensonii as a model, we are evaluating the likelihood of the proposed evolutionary scenarios for photosynthesis: the physiology of a one-reaction center Cyanobacteria that performs anoxygenic photosynthesis via selfie oxidation. We aim to define the molecular basis for anoxygenic photosynthesis in Cyanobacteria as well as the cost and efficiency of anoxygenic photosynthesis (or one-reaction center photosynthesis). From

these data, we aim to evaluate the potential success of this physiology under Precambrian conditions.

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## DIETARY ECOMORPHOLOGY OF DIRE WOLVES FROM THE MCKITTRICK ASPHALT SEEPS, SOUTHERN CALIFORNIA, U.S.A.

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Dire wolves (*Aenocyon* [formerly *Canis*] *dirus*) were apex predators of the Pleistocene epoch but went extinct ca. 11,700 years ago. The causes and consequences of their extinction are well studied at the Rancho La Brea (RLB) asphalt seeps in Los Angeles, California, U.S.A., but remain to be evaluated at other late Pleistocene sites with differing ecological and environmental contexts. Here, we analyze the dietary ecomorphology of dire wolves from the Pleistocene-age McKittrick asphalt seeps on the southern end of the Central Valley of California, 200 km northwest of RLB. While we expected all dire wolves to display traits for specialized feeding behavior like bone-cracking, we hypothesized that differences in faunal composition and/or environment between McKittrick and RLB would produce differences in dire wolf diet across the two sites. For instance, RLB dire wolves—having more prey options near the coast, including marine resources—might have traits maximizing dietary variability, like retaining tooth areas for both slicing meat and crushing bone, as opposed to McKittrick inland. We examined McKittrick dire wolves (89 specimens of lower jaws and teeth) at the University of California Museum of Paleontology, Berkeley, comparing them with RLB dire wolf lower jaws ($n$ = 45) at the La Brea Tar Pits & Museum, Los Angeles. Using calipers, we collected 15 measurements of the jaws and teeth, combining six of them into three indices of dietary function: relative blade length (carnivory or slicing ability), relative lower molar grinding area (cracking or crushing ability), and relative jaw depth (jaw robustness). Our raw measurements did not differ between the two RLB deposits sampled (Pits 3/4 and 13); therefore, we combined all RLB dire wolves and compared them as one category to McKittrick. Using Wilcoxon rank-sum tests, we found that dire wolves were generally larger at McKittrick than at RLB: McKittrick dire wolves had longer (but not wider) lower fourth premolars and second molars, longer and wider carnassials, and dorsoventrally deeper jaws. However, functional indices differ little between McKittrick and RLB: controlling for size, the ability of McKittrick dire wolves to slice meat or crack bone was on par with RLB dire wolves. Regardless, the larger absolute size of McKittrick dire wolf jaws and teeth suggests that they could specialize on larger prey than at RLB—although common prey at McKittrick (*e.g.*, horse, llama) tended to be smaller than at RLB (*e.g.*, bison, camel). Alternatively, larger dire wolf size at McKittrick may relate to local climate factors; while previous work has reconstructed greater aridity at McKittrick than today, temperature proxies currently in progress should aid in testing this hypothesis in the future. Furthermore, as the McKittrick specimens measured here were quite fragmentary, our work continues to supplement the current sample with additional specimens to improve understanding of predator diet.

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## QUANTIFYING PRESERVATION OF MODERN RODENT SPECIES IN THE FOSSIL RECORDS OF COLORADO AND ECUADOR

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Topographically complex regions contain a high proportion of terrestrial vertebrates, despite occupying less than one quarter of the planet's land surface. Modern biodiversity is readily observed in the context of gradients in climate or vegetation cover, but investigations of prehistoric biogeography are inherently limited by the incomplete nature of the fossil record. Processes of sedimentation and preservation are not uniform across all environments and elevations. Most fossils are recovered from low-elevation sedimentary basins, potentially obscuring a considerable portion of species that once inhabited a given region. We documented the intersection of rodent geographic ranges with active depositional environments throughout highland and lowland regions of Colorado and Ecuador. We selected these areas due to their similarities in geographic area and topographic expression of tall mountain ranges. Colorado is continental, with an elevational gradient from 1000 m in the Eastern Plains to 4400 m in the Rocky Mountains (uplifted 80–55 Ma). Ecuador is coastal, with a relief of 6300 m between the coast and the Andes Mountains (uplifted 10–6 Ma). Rodents are sensitive to changes in climate and vegetation, making them useful in environmental studies in both the modern and fossil records. Approximately 56 rodent species are native to Colorado; 92 are native to Ecuador. Approximately 25% of Colorado's surface area is covered by unconsolidated sediments, the majority of which are alluvial and eolian in origin. Up to 60% of Colorado rodent species have geographic ranges that overlap with unconsolidated sediments at elevations below

1600 m. Numerous montane species, including nearly 56% of sciurids and 26% of cricetids, are poorly represented within this intersection, suggesting that their preservation in the fossil record would be rare. In contrast, only 10% of Ecuador is covered by unconsolidated sediments, with estuarine deposits dominating the western coastal plains and fluvial systems in the eastern lowland rainforest. 70% of Ecuador rodent species have geographic ranges that overlap with unconsolidated sediments, most of which occur at elevations less than 500 m. Nearly half of Ecuador's cricetids are poorly represented within this range. Montane species represent nearly a third of native rodents in both regions, but are significantly less likely to be preserved in the fossil record due to taphonomic and erosive properties associated with high-elevation sedimentary deposits. Our findings have implications for interpretations of past biogeographic patterns and diversity gradients. By quantifying differences in mountain-proximal and mountain-distal diversity, composition, and preservation patterns, we contribute to a greater understanding of the fossil record of small mammals in regions with complex topography.

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## VERTEBRATE TEETH AROSE AS SENSORY ORGANS

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The origin of vertebrate teeth has been an enigmatic problem in paleontology. While antecedents of teeth, known as odontodes, are first seen in the dermal exoskeleton of jawless vertebrates, an understanding of their function remains obscure. Multiple untested hypotheses on the original function of odontodes exist, from providing predator protection or being a structural support to sensory capability. However, to date there has been no fossil or developmental evidence to support any hypothesis. To test the timing, structure, and function of odontode origin we synchrotron scanned the earliest mineralizing vertebrates and diverse cuticles of fossil and living invertebrates. We show that the putative oldest vertebrate odontodes from the Late Cambrian, *Anatolepis*, are sensory sensilla belonging to an aglaspidid invertebrate. Middle Ordovician fossils now represent the oldest known vertebrate mineralized materials. These definitive Ordovician vertebrates such as *Eriptychius*, exhibit remarkably large dentin tubules convergent to invertebrate sensory structures suggestive of sensory function similar to that documented in teeth. Developmental study of diverse extant fishes reveals extensive pulp cavity sensory innervation of modern external odontodes. Together these data support the hypothesis that odontodes arose as sensory structures in the exoskeleton of earliest jawless vertebrates by the middle Ordovician.

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## REDEFINING AND CONTEXTUALZING PALEOZOIC ECHINODERM DIVERSITY DYNAMICS

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Within the Paleozoic, the Ordovician Period holds some of the greatest shifts in biodiversity, encompassing both a major radiation event and a mass extinction, as well as global changes in ecology with the explosion of niche differentiation across environments. The Great Ordovician Biodiversification Event (GOBE), occurring in the Middle Ordovician, was a large radiation of lower-level taxonomic groups (i.e., families, genera, and species), occurring across various phyla with differences in the timing and magnitude of diversification across these groups. The Late Ordovician Mass Extinction (LOME) was two-pulsed: first, a major glaciation in the Southern Hemisphere lowered sea levels globally, followed by a subsequent warming. These events led to the second most disastrous extinction in Earth's history, leading to the extinction of ~85% of marine genera. An active area of paleobiological research is determining what abiotic and biotic factors drove changes in biodiversity across large geologic events. Fossil echinoderms are an excellent model system to test hypotheses of biodiversity change, as they are globally distributed, temporally expansive, and the group is responsive to climate changes. However, our current understanding of Paleozoic echinoderm biodiversity patterns is not well constrained, as many studies focused on crinoids because they are highly speciose and their occurrences are well documented. Crinoids alone cannot capture the entire clade's biodiversification patterns throughout the Paleozoic. To expand our understanding of echinoderm evolutionary dynamics, we investigated the biodiversity patterns of all major clades of Echinodermata, represented by 367 genera with a global distribution. We collected the temporal ranges and geographic occurrences for genera from both the primary literature and online fossil databases, such as the Paleobiology Database, and we calculated rates of genus diversity, origination, and extinction at a resolution of 1 Ma. Our

Paleozoic biodiversification patterns do not follow previously published analyses on echinoderms. Biodiversity trends uncovered in this study join a growing body of literature that suggests the LOME was a 3-pulsed mass extinction event. To infer the abiotic drivers of our recovered diversity patterns and evolutionary rates during the Ordovician, we performed least square regression analyses using the calculated biodiversification rates of a subset of 227 Ordovician genera and compiled stable isotope data. We found varying levels of correlation between environmental proxies and echinoderm biodiversity, indicating further work is needed to better quantify what abiotic drivers were responsible for recovered evolutionary patterns calculated from the fossil record.

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## ANOTHER DECADE OF SCIENTIFIC CONTRIBUTIONS FROM THE CINCINNATI DRY DREDGERS: 2014–2024

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Dating back to their founding in 1942, the Dry Dredgers of greater Cincinnati, Ohio have a rich history of collaboration between professional and amateur paleontologists. In this overview, we highlight numerous examples of public outreach, donated specimens, co-authored publications, collaborative field work, conference participation, and ongoing research from 2014 to 2024. Central to this success are the long-standing relationships that the group has cultivated with paleontologists at the University of Cincinnati (UC), the Cincinnati Museum Center (CMC), and other regional institutions. These connections facilitate an exchange of information, allowing researchers to quickly learn about important discoveries made by amateur collectors, leading to donations, publications, and recognition. In return, the Dry Dredgers gain access to expertise in stratigraphy and fossil identification. Recent examples of published Dry Dredger research include: investigation into the preservation of "micromorph" faunas from phosphate-rich beds; discovery of rare and unusual taxa such as a new *Glyptocrinus* species, anomalous corals from the Kope Formation of Kentucky, as well as a new cyclocystoid from the Lower Silurian Brassfield Formation near Fairborn, Ohio; extensive collection and study of Silurian echinoderm assemblages from southern Indiana, especially the *Holocystites* fauna of the Wenlock-age Massie Formation; and ongoing work to clarify and correlate the Ordovician-Silurian strata of the Cincinnati Arch in a sequence stratigraphic context. Furthermore, the organization has made notable contributions to the CMC's new *Ancient Worlds Hiding in Plain Sight* permanent exhibit, which showcases the Upper Ordovician fossils of the Cincinnati Arch as well as later Paleozoic faunas of Ohio. Individual Dry Dredgers members have donated specimens, volunteered their time, and provided expertise to help develop the exhibit, which also features paleontological artwork by two Dry Dredgers members: Bruce Gibson and Kyle Hartshorn.

## CORALLINE ALGAE RESPONSE TO THE PALEOCENE-EOCENE THERMAL MAXIMUM IN NORTH-EASTERN INDIA AND SOUTHERN TIBET

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Coralline algae are important calcifying plants in modern oceans, producing carbonate sediment, providing food and shelter for many organisms, and cementing reef structures. Due to their high-Mg calcite skeletons, corallines may be vulnerable to ocean acidification, although their current response remains equivocal. Lab studies show negative effects of acidification on coralline physiology although the nature and magnitude of effects varies between species, making it difficult to extrapolate to a regional scale. Hyperthermals occurred throughout Earth's history and provide an opportunity to examine the impacts of acidification and warming over evolutionary timescales. The Paleocene-Eocene Thermal Maximum (PETM), the largest Cenozoic hyperthermal, is considered the best analogue for modern climate change, resulting in 5–8 degrees C warming and widespread acidification over ~10 kyr. Paleoecological studies of PETM sediments reveal important biotic effects in many marine groups, but corallines have not been studied as extensively. I studied thin sections from the upper Paleocene-lower Eocene Lakadong Limestone in the east Janita Hills, Meghalaya, India, and the Jialazi Formation in southern Tibet, using point counts to quantify coralline abundance. I used carbon isotopes to locate the negative carbon isotope excursion that marks the onset of the PETM. Before the PETM, coralline abundance is low due to unsuitable environmental conditions. Surprisingly, coralline abundance increases to >20% during the early PETM, suggesting initial warming and acidification were not detrimental to coralline health. Subsequently, a drastic decrease in abundance during the PETM coincides with increased siliciclastic sedimentation. In the post-PETM corallines did not return to the carbonate platform as quickly as larger benthic foraminifera and other calcifiers. This may indicate a short-term response to PETM-induced acidification, however a lack of extinction or significant taxonomic turnover suggests corallines did not exhibit an evolutionary response to PETM environmental changes.

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## CLUMPED ISOTOPE THERMOMETRY RECORD OF THE PALEOCENE EOCENE THERMAL MAXIMUM FROM POLECAT BENCH

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For decades, researchers in Bighorn Basin have been interested in constraining the magnitude of warming and hydrologic changes during the Paleocene-Eocene Thermal Maximum (PETM). Previous thermometry efforts have been limited by sample availability and assumptions about the relationship between water oxygen isotopes and temperature. Here, we present a pedogenic carbonate clumped isotope thermometry record through the PETM. We used a previously studied collection of pedogenic carbonate nodules collected from the Polecat Bench section, that were originally used to generate a high temporal resolution carbon isotope record through the PETM. We analyzed 10 new samples across an approximately 250 kyr interval that begins before the CIE onset and ends after recovery to pre-PETM carbon isotope values. This resolution allows for greater interrogation of terrestrial amplification of warming during the PETM, the relative timing of the onset of warming and the negative carbon isotope excursion, and therefore, mechanisms behind warming. Our clumped isotope temperatures overlap within uncertainty of previous estimates of mean annual temperature (MAT) derived from leaf physiognomy both before and after the PETM. This finding is supported by new modern calibrations of pedogenic carbonate clumped isotope thermometry data that indicate that clumped isotope temperatures from fine-grained, clay-rich soils overlap with mean annual air temperature. However, during the PETM, pedogenic carbonate clumped isotope temperatures are approximately 10°C warmer than leaf physiognomy estimates and 6°C warmer than estimates from the vertebrate fossil record. We will explore the potential mechanisms that would explain the discrepancy between clumped isotope temperatures and other records including isotope disequilibrium, and possible changes in seasonal bias or radiative soil warming. We will also highlight analytical challenges with creating a reliable clumped isotope record (e.g., isobaric contamination, solid state reordering). In addition, we estimate the oxygen isotope value of soil water from the clumped isotope data, and compare those data to other records of hydrologic change. Modern calibration work in fine-grained and clay-rich soils suggests that the calculated oxygen isotope value of soil water from pedogenic carbonate is indicative of a mean annual isotope value of precipitation. Our record shows a positive 4‰ shift in oxygen isotope values, which is the same magnitude shift from a *Coryphydon* tooth enamel record. Previously, those data were interpreted as a shift in the mean annual isotope value of precipitation, and our data support that interpretation. We will discuss mechanisms that may lead to a discrepancy between our oxygen isotope data and leaf wax hydrogen isotope data such as soil water compartments, local water isotope variability, and the seasonality of plant growth.

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## RECONSTRUCTING HIGH-LATITUDE DEGLACIATION IN THE LATE PALEOZOIC VIA MACHINE LEARNING INFERENCE AND BIOSTRATIGRAPHIC OPTIMIZATION: CANNING BASIN, WESTERN AUSTRALIA

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During the Late Paleozoic Ice Age (LPIA, ca. 340–290 Ma) glaciers covered vast areas of the Gondwanan realm. The latest Carboniferous to early Permian Grant Group in the Canning Basin records the terminal deglaciation of western Australia. Palynological assemblages within the subsurface of this unit lie amongst sediment packages interpreted to represent the last glacial tills of the LPIA in the basin. We present a basin-scale reconstruction of terrestrial biotic change coincident with the withdrawal of glacial ice from these high-latitude environments. Our analysis involves three discrete data sets: (1) 2.7 kilometers of Grant Group sediments distributed across 19 cores with associated sedimentological interpretations; (2) 15,634 occurrences of palynological taxa in 578 palynological assemblages across 60 drill holes; and (3) wireline logs recording the geophysical attributes of sediments with depth in both these holes and the cores. We synthesized these data with a two-step modeling procedure. We first reconstructed subsurface lithofacies using an XGBoost machine learning model, developed using empirical relationships between the interpretive sedimentological framework and recorded geophysical attributes of the available core. Our development pipeline split these cores between a training set, used to build the model and tune hyperparameters during a nested cross-validation procedure, and a holdout test set used to assess model performance on unseen data. The final lithological model allowed us to assess the distribution of major facies throughout holes furnishing palynological data—even petroleum wells without associated cores. Next, we used the biostratigraphic model Horizon Annealing to order all palynological assemblages into a single composite sequence, calibrated to the geologic time scale by way of high-precision U-Pb CA-TIMS dates directly associated with the assemblages in the basin. The botanical affinity of *in situ* pollen and spore taxa was used to reconstruct vegetation change in the basin. The result is a time-calibrated composite sequence of floral change in direct association with a reconstructed lithological

succession signifying glacial retreat from the basin. This unique synthetic model provides novel insights into the rate and magnitude of vegetation changes associated with the demise of the LPIA, and invites comparison with similar sequences elsewhere in Gondwana.

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## EXTINCTION RECOVERY AND ECOLOGICAL IMPLICATIONS OF MISSISSIPPIAN SOLITARY AND COLONIAL RUGOSE CORALS IN NORTH AMERICA

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After the end-Devonian mass extinction, rugosan coral reefs took millions of years to recover in the Mississippian because of the waxing and waning of the Late Paleozoic Ice Age (LPIA), among other factors. While coral recovery is better known in Europe, much less is known about their recovery in North America during this time. Here we use the Paleobiology Database (PBDB) supplemented by scientific publications and field data to document their recovery in North America (Canada and United States) focusing on two families, the solitary Hapsiphyllidae and colonial Lithostrotionidae. Specifically, we wanted to know if solitary rugosans were the first to recover, followed by colonial forms and if they had similar occurrences throughout the Mississippian. We also examined the morphology of solitary and colonial rugose corals (colonial *Acrocyathus floriformus*, formerly *Lithostrotion*, and solitary *Zaphrenites spinulosum*, Hapsiphyllidae) from the early Serpukhovian Bangor Limestone, Alabama, to deduce ecological characteristics that might facilitate living during environmental LPIA instability. Results indicate rugosans were extremely rare in the Tournaisian of North America and most were solitary (86%). Like elsewhere in the world, North American corals started to flourish in the Viséan, but by this time, colonial Lithostrotionidae were very abundant (72%), outnumbering collected occurrences of Hapsiphyllidae (28%). During the Serpukhovian, rugosans declined, but colonials still outnumbered solitary coral occurrences (75%:25%). Almost all of these PBDB occurrences were in western North America, indicating most coral recovery in the western Panthalassic Ocean. However, much work on reef systems is now known from the southeastern United States for the late Viséan to early Serpuhkovian, but not included in the PBDB, indicating relatively widespread reefs on both major coasts of Laurussia. Why were colonial species more common? Colonial *A. floriformus* had higher variation in septal number, but the average number of septa (46) was not significantly different from *Z. spinulosum* (40), which had thicker septa and a larger diameter. Both species had low correlation between septal number and diameter ($r = 0.25$), while for surface area and septal number, the colonial coral was correlated ($r = 0.64$), but the solitary coral was not ($r = 0.41$). For *A. floriformus*, corallite side walls ranged from four to six, with five sides the most common. The variation in the number of corallite sides in *A. floriformus* and the robust septa and larger surface area in *Z. spinulosum* are likely adaptations to current swept shallow seas and cohabiting a similar niche, allowing their clades to survive during the challenging environmental fluctuations during the LPIA.

Funding source: UGA Shellebarger Endowment

## SQUAMATE REPTILES FROM THE EARLY MIOCENE OF EQUATORIAL AFRICA INDICATE COMPLEX DISPERSAL BIOGEOGRAPHIC HISTORIES AND WET-FOREST PALEOENVIRONMENTS

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The highest species richness and ecological diversity of extant squamates are in the tropics. Both their taxic richness and functional traits are predictably correlated to environmental factors, and the utility of these measures in the squamate fossil record is an emergent tool for paleoenvironmental reconstruction. Ongoing field research in the early Miocene (approx. 20–19 Mya) Tinderet sequence of western Kenya has produced a diverse record of squamates which provides environmental data for hominoid-bearing localities. The record consists of chamaeleonid, agamid, varanid, and amphisbaenid lizards as well as snake lineages including pythonids, colubroids, elapoids, and a newly discovered taxon sharing unique vertebral apomorphies with extant tropical South American *Anilius scytale*. Combined with additional fossils from the Eocene of North Africa, the new Tinderet taxon demonstrates an unambiguous past record of an extant neotropical snake lineage in Africa and falsifies previous vicariance hypotheses to explain the biogeographic histories of basal divisions within snakes. Recent stable isotopic and phytolith studies of Early to Middle Miocene eastern African

fossil localities have indicated heterogenous environments, including C4 grasses and wood- to scrubland, associated with vertebrate faunas. The composition of squamate faunas is generally consistent with these reconstructions, with the new taxon providing precise evidence for precipitation. Comparing climate parameters of habitats for *Anilius* and other extant ecological analogues equivalent to those reconstructed for the eastern African Early Miocene indicates annual precipitation between 1500–2500 mm/year, consistent with wet tropical seasonal forests and rain forests.

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## REPTILES OF THE SIWALIK GROUP OF PAKISTAN: FAUNAL RESPONSES TO ENVIRONMENTAL CHANGE THROUGH DEEP TIME AND THE ORIGINS OF MODERN SOUTH ASIAN HERPETOFAUNAS

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The Siwalik Group on the Potwar Plateau of Pakistan preserves a dense, nearly continuous fossil record of reptiles which provides evidence for faunal responses to environmental transitions from equable, subtropical climates to increased seasonality through the middle to late Miocene and minimally constrains the timing of development of distinct bioregions from South Asia to Sahul. Surface-collection and screen-washing over 100 localities spanning a temporal interval of approximately 18–6.5 Mya has produced a diverse record of squamates, turtles, and crocodilians. Squamates consist of acrodontan, scincid, varanid and gekkonid lizards, as well as snakes including *Python*, viperids, elapoids, colubroids, the diagnostic elapid genus *Bungarus* and the nearly ubiquitous aquatic genus *Acrochordus*. Turtles include carretochelyid, cyclanorbine, and trionychine trionychoids, geoemydids, and large bodied testudinids. Crocodilians include a large tomistomine taxon, *Gavialis*, and the oldest Asian record of *Crocodylus*. Patterns of faunal change within the reptile record correspond with environmental transitions. Body size maxima and relative abundance of obligately aquatic *Acrochordus* both decrease with the transition from large trunk river systems in the Chinji and Nagri formations to smaller rivers in the Dhok Pathan Formation. The first isotopic evidence for the initiation of increased seasonality and environmental heterogeneity in the western Siwaliks is approximately coeval with increasing species richness in terrestrial and semi-aquatic colubroid snakes and the first appearance of large-bodied tortoises. The composition of Siwalik reptile faunas indicates an early establishment of modern South Asian endemics within the aquatic turtles and *Gavialis*, as well as representatives of the greater Indomalayan province such as *Bungarus* and *Python*. The record also includes lineages that are extirpated from modern South Asia, including freshwater *Acrochordus* species, tomistomines that are currently restricted to insular Greater Sunda, and carretochelyids which are now endemic to the Sahul platform. The cosmopolitan composition of the Siwalik Group record thus suggests greater higher-order taxic diversity during the middle Miocene than today and indicates that subsequent geographic portioning of, at least, reptile faunas occurred during the later Neogene, at earliest.

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## USING THEORETICAL MORPHOLOGIES AS A FOUNDATION TO GETTING NOT SO THEORETICAL RESULTS IN FUNCTIONAL PERFORMANCE STUDIES

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The last decade has seen tremendous strides in the availability of 3D models and the accessibility of tools to create them. These tools have given a virtual second life to fossil specimens and have sparked something of a renaissance in biomechanics and functional morphology research within the realm of paleontology. Digital replicas of specimens can be measured or included in simulations and experiments that were previously not an option. This digital medium also provides an unprecedented ability to control and manipulate these fossils, allowing for the creation of theoretical morphologies and the population of whole theoretical morphospaces. Here we discuss two recent applications of theoretical morphospaces in both vertebrate and invertebrate systems. First, we discuss our use of theoretical morphologies in ammonoid hydrodynamics. Using theoretical geometries, we can isolate morphological variables that other otherwise changing in tandem across both ontogeny and through the evolutionary history of these animals. Taking this approach we observe that conventionally the streamlining of planispiral ammonoids only starts to benefit them at very large sizes and that increased umbilical exposure provides more consistent performance across a range of speeds and sizes. Our second example focuses on cranial morphology in canids, specifically that of the nasal passage. Substantial lore exists about how humans have driven selective breeding and the development of purpose made dog breeds for their performance at tracking scents. Using geometric morphometrics as a baseline we generated a simplified geometry of the nasal passage with parameters that could be easily altered independently. We used this to explore how the changes to airflow patterns and chemical deposition across different nasal passage configurations

to test how. We observe that many of the characteristics of scent hounds, such as proportionally large nasal passages and elongated nasal length have little impact on performance and that the internal anatomy associated with olfaction between dogs is functionally unchanged between breeds. We conclude by discussing how building in theoretical components into a study can be used to both refine our understanding of a system and to build data sets that can be used to interrogate a range of hypotheses.

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## HOW TO EAT WITH A FORK: UNPRECEDENTED POST-ANTENNAL APPENDAGE DIFFERENTIATION IN THE TRILOBITE *ISOTELUS* (ASAPHIDA; ORDOVICIAN)

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Since the discovery of trilobite legs in the late 1800s, our understanding of trilobite limb differentiation has been static. Trilobites had one pair of antennae anteriorly, and behind it, nearly identical walking appendages that decrease in size posteriorly with some changes in proportion between the protopodite, exopodite, and endopodites along the body. The lack of cephalic appendage specialization was interpreted as a primitive feature—perhaps even a constraint in their body patterning, but recent discoveries of appendicular morphology in non-trilobite artiopodans such as *Pygmaclypeatus daziensis* shows this may not have been the case. And while for most trilobites, this story holds, there are a number of trilobites whose hypostomal morphology suggests that they broke the appendage differentiation constraint. The best example of these potential rule-breakers are the asaphid trilobite—a largely Ordovician group of trilobites that mostly possess large hypostomes with a prominently forked posterior margin. As observed by Hegna (2010), these forked margins possess unique parallel ridges that form a grinding surface. Such a surface, according to Hegna, implied an appendage to oppose it. In eastern North America, there are several understudied asaphid trilobite specimens, belonging to the genus *Isotelus*, with preserved non-biomineralized structures. Four specimens of asaphid trilobites with preserved appendages have been reported which we reevaluate herein. The most intriguing of these is a specimen first discussed by Canadian paleontologist Elkanah Billings in 1870 with 3D appendages in a limestone. While the exact mode of preservation remains unknown (differing from the roughly co-eval Walcott-Rust Quarry preservation), it clearly shows the traces of appendages. Interestingly, adjacent to the hypostomal forks are the bases of appendages that are oriented parallel to the food groove. This demonstrates a hitherto unknown flexibility of limb differentiation in trilobites. Other trilobites bearing odd hypostomes may likewise be rule-breakers. *Asaphids*, like *Isotelus*, used this morphology to great success in the Ordovician. They grew to be the largest known trilobites. Despite the suggestion of previously paleontologists, it is hard to imagine these cephalic adaptations suited to a predatory lifestyle. This suggests that another early Paleozoic giant, like *Anomalocaris*, fed low on the food chain. Whatever the food source exploited by *Isotelus* was, the niche seems to have disappeared following the end-Ordovician extinction.

**WITHDRAWN**

## THE DELIVERY OF SHALLOW-WATER CONODONTS INTO DEEPER OFFSHORE SETTINGS: LOWER PERMIAN AND LOWER TRIASSIC CASE STUDIES

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Conodonts are valuable for biostratigraphic correlation and paleoecologic interpretation over a 300-million-year interval of Earth history from late Cambrian to end-Triassic. Conodonts are nektic and individual taxa are often interpreted as shallow-water or deeper-water genera. Temperature was a major control on ecologic distribution suggesting that shallow-water taxa lived above a thermocline while deeper-water forms lived below. This scenario suggests that shallow-water taxa could be found frequently over a wide range of environments from nearshore to offshore. Constraints on this paleoecologic distribution may be resolved by testing how shallow-water taxa were transported into offshore deeper water facies. In an Early Permian case study, the genera *Adetognathus*, *Ellisonia*, and *Sweetognathus* characterize shallow-water environments, while *Mesogondolella* and *Streptognathodus* were common in deeper water settings; the latter taxon may have an intermediate distribution. A wide range of carbonate lithofacies characterize the Asselian to Sakmarian Strathearn Formation in north-central Nevada. Dendroid and fenestrate bryozoa were locally abundant in bafflestones on the mid-shelf and numerous tempestites characterized slope deposits. Each tempestite includes coarse bryozoan debris grading upward into wackestone, with a few articulated productid brachiopods. Conodonts are not abundant in the coarse packstone to grainstone part of each tempestite bed, but those present are restricted to shallow-water forms. The wackestone part represents slope background sedimentation and includes common specimens of *Mesogondolella* and *Streptognathodus*. In a second case study, two overlapping circular organic impressions were observed in association with several *Ellisonia* elements on a Lower Triassic Montney Formation core-slab from east-central British Columbia. My excitement level was rising by this possible discovery of *Ellisonia* eye structures, but upon closer examination using a field-emission scanning electron microscope (FESEM) my enthusiasm dropped. The FESEM elemental scans revealed the circles were primarily carbon and the *Ellisonia* elements mapped as phosphorous. However, many very small fragments of similar phosphatic material were also revealed indicating that they were fecal pellets, probably from a fish that swam close to shore, ate an *Ellisonia* animal, and headed offshore while digesting and eventually dropping the remains. The sample was from a distal offshore setting and the remainder was disaggregated using normal processing techniques that yielded several specimens of the offshore genus *Novispathodus*, but no specimens of shallow-water *Ellisonia.* These two case studies support the interpretation that these shallow-water taxa lived exclusively in nearshore environments and were transported offshore within the turbulent flow of a storm deposit or within the dark recesses of an intestinal tract.

## THE PLIO-PLEISTOCENE PINECREST BEDS: PROBLEMS, PROGRESS, AND POTENTIAL

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The Plio-Pleistocene Pinecrest beds (Tamiami Fm.) of southern Florida rank amongst the most species-rich assemblages known from the Cenozoic macrofossil record. The tropical to subtropical fauna of the Pinecrest beds includes hundreds of mollusk species and subspecies (perhaps over 1,000), as well as diverse corals, bryozoans, and vertebrates. Some elements of the Pinecrest fauna are extant, but most species went extinct during one or more extinction pulses early in the Pleistocene. There was significant species turnover, but perhaps limited overall change in biodiversity relative to the present. Characterization of biotic change during this interval is important for understanding the evolution of the modern molluscan fauna of the southeastern United States but is unfortunately stymied by two major confounding factors. First, there are no natural exposures of the Pinecrest, and detailed sections have only been exposed in now-flooded quarries near Sarasota, Florida. Most samples from these and other quarries and canal cuts come from spoil piles, which often mix shells from multiple time intervals and habitats, limiting stratigraphic and ecological resolution for occurrence records. Second, the mollusks of the Pinecrest have not been comprehensively treated systematically and some elements of the macrofauna have likely been taxonomically over-split, leading to confusion and wariness among researchers about using published records in analyses. Conversely, the micromollusk fauna (<5.5 mm) has been understudied and many new species await description. Refining our understanding of this major regional turnover event is dependent upon a stable taxonomic foundation and supporting specimen occurrence data. Current estimates of diversity from literature and museum datasets do not closely align. Literature from the mid 1990s suggest over 550 species of gastropods and 250 species of bivalves in the Pinecrest beds, but numerous species have been described subsequently, the majority in the gray literature. In contrast to published tallies, over 1,000 and 400 names have been applied, respectively, to Pinecrest gastropods and bivalves in the collections the Florida Museum of Natural History, representing 140 families. Over 280 micromollusk species may also be present in the Pinecrest fauna. We have begun a project to comprehensively refine and substantiate these estimates of biodiversity to better characterize the Plio-Pleistocene turnover event(s) that led to the establishment of the modern fauna.

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## PRI'S ONLINE RESOURCES FOR LEARNING ABOUT FOSSILS, EVOLUTION, AND EARTH HISTORY

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The Paleontological Research Institution (PRI) has developed extensive online learning resources related to paleontology and Earth science. These serve undergraduate students, teachers, avocational paleontologists, and the wider public and receive strong web traffic. The Digital Atlas of Ancient Life project (https://www.digitalatlasofancientlife.org) includes an open access textbook about paleontology and evolution, a virtual collection of over 500 interactive 3D models of fossil specimens from PRI's collections, and several regionally focused field guides to fossils. Earth@Home (https://earthathome.org) has introductions to the Earth science of eight different parts of the United States and includes overviews of the fossil record and geologic history of each region. Additionally, a new portal on Earth@Home is focused on evolution (https://evolution.earthathome.org) and is under active development. Finally, PRI now creates full online versions of all its temporary exhibits at the Museum of the Earth. Examples include "Daring to Dig: Women in American Paleontology" (https://www.museumoftheearth.org/daring-to-dig/) and "NY Rocks! Ancient Life of the Empire State" (https://www.museumoftheearth.org/ny-rocks). Development of most of these online endeavors has been supported by grant funding (NSF and IMLS). PRI is interested in forging new partnerships on grant-supported broader impact projects to help share the science of paleontology with new audiences via the online platforms above.

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## DIGITIZATION OF INVERTEBRATE PALEONTOLOGY COLLECTIONS: LOTS OF PROGRESS BUT LOTS OF REMAINING CHALLENGES

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Digitization of library card catalogs of books in the U.S. began in the late 1960s, and was for most libraries essentially completed by the late 1980s. The total number of books in the 100 largest libraries in the US is around 700 million. The equivalent process for invertebrate paleontology (IP) collections also began in the 1960s and accelerated in fits and starts since then. A major increase began in the 2010s with the inception of Advancing Digitization of Biological Collections funding from NSF. All of the largest type collections are now available online, and a number of major initiatives have added large numbers of nontype records from many parts of the stratigraphic column. Yet the process is nowhere near complete. The most recent estimate of the total number of fossil specimens in North American collections (from 1996) was around 60 million, but anecdotal updates suggest a real number at least twice that. What proportion of this total actual collection size is digitized is also difficult to estimate. Queries of current data aggregators (Global Biodiversity Information Facility [GBIF] and Integrated Digitized Biocollections [iDigBio]) suggest that close to 10 million records have been contributed by North American collections, but there are likely more that have not been publicly shared. In any case, the proportion of all existing collections that are digitized is extremely small. Planning for the future of digitization of IP collections should take these realities into account. Much progress has been made, but many significant challenges remain. These include: 1) Data quality. Many specimens in most collections are not adequately identified or lack sufficient provenance data. There are often no longer systematic experts to update them or the knowledge and resources available to add contextual data. The community may therefore sometimes be capturing records of doubtful value. 2) Funds to do the work. With current institutional and external funding levels it is unlikely that museums will be able to digitize the majority of even the identified portion of their collections any time soon. This leads to a third major issue. 3) Priorities. If everything can't be digitized, then the community must prioritize. NSF awards millions of dollars a year for digitization, but this does not always go to where collections managers think it should. In the present funding model, the museum community is incentivized to select specimens to digitize because there's money for those specimens, not because they think those are the most important specimens for their users or their collections. Fifty years on from the landmark Committee on Resources in Invertebrate Paleontology report, huge strides have been made, but we should continue to ask what are the priorities for collection stewardship and for the research community, how can we ensure we are advancing those goals, and how can our funding agencies better support those initiatives.

## KOUROU—A NEW AND HIGHLY DIVERSE PLEISTOCENE FOSSIL RECORD FROM THE EQUATORIAL WESTERN ATLANTIC

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Despite a well-studied and globally extensive last interglacial fossil record, little is known about biotic assemblages near the Equator, most especially in the Western Atlantic region. This gap notably prevents characterization of the tropical Atlantic biotic communities during a time of warmer temperatures and higher sea-level than today, conditions that are a deep-time analog for near-term future projections. Here we report on new and highly diverse fossil communities of coastal marine and mangrove affinities, dated from this interval from equatorial South America. This remarkable assemblage was uncovered during titanic earthworks undertaken for a launching pad at Europe's Spaceport, near Kourou, French Guiana. The ca. 230 species include bryozoans, corals, decapods, echinoderms, foraminifera, molluscs, as well as bony fish and sharks, and diverse plants. These are well constrained to the 130–115 ka time interval through U-Th and OSL dating. The coastal area of Guiana is impacted by sediment and freshwater from the major rivers of Guiana and the Amazon, preventing extensive growth of seagrasses and coral reefs. Much of the littoral area is therefore covered by mangroves and estuaries protected by ephemeral offshore sandy bars. Despite the limited habitat diversity, a total of 580 marine species are known from French Guiana today. It is notable therefore that more than 80 species are reported from the Kourou fossil assemblage, which encompasses such a small geographic area, and presumed limited range of marine habitats. The assemblage include 35 species of bivalves, 50 species of gastropods, as well as include two species of scaphopods. Bivalves and snails are recorded by thousands of individuals in all the marine levels that were sampled, with shallow water *Costoanachis avara*, *Sheldonella bisulcata*, and *Chione cancellata* most abundant. Most molluscan taxa have affinities to intertidal and shallow subtidal sands, muds, or rocks and several species are characteristic of mangrove habitats (e.g., Vitta, Isognomon). The excellent preservation of the molluscan fossils (articulation, low fragmentation, numerous smaller specimens) also suggest deposition in-situ in a low-energy habitat. Several species retain colored patterns visible to the naked eye or revealed under UV light. The Guianese coast is strongly impacted by the huge flux of surface waters of Andean-Amazonian origin, termed the Amazon Plume. This northwestward flux strongly structures the composition of recent tropical Western Atlantic biotic communities today, although we have little evidence of how it impacted biodiversity in depper time. The Kourou assemblage suggests stronger affinities between Guianese and Caribbean coastal waters during the Last Interglacial than today. However more data are needed from the very limited fossil record of this region in order to understand how the evolving Amazon Plume has structured tropical Western Atlantic communities through the late Neogene.

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## TIME ISN'T ALWAYS A FACTOR: ISOTOPIC EVALUATIONS OF RECENTLY EXTINCT AND THREATENED HISPANIOLAN RODENTS SUGGEST ECOLOGICAL NICHE PARTITIONING AND LITTLE TEMPORAL ISOTOPIC CHANGE PRIOR TO SPECIES LOSS

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Until recently, the island of Hispaniola boasted at least ten endemic rodent species. Today, just one, the threatened *Plagiodontia aedium* persists and introduced rodents (primarily murids) are prevalent. We know surprisingly little about the ecology of *P. aedium* and even less about the extinct rodent taxa. Stable carbon (C) and nitrogen (N) isotopes from bone collagen can help shed light on how these extinct rodents coexisted, the environments they inhabited, and why they went extinct. We measured C and N isotopes for over 200 subfossil specimens of seven endemic species (*P. aedium*, *P. ipnaeum*, *Rhizoplagiodontia lemkei*, *Isolonodon portoricensis*, *I. montanus*, *Hexolobodon phenax*, *Brotomys* sp.) as well as introduced *Rattus* from two sites on the Tiburon Peninsula in SW Haiti: Trouing Jérémie 5 (TJ5), and Trouing Marassa (TM). Radiocarbon dates suggest specimens have been accumulating at both sites since the terminal Pleistocene. There are minimal temporal isotopic shifts for any species at either site, suggesting foraging niches were stable through time. Isotopic differences between sites for some taxa (*H. phenax*, *I. portoricensis*, *P. ipnaeum*) may indicate regionally variable foraging ecologies or geographically variable vegetation cover. Isotopic data are highly variable for some taxa within sites. N isotope values range by 4–5.5‰ for *Brotomys* sp. at TJ5. *Plagiodontia ipnaeum* and *H. phenax* also demonstrate a 4–5.5‰ N range at TM, and *I. portoricensis* shows the same N value range at both sites. C isotopes range by 4‰ for *P. ipnaeum* at TM. This variability is not a temporal artifact and may indicate local environmental heterogeneity or broad dietary niches for certain taxa. Significant isotopic differences among endemic taxa within sites indicate niche partitioning. Isotopic overlap between *Rattus*, *P. ipnaeum*, *I. portoricensis*, and *Brotomys* sp. could indicate competition, or that *Rattus* filled niches that were left vacant by extinct taxa. The extant *P. aedium*, has significantly lower C isotopes than other endemic species at TM, but there are no other notable

isotopic differences between this species and the extinct taxa. These results suggest there is nothing particularly unique about the foraging ecology of *P. aedium* that can help explain why it persisted while other rodent species went extinct. Isotopic data for modern *P. aedium* will clarify if this species has shifted its foraging niche in response to extensive recent anthropogenic activity. Morphologic data will also illuminate if *P. aedium* has unusual physical characteristics that helped it survive.

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## ECOLOGICAL IMPACTS OF THE RICHMONDIAN INVASION: COMPARING NICHE STABILITY IN NASHVILLE DOME VERSUS THE CINCINNATI ARCH

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The Richmondian Invasion was the immigration of a diverse suite of marine taxa into southeastern Laurentia during the Late Ordovician (Katian), which is preserved in the strata of the Cincinnati Basin and Nashville Dome of Eastern North America. The evolutionary and ecological impact of the invasion has been well studied in the Cincinnati region; however, faunal change in the Nashville Dome is more poorly constrained. In this study, we hypothesized that before the invasion, there will be high niche stability among the taxa, but that this stability will decline during the invasion interval, and that there will be evidence of overall niche contraction after the invasion. Late Ordovician strata of the Nashville Dome comprise highly fossiliferous limestone and shale units. Fossils are distributed across a large geographic area, which provides a robust framework on which to apply Paleo-Ecological Niche Modeling to quantify the amount of change in species' niches between the intervals before, during, and after the invasion. In-situ data were collected to gather both occurrence data for different fossil taxa and environmental proxy data for niche modeling. Niche models were developed using MAXENT, an R-based modeling package. Niche models were produced for taxa with at least seven geographically discrete occurrence points among twenty field locations spanning the western edge of the Nashville Dome. Articulated brachiopods, bryozoans, gastropods, and a few other benthic clades were included in the modeled taxa. Different sedimentary proxies for environmental parameters, such as carbonate bedding style and thickness, sedimentary structures, and limestone/shale percentage were used. It is possible to characterize changes in niche dimensions across the invasion event in the Nashville Dome by examining temporal changes in environmental parameters coupled with the distributional data for taxa. Comparing these results with similar analyses previously conducted for taxa of the Cincinnati region permits analysis of how species responses to the Richmondian Invasion varied among basins. Quantifying niche stability and comparing the similarities between different stages of the invasion further constrains niche evolution within geographic space and improves the current understanding of how Biotic Immigration Events alter ecological systems in geologic time. Preliminary models have demonstrated that biotic shifts can be observed across time slices, taxa change their niche breath as a response to the invasion. Patterns of niche contraction have been observed between post to pre-invasion conditions across clades, with some taxa being more affected than others. Continuing work will elucidate significant patterns between time slices and allow for a detailed comparison of patterns between the Cincinnati region and Nashville Dome.

## AN INTRODUCTION TO THE SYMPOSIUM "INTERCONNECTED PATTERNS OF NATURAL HISTORY: A TRIBUTE TO THE CAREER AND CONTRIBUTIONS OF LANCE GRANDE"

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Lance Grande spent his entire career at the Field Museum, and made outstanding contributions to our understanding of the morphology, systematics, and biogeography of fossil and living fishes. Emphasizing freshwater taxa from the Late Cretaceous and early Cenozoic, Lance's work has refined our understanding of a wide variety of taxa, including chimaeras, sturgeons, paddlefishes, gars, bowfins, bony-tongues, herrings, beaked salmon, catfishes, suckers, pikes, and pirate perches, among others. He also used these studies to explore more philosophical topics such as the importance of ontogenetic data for homology assessment, biogeography, the interplay of data from fossil and living taxa, and other general issues in systematic ichthyology. Outside of "fishes" Lance authored several books, including *Gems and Gemstones*, *Curators*, and his most recent book *The Evolution of Religions*, and was a co-author on *Functional Anatomy of the Vertebrates (3rd ed.)* and a co-editor of *Interpreting the Hierarchy of Nature*. Lance also collaborated on studies of taxonomically broad groups of organisms, including decapods, amphibians, mammals, squamates, and birds from the Eocene Green River Formation of southwestern Wyoming, which in part culminated in his book *The Lost World of Fossil Lake*. Based on annual collecting trips to the Green River Formation for more than 40 years, often in association with an undergraduate course, Lance developed the most extensive collection from this Lagerstätte anywhere in the world at the Field Museum. This

presentation will provide an overview of Lance's life, career as a museum curator and administrator, and his impact on paleontology and systematic biology.

## FURTHER NOTES ON MORPHOLOGICAL VARIATION: A HIERARCHICAL CONCEPTUAL FRAMEWORK FOR INTERPRETING EMPIRICAL DATA

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In 2004, Lance Grande published a paper titled, "Categorizing various classes of morphological variation, and the importance of this to vertebrate paleontology." This paper summarized his approach to the study of morphology by offering a classification of morphological variation across two "vectors": continuous vs. discontinuous variation (vector 1) and taxonomic vs. ontogenetic vs. individual variation (vector 2). Each type of vector 2 variation was considered to be expressed in multiple fashions (e.g., individual variation could be in the form of polymorphisms, sexual dimorphisms, or anomalies, as well as inter- or intraindividual variations). This classification of variation has been a useful framework and has provided a vocabulary for my own studies examining, describing, and interpreting morphological data. One important consideration is that the expression of morphological variation is frequently a mosaic of forms, with different sources of variation coming together to form an individual's phenotype. As with other aspects of morphological research (e.g., osteology), I have adopted a hierarchical approach to interpreting empirical observations of morphology, with Lance's terminology as serving as a basis. Here I will discuss this framework, emphasizing that consideration of the source of variation is a product of collecting observational (and in some cases experimental) evidence, i.e., empirical data, that is best approached in a series of hierarchical analyses (consciously or subconsciously). These analyses, in turn, are reciprocally connected, in that the analysis of each (i.e., taxonomic, ontogenetic, and individual variation) inform future comparisons, thus refreshing the cycle of morphological study.

## AN INTRODUCTION TO THE CONODONT DATA ANALYSIS TOOL (CDAT) FOR VISUALLY ANALYZING RANGE, COUNT, AND DISTRIBUTION DATA

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The conodont data analysis tool (CDAT) is a digital data visualization tool developed to analyze and interact with the range, count, and distribution data of conodonts. A proof-of-concept prototype is currently functional with data stored in Microsoft Excel and visualized in Microsoft PowerBI. There are two primary data table sources: the occurrence data table and the range chart data table. The occurrence data table includes columns that identify the locality, stratigraphy, taxonomy, abundance counts, and other reference information. Each row in the occurrence data table represents a count of a unique taxon from a specific outcrop and stratigraphic sample position. The range chart data table quantifies each biozone as a whole number, with decimal places representing a relative percentage through each zone. Each biozone number is coded to a biozone name with vintage names and translation tables available for cross-referencing literature. Each row represents a unique taxon. Some taxa have multiple entries based on different paleogeographic regions or different taxonomic interpretations. The columns for the range data table include several levels of taxonomic rank, multiple interpretations of ranges, and the author information for ranges and original taxonomic identifications. The interactive visual plots include an editable range chart, a deconstruction tree to dissect data by any column filter, stratigraphic bar charts, and map-based pie charts used to display geographic changes in biofacies or sampled formations. Data visuals can be modified with any column attribute to support the direct incorporation of published data in comprehensive research.

## DINOSAURS PERISHED BUT FERNS FLOURISHED: RESILIENT FLORA DURING THE CRETACEOUS-PALEOGENE MASS EXTINCTION

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The Chicxulub asteroid impact, occurring 66 million years ago at the Cretaceous-Paleogene (K-Pg) boundary, marks the most recognized mass extinction in Earth's history. Ferns not only withstood the impact but thrived in its aftermath. They were the first flora to recolonize the demolished landscape and rose to dominance resulting in a "fern spore spike" in the fossil record. Despite the significance of the fern spore spike, attributes that allowed ferns to thrive post impact have not been thoroughly investigated. This study will focus on three research sites: the Raton Basin (Colorado, New Mexico), the Denver Basin (Colorado), and the Williston Basin (North Dakota, Montana). We compiled a list of terms used in characterizing ferns, drawing from what is commonly used in paleobotanical literature along with descriptors associated with extant ferns. This included attributes such as

frond division, vein types with termination location, margin type, overall leaf shape, and the presence of sori with their shape, location, and indusium description. To examine species turnover and morphological changes in response to the impact, we used these descriptors to identify leaves from newly collected fern fossils and specimens from the Denver Museum of Nature & Science. This analysis involved determining the number and percentage of morphotypes that occur 1) only in the Cretaceous, 2) only in the Paleocene, and 3) in both time intervals. We anticipate an increase in fern diversity and a shift in dominant fern morphotypes across the boundary. This research is important for understanding K-Pg recovery dynamics along with fern adaptation and relating it to our ongoing climate crisis.

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## BRIDGING THE GAP: THE DISPARATE EXPRESSIONS OF BIOTIC EVENTS IN NONMARINE, SHALLOW SILICICLASTIC, AND SHALLOW CARBONATE SETTINGS

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An important goal is to compare biotic events such as mass extinctions, radiations, and biotic invasions among different regions. Comparative stratigraphic architecture must be considered because different depositional settings vary in their dominant systems tracts and types of sequence-stratigraphic surfaces. As a result, settings differ in the timing of their dominant sedimentary record, as well as in how primary ecological gradients (water depth, elevation) are sampled through time. These differences arise from geomorphological position, spatial patterns of subsidence, as well as where and how sediment is introduced to the basin. Here, I discuss these differences for coastal plain, shallow-marine siliciclastics, and shallow-marine carbonate settings. For shallow marine siliciclastics, their sedimentary record is generally dominated by the late TST and HST in depositionally updip settings, and increasingly by the FSST and LST in downdip areas. In updip areas, deposits record progressively deeper-water environments through the TST, frequently punctuated by major flooding surfaces, and progressively shallower-water environments in the HST, and this record is interrupted at subaerial unconformities. In downdip areas, the record is dominantly shallowing upward, tends to lack subaerial unconformities, and contains surfaces of forced regression and weakly expressed flooding surfaces. In contrast, shallow-marine carbonates are commonly dominated by thick subtidal deposits in the late TST, whereas the HST tends to contain increasingly thin parasequences dominated by peritidal facies. The FSST and LST are generally absent or minor in shallow-marine carbonates, being replaced by a substantial subaerial unconformity. Coastal plain settings display differences among valley and interfluve settings. Valley settings typically preserve deposits through the LST, TST, and earliest HST. These vary markedly in aggradation rate, such that the LST and HST tend to be channel-dominant (LAST), and the TST tends to be floodplain-dominant (HAST). In contrast, interfluve settings tend to preserve later TST through the full HST, with the TST being floodplain-dominant and the HST being increasingly channel-dominant. Changes in the preserved elevation of nonmarine deposits tends to be gradual, except across subaerial unconformities in valley and interfluve settings, and across expansion surfaces in interfluve settings. Moreover, the greater subsidence rates in proximal foreland settings tend to favor the development of floodplain-dominated HAST with widely spaced subaerial unconformities, whereas passive margin settings generally tend towards channel-dominated LAST with numerous subaerial unconformities. These architectural differences must be considered when comparing settings as each will display inherent differences in their fossil record owing to stratigraphic architecture.

## AVIAN CRANIAL KINESIS IS THE RESULT OF INCREASED ENCEPHALIZATION DURING THE ORIGIN OF BIRDS

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The evolution of the avian skull from that of non-avian theropod dinosaurs involved dramatic increases in brain size but also significant biomechanical modifications in the feeding apparatus, resulting in a segmented palate and the origin of powered prokinesis in neognath birds. Powered kinesis is considered in part responsible for the trophic diversity and phyletic success of birds, but how changes in neuroanatomy impacted the jaw muscles and cranial joints of the feeding apparatus has remained unclear. Using an integrated approach of 3D reconstructions of skull morphology, jaw muscle modeling, and linkage analysis, we quantified the changes in muscle forces and their roles in loading the palate across the theropod transition to birds. We show the expansion of the neurocranium during non-avian theropod evolution reoriented the plesiomorphically mediolaterally diagonal orientations of jaw muscles used in simple orthal feeding into more rostrocaudally oriented positions in birds. These

phenotypic transformations resulted in increased muscle force transmission through the pterygoid, enhancing the effectiveness of powered cranial kinesis. Only after these loading conditions were in place did the weakening and ultimate breakdown of kinematic linkages occur (e.g., via loss of bones), releasing the avian skull to attain their characteristic cranial kinesis. These findings illustrate the coordinated evolution of the neurosensory and feeding systems during the origin of birds and provide a new approach to identifying cranial kinesis in extinct vertebrate species.

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## DINOSAURIAN VS. MAMMALIAN ONTOGENY AND ECOLOGY: THE EFFECT OF A MOTHER'S LOVE ON COMMUNITY STRUCTURE

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Mesozoic dinosaurs and Cenozoic mammals are often regarded as broadly ecologically equivalent, as they included the majority of medium-to-large-bodied terrestrial vertebrates of their respective eras. One of the most significant differences between them is their mode of reproduction: oviparity and large clutch size regardless of adult body size in the former; viviparity and litter size decreasing with adult body size in the latter. Furthermore, the disparity between hatchling and adult body size is much greater in dinosaurs than neonate and adult body size in mammals on average. The effects of these differences are examined with regards to the size distribution and species counts in fossil communities. Species lists and estimated adult body sizes were assembled for Jurassic and Cretaceous dinosaur and Cenozoic mammal communities based on the instantaneous diversity within well-sampled formations: only communities in which at least one taxon equal or exceeded 1000 kg mass were chosen. The distribution of adult sizes within communities were compared to cases in which earlier growth stages were included: dinosaur hatchling size was estimated from known egg sizes of related taxa, while mammalian neonate size was estimated from those of extant relatives. The size distribution including the entire ontogenetic series results in a greater shift of average body size in dinosaurian communities than in mammals due to the much smaller dinosaur baby size. However, these two sets of plots may not reflect the ecological realities of their respective communities. In many mammals the young are provisioned via lactation and later by provisioning by mothers until they are a substantial fraction of adult body size: thus, the adult-only plots for mammals may be accurate reflections in terms of the realized feeding community structure. In contrast, evidence for long-term parental care in non-avian dinosaurs is scanty for most clades, with many juvenile dinosaurs living (individually or in small groups) independently for most of their lives. Thus, due to these ontogenetic niche shifts, plots in which different growth stages are counted as their own "taxa" might more accurately represent the trophic ecology within dinosaurian communities.

## OVER 100 YEARS OF PALEONTOLOGICAL COLLECTIONS AT THE NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

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The Natural History Museums of Los Angeles County (NHMLAC), including La Brea Tar Pits and Museum, ranks as the largest collections-based natural history museum in Western North America with over 35 million objects in its collection. Nearly 13 million of these are fossil specimens. Four departments house the paleontological materials of the institution: Vertebrate Paleontology, Invertebrate Paleontology, Dinosaur Institute, and La Brea Tar Pits. These collections have grown not only through a century of museum-sponsored field work and active on-site excavation but also by the acquisition of extensive research and teaching collections from local universities and state mandated mitigation monitoring of construction projects. Highlights of Vertebrate Paleontology are extensive collections of marine mammals from western North America and late Cenozoic vertebrates from Mexico. Invertebrate Paleontology is noted for comprehensive collections from the Late Cretaceous and Pleistocene of southern California and Mexico. The Dinosaur Institute houses extensive collections from the Morrison Formation, dinosaurs and marine reptiles from the Cretaceous of California, as well as ichthyosaurs from Nevada, and Triassic tetrapods from Antarctica. Most notably, La Brea Tar Pits represents the type locality for the Rancholabrean North American Land Mammal Age and a newly recognized Geological Heritage Site by the International Union of Geological Sciences. Institutional support, external funding, especially grants focused on collection digitization, and the financial resources afforded by mitigation paleontology have enabled the collection not just to survive but to grow. Almost one million vertebrate specimens and over two million invertebrate specimens from these collections have been digitized. Many of these are shared

through database aggregators to researchers and the public alike, exemplifying the concept of the "extended specimen." Currently, 27 staff members including curators, collections managers, preparators, and an imaging specialist steward the collections along with the support of PhD students, postdoctoral scholars, 90 honorary appointees, and numerous volunteers. This is achieved in traditional collection spaces, together with offsite collection centers, and three preparation labs, two of which are public facing. Through the decades, a core group of experienced staff have sustained and shared scientific and institutional knowledge with early career professionals and our avocational paleontology community. Endowments and donor support as well as partnerships forged with local academic institutions have allowed the museum to increasingly connect with and support students and postdoctoral scholars. An institutional mission to focus on the Los Angeles region, and the support of NHMLAC leadership, has played a vital role in maintaining and championing local paleontological heritage through collections stewardship, research, education, and exhibits.

**WITHDRAWN**

## PERFORMANCE OF MODEL-BASED PREDICTIONS OF BODY SIZE AND BODY PROPORTIONS OF TRILOBITES AT A KEY TRANSITION POINT IN DEVELOPMENT

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Trilobites had a heavily biomineralized exoskeleton for almost the full extent of their post-embryonic life history. Because of this, body fossils and molts from all ontogenetic stages had high preservation potential and it has been possible to piece together the ontogeny of many species. From this it is evident that trilobites were hemianamorphic, meaning there was a post-hatching interval of their life history where body segments were still being generated followed by an interval where segment generation had ceased but the individual continued to molt and grow. Segments were generated at the posterior of the body. Sections of the anterior part of the pygidium (tail shield) were sequentially "released" into the thorax to act as articulating tergites and giving the exoskeleton increased flexibility. This interval of tergite generation ("meraspis") provides a size-independent measure of relative time, making it possible to estimate growth rates for select species for which large samples of articulated specimens have been sampled. Using the results of these studies, I created a generative model of trilobite growth. Although simple, modification of input and growth parameters produced a large range in body sizes and body proportions comparable to those seen in the trilobite fossil record. Nonetheless, predicted body sizes and proportions are highly sensitive to the number of molts during the post-tergite-generation interval ("holaspis"), and to assumptions of constant per-molt growth rates that are probably unrealistic. These model limitations in the context of indeterminate growth makes it difficult to compare model output to the actual fossil record of holaspid specimens across different species. Instead I focus here on the universally shared transition point from meraspis to holaspis and ask: 1) given realistic ranges of input and growth parameters, what does the model predict for body size and body proportions at this point in life history; and 2) how does this compare to empirical data gathered from specimens in the ultimate meraspid stage? Preliminary analysis suggests that even with conservative parameter ranges, a large range of body size and body proportions are theoretically achievable, including some extreme forms. In comparison, realized body sizes and body proportions are highly constrained.

## HOLARCTIC SMALL MAMMALS SHOW HETEROGENEOUS RESPONSES TO THE SPREAD OF OPEN HABITATS DURING THE MIDDLE AND LATE CENOZOIC

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The spread of open habitats during the mid-Cenozoic represents a substantial and global change in the structure of terrestrial habitats. The impact of this vegetation change has wide-ranging implications for the evolution of mammals, but an assessment of its effects is complicated by regional variations in the timing and degree of habitat change, as well as local differences in the vegetation characteristics of open habitats. Rodents in particular and small mammals in general offer a sensitive indicator of faunal responses to community change as a result of their tight connection to the local landscape. Their community structure can offer insights into fossil ecosystems during the restructuring of Cenozoic vegetation. Using ecological data coded for fossil rodents over the last 40 million years, I assess the impact of vegetational change in Holarctic ecosystems both at the continental and regional scales. Local variation in ecological structure of rodent faunas is evident at a variety of scales. Comparing the Cenozoic history of rodent ecology across the Holarctic reveals some key differences in the timing and extent of grassland-related changes in small mammal ecology; North America experienced much more dramatic ecological change in rodent community structure than did Asia and Europe, and those changes happened quite a bit earlier in spite of similar timing in the first appearance of evidence for open habitats. Even within North America, there are differences between the Great Plains and the Northwest in the timing and extent of ecological changes, indicating that the nature of vegetation change during the mid to late Cenozoic varied significantly across the American West. Our improved understanding of the heterogeneity of these community structure changes reveals the complex biological dynamics that characterized the shift in ecological composition as vegetation structure adapted to cooling and drying climates. Ongoing work on the local relationship between vegetation and faunal change will be key to untangling the drivers of changing ecological roles in terrestrial mammals through the Cenozoic.

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## PLACE-BASED FOSSIL KITS FOR ACCESSIBLE PALEONTOLOGICAL EDUCATION

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Natural history museums are one of the most powerful outreach tools for communicating paleontological principles. They offer a safe and engaging environment for visitors and are introductions to the natural sciences for many children and other community members. While natural science museums have historically been a field trip destination for many K-12 classrooms, transportation and admission costs and restricted logistical capacity for museum staff have made trips to museums complicated and unrealistic. Providing museum resources to K-12 classrooms can overcome financial and physical barriers that restrict accessibility and give educators the chance to bring paleontology into their classrooms. To meet this need, we partnered with the Ohio Geological Survey to assemble educational kits containing fossils from the Ohio Silica Shale Formation and developed lesson plans focused on these specimens. The fossils themselves provide hands-on engagement for students and an example of what they could find in their backyards. Key components of these kits are background documents and lesson plans to help guide educators throughout the activities, as many educators, particularly in K-6 classrooms, may lack the specialized background to confidently teach these topics. Lesson plans are tailored in accordance with grade-specific requirements for earth and life sciences to insure they comply with the state educational standards for Ohio and include activities focused on fossil-based inferences, interactions between organisms, adaptation, and how ecosystems change throughout time. We are piloting these fossil kits in Franklin County public schools and conducting pre- and post-assessment surveys of students and educators to determine utility and tailor kits accordingly. Ultimately, this project is intended to bring accessible paleontological education into classrooms throughout the state of Ohio, specifically to those that lack the resources for costly museum excursions.

## PALEOECOLOGY OF CRINOID COMMUNITY FROM THE GLEN DEAN FORMATION OF KENTUCKY

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Understanding ecological interactions in ancient environments is challenging due to the nature of the fossil record yet it is imperative to fully appreciate the function of extinct organisms in their environments and the structure of fossil communities. Morphology allows us to determine inference-based relationships between organisms and their environment, which can help us to reconstruct past ecosystems and better understand the relationship between organisms and their environment. The morphologic traits of multiple species from

the same ecosystem can be used to predict ecologic aspects such as microhabitats and resource partitioning. Crinoids provide an excellent example of this, as their morphology is directly tied to ecological traits such as maximum food size and efficient current velocities. Here, I present data on a Mississippian-aged crinoid community, including *Zeacrinites* sp., *Phacelocrinus debrachiatus*, *Phanocrinus maniformis*, and *Dasciocrinus florialis*, collected from the Glen Dean Formation of western Kentucky, which occurs during a period of high crinoid diversity and is associated with a productive deltaic environment. I measured calyx volume, fan area, and fan density for approximately 10 individuals to determine ecological role and infer paleoenvironmental conditions. Using the combined traits of this crinoid assemblage, I was able to assess relative environmental conditions and determine ecological niches. As the original outcrop has deteriorated immensely since collection of the specimens, this morphological data is one of the only remaining methods to understanding the environmental systems and evolutionary paleoecology of this area.

## NOVEL INSIGHTS INTO THE EVOLUTION OF ONTOGENY IN LYSTROSAURIDAE (THERAPSIDA, ANOMODONTIA)

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*Lystrosaurus* is a late Permian to Early Triassic dicynodont therapsid that is noteworthy for surviving the End Permian Mass Extinction (EPME). *Lystrosaurus* is an abundant and geographically widespread taxon, with thousands of specimens in collections including extensive ontogenetic series.This sample size makes *Lystrosaurus* an ideal system for studies of life history, biostratigraphy, paleoecology, and biogeography in the EPME. Despite the relevancy of *Lystrosaurus* to paleobiological questions, the evolutionary mechanisms that produced its unique morphology and contributed to its success remain poorly understood. To help resolve this issue, we explored *Lystrosaurus* ontogeny in the context of broader dicynodont evolution, incorporating new specimens from the upper Permian upper Madumabisa Mudstone Formation (Luangwa Basin, Zambia). In addition to a variety of non-lystrosaurid dicynodontoids (e.g., *Daptocephalus*), this sample includes a new taxon of Permian lystrosaurid exhibiting a growth series. Although the adults of the new taxon retain a generalized Permian dicynodontoid morphology, juveniles appear more similar to *Lystrosaurus*. Using µCT scanning, we digitally reconstructed adult and juvenile skulls of the new Zambian lystrosaurid and a juvenile dicynodontoid skull attributed to *Daptocephalus*. We compared the morphology of these specimens with surface scans of *Lystrosaurus curvatus* crania and an adult skull of *Daptocephalus leoniceps*, describing ontogenetic and taxonomic variation between the three species. The juvenile skull of the new lystrosaurid presents *Lystrosaurus*-like characters, including a deep, foreshortened snout, large orbits, short postorbital region, and a wider intertemporal region with exposed parietals. In this way, the juvenile lystrosaurid is strikingly similar to *L. curvatus*. By contrast, the adult lystrosaurid presents characters seen in non-lystrosaurid Permian dicynodontoids, including an anteroposteriorly longer and shallower snout, longer postorbital region, and a narrow intertemporal bar in which the postorbitals overlap the parietals. Given the degree to which the juvenile lystrosaurid reflects the morphology of adult *L. curvatus*, and general craniofacial changes across dicynodont ontogeny as seen in *Daptocephalus*, the new species suggests that ontogenetic shifts were key to *Lystrosaurus* evolution. Curiously, recent and ongoing studies of *Lystrosaurus* life history and EPME survivorship in the Karoo Basin, South Africa, suggest that *Lystrosaurus* species had altered ontogenetic trajectories, potentially including paedomorphism or paedomorphic-like allometric repatterning. The new lystrosaurid suggests that such changes may represent a line-of-least-resistance in its evolution. With the new species as both a phylogenetic and ontogenetic waypoint, we can begin to understand the evolution of this iconic genus, as well as the many factors that make *Lystrosaurus* such an important genus to terrestrial EPME paleobiology.

## PALEOPHYLOGEOGRAPHIC MODELS: AN R PACKAGE FOR INTEGRATING PALEONTOLOGICAL, NEONTOLOGICAL, AND SPATIAL DATA IN A PHYLOGENETIC COMPARATIVE FRAMEWORK

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The fossil record combined with paleoclimate data provides an unparalleled resource to understand how species have responded to climate in the past and to predict how species will respond in the future. Understanding how species spatially respond to climate allows us to answer questions about range shifts and how communities organize in geographic space. Methods that project climatic niches into deep time typically do not account for the evolution of the climatic niche and as such may not accurately detect areas of ancient diversification. Here, we present an R package,

PaleoPhyloGeographic Models (PPGM), that fills this gap by testing for the evolution of the minimum and maximum climatic tolerances and uses the detected evolutionary change to reconstruct ancient climate envelopes across the changing paleoclimate of the past. Our approach implements these models for any occurrence data with an associated phylogenetic framework. We show the utility of PPGM using a case study of *Sceloporus*, a genus of lizards found across North America. Previous work has shown that while modern diversity of *Sceloporus* is concentrated in Mexico, this genus initially diverged and evolved in the climate of the northern U.S.A. Building on these previous findings, we examine the longevity of sympatric congener species communities throughout deep time (i.e., residence time). We also examine how communities assemble across their geographic range and whether different assembly patterns result in concert with changing climate. By integrating paleontological, neontological, and spatial data into a phylogenetic comparative framework, PPGM facilitates the study of macroevolution in a spatial context, and also answers questions that directly relate to conservation management and how communities of organisms organize and persist throughout time and across geographic space.

## REFRAMING THE SEARCH FOR ARCHEAN LIFE

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Traces of early organisms on Earth provide our best window into the origins and diversification of life during the Archean. Many types of evidence can reveal the presence, habitat, or functions of life in the Archean, including macro-and mesoscopic microbialites, microfossils, and geochemical traces such as organic carbon and isotopes. Much of the focus of investigations into Archean life has been on marine ecosystems, with terrestrial influence often considered negligible. We counter this perception by compiling occurrences of Archean microbialites and their depositional environments, gathering 74 instances of microbialites (divided by depositional environment) and 35 entries of evidence for terrestrial life (including microbialites), with both terrestrial and marine evidence spanning from 3.48 Ga to the end of the Archean at 2.5 Ga. Evidence for terrestrial life was found in diverse depositional environments for this entire span. The temporal consistency of evidence for life in fluvial systems is especially notable, as Archean fluvial deposits are fairly widespread, but most have not yet been studied with a focus on evidence for life. Further, we found that at least 45% of "marine" microbialites formed in tidal zones and less than half of all Archean microbialites were truly marine. During the Archean, tidal magnitude and strength would have been greater, sweeping across large expanses and likely leading to frequent subaerial exposure and high input of terrestrial materials to these microbial ecosystems. Our investigation into microbialites in the 3.48 Ga Dresser Formation found likely tidal influence that supports these modeled high velocities and reveals a possible taphonomic role of such extreme tides in limiting microbialite preservation. This would suggest that life in Archean tidal ecosystems could have been even more extensive than what is revealed by the rock record. Hydrothermal influences may also be confounding the divide between terrestrial and marine ecosystems: studies have found evidence for terrestrial hot springs in some of the earliest preserved evidence of life, and we found in our compilation multiple instances of microbialites in hydrothermal settings with subaerial exposure. Broadly, we found that default assumptions of minimal terrestrial influence and predominantly marine Archean microbial ecosystems may be downplaying the diversity of environments in which early life thrived. The ubiquity of life across ecosystems for as long as we have evidence of life on Earth suggests that we should not limit ourselves to narrow sets of analogue systems in our search for early life here and on other planets, and should instead take a wider view that incorporates the diversity of potential niches life that has occupied for at least 3.5 billion years.

## A SIMULATION FOR ESTIMATING EXPECTED DIVERSITY OF A CLADE

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Morphological disparity has been widely used in paleobiology over the last 30 years as a tool for assessing ranges of anatomical variety and as a guide to identifying potential changes in evolutionary rules. One issue with disparity studies is the lack of null models that we can use to establish what disparity should be under different circumstances. Here, we use inverse-modeling simulations to estimate the potential range of disparity within genera of various species numbers within a larger clade given the compatibility among those characters within that clade. The simulations evolve trees with the same number of sampled taxa using origination, extinction and sampling rates from empirical estimates and then evolve characters until the compatibility among characters matches that of the real matrix. The simulations uses two simple techniques to assign N species to X monophyletic or paraphyletic genera: 1) the X branches with the most change and, 2) new genus in every 1 in X branches. This is repeated and provides a range of expected intrageneric and intergeneric disparities expected given rates of anatomical change comparable to the real data and realistic ranges of phylogenies. Unusually high disparity within genera might indicate either polyphyly or elevated rates of change within genus due to factors such as correlated change or ecological disturbance; unusually low disparity might represent oversplitting of species. This approach might also be used

to standardize the study of disparity across groups, allowing comparisons between and among different clades.

## AUTOMATICALLY IDENTIFYING, DETECTING AND MEASURING OSTRACODS WITH DEEP LEARNING

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Microfossil ostracods can give us abundant information to understand climate and environmental changes. But an issue is, for example, in studies using ostracods as a proxy for past climates, massive amounts of ostracods need to be identified by researchers. However, the identification work of ostracods requires at least multiple years of training on taxonomy and identification and includes time-consuming scanning of residue sample and repeating manual operations under a microscope. For the measurement of ostracods, researchers must accurately mark the outline and locate the corresponding measurement points. Moreover, the number of experienced specialists is decreasing while we need more ostracod data to conduct global scale study. Therefore, it is imperative to incorporate cutting-edge deep learning technologies into the identification pipeline as an automated tool for researchers. Here we introduced a workflow to integrate deep learning technology as an automation tool for ostracod genus and species detection and identification as well as their morphometrics. In the workflow, we created a dataset with 69630 images of Hong Kong marine ostracods containing 79 genus and 139 species then implemented the workflow into a framework to detect and identify ostracod genera and species using the dataset. Each ostracods' height, width and area can be measured by applying segmentation on top of the detection result. We reached 95.01% accuracy in genus identification and 91.63% in species identification. In the object detection task, the trained model reached 76.53% and 89.81% average precision in species detection and genus detection task. Finally, we utilize trained models to quantitatively measure species distances (i.e., morphological similarities), construct a phenotype tree based on these measurements, and visualize critical differences between species using grad-cam to aid taxonomists in correcting potential misidentifications. The promising result reveals the potential to apply deep learning to power the future automatic identification system for ostracods. We will opensource the detailed workflow to encourage researchers with similar need to adapt deep learning in their future research.

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## MICROFOSSIL AUTOMATIC IDENTIFICATION USING INTEGRATED DEEP-LEARNING MODELS

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Accurate and efficient identification of fossil species is crucial to evolutionary studies but is often frustrated by restrictions, including the quantity and quality of fossil specimens, the relatively small community of taxonomists, and the inconsistency in taxonomic opinions among experts. These restrictions also pose challenges to the development of automatic fossil identification techniques. To address these challenges, we developed a pipeline for automatic fossil image acquisition and identification and applied it to fusulinid, a group of Paleozoic benthic foraminifera. BlendMask, a neural network model for instance segmentation, was trained and used to segment fossil individuals from the rock slice images, followed by an image standardization procedure. The largest to-date dataset of fusulinid consisting of 2400 images of 16 genera was generated for subsequent identification model training. To achieve better identification capability for fossils, we designed a multi-view ensemble learning framework. It collects multiple views of each fossil specimen image, reflecting its different characteristics, to train multiple base deep learning models, and then makes final decisions via soft voting. We further proposed a method that integrates Original, Grey, and Skeleton views (called the OGS method) under this framework, and demonstrated its effectiveness on the fusulinid dataset. The results show that the ensemble framework consistently outperforms the baseline using a single base model. As the available training data decreases, the proposed framework achieves more performance gains compared to the baseline. A consistency test with two human experts shows that OGS obtains the highest agreement with both the labels of the dataset and the two experts, showing its ability to resolve conflicts. Furthermore, a Class Activation Map (CAM) technique is applied to visualize the distribution of model attention, providing better explainability of the framework. This proposed pipeline is designed for general fossil identification and is expected to see applications in other groups. Notably, the result, which shows less performance loss with decreasing training data, suggests its strength when faced with a restricted amount of labelled data, such as in the case of rare fossils. The consistency test indicates that the model can integrate the opinions of multiple experts, demonstrating its potential for dealing with inconsistencies in fossil identification.

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## DOES RESOURCE STABILITY THROUGH SYMBIOSIS PROMOTE DIVERSITY?—A COMPARATIVE BIOGEOGRAPHIC PERSPECTIVE

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Resource stability has long been hypothesized as a key factor in promoting biodiversity (Valentine 1971, *Lethaia*), including high diversities in the seemingly contrasting tropical and deep-sea environments. This hypothesis implies that resource stability provided by symbiosis should boost species diversity of the involved clades. Yet, symbiotic species are rare (~8%) among the shallow-marine bivalves (~7000 extant species), where symbiotic lifestyles have evolved repeatedly, ranging from parasitism (in some galeommatoids) to mutualism (e.g., lucinids and some cardiids). All of these symbioses, despite their many differences, might achieve larger geographic ranges if they are buffered by their partnerships from external pressures such as temperature gradients and seasonality in productivity and other limiting factors. Conversely, with more stable food sources, symbiotic species might persist even with narrow geographic ranges and lower investment in dispersal ability, at least in the short term, albeit leading to higher long-term extinction rates. Here, we investigate the ecological and thus evolutionary advantages in the different symbiotic bivalve lifestyles via global comparison of their biogeography, functional traits and the fossil record. Using a global bivalve database, we analyze their provincial distributions plus two key traits: geographic range size—a species-level trait associated with extinction risk in many taxa—and body size, which relates to fecundity, dispersal, and resource use. Our preliminary analyses found significant differences among species in different lifestyles. For example, the photosymbiotic species (cardiids) are largely limited to the tropical environment, which is spatially widespread and thus allows broad longitudinal ranges in this group. In contrast, commensal galeommatoid species (including parasitic species) occur from the tropics to the poles but also more often restricted to a single biogeographic province than any other groups. Chemosymbiotic species are the most diverse symbiotic group taxonomically and phylogenetically (from five families), with marginally narrower geographic ranges than the asymbiotic taxa. Differences in body size among bivalve lifestyles mirror those for geographic range size, but stronger among lifestyle groups, suggesting a more direct link to lifestyle, due to the functional requirement of the symbiotic interactions (e.g., resistance to predation and surface area for photosymbiosis or physical limitation on commensal species with burrowing hosts). The two rarer lifestyles, commensalism and photosymbiosis, select for contrasting body sizes, and yet both exemplify the ecological trade-off between specialization for reliable resource supply and dispersal ability, thereby hindering expansion of their geographic distribution. Geologic age-frequency distributions are less clearly differentiated between symbiotic and asymbiotic taxa, perhaps owing to those trade-offs.

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## PURSUIT OF AN EXPLANATION FOR THE PLANKTONIC FORAMINIFERAL MASS EXTINCTION AND CARBON CYCLE PERTURBATION ACROSS OCEANIC ANOXIC EVENT 1B (113 MA)

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One of the largest turnovers in the evolutionary history of planktonic foraminifera occurred across the Aptian-Albian Boundary Interval (AABI) 113 million years ago during a carbon cycle perturbation identified as Oceanic Anoxia Event 1b (OAE1b). The 80% extinction eliminated all large, heavily calcified and macroperforate planktonic taxa and was accompanied by a precipitous drop in the total abundance of planktonic relative to benthic species. However, while widespread, the event did not seem to affect other groups as no taxonomic turnover has been observed across the AABI among other fossil groups including calcareous nannofossils. At Deep Sea Drilling Project (DSDP) Site 511 (southern South Atlantic), which is the most complete and best preserved of the studied AABI sections, only two thin- and smooth-walled, small-sized, microperforate species of *Microhedbergella* survived the extinction. These survivors are replaced by one and then two small, smooth-surfaced, thin-walled microhedbergellid species in the early Albian. Consistent presence of the small, thin-walled species across the AABI argues against a major decrease in pH of surface waters during the event. Benthic foraminiferal census counts across the AABI at sites 511 and

1049 reveal elevated relative abundances of agglutinated and weakly calcified benthic foraminifera in the latest Aptian and suggest deep-water carbonate ion depletion in the Atlantic Ocean. A subsequent increased abundance of infaunal benthic species within OAE1b correlative with a negative carbon isotope excursion indicates decreased bottom water ventilation and increased organic carbon flux to the ocean floor during the Kilian OAE1b sub-event. During the early Albian more heavily calcified epifaunal species increase in abundance, suggesting increased bottom water ventilation and carbonate ion saturation. Although oxygen and carbon isotope ratios from analyses of single benthic and planktonic species as well as bulk carbonate show a 2.5‰ negative excursion beginning ~0.5 m.y before and ending ~0.5 m.y. after the extinction event, Mg/Ca analyses of test wall cross-sections in four benthic foraminifera species from the same samples show comparatively small temperature changes. These results suggest that the negative stable isotope excursions are a diagenetic artifact. Further geochemical analyses will be pursued to characterize changes in the carbonate ion saturation across the AABI in the hope of deciphering the cause of the enigmatic mass extinction of planktonic foraminifera at the end of the Aptian.

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## EVOLUTIONARY MYSTERIES IN THE PLANE TREE (PLATANACEAE) FOSSIL RECORD

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The sycamore or plane tree family (Platanaceae) is renowned for its fossil record, which dates back more than 100 million years and includes an incredible array of morphological diversity. However, the sequence of trait evolution in this family remains largely unknown. Here, I discuss some of my research on the family and some of the most compelling mysteries pertaining to its diversity and evolution. In particular, I focus on what we know about stipule evolution, the evolution of basilaminar lobes, compound leaf evolution, the diversification of lineages with unlobed leaves, the evolution of globose capitula, and transitions in inflorescence sexuality, flower symmetry, and evolutionary stability based on the fossil record of this plant family. Stipules, foliar and showy in modern *Platanus*, are unknown for many Platanaceae lineages; putative stipules are presented for *Langeria*. The developmental and evolutionary relationship between basilaminar lobes and stipules is uncertain, but consistent patterns develop between basilaminar lobes and typical leaf lobes. Compound leaves evolved in multiple lineages of Platanaceae, but the relationship between these lineages and to modern *Platanus* remains unknown. Elongate inflorescences like those in *Distefananthus* and *Tanyoplatanus* could represent a plesiomorphic condition preceding globose inflorescences. However, this presents further complications, since *Distefananthus* is associated with *Sapindopsis* leaves in the Dakota Formation, whereas *Sapindopsis* occurs with globose inflorescences at other localities. Morphospace approaches could be used to better quantify the transitions in this family's history. Phylogenetic analyses using morphology could help infer the sequence of evolution in this family, but this requires reconciling with many challenges, including how to interpret homology in a group known for hybridization and high intraspecific variation (polymorphism).

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## EVOLUTIONARY TEMPO AND MODE IN STRATIGRAPHIC CONTEXT: DIKELOCEPHALID TRILOBITE EVOLUTION IN THE UPPER MISSISSIPPI VALLEY CAMBRIAN

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Uppermost Cambrian rocks of the upper Mississippi Valley bear disarticulated sclerites of dikelocephalid trilobites in moderately high abundance. Of these, specimens of *Dikelocephalus* are the most common, and are found among foreshore to toeset deposits spread among numerous localities. These deposits preserve the early stages of falling stage systems tract development deposited over an interval of some 1 million years. The *Dikelocephalus* they contain differ notably from congeners in the uppermost transgressive systems tract lying stratigraphically immediately below. *Dikelocephalus* within the falling stage systems tract show notable morphological variation both within and between collections, with their cranidial shapes defining a morphological landscape of continuous array of form with four common morphotypes emergent. Variation accords with that described by Darwin in dominant and enduring species rich in individuals and morphospecies recognition among these *Dikelocephalus* is not straightforward. The smaller body sized, co-occuring genus *Osceolia* appears abruptly above the maximum flooding surface that locally separates the transgressive from the falling stage systems tract. Phylogenetic analysis suggests its closest relatives may occur outside the area. *Osceolia* also shows notable morphological variation during its range of about 0.5 million years in the upper Mississippi Valley, with marked intracollectional variation of partly ontogenetic and partly uncertain biotic origin, and apparently

more than a single species. Variation within *Osceolia* mimics that of *Dikelocephalus* in some ways, but on a lesser scale, consistent with its more restricted stratigraphic occurrence. *Walcottaspis vanhornei*, on the other hand, is the sister taxon of a comparably large *Dikelocephalus* species, and both enters and exits from the fossil record within the regional temporal range of *Dikelocephalus*, which it apparently excluded locally. Its occurrence appears confined to a single parasequence, possibly representing an interval of ~50,000 years. Despite marked intraspecific variation within *W. vanhornei*, its striking difference from its sister taxon along with the other observations listed above, suggest its punctuated appearance to be biologically mitigated. Accordingly, dikelocephalids within the region apparently show marked intracollectional variation and punctation related to both stratigraphic (*Osceolia*) and evolutionary (*W. vanhornei*) origins. The enduring genera *Dikelocephalus* and *Osceolia* show nuanced patterns of continuous morphological variation, limited in part by their stratigraphic ranges, within early falling stage systems tract deposits that record a relatively short interval of time with high fidelity. Local dikelocephalid evolution may thus contrast the evolutionary histories of localized and ephemeral species such as *W. vanhornei* with species of more widespread and enduring genera that commonly show indistinct boundaries among close relatives.

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## NHM UNLOCKED, PREPARING COLLECTIONS TO MOVE

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The Natural History Museum in London is undergoing some big changes. We are currently in the midst of an exciting project, NHM Unlocked, the culmination of which will be the opening of our new facility at the Thames Valley Science Park (TVSP) in Reading, Berkshire. This is a collaboration with the University of Reading. 38 million specimens will be moving, across the recent and palaeontological collections, encompassing mammals and non-insect invertebrates. This move will improve the collections storage and facilities and provide space for the collections to grow. Significant preparation work is underway, with a plethora of work streams underway to get the collection ready to move. This has included assessing the conservation requirements of the collections moving. The entire palaeontological collection has been assessed, and the interventions have begun. It is not just the physical collections we are assessing; this project is giving us a great opportunity to get a handle on our documentation and paperwork. We want to reduce the impact on our collections users as much as possible, if you may require the NHM collections in the period up until 2030, please reach out and discuss your collections access needs with the relevant curatorial teams as soon as possible. If you have datasets containing NHM specimens, especially images or transcribed specimen metadata, this could help us prepare the collections. Please get that information to us. If you have overdue loans of NHM material, please send them back.

## PROBOSCIDEA (MAMMUTIDAE AND GOMPHOTHERIIDAE) FROM THE LATE MIOCENE MONTBROOK LOCALITY, FLORIDA, U.S.A.: TAPHONOMY, PALEOBIOLOGY, AND PHYLOGENETIC IMPLICATIONS

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The 2015–2023 excavations at the Montbrook Site in Levy County, north-central Florida, recovered more than 125,000 vertebrate fossils from an area of about 500 $m^2$. Of these, over 90% are from aquatic or semi-aquatic taxa. The site's age is latest Miocene (late Hemphillian), ca. 5.5–5.8 Ma, based on mammalian biochronology. The depositional environment is hypothesized to be a large, slow-moving river near the coast. Fossils of Proboscidea comprise 61% of the terrestrial mammals from Montbrook. Four dentaries and associated lower dentitions of *Mammut* have been collected, and 35 of *Rhynchotherium*. Fewer skulls, maxillae, and upper dentitions are known, two of *Mammut* and 23 *Rhynchotherium*, of these, one and six, respectively, are securely associated with lower dentitions. About 2,500 postcranial bones of proboscideans representing all portions of the skeleton are also known. Partial to nearly complete associated or articulated skeletons are common. These lack evidence of weathering, water wear, or bite marks made by scavengers. Spatial and stratigraphic relationships of the carcasses suggest that this assemblage was not the result of a single event, but rather records mortality that lasted for many decades if not centuries. The Montbrook sample of *Mammut* ranges in age from young juvenile (dp2–dp3 in wear, dp4 slightly worn) to young adult (dp4–m1 in wear, m2 slightly worn). These are the first records of juvenile dentitions of *Mammut* from the Hemphillian. Cheektooth size and morphology falls within the range of Pleistocene *Mammut americanum*, but the mandibular symphysis is longer and bears straight lower tusks. Length of the symphysis relative to the entire dentary increases from 16% in the young juvenile to 26% in the young adult. No upper tusks or third molars have been recovered. The sample is tentatively referred to *Mammut sellardsi*, a species named from the late Hemphillian of south-central Florida. The gomphotheres from Montbrook range in age from young juveniles to mature adults. Almost 60% of the dentaries belong to the youth age class (dp4–m1 in wear, m2

either unerupted or in the process of erupting); these include both males and females, so the high mortality in this age class is not related to gender. Reference to *Rhynchotherium* is based on: sharply downturned symphysis in adults; vertically oriented ascending ramus; trilophodont DP4–M2/dp4–m2; tetralophodont M3/m3; and upper tusks with spiraled enamel band. Strong sexual dimorphism is evident in both lower and upper tusks. In addition to larger size, upper tusks in older males are relatively straight, while downcurved in females and immature males. Lower tusks lack enamel bands and are curved upwards in both sexes but are frequently lost in mature females. Changes in cranial morphology through ontogeny in the Montbrook sample support the hypothesis that *Rhynchotherium* evolved from North American "*Gomphotherium*"; *sensu lato*.

## CINCINNATI MUSEUM CENTER AS A REPOSITORY FOR ORPHANED PALEONTOLOGICAL COLLECTIONS

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Museums are experiencing an upsurge in requests to adopt and/or salvage endangered natural history collections as universities and other institutions no longer dedicate resources to the management and care of these important scientific resources. This can result from reduction or absence of staff and support, or negative or uninformed institutional policy decisions. Many of these collections hold type material and other significant scientific research specimens. The collection and irreplaceable scientific information are thus in danger of becoming lost to the research and education communities. The acquisition and care of orphaned collections by mission-driven museums is therefore increasingly necessary. In the case of paleontological collections, the situation is particularly acute where college or university departments holding such materials are not associated with a large public-facing museum. The loss of a faculty position and/or diminished number of courses and students in paleontology may then result in collections without dedicated custodial care. Disappointingly, the downsizing or deemphasis of paleontology programs in some academic departments continues. Additionally, many privately held collections of avocational paleontologists, even if ideally not containing published specimens, include research and exhibit quality specimens and data. These too require preservation and may be offered to museums for inclusion in the public domain. Cincinnati Museum Center is a private, non-profit AAM accredited institution that is playing a vital role in securing our region's natural history collections. CMC strives to be a regional repository for paleontological materials acquired by universities, researchers, private individuals, government, and other institutions with the loss of or no dedicated collection facilities. The strategic Collections and Research Plan (2021) of CMC envisions the expansion of its holdings via collections from regional researchers, private individuals, and organizations, and the acquisition of orphaned collections that emphasize biodiversity, both fossil and recent, in the Ohio Valley region and beyond. To that end, CMC continues to expand its collection facilities and capabilities in order to accommodate and preserve collections with a view to research and education accessibility. Explicitly stating the goal of orphaned collection acquisition, both at the collections policy level and institutional level are critical to the collecting mission of the organization. Benefits of becoming a center of orphaned collections recovery include expanding the scope of the collection; securing valuable scientific specimens, some of which may include types that have not been accessible for research for decades; and increasing the visibility and use of collections at the institution. Resources, time, and personnel are always limiting factors in the ability to accept large or multiple orphaned collections.

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**WITHDRAWN**

## USING STATE SPACE MODELS TO UNDERSTAND THE EVOLUTION OF MORPHOLOGY IN THE LAKE DIATOM *STEPHANODISCUS YELLOWSTONENSIS* OVER THE PAST 14,000 YEARS

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Time-series of morphological observations have been central to paleontology's attempts to understand evolutionary patterns and processes in species-level lineages. Recent analyses of these time-series are generally based on computing likelihoods of data given a model or set of models, and then using information criteria or Bayesian methods to compare model support. Here, we discuss the utility of state space models (SSMs) to provide an alternative framework for computing these likelihoods. SSMs have a state equation to define the true condition of a system, and an observation equation representing measurable variables that depend on the unobserved true states. In evolutionary time-series, the state equation governs the evolution of the true population means over time (for example, as a random walk), whereas the observations are the noisy data from our actual fossil samples. Application of the Kalman filter in the SSM approach allows for computation of model likelihoods for many evolutionary models of interest. These likelihoods are equivalent (within a constant) to standard likelihoods based on multivariate normality but the SSM approach has several practical benefits: (i) because it does not need to invert the sample-by-sample covariance matrix, SSM likelihoods are faster and more robust for time-series with many samples; (ii) the Kalman filter produces quantities that can be treated as residuals, providing a useful tool for evaluating model adequacy; and (iii) the modular nature of the Kalman filter allows one to readily combine different evolutionary components, greatly facilitating the development of complex models. We illustrate the potential of the SSM approach by applying it to understand trait evolution in the lake diatom *Stephanodiscus yellowstonensis* sampled 63 times over the past 14,000 years, using published data from Theriot and co-authors. SSMs were applied to fit a series of evolutionary models of increasing complexity, with modeling choices guided by environmental changes documented in that study. Model fits suggest that measured traits in this lineage adaptively followed changes in conditions, with solar insolation as a particularly important correlate of morphological change.

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## NEW DATA ON THE LOWER JAWS OF THE FIRST ACTINOPTERYGIANS; IMPLICATIONS FOR THE FIRST RADIATION OF THE EARLIEST RAY-FINNED FISH

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Ray-finned fishes (actinopterygians) comprise approximately half of all living vertebrate species, and are the most diverse living group of osteichthyans. The group diverged from their sister lineage, the lobe-finned fishes (sarcopterygians) during the late Silurian or Early Devonian, but their early fossil record is comparatively sparse. Available fossil evidence suggests that actinopterygians remained taxonomically and morphologically depauperate during their early history in the Devonian before undergoing rapid morphological and

taxonomic diversification in the Carboniferous, following the End-Devonian Mass Extinction. However, the diversity and morphology of Devonian actinopterygians is poorly understood, and the phylogenetic relationships of early actinopterygians are highly unstable and far from reaching a consensus. Here, we use micro-CT scanning to reveal new morphological data on the lower jaws of Devonian actinopterygians, with a dataset encompassing almost all known Devonian taxa. The lower jaws of Devonian actinopterygians are generally held to be morphologically conservative in overall size and shape, with a small number of exceptions such as the large, predatory *Tegeolepis* from the Famennian Cleveland Shale. However, our novel data reveals surprising anatomical diversity, with substantial variation observed in the curvature of the jaws, the size and shape of the teeth, the number and arrangement of lateral and medial dermal ossifications, and the condition of the adductor fossa and articular cotyles. These new data contribute significantly to an increased understanding of the morphological diversity of ray-finned fishes in the earliest phase of their evolutionary history, as well as the ecological roles and phylogenetic relationships of actinopterygians during their earliest radiation in the Devonian. Our new data also support the hypothesis of cryptic phylogenetic diversification of actinopterygians during the Devonian and the survivorship of many lineages through the End-Devonian Mass Extinction.

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## EVALUATING THE EFFICACY OF INFORMAL EDUCATION THROUGH MUSEUM POP-UP DISPLAYS AT CALIFORNIA STATE UNIVERSITY, STANISLAUS'S VASCHÉ LIBRARY

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At California State University, Stanislaus, the Departments of Biological Sciences and Geology have a small, but impressive teaching collection of unique specimens from around the world. Our collections span the range from vertebrates to invertebrates and plants, including marine and terrestrial taxa. Stan State is an emerging research, graduate, and Hispanic Serving Institution (HSI). However, few STEM majors are aware of the collections, much less students from other majors. Located in the Central Valley, there are a limited number of easily accessible science-orientated museums. To bridge the gap between the Biology Department and the rest of the Stan State community, we have implemented a "pop-up" museum display in the Vasché Library on campus, as well as at 'Science Day' events, focusing on natural sciences. Having a "pop-up" museum display in the library is an opportunity to reach a larger audience in a space that is not typically themed for STEM. Through the informal education of museum displays, the principles of evolution, variation in species, adaptations to the environment, and the influences of selection will be communicated to a rural farming community that does not have a strong understanding of the concepts regarding evolution and climate change. The goal is to demonstrate the importance of these concepts in an approachable and effective way that will excite the student body. Natural history collections have a long history of inaccessibility to marginalized groups. Stan State is the ideal location for natural history education as we serve a diverse community, specifically groups that have been historically excluded by collections like first-generation students and those from low-income backgrounds. Often students who attend institutes of higher education are not exposed to scientific concepts unless they enroll in a science-based class. This project will bring accessible natural history learning spaces to our campus, affecting not only our students and staff but also community members who view the display. To gauge the efficacy of the exhibit, we implemented a survey, accessible via a QR code for students to complete. Each display is evaluated, while a summative evaluation study will be used to understand the impact of the project after its completion. These evaluations will inform and improve future projects to better understand the significance of evolution-based outreach on our Stan community. We showcase different displays with an emphasis on evolutionary changes and climate change through time, using actual and 3D printed specimens. We have chosen these themes because they will communicate the principles of evolution and will have sub themes such as variation, selection, time, and adaptation. The utilization of the Vasché Library, a typically non-traditional space for science education, will help illustrate the importance of the natural sciences to the broader student body.

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## FAUNAL PATTERNS ARE CONTROLLED BY FACIES CHANGES THROUGH THE DRUMIAN ISOTOPE CARBON EXCURSION (DICE) IN SW MONTANA, U.S.A.

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The Cambrian is marked by anomalously high background extinctions rates with punctuated extinction events in the middle to upper Cambrian. It has been hypothesized that persistently low oxygen conditions in marine settings was a main driver of extinctions during this time. Here we use the Drumian Isotope Carbon Excursion (DICE), which has been related to expanding anoxic conditions in other regions, to define the relationship between fluctuating oxygen levels

and faunal change. To achieve this goal, we have created a carbon isotope curve, high-resolution redox proxy record, and quantitative paleontological collections from Cambrian age strata in Silver Bow County, Montana, U.S.A. These data were evaluated through a sequence stratigraphic framework, to parse out faunal change related to water depth changes. The uppermost Meagher Limestone (Wuliuan) and Park Shale (Drumian) are the focus of this analysis. The Drumian Isotope Carbon Excursion (DICE), a negative carbon isotope excursion of -2 to -4‰, was identified in the Park Shale. Water depth change, with a trend towards deepening, is concurrent with the DICE in this region. The uppermost Meagher Limestone represents the shallowest environment in this section and does not contain any macrofossil or skeletal elements, but small burrows are common. Overlying the Meagher Limestone is the Park Shale, represented by an interval of deepening and an increase in faunal abundance and diversity. Two distinct faunal communities exist within the Park Shale, a low diversity inarticulate brachiopod dominated fauna in the deep subtidal shales and a higher diversity trilobite dominated fauna in the shallow subtidal carbonates. Redox conditions through this interval are defined using the cerium anomaly proxy. Almost all samples indicate oxic conditions, however, these samples are close to the oxic (>1) - anoxic (>1) threshold, indicating that the environment was not well-oxidized. Despite this, oxygen levels were high enough at times to support a marine invertebrate community as indicated by the occurrence of macrofossils and bioturbation. Our main findings are that the DICE is not a time of dramatically expanded anoxia in this region, but that low oxygen conditions typical of the Cambrian are prevalent, and that water depth changes are the main driver of faunal change. The next step in this study is to expand to other areas in the western US to study similar environments in the same time interval and determine whether regional variability in oxygen levels affected community diversity and composition.

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## A NEW TITHONIAN ICHTHYOSAURIAN SKELETON FROM VIÑALES, WESTERN CUBA

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The fossil record of Mesozoic reptiles in Cuba is represented by several mid-late Oxfordian taxa (dinosaur, pterosaur, oceanic crocodile, pliosaur, plesiosaur, ichthyosaur, and turtle), Tithonian unidentified marine reptiles, and Campanian-Mastrichtian mosasaur and pterosaur. Most of these specimens correspond to isolated remains, whereas associated fossils and partial skeletons are rare. Here we report a partially articulated early Upper Tithonian ichthyosaurian skeleton exposed in the interior of a fluvial cave in Cuajaní, Viñales Valley, in western Cuba. This specimen is the most complete fossil of marine reptile hitherto reported in Cuba. The fossil is embedded in a slab, nearly 30 cm thick, composed of laminated dark-gray biomicrite, intercalated with well-stratified limestone and scarce thin layers of black chert. This stratigraphic section corresponds to the upper part of El Americano Member of the Guasasa Formation. Several samples recovered from the slab yield a microfossil assemblage of early Upper Tithonian *Bonetilla boneti* subzone, represented by *Bermudeziella* cf. *bermudezi*; *Bermudeziella* cf. *cubensis*; *Furrazolaia cristobalensis*; *Bonetilla* sp.; *B*. cf. *bermudezi*; Globochaete alpina; *Colomisphaera* ex gr. *lapidosa-sublapidosa*; Saccocomidae; *Nannoconus* cf. *infans* and *Nannoconus* sp. and several microbial filaments interpreted as bacteria. The fossil was deposited in normal marine conditions at a relatively deep marine bottom of the proto-Caribbean basin. The skeleton is mostly disarticulated and partially disaggregated, with only one of the anterior flippers and most of the vertebrate column preserving anatomical relationships. Most remains are concentrated around the vertebral column except for a few ribs, vertebrae, and anterior flipper, which are scattered around the specimen. The vertebral column is bent in U-shape, with the caudal vertebrae located above the cervical region and the skull. Considering the disaggregation of the skeletal elements and the spatial relationship of the preserved remains, we suggest the ichthyosaur carcass was likely exposed to extensive decomposition by bacteria on the ocean floor, as well as the activity of scavengers before final burial. The cave where the fossil was found lies within the Viñales Geopark and National Park, which also features other important fossil-bearing localities. The skeleton, which originally was embedded in the interior of the slab, is now exposed due to an active weathering process of peeling off small rock fragments, which eventually will lead to the loss of its integrity. A detailed 3D photogrammetric model of the cave and the fossil-bearing slab surface was created as part of ongoing interest in preserving the specimen in situ.

## NEW INSIGHTS INTO CARIBBEAN BIO- AND PALEOGEOGRAPHY DURING THE EOCENE-OLIGOCENE TRANSITION

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Global tectonic events during the Eocene-Oligocene transition (35–32 Ma) induced important changes in geomorphology (uplift and exposure of large areas), climate (Antarctic ice sheet formation and global cooling) and oceanography (sea level drop and reorganization of marine current patterns). These events impacted Caribbean paleogeography and biogeography in ways not yet fully understood. In the Caribbean area the combined effect of EOT uplift/sea level drop produced GAARlandia as a peninsular extension of South America. New geological and geophysical data provided the opportunity to update the Caribbean paleogeographic reconstruction. The new maps are consistent with GAARlandia having an important biogeographical role by providing migratory routes for terrestrial biotas from South American into the Greater Antilles, and, possibly, back again. Furthermore, the uplifted Aves Ridge-Virgin Islands may have forced the Equatorial Atlantic current into the Old Bahamas channel, facilitating docking of African rafts onto GAARlandia. Constraining such events and identifying their biogeographical importance is difficult because of the absence of a good dating framework for the localities in which early primates and rodents have been found in South America as well as the Greater Antilles.

## BIODIVERSITY HOTSPOTS AND LATITUDINAL GRADIENTS: DIFFERENT PATHS FOR LAND AND SEA?

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Biodiversity hotspots—regions with anomalously high counts of species or other diversity metrics—can be underlain by a variety of biogeographic and evolutionary processes. The rich fossil record of marine bivalves provides an evolutionary and biogeographic laboratory for analyzing the dynamics underlying such diversity patterns in time and space, thereby aiding in the search for general rules governing biodiversity. Like many marine and terrestrial groups, shelf-depth bivalves today show a strong latitudinal diversity gradient, with a dramatic increase in species richness, ecological variety, and morphological disparity from poles to equator, and a distinct longitudinal structure of diversity hotspots. When defined by taxonomic richness (number of co-occurring species or higher taxa), bivalve hotspots lie in the tropics, with the West Pacific "Coral Triangle" towering above all other regions; when defined as concentrations of narrow geographic range sizes ("weighted endemism" as in Igea & Tanentzap 2019 and Daru et al. 2020 for birds, mammals, and amphibians), hotspots shift to the eastern boundaries of tropical seas (confined on the north by equatorward-flowing ocean currents and on the south by cold upwelling waters), and to the south-temperate regions: New Zealand, southeast Australia, southern South America, South Africa. This pattern is a striking contrast to terrestrial vertebrates, where hotspot types mostly coincide. Some tropical mountain hotspots are more like marine hotspots in their biogeographic structure, with endemism not always coinciding with maximum richness, and thus perhaps operating more like marine archipelagos in their accumulation of taxonomic richness. For bivalves, the two polar regions both show an order-of-magnitude drop in taxonomic richness relative to the tropics, but differ significantly in weighted endemism and in both the median and the shape of the genus age-frequency distributions. The late Cenozoic fossil record indicates that the latitudinal diversity gradient in bivalves is underlain by an Out-of-the-Tropics dynamic, with genera tending to originate in the tropics and expanding to higher latitudes; global analyses of geologic ages of genera suggest that this dynamic operates in all tropical richness-hotspots. Narrow-range hotspots in the temperate zone are composed of significantly older genera than are tropical faunas, suggesting extratropical range-hotspots are mainly diversity accumulators or sinks (albeit with some local origination). Geographic range expansion is as important as in-situ diversification for the origin and maintenance of marine hotspots, and changing configurations of continental shelves and ocean currents have governed the formation and decline of hotspots over geologic time.

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## ANOLE NEW WORLD: HOW ANOLIS SKULL ELEMENTS HELP CHARACTERIZE THE TEMPO AND MODE OF AN ADAPTIVE RADIATION

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Greater Antillean *Anolis* lizards are a model system for adaptive radiation and ecological convergence, as many species have diversified into distinct ecomorphs with unique ecologies. While the Caribbean fossil record is rich with fossils of *Anolis*, few studies have examined the ecomorphological affinities of these specimens, in part due to a lack of methodological frameworks that can be applied to both fossil and modern specimens. Here we develop a framework for characterizing morphological diversity in

extant and ancient assemblages of *Anolis* using individual skull elements, which are prevalent particularly in the Quaternary fossil record. We assembled a high-resolution CT dataset of over 400 specimens representing more than 80 species, including full coverage of all extant species of *Anolis* on Jamaica and Puerto Rico. We used landmark-based 3D geometric morphometrics to explore how extant species of *Anolis* partition morphospace and to what extent skull elements express phenotypic divergences consistent with a multi-peak adaptive landscape. We determined that differences exist between how well different skull elements recapitulate the six-peak morphospace that defines the *Anolis* radiation, with elements such as the nasals, frontal, parietal, maxilla, and quadrate exhibiting greater divergence of morphologies between ecomorphs. Individual islands also varied in the level of divergence between ecomorphs, with Jamaican species showing much less morphological divergence than other islands, potentially as a function of the island's younger age and more recent *Anolis* radiation. We also establish that crown giant anoles consistently showed the most divergence from other ecomorphs even after size adjustment, perhaps indicating stronger selective pressures on the skulls of this group relative to others. Finally, we integrated our extant dataset with fossil data, and preliminary results suggest that we can successfully detect multiple ecomorphs from isolated skull elements. This dataset thus provides a framework for characterizing ancient *Anolis* assemblages and unveiling the shifting phenotypic landscape of the *Anolis* radiation during past periods of environmental change.

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## ALETHOPTERID OR NEUROPTERID? DISTINGUISHING MYELOXYLON IN COAL BALLS

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In the Pennsylvanian, medullosan seed ferns that grew on flood plains preserved in the fossil record as adpressed pinnules, and those in coal swamps preserved as permineralized peat in coal balls. Medullosan seed-fern pinnules belonging to *Alethopteris* and the neuropterids (e.g., *Neuropteris*, *Macroneuropteris*, and *Lavineopteris*)are the most common medullosan fossils, and often the most common land-plant fossils in flood-plain assemblages of Pennsylvanian age. These pinnules also occur in coal balls; however, the most common medullosan debris in coal-ball peat are the petioles and rachides (i.e., the branch system) of medullosan compound leaves, known as *Myeloxylon*. It has been difficult to determine whether most *Myeloxylon* specimens bore *Alethoperis* or neuropterid pinnules. The exception is *Myeloxylon* in coal balls from the Duquesne Coal, which is mid-Gzhelian in age. In the Duquesne Coal, *Myeloxylon* that bore neuropterid pinnules can be distinguished from *Myeloxylon* that bore *Alethopteris* pinnules. Our goal is to apply and extend the criteria used to associate *Myeloxylon* specimens with either *Alethopteris* or *Neuropteris* foliage to the Williamson No. 3 coal ball deposit from the Kalo Formation of Iowa, which is mid-Moscovian in age and approximately 9 million years younger than the Duquesne Coal.Features used to separate alethopterid from neuropterid *Myeloxylon* in the Duquesne Coal that also apply in the Williamson No. 3 Mine include: 1, the shape of the sclerenchyma strands in the hypoderm; 2, the shape of sclerenchyma strands in the separation zone formed as the petioles of medullosan compound leaves separate from the stem, and 3, presence or absence of a palisade epidermis, although this is rarely preserved. Sclerenchyma strands that curve around resin ducts is a new character that may help to identify alethopterid *Myeloxylon* in both deposits. The Duquesne Coal in the Ghzelian is one of the youngest coal-ball localities in North America, and the Williamson No. 3 Mine in the mid-Moscovian is among the oldest. If the criteria used to separate alethopterid from neuropterid *Myeloxylo*n in the Duquesne Coal can also be applied to *Myeloxylon* in Williamson No. 3 coal balls, we should be able to use these criteria to identify alethopterid and neuropterid *Myeloxylon* in most North American coal-ball deposits.

## A NEW BASAL SAUROPODIFORM FROM THE EARLY JURASSIC OF ANTARCTICA

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Here, we present the cranial anatomy of a new species of basal sauropodomorph from the Early Jurassic of Antarctica. Basal sauropodomorphs are a paraphyletic clade of animals that make up the evolutionary precursors to true sauropods. These non-sauropod sauropodomorphs arose during the Late Triassic and diversified throughout the Early Jurassic until their extinction at the Early/ Middle Jurassic boundary. Basal sauropodomorphs achieved a global distribution during their reign, including ranging into high latitudes. This new specimen, FMNH PR 3051, is a juvenile and was collected from the lower Hanson Formation on Mt. Kirkpatrick and represents the only cranial remains of a sauropodomorph from that continent. Only one other basal sauropodomorph, Glacialisaurus hammeri, is currently described from Antarctica, but differs from FMNH PR 3051 in femoral anatomy. The skull is mostly complete apart from missing the parietals, one frontal, supraoccipital, and orbitosphenoids, but is mediolaterally compressed and sheared

obliquely. We also present our interpretation of the retrodeformed skull. We used μCT scans to create a digital model of each preserved skull bone in three dimensions. An autapomorphy of FMNH PR 3051 is having unserrated teeth, unlike other basal sauropodomorphs. The teeth are imbricated with each anterior tooth overlapping the successive teeth. The distal margin of each tooth near the apical end is concave rather than straight, a feature seen only in a few other sauropodomorphs. The lingual margin of the teeth is concave. The ratio of the anteroposterior length of the external naris to the orbit is smaller relative to other basal sauropodomorphs. The dentary is dorsoventrally expanded near the symphyseal region. The vomers have forked anterior processes. Phylogenetic analysis suggests that FMNH PR 3051 is a sauropodiform, close to the base of Sauropoda, and sister to the two species of *Eucnemesaurus*. The placement of this species near the transition from basal sauropodomorph to sauropod indicates that it is uniquely positioned to shed light on the morphological and functional transitions that occur in the lineage. The distinctive teeth of FMNH PR 3051 provides insight to the disparity of tooth morphologies and imbrication patterns present within Sauropodomorpha. Studying this specimen within an evolutionary framework will provide insight on the evolution of feeding capabilities within the group.

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## THE BENGUELA UPWELLING SYSTEM AS SEEN FROM ITS CRETACEOUS NORTHERN LIMIT

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The Benguela Upwelling System (BUS), extending from southern South Africa to southern Angola, drives an extremely productive ecosystem and rich fisheries that account for some 20% of global annual catch. Generally considered to have a Miocene origin and to have had fluctuating intensity throughout the Neogene, upwelling in the same region occurred in the Cretaceous. The BUS is now subject to natural and anthropogenic threats common to other parts of the global ocean and others unique to its location. In its long history, the BUS, or its Cretaceous precursor represented along the coast of Angola, suffered the K-Pg extinction. Vertebrates, notably mosasaurs and plesiosaurs went extinct, but in time the community recovered with ecologically similar taxa replacing the extinct species globally. In this example, cetaceans of the Cenozoic replaced the ecological roles of plesiosaurs and mosasaurs of the Cretaceous. All of these taxa can be considered migratory species. Later, the Miocene increase in productivity of the BUS was shown to be a global oceanographic phenomenon as opposed to being specific to the BUS. The warm Pliocene caused, in part if not completely, a reduction in the BUS similar to the southward shift of its northern margin by the incursion of warm Angola Current water effected by present day Benguela El Niños. However, the persistent warmth across the Benguela Current in the Pliocene lasted on the scale of $10^5$ years. The tectonic narrowing of the Indonesian Seaway facilitated the end of the Pliocene warm interval. The end of the Pliocene also saw a marine megafauna extinction in which 36% of Pliocene marine mammal, seabird, turtle, and shark genera did not make it to the Pleistocene, possibly caused by oceanographic changes and reduction of the neritic zone globally. All of these species can be considered migratory and some may have may have foraged in the BUS. Upwelling intensified at the Plio-Pleistocene transition related to the development of cooler global temperatures, glacial conditions, and orbital forcing. The details of productivity, intensity, nutrients, biogeochemistry, and other basic components of this complex system have been and are being determined, especially in Miocene and younger sediments, while the longer view back in geologic time demonstrates a resiliency in the BUS that provides a context for bioconservation. Models predict coastal warming, enhanced stratification, strengthening poleward and weakening equatorward of upwelling, and uncertain productivity. Benguela El Niños will occur with warm, nutrient poor Angola Current water intruding the northern BUS, weakening equatorward intensity, but perhaps not on the scale of the Pliocene warm interval. For the northern limit of the BUS in Angola, during Benguela El Niños currently, less valued species of fish from the less productive and warmer waters at the northern extent of the BUS are exploited. A number of local bioconservation efforts are underway.

## HIGH-PRECISION CA ISOTOPE MEASUREMENTS REVEAL POTENTIAL BIOMINERALIZATION CRISES DURING MAJOR CARBON CYCLE PERTURBATIONS

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Earth Scientists have long hypothesized that $CO_2$ outgassing during LIP eruptions can acidify seawater and impair biocalcification. To test this hypothesis, our group has worked over the past decade to generate high-precision Ca isotope ($\delta^{44/40}Ca$) records spanning multiple candidate ocean

acidification events, including Ocean Anoxic Event 1a (OAE1a), Ocean Anoxic Event 2 (OAE2), the Cretaceous-Paleogene boundary (K-Pg), and the Paleocene-Eocene Thermal Maximum (PETM). Notable patterns emerge when the records are aligned relative to operationally defined event boundaries/onsets. All records display similar signals, including both negative and positive shifts *before* the boundaries, negative excursions *after* the boundaries, and subsequent positive recoveries. The consistently repeated pattern is striking given that the records represent different depositional settings, archives, mineralogies, and durations. The signals appear to derive from kinetic isotope effects (KIEs) during primary carbonate mineral formation, which implies that any diagenesis occurred under closed system conditions. Studies focused on inorganic carbonates show inverse correlations between precipitation rate and Ca isotope fractionation, with faster precipitation rates yielding lower $\delta^{44/40}$Ca and slower precipitation rates yielding higher $\delta^{44/40}$Ca. Our findings support assertions that many forms of biogenic carbonate behave similarly. Here, we highlight insights gleaned from OAE2 and the K-Pg boundary. Two bulk carbonate records from the Western Interior Seaway (Colorado), as well as one bulk carbonate record and one foraminiferal (*R. cushmani*) record from the Tethys Ocean (Gubbio), exhibit synchronous patterns featuring a distinctive positive shift preceding OAE2. Shifts toward higher $\delta^{44/40}$Ca before and during OAE2 correlate with shifts to lower Os isotope ratios. The latter reflects volcanic inputs to the surface Earth, but Ca and Os have dramatically different response times. However, Os and $CO_3^{2-}$ have similar response times, and $CO_3^{2-}$ affects calcification rate via saturation state. Meanwhile, in the Lower Critical Interval at Gubbio, *R. cushmani* $\delta^{44/40}$Ca increase as tests become smaller and malformed. Progressively reduced calcification rates provide the simplest explanation for this pattern. Some shoaling of the CCD across OAE2 may reflect reduced carbonate production, while subsequent alkalinization could have drawdown $CO_2$ and caused the Plenus Cold Event. The K-Pg dataset generated from molluscan aragonite identifies an equilibrium fractionation factor of -1.59‰, which matches the value measured in synthetic aragonite precipitation experiments. This contextualizes the K-Pg $\delta^{44/40}$Ca record as the byproduct of KIEs. An argument can be made that the Chicxulub impact coincided with a period of preexisting biocalcification instability. High-precision Ca isotope measurements offer a novel tool for linking geochemical and biological changes in Earth history.

## TENACIOUS TURDS FROM THE UPPER CRETACEOUS SMOKY HILL MEMBER, NIOBRARA CHALK, KANSAS

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The Smoky Hill Member of the Niobrara Chalk (Late Coniacian to Early Santonian), Kansas is renowned for its diverse assemblage of bromalites including coprolites, enterospirae, and even rare regurgitates. Producers of these fecal products are attributed to sharks, teleost fish and marine reptiles based on their variously spiraled and non-spiraled morphologies, containing a range of invertebrate and vertebrate inclusions. Traditionally, examination of these fossils has necessitated sub-sampling via consumptive techniques like disaggregation or dissolution on either portions or the entirety of the specimen. Three-dimensional imaging techniques such as X-ray tomographic microscopy (μCT) offer a non-destructive alternative to reveal both macroscopic and microscopic inclusions. Due to the minimal diagenetic alteration of specimens from this locality, μCT imaging and segmentation facilitates the extraction of structural and taphonomic information potentially obscured by physical extraction methods. This study employes non-destructive methods to explore the diversity of gross morphotypes represented by coprolites and a possible regurgitate from this member alongside their internal structure and inclusions. Preliminary results from segmented specimens offer insights into the taphonomic attributes of the coprolites and their ability to preserve exceptionally delicate structures, with remains of vertebral columns still partially articulated. Lightly to non-mineralized inclusions, possibly crustaceans and scale remains, represent a hidden component of the assemblage rarely preserved otherwise. Virtual renders also enable quantitative analysis of the inclusions with respect to the degrees of fragmentation, the orientation and alignment of bone inclusions relative to the longitudinal axis of the specimen, and the relative proportions of bone, pore space, and phosphatic matrix. This work offers a rare glimpse into the feeding, digestive, and excretory behaviors of producers whilst simultaneously capturing unique paleoecological and paleoenvironmental information.

## INVESTIGATING THE RESPONSES OF DEEP SEA SEDIMENTS TO CENOZOIC PALEOCLIMATE AND PALEOCEANOGRAPHIC EVENTS USING DATA SYNTHESIS AND THE EODP PROJECT

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Deep-sea sediments are exceptionally well preserved in the geological record and provide extensive insights into how ocean-atmosphere interactions have evolved through time and across space. Quantifying changes in sedimentation patterns

through time offers a fundamental understanding of climatic and oceanographic processes across various scales. Biogenic sediments, in particular, are exceptional indicators of marine biogeochemical cycles, especially carbon and silica. Skeletal material from microorganisms such as planktic foraminifera and radiolarians, contribute significantly to the composition of biogenic sediments. Calcifying and silicifying organisms rely on the saturation state of both carbonate ions and silicic acid in the ocean, respectively. This saturation state is influenced temporally and spatially by abiotic and biotic factors; including temperature, ocean gateways, circulation patterns, surface productivity, and biogeochemical cycles. Subsequently, deciphering paleo-sedimentation patterns can be utilised to reconstruct the nature of marine ecosystems and inform about the corresponding climate through time. Biogeographic information, however, is often neglected or poorly represented in academic studies in micropaleontology, with most globally-focused studies typically concentrating on a 'through time' approach, ignoring the concept of space. Neglecting space fundamentally misses important regional and local signals that influence temporal trends, and this can be exacerbated by the differences in over and under sampled intervals. Here, we focus on temporal and spatial changes on a variety of scales to answer some of the most central questions of paleobiology and macroevolution. Utilizing vast quantities of scientific ocean drilling data compiled and harmonized in the extending Ocean Drilling Pursuits (eODP) project, initial biogeographic distributions of four microfossil groups and their corresponding lithologies are mapped, to infer how and why sedimentation patterns have developed through time and across space. Preliminary observations show that moving from the Miocene to the Pleistocene, there are clear increases in the deposition of siliceous sediments, particularly in the Southern Ocean and equatorial Pacific, while there is evidence of significant increases in carbonate deposition in Oceania and the South Pacific. In the future, this data could potentially be used to interpret how sediment distributions and biogeochemical cycles may respond in the future to anthropogenic climate change.

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## THE PHYLOGENETIC AFFINITIES OF THE EARLY AND MIDDLE MIOCENE SMALL-BODIED CATARRHINES FROM EASTERN AFRICA

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The Early and Middle Miocene small-bodied catarrhines from Kenya and Uganda form a diverse species assemblage with contested affinities relative to the crown catarrhine clade. Individual species have historically been identified as early hylobatids, hominids, oreopithecids, pliopithecoids, or more generally as predating the cercopithecoid-hominoid split. The resulting ambiguity hinders critical efforts to resolve ancestral state reconstructions during the initial stages of the hominoid radiation. To investigate the affinities of the eastern African Early and Middle Miocene small-bodied catarrhines, I conducted a new phylogenetic analysis comprising 246 characters coded across 100+ taxa analyzed in TNT 1.6. The comparative sample includes substantial representation of both pliopithecoids and oreopithecids, and takes advantage of the recently published detailed description of the stem hylobatid *Yuanmoupithecus*. Maximum parsimony analyses recover all eastern African small-bodied catarrhines as basal hominoids, with *Kalepithecus* found more basal than the other taxa included in this species assemblage. The putative pliopithecoid *Lomorupithecus* from Napak (Uganda) is found as the sister taxon to *Simiolus* and *Dendropithecus* from Kenya, and all three taxa form a Dendropithecidae that is broadly separated from the more crown-ward Oreopithecidae in the cladogram. Consistent with previous work, *Limnopithecus* is resolved as a polyphyletic taxon, with the referred *L. legetet* material from Koru (Kenya) being closely allied with *Kogolepithecus* from Moroto II (Uganda). These and other findings shed light on early hominoid diversity and underline the similarities in catarrhine primate faunas in the Lake Victoria region during the early Miocene.

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## INVESTIGATING THE TIMESCALE OF TRAIT RE-STRUCTURATION IN A JURASSIC LAKE

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Investigating the evolution of trait covariation is key to understanding how microevolutionary processes create the large-scale patterns commonly studied in macroevolution. Particularly, although many trait evolution models predict characters to diverge through time, qualitative breaks (i.e., change in the structure of traits) are not embedded in such models, and the timescale where such breaks occur is commonly blurred by the lack of temporal resolution intrinsic to most fossil records. Here, I use a high-resolution temporal series of *Semionotus*† (Semionotidae, Actinopterygii) fossils from the Newark supergroup to investigate the timescale in which qualitative breaks in trait covariation among traits occur, relative to an ancestral covariation pattern. In the simple methods (mainly partition of variance) that I apply, I

find no reason to reject covariance breaks within 2,000 years. However, additional suggestive patterns beg the use of more powerful models and additional measurements.

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## UTILIZING ARTIFICIAL INTELLIGENCE FOR EFFICIENT MORPHOLOGICAL DATA INTEGRATION

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MorphoBank (morphobank.org) is a web application and database permitting real-time collaboration on, and archiving of, morphological matrices for phylogenetics, many of which include primary data from fossil species. Administered by Phoenix Bioinformatics, a non-profit organization specializing in digital research resource sustainability, MorphoBank's goal is to intersect with, but not duplicate, the efforts of other digital initiatives in the same scientific domain. MorphoBank has partnered with the Paleobiology Database (PBDB) to transfer 595 peer-reviewed Nexus files describing phylogenetic research on fossils from PBDB to MorphoBank. Student interns, under the supervision of a curator, have been working on this transfer. The matrices are in a Nexus file format, which is widely used for taxa and morphological character data. Each Nexus file is linked to a peer-reviewed published paper, however, the files lack information needed for the data to be fully Findable, Accessible, Interoperable, and Reusable (FAIR). Researchers downloading the file in the original state would not know the names of the characters or the states and would need to backtrack to the original or even older publications to find them. Initial data transfer efforts relied on manual data curation using Mesquite; this was a labor-intensive task due to the highly variable structure, number, and length of character names and states. To increase efficiency in adding this information to the Nexus files, an Artificial Intelligence (AI)-aided solution was developed to automate the process. The result is a web-based tool that streamlines the extraction of character name and state data from published articles. GROBID, a machine learning library widely used in text extraction and structuring, is leveraged to extract text from PDF files and then these data are parsed to filter out extraneous content such as section titles, references, and figures. Gemini Pro, Google's most current large language model, is used to generate a comprehensive list of characters and states. The list is then formatted into an XML tree and the tree is utilized in the construction of character state information for the final Nexus file. Upon completion, the integrated Nexus file is made available for download and this file is now ready for uploading into MorphoBank. This innovative, AI-based approach to data mining offers great promise for capturing morphologic (and other published) data. Current challenges, such as memory limitations with Gemini Pro, have been identified and are actively being addressed to ensure the reliability and efficacy of the system. The implementation of this AI solution represents a significant leap forward in the realm of data transfer and curation, offering a streamlined approach to migrating morphological data matrices from PBDB to MorphoBank. We hope to make a future, well-tested, and stable version of this AI solution available for public use through MorphoBank.

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## THE INDIANA UNIVERSITY PALEONTOLOGY COLLECTION—CURRENT STATUS OF PALEONTOLOGICAL RESOURCES

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The IU Paleontology Collection (IUPC) is a public trust research repository housed in the Department of Earth and Atmospheric Sciences, Indiana University. The IUPC holds >1.5 million fossils, including 1,000 type specimens. Fossils are global in geographic scope, mostly from Paleozoic of North America, with many from Indiana.?Specimens are organized stratigraphically and by locality. Formalized policies for acquisition, collections management, and deaccessions are available on IUPC's website. Although IUPC specimens are not yet organized in a data management system, stated acquisition policy priorities describe major repository holdings and unique segments of the Collection. IUPC curators are tenure-track paleontology faculty appointed by department Chair. A collections manager holds a research faculty position and provides centralization of intellectual resources and knowledge in collections management. Faculty, graduate, and undergraduate students carry out independent research and maintain the integrity and accessibility of the collections. Teaching and training of STEM and all students interested in specimen-based research, collection management, and digitization of fossils and associated metadata form the core of IUPC's outreach endeavors, complimented by specimens loaned for museum exhibits, university classes, and university-sponsored community events. Federal funding allows for research, reorganization of IUPC holdings, and management updates to safeguard the collections. Building remodeling resulted in temperature and humidity-controlled facilities now overseen by a building manager. Financial contributions of private donors provide supplementary support for infrastructure, curation, and staffing. Pairing with IU's zooarchaeology repository under the Center for Biological

Research Collections (CBRC) brings to the IUPC current technological fields of 3D imaging and digital infrastructure development that enhance use of fossil specimens for digitization and metadata preservation. A summer repository research fellowship from IU's Institute for Advanced Study provides opportunity for non-IU researchers to utilize IUPC specimens. The IUPC serves as a recruitment tool for graduate students seeking collections management experience. IUPC teamed with Notes from Nature to bring digitized fossils to desktops. Ongoing efforts link IUPC materials with Tanzania institutions to promote international collaborations and increase scientific, educational, and curatorial cooperation between U.S.A. and Tanzania. Challenges range from placing IUPC holdings into a data management system, advertising effectively to the research community and State of Indiana teachers, making an efficient transition from paper to digital, data storage costs associated with newer digitized data collections, a tenure-track faculty who curate and manage the collections with no formal duties for performance evaluation and promotion, and retention of physical space.

## BEST PRACTICES FOR DESIGNING EXPERIMENTS USING 3D DEFOSSILIZED MORPHOLOGIES

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Collecting and creating 3D morphological data allows us to analyze extinct forms more directly through "defossilization." The form-function relationships of defossilized morphologies can be probed in both virtual and physical experimental environments to examine their suitability for different roles (e.g., defense, locomotion, feeding). However, meaningfully applying 3D data is non-trivial and requires careful consideration of a multitude of factors. For example, investigators must consider how closely their shape data must align with the morphologies they represent because using 3D data can be computationally and financially expensive. Experimental setups must have properly constrained boundary conditions and means of validation. Additionally, for some tests, choosing appropriate materials for the analysis of extinct morphologies can be crucial (e.g., the failure mode of the material may be key for meaningful results). However, in other cases, material properties of morphologies may be less important (e.g., testing how morphologies interact kinematically). This presentation will provide an outline of best practices throughout the decision-making process of experimental design when physically rendering and testing the morphologies of ancient life. Specifically, it will highlight case studies of the functional morphology of mollusk shell shapes. These practices can also be extended beyond experimental work for applications in outreach and education.

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## ARE COMMUNITY TRAIT CHANGES A RESULT FROM ENVIRONMENTAL DRIVERS OR SHIFTS IN SPECIES COMPOSITION?

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Diversity is multifaceted and encompasses various dimensions within ecosystems, including taxonomy, community, and species traits. Diversity is difficult to measure in deep time as we typically cannot directly observe biotic interactions in dynamic abiotic settings changing at a higher frequency than sedimentation typically reveals. Without fossils, though, studies struggle to distinguish between multiple competing hypotheses for how the interplay between biotic and abiotic variation shapes diversity dynamics. Community dynamics, i.e., the number of species present and their abundances within their communities, are influenced by many factors. These communities comprise individual species, each characterized by a unique set of traits that contribute to species' ecological roles within their respective habitats. The spatially, biogeographically, and taxonomically comprehensive fossil record of Plio-Pleistocene planktic foraminifera (PF) allows high-resolution studies of long-term eco-evolutionary change within ecosystems over time. We first show a decoupling of abiotic controls on PF communities during extinction events in the Plio-Pleistocene through an ongoing period of species loss despite no resetting of community structuring rules. We then merge this individual, species, and community resolution with morphometric data from 15,000+ specimens to demonstrate how dynamic size distributions affect key community composition metrics and the proportion of variation in community dynamics that can be explained by individual-level trait variation. Palaeontologists can benefit from integrating the concept of trait diversity with species and community shifts to understand the largest shifts in biodiversity on the longest time scales more comprehensively. Ultimately, recognizing the significance of trait diversity allows for a more nuanced interpretation of the complex interactions driving biodiversity dynamics across different spatial and temporal scales and the idiosyncratic nature of maintaining ecological function through mass extinction events.

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## MIND THE UNCERTAINTY: GLOBAL PLATE MODEL CHOICE IMPACTS DEEP-TIME PALAEOBIOLOGICAL STUDIES

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Global Plate Models (GPMs) aim to reconstruct the tectonic evolution of the Earth by modelling the motion of the plates and continents through time. These models enable paleobiologists to study the past distribution of extinct organisms. However, different GPMs exist that vary in their partitioning of the Earth's surface and the modelling of continental motions. Consequently, the preferred use of one GPM will influence paleogeographic reconstruction of fossil occurrences and any inferred paleobiological and paleoclimatic conclusion. Here, using five open-access GPMs, we reconstruct the paleogeographic distribution of cell centroids from a global hexagonal grid and quantify paleogeographic uncertainty across the entire Phanerozoic (540–0 Ma). We measure uncertainty between reconstructed coordinates using two metrics: (1) paleolatitudinal standard deviation and (2) mean pairwise geodesic distance. Subsequently, we evaluate the impact of GPM choice on paleoclimatic reconstructions when using fossil occurrence data. To do so, we use two climatically-sensitive entities (coral reefs and crocodylomorphs) to infer the paleolatitudinal extent of subtropical climatic conditions for the last 240 million years. Our results indicate that differences between GPMs increase with the age of reconstruction. Specifically, cell centroids reconstructed to older intervals show larger differences in paleolatitude and geographic spread than those reconstructed to younger intervals. However, high paleogeographic uncertainty is also observed in younger intervals within tectonically complex regions (i.e., in the vicinity of terrane and plate boundaries). We also show that when using fossil data to infer the distribution of subtropical climatic conditions across the last 240 Ma, estimates vary by 6–7° latitude on average, and up to 24° latitude in extreme cases. Our findings confirm that GPM choice is an important consideration when studying past biogeographic patterns and paleoclimatic trends. We recommend using GPMs that report true paleolatitudes (i.e., use a paleomagnetic reference frame) and incorporating paleogeographic uncertainty into paleobiological analyses.

## PALAEOVERSE: A COMMUNITY-DRIVEN R PACKAGE TO SUPPORT PALAEOBIOLOGICAL ANALYSIS

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The open-source programming language 'R' has become a standard tool in the paleobiologist's toolkit. Its popularity within the paleobiology community continues to grow, with published articles increasingly citing the usage of R and R packages. However, there are currently a lack of agreed standards for data preparation and available frameworks to support implementation of such standards. Consequently, data preparation workflows are often unclear and not reproducible, even when code is provided. Moreover, due to a lack of code accessibility and documentation, paleobiologists are often forced to 'reinvent the wheel' to find solutions to issues already solved by other members of the community. Here, we introduce palaeoverse, a community-driven R package to aid data preparation and exploration for quantitative palaeobiological research. The package is freely available and has three core principles: (1) streamline data preparation and analyses; (2) enhance code readability; and (3) improve reproducibility of results. The palaeoverse toolkit provides a user-friendly platform for preparing data for analysis with well-documented open-source code to enhance transparency. The functionality available in palaeoverse also improves code reproducibility and accessibility, which is beneficial for both the review process and future research. Through palaeoverse, we hope to help bring paleobiologists together to establish agreed standards for high-quality quantitative research.

## TESTING THE EFFECTS OF COVERAGE-BASED SAMPLING STANDARDIZATION ON FOSSIL TIME SERIES OF MORPHOLOGICAL DISPARITY

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Reconstructing past biodiversity using the fossil record is a central goal of paleobiology. It is widely recognized that face-value (i.e., "uncorrected," or "raw") estimates of biodiversity may be biased by variation in sampling intensity across time, space, environments and taxonomic groups. Because of this, sampling standardization approaches are routinely used when estimating measures of taxonomic diversity, such as species richness. However, sampling standardization approaches are less commonly used when estimating alternative currencies of biological diversity, such as morphological disparity. Here, we show the effects of standardizing fossil time series of morphological disparity to equal sample completeness, or coverage of the underlying frequency distribution (coverage-based rarefaction, also known as shareholder quorum subsampling or SQS). We apply coverage-based standardization to three published datasets of discrete morphological character (echinoderms, trilobites, and ornithischian dinosaurs), and quantify disparity using two metrics: weighted mean pairwise dissimilarity (WMPD) and sum-of-variance (SoV). We also contrast the effects of coverage-based and sample-size-based standardization. Our results show that coverage standardization can yield estimates of disparity through time that dramatically deviate from face-value estimates, both in magnitude and direction of changes through time. These findings demonstrate that future studies of morphological disparity should control for variation in sampling intensity to make more reliable inferences.

## PLEISTOCENE MAMMALS FROM A KARSTIC FISSURE FILL IN PENDER COUNTY, NORTH CAROLINA

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In 2011, local collectors discovered deposits of fossiliferous Pleistocene sediments preserved within the Eocene Castle Hayne Formation Limestone in a North Carolina quarry. The Pleistocene sediments were exposed and excavated by quarry operations, and the majority of the fossil material was found in discard piles. Recent efforts to curate the specimens have allowed for better understanding of the fauna despite a very abbreviated collection window and lack of systematic collection. Given the lack of fossiliferous fissure fills reported in the Atlantic Coastal Plain outside of Florida, and the sparsity of North Carolina's terrestrial Pleistocene mammal record, this material provides unique insights into an understudied area. Here we provide a description of the mammal fauna found in this quarry and attempt to discern the depositional age and paleoenvironment. The recovered mammal fossils consist of mostly postcranial elements from *Tapirus haysii* (tapir), *Paramylodon* cf. *harlani* (giant ground sloth), *Dasypus bellus* (giant armadillo), *Equus* (horse), and *Castoroides* (giant beaver). Though rare, cranial elements are represented (e.g., paired dentaries from a juvenile *T. haysii*). The bias towards large mammals is a result of collection and preservation biases due to quarry operations and the nature of the collecting. Tapirs are overrepresented compared to the other taxa, with a minimum individual count of three tapirs present at the site. Juvenile material is also overrepresented in this sample. The deposition of the fissure fill is temporally constrained by the co-occurrence of *Tapirus haysii*, *Castoroides*, and *Paramylodon harlani*, which suggests an early Irvingtonian (1.6–1.0 Ma) age, although some time averaging cannot be ruled out at this point. This deposit represents the first reported occurrences of *Paramylodon* and *Castoroides* in North Carolina, although it is not outside of their expected ranges. Based primarily on the presence of *Tapirus*, along with the presence of pond turtle material, and comparisons to the Haile 7C Quarry site in Florida, the deposits most likely represent a pond surrounded by dense vegetation. The presence of *Equus* could indicate access to more open habitat nearby. Analysis of non-mammalian and smaller mammal fossils from the site may help further resolve the depositional age and environment.

## TRILOBITE CO-OCCURRENCE PATTERNS ACROSS THE DEVONIAN-CARBONIFEROUS BOUNDARY

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Trilobites, once major prolific members of benthic communities in the Paleozoic, were reduced to one order, Proetida, following the Devonian extinction events. Curiously, proetid trilobites were riveled in diversity by other trilobites, such as phacopids, throughout the Devonian. Phacopids especially surpassed proetids in diversity for much of the mid-to-late Devonian before complete extinction. Despite the differing selection pressures of each group being well studied separately, the two orders have not been examined together to determine if any co-occurrence transpired across this interval of change. In order to tease apart any potential biotic interactions between these two groups, a co-occurrence analysis was conducted. This co-occurrence analysis examined trilobite relationships across space in two ways: biogeographic regions across the Devonian world and position on the continental shelf. I found that proetids and phacopids did not overlap biogeographically much across the Devonian but, when there was overlap, they did overlap on continental shelf space in the late Devonian. Both groups, considered "morphologically conservative" in comparison to other trilobites, may have resembled each other morphologically (e.g., eye-less) due to similar overlap in continental shelf space (e.g., deep benthic). More work needs

to be done to determine the potential for biotic interactions amongst major trilobite clades in the Paleozoic.

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## CAN CRYSTAL ORIENTATION BE USED TO RECOGNIZE MICROBIAL INFLUENCE IN MINERALIZATION? ANALYZING CRETACEOUS CALCAREOUS COPROLITES USING ELECTRON BACKSCATTER DIFFRACTION (EBSD)

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Crystal orientation within fossils may help identify whether microorganisms were involved in mineralization by revealing a distinctive crystallographic "fingerprint" of microbially-mediated mineralization. Previous studies have shown that calcite precipitated by bacteria can be described as "messy" because the crystals are not aligned with each other. This crystallographic feature is called misorientation and is quantified by how adjacent crystals' orientation differ from each other in terms of a rotation angle or axis. Although experimental evidence has demonstrated that crystals formed in association with microbes have more frequent and greater misorientation than abiotic crystals, few studies have tested this in fossils. Electron backscatter diffraction (EBSD) is a microscopy technique capable of measuring the orientation of crystals on the micron scale. In this technique electrons shot at a sample are reflected back towards a sensor at an angle which indicates the orientation of the crystal's lattice pattern. In this study we use scanning electron microscopy (SEM) to look for morphological evidence of microbes and EBSD to analyze crystal misorientation in fossil wood within calcareous coprolites and non-coprolite fossil wood. We analyzed fossilized feces because of the high density of bacteria within feces and because taphonomic studies suggest that bacteria likely play a role in the fossilization. The specimens examined in this study are from the Cretaceous Two Medicine Formation, Montana and were likely produced by herbivorous dinosaurs. SEM revealed morphological evidence of diverse mineralized structures resembling bacteria within the coprolites which appear to be fossilized remains of the fecal microbiome. EBSD showed that organic rich samples in both coprolite and non-coprolite wood had a greater frequency of large misorientation angles compared to organic poor non-coprolite wood. However, EBSD also showed that crystal c-axes tended to be aligned with the long axis of the tube-like wood cells, indicating that the shape of the wood cells likely influenced the orientation of crystal growth. Nevertheless, EBSD also showed that the trends in crystal misorientation angle and axis of the organic rich samples are consistent with previous studies characterizing microbially precipitated minerals. We suggest that the abundance of organics correlates with abundance of bacteria. If this is correct, our EBSD results indicate greater misorientation in microbially (organic) rich samples than microbially (organic) poor samples. This is consistent with previous findings that involvement of microbes in mineralization will result in more frequent and greater misorientation between crystals. Even so, our data cannot address whether bacteria played an active or passive role in mineralization. These findings support the potential utility of EBSD crystal misorientation analysis as a tool for identifying microbial mineralization in fossils.

Funding source: University of Colorado Museum of Natural History; The Geologic Society of America; Evans Award, CU Boulder Geological Sciences

## ECOLOGICAL PATTERNS OF THE ANGIOSPERM DIVERSIFICATION IN THE EARLY CRETACEOUS DEPOSITS OF THE CLOVERLY FORMATION

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Plant megafossils and microfossils from the Lower Cretaceous Cloverly Formation in the Bighorn Basin document a dramatic shift in plant community composition. This shift corresponds with the appearance and diversification of angiosperms in North America. To better understand this transition, we collected plant fossils from the Little Sheep Mudstone Member, the Himes Member, and the Greybull interval of the Cloverly Formation and compared species diversity and species composition across sites and depositional environments. Collections of plant megafossils from sites in Little Sheep Mudstone Member include ferns and gymnosperms, whereas collections from the Himes Member and Greybull Interval also include angiosperm foliage. Although mean site richness is similar in the Little Sheep Mudstone Member and the Greybull Interval, maximum site richness is much higher in the Greybull interval. This difference is largely explained by the appearance of herbaceous angiosperms, particularly in fine-grained channel-fill or estuarine deposits. These herbaceous angiosperms have small leaves with low-rank venation and most show patterns of leaf dissection and venation more typical of extant eudicot angiosperms than of ANA-grade, monocot, or magnoliid angiosperms. We have not detected angiosperm pollen in the Little Sheep Mudstone Member, and it is very rare in samples from the Greybull Interval, consistent with the hypothesis that these angiosperms produced low amounts of pollen compared to the co-occurring gymnosperms and were likely insect-pollinated. Together, the available evidence so far suggests that during the mid-Cretaceous herbaceous

angiosperms augmented plant diversity and not that they competitively displaced other lineages of vascular plants.

Funding source: Smithsonian Peter Buck Predoctoral Fellowship, University of Maryland College Park, Evolving Earth Foundation, William Jewell College

## THE IDENTITY OF AMEBELODONTIDS FROM MIXSON'S BONE BED AND ITS BIOGEOGRAPHIC IMPLICATIONS

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The Amebelodontinae is a subfamily of Neogene shovel-tusked gomphotheres that is found extensively across Africa, Eurasia, and North America. While several lineages have been described, their systematics and phylogeny remain poorly resolved. The genus *Amebelodon* was first described in North America for a longirostrine shovel-tusker from Nebraska. Since then, other similar longirostrine shovel-tuskers from Florida and the mid-continent have been referred to this genus. One such, *A. floridanus*, originally described from specimens collected from the late Miocene-early Pliocene Mixson's bone bed in Levy County, Florida, has a long and convoluted taxonomic history. Through a comprehensive historical analysis, we clarify the type status and taxonomy of the amebelodontid from Mixson's bone bed, and demonstrate that the type material of *A. floridanus* is lost. Further, we assign a neotype, and by analyzing cranio-dental morphology, we argue that the amebelodontid from Mixson's bone bed should remain classified under the genus *Amebelodon*. We also exclude *A. hicksi* and *A. paladentatus* from being synonymous with *A. floridanus*, and tentatively retain them as valid taxa until further comparisons are made with amebelodontids from across Afro-Eurasia. Lastly, based on our biochronological analysis, we present new hypotheses for multiple amebelodontid dispersals into North America.

## FOSSILS ACROSS BORDERS IN TIME AND SPACE: THE IMPACT OF THE HARVARD-GSP PROJECT ON THE DEVELOPMENT OF EVOLUTIONARY PALEOECOLOGY IN THE INDIAN SUBCONTINENT

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The first scientific collections of fossils in the Siwalik Group were made by British explorers in the 1830s is what is now northern India and Pakistan. So unparalleled was the find that the Wollaston Medal was awarded for the discovery. This, along with subsequent collections made by the then colonial Geological Survey of India, and by American paleontologists in the late-19th and early-20th centuries produced one of the largest assemblages of fossil vertebrates known from the last 20 million years. But it was the Siwalik primates collected by Yale's G. Edward Lewis in 1932 that set the stage for modern expeditions by American and European teams in India and Pakistan, including the Yale, then Harvard-Geological Survey of Pakistan (GSP) expeditions over the last 50 years. These studies have resulted in the most comprehensive picture of faunal evolution and dynamics of the Neogene of South Asia. In contrast, India Siwalik paleontology at the same time was largely focused on systematics and biostratigraphy. Faunal dynamics were not systematically investigated despite new paleomagnetic chronologies now available for several Indian sections. It wasn't until a new generation of Indian paleontologists inspired by work done by the Harvard-GSP group came to the forefront, that new techniques and data such as stable isotope geochemistry, functional traits, and turnover analyses already used on the Pakistani record were used in the study of the Indian Siwaliks. These studies showed that there was a significant change in the mammalian fauna in the late Pliocene and early Pleistocene with the inception of glacial-interglacial cycles, the immigration of several new African and Eurasian lineages into the Siwaliks following the extinction of older Neogene lineages, and a pronounced impact of monsoonal forcing on the ecosystems. Furthermore, new paleontological explorations in Kutch in western India have produced faunas that are co-eval with those from the Potwar Plateau. The Potwar record developed by the Harvard-GSP group has helped Indian paleontologists identify the fauna, and place them within a broad temporal framework in the absence of independent chronological constraints. The most significant contribution of the Harvard-GSP project is the development of finely resolved fossil record in South Asia that parallels or even surpasses the more extensively studied records from North America, Europe, and the East African rift. This record can reveal novel insights into macroevolutionary patterns and dynamics, such as long-term mammalian extinction and origination rates, that are largely understood today based on the North American fossil record. The Harvard-GSP project has set the gold standard for paleontological and geological investigations in the Cenozoic of South Asia, and put the region firmly back on the map of the most significant fossil records ever found.

## UNRAVELING THE EFFECTS OF PRESERVATIONAL BIASES ON GASTROPOD DIVERSITY TRENDS FROM THE JURASSIC TO THE PALEOGENE

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A consistent challenge that paleobiologists face when trying to discern evolutionary and ecological trends in deep time is the effect of preservation biases on fossil assemblages. Processes that can bias paleontological data include the lithification of sedimentary deposits and the preferential dissolution of aragonitic fossils like gastropod shells during diagenesis. Starting in the Jurassic, partially lithified and unlithified sediments become increasingly common in the geologic record while gastropod preservation quality, taxonomic diversity, and size range all appear to rise. The simultaneous timing of these changes creates uncertainty about the extent to which the apparent gastropod radiation represents a real biological trend versus a trend in preservational quality. To address these questions, we have compiled a dataset of gastropod species-occurrences in assemblages from the Jurassic to the Paleogene based on a survey of published books, journal articles, and monographs. We recorded the length and width of illustrated gastropod fossils and calculated overall shell size as their geometric mean. The preservational conditional of each specimen was assessed using three semi-quantitative metrics: shell completeness, surficial pristineness, and degree of lithification, each of which was rated on a three-point scale based on attributes that were observable in photographs. Our preliminary results support the notions that preservational quality on average improves from the Jurassic to the Paleogene and that smaller fossils are underrepresented in assemblages with poor preservation. Here, we explore how these preservational issues differentially impact various taxa within Gastropoda, as well as any implications for our understanding of gastropod ecological and evolutionary history.

## INFLUENCE OF LOCOMOTOR BIOMECHANICS ON MORPHOLOGICAL AND PHENOTYPIC DIVERSIFICATION IN CARNIVORAMORPHA (MAMMALIA)

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Fundamental laws of physics govern all biological motion. Locomotion, in particular, resides at the intersection of anatomy and physics. Therefore, an in-depth investigation of locomotion can provide valuable insights into understanding how biomechanics contributes to morphological diversification. This study focuses on the Carnivoramorpha, the mammalian group that includes Carnivora (crown group) and its nearest sister clades (stem Carnivoramorpha). Dating back at least 60 million years, the group exhibits a range of body sizes, ecologies, and locomotor behaviors. Relating limb morphology to locomotor function among carnivoramorphans offers new insights into the broader relationships between biomechanics and phenotypic diversification, particularly as locomotion is a key aspect of vertebrate biology. By integrating biomechanical models—specifically Finite Element Analysis (FEA)—with phylogenetic comparative methods, we are establishing more precise connections between phenotypic variation and biomechanical function. Our dataset includes extant and fossil taxa (the latter spanning from the early Eocene to the Pleistocene), sampling the humerus and femur of species exhibiting climbing, digging, running, and swimming behaviors. External dimensions of the humerus and femur from approximately 60 extant and 10 fossil taxa were measured, aiming to identify morphological convergence using external bone dimensions. This dataset enables us to compare and contextualise extinct and recent species relative to each other for a better understanding of the range of variation within Carnivoramorpha and ancestral conditions for its major groups. 3D FEA models were also created for exemplar taxa to quantify how bones as physical structures withstand external forces. From the models, bone strain and bending moments were calculated to facilitate a biomechanical comparison among fossil and extant carnivoramorph species exhibiting varied locomotor behaviors. Phylogenetic comparative methods will help reveal whether convergence in biomechanical function (e.g., strain or bending moments) coincides with morphological convergence (e.g., linear dimensions).

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## HIGH-THROUGHPUT PHENOTYPING REVEALS A 19TH-CENTURY DECLINE IN CLONAL REPRODUCTION OF BENTHIC FORAMINIFERA IN THE SANTA BARBARA BASIN, CALIFORNIA

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Marine microfossils have long been used to investigate environmental and eco-evolutionary dynamics at high resolution, but few studies have taken advantage of their ability

to record life history variation. In annually- to decadally-resolved systems such as the Santa Barbara Basin (SBB, Northern California), reproductive variation in the microfossil record can provide insight into baseline trends over long timescales as well as into the impacts of recent, rapid climate and anthropogenic change on reproductive allocation. Here we present an ~800-yr (1248–2008 CE) record of reproductive mode from ~45,000 Bolivina benthic foraminifera from the SBB. Using a high-throughput morphometrics data, we phenotyped individuals, scoring each as the product of either sexual or asexual reproduction, to examine changes in individual accumulation rate and the prevalence of reproductive mode. Across four different Bolivina species, increases in accumulation rate tend to be associated with increases in the proportion of asexual reproduction, suggesting clonal blooms during permissive environmental conditions. However, in the mid-19th century asexual "blooms" abated, as both abundance and the proportion offspring of asexual reproduction dropped and remain low through the present day. Interestingly, terminal test size (here, a proxy for body size) changes within these same species are lagged, with most undergoing size decreases in the mid-20th century CE. While proxy records for oxygenation state of the SBB predict Bolivina abundance until the 19th century, the loss of high-abundance asexual events following this interval is unexplained by any of the proxies we examined. As the timing of change in Bolivina life history and body size corresponds with major shifts in human-environmental interactions that accompanied the intensifying colonization of California. Our study suggests that Bolivina reproduction may have undergone a state change in the SBB in the mid-19th century CE, and opens new avenues for the study of the impacts of global change through the lens of life history evolution.

## DECODING CALCIUM COMPENSATION DEPTH VARIATIONS AT EOCENE-OLIGOCENE CLIMATE TRANSITION: AN OUTLOOK FROM IODP HOLE 1218 A

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The studies on paleoclimate depends upon the reliable measurements of past ocean temperature coupled with the understanding of paleoenvironmental niche. Faunal analysis record of benthic foraminifera along with total organic carbon and calcium carbonate from the IODP Hole 1218A were studied, to comprehend the EOT of the East Equatorial Pacific Ocean (EEP). TOC records shows a maximum value of 3.21 wt. % and a lowest value of 0.05 wt.% demonstrate a minimal organic carbon flux during this transition. Sudden increment of concentration from 0.13 wt. % at ~ 33.92 Ma and 54.29 wt. % at ~33.72 Ma of CaCO3 values suggest an accurate capture of the E-O Calcite Compensation Depth (CCD) deepening in EEP. The formation of the Antarctic Circumpolar Current and opening of Southern Ocean gates thermally isolated Antarctica, resulted in a significant temperature cooling during the E-O boundary and simultaneously increased ocean mixing ventilated the deep ocean and reduced deep-ocean acidity sufficiently to deepen the CCD. The quantitative faunal analysis of benthic foraminifera shows a dominance of epifaunal species in the study area over infaunal species infers an oligotrophic, well-oxygenated bottom water habitat during the EOT. The major change from opal to carbonate-rich sediments support the abundance of benthic foraminifer accumulation rate during the EOT which enhanced the productivity of the Pacific Ocean.

## EMPOWERING CLUBS TO ADVISE ON ACADEMIC GRANT PROPOSALS' BROADER IMPACTS SECTIONS: FULFILLING AVOCATIONAL NEEDS WHILE BOOSTING GRANT FUNDING RATES

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Collaborations between avocational and academic professional paleontologists achieve remarkable outcomes year after year: new species, new evolutionary insights, new domains of study made possible. However, opportunities for avocational participation in discovery depend on site access, which has become increasingly limited (the "avocational pain point") as a result of ongoing trends: legalism, aging exposures, and industry consolidation under multinational corporations. In this context, we ask whether a matching pain point exists for academics and, if so, what particular interaction with avocationals would align the incentives of these two groups so that they resolve each others' pain points. Indeed, academics do experience a matching pain point: the crucial Broader Impacts sections of academic grant proposals often fail to convincingly propose local public engagement opportunities relevant to the proposed research. These sections are now so critical to proposal success that lackluster Broader Impacts sections cause scientifically worthy grant proposals to go totally unfunded (the "academic pain point"). Such failures could be mitigated if only a local avocational leader were in place to bridge the geographic divide between remotely located academics and the interests of their research sites' local communities. Indeed, local avocational leaders possess the precise knowledge of concrete public engagement opportunities that makes for a convincing Broader Impacts section. This knowledge can include potential fossil park sites, personal relationships with quarry managers, and community stakeholder awareness. To match each group's pain point with the remedy held by the other group, collaboration should be actively facilitated between

each local area's avocational paleontology community leaders and remote academics seeking grants related to fieldwork in that area. As noted above, local avocational paleontology community leaders are uniquely positioned as the academics' remedy. In turn, successfully funded grants with Broader Impacts sections informed by local avocational leaders fund exactly those components prioritized by the avocational community: meaningful improvements to fossil access, exposure freshening, and hands-on opportunities for children and families. Funding through such grants thus uniquely positions academics as the avocationals' remedy, completing the circle and aligning the two groups. In concrete terms, we propose the establishment of an entity that (1) maintains a network of local avocational paleontology community leaders, (2) guides grant-seeking academic paleontologists and their institutions' grantwriting departments to the relevant local avocational paleontology community leader(s), and (3) facilitates individual conversations between local avocational leaders and grant-seeking remote academics to locate and develop concrete strategic alignments for Broader Impacts.

## FOSSIL COLLECTIONS DATA: RESOURCES, STANDARDS, COMMUNITY

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The last two decades have seen an exponential rise in digitization of fossil collections, ways to access newly digitized data, and ways to discover information about the collections themselves (contacts, holdings, etc). Over 10 million fossil specimen records, including millions of images, are currently available via online biodiversity-focused portals such as GBIF.org and information about many fossil collections themselves can be found on the Global Registry of Scientific Collections (GrSciColl, now hosted by GBIF.org). The Paleo Data Working Group (PDWG) was launched in 2020 as a way to engage the paleo collections community with the growing amount of digital resources, databases, and data standards, and to provide a virtual community learning space for understanding this rapidly expanding ecosystem. With this mission, one of the aims of PDWG is to "leave no collection behind" in terms of digitization and sharing data. Biweekly virtual Happy Hour sessions focusing on different topics help to both raise the overall level of understanding of the collections digitization landscape and also provide a means for engaging with non-paleontology focused digital initiatives. Building on the foundational work of PDWG, a project funded through the NSF GEO OSE program (November 2023-November 2025) will synthesize existing resources and standards for fossil collections and their data into a centralized knowledge hub, which will serve as a community resource for all things related to digitized fossil specimens. The project will also facilitate up to 10 non-digitally mobilized collections joining a newly developed Symbiota portal, where collections can manage specimen data, enable public access digitally, and share data with GBIF, as well as engage in related activities like registering their collection information with GRSciColl. Leveraging existing biodiversity tools and infrastructure for the needs of the paleontological community will enhance discoverability of collections and their data, and make possible ground-breaking research using big data.

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## NEOGENE CLIMATE-FIRE-VEGETATION FEEDBACKS IN THE SIWALIKS AND BEYOND

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Today, frequent fires maintain savanna ecosystems across the globe. Based on these observations, Keeley and Rundel (2003, 2005) hypothesized that increased incidence of fire, alongside other climatic drivers, may have contributed to the expansion of C4 dominated ecosystems in the Miocene. Perhaps the most robust carbon isotope evidence of Neogene C4 grassland expansion in the world is recorded material in the thick sequence of well-calibrated Miocene fluvial deposits forming the Siwalik Series of the Potwar Plateau, Pakistan, making this unique section an ideal place to test this longstanding idea. We measured polycyclic aromatic hydrocarbons (PAHs), a suite of molecules that can derive from the incomplete burning of terrestrial vegetation, from both paleosol samples from the Siwaliks as well as marine sediments from the Bengal Fan (ODP 717/718). We then compared these records to other biomarker proxies for vegetation and hydrologic change. We found evidence for two increases in fire activity, one that predates C4 dominance at ~10 Ma and one coincident with it at ~7–6 Ma. This supports the idea that climate-driven feedbacks between fire and vegetation 1) facilitated landscape opening, and 2) maintained grasslands once they were established. This work emphasizes that landscape level disturbance processes can have profound impacts on ecosystem transitions even on long (~Ma) timescales.

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## THE NEOPROTEROZOIC EMERGENCE AND ENVIRONMENTAL CONSEQUENCES OF BIOMINERALIZED SPONGE GRADE ANIMALS

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While molecular clock studies suggest a Tonian-Cryogenian (~800–635 Ma) emergence of the Porifera, convincing fossil evidence of sponges is seen only as far back as ~530 Ma. The >100 Ma lacuna for sponges represents a critical missing piece of the Neoproterozoic puzzle. Assembling an evolutionary framework requires that Poriferan antiquity be understood in terms of sponge form and function, and the emergence of suspension-feeding amid profound environmental and climatic change. Here we report newly discovered biomineralized fossils of sponge-grade animals in Neoproterozoic carbonates of Siberia, Australia, and Brazil. Using a wide range of petrographic, eProbe, μXRF, μCT, and serial grinding techniques, the sponge-grade fossils are shown to be remarkably preserved in three dimensions, displaying broad morphological characters associated with early experiments in biomineralization such as siliceous spicules and external carbonate shells. Reconstructions of their bauplan reveal forms evolutionarily equipped for a suspension-feeding lifestyle, well-prepared for pumping seawater through their bodies. As ecosystem engineers that clarified the water column and allowed for greater depths of photosynthetic activity, the emergence (and dominance) of sponge-grade animals in shallow marine carbonate reefs had the potential to drive environmental change that is arguably recorded during extremes in the Neoproterozoic carbon cycle. With their global distribution, these animals would link the planktic and benthic realms for the first time in Earth history and represent a sink for the photosynthetically derived organic matter that impacted the oxidation state of the oceans and atmosphere. Notably, most of these fossils are archived in carbonates preserving global expressions of profoundly negative carbon isotope perturbations. These include the Ediacaran Period Shuram Excursion, which foreshadowed the widespread appearance of the Ediacara biota, and the terminal Cryogenian Period Trezona Anomaly, which immediately preceded the Marinoan snowball Earth.

## INVESTIGATING THE TIMING AND SPATIAL VARIATION OF PLANKTIC ECOSYSTEM RECOVERY FOLLOWING THE END-CRETACEOUS MASS EXTINCTION EVENT

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A cacophony of human activities, including anthropogenic warming, is changing the oceans impacting biodiversity as well as complex systems such as primary productivity and the carbon cycle. Our understanding of how planktic ecosystems will respond and recover from ongoing global change is limited. Using the fossil record we can investigate the long-term impacts of various perturbations through geological time to understand the processes and timings of recovery. In this study we use sediment from the Tethys Ocean (El Kef, Tunisia) and Gulf of Mexico (Texas) capturing the recovery of neritic planktic ecosystems in the aftermath of the end-Cretaceous mass extinction (K/Pg). We present a combined record of planktic foraminifera, calcareous nannofossils and organic biomarkers from the latest Maastrichtian through the earliest Danian capturing both fossilizing and non-fossilizing plankton recovery. Using effective diversity analysis (Hill numbers) we show diachronous recovery of different plankton groups at El Kef. Both planktic foraminifera and calcareous nannofossils are dominated by disaster taxa in the initial 300 Kyr of recovery. Planktic foraminifera assemblages show rapid turnover within this period with shifts in the abundance of dominant taxa (*Guembelitria* and *Chiloguembelina*) as well as the occurrence of new Danian species. In contrast calcareous nannofossils have subdued diversity within this initial recovery phase with one taxon, *Neobiscutum* spp, dominating for 1.5 Myr. Only once dominant taxa in both these groups disappear does diversity of fossilizing plankton increase and return to pre-extinction levels approximately 2.5 Myr post extinction. Organic biomarkers indicate that non-fossilizing plankton also show fluctuations in dominant groups with blooms of dinoflagellates, diatoms and prymnesiophytes gradually replaced by red algae. Initial analysis of planktic foraminifera from the Brazos River site indicates that this section features an expanded initial recovery phase which will allow for high-resolution investigation of planktic ecosystems within the first 300 Kyr of recovery.

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## CLIMATE CHANGE AND BIODIVERSITY LOSS SHAPE MICROMAMMAL COMMUNITY ECOLOGY OVER THE LAST 22,000 YEARS AT HALL'S CAVE, TEXAS

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North American micromammal communities endured the terminal Pleistocene megafaunal extinction and post-glacial warming with relatively minor turnover. To characterize how these communities persisted *in situ*, we examined fossils of ten micromammal taxa (*Geomys*, *Thomomys*, *Neotoma*, *Sigmodon*, *Microtus*, *Chaetodipus*, *Onychomys*, *Reithrodontomys*, and two *Peromyscus* morphotypes) found throughout the 22,000 year record at Hall's Cave, Texas. We evaluated community ecology over time via microCT-derived 3D dental ecomorphological diet proxies (n>600 lower jaws), $\delta^{13}C/\delta^{15}N$ isotopic niche (n>2000), and body size measures (n>6000) for each taxon spanning 13 time intervals. Analyses were nested such that all jaws analyzed for 3D dental ecomorphology were also sampled for $\delta^{13}C/\delta^{15}N$ stable isotopes, and body size was reconstructed for all specimens sampled for isotopes using dental allometric regressions. We characterized isotopic niche width using Bayesian standard ellipse areas (SEA ‰), targeting 15 individuals/species/time bin. We quantified mean pairwise niche overlap between all taxa within each time bin as a proxy for potential resource competition. For most taxa, isotopic niche widths contracted in the Holocene consistent with decreased habitat heterogeneity. Potential resource competition decreased from ~51% in the Pleistocene to >45% in the post-extinction millennium before increasing to ~60% for much of the Holocene. More defaunated, homogenous Holocene micromammal communities may thus experience greater interspecific competition relative to megafauna-generated, mosaic Pleistocene habitats. Different micromammal taxa responded to climate change and biodiversity loss with unique shifts in body size and isotopic niche. For several taxa, dental ecomorphology shifted together with stable isotopes, suggesting rapid adaptation. MicroCT scans facilitated species-level identifications, revealing finer-scale patterns of body size and diet adaptation as well as coexistence of multiple congeneric species for several taxa. Climate variables generally best explained body size shifts over time within taxa, but biodiversity loss associated with the terminal Pleistocene megafaunal extinction briefly overwhelmed the climate body size signal and permanently shifted micromammal community dynamics at Hall's Cave. Our results emphasize the cascading effects of megafaunal extinction and climate change at the microfaunal level and inform long-term ecological consequences of modern anthropogenic extinctions in a warming world.

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## PRIMATES IN THE MIOCENE SIWALIK RECORD OF PAKISTAN IN FAUNAL AND PALEOENVIRONMENTAL CONTEXT

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Primates are found throughout much of the Miocene record sampled in the Potwar Plateau, from about 16.1 to 6.5 Ma. They are highly diverse at higher taxonomic levels, but not speciose, and are uncommon to rare elements throughout most of this time span. Here we examine the Potwar primate record in the context of the broader faunal and paleoenvironmental records, and with respect to variation in the quality of the faunal record through time. Lorisids and sivaladapids first appear at 16.0 and 15.6 Ma, respectively, but record quality is patchy prior to 14.3 Ma and both groups are found in earlier, non-Siwalik sediments in the region. Arboreal small mammals appear to be underrepresented in the Potwar record in general and species of small primates are known from relatively few localities. The last records of sivaladapids (11.6 Ma) and lorisids (8.9 Ma) both fall during periods of relatively good record quality, with the former occurring during a period of declining species richness, particularly among small mammals. The large-bodied ape Sivapithecus first appears at 12.8 Ma, preceded by a lengthy period of high record quality. Two Sivapithecus species, the relatively poorly represented S. indicus (LAD 11.4 Ma) and the more well represented S. sivalensis (FAD 10.2 Ma), may be time-successive, but the intervening record is mostly poor. A third, very large and well represented species, S. parvada, is known from a single locality at 10.1 Ma (Y311), by far the most productive mammal locality in the Potwar sequence. Compared to other localities of similar age, Y311, a large and complex abandoned channel within a large-scale river system, is unusual in the greater proportion of tragulids relative to bovids, equids and suids. Prior to 10.1 Ma was a period of substantial faunal turnover among artiodactyls, which introduced many larger species, and saw the first appearance of equids, at 10.8 Ma. The interval from 9.4 to 9.2 Ma was a period of relatively very high abundance of Sivapithecus (S. sivalensis), which, given the generally high quality record both before and after this interval, appears to represent a genuine occurrence. However, there is nothing

obvious in either the faunal or paleoenvironmental records that might explain this. The last occurrence of Sivapithecus is at 8.5 Ma, at the very beginning of an acceleration in the transition from C3- to C4-dominated vegetation. By this time, relative equid and proboscidean abundance had increased at the expense of bovids and rhinocerotids, suggesting changes in vegetation structure to progressively more open habitats. The first appearance of the monkey Mesopithecus, an immigrant from southwestern Europe, is more than 0.5 m.y. later, at 7.8 Ma, during a period of declining species richness in which C4 grasses are an increasing component of the vegetation. Lastly, we explore differences through time in the primate faunas of the Potwar Plateau and the Siwaliks of India.

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## DEVELOPING PEDAGOGIES TO FOSTER CORE COMPETENCIES FOR THE NEXT GENERATION OF CONSERVATION PALEOBIOLOGISTS: A WORKING GROUP PROGRESS REPORT

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The future of conservation paleobiology (CPB) depends on appropriately training students to translate research results into management policy and practice. However, the developing field of CPB is only beginning to address how to train students. We need to consider new approaches, beyond developing research skills in our students, to prepare them for conservation science careers both within and beyond academia. CPB may be guided by advancements in allied disciplines: recent years have witnessed expanding interest in competency-based learning, and the field of sustainability has been at the forefront of conservation-related fields in identifying competencies. Core competencies such as systems thinking, temporal thinking, normative thinking, strategic thinking, and interpersonal competence may be appropriate for CPB students. A new Working Group, recently funded through the Conservation Paleobiology Network (CPN), brings together a diverse group of participants, selected based on their interest, experience, and current activities in the classroom, in mentoring students, and in working with stakeholders to identify core competencies needed by CPB students and best pedagogical practices for fostering them. Goals of the working group are to: survey the CPB community about existing pedagogical practices; identify core competencies for CPB students; and identify best pedagogical practices for infusing these competencies into training in CPB. We will also develop and/or compile resources for use in training CPB students, such as model curricula, syllabi, reading lists, and examples of pedagogical tools (e.g., exercises, case studies, data bases, projects, assessment vehicles), to be made freely available on the CPN website. This presentation provides a progress report on Working Group activities to date.

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## DEFAUNATION AND COLONIZATION SHIFT THE FUNCTIONAL DIVERSITY OF CARIBBEAN VERTEBRATE COMMUNITIES: IMPLICATIONS FOR ECOSYSTEM SERVICES AND CONSERVATION IN THE ANTHROPOCENE

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The Caribbean has experienced significant biodiversity decline throughout the Quaternary, with extinction and extirpation events linked to anthropogenic impacts. At the same time, introductions of novel species into ecosystems have rapidly increased. These extinction and colonization dynamics influence functional diversity, the suite of functional traits present within an ecosystem, and the prevalence of ecosystem services that humans depend upon such as pollination, seed dispersal, and pest control. Here, I quantify functional diversity change in Caribbean reptiles, a species-rich insular fauna whose contributions to ecosystem services remain poorly understood relative to other taxonomic groups. Species are partitioned into functional entities (FEs), groups of species with similar traits that are expected to provide similar ecosystem services, based on traits such as body size, habitat affinity, and diet. Archaeological and paleontological data are used to reconstruct ecological communities through time, with an emphasis on ancient, native extant, and modern (native extant plus introduced) faunal assemblages. I find that several key FEs are lost due to extinction, and the largest losses of functional diversity occur on small islands, which lost up to 67% of their native FEs. On the other hand, functional redundancy on large islands served as a buffer to major functional diversity loss in the past. Species introductions not only increase functional diversity, but they shift the functional space of reptile assemblages, meaning that introduced species exhibit novel functional trait combinations not found in extinct or native taxa. These shifts in functional diversity leave many native FEs and the communities that they support vulnerable to additional biodiversity loss. I also identify places that have retained a significant amount of native functional diversity, indicating that the anthropogenic history of an island contributes to present-day conservation prospects. I then focus on frugivorous reptiles, which have undergone significant biodiversity decline, but may overlap with frugivorous mammals and birds in terms of plant

mutualisms and the ecosystem services that they provide. By reconstructing Caribbean frugivore communities over the Quaternary, I reveal a non-random loss of large-bodied mammalian and reptilian frugivores, and an influx of avian frugivores through recent species introductions. Similar to the reptile-only dataset, the recent reorganization of frugivore communities is driven by anthropogenic impacts and sets the stage for continued declines in native plant-frugivore interactions. This research provides critical data on long-term functional diversity change in a taxonomic group whose contributions to ecosystem function are understudied and often undervalued, and provides a path forward for conservation management.

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## NEARLY 150 YEARS OF FOSSIL INVERTEBRATES AT THE AMERICAN MUSEUM OF NATURAL HISTORY

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The AMNH collections lie at the heart of the Museum's commitment to protecting, preserving, and disseminating a record of life on Earth. The collection of fossil invertebrates is one of the largest in the world, comprising over 5.1 million specimens including around 16,000 primary types. It was founded in 1875 with the purchase of the James Hall Collection, and since then has grown primarily through fieldwork by AMNH curators and their students, but also through numerous donations from professional and avocational paleontologists. The collection has wide taxonomic, stratigraphic, and geographic coverage, and is particularly strong in Paleozoic marine invertebrates and Cretaceous molluscs. Along with other AMNH departments, Invertebrate Paleontology has recently finished a project to migrate collections data (~140,000 catalog records) to a new Collections Management System. Our priority is now to widen access to these data by making them available online on our website and through external data aggregators. The AMNH has recently invested in a large amount of excellent collections storage space in the new Gilder Center. This has made more space available for fossil invertebrates, giving us the opportunity to embark on further large-scale collections development projects. We are aiming to raise external grant funding to target scientifically and historically important but under-used areas of the collection for re-housing and digitisation.

## THE PARAGARICOCRINIDAE (CRINOIDEA)—A LATE PALEOZOIC DEAD CLADE WALKING

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Robustly constructed camerate crinoids were dominant during the Middle Paleozoic (Llandovery through early Viséan) and relatively rare thereafter. The Paragaricocrinidae are an exception. The oldest member of this family is a new genus from the middle Viséan of northern Alabama, and it was a seed for the radiation of this anachronistic family, which persisted through the Middle Permian (Wordian). The phylogeny of this clade was evaluated with both parsimony and model-based phylogenetic analyses that indicate four new genera should be named in in this family. Although a family known from very low relative abundance, it diversified globally by the Middle Pennsylvanian (Moscovian), with Moscovian paragaricocrinids known from China, Japan, Russia, Spain, and the United States. After the Moscovian, the rate of diversification of this family was greatly reduced with both abundance and taxonomic diversity very low. Yet, it persisted through the Wordian. During the Permian, this family is only known from eight specimens assigned to two genera. Permian paragaricocrinoids are known from Sicily, Timor, Tunisia, and possibly Canada. From the Moscovian through the Wordian, the Paragaricocrinidae was a prime example of an anachronistic, dead clade walking.

## NEW EVIDENCE FOR THE EVOLUTION OF TIME-AVERAGING: HOW TIME IS TANGLED, NOT LOST, IN MARINE RECORDS

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'Gaps in the record' and 'lost time' are long-standing tropes in paleontology, dating back even before Darwin blamed them for an apparent scarcity of evolutionary 'missing links.' However, this somewhat binary view of stratigraphic records oversimplifies the abundant implicit (taphonomic features, sequence stratigraphic context, mixed ecology or diagenesis) and explicit evidence (direct age-dating of shells and bones) for considerable age-mixing of fossils per assemblage. Time isn't lost so much as it is condensed, i.e., tangled and palimpsest by the multiple generations of skeletal remains that have become admixed, no matter the amount of fine sediment that has been winnowed away or never delivered. Over the last few decades, workers have increasingly realized that most fossil assemblages are not suddenly concentrated and/or buried, high-acuity snapshots but rather are 'attritional'

(VP) or 'hiatal' (IP) assemblages that exhibit significant 'age-offsets' (deep-sea micropaleo), providing a temporally coarse but still potentially unbiased signal of local to regional input. The duration of time-averaging (e.g., IQR of ages per assemblage) of shells of diverse carbonate-producing organisms in shallow-marine settings—such as dominate the stratigraphic record—is now well documented as being 100s to 1000s of years (with similar or longer scales in the deep sea record): the majority of individuals were input during the final few 10s to 100s of years, but there's a long tail of much older specimens. Here, we summarize the major take-homes from our surface-grab and core-based tests of the dynamics of molluscan shell time-averaging and burial on the southern California shelf, where ~50 years of solid sediment and pesticides from a wastewater outfall created a strong gradient in rates of sediment accumulation (2 cm/y near the outfall, 0.1–0.2 cm/y distally) and in rates and depths of bioturbation (legacy toxicity stunts burrowers to Paleozoic levels at one site, even now). We find that the first-order control on the scale of time-averaging is the rate of sediment accumulation, as predicted and also found in deep-time stratigraphic sequences, and notwithstanding that it prolongs the average residence of shells within the taphonomically active zone. Biogenic mixing, however, is the second-order control on time-averaging, and it is the primary factor that coarsens the temporal resolution of assemblages as they enter 'final and permanent burial' below the actively mixed layer. Although additional factors need to be considered—e.g., changes in the likelihood of hardground formation, the evolution of deep-burrowers versus surface mixers, evolution in the inherent durability of biomineralized hardparts or their rates of production, and the evolution of hardpart crushers and bioeroders –the key role of bioturbation suggests that, as a testable hypothesis, the scale of time averaging of marine assemblages has in fact increased over the Phanerozoic.

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## PHANEROZOIC REEF BUILDING IN RELATION TO CLIMATE CHANGE

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Modern coral reefs are assessed by the IPCC to be one of the world's most vulnerable ecosystems to climate change but there is some hope among reef biologists that corals and reefs might adapt to anthropogenic climate change. The fossil record can provide critical information about the long-term adaptation potential of reefs to past climatic changes. A global compendium of Phanerozoic reefs, the PaleoReefs Database, serves to evaluate the responses of ancient reefs to rapid and long-term temperature changes. Previous analyses found few significant correlations between reefs and paleoclimatic proxies, but newly available proxy data, and climate models, as well as an improved statistical approach on stratigraphically better resolved data now allow for a much richer understanding of climate impacts on reef development. We can now see patterns in time and their connection with paleoclimates that have previously been observed only spatially. Importantly, many of the correlations with temperature are non-linear. For example, coral reefs tended to proliferate with mean seawater temperatures neither to cold (>16°C) nor too warm (<25°C). Large scale clade-replacements among reef builders as well as reef crises can confidently be attributed to long-term and rapid climatic changes, respectively. Similar to previous findings, latitudinal limits of reef growth (including that of tropical coral reefs) are not correlated with paleoclimate, suggesting limited scope of reefs to escape to higher latitudes under warming. These new results imply that the adaptation potential of coral reefs to climate change is low on short and long geological time scales. The hope that modern coral reefs might adapt to projected climate warming is thus likely in vain. Without mitigation of climate change coral reefs may be lost by the end of this century regardless of conservation efforts. Corals will survive and eventually build new reefs, but the geological record tells us that full reef recovery may take up to millions of years.

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## DEATH BECOMES THEM: UNDERSTANDING THE EXCEPTIONAL

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Konservat-Lagerstätten, geologic deposits containing exceptionally preserved fossils (e.g., complete fossils, soft-tissues, etc.), are some of the most important windows into the history of life. Introduction of the term by Seilacher in 1970 has drawn contentious debates into not only the classification of Konservat-Lagerstätten, but also in comparing Lagerstätten in geologic time and space. Debatable topics include the nature of the fossil record, as deposits from different geologic settings or different time periods will contain a wide variety of taxa; others are related to the historical classification of Konservat-Lagerstätten. While Seilacher

emphasized the importance of fossilization processes (rapid burial, redox conditions, microbial mats) as the key to exceptional preservation, as well as sedimentary facies in the classification of Konservat-Lagerstätten: These factors alone do not yield easy evaluation. Following the wider acceptance of the Konservat-Lagerstätten term in the paleontological community, several attempts were made to classify those in a way that allows for comparison of deposits. In 1988, Allison proposed a mineralogy-based classification, which has since been fleshed out with sedimentary geochemistry and microbial metabolic pathways by Muscente and colleagues in 2017. However, the most common classification followed today is the site-based nomenclature introduced by Butterfield in 2003. This classification refers to localities with a typical style of fossil preservation (e.g., Doushantuo-type, Ediacara-type, Orsten-type, Burgess Shale-type, etc.) and assigns a type to localities bearing the same style of preservation. While in concept a good idea, this has led to ambiguity in assigning sites to certain locality types, as there are no true boundaries in how far depositional environment can stray from the type locality, or how diagenetically overprinted fossil deposits should be treated when the original mineralogy was the same. Another chief concern in the comparison of Konservat-Lagerstätten is the shift of exceptional preservation from open marine settings to transitional and non-marine settings in the Phanerozoic. Here we promote the application of mineralogy as a primary classification, as it not only permits better comparison of Konservat-Lagerstätten through geologic time and space, but also removes a much ambiguity that is introduced by other classification systems. We also show how future efforts at recording mineralogy for newly described deposits, as well as improving our mineralogical knowledge of already described ones, can significantly improve our understanding of exceptional preservation and the geological, evolutionary, and ecological processes behind it.

## FEEDING-CONTROLLED EXPERIMENTS IN MODERN RODENTS IMPROVE PALEOECOLOGICAL INTERPRETATIONS OF ISOTOPES FROM SIWALIK MOUSE TEETH

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The Siwaliks are considered to offer the best Neogene terrestrial record of long-term climate change, vegetational environments, and their biotic influences at both micro and macro scales. Carbon isotope analyses applied to Siwalik fossils provided substantial evidence of differential adaptations in various mammal lineages to a newly emerged C4-dominated vegetation. In early studies, the analyzed taxa were limited to large mammals due to analytical requirements for sample size, whereas laser-ablation techniques later allowed for microvolume analysis even on single small mammal teeth. Murine rodents from the Siwaliks, the most abundant micromammals in the region, have contributed to laser-based pioneer studies, showing that diverging clades consumed C4 grasses corresponding to change of existing vegetations but that the one clade consumed more C4 grasses than its sister clade, thereby partitioning ecological niches through evolutionary history. These results revealed the value of stable isotope analyses in small mammals. Nevertheless, there remains an issue that isotope enrichment between diet and teeth at different loci in the dental series is not well constrained for small mammals because the formation of anterior (especially first) molars overlaps with the lactation period, which causes isotopic uncertainties when paleoecology of large and small mammals is compared. In this study, we present results of feeding-controlled experiments on rodents to model intra-dentition isotopic variation and derive new isotope enrichment factors. Four rodent species, *Mus musculus* (mice), *Rattus rattus* (rats), *Mesocricetus auratus* (golden hamsters), and *Meriones unguiculatus* (Mongolian gerbils) were raised with commercial rat chow with water of known isotopic values. Carbon isotopes of breath of mother-cub pairs were monitored during the lactation and until at least day 40. Molars and incisors of the cubs were analyzed for carbon isotopes by $CO_2$-laser ablation technique. The experiments were conducted between 2018 and 2022 with approval in accordance with the Guidelines for the Care and Use of Laboratory Animals (AAALAC International). Combined carbon isotope values of all molar loci show a logarithmic pattern of a dietary shift from milk-dominated to adult diet along the timing of tooth eruption. This pattern was tracked well by carbon isotope values of breath. These data suggest a consistent value of ~11 per mil for the isotopic enrichment factor even during and after lactation regardless the phylogenetic relationships among the analyzed taxa. The milk effect on first molars accounts for a few permil more negative than carbon isotopes of teeth formed fully with adult diet. Our results provide correction factors for intra-dentition and inter-species variations that allow more precise isotopic comparisons for the interpretation of diet and paleoecology.

## LITTLE BIGFOOT: A PATHOLOGIC ARTICULATED PES OF A SAUROPOD DINOSAUR FROM THE MORRISON FORMATION, BIGHORN BASIN, WY

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Settled within the fossil-rich Bighorn Basin in Hot Springs County, WY, the Foot Site (FS) quarry has produced partially articulated and well-preserved individuals closely resembling *Diplodocus* (Dinosauria: Sauropoda). In the late summer of 2020, an articulated right pes of a subadult diplodocine sauropod was found and later excavated in the spring of 2021. Preparation in the following summer revealed the possibility of a distressed life for this dinosaur. CT scans of the foot showed extensive trauma in the first metatarsal, the medial phalanges of the second and third digits, and the second ungual. The most prominent of those injuries are a spiral fracture in the medial phalanges with evidence of osteomyelitis, a type of bone infection, and a large longitudinal fracture in the first metatarsal. Based on analyses of sediment and microfossils, the paleoenvironment of the larger area containing the FS quarry is currently understood to have been lacustrine, or a similar wetland environment. Microfossil assemblages within the FS sediments suggest that deposition may have occurred on the periphery of the lake or wetland where sediments were periodically inundated, with an infrequent ability to support diverse aquatic life. These conditions, as well as the fact FS has produced several well-articulated, vertically oriented sauropod feet, suggest the quarry was quite muddy, and therefore primed for miring. Some of the pathologies observed in our specimen could be the result of such an accident, as it would have been traversing on a slippery footing. It is equally likely that the dinosaur sustained these injuries elsewhere and became stuck in the FS muds, meeting its demise. In either scenario, the notable lack of osteomyelitis in some of the injuries suggests those pathologies did not have time to become infected or sufficiently heal, indicating the dinosaur acquired them close to the end of its life.

## PALEOECOLOGY OF THE MIDDLE PLEISTOCENE KAPTHURIN FORMATION CHIMPANZEE (*PAN*) FOSSIL LOCALITY, BARINGO BASIN, KENYA

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While the hominin fossil record is relatively extensive, paleontological evidence of the African great ape genera is limited to a single fossil site dated to ~545 kyr in the Kapthurin Formation sequence in the Baringo Basin, Kenya Rift Valley. The site (Loc. 99) occurs 640 km east of the distribution of living chimpanzees (*Pan*) indicating that the prehistoric range once included the East African Rift System, traditionally perceived as a potential ecological barrier. Furthermore, Loc. 99 is penecontemporaneous with a series of archeological sites and remains of Pleistocene *Homo* within the Kapthurin Formation, suggesting sympatry between *Homo* and *Pan*. The remains from Loc. 99 include several teeth of at least 1 individual that have been identified as *Pan* sp., with affinities to *P. troglodytes*. Faunal remains directly associated with the *Pan* fossils include bovids, suids, equids, rhinos, rodents, cercopithecoid primates, and aquatic fauna (catfish and crocodiles). Based on faunal assemblages and lithofacies analyses, previous paleoecological reconstructions of the Kapthurin Formation, in general, tend to converge on lake margin habitats dominated by wooded grasslands. However, Loc. 99 has been interpreted to represent a more mesic interval set within oscillating semi-arid conditions based on analyses of paleosols and lithofacies associations. There is a need to refine the nature of the habitat heterogeneity inherent in these reconstructions of the Kapthurin sequence, with a focus on the *Pan* site. Isotopic analyses of 84 fossil herbivore enamel specimens from the Kapthurin Formation succession, with 23 samples directly associated with the *Pan* fossils at Loc. 99., provide an overview of foraging strategies (grazing, browsing, mixed feeding) that reflect aspects of vegetation physiognomy. In general, the carbon isotopic values of enamel ($\delta^{13}C_{enamel}$) yielded a wide range of C3 and C4 dietary signals (-13.6‰ to 2.9‰), dominated by evidence of C4 grazing and some mixed C3/C4 feeding. $^{13}C$ depleted dietary values of -13.6‰ to -9.4‰ reflect obligate browsing, especially with tragelaphines, and indicate a wooded component to the ecosystem(s). There is no clear evidence for any closed-canopy foraging and $\delta 13C_{enamel}$ values in the Kapthurin Formation consistently converge on open woodland/grassland habitats with well-established grazing herbivore guilds. Within this framework, herbivore $\delta^{13}C_{enamel}$ values from Loc. 99 exhibit values and a range indistinguishable from other sites, indicating that the fossil *Pan* were living in open woodland to grassland habitats, possibly similar to modern 'savanna' chimpanzee environments such as Fongoli (Senegal) or Ugalla (Tanzania). While it is possible that preservation of the *Pan* site represents a taphonomic outlier (forest sites typically are not well represented in the fossil record), emerging evidence of hominoids in open woodland habitats 21 Ma suggests that interpretations of hominoid evolution should not be tethered to forest ecosystems.

## EXCEPTIONALLY DIVERSE LATE TRIASSIC LEPIDOSAUR ASSEMBLAGE ILLUMINATES SQUAMATE ORIGINS

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Extant lepidosaurs include two lineages that diverged during the Triassic Period or earlier, the diverse Squamata (~11,000 living species, including lizards, snakes, and amphisbaenians) and the Rhynchocephalia (represented today by only *Sphenodon punctatus*). Gaps in the early Mesozoic record of lepidosaurs and their stem lineage as well as conflicting morphological and molecular hypotheses of squamate evolutionary relationships and diversification timing has generated uncertainty in the tempo and mode of early lepidosaur evolution. The lack of unambiguous pre-Jurassic squamate fossils suggests that new fossils from the Triassic are key for resolving questions of squamate origins. A new exceptionally diverse lepidosaur assemblage collected from continental microvertebrate bonebeds in Upper Triassic (~220 to ~215 million years old) strata deposited in equatorial Pangaea (lower Chinle Formation in Petrified Forest National Park, Arizona, U.S.A.) adds new evidence for the stepwise acquisition and transformation of craniodental features at the divergence of rhynchocephalian and squamate lepidosaurs. Importantly, some of these fossils exhibit features apparently homologous with those of extant squamates such as gekkotans, scincomorphs, and xantusiids. Phylogenetic analyses suggest that these squamate-like features were first acquired in Triassic lepidosaurs by at least 220 million years ago, and their presence in post-Triassic squamates are conserved plesiomorphies. These findings introduce the first empirical evidence from the time of squamate origins consistent with molecular-based phylogenies in which gekkotans are the earliest-diverging crown squamate group. Dietary reconstructions of the new forms suggest a major radiation in insectivorous lepidosaurian ecomorphologies prior to 220 million years ago, possibly linked to the concurrent radiation of holometabolous insects. The addition of this assemblage from the humid paleotropics of Late Triassic equatorial Pangaea suggests that this spatiotemporal setting not only hosted the highest lepidosauromorph species richness known from the Triassic, but also illuminates key steps in the origins of living lepidosaur craniodental disparity.

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## WERE DECAPOD CRUSTACEANS IN ALABAMA ADVERSELY AFFECTED BY THE CRETACEOUS-PALEOGENE MASS EXTINCTION?

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The Cretaceous-Paleogene (K-Pg) extinction is one of the most severe mass extinctions in Earth's history, linked to a meteorite impact near Chicxulub in Mexico and Deccan Trap volcanism in India. Many major groups became extinct (ammonites, belemnites, non-avian dinosaurs, etc.) or experienced major losses in their biodiversity (bivalves, insects, echinoids, etc.). Conversely, decapod crustaceans, major contributors to marine ecosystems since the Mesozoic Decapod Revolution, are thought to have experienced limited losses based on global analyses. Scenarios for this apparent pattern include: (1) decapod diversity was indeed not affected significantly, if at all by the K-Pg event; (2) there was a substantial loss in diversity, but taxon richness rebounded rapidly and was not detectable in coarse global analyses; or (3) uneven sampling has distorted the true signal. Distinguishing between these scenarios has never been carried out by controlled, quantitative sampling of the stratigraphy on both sides of the K-Pg boundary at sites where both latest Cretaceous (late Maastrichtian) and earliest Paleogene (early Danian) crustacean-bearing sediments are exposed. Previous research has attempted to assess a possible crustacean K-Pg extinction at a more regional scale, but sampling strategies were not provided and/or only very few decapod species were encountered on either side of the boundary, insufficient for detailed comparative analyses. Here, we present the results from sampling at a K-Pg site in Alabama (U.S.A.). We performed standardized sampling per time unit from relatively comparable sediments (fine-grained siliciclastics) from a ~12 m section spanning the boundary. Specimens from museum collections gathered at the site augment the specimens found during fieldwork since 2022. Most specimens studied from both sides of the boundary are interpreted to have been deposited on a shelf during a highstand systems tract. After working out the decapod taxonomy and biostratigraphy using calcareous nannofossils, relative diversity, abundance, composition, and body size are compared.

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## HABITAT SUITABILITY MODEL SUGGESTS CLIMATIC CHANGE DID NOT DRIVE RECENT PRIMATE EXTINCTIONS IN THE CARIBBEAN

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The extinct endemic monkeys of the Caribbean have been difficult to place phylogenetically and, despite some last appearance dates postdating human arrival on these islands, we have only a basic understanding of their paleobiology and no direct evidence explaining the timing and drivers of their demise. Of the four genera, one is associated with each of four current or former divisions of land in the Greater Antilles, excepting Puerto Rico: *Paralouatta* from Cuba, *Xenothrix* from Jamaica, *Antillothrix* and *Insulacebus* from northern and southern palaeo-island divisions of Hispaniola, respectively. Radiocarbon dates bracket a long tenure from the Early Miocene for *Paralouatta* to the most recent date of 1477 calibrated years before present for *Xenothrix*. To better understand the paleobiology of the Caribbean primates, we applied a habitat suitability model to identify the climatic attributes of the regions where primate remains are found. We then mapped the probability of suitable habitat across the Greater Antilles at four time intervals from the last interglacial to present. Climatic variables were sourced from WorlClim1.4 and prepared using QGIS 3.34.3. Predictive models were generated using Maxent 3.4.4, using the Mid-Holocene dataset from WorldClim. Sites containing primate remains on Hispaniola were used for primate presence data to train the model because Hispaniolan sites are more numerous (n = 11), and Hispaniola is topographically and climatically diverse. The resulting model's discrimination was good (AUC = 0.84), with permutation tests of importance indicating that (low) annual temperature variability is the primary climatic attribute explaining the distribution of known primate sites in Hispaniola. Next, we projected the model onto the full primate range and tabulated the areas of each island, in each time interval, where probability of suitable primate habitat was 0.25 or greater. Finally, we used this data to consider two extinction hypotheses: 1) Primate habitat was abundant and stable prior to the modern era, i.e, documented mesic-xeric habitat fluctuations did not affect the primates as they did xeric-adapted species; 2) Primate habitat contracted between the middle Holocene and modern era, keeping with the drying trends identified in regional lake cores prior to human arrival. Habitats modeled across the four landmasses fluctuated over time, but a trend is evident: the sum area of modeled primate habitat has remained largely unchanged (Jamaica, North Hispaniola), or increased (Cuba, South Hispaniola) since the Last Interglacial and Last Glacial Maximum. Thus, 1) habitat did remain largely stable and abundant leading up to the modern era; however, 2) primate habitat did not contract in recent time; it has expanded. Though direct evidence of a causal factor for the extinction of the Caribbean primates still eludes us, this study suggests that climatic changes were not primary driver of extinction.

## TRADE-OFFS AMONG CRANIAL SOFT TISSUES IN AVIAN CRANIAL EVOLUTION

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Birds are the only surviving lineage of Dinosauria and have evolved vastly different craniofacial anatomy compared to their extinct theropod relatives. Perhaps most notable of their derived cranial features is the enlarged, globular brain, which is thought to have enabled diversification into new ecological niches through increased cognitive and sensory capabilities. The enlargement of the brain in birds seems to be correlated with drastic changes in other anatomical features of the head, especially reduction of the jaw adductor muscles, suggesting that there may be trade-offs among these and other cranial structures in this clade. Evidence from developmental studies in mammals and birds suggest that the growth of the brain and jaw adductor muscles influence the morphology of the skull (i.e., the functional matrix hypothesis), but little work has been done to investigate these constraints over evolutionary timescales. We use evolutionary causal models to test for trade-offs among cranial structures in crown birds. We used 3D high-dimensional geometric morphometrics to quantify brain and skull shape, including adductor muscle attachment sites, in a sample of extant and extinct birds (n = 200). We used phylogenetic path analysis adapted for multivariate data to test for trade-offs among brain shape, neurocranium shape, jaw adductor muscle size and shape, and eye:brain size ratio in birds using ten competing hypotheses. Our best-supported model supported the hypothesis that brain shape influences the morphology of the other cranial organs, having a significant influence on neurocranium shape and consequently jaw musculature and relative eye size. Globular brains with large cerebrums are correlated with small jaw adductor chambers, whereas elongate brains with relatively smaller cerebrums are correlated with elongate neurocraniums and larger jaw muscles. These findings suggest that the cost of encephalisation is a constraint on jaw muscle size and shape in birds.

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## PROTEIN METABOLISM IN EXTANT AND EXTINCT LARGE MAMMALS: DIFFERENCES IN *DE NOVO* AND GUT MICROBE AMINO ACID SYNTHESIS

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Large herbivorous mammals build and maintain massive, protein-rich bodies while feeding on plants that are low

in nitrogen (N) and composed of a mix of amino acids (N-rich building blocks of protein) that differ from their tissues. Amino acid (AA) isotope analyses have been used to assess N balance, as well as the contributions to body protein of newly synthesized, non-essential AAs ($AA_{NESS}$) vs. AAs routed directly from diet. Recently, experiments and field studies on small mammals have shown that the gut microbiome contributes to the protein balance of mammals by generating essential AAs ($AA_{ESS}$), molecules that mammalian biochemistry cannot create at all or fast enough to meet needs. The role of microbially-derived $AA_{ESS}$ and *de novo* produced $AA_{NESS}$ to the protein metabolism of wild large mammals can be examined with stable isotopes, potentially revealing adaptations to forage with different nutritive value. We are using carbon isotope ($\delta^{13}C$) values of amino acids to study these questions in extant large herbivores from Amboseli National Park, a savanna-woodland ecosystem in Kenya, and in Pleistocene proboscideans from the Great Lakes and Alaska. In Kenya, we are comparing browsers (e.g., giraffe, some elephants), grazers (e.g., zebra, wildebeest), and mixed-feeders (e.g., impala, other elephants). Zebra and elephant are hindgut fermenters; the other taxa are foregut fermenters. The grasses in Amboseli use the $C_4$ photosynthetic pathway, whereas the trees and most shrubs use the $C_3$ pathway. Beyond large differences in foliar $\delta^{13}C$ value, plants using these two pathways also differ in protein (lower in $C_4$ plants) and fiber (higher in $C_4$ plants) content. We predict that consuming N-poor, high-fiber $C_4$ plants will lead to greater *de novo* $AA_{NESS}$ synthesis and gut microbe-derived $AA_{ESS}$ in grazers and mixed-feeders. These hypotheses are being explored by examining isotopic differences between pairs of $AA_{ESS}$ and $AA_{NESS}$ and by carbon isotope fingerprinting, which exploits differences in the patterns of $\delta^{13}C$ values in $AA_{ESS}$ that are synthesized by $C_3$ and $C_4$ plants, gut bacteria, and fungi. Preliminary AA pair analysis suggests browsers do less *de novo* $AA_{NESS}$ synthesis than grazers or mixed-feeders. Isotope fingerprinting suggests greater gut microbe $AA_{ESS}$ synthesis for grazers than for browsers. Among mixed-feeders, microbiome synthesis is greater for foregut (impala) than hindgut (elephant) fermenters. Alaskan and Great Lakes proboscideans (mastodons and mammoths) lived in pure $C_3$ ecosystems, so differences in *de novo* synthesis, routing, and microbiome contributions may reflect diet quality related to plant functional type. In addition, isotope fingerprinting may explain the enigmatic, high $\delta^{15}N$ values seen in mammoths from Eurasia and North America. Together, these studies have the potential to reveal how large mammal communities, past and present, meet the critical ecophysiological challenge of body building on relatively low-quality plant resources.

## RECENT DECALCIFICATION OF LIVING MOLLUSKS IS NEGATIVELY CORRELATED WITH DEAD SHELL DENSITIES IN PUGET SOUND: AN AGENCY-ACADEMIC COLLABORATION MOTIVATED BY CONCERNS FOR OCEAN ACIDIFICATION

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Within the past decade, live-collected mollusks from soft-sediment habitats in Puget Sound have exhibited increasing evidence of shell dissolution during life, to the point where some shells are flexible, transparent, or even absent. Shellfish that struggle to secrete and maintain biomineralized hardparts like carbonate shells are likely to experience both (1) elevated local mortality and (2) failure of shells post-mortem to be incorporated into sediments as part of surficial death assemblages, reducing persistence into the permanent fossil record. Does the intensity of dissolution damage observed on living mollusk shells vary along environmental gradients and/or with dead shell availability in Puget Sound, such as suspected from ocean acidification? To begin elucidating this question, we assessed damage patterns on 7,275 live-collected bivalves and gastropods (68 species) from sediment grabs at 48 subtidal monitoring stations in 2019. Each specimen was assigned to a within-species size class (small, medium, or large) and a damage score based on a rapid-assessment scheme co-designed between agency ecologists and academic paleontologists. This damage scoring scheme is the product of the highest intensity of damage observed on a specimen (0 = pristine, 1 = surface pitting, 2 = subsurface delamination, 3 = flexible shell, 4 = transparent/absent shell) and the extent of that level of damage (0 = none, 1 = localized, 2 = ~half shell, 3 = widespread), resulting in a possible score between zero and 12. Two separate data recorders were able to produce similar score distributions for an initial pilot dataset, indicating the method is robust to operator error. Dead-shell assemblages recovered from the same sediment grabs were also processed for the total number (density) of dead shells. We found that damage to living shells varied strongly across Puget Sound with no clear relationship to water depth, grain size, or sediment organics. However, higher damage scores were found for individuals classified as small-bodied for most species. Further, sediment shelliness was anticorrelated with damage to living shells. The implication is that dissolution damage to the living assemblage is also leading to the loss of dead shells from the same seabeds (i.e., dead shells are buffering local acidity) or, at least, lower rates of shell input are failing to compensate for ordinary rates of postmortem shell loss. The mechanisms driving this apparent dissolution stress are unknown, but the possibility of ocean acidification is a strong motivator. This collaborative effort exemplifies the power of adapting pre-existing methods (here, damage scoring from academic taphonomy) to new sources of data (here, living assemblages from agency monitoring programs) to

elucidate animal-sediment interactions within the framework of conservation paleobiology.

## CYCLOCYSTOIDS (ECHINODERMATA) FROM THE UPPER ORDOVICIAN (EARLY KATIAN) BRECHIN LAGERSTÄTTE OF ONTARIO, CANADA: IMPLICATIONS FOR CYCLOCYSTOID SYSTEMATICS, ANATOMY, FUNCTIONAL MORPHOLOGY, AND LIFE MODE

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New discoveries prompt reinterpretations of one of the most enigmatic echinoderm classes, the Cyclocystoidea. Exceptionally well preserved cyclocystoids have been discovered in the Upper Ordovician (Katian) Kirkfield and Veralum Formations in the Lake Simcoe region of southern Ontario, Canada. Four different cyclocystoid taxa are present, including *Cyclocystoides* cf. *C. scammaphoris*, *Apycnodiscus* sp., *Zygocycloides marstoni*, and *Brechincycloides stanhynei* (new genus and species). These enable new insights into homologies, anatomy, and functional morphology of cyclocystoids. Application of the Extraxial-Axial Theory (EAT) of echinoderm skeletal homologies reveals that the ring of marginal ossicles is axial in origin and supported the ambulacral system with tube feet in a circumferential arrangement. Furthermore, the central disk has varied symmetries and is pierced by numerous epispires indicative of extraxial origin. We document evidence of orientation in life with epispires facing upward and the cupule-bearing surface of the marginal ossicles directed towards the substrate.

## AN AMATEUR'S CONTRIBUTIONS TO PALEONTOLOGY

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Many amateur collectors start collecting at a very young age, but not all. Some of us were in high school before we were introduced to fossils. A high school collecting trip started me on a passion that would last a lifetime. Later, collecting the Arkona Shales alongside like-minded friends were some of my most enjoyable years. Some very outstanding echinoderms were collected and donated to Dr. Robert Kesling. Due to our collecting, Dr. Kesling described *Acinetaster* and *Arkonaster*, two new genera and a new family of asteroids. In later years, collecting the Ordovician quarries of the Brechin, Ontario area would lead me to amass a very large collection of various outstanding fossils. My research led me to believe that there were many specimens in my collection that were new and many that had never been recorded from the Brechin area. Eventually, I began a search for a professional collaborator to work on my crinoid collection from the Brechin area and that led to Dr. William Ausich et al. They published five papers on the taxonomy and phylogeny of the Brechin fauna. At the end of their research, we had described 27 genera and 39 species, and of these, 3 genera and 15 species are new. Additional work with Dr. Daniel Blake led to the publication of two manuscripts on asteroids from the Brechin area. There is also on-going work by Dr. Blake on an ophiuroid project to which several members of FUMMP have contributed specimens. Our contribution will expand the range of *Acinetaster* and allow for redescription of the genus. There is also an on-going project with Dr. Forest Gahn on a *Cleiocrinus* which will confirm that *Astroporites ottawaensis* is the tegmen of *Cleiocrinus*. My newest collaboration is with Dr. Dennis Kolata et al, on a cyclocystoid project using specimens collected over the past 30 years. A poster session at this conference outlines the project and proposes morphological conclusions. Dr. Brad Deline and students have a poster at this conference using cystoid specimens from my collection. Amateurs not only make contributions to publications and collections, but also to museum exhibits. Specimens from my personal collection are on exhibit at the Smithsonian, Royal Ontario Museum, University of Michigan Museum of Natural History and Brigham Young University-Idaho. To date, about 400+ specimens from my collection have been donated to research and exhibits. My private collection currently has over 5000 specimens, many of which are destined for the University of Michigan Museum of Paleontology collection. What does the future hold for amateur collectors like me? Unfortunately, it is bleak. There are just too many restrictions on collecting fossils from both public and private lands. Barring any changes, the amateur's ability to collect fossils will be extremely limited. Gone will be the contributions an amateur makes, but also gone will be the spark that gives us the next gifted paleontologist.

## USING PALEOBOTANY TO INFORM CONSERVATION OF THE AUSTRALIAN RAINFORESTS

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Australia's threatened rainforests provide an outstanding example of success and unrealized potential for using

paleobotany to inform conservation. They survive in ~1% of the continental area but protect diverse ancient plant lineages known from fossil discoveries across the mid-high latitude Cretaceous and Paleogene Southern Hemisphere. Paleobotany shows that these Gondwana-sourced plants (Paleo-Antarctic rainforest lineages, PARLs) have survived past tectonic movements and climate change through massive range shifts to track their preferred cool-wet rainforest biomes. The PARLs have high ecological significance today in threatened Australasian and Southeast Asian rainforests, and Australian examples include *Agathis* (kauri), *Nothofagus* (southern beech), *Tasmannia* (pepperbushes), *Orites* (silky oaks), *Ceratopetalum* (coachwoods), *Ackama* (rose alders), *Wilkiea*, *Doryphora* (sassafras), *Daphnandra* (socket woods), *Eucryphia*, *Elaeocarpus* (Quandongs), *Austrobuxus* (southern boxes), *Ripogonum* (supplejacks), and *Akania*. The PARLs include some of the most abundant tree species in Australia's rainforests, and their remarkable fossil history was central to the World Heritage listing of the subtropical Gondwana Rainforests of Australia based on outstanding universal values. However, Australian PARLs face substantial risks, including small areal coverage, climate change, fire, and inappropriate forest management. More than a hundred years of old-growth eucalypt logging and land clearing in adjoining areas have substantially altered forest structure and increased the risks to the rainforest from climate extremes, drought, and fire. These factors culminated in the catastrophic 2019–2020 fire season, which adversely impacted approximately 30% of the Gondwana Rainforests. Current management responses to fire are to burn more; thus, despite the impacts of the recent wildfire event, planned burning in national parks has increased, and Gondwanan rainforests are used as convenient firebreaks rather than being specifically protected. Additional hazards come from statutory obligations that require conservation managers to prioritize listed Threatened Species for protection over the locally abundant but often range-restricted tree taxa, including many PARLs, that create the habitat structure of the forests in which the rare species survive. The fossil record shows that the same conservative plant traits that enabled PARLs to disperse and persist through wet-biome tracking in the face of past climate and tectonic changes now limit their ability to reach vanishing refugia in a rapidly changing world. Australia's rainforests demonstrate how paleobotanical data improve baseline knowledge for setting conservation priorities, provide a temporally and spatially enlarged view of landscape processes, and enable better protection of unique evolutionary heritage and threatened surviving ecosystems.

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## PALYNOFLORAL CHANGE THROUGH THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN, WYOMING

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To better understand the effect of the Paleocene-Eocene Thermal Maximum (PETM) on continental ecosystems, we studied 40 new palynological samples from the Bighorn Basin (BHB), northwestern Wyoming, U.S.A. We see palm and fern abundances increase in the last 20–40 ka of the Paleocene, then dramatically with the onset of the carbon isotope excursion (CIE) defining the base of the PETM. Palynomorphs of plant groups with modern temperate climate distributions are absent from the CIE body, and this is when tropical plants are most diverse and abundant. During the CIE recovery, pollen of mesophytic/wetland plants become more common while tropical taxa persist. In the post-CIE early Eocene tropical taxa are rare and temperate forms abundant, similar to the late but not latest Paleocene. Changes in the palynoflora are more easily detected if reworked palynomorphs are removed from analyses. We interpret palynofloral changes to indicate warming in the latest Paleocene, rapid warming and drying with the CIE onset, dry tropical climates through the CIE body, a return to wetter floodplains during a very warm CIE recovery, and cooler wet conditions in the post-PETM early Eocene. These inferences are consistent with geochemical and paleobotanical proxies. Strikingly similar patterns in the palynoflora and megaflora suggest changes in vegetation were a basin-wide phenomenon. These rapid, climatically forced changes in floral composition occurred without major extinction, perhaps indicating nearby refugia in which plants adapted to cooler and wetter climates persisted through the PETM.

## SPEED OR ENDURANCE: WHAT IS THE ECOLOGICAL ADVANTAGE OF CURSORIALITY IN CARNIVORANS?

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Cursoriality evolved in mammals beginning in the Oligocene and increasingly in the Neogene as more open, less densely vegetated environments expanded globally. Cursorial morphologies, like elongated distal elements of the limbs, are clearly advantageous in these less densely vegetated environments, but it is less clear why. The muddled definition of cursoriality contributes to this issue; cursoriality is both used to describe animals that can run fast (speed) and animals that can run far (endurance). While these characteristics overlap, morphological differences between animals like the

cheetah, known for speed, and the wolf, known for endurance, demonstrate distinct evolutionary drivers for cursoriality. Among carnivorans, locomotor adaptations simultaneously affect how efficiently an animal can navigate the landscape and locate, chase, and capture prey, all activities essential to survival. We hypothesized that endurance, essential to searching for prey, rather than speed, advantageous for catching prey, drove the initial evolution of cursoriality in carnivorans. We first tested the association between cursorial morphology and endurance by acquiring GPS collar data for 292 individuals across 10 species of extant carnivorans (5 canids, 3 felids, 1 procyonid, and 1 mustelid) from the database MoveBank. We calculated the daily distance travelled by each individual as a proxy for endurance, subsampling GPS points to every 1.5 hours. We found the maximum and median daily distances for each individual. We measured morphological cursoriality as the length of the radius relative to the humerus. Because we did not have access to the GPS-collared individuals, we used specimens from University of Michigan Museum of Zoology collections and took species averages for each variable. We did not find a significant correlation between median or maximum daily distance travelled and humerus/radius ratio using a linear regression, but given the limitations of the current dataset, adding species may change this result. Notably, species traditionally categorized as cursorial, like *Canis latrans* (14.2 km/day), had significantly higher median daily distances than species traditionally categorized as scansorial, like *Lynx rufus* (4.1 km/day), even with distances normalized by body size. To assess cursoriality in fossil carnivorans, we used 2D geometric morphometrics (GMM) of the distal humeral trochlea and capitulum. We found a high level of correlation (R2 = 0.62) between distal humerus morphology and humerus/radius ratio using a multiple regression on our extant specimens. We used this linear model to estimate the humerus/radius ratio for extinct carnivorans for which we had corresponding 2D GMM data. Smaller Arikareean bear-dogs (amphicyonids) tended to have longer estimated radius lengths than later, larger Barstovian amphicyonids, suggesting cursoriality was more important early on in this group.

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## ACCOUNTING FOR DATING UNCERTAINTIES IN TIME-AVERAGING ESTIMATES

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Time-averaging is the hard limit to the resolution of the fossil record and it is of fundamental importance to the interpreting fossil assemblages. To accurately estimate time-averaging it is essential to separate the variation in fossil ages from the uncertainties in the estimates of the ages of the individual fossils. Here I use simulations as well as previously published dated assemblages from the Holocene of Australia to examine the effectiveness of different analytical methods used to separate dating uncertainty from the variation associated with different aged fossils (time-averaging). Despite its parametric roots the Estimated Time Averaging (ETA) performs well across a wide range of underlying assemblage age distributions, and relatively modest sample sizes (N ~ 12) yield reasonable ETA values. While ETA values are not directly comparable to most published time-averaging values, ETA is the most effective method available for removing the impact of dating uncertainty from time-averaging estimates.

## ASSESSING LIVE-DEAD FIDELITY IN MARINE BENTHIC COMMUNITIES

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By comparing living communities of marine benthos and sympatric death assemblages (surficial accumulations of skeletal remains) we can estimate the potential fidelity of the fossil record. Measuring live-dead fidelity is also an important strategy in conservation paleobiology studies to assess recent ecosystem changes due to human impacts. Standard methods for measuring live-dead congruence, based on correlation and similarity measures, tend to yield biased estimates of fidelity because live-dead comparisons are based on unbalanced sampling and sparse data affected by under-sampling of rare species. Simple resampling strategies can be used to correct for those biases and obtain more realistic fidelity estimates. These resampling strategies also highlight idiosyncratic limitations of common correlation and similarity measures used to assess the live-dead fidelity of marine benthic ecosystems.

## TRACKWAYS OF A SMALL, QUADRUPEDAL DINOSAUR FROM THE MIDDLE JURASSIC OF PATAGONIA AND ITS IMPLICATIONS FOR LOCOMOTOR EVOLUTION WITHIN ORNITHISCHIA

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Recent exploration of the Middle Jurassic La Matilde Formation at Estancia Laguna Manantiales in Patagonia,

Argentina, exposed two large track surfaces containing more than 1,000 well-preserved footprints. The unit records a diverse ichnofauna—including traces of early mammals, dinosaurs, and invertebrates—together with permineralized plant remains. One of the sites, "Cantera Casimiquela," preserves a sequence of 36 manus-pes pairs of *Delatorrichnus goyenechei*. The tracks are notable for their small size: the pes impressions are approximately 3 cm long, and manus impressions are approximately 2 cm long. The size and spacing of the tracks imply a glenoacetabular length of 35 cm and a body mass of approximately 3.4 kg. The manus-pes pairs are more superimposed on one side than on the other, but the manus is typically closer to the midline than the pes. It is not clear whether the manus-pes pairs represent the ipsilateral or contralateral sides. The pace angulation for both the manus and pedal impressions are high (>160 degrees) indicating a parasagittal stance. The pes is tridactyl, and none of the prints indicate the presence of large claws. The manus impressions are without defined digits or claw impressions, although examples from other localities suggest the presence of three manual digits. Other known occurrences of *Delatorrichnus* in the La Matilde Formation preserve tracks that are similar in size to the 36-print trackway from the Cantera Casimiquela, suggesting that the trackmaker is an adult individual of a small species, rather than a juvenile individual of a larger species. The tridactyl manus and pes impressions, absence of pronounced claw impressions, parasagittal posture, and quadrupedal gait are consistent with an ornithischian trackmaker; its Middle Jurassic age makes it unlikely to be a non-dinosaurian trackmaker such as a silesaurid or a rauisuchian). Secondary quadrupedality appeared at least three times independently within Ornithischia: in Thyreophora, Ornithopoda, and Marginocephalia. In each of these clades, the apparent correlation between size and posture (large secondarily quadrupedal species and small, basally diverging bipedal species) has lent support to the inference that the postural shift was triggered by body size. However, the discovery of the small quadrupedal ornithischian trackway *Delatorrichnus* suggests that quadrupedality and body size are decoupled, and that other factors may be more important in determining posture in these and other dinosaurs.

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## THE CORALS OF THE DEVONIAN OF NEW YORK: FACILITATING THEIR IDENTIFICATION AND STUDY

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Over 175 years of research has generated a wealth of data concerning the Devonian corals of New York state however the usefulness of this data for specimen identifications, as well as taxonomic and paleoecologic studies is hampered by its publication in a multiplicity of journals and books spanning many years. The existing data is, to a degree, further compromised by its age. A significant portion of the data was generated before the advent of modern taxonomic principles such as population-based species definitions and in-depth species descriptions. To facilitate access to the existing information a database has been created that aggregates all taxonomic and biostratigraphic data for the Devonian coral taxa in New York State into a single source. The incorporated data for each taxa includes type species, type specimens, diagnostic features, biostratigraphic occurrences, and a comprehensive list of references. The completed database has allowed for the creation of a guide for the Devonian coral faunas in New York state that will facilitate improved identification of specimens in ongoing paleoecologic and biostratigraphic studies. The guide will also provide a baseline for future taxonomic studies aimed at the validation and improved definition of existing species as well as, when warranted, the delineation of new taxa.

## A POTENTIALLY NEW DRYOMOPRH ORNITHOPOD FROM THE LATE JURASSIC MORRISON FORMATION SIMON QUARRY OF THE BIGHORN BASIN, WYOMING

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The Late Jurassic age Morrison Formation, well-exposed in the Bighorn Basin of Wyoming and Montana, has long been known for a diversity of dinosaurian taxa. Among these forms are dryomorph ornithopods such as the long recognized *Camptosaurus* and *Dryosaurus*. These two taxa are widespread throughout the Morrison depositional basin. The Simon Quarry (Red Canyon Ranch Quarry), near Shell, Wyoming, has produced an extremely diverse dinosaur assemblage including numerous ornithopods. Among these ornithopods is a dryomorph iguanodontian that has been referred to *Camptosaurus*. While ornithopods are generally a less common component of Morrison Formation assemblages, this taxon is rather common at the Simon Quarry. Articulated to isolated and associated specimens have come from a number of lithofacies and stratigraphic positions at this location. Lithofacies of occurrence include plant-rich siltstones, grey siltstones, and channel sandstones. These specimens have commonly been found in association with articulated to isolated specimens of sauropods and theropods as well. Intriguingly, this taxon

has morphological features disparate from *Camptosaurus* specimens reported from farther south in the Morrison Basin. While investigation is preliminary, so far differing features include tibiae longer than the femora, and much more gracile metatarsals than those in other *Camptosaurus* specimens. Specimens available for follow up research from the Simon Quarry include "Arky the Camptosaurus" at the Aathal Museum in Zurich, a partial skeleton in the Naranjo Museum of Natural History in Lufkin, Texas, and a braincase at the Idaho Museum of Natural History. While this investigation is preliminary, the noted differences suggest three possibilities: 1) this being an unrecognized taxon closely related to *Dryosaurus* and *Camptosaurus*; 2) this being a more mature form of *Dryosaurus* than has previously been recognized; or 3) these specimens being an ontogenetic stage of *Camptosaurus* that has been unrecognized or undescribed. Follow up research will be occurring to assess the taxonomic and ontogenetic status of this ornithopod, and its relationship to more well-known forms; with more in-depth description to follow.

## USING LIVE, DEAD, AND FOSSIL GASTROPODS TO ASSESS RESPONSE AND RECOVERY TO LONG- AND SHORT-TERM DISRUPTIONS IN FLORIDA FRESHWATER SPRINGS AND RIVERS

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Freshwater ecosystems in Florida face increasing threats from human impacts, climate change, and environmental disturbances. In coastal springs and rivers, rising sea levels, increasing storm frequency, and amplified storm surges may cause salinity disruptions and associated impacts to freshwater vegetation and molluscan communities. In these freshwater systems, molluscan fossil assemblages record the protracted history of community restructuring while associated death and live assemblages document community disruptions. These disruptions likely contribute to the displacement or even extirpation of freshwater species and their replacement by both brackish-tolerant and introduced taxa. Combined analysis of live, death, and fossil assemblages documents community recovery or restructuring in response to these events. Hurricane Michael made landfall in the Florida panhandle on 10 October 2018. Among other impacts, the storm brought more than three meters of storm surge up the Wakulla River and inundated freshwater portions of the river with more brackish salinities. Using death and living assemblages collected before and after the hurricane, we documented the response and recovery of Wakulla's molluscan community. We also compared these recent communities with fossil (late Pleistocene-Holocene) assemblages to assess long-term restructuring. A total of 124 live, 38 dead, and 32 fossil samples were collected between 2017–2023, yielding a total of 30,944 specimens representing 23 taxa. Thirteen taxa (all native) were identified in fossil assemblages. Before the storm, modern species richness had dropped to ten taxa, including two introduced species and one brackish-tolerant gastropod. This drop reflects the local loss of multiple native freshwater species from the Wakulla River. Of extant native species, half were found at severely diminished abundances (< 20 individuals). Following the storm, species richness did not change but the relative abundance and distribution of species shifted with introduced species flourishing in the short-term, while brackish-tolerant taxa saw a large range expansion upriver in subsequent post-storm surveys. Native species saw relative decreases, though the decline was less severe within Edward Ball Wakulla Springs State Park, a protected region surrounding the headspring and upper river. These trends suggest that upstream and headspring regions likely act as a refugia and are critical for maintaining biodiversity as rivers are increasingly at risk from storm and climate disturbances.

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## MAJOR QUESTIONS ADDRESSING ARTHROPOD AND PATHOGEN HERBIVORY IN DEEP TIME

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A central issue for the deep-time origin and evolution of arthropod and pathogen herbivory is how physical and biotic events have substantially affected the richness and intensity of herbivory for plant hosts, their herbivores, and resulting interactions. The functional feeding group–damage type (FFG-DT) system was designed toaddress eight important questions across time, space, and plant assemblages. How did herbivory originate on land? From late Silurian to Late Mississippian, a land flora of nonvascular and vascular plants supported herbivores engaged in spore consumption, borings, and piercing and sucking initially on plant axes and liverworts and later on foliage, with time lags when an organ originates and its initial herbivorization. What effect on herbivores was the expansion of Pennsylvanian biomes? An expansion of herbivory, beginning with piercing and sucking, occurred during the Pennsylvanian with initial diversification of 12 major insect lineages. Included was a diverse herbivore community on marattialean ferns and antiherbivore defenses by medullosan seed ferns. How did the initial expansion of

seed plants affect herbivores? Insect galls, occurring on stems and rachises during the Pennsylvanian, shifted to targeting seed plant foliage in the early Permian. Piercing and sucking increased in a second phase at the expense of chewing on seed-plant foliage, followed by a Late Permian increase in pathogens. How did the P-Tr ecological crisis effect the trajectory of herbivory? A substantial drop in herbivory followed the end-Permian ecological crisis. By the late Middle Triassic, herbivory levels resumed to levels seen in the Late Permian. What was herbivory like in a world of ferns and gymnosperms? A dramatic, Late Triassic increase in herbivory of almost all FFGs on gymnosperms continued into the Jurassic and Early Cretaceous. This increase is illustrated by the broad variety of mines on bennettitaleans, ginkgophytes, and conifers from the mid-Mesozoic of Northeastern China. Did the initial rise of angiosperms provide herbivores new resources? Herbivory style on gymnosperm hosts during the earlier Early Cretaceous was largely unchanged for emerging angiosperms during the later Early Cretaceous. Notably, ferns were minimally herbivorized. What effect did the K-Pg ecological crisis have on herbivory? Immediately before the end-Cretaceous ecological crisis, herbivory climbed to new levels, followed by a drastic post-event reduction that lasted up to 10 million years to equilibrate to K-Pg levels. How did the Paleocene–Eocene Thermal Maximum (PETM) affect herbivory? The PETM was the most dramatic, transient shift in Cenozoic temperature and $CO_2$ levels, associated with an increase in herbivory. When did modern herbivore associations begin? Modern, often specialized, associations appear during the Paleogene. Examples include coconut–pachymerine beetle seed predation and several angiosperm–gall associations.

## TRILOBITE DIVERSITY RESPONSE TO THE END-ORDOVICIAN MASS EXTINCTION: BETWEEN-HABITAT DISSIMILARITY (BETA DIVERSITY) AS A MECHANISM TO MAINTAIN WITHIN-HABITAT RICHNESS (ALPHA DIVERSITY)

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The family and genus richness of trilobites was reduced at a global scale by at least 50% across the end-Ordovician mass extinction and Silurian diversity never approached pre-extinction levels. However, it has been demonstrated that the within-habitat species richness (alpha diversity) of the group did not vary in most habitats between the Ordovician and Silurian. To account for the disparity between strongly reduced global yet stable within-habitat richness after the extinction event, a reduction in either between-habitat (beta diversity) or geographic (provincialism) diversity during the early Silurian (Llandovery–Wenlock) has been proposed. Multiple qualitative descriptions exist of reduced provincialism throughout the Late Ordovician and early Silurian, associated with a narrowing of the Iapetus Ocean. However, a study that uses quantitative data to investigate the two dissimilarity components of diversity in response to the trilobite extinction event has not been attempted. This study leverages the wealth of published data to investigate whether trilobite taxa became more widespread among habitat types in the wake of the end-Ordovician mass extinction, and therefore contributed to maintaining the group's alpha diversity. The trilobite literature was reviewed to obtain all published taxonomic occurrence lists and taxon abundance counts from the Late Ordovician and early Silurian of Laurentia. These data were then supplemented with unpublished datasets and theses. Taxonomic identifications were updated or revised for all species. All fossil assemblages were assigned to one of five general depth-related habitat types on the basis of their lithologic/sedimentologic characteristics. Trilobite biofacies were delineated through the use of Q- vs R-mode two-way cluster analysis of fossil collections and taxa. Genera that were uninformative for the analytical method were combined at higher taxonomic hierarchies resulting in analyses using mostly the subfamily level. Fossil collections from the Hirnantian (extinction interval) were excluded from analysis. In the Late Ordovician, multiple distinct depth-related biofacies were identified. Analysis of early Silurian assemblages recovered little distinction of biofacies along a depth gradient, but did recover a distinct biofacies associated with reef carbonates. The results are consistent with an interpretation of trilobite taxa becoming more widely dispersed among habitat types after the end-Ordovician. Wider habitat occupancy likely enabled alpha diversity to remain stable, or quickly rebound, after the extinction event. A similar study is currently underway to examine the trilobite record of Baltica and Avalonia to determine if the pattern can be confirmed on neighboring paleocontinents. Incorporation of data from Baltica and Avalonia will also facilitate investigation of the geographic component of dissimilarity response to the end-Ordovician extinction within and between these tectonic units.

## EVALUATING LONG-TERM CALVING GROUND VARIABILITY OF CARIBOU (*RANGIFER TARANDUS*) FROM IVVAVIK NATIONAL PARK, YUKON, CANADA

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Age-frequency distributions of skeletal materials generally incorporate a combination of skeletal production and taphonomic loss over timescales that exceed wildlife monitoring data. Although extensive work has examined age-frequency distributions of carbonate shells, including their potential to record changes in skeletal production through

time, limited work has applied these findings to vertebrates. To evaluate the shape of age-frequency distributions in terrestrial vertebrate systems, including the ability for skeletal assemblages to record patterns of landscape use or demographic histories, shed female antlers (which are shed within days of giving birth) from the Porcupine Caribou Herd (PCH) were evaluated to assess the age-frequency distribution of bone remains from a single locality. For migratory caribou, access to calving grounds is considered important for maintaining herd viability. However, a challenge for managing the PCH is that there is high annual variability as to which portions of the calving grounds are used. Today, the calving grounds of the PCH are concentrated on the northern Coastal Plain of Alaska and Canada. Although annual shifts in preferred calving locations have occurred since monitoring began (~1980s), the relatively limited sample size of radio- or GPS-collared cows (~50–70 of a herd of 200,000+ individuals) used for determining the spatial structure of calving activity may not sufficiently capture spatial variability in calving ground locations of the herd. Shed antlers provide a skeletal record of calving activity at a high spatial resolution. While shed antlers have been used to develop our appreciation for calving histories in Alaska (Arctic National Wildlife Refuge), we do not have comparable data for the other half of the PCH calving grounds in Ivvavik National Park, Yukon, Canada. To obtain an historical perspective on calving histories in Canada, in 2022 we conducted eight standardized antler surveys near the Firth River (Ivvavik National Park). Forty antlers were recovered from these preliminary surveys. To estimate years of shed for each antler, we used a combination of radiocarbon dating and taphonomic grading of bone weathering (using both visual evaluations of weathering features and quantitative estimates of surface texture roughness based on 3D optical surface profilometry). We then reconstructed the local calving history using an age-frequency distribution divided into 20-year time bins. While considering both age uncertainty and a limited sample size, antlers from 1980–2000 outnumber those observed in recent decades (2000–2020), overshadowing the typical "L"-shaped distribution expected in skeletal assemblages and suggesting that this calving area had higher use in the late-1900s than over the last ~20 years. Additional surveys and future work quantifying taphonomic loss of bone will better illuminate the influence of changing skeletal production on age-frequency distributions for arctic herbivores.

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## A TAXONOMIC CLASSIFICATION AND DIVERSITY ASSESSMENTS OF TERRESTRIAL ARTHROPOD COPROLITES IN THE CALHOUN COAL BED FROM PENNSYLVANIAN COAL BALLS

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Coal balls are concretions of permineralized peat that occur in coal seams and contain a rich fossil assemblage of plant debris and invertebrate material. They serve as our primary source of information about Pennsylvanian tropical peat swamps, documenting the community composition and complex ecological interactions between terrestrial arthropods and plants. Coprolites (fecal material) and other traces from terrestrial arthropods commonly occur in coal balls and can be found in association with plant organs or distributed throughout the peat matrix. These traces can originate from several sources, representing the feeding behaviors of terrestrial arthropods on living or dead plant material in the forest canopy, understory, or forest floor. Coal ball research has primarily focused on the paleobotanical assemblage, with little attention given to arthropod coprolites. To better understand the coprolite diversity in coal balls, we introduce a taxonomical classification for accessing coprolite morphotypes. We analyzed peels of coal balls from the Phillips Coal Ball Collection at UIUC, collected from the Late Pennsylvanian Calhoun coal bed (Mattoon Formation) of the Illinois Basin (U.S.A.). Coprolite morphotypes were identified based on similarities in size, shape, composition, surface features, spatial/temporal distribution, and degree of mastication. These morphotypes were cross-referenced with fecal pellets collected from modern arthropod groups to reference possible producers based on similarities in size, shape, and known feeding behaviors. Coprolites represent three types of feeding behaviors by terrestrial arthropods-targeted herbivory, detritivory, and coprophagy. Coprolites representing targeted herbivory are found in association with a plant organ and are homogeneous in composition. Detritivorous coprolites are heterogeneous in composition and are found generally in the peat matrix. Coprolites resulting from coprophagy are found in association with other coprolites and are highly masticated. Coprolites in the Calhoun coal bed range in size from 40 µm to 2 cm, with the smallest coprolites being produced by oribatid mites and larger coprolites by mandibulate insects such as orthopteroids or millipedes. To further develop our understanding of Pennsylvanian peat swamps, this dataset will be used to create a multipartite food web of the Calhoun coal bed. This project aims to further expand our understanding of feeding behaviors on Pennsylvanian floras and the evolution of herbivory and detritivory in terrestrial arthropods.

## TIME SCAVENGERS: EDUCATING AND SUPPORTING THE PUBLIC AND FUTURE EARTH STEWARDS

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Time Scavengers (TS) is a non-profit organization with several goals: 1) increase science literacy around evolutionary theory, climate change, and geoscience knowledge; and 2) support the next generation of STEM scientists, especially those working in the realms of paleoclimate, paleoceanography, and paleontology. To accomplish the first goal, the organization hosts a web environment (TimeScavengers.org) that contains permanent informational and resource pages for educators and lifelong learners. Additionally, Time Scavengers hosts blog series with the goals of showcasing scientists' research endeavors, the diversity of people and research in STEM, and the work being done by scientists in the field, lab, and within our communities. The permanent resource pages and blog posts are released on three social media platforms (Twitter/X, Facebook, and Instagram) to promote and further distribute website content. To achieve our second goal, the TS team has developed two new initiatives: the Tilly Edinger Travel Grant (TETG) and the Virtual Internship Program for Science Communication (VIPSciComm). TETG increases accessibility to conferences for students and avocational scientists from historically underserved identities in STEM. TETG pays for conference registration and abstract submission costs up-front, eliminating the reimbursement structure that is strongly limiting to many without financial security. Since early 2021, TETG has funded 24 early career researchers from 8 countries across the world. TETG awardees contribute two blog posts each: one highlighting themselves and their research, and one recapping their conference experience. VIPSciComm had its inaugural iteration the summer of 2022, with five student interns mentored by TS team members. The interns learned different aspects of science communication, attended weekly seminars with communication experts, and wrote articles for TS blogs. Going forward, TS has several goals: 1) continue growing the number and diversity of educational material hosted on the website; 2) expand the Tilly Edinger Travel Grant and continue funding more students and encourage avocational scientists to apply; 3) increase the frequency at which we run VIPSciComm, ideally every summer. In this way, Time Scavengers can continue to grow and increase our support for the current and next generation of Earth stewards. These initiatives all require continued community support from the geoscience community and a sustainable financial model. Currently, costs associated with the website, social media platforms, TETG, and VIPSciComm are 100% supported by small donations and outreach grants.

## FOSSIL CHELICERATES AS AN EVOLUTIONARY CASE STUDY INTO MECHANISMS AND DRIVERS OF MORPHOLOGICAL CHANGE

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The importance of both intrinsic biological and external environmental factors in defining macroevolutionary patterns has been recognized since its popularization by G. G. Simpson. However, there is still much discussion about how the genealogical and ecological hierarchies interact, the outcome of these interactions on patterns of morphospace occupation, and the general repeatability of the evolutionary outcome of any given situation. Of particular interest are the drivers of morphological innovation and whether novel morphologies are associated with shifts in Hutchinsonian niche. One group in which these issues have been explored in some detail are the Xiphosurida, or horseshoe crabs. Tracking ecological changes across the evolutionary history of xiphosurids reveals correlation between the occupation of non-marine environments and an increase in rates of morphological evolution, with lineages that transition to non-marine environments occupying novel regions of morphospace. Novel morphologies are achieved through the onset of heterochronic trends; the Paleozoic belinurines exhibit an overall paedomorphic trend, while the Paleozoic–Mesozoic austrolimulids follow a peramorphic trajectory. Heterochronic processes also appear to be involved in chasmataspidid evolution. Chasmataspidids are rare fossil chelicerates ranging from the Middle Ordovician to Middle Devonian that demonstrate remarkable convergence toward a eurypterid morphology which entailed a radical shift from that of the more xiphosuran-like Ordovician *Chasmataspis*. The discovery of juvenile *Chasmataspis* indicates that the eurypterid-like morphology in some chasmataspidids is due to paedomorphosis. Given shared developmental trends between eurypterids and chasmataspidids, the convergent similarities between chasmataspidids and eurypterids may be due to developmental parallelisms. Interestingly, later chasmataspidids develop unusual morphologies that may be due to peramorphic processes, indicating a shift within the lineage from predominantly paedomorphic to an overall peramorphic trend. Finally, eurypterids undergo multiple evolutionary transitions from marine to non-marine environments associated with the occupation of novel morphospace. Study of these events is ongoing, but preliminary analysis of eurypterid ontogeny appears to

indicate that heterochronic processes may also be at play within eurypterids. These three clades therefore afford a unique window into the mechanisms by which morphological change occurs and the importance of intrinsic factors within lineages (peramorphic vs. paedomorphic trends) and external (ecologic) elements in mediating morphological innovation.

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## ENDOCRANIAL SHAPE VARIATION IN MADAGASCAR'S SUBFOSSIL LEMURS

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Late Quaternary Madagascar was home to a diversity of lemurs, including three recently extinct families: Paleopropithecidae ("sloth lemurs"), Megaladapidae ("koala lemurs"), and Archaeolemuridae ("monkey lemurs"). These subfossil lemurs are characterized by a variety of adaptions not seen in their living kin. While cranial and postcranial anatomy has been thoroughly assessed in these groups, limited work has been performed on their neural anatomy. As the brain is where sensory input is processed into actionable information, understanding its variation is significant to understanding how an extinct animal functioned within its environment. We present the first 3D geometric morphometric (GM) analysis of subfossil lemur brain endocasts. Virtual endocasts were produced from CT material of the cranium for five subfossil lemur species, with representation from each of the three families. These species include: *Babakotia radofilai* (DPC 10994; DPC 24813), *Archaeolemur sp*. (DPC 9104; DPC 7850), *Megaladapis madagascariensis* (DPC 24801); *Mesopropithecus dolichobrachion* (DPC 11755); and *Palaeopropithecus sp*. (DPC 5474). We used landmark-based 3D GM to analyse the virtual endocasts and examine endocranial shape variation among the subfossil lemurs within the context of a dataset of 140 extant Euarchontoglirens. The landmarks used were designed to capture shape variation among major brain regions while allowing for the inclusion of fossil or subfossil material which may be incompletely preserved. Principal component analyses on Procrustes shape variables show that among the broader dataset of Euarchontoglires, the subfossil lemurs expand the range of variation documented for both Strepsirrhini and Primates. For instance, *Archaeolemur*, which is often likened to monkeys in its anatomy and hypothesized ecological niche, plots closer to the anthropoid morphospace than any other strepsirrhine and exhibits marked gyrification. Similarly, *Babakotia*, a representative of the "sloth lemurs," is an outlier among Lemuriformes. Though it is nearest to lemuriform is *Indri*, its closest extant relative, its distinct shape may reflect its unique ecological niche. These unique endocranial morphologies, paired with what we know about the ecological niches occupied by these taxa, make them not only an area of research interest within the broader topic of primate brain evolution, but also an important avenue of insight into convergent and divergent evolution in brain morphology.

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## REVEALING PATTERN AND PROCESS OF EAST AFRICAN RODENT DIVERSITY

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Modern African rodents are a taxonomically rich group, encompassing thirteen families, nine of which are endemic to or originated in Africa. Their fossil record preserves additional diversity, with at least six extinct families. Yet the patterns of African rodent taxonomic diversity through the Cenozoic—and their potential ecological and abiotic drivers—have not been as well-studied compared to those of larger mammals. For example, evidence supports early and late Miocene turnover events in many large-bodied African mammal guilds, likely driven by a combination of tectonic activity (e.g., connection with Eurasia) and environmental change (e.g., the expansion of open habitats). If influenced by these same abiotic processes, rodents may demonstrate similar patterns of diversity. However, ecological differences due to body size—such as rodents responding to habitat changes at smaller temporal and spatial scales, or being more limited in dispersal ability—could contribute to different diversity patterns in rodents and larger mammals, emphasizing the need to incorporate the rodent fossil record into our knowledge of African faunas. My project synthesizes the East African rodent fossil record, integrating information from several fossil databases with additional faunal lists from the literature. I implement Foote's diversity metrics at the Genus level to estimate the magnitude, timing, and patterns of East African rodent origination, extinction, and total diversity through the Cenozoic. I examine these patterns within and between individual rodent clades to evaluate the relative contributions of endemic and immigrant taxa to overall diversity. My results highlight an interval of elevated rodent turnover through the Miocene, characterized by the extinction of several endemic families coupled with the radiation of immigrant taxa, such as the family Muridae (which today comprises the majority of African rodent species). Taxonomic turnover during the Miocene suggests that rodent diversity may have been influenced by the tectonic and environmental factors also hypothesized to be affecting large mammal diversity around this time. However, additional or alternative abiotic processes

may be at play. To evaluate possible factors influencing rodent taxonomic diversity and turnover—e.g., prominent shifts in the abiotic environment (as well as potential taphonomic biases and sampling effects)—I will take advantage of East Africa's nearly continuous geologic record of tectonic activity and environmental change through the later Cenozoic. By correlating higher-resolution taxonomic data with these abiotic factors, I expect to find distinct patterns for rodent diversity in relation to landscape change (e.g., earlier responses) compared to those found in large mammals. In my future research, I also plan to generate patterns of functional diversity, mechanistically linking taxonomic diversity patterns to environmental processes through functional traits.

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## CHANGES IN A CENTRAL TEXAS LIZARD COMMUNITY IN RESPONSE TO SHIFTING VEGETATION AND CLIMATE OVER THE LAST 16,000 YEARS

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Rapid environmental change in the Anthropocene presents a major threat to global biodiversity and ecosystem functionalities. Long-term data are critical for developing strategies to mitigate these negative effects and paleontological data serve as a powerful tool for furthering our understanding of long-term biotic responses. Here, we use a late Quaternary fossil site, Hall's Cave, as a study system for investigating how environmental changes impacted a lizard community over the last 16,000 years. We identified nearly 3,000 fossil lizards to at least the family level. We calculated Shannon diversity within time bins spanning about 500 years and identified distinct minima and maxima in diversity associated with known environmental changes. Within at least two lizard families (Anguidae and Phrynosomatidae) we discovered a turnover in the composition of taxa in the early Holocene. We found a statistically significant correlation between the relative abundance of several lizard families and the relative abundance of select plant taxa based on a previously published pollen record from Hall's Cave. Teiid lizards, for example, are positively correlated with plants found in open habitats. Redundancy analyses showed that lizard community composition is significantly explained by both pollen records and paleoclimatic variables. We assessed to what extent taphonomic processes influence the reconstruction of the lizard community by collecting data on taphonomically relevant variables. We found that pollen and paleoclimatic data still significantly explained variation in lizard community composition with taphonomic variables included as covariates. Moreover, taphonomic variables alone do not significantly explain variation in lizard community composition. Several paleoclimatic variables do not have a linear relationship with lizard community composition, so we modeled changes in lizard relative abundance using generalized additive mixed models. We used a subset of our data to train models and compared predicted values to observed values during the late Holocene and the late Pleistocene. Models were able to predict trends accurately for a few families such as teiids and crotaphytids, but in many cases showed large deviations from observed values. These large deviations from observed values could be explained by substantial lizard diversity observed below the family level. Fossils identified below the family level likely give a more detailed picture of the lizard community through time, but this results in a substantially reduced sample size and fossils from some families are more readily identifiable making comparisons difficult. Overall, these results demonstrate that long term changes in the lizard community are likely tied to both climatic and vegetational changes that occurred in the region.

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## WE NEED EACH OTHER: BRIDGING PALEONTOLOGY AND ARCHAEOLOGY FOR THE FUTURE OF CARIBBEAN VERTEBRATE DIVERSITY

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As is increasingly recognized across both natural and social sciences focused on biodiversity conservation in the Anthropocene, deep-time diversity baselines spanning pre-human to human time-scales are essential to understanding differential species loss or persistence through time, across space, and among cultures. When used together, paleontology and archaeology are uniquely positioned to provide critically needed baselines informing histories of taxonomic diversity and distribution—particularly within the context of elucidating anthropogenic impacts. Here, we discuss interdisciplinary paleontological and archaeological efforts to document late Quaternary non-volant mammalian and avian diversity in the Caribbean. We synthesize previous and current research, and propose an agenda for integrated vertebrate paleobiological research with an eye toward supporting conservation goal-setting and management.

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## HUMAN IMPACTS, RATHER THAN THE LATITUDINAL PREDATION GRADIENT, DRIVE CRAB PREDATION ALONG THE WEST COAST OF NORTH AMERICA

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Uniformitarianism has long been a paradigm for paleontology; paleontologists routinely use modern data to understand ancient systems better and to ground-truth concepts and techniques. However, given widespread anthropogenic stresses on modern ecosystems, recent research has questioned whether modern systems are still appropriate models for comparison with the past. In the present study, we examine how human activity may affect a broad-scale ecological pattern, the latitudinal predation gradient. Predation intensity generally increases with decreasing latitude. At lower latitudes, predators are larger, stronger, faster, and more specialized, and their prey are better defended. This latitudinal gradient is observed in the Recent and in deep time as well. However, while predator and prey morphology are consistent with the gradient, it would be useful to test how more direct measures of predation intensity, such as repair % (R%), vary with latitude. Here we test the potential impacts of humans on this foundational ecological principle by examining the relationship between R%, latitude, and human impact in a common, modern crab-gastropod system from the west coast of North America, rock crabs (e.g., *Cancer productus*) preying upon the black turban snail (*Tegula funebralis*). We collected repair data from >3000 gastropods from 28 localities ranging from Vancouver Island, B.C., Canada to San Diego, CA, U.S.A. R%, the number of individual gastropods with repaired shells within a sample, ranged from 93% to 11% (mean = 41%). We used Cumulative Human Impact Factor (CHIF) scores from studies done by Halpern et al.; CHIF summarizes the influence of 17 different human impact drivers (e.g., sea-surface temperature rise, ocean acidification, pollution from land, fishing etc.) on marine systems. CHIF scores ranged from 1 to 15 at the localities (0 = pristine). A mixed-effects regression using the beta distribution with R% as the response, CHIF and latitude as independent variables, and locality as a random effect found that the best model (lowest AIC) included both CHIF and latitude (but not their interaction). CHIF had the greatest influence on R% ($p < 0.001$) with sharp declines in R% with increasing CHIF. As previous work demonstrated that R% in this particular system is primarily driven by crab abundance, our results suggest that human impacts likely have adversely affected crab populations in the region. Regardless of the underlying cause, human impact at local scales was severe enough to overwhelm any natural latitudinal signal.

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## INTERROGATING ABLEISM AND THE PRIVILEGE OF SCIENCE: STUDENT PERCEPTIONS OF ACCESSIBILITY AND DISABILITY IN PALEONTOLOGY COLLEGE CLASSROOMS

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Academic systems have had a historic role in upholding forms of othering, such as elitism, racism, and ableism. This is particularly true in evolutionary biology, which formed some of the early "scientific" justification for othering using racial pseudoscience and eugenics practices. This study surveyed undergraduates in evolutionary biology courses, as practitioners of inclusive education such as Universal Design for Learning (UDL), and assessed their understanding of concepts such as accessibility and disability. By teaching undergraduate students how to use concepts of inclusive design in their class assignments, we intended to increase student awareness of and appreciation for disability accessibility, and provide a deeper sense of social justice education in evolutionary biology. During fall 2020, we designed and implemented a 6-week-long digital media project in an online, undergraduate non-majors human biology course with strong paleontology and paleoanthropology frameworks. The curriculum was then implemented during spring 2022 in three additional paleobiology-centered courses. Students produced a digital product—a video, podcast, or series of curated social media posts—that explained aspects of a peer-reviewed scientific article related to the course material. In addition to their broader science communication goals, students incorporated aspects of inclusive design, such as closed captioning for d/Deaf and Hard of Hearing audiences, audio narration for blind or low vision audiences, colorblind accessible palettes, or alt text for social media posts. Students were provided with pedagogical scaffolding throughout. From the 2020 post-course Likert-scale reflections (N = 336), over 96% of students responded they agreed that they had "grown in [their] awareness of disability and accessibility accommodation," and 93.8% "now consider disability to be a part of human diversity more than before this project or course." In addition, 85.5% of student respondents shared that they agreed with the statement, "as a student, I feel more included in science because of this project or course." Analysis of spring 2022 data indicates that 93.4% of students (N = 106) agreed they had grown in disability awareness and accessibility accommodation, while 87.7% of students agreed that they considered disability to be part of human diversity

more than before the project. A key component of this work involved mixed method analysis, where qualitative thematic analysis of text was used to inform the quantitative process. Using digital media projects that incorporate inclusive design, we can interrogate ableist systems in academia and help more students feel welcome in STEM fields. Ultimately, having more frequent dialogue about disability accessibility in STEM courses can make a tangible difference in creating a more just and equitable learning experience for every one of our students.

## TESTING THE BOREAL-TETHYAN SHIFT OF NERINEOIDEAN GASTROPODS: TAXONOMIC CLASSIFICATION USING CONVOLUTIONAL NEURAL NETWORKS

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The opening of the North Atlantic during the Middle Jurassic allowed Arctic currents to reach Western Europe, leading to a southward shift in the biogeographic distribution of invertebrate macrofauna from the northern Boreal Realm. This phenomenon, known as the 'Boreal spread,' has been proposed for several groups, including nerineoidean gastropods, but has not been quantitatively evaluated. Nerineoidea, an extinct group of gastropods, was highly abundant and diverse in Jurassic–Cretaceous shallow marine environments. The group is characterized by internal spiral folds visible in polished cross-sections, which form the basis of their classification. However, conflicting taxonomic classifications among authors hindered large-scale analyses based on species occurrences. Our developed geometric morphometrics protocol effectively distinguished five nerineoidean families into three groups based on internal whorl outlines: Ceritellidae, Ptygmatididae, and a combined Nerinellidae+Eunerineidae+Nerineidae group, utilizing data from CT scans, online databases, and published literature. This study introduces the first automated taxonomic identification method for nerineoidean gastropods, employing machine learning to classify images. The compiled database was then used to test for changes in the biogeographic distribution of Nerineoidea across the Jurassic Tethyan and Boreal Realms. Through compilation of a comprehensive image database from diverse sources, including figures and illustrations in published literature, we trained a convolutional neural network (CNN) to classify images into the three predefined groups. Our model exhibited promising accuracy (89%) and recall (90%) despite a relatively modest dataset size (1067 images). The CNN notably excelled in classifying images of Nerinellidae+Eunerineidae+Nerineidae, reflecting their prevalence in our dataset. Our findings support a southward nerineoidean expansion from the Early Jurassic Boreal Realm to the Middle Jurassic Tethyan Realm, potentially influenced by paleoecological adaptations to changing environments. This CNN framework lays groundwork for expanding the datasets and conducting robust quantitative analyses across various sources in the future. Our data compilation underscores the challenges in transitioning to digital repositories encompassing complex data formats, including publication figures and illustrations.

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## THE EMERGENCE OF POLYMORPHISM IN A CHEILOSTOME BRYOZOAN

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Morphological polymorphism is strongly associated with division of labor, as divergent morphologies in groups or multicellular individuals often correspond to specialized functions. Division of labor presumably evolves as phenotypic variation in novel polymorphs is channeled into distinct morphologies, corresponding to particular functions. In the cheilostome bryozoans, the connection between division of labor and polymorphism is unclear because the functionality of certain polymorphs in colonies remains ambiguous. Here we analyze the evolutionary morphology of one such polymorph type, termed avicularia, after it first appears in the fossil record of the middle Cretaceous genus Wilbertopora. In this genus, avicularia first appear as slightly modified feeding individuals, termed autozooids, in colonies. We find that avicularia experience two pulses of high disparity within colonies shortly after their appearance in the fossil record. This high disparity is associated with loss of function—indicated by the loss of associated ovicells showing a reduction of lophophores and a loss of sexual functions and the ability to feed. After this loss of function, avicularia become progressively divergent from autozooids within colonies, expanding into novel regions of morphospace.

## KINEMATIC MOBILITY AND MODULARITY OF ANCESTRAL MAMMALIAN HYOID

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The basi- and thyrohyals of the mammalian hyoid cradle the larynx, while an ossified chain called anterior cornu connect the basihyal to the basicranium. First seen among Jurassic mammals, the saddle-shaped basi-thyrohyal complex and ossified anterior cornu are hypothesized to be critical for the evolution of mammalian swallowing behavior. Extant mammals exhibit variable ossification of anterior cornu, but how this variation impacts swallowing biomechanics is unknown. One hypothesis suggests completely ossified cornua (integro-cornuate) constrain basihyal excursions compared to incompletely ossified (discreto-cornuate) cornua. In contrast, integro-cornuate hyoids may allow individual elements to move differently and expand hyoid functional repertoire. We used XROMM to quantify 3D hyolingual swallowing kinematics in dogs, which have integro-cornuate hyoids. During swallow-transport cycles, absolute and relative magnitudes of dog basihyal excursion exceed those of discreto-cornuate mammals like opossums; interspecific difference in basihyal excursion is driven by larger tongue protraction post-swallow in dogs. During dog tongue base retraction (TBR), proximal cornu elements (stylo- and epihyals) remain stationary while cerato- and basihyal protract and elevate. We hypothesize that kinematic decoupling between proximal and distal cornu elements help integro-cornuate hyoids perform two divergent functions during swallowing: airway protection and bolus propulsion. While distal hyoid elements could divert the larynx from the bolus, proximal elements could anchor the styloglossus muscle during TBR. Kinematic modularity of integro-cornuate hyoids may contribute to the diversity of mammalian TBR mechanisms.

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## MESOPHOTIC REEFS IN THE SILURIAN: INSIGHTS FROM SOUTH CHINA

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After the mass extinction at the end of the Ordovician period, metazoan reefs underwent a recovery and became widespread on the Yangtze carbonate platform by the late Aeronian. The early Telychian Hanchiatien Formation, characterized by siliciclastic sediments, marks a transitional period from full recovery to a global peak of reef ecosystems in the Wenlock. The reefs within the Hanchiatien Formation exhibit limited size and biodiversity. The meter-scale metazoan reefs were primarily constructed by abundant bryozoans and corals, prominently exposed in the lower part of the Formation at the Chayuan Section in northern Guizhou, Southwest China. Encircled by gray-green shales and silty shales, the reef limestones feature a significant proportion of thin encrusting bryozoans and platy corals, while branching and massive skeletons are also prevalent. This case might represent the mesophotic reef ecosystems during the Paleozoic, mirroring some of the contemporary examples in offshore shelf areas of the Great Barrier Reef. The Hanchiatien reefs may have grown in murky and shallow environments, where light penetration was obstructed by sediment particles suspended in the water column, therefore resembling the "brown mesophotic" ecosystems. These results reveal crucial environmental drivers of reef composition, providing insights into the co-evolutionary mechanisms of life processes and regional tectonic events in deep time.

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## THE LOCAL/REGIONAL HETEROGENEOUS BENTHIC REDOX RESPONSES TO THE OCEANIC ANOXIC EVENT-2 AS INDICATED BY SEDIMENTARY VANADIUM ISOTOPIC COMPOSITIONS

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The oceanic anoxic event-2 (OAE-2), which occurred ~94 million years ago, was characterized by the global expansion of reducing conditions, i.e., oceanic anoxia and euxinia. Additionally, there were perturbations to marine cycling trajectories of nutrient elements (e.g., carbon, sulfur, and other redox-sensitive trace metals), and associated marine biological turnover. Despite the general idea of homogeneous widespread and consistent expansion of oceanic anoxia/euxinia during OAE-2, various localities likely experienced asynchronous redox fluctuations throughout the roughly 500-thousand-year-long event. Such local/regional redox fluctuations, like across the anoxic to the low-oxygen conditions, remain more or less equivocal as indicated by the discrepancies between the geochemical proxies and the paleontological evidence. Such discrepancies likely result from sampling resolution, proxy redox sensitivity, and/or time-integration of signals, particularly for the low-oxygen condition which is underestimated with current widely applied geochemical proxies. We applied vanadium isotopes ($d^{51}V$), a novel geochemical proxy that has been suggested to be sensitive to benthic redox conditions. Three organic-rich black shale localities in the tropical proto-North Atlantic Basin were analyzed. The sedimentary $d^{51}V$

signals distinguished the previously under-constrained benthic low-oxygen conditions and thus reconciled the discordance between previous geochemical proxies and paleontological records. This suggests there were heterogeneous regional/local redox variations during a general background of expanded anoxia. More importantly, such short-term oxygenation perturbations in bottom waters likely allowed for the survival of the low-oxygen-tolerant species. Together, these data indicate heterogeneous local/regional redox and biological responses to the OAE-2 in the tropical proto-North Atlantic Basin and likely for many other events in Earth's history.

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## A NEW TYPE OF RAPTOR: RECREATION AND PERMIT TRACKING ONLINE REPORTING

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The Bureau of Land Management (BLM) has developed a new online platform for applications and reports for several BLM programs. RAPTOR (Recreation And Permit Tracking Online Reporting) includes Paleontological Resource Use Permits, Special Recreation Permits (SRP), and General Science permits. The motivations for creating the system include establishing a digital system of record for these federal records; making internal and external communication easier; increasing transparency; providing consistency across the bureau; providing tracking and automation features; and offering flexibility. Currently, the Paleontology module of RAPTOR is being used primarily in the BLM's Montana/Dakotas State Office, where we are responding to feedback from both internal and external users. This pilot of the system has proven to be very valuable for identifying bugs and system enhancements that will result in a better user experience. External paleontology users create an account to access RAPTOR. Requirements include uploading a resume or CV and uploading a repository (museum) agreement indicating the repository is aware of the work and agrees to curate the material collected. The system allows long narratives to address basics about the proposed work and allows an applicant to attach additional documentation, including photographs, publications, and Google Earth files to help the BLM evaluate the proposal. The system will route the applications to the appropriate reviewing office, and internal users are notified that an application is awaiting review. Internal review consists of making sure the applicant(s) are minimally qualified to conduct the work; reviewing the proposed work; satisfying the mandates of the National Environmental Policy Act (NEPA) of 1970; and applying appropriate terms and conditions. Once a permit is issued, the external user gets three reporting tasks: the Report, the Repository Receipt, and the Locality Report. A tremendous benefit of the paleontology module of the RAPTOR system is that BLM created a corporate data schema for our locality data. Several templates were developed that users enter locality data into, and then they upload those completed files. After review, the uploaded locality data goes into the corporate locality data without needing additional manipulation.

## WHAT'S THE DEAL WITH PROBOSCIDEANS AT RANCHO LA BREA?

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Proboscideans are among the most abundant, latest-surviving, and best-studied Pleistocene megafauna in North America, yet their record at Rancho La Brea (RLB; California, U.S.A.), the world's richest Pleistocene terrestrial locality, is surprisingly sparse. In contrast with the remains of thousands of saber-toothed cats and dire wolves, and hundreds of individual bison, horses, and camels, the site preserves fewer than 50 mammoths (*Mammuthus columbi*), and only around 30 mastodons (*Mammut pacificus*). Moreover, despite phenomenal preservation of biotic tissues that has allowed detailed geochemical analyses on specimens ranging from insect elytra and plant leaves to the bones of dozens of species of extinct birds and mammals, proboscidean remains at RLB have proved vexingly difficult to radiocarbon date. Despite recent intensive efforts, currently only three individual proboscideans have been successfully dated at RLB: a mammoth ("Zed") dated to ~40,000 calendar years BP (cal BP); a mastodon dated to ~17,000 cal BP, and a second mastodon dated to ~14,000 cal BP. Interestingly, most of the proboscidean remains at RLB (>600 bones representing at least 27 *M. columbi* and five *M. pacificus*) were discovered in a single deposit, Pit 9. Aside from this, the two proboscidean species only co-occur in four deposits across the site, none in great abundance nor with good chronological control. Notably, mammoths (but not mastodons) are completely absent from the site's youngest-dated deposits, suggesting that they may have become extirpated from the region well before the regional megafaunal extinction or the continent-wide extinction of their species. In this talk we will use various lines of evidence to explore some of the longstanding mysteries of the proboscidean community at RLB, including: What is the chronology of *Mammut* and *Mammuthus* presence at RLB, did they ever coexist at the site, and when did each species disappear from southern California?; What were the ecological niches of *Mammut* and *Mammuthus* in southern California, and how did they compare with other regional

populations; How did ecosystem structure across the last 50,000 years of the Pleistocene impact the presence of proboscideans at RLB, and vice-versa?; and, Why are most of the proboscidean remains at this site concentrated in a single deposit (Pit 9), and when and how did this deposit form?

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## THE EVOLUTION OF MAMMOTHS: MORPHOLOGY MEETS DNA

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A history of mammoths is presented, from their origins in Africa ca. 6 Myr, spreading to Europe and Asia c. 3.5 Myr, and into North America ca. 1.3 Myr. A major morphological and adaptive step occurred in the transition from *Mammuthus meridionalis* with relatively low molar crowns, to the high-crowned *M. trogontherii*, with the earliest remains of the latter (the so-called steppe mammoth) found in China at ca. 1.7 Myr. The idea that the earliest North American mammoths were of *meridionalis* type conflicts with the *trogontherii* morphology of the first mammoths to appear at the departure lounge in NE Siberia. Moreover, no convincing remains of *meridionalis* morphology have been found in North America; instead, even the earliest representatives, through to later *M. columbi*, are of very similar morphology to Eurasian *M. trogontherii.* The earliest fossils of woolly mammoth, *M. primigenius*, are found in NE Siberia ca. 0.7 Myr, where they appear to descend from the resident *trogontherii*-like population. Recent research on ancient DNA has contributed significantly to our understanding of mammoth evolution. The new data confirm the morphological model that Early Pleistocene mammoths from northeast Siberia, of relatively advanced form comparable to European *M. trogontherii*, were firstly the source of endemic North American mammoths, and subsequently gave rise to the woolly mammoth. The latter species then spread westward into Europe and eastward into North America, where it met indigenous *M. trogontherii* and the precursor of *M. columbi*, respectively. The genomic data reveal at least two introgression events in the North American Middle Pleistocene, resulting from hybridisation between the endemic form and immigrating woolly mammoth populations. Whether these introgression events constitute hybrid speciation is open to debate. The taxonomic implication, that only post-hybridisation mammoths should be named *Mammuthus columbi*, would pose significant practical issues for researchers and curators. Since there is as yet no DNA evidence from pre-hybridisation North American mammoths, nor clear morphological features distinguishing them from later populations, there would be no reliable way to select a type specimen on which the 'early species' could be based. By the same token, the only clue to the identity of any North American mammoth fossil as *columbi* versus its predecessor would be its age—but many mammoth fossils are poorly dated, and the date of the hybridisation event itself is only broadly constrained. This warrants a conservative approach to taxonomy, in which paleontologists continue to employ a morphospecies concept and label all North American mammoths as *M. columbi* or *M.* cf. *columbi* until/unless we locate consistent morphological changes at the hybridisation event. Further DNA evidence from the early forms in Siberia and N. America, as well as craniological data, should aid the resolution of these evolutionary and taxonomic issues.

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## THE RICHMONDIAN INVASION: ECOLOGICAL IMPLICATIONS OF INCUMBENT AND INVADER DISTRIBUTION PATTERNS

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Species invasions and their causes are of major interest to ecologists because of potentially detrimental effects on native (incumbent) communities. The upper Ordovician of the Cincinnati Arch region (OH, IN, and KY) geologic record permits study of these events over scales of 103 to 105 yrs. During the Late Ordovician Richmondian Age (~447.5 to 445 Ma) a diverse suite of marine invertebrates, including brachiopods, bryozoans, and corals, immigrated into the area. Previous studies have examined the "Richmondian Invasion" at a coarse scale, but questions remain as to first appearance, persistence, and dominance of invading taxa and effects on incumbent taxa. This study utilized a two-pronged approach to study these questions at a high stratigraphic resolution. First, it employed an extensive presence/absence dataset (187 genera, 128 samples across 5 formations) spanning the Richmondian Stage, to study aspects of the diversity of incumbents (111 total genera) and invaders (76 total genera) and patterns of appearance and persistence. Second, a series of 125 bulk samples through a critical ~20 m interval, were counted to quantify patterns of relative abundance of incumbents and invaders. A majority of incumbents span the entire 2.5-to-3-million-year Richmondian interval, with only a single extinction, despite the influx of invaders. Only about half of the invading genera were successfully established; a majority (67%) of these genera invaded in two brief events (Clarksville and Liberty phases) and then persisted, without changing to the end of the Richmondian. The Clarksville invaders did not expand during the subsequent interval, but persisted in extremely low abundance for several hundred thousand years. Subsequently, in the overlying Liberty Formation, invaders once more became abundant with a lesser number

of newly established invaders. However, even here, invaders dominated only in limestone rich packages associated with transgressions, while incumbents remained strongly dominant in shale rich highstands. This pattern indicates that invaders remained at a disadvantage throughout their history, likely had little impact on incumbent communities, and were more sensitive to environmental changes. From our results, it appears that immigration events and relative success of invaders were controlled mainly by environmental changes rather than ecological interactions. Future work is planned for examining the distribution patterns of these taxa by sampling higher Richmondian strata (Whitewater Formation), as well as comparing these Ordovician species invasions with those of the Devonian recorded in Appalachian Basin strata.

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## ESTABLISHING THE ENVIRONMENTAL CONTEXT FOR EARTH'S FIRST 'MASS EXTINCTION'

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Reported declines in taxonomic diversity between the White Sea (~560–550 Ma) and Nama (~550–539 Ma) biotic assemblages of the Ediacaran macrobiota strongly influence current understanding of early animal evolution. Models invoking biotic replacement or mass extinction events seek to explain these trends, but there is limited geological evidence for extrinsic causes for a mass extinction, or for compelling intrinsic drivers of biotic replacement. Since the influence of local paleo-environmental controls on Ediacaran taxonomic diversity is not adequately accounted for in existing datasets, the shifts in diversity may feasibly be an artefact of our poor understanding of the environmental conditions under which these organisms lived and were fossilised. Highly generalised paleo-environmental descriptions for key localities, limited facies analysis of non-fossiliferous units, and differences in facies interpretative frameworks amongst research teams all complicate paleo-environmental reconstructions and global site comparisons. Here, we apply consistent, field-based sedimentological and stratigraphic methods to reconstruct the paleo-environmental context of key sites representing pre- and post- 'extinction' biotic assemblages, with a focus on the Aar and Kliphoek members of the Nama Group of southern Namibia, with insight from the Ediacara Member of South Australia, considering both fossiliferous and non-fossil-bearing intervals. Our approach permits direct comparison of similar paleo-environments between assemblages and through time, allowing us to decouple paleo-environmental and evolutionary controls on the observed distribution of Ediacaran macrobiota. Macrofossils are strongly facies- and environment-dependant in all studied sections. Our findings suggest broad overlap in paleo-environments between key sites, with deltaic, shoreface, and offshore shelves represented in all studied basins. However, subtle but important differences between sites have the potential to influence interpretation of true organismal diversity and community structure. For example, the majority of soft-bodied macro-organisms previously documented in the Aar Member have undergone transport before burial, and are not preserved in their original habitats. Moreover, the frequency of occurrence of specific facies across different sites can be highly variable. These differences may account for aspects of the variation in community composition, ecosystem maturity, and organism size between pre- and post-extinction localities, adding nuance to interpretations of existing patterns of biotic diversity across this interval.

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## CROWN GROUP SPONGES FROM THE NAMA GROUP OF NAMIBIA, AND THE EVOLUTION OF SPICULOGENESIS ACROSS THE EDIACARAN-CAMBRIAN TRANSITION

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Macrofossils of late Ediacaran age are increasingly recognized to include representatives of stem and crown group metazoan phyla, but robust fossil evidence for Ediacaran Porifera has proven elusive. Here we describe a new Ediacaran macrofossil genus, comprising two distinct species, from the late Ediacaran Aar Member (~548 Ma) of the Nama Group of southern Namibia. The two new taxa, which are globular and bowl-shaped respectively, can reach at least 40 cm in size, are often preserved three-dimensionally, and exhibit surface impressions of a grid of sub-divided quadrate boxes that covers the entire body. Preservation of some specimens in the assemblage with regions showing entirely smooth surfaces (lacking the grid, which often occurs on sub-millimetric surface veneers), and wrinkling, suggests that these taxa possessed a smooth and

flexible internal membrane. Such specimens find comparison with a number of similar smooth, three-dimensional, bag-like structures preserved in sandstones in other global localities. The grid impressions are interpreted to indicate the presence of a non-mineralized organic exoskeleton comprised of cruciform skeletal elements, similar to that seen in several biomineralized Cambrian hexactinellids. Reappraisal of late Ediacaran candidate sponges and earliest Cambrian sponge spicules supports the suggestion that spiculogenesis evolved prior to the evolution of biomineralization, and is consistent with the independent acquisition of biomineralization amongst the major poriferan clades. The Namibian specimens provide a new search image for fossil sponges prior to the evolution of mineralized spicules, and suggest that the fossil record of late Ediacaran sponges may be far more diverse than previously recognized.

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## FOSSIL RECORDS OF PALEOGENE CATOSTOMIDS AND JIANGHANICHTHYIDS (OSTARIOPHYSI: CYPRINIFORMES) FROM ASIA: REVISION, REMARKS, AND NEW SPECIES

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The known Paleogene non-cyprinid cypriniforms belong to two families: Catostomidae and Jianghanichthyidae. While catostomids occurred in Asia and North America, jianghanichthyids were only known from Asia. Both families barely have any extant members in Asia. Several nominal Eocene "*Osteochilus*" (an extant cyprinid genus) from China were believed to be catostomids and previously referred to as problematic catostomids. This study aims to systematically review the fossil record of catostomids and jianghanichthyids from Asia, comprehensively revise the position of problematic catostomids, and briefly report new materials of Paleogene non-cyprinid cypriniforms. Three skeleton-based, single-species genera, namely *Amyzon*, *Plesiomyxocyprinus*, and *Vasnetzovia*, have been identified from Eocene Asia. The skeletons and pharyngeal teeth materials of *Amyzon hunanense* from Hunan, China, represent the southernmost geographical occurrence of catostomids in Asia. Disarticulated bones and pharyngeal teeth extend the geological occurrence of catostomids to the early Oligocene in Central Asia. Several rediscovered specimens from the collection of the AMNH Central Asia Expedition confirm the occurrence of catostomids in Oligocene Central Asia. Compared to the widespread fossil record of fossil catostomids, jianghanichthyids are currently known to be confined to southern East Asia and are found in Paleocene and Eocene sediments. Several nominal species of the extant cyprinid "*Osteochilus*" from Paleocene-Eocene China have been revised to be species of *Jianghanichthys*, thus belonging to the family Jianghanichthyidae. New materials of jianghanichthyids have been recovered from Eocene Huachong Formation in Foshan, Guangdong, China, and are herein described as a new species. In conclusion, Asian fossil catostomids have been distributed in present-day China, Siberia, Mongolia, and Kazakhstan from the early Eocene to the early Oligocene, whereas jianghanichthyids are the oldest known unambiguous cypriniforms and are found in late Paleocene to Eocene sediments of southern China. Oligocene catostomids of Asia so far are only observed in the central Asia area, including northern China, Mongolia, and Kazakhstan, which appears to be catostomids' vestige in Asia near the Bering Land Bridge.

## LIVE-DEAD FIDELITY OF ECOLOGICAL HEALTH INDICES (AMBI AND M-AMBI) IN BENTHIC MARINE ASSOCIATIONS: A CASE STUDY FROM COASTAL NORTH CAROLINA, U.S.A.

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Benthic marine communities are often used as indicators of environmental health because their species composition and abundance are closely linked to key environmental parameters. By comparing living (LA) and death assemblages (DA), one can uncover crucial ecological alterations that have arisen due to human activities. However, we lack empirical studies that compare live and dead assemblages in terms of ecological indices like AMBI and M-AMBI, which are effective at quantifying human impacts. To calculate AMBI and M-AMBI and assess their live-dead concordance, 221 dredge samples were collected at 52 sites in Onslow Bay, North Carolina, U.S.A. 12,587 live and 55,531 dead individuals from six phyla (Annelida, Arthropoda, Brachiopoda, Cnidaria, Echinodermata, and Mollusca) were counted and identified to the lowest taxonomic level. As many organisms have multiple skeletal components (e.g., valves, plates, or spines) that may disarticulate after death, component counts were divided by the estimated number of components in a single living organism. Community health assessments based on the AMBI index differed notably between the LA and DA. The DA yielded significantly higher estimates of AMBI (median = 0.72 for the LA and median = 2.26 for the DA; $p << 0.0001$, Wilcoxon rank test). At the locality level, there was no significant correlation between AMBI scores for the LA and

DA (rho = -0.026, $p$ = 0.75). The poor live-dead agreement in AMBI estimates primarily reflected the dominance of the opportunistic bivalve *Mulinia lateralis* in the DA due, at least partly, to taphonomic processes. In contrast, M-AMBI was consistent for the LA and DA (median = 0.40 for the LA and median = 0.42 for the DA; $p$ = 0.82, Wilcoxon rank test). At the locality level, there was a significant correlation between M-AMBI scores for the LA and DA (rho = 0.69, $p << 0.0001$). The results remained consistent when data were restricted to mollusks (median = 0.22 for the LA and median = 2.32 for the DA; $p << 0.0001$, Wilcoxon rank test). However, for non-mollusks, agreement improved between AMBI scores for the LA and DA (median = 0.43 for the LA and median = 0.48 for the DA; $p << 0.0001$, Wilcoxon rank test). These results highlight that the choice of the metric used to assess community health is important. M-AMBI, which is less sensitive to the presence of individual dominant species, maybe a more robust estimator. In particular, caution should be used when utilizing surrogate taxa such as mollusks as a proxy for AMBI in the entire community in geohistorical comparisons. Because of taphonomic and time-averaging filters that amplify the dominance of opportunistic mollusk taxa, M-AMBI may be more appropriate. In coastal North Carolina, we find that meaningful estimates of M-AMBI indices can be derived from time-averaged death assemblages. Whereas a single case study cannot provide universally applicable generalizations about the comparative fidelity of M-AMBI, these results are promising.

## IS "EQUAL WEIGHT" PARSIMONY A LIE? (AND WHAT HAPPENS IF WE ACTUALLY WEIGHT CHARACTERS EQUALLY IN MAXIMUM PARSIMONY PHYLOGENETIC INFERENCE?)

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The default approach to phylogenetic inference of fossil taxa has historically been dominated by maximum parsimony inference from discrete morphological characters. More recently this approach has been dubbed "equal weights parsimony" (EWP) and used as a baseline comparison to other approaches, such as implied weights maximum parsimony (IWP), maximum likelihood, or Bayesian inference. I argue that whether this approach truly represents "equal weights" in the first place has not been adequately addressed. Specifically, I consider a property of individual characters, $h_{max}$, which is defined as the difference between the highest and lowest cost a character can have on any tree under maximum parsimony. I show that $h_{max}$ is variable across characters in almost all empirical data sets, even when characters are invariable in terms of general type (e.g., all binary), and that characters with high values of $h_{max}$ are less likely to be maximally incongruent with the set of most parsimonious trees. In other words, EWP in practice upweights characters with higher $h_{max}$ values and thus does not truly equally weight characters in phylogenetic inference. I propose a new approach I term equalised weights parsimony (EqWP), where the influence of $h_{max}$ is equalised across characters. Using a database of 1,447 independent empirical cladistic data sets I then show that EqWP (when compared to EWP): 1) genuinely ameliorates the influence of $h_{max}$, 2) tends to generate novel sets of relationships (distinct from EWP), 3) tends to produce fewer most parsimonious trees, 4) tends towards less homoplasy (= higher Consistency Index), and 5) tends towards less imbalanced trees (= lower mean corrected Colless' I). EqWP thus has some empirical properties that may be considered more desirable than EWP, especially if we accept the premise that evidence (= characters) should be equally weighted *a priori*. I.e., in the absence of reasons to consider some characters to be more reliable than others at inferring evolutionary relationships. I then discuss the properties of EqWP with respect to alternative weighting schemes such as IWP and conclude that, despite decades of work, there remain many open questions regarding how morphological phylogenetic inference can, and should, be conducted.

## DECLINES IN BIVALVE BODY SIZE ACROSS THE MID-PLIOCENE WARM PERIOD IN SOUTHEASTERN VIRGINIA: IMPLICATIONS FOR ECONOMICALLY IMPORTANT TAXA?

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The Neogene marine fossil record of the mid-Atlantic U.S. provides an ideal system in which to study biotic response to environmental change. One of these intervals of climate change, the mid-Pliocene Warm Period (MPWP), is associated with a 3 °C increase in temperature along with ocean acidification. Many of the fossil bivalve genera that are abundant and well-preserved across the MPWP have representatives that are economically important to the shellfish industry in the western Atlantic today. This suggests that the MPWP can provide insight into how these taxa may respond to anthropogenically driven warming in the next century. Physiological experiments and latitudinal patterns suggest that trends in bivalve body size vary in response to warming. To assess how body size in bivalves shifts across the MPWP, we collected data across a variety of fossil genera, including *Chesapecten*, *Ostrea*, *Astarte*, *Mercenaria*, and *Glycymeris*, representing a broad range of bivalve life habits, mineralogy, and taxonomy. Specimens were obtained from both museum and field collections, from time intervals before, during, and after the MPWP in southeastern Virginia. Although temperature and acidification increased throughout this time interval, localities were selected to ensure that other environmental and taphonomic variables, including salinity, water depth,

latitude, and preservation did not vary. Whole specimens were sampled across a minimum of five localities per genus, with at least 25 specimens per time interval per genus. Bivalve size was measured as two- or three-dimensional linear dimensions, either using landmark analyses or digital calipers, depending on the genus. Preliminary results suggest that multiple genera decrease in body size across this event, regardless of life habit or shell mineralogy. *Mercenaria* and *Ostrea*, in particular, are related to economically important species today, suggesting that warming is likely to cause a decline in harvest volume in the near future. Future work includes three-dimensional scanning and visualization to estimate shell volume, and by extension soft tissue volume, more accurately.

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## MORE MICHIGAN MARINE MACROALGAE (SILURIAN, LLANDOVERIAN)

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The Llandoverian (Telychian) Schoolcraft Formation of Schoolcraft County in the Upper Peninsula of Michigan includes several intervals of exceptional preservation, each of which is characterized by abundant specimens of the noncalcified *Codium*-like macroalga *Thalassocystis*. Here, three additional macroalgal taxa are reported from one of these algal-Lagerstätten intervals. One of the new forms is characterized by a monopodial thallus with whorls of branched laterals similar to the living dasycladalean green alga *Batophora* as well as the Ordovician taxon *Archaeobatophora*, the latter previously reported only from the Katian Big Hill Formation in neighboring Delta County. A second form belongs to *Palmatophycus*, a heavily branched monopodial taxon known previously only from the mid-Silurian Eramosa Formation of southern Ontario and the type locality in the Czech Republic (Motol Beds). Details provided by the new *Palmatophycus* material, when evaluated in the context of other macroalgal taxa documented from the Silurian within the last few years, point to a bryopsidalean green algal affinity for this taxon. A third form comprises rows of pinnate fronds broadly comparable to those of *Earltonella*, a *Caulerpa*-like bryopsidalean alga recently described on the basis of material from the Silurian Earlton Formation in Ontario (Lake Timiskaming area). Additionally, a new *Thalassocystis* locality is reported from the Schoolcraft Formation in neighboring Mackinac County, thereby extending the geographic range of this taxon along the northern rim of the Michigan Basin by some 12 km to the east and indicating a total east-west within-basin distribution of at least 55 km. In broader terms, this new algal material is important because it helps to increase understanding of a major radiation of siphonous green macroalgae—both Bryopsidales and Dasycladales—that began in the Ordovician, roughly concomitant with the GOBE, and continued into the Silurian. The picture that is beginning to emerge in this regard suggests that the outcome of this event emplaced a flora of siphonous green macroalgae in shallow Silurian seas, including the carbonate ramp setting of the northern Michigan Basin, that in broad brushstrokes at least was not markedly dissimilar from that of today.

## MORPHOBANK: A PALEONTOLOGICAL RESOURCE FOR COLLABORATIVE RESEARCH AND AN OPEN-ACCESS REPOSITORY FOR MORPHOLOGICAL DATA

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MorphoBank (www.morphobank.org) was initiated in 1999 at Stony Brook University with NSF support, and is an analog to the GenBank sequence repository, serving as a publicly accessible open access repository for morphological data. Since 2021, MorphoBank has been housed within the nonprofit scientific database hub, Phoenix Bioinformatics. MorphoBank facilitates the collection and dissemination of morphological character data through matrix building, phylogenetic analyses, and publication of reusable and downloadable matrices. Functioning as an open-access database and curation platform, MorphoBank enhances the discoverability and unrestricted reuse of morphological character matrices linked to peer-reviewed publications. The repository houses over 1,000 published matrices, spanning taxonomic groups including invertebrates, vertebrates, plants, and microorganisms. For matrix-based projects, users can upload existing matrices in Nexus or TNT format and can edit these matrices in the web environment with collaborators in real time. MorphoBank is the only software that offers this tool, automatically incorporating taxonomic names and characters. MorphoBank supports both discrete and continuous characters and accepts various 2D and 3D image formats, CT data, and pre-rendered 3D animations. MorphoBank assigns persistent digital object identifiers (DOIs) and links MorphoBank-hosted projects back to their original publications. To secure data for future researchers, weekly backups are performed. MorphoBank curators actively search for published papers with associated matrices, ensuring adherence to FAIR (Findable, Accessible, Interoperable, Reusable) data standards, with over 300 projects added in the past year alone. Collaborative efforts with UC Berkeley interns from underrepresented groups have led to the cataloging of 89 of 643 morphological matrices into

MorphoBank from peer-reviewed publications collected by the Paleobiology Database (PBDB). Ongoing enhancements include the incorporation of a parsimony tree-searching tools in TNT for the first time within a web environment, and integration with CIPRES for Bayesian analyses. An NSF-funded software re-platform scheduled for release in 2025 aims to modernize MorphoBank's source code, ensuring a more future-proof, maintainable, and expandable architecture with new and enhanced capabilities. We are exploring funding opportunities to broaden MorphoBank's scope to encompass diverse datasets (e.g., geometric morphometric landmark data, fossil calibration data, etc.). The repository's visibility and growth is further supported through the hosting of training workshops at conferences and the establishment of a volunteer program through the American Museum of Natural History (AMNH). Ideas for new features are welcomed, encouraging collaborative discussions for the continued benefit of the MorphoBank community.

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## GEOMETRIC MORPHOMETRICS AS A TOOL FOR CONSERVATION PALEOBIOLOGY: DETECTING ENVIRONMENTAL CHANGE USING LIVE-DEAD COMPARISONS OF LUCINID BIVALVE SHELL SHAPES AND SIZE

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Within the framework of conservation paleobiology, most live-dead comparative studies measure the fidelity of taxonomic composition to detect recent environmental changes that may be associated with anthropogenic impacts. However, despite well-documented examples of intraspecific changes in body size or morphology from biomonitoring time series, live-dead comparisons are less explored. Here, we propose the use of landmark-based geometric morphometrics as an inexpensive tool for future endeavors in conservation paleobiology. We present three case studies using geometric morphometrics to analyze shape and size differences between live and dead shells belonging to the family Lucanidae, which are chemosymbiotic, infaunal marine bivalves that inhabit environmentally-sensitive ecosystems worldwide. Landmark-based geometric morphometrics were used to quantify the shell shape and size of live and dead-articulated (1) *Stewartia floridana* (seagrass-inhabiting) from Bokeelia, Florida, (2) *Phacoides pectinatus* (mangrove sediment-inhabiting) from Wildcat Cove, Florida, and (3) *Ctena* sp. (marine pond and seagrass-inhabiting) from San Salvador Island, Bahamas. We find that intraspecific morphology of these species may be used to assess environmental change even if life and death taxonomic assemblage composition are comparable. For all three cases, live-collected individuals were significantly different in shape from co-occurring dead-articulated individuals. While live specimens exhibited morphological differences that relate to unique aspects of the environment they are found (e.g., seagrass density, isolated lakes), dead-articulated morphologies were distinct from the live morphologies. These finding may indicate that the living population is being impacted by distinct environmental factors, such as anthropogenic activities. This suggests that live morphology may have changed over time, raising questions as to whether this variation could be allopatric drift or possibly caused by recent disturbances. Although we do not know the duration of time averaging represented by these dead specimens, post-mortem transport of articulated shells was likely minimal. Taphonomic alteration has potential to be a factor in these morphological differences, however this alteration has been examined for *Stewartia* and is likely not the causes for the morphological differences between live and dead, but this has not yet been examined in *Phacoides* or *Ctena*. Live-dead morphometric comparisons (traditional or geometric) can be inexpensive and powerful tools for conservation managers to track the historical distribution of habitats and their ecosystem function through time, especially when used in conjunction with molecular phylogenetics (e.g., phylomorphospaces) and data that document environmental change (e.g., seagrass densities, porewater geochemistry).

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## THE *TREATISE ON INVERTEBRATE PALEONTOLOGY*: NEW DIGITAL INITIATIVES AND FUTURE-FORWARD VISION

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For over 70 years, the *Treatise on Invertebrate Paleontology* has been one of the most authoritative and comprehensive resources on invertebrate fossil groups, containing information on morphology, taxonomy, systematics, stratigraphy, biogeography, and more. The conception, development, and evolution of the *Treatise* has played a fundamental role in the field of invertebrate paleontology, particularly in how information has been compiled and shared. Yet, since the publication of its first volume in 1953, the scientific publishing and data dissemination landscape has changed radically. With

the increasing need for discoverable, accessible, and reusable data in paleontological research, the Paleontological Institute at the University of Kansas aims to go FAIR–improve Findability, Accessibility, Interoperability, and Reuse–with the vast and invaluable data contained in the *Treatise*. A significant first step has been to transition from printed physical volumes to open-access digital formats (OCR PDFs) to increase accessibility and reach a broader audience of researchers, avocational paleontologists, or anyone with an internet connection who is interested in invertebrate paleontology. Yet, the raw data contained in the *Treatise* text (e.g., taxonomic trees, nomenclatural history, morphological descriptions, stratigraphic and biogeographic ranges, specimen images, etc.) remains challenging to obtain directly for research or other purposes. To extract and normalize these data, we have developed *Treatise*-specific Python scripts to facilitate text processing and metadata extraction from the PDFs. These tools are instrumental in current and future efforts to make the *Treatise* text available, reusable, and linkable to other online resources. For the over 12,000 specimen images, our goal is to deposit them on MorphoSource, a digital repository for 2D and 3D media. Making the *Treatise* images and their respective specimen metadata widely available and discoverable on an individual basis on MorphoSource, a public and searchable resource, allows us to further integrate these media with specimen records through aggregators like iDigBio, maximizing their potential for use and join them more fully to museum collections records. Other *Treatise* integrations include working with the Earth History Visualization team of Purdue University and their International Union of Geological Sciences Deep-time Digital Earth program, which will link taxa to their biostratigraphic ranges, paleogeographies, and lithostratigraphic context, and with the Open Tree of Life, to incorporate *Treatise* classifications of fossil taxa into a digitally-available phylogenetic tree. The Paleontological Institute's new digital initiatives will enable researchers to leverage *Treatise* data more efficiently, helping to strengthen and streamline research produced using this essential resource.

## THE SHAPE OF SPEED: THE RELATIONSHIP BETWEEN 3D HUMERUS SHAPE AND MAXIMUM RUNNING SPEED

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Estimates of running speed are useful for many kinds of paleontological reconstructions, including the co-evolution of predators and prey and inferring the hunting strategies of extinct species, however previous studies have failed to find a significant relationship between skeletal morphology and speed. This study capitalizes on the high degree of variation in morphology and functional ability across domestic dog breeds to investigate whether shape data can be used for estimating running speed effectively. Here I utilize three-dimensional landmark-based geometric morphometrics and the exceptional historical records from competitive dog races to assess the relationship between humerus shape and relative maximum running speed across dog breeds. Selective breeding of dogs has pushed the morphological variation in dog breeds to the extremes, creating breeds with a variety of humeral shapes and a wide range of maximum running speeds from the Basset Hound and Shih Tzu at 34 km/h to the Whippet and Grey Hound at 65 km/h. For each breed, maximum running speed was determined using records from the American Kennel Club's (AKC) Fast Coursing Agility Test, which is a timed 100-yard sprint. Speeds were normalized by calculating their Froude number and then regressed onto shoulder height in order to obtain an accurate metric of breeds that are fast for their size. Results indicate that there is a strong and significant relationship between the maximum relative speed of the breed and shape of the humerus driven by a combination of the shape of the distal articulation and bone robustness ($R2 = .47$, $p < .001$). Overall, breeds that are fast for their size have generally more slender humeri with less curvature in the shaft. Tests of this dog-based predictive equation on wild canids have low error rates (%SEE = 12.9%, PPE = 12.4%) and support the use of these methods to estimate locomotor performance in fossil canids. Additionally, this method is applied to estimate maximum running speed in a selection of fossil canids, including the dire wolf.

## MISSISSIPPIAN (EARLY SERPUKHOVIAN ~331–327 MA) FRAMEWORK REEFS HIDDEN IN THE CAVES OF PIGEON MOUNTAIN IN NORTHWESTERN GEORGIA, U.S.A.

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After the devastating Devonian mass extinctions, coral species and communities took a long time to recover. The first Mississippian framework reefs began to reemerge by the middle Mississippian (late Viséan) in parts of the world, notably Australia, Western Europe, China, and North Africa. In North America, contemporaneous buildups are generally represented by rugose-microbial and sponge-microbial mounds and biostromes, which extended into the early Serpukhovian, before episodic cooling from the Late Paleozoic ice age caused another reduction and reorganization of these marine communities. Our study presents what we consider to be the first documented North American metazoan-dominated framework reefs for the late Mississippian (early

Serpukhovian). These framework reefs were discovered in three different caves within the extensive karst system of the Bangor Limestone on Pigeon Mountain in Walker County, Georgia, U.S.A. They were likely previously overlooked due to surface vegetation and unforgiving topography, leaving subsurface cave passages as an untapped environment in which to identify and study these reefal communities. Here, we describe their taxonomic composition, ecological associations, stratigraphy, and diagenesis. The caves containing the reef exposures are found on both sides of Pigeon Mountain, about 5000 m apart. The reef on the eastern flank of the mountain measures 2.7 m thick. On the western flank of the mountain, there are two distinct reefal sequences, separated by 6.3 m of cross-bedded crinoidal grainstone. The lower reef measures 4.3 m thick and is comprised chiefly of rugose colonies in various orientations. The upper reef is 5.2 m thick and shares the same ecology as seen on the eastern flank. Both are coral-sponge framestones (Caninostrotion sp. and Chaetetes). Individual chaetetids grow up to 45 cm in diameter, but often form interlocking masses that may reach up to 1 m in height. They appear to be the pioneer species, creating hard surfaces on which the corals settled. The rugose corals formed clusters measuring up to 1.5 m wide and appear in a mix of orientations, from in situ to overturned, indicating periodic storms. Thin sections from samples outside of the cave revealed that secondary microbial-fistuliporid bryozoan encrustation further stabilized the reef. Biodiversity in these reefs is high, with bafflers, such as crinoids, blastoids, and fenestrate bryozoans, and other organisms, such as brachiopods, spiny echinoids, gastropods, and benthic foraminifera. Matrix material between framework organisms ranges from wackestone to grainstone. Petrographic and X-Ray Fluorescence indicate late-stage dolomitization, mostly seen in portions of the matrix. Coral framework reefs struggled to regain their prominence in the Mississippian oceans. With other parts of the world showing a slow reemergence of coral-based framework reefs during this time, southeastern U.S.A. may now be tied into the global narrative of reef recovery.

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## TRILOBITES FROM THE WALCOTT-RUST QUARRY (MOHAWKIAN; ORDOVICIAN), NEW YORK: NEW INSIGHTS AFTER 150 YEARS

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Trilobites with preserved appendages have been known since the 1870s, first published by Charles D. Walcott based on material from the Ordovician Rust Formation in upstate New York. These unusual fossils preserved in three-dimensional calcite casts represent some of the earliest known complete trilobite appendages, but the nature of the fossils and their preparation as thin sections affixed to glass slides complicated the study and interpretation of their morphology. Not only has the organization of the non-biomineralized ventral structures been controversial, with many different interpretations over the last 150 years, but also the processes leading to the exceptional calcite cast preservation has been poorly understood. New investigations of historic collections houses at the Museum of Comparative Zoology at Harvard University reveal new insights on the taphonomy, anatomy and functional morphology of the Walcott-Rust trilobites, with direct implications for the preservation of non-biomineralized tissues and trilobite autecology. We present an updated taphonomic model showing the crucial role of sediment supporting the external cast during decay. Trilobites were entombed by a turbidity flow, in partially enrolled to flexed specimens, sediment surrounded the appendages and produced and external mold. Framboidal pyrite formed early during decay, followed by precipitation of calcite. The calcite crystals of the fossils lack a density difference with the surrounding matrix, preventing use of computed tomographic scanning to study the morphology, but comparison with enrolled specimens allows for more accurate interpretations of the historic thin sections. The contentious appendicular morphology has been updated, with the notably 7 segment exopodite of *Ceraurus pleurexanthemus* being an artifact of the difficulties of interpreting the fossils. Instead, *C. pleurexanthemus* is shown to have a similar exopodite to the early Ordovician cheirurid *Anacheirurus adserai* from the Fezouata Shale showing remarkable stability over 25 million years and in different environments. The appendages of *Flexicalyeme senaria* are less well known but appear broadly similar to those of *C. pleurexanthemus* with the exception of the exopodite which has ca. 40 thin dumbbell shaped lamellae instead of the thicker and fewer seen in the latter species. The partially enrolled specimens from the Walcott-Rust Quarry provide insights into the mechanism of enrollment, including the cross-sectional shape of protopodites and how sternites articulated. During enrollment, the sternites become anteriorly imbricated with the anterior margin dipping ventrally to be accommodated during flexure. Comparison with modern millipedes and isopods shows the same mechanism of enrollment, a striking case of convergence in lineages separated by 250 million years.

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## CLIMATE, LANDSCAPE, AND TAPHONOMIC SIGNALS OF FOSSIL ASSEMBLAGES FROM THE MIOCENE BASIN AND RANGE, WESTERN US

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In the nonmarine record, tectonics and climate control the stratigraphic record and influence the distribution of biota, which in part controls the patterns of biological occurrences in the fossil record. It is often difficult or impossible to examine the differing influences of tectonics or climate in deep time, owing to the availability of data about the environments, climate, or elevation during the time of deposition of many fossil accumulations. The Basin and Range of North America offers a potential opportunity to explore the degree to which the influence of tectonics, climate, and environment can be parsed in the fossil record. The Miocene Climatic Optimum (MCO, 17–15 Ma) was an interval of global climatic warming that occurred as western North America underwent significant elevation and landscape changes. Through this interval, numerous fossil localities formed in the developing Basin and Range that preserve plants and vertebrates that inhabited the region during these changing tectonic and climatic conditions. Many of these fossil localities formed localities in central Nevada that formed between 17 and 12 Ma were compiled from the literature and the MioMap database (now part of neotomadb.org) in order to evaluate whether changes in floral and faunal composition are related to changing climate or elevation. Floral localities represent broadly similar depositional environments in marginal lacustrine settings, but appear to represent different elevational or climatic conditions. Mammalian faunas from the same geographic area, however, offer a limited ability to detect elevation or climate signals. These mammalian faunas are typically poorly preserved and are more likely to represent the taphonomic modification of assemblages in fluvial and nearshore environments than biotic responses to elevation or climate changes. This underscores that different types of fossil assemblages have differing abilities to preserve signals of landscape or climate changes in the past.

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## PALEOENVIRONMENTAL PROXIES, FACIES DATA, AND RESEARCHER INTERESTS

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The current era of big data and big data sets has enabled many impressive analyses of large-scale patterns in the fossil record and the evolution of life. For example, large online databases provide a wealth of data that can be mined for different types of information to be used by researchers focusing on many different topics. For paleobiologists, these resources are valuable for providing access to paleoenvironmental proxy data or environmental interpretations of individual fossil localities or geological units. Often, these data or interpretations may be taken as they are presented and used in new analyses, or they may serve as the basis for new interpretations. Sometimes, however, environmental data is missing or insufficient, or the available proxy data require more effort to interpret within the scope of the researcher's goals. At worst, environmental information may be presented in categories so broad as to diminish its usefulness (i.e., "terrestrial" or "marine"). For a paleobiologist searching for environmental information, it may be difficult to find helpful data or interpretations, especially if the data types and methods fall outside their area of expertise. In particular, the most straightforward environmental information is sedimentological and facies data that is collected in the field, yet this information is often underreported and underused. This presentation offers some perspective on the use of paleoenvironmental proxies, their context, and how they intersect with the intentions and interests of researchers working to address paleobiological questions.

## CARNIVORAN BIRTH CERTIFICATES: UTILIZING MULTIPLE VISUALIZATION METHODS TO PINPOINT DENTAL NEONATAL LINES IN NEW TAXA

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Certain mammal teeth record internal evidence of placental birth. The neonatal line (NNL) is well-documented in humans and non-human primates, and is a dark, incremental growth line that serves as a potential marker of placental neonate birth stress. In humans, it is impacted by factors such as neonatal birth weight and mode of delivery, and is often located in deciduous teeth and adult first molars. However, the NNL isn't broadly identified across mammal taxa. If NNLs are known from primates and sparse non-primate examples, we hypothesize they will be present in Carnivorans. We share results from the literature and from new analyses which aim to identify putative neonatal lines in a variety of extant Carnivoran taxa (N = 5) and two fossil Carnivoran taxa, analyzing this trait for the first time in a phylogenetic context, with implications for identifying placental birth in other extant mammals and fossil taxa. Our team produced and examined dental histology thin sections from a selection of Carnivoran molars known to develop pre-birth and across the birth transition, aiming to visually identify the presence or absence of the NNL. Additional identification methods included a combination of CT density scanning, polarized light microscope dental histology, and laser ablation mass

spectrometry for zinc and barium analysis. Zinc and barium are putative markers of the NNL and the weaning transition, respectively. We compared these Carnivoran taxa with previously sampled marsupial teeth (*Monodelphis domestica*) which do not appear to have the neonatal line. The new Carnivoran taxa broaden the phylogenetic scope of mammals with putative NNLs, especially litter-bearing extant mammals. Our combined visualization methods provide an assessment of best practices for NNL identification in non-primate taxa. Preliminary histology and literature review results suggest the neonatal line is a shared trait in carnivorans, cetaceans, and Primates. Future work will further integrate dental neonatal lines into discussion of the timing of placental birth evolution, using staining, nanoCT, and laser ablation spectrometry identification techniques, expanding the scope of understanding mammalian birth through dental signatures.

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## SEPARATING THE PLANKTONIC AND BENTHIC FORAMINIFERAL RESPONSE TO ENVIRONMENTAL CHANGES ACROSS THE EOCENE-OLIGOCENE TRANSITION

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The Eocene-Oligocene transition (EOT) marks a pivotal moment when Earth's climate transferred from previous "warmhouse" condition to the present-day "icehouse" state. Despite years of research into this significant shift, the biological responses to this event, particularly among organisms with varied ecological niches, remain a subject of ongoing debate. Foraminifera, a major group of marine microorganisms living in the Cenozoic ocean, are typically categorized into three groups based on their distinct life-history strategies, morphology, and ecology: planktonic foraminifera, larger benthic foraminifera, and smaller benthic foraminifera. This organism serves as an ideal subject for examining how organisms with different ecological backgrounds responded to the pronounced environmental changes during the EOT. In this study, we present a novel 28-million-year-long record of foraminiferal species richness, achieving an average temporal resolution of approximately 26,000 years. This record is constructed using a comprehensive global dataset and the quantitative stratigraphic method known as CONOP. Our analysis reveals that larger benthic and planktonic foraminifera exhibited similar trends in diversity changes throughout the EOT, evidenced by a high correlation coefficient (? = 0.89). Conversely, smaller benthic foraminifera experienced a protracted decline in diversity, lasting approximately 7.53 million years across the Eocene and Oligocene. The diversity fluctuations in planktonic and larger benthic foraminifera near the EOT are linked to a rapid cooling of the deep ocean, a substantial sea-level fall, and a marked positive shift in carbon isotopic values. Meanwhile, the prolonged decline in smaller benthic foraminiferal richness is composed of two distinct phases: the first coincides with shifts in marine primary producer communities, whereas the second corresponds temporally with the volcanic activity of the Afar-Arabian Large Igneous Province (LIP). This study not only sheds light on the differential responses of foraminiferal groups to the environmental changes during the EOT, but also highlights the intricate relationships between marine biodiversity and global climate changes.

## MIND THE GAP: REVISING THE DESMOINESIAN (MIDDLE PENNSYLVANIAN) VERDIGRIS CONODONT ASSEMBLAGE

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Conodonts are useful as high-resolution biostratigraphic correlation tools, particularly in the application to Pennsylvanian cyclothems. The Upper Pennsylvanian has well-established, cycle-by-cycle, regional conodont biozones. The Desmoinesian (Middle-lower Upper Pennsylvanian) has a dual *Idiognathodus* and *Neognathodus* biozonation in North America, in response to provincialism, which results in challenging correlations at the biozone and cyclothem level (e.g., the Verdigris Cyclothem). Revisions and redescription of key faunas and of taxonomic name bearers of *Idiognathodus* species are fundamental to improving the established biostratigraphy. Idiognathodids comprise a large morphological spectrum, justifying the need to reevaluate species, establish accurate biozones, and refine biostratigraphy in the Desmoinesian. Knoxville, Iowa, is the type locality of the current index taxa *Idiognathodus iowaensis* and *Idiognathodus rectus*, which were established in the late 1940s. Recently, the type section has been rediscovered. New samples permit preliminary morphological groupings of the idiognathodid specimens, redescription of the Verdigris fauna, and re-evaluation of taxonomic classifications for the first time in recent history. It is vital to analyse the entire faunal assemblage characterising the Verdigris Cyclothem. High-resolution SEM images will be used for an initial analysis in which the specimens will be assigned into informal groups defined by diagnostic morphological features. Presently, two groupings are recognized that may correspond to *I. iowaensis*. The first group resembles the holotype morphology (slightly prominent caudal lobe, narrow/poorly developed rostral lobe, pointed dorsal tip, erratic nodose platform, and irregular undulate transverse ridges) and the second group resembles the paratype morphology (narrow rostral and caudal lobes,

complex undulate adcarinal ridges, sub-rounded dorsal tip, erratic nodose platform, and irregular undulate traverse ridges). Next steps will include further groupings of the idiognathodid and neognathodid specimens from Knoxville and result in an improved knowledge of the Verdigris assemblage.

## QUANTITATIVE RECONSTRUCTION OF C4 PLANT FRACTIONS IN PALEOSOLS AND MAMMAL DIETS IN THE CENOZOIC RECORD OF EASTERN AFRICA

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Reconstructing the history of biomes in eastern Africa is essential for understanding the assembly of modern ecosystems and the environmental context of ape and human origins and evolution. The East African Rift System preserves a vast archive of fossil mammals throughout the Neogene and Quaternary Periods, frequently within sedimentary deposits that include ancient soils (paleosols). The stable carbon isotope ratio ($d^{13}C$) of mammalian tooth enamel and pedogenic archives (organic matter and carbonates) are sensitive to inputs by the isotopically disparate $C_3$ and $C_4$ plants, the latter of which occur in outsized proportion in equatorial grassland and savanna biomes today. Past efforts to quantify the relative fractions of each vegetation type using tooth enamel and pedogenic archives have been inhibited by limited modern reference data and a lack of rigorous treatment of statistical uncertainty, leading many researchers to rely on qualitative assessments and expert judgement. This talk will present a new, global data compilation of >10,000 modern plant $d^{13}C$ values that includes local climate and geographic data, plant taxonomy, and plant characteristics. We use a Monte Carlo mixing model to quantify fractions of $C_4$ biomass for measured $d^{13}C$ values in mammalian tooth enamel and pedogenic archives over the past ~20 Myr. This data-driven approach incorporates uncertainty in plant endmember $d^{13}C$ distributions based on the modern reference data, paleo-atmospheric $CO_2$ $d^{13}C$ value using benthic foram proxies, fractionation factors in each isotope system, and analytical uncertainty in measured $d^{13}C$ values. Surprising results that emerge from these analyses include lower $d^{13}C$ threshold values for non-zero $C_4$ fractions in $d^{13}C$ observations compared to earlier approaches, and common Early and Middle Miocene enamel and paleosol $d^{13}C$ values that suggest substantial $C_4$ input. The modern data compilation also allows for filtering of $C_3$ plant endmember values based on climate regime, growth form and habit, and taxonomy. When semi-arid to sub-humid hydroclimate is assumed for Neogene sites that include calcareous paleosols, the estimated fraction of $C_4$ plants decreases in reconstructed diets and paleosols due to the exclusion of $C_3$ endmembers with low $d^{13}C$ values typically found in closed-canopy forests. However, even this conservative approach results in $C_4$ plant signals occurring in diets and paleosols throughout the Early to Middle Miocene. This new, data-driven framework supports recent qualitative interpretations of $C_4$ plant presence across eastern Africa prior to 10 Ma and highlights the persistence of large data gaps in mammal and paleosol records in the Middle to Late Miocene in the interval 15–10 Ma, leading up to widespread $C_4$ grass expansion after 10 Ma. The results of this work offer strong evidence that local ecological feedbacks exerted dominant control on $C_4$ plant emergence and proliferation compared to global drivers such as atmospheric $COC_2$.

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## THE CHIMAERA BEDS LAGERSTÄTTE: TAPHONOMIC WINDOW FOR BURGESS SHALE-TYPE PRESERVATION OF MARINE INVERTEBRATES STILL OPEN DURING THE CRETACEOUS

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Deposits with exceptional preservation (Konservat Lagerstätten) of Burgess Shale-Type (BST), characterized by the conservation of organisms as carbonaceous films with accessory authigenic minerals within a siliciclastic matrix, are common in lower Phanerozoic rocks. Several works have shed light on the taphonomic window of BST deposits, but little is known for post-Paleozoic BST, especially from modern tropical latitudes. Here, we present the Chimaera Beds Lagerstätte (CBD), a Cretaceous tropical deposit with exceptional BST preservation, from Colombia, South America. The CBD preserves hundreds to thousands of specimens of complete upper Cenomanian–lower Turonian (95–90 Ma) arthropods. Among the most significant arthropods in this Lagerstätte are the comma shrimp *Eobodotria muisca* and the enigmatic crab *Callichimaera perplexa*, and caridean shrimps, axiidean mud lobsters, and eubrachyuran-like crab larva (megalopa). Despite the small size of the fossils in this Lagerstätte, including ammonites

and aptichy, linguloid and discinoid brachiopods, bony fish, and plant remains, ranging from 1 mm to 30 mm, they exhibit a remarkable preservation of soft to poorly biomineralized tissues, including antennae, pleopods, setae, guts, muscles, compound eyes, and neural tissues. To characterize this Lagerstätte, we used multispectral imaging, x-ray diffraction (XRD) and fluorescence (ED-XRF) analyses, and Scanning Electron Microscopy (SEM). Our findings suggest that the preservation of arthropods in the CBD is similar to other BST Lagerstätte previously studied. Non-weathered fossils are preserved as carbonaceous compressions within a kaolinite-rich matrix, with kaolinite constituting ~50% of the rock sample. Weathered samples are depleted in carbon and show a similar signature to the surrounding matrix. The similarities of the CBD Lagerstätte with those of BST deposits have broad implications for our understanding of this preservation mode throughout the Phanerozoic. It is widely accepted that BST preservation was prevalent until the Ordovician. After the Ordovician, preservation in carbonaceous compressions is somewhat patchy, being particularly scarce in the Mesozoic, during which most exceptionally preserved fossils are often found in phosphate and pyrite. In the CBD, kaolinite likely played a positive role in exceptional fossil preservation at this site by inhibiting bacterial activity and inducing damage to bacterial membranes in the presence of oxygen, thus limiting the recycling of organic material. It seems unlikely that the window of BST preservation in the Cretaceous, as presented here, reflects global settings in the oceans but instead locally dominated by the weathering of oxysols in tropical regions, which contribute the kaolinite. The newly presented Cretaceous Chimaera Beds Lagerstätte opens new avenues to explore Burgess Shale-Type deposits outside of the Early Palaeozoic, as well as in modern low-latitude tropical settings worldwide.

## ENDOCAST MORPHOLOGY DIFFERS SIGNIFICANTLY WITHIN NORTH AMERICAN RIVER OTTERS

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The degree of phenotypic variation found among organisms is perhaps best appreciated through millions of years of disparity captured within the fossil record. Advances in imaging and tomography have enabled us to capture phenotypic variation that had been previously unobtainable, and this has allowed for macroevolutionary analyses of many novel traits. While these studies are extremely powerful, for many traits we lack a foundational microevolutionary understanding of the selective pressures influencing phenotypic evolution. For example, interspecific variation in mammalian brain size and morphology has been attributed to multiple selective pressures, including diet, environment, and sociality, as well as constraints on both brain and skull development but we still lack a fundamental understanding of the causes of intraspecific variation in endocranial and skull size and morphology in most taxa. Using the relatively large brained, and geographically wide-spread *Lontra canadensis* as a model, we quantified population variation in endocast volume and shape from microCT data from ecologically distinct regions of North America (AK, AR, FL, TN, WA) (n = 25 individuals). Endocast shape and skull size were quantified using 3D geometric morphometrics. Results show covariation between relative endocast volume and latitude (R2 = 0.31), with the largest relative volumes found in Alaskan populations. Arkansas specimens differ significantly from all other populations in endocast shape ($p<0.01$), with shorter and shallower lateral and entolateral sulci than higher latitude populations, as well as more rostrally-angled cruciate sulci than Floridian specimens. Our results suggest that climatic factors contribute to the variation in otter endocast size and morphology, with cold-climate populations developing larger brains with increased gyrification. These results further emphasize the importance of considering intraspecific variation when modeling macroevolutionary trends through the fossil record.

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## NEW RECORDS OF THE ACTINOPTERYGIAN *PROGYROLEPIS* FROM THE CARBONIFEROUS-PERMIAN LOWER CUTLER BEDS IN THE BEARS EARS NATIONAL MONUMENT, UTAH

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The lower Cutler beds of southeastern Utah preserve a unique window into continental ecosystems during the Carboniferous-Permian transition in western Pangea. Its diverse vertebrate record includes temnospondyl amphibians, diadectomorphs, edaphosaurids, ophiacodontids, sphenacodontians, araeoscelidan reptiles, the chondrichthyan *Orthacanthus,*

dipnoans and the megalichthyid *Lohsania* . However, little is known about the genus-diversity of its actinopterygian fauna, reflecting a broader pattern seen at other late Paleozoic sites. New material collected from multiple localities in the Bears Ears National Monument, Utah (Valley of the Gods and Indian Creek) present precious diagnostic records of actinopterygian material from this area. Consisting of one fragmentary maxilla and a second associated jaw skeleton, the specimens bear distinctive features such as a high quadrate, invaginated maxillary plate, and naked anteriormost maxillary flange which bear great similarity to the actinopterygian genus *Progyrolepis*. The recognition of a "large-bodied" actinopterygian (up to 60 cm) adds to our understanding of this region's ichthyofauna and confirms the presence of this size guild from the Paradox Basin while corroborating Carboniferous-aged *Progyrolepis* records from the southwestern region. The discovery of *Progyrolepis* is unsurprising, as it is during the latest Gzhelian and earliest Asselian that this genus appears contemporaneously along the paleoequator for reasons that are not understood. *Progyrolepis* appears alongside other superficially similar large-bodied actinopterygians; thus, further work should concentrate on standardizing the interrelationships of this and other genera. This occurrence assists in reconstructing biodiversity following the hypothesized "Carboniferous Rainforest Collapse" and the peak Late Paleozoic Ice Age. Moreover, it highlights the value of continued scientific discovery as constituted in the proclamation of the Bears Ears National Monument, an area that has been the subject of political controversy.

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## REVISITING ORDOVICIAN TEMPERATURE RECORDS

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The Ordovician was an extremely turbulent period for the Earth system, where the Great Ordovician Biodiversification Event (GOBE) occurred in the Early and Middle Ordovician, interrupted by the Late Ordovician Mass Extinction (LOME). How the climate changed during this period is attracting broad attention. An overall Ordovician cooling trend has been recognized using $d^{18}O$ data from well-preserved fossil shells and bulk-rock $d^{18}O$ records. However, assessment of the potential influences of heterogeneous spatial sampling on the results derived from these $d^{18}O$ data has been neglected, which could lead to biases in the reconstructed Ordovician paleotemperature curve. We have compiled a global carbonate $d^{18}O$ dataset (10,636 records) spanning the entire Ordovician and assessed this summary for bias induced by uneven spatial sampling. Except for the Sandbian, we documented statistically significant differences in estimated marine sea surface temperatures (SSTs) between low and middle latitudes, similar to the current pattern based on modern Köppen climate classification. To minimize this effect, we reconstructed SSTs for the low and middle latitudes, respectively. Both curves show a general cooling trend during the Ordovician. In addition, we also discovered evidence for an apparent, previously unrecognized warming in the late Darriwilian and for climate fluctuations that may be related to tectonic activity in the Middle and Late Ordovician. These results provide new insights into the reconstruction of the Ordovician climate and the evolution of life during this period.

## FROM FOSSILS TO THE FOREST: FRUIT, LEAVES AND HOMINOID LOCOMOTOR EVOLUTION

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Despite large body size, the living apes are able to forage successfully in the trees by adopting an upright torso (orthogrady), which allows the fore- and hindlimbs to be employed in different directions, and so distribute body weight by grasping multiple supports. Given the forest-dwelling, ripe fruit feeding preferences/specializations of most living apes, it was proposed that the signature anatomical features permitting apes to adopt versatile positional behaviors (e.g., orthogrady, vertical climbing and suspension) evolved to allow apes to feed on ripe fruit from the small, terminal branches of tree crowns in forest canopies. Such terminal branch forest frugivory hypotheses relied heavily on the overall locomotor ecology of living apes. However, recent behavioral reconstructions of *Morotopithecus*, a 21 Ma ape from Uganda, indicate that the oldest evidence of orthogrady in the ape fossil record occurs in combination with a folivorous diet component. Moreover, paleoenvironmental reconstructions indicate *Morotopithecus* was living in seasonal, grassy woodlands where ripe fruit availability may have varied seasonally. To better understand the relationship between feeding postures, food type and canopy location during arboreal feeding, we collected focal follow data on the positional and feeding behavior of 103 chimpanzees from Ngogo, Kibale Forest, Uganda over a period of 10 months. In total, 8498 arboreal feeding observations were made. We categorized all feeding postures involving orthogrady (excluding sit and squat), bridging and/or suspension as versatile. As in all chimpanzees, ripe fruit was most commonly consumed (56.7%), compared to unripe fruit (14.3%) and young leaves (14.8%). Chimpanzees usually used non-versatile postures, principally sitting, while feeding arboreally. When we examined terminal branch feeding (defined as feeding in the outer 1/3 of a tree crown), we found chimpanzees used versatile postures 8.3% of the time when

feeding on ripe fruit, 5.9% of the time when feeding on unripe fruit and 7.8% of the time when feeding on leaves. Thus, while leaves were consumed less often than fruit, versatile postures played a similar role in the acquisition of leaves vs. fruit in the terminal branches. Postural versatility in large apes may thus relate more to feeding on small branches per se, where both young leaves and many fruits tend to be found. This neontological data strengthens the paleontologically-derived hypothesis that foraging for leaves in an arboreal setting may have contributed to the evolution of hominoid positional behavioral versatility.

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## A STRANGE OLD WORLD: PROBOSCIDEAN DIVERSITY AND COEXISTENCE IN THE EARLY MIOCENE OF EASTERN AFRICA

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Modern eastern African faunas have only a single proboscidean species, the savanna elephant, whereas regional mammalian assemblages from older intervals had much greater proboscidean diversity. This is exemplified by Early Miocene eastern African faunas, which reveal co-existence of multiple proboscidean taxa that probably occupied some of the ecological niche space of later pecorans and suids. The current project is part of systematic investigation of Afro-Arabian proboscideans that seeks to refine proboscidean taxonomy and place taxa in their proper chronostratigraphic, climatic, paleoecological, phylogenetic, and biogeographic contexts. In addition, the project addresses questions about relative success of taxa, ecological relationships of proboscideans to other herbivores, and evolutionary/adaptive responses of taxa to significant climatic/ecological/faunal changes. Morphological features studied encompass dimensions and occlusal features of cheek teeth: relative size and number of main- and meso-conelets; loph(id) formulae; distribution and size of accessory conules or crescentoids; configuration of half-loph(id)s; tooth emergence mechanisms; and size and shape of tusks, supplemented by isotopic and meso- and microwear data. Proboscidean assemblages investigated span the Early Miocene, from Nakwai through Buluk, incorporating specimens from key sites throughout the interval (e.g., Rusinga, Moroto, Meswa Bridge, Kajong, Napak, Songhor, Nachola, Karungu), supported by observations on proboscideans from other coeval Afro-Arabian sites. The results indicate sympatry of primarily browsing deinotheres, mammutids, and multiple gomphotheres, despite evidence of $C_4$ grasses and strong seasonality fluctuations, in non-analog ecological conditions compared with modern faunas. Contrasting adaptations include deinothere lophodonty and emphasis on Phase I mastication; horizontal tooth displacement of elephantimorphs (gomphotheres and mammutids); increased efficiency of Phase II grinding by incorporation of enlarged crescentoids (mammutids) and accessory conules (gomphotheres); and enlarged molar grinding surfaces by offset and oblique angulation of half-loph(id)s in choerolophodontine and amebelodontine gomphotheres. Deinotheres were successful as hyperfolivore specialists, whereas the success for a wider choice of resources (including tougher food items) of amebelodontines resulted from scythe-like lower tusks coupled with complex Phase II grinding surfaces. Proboscideans in the interval appear to have been less affected by arrival of Eurasian mammal immigrants than by interordinal competition, yielding taxonomic successions of mammutids and amebelodonts that are biochronologically useful. As major seed dispersers and fertilizers, the proboscidean cohort of the Early Miocene maintained ecosystems, and their activities on the landscape likely opened feeding opportunities for smaller herbivores.

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## DOES DIMENSIONALITY-REDUCTION METHOD MATTER FOR MORPHOLOGICAL DISPARITY (AND OTHER) STUDIES?

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In order to assess the history of morphological variation across intervals of deep time some means must be found to display and/or characterize patterns of similarity and difference among fossil morphotypes. To date, morphological disparity studies have focused on representations based either on sets of measured morphometric variables or numerically coded morphological character states. Once these data have been obtained patterns of morphological variation they encode have usually been portrayed in low-dimensional mathematical spaces via use of eigenanalysis (PCA, PCoord, metric MDS) or a ranked version of the Euclidean distance metric (nonlinear MDS). These methods have been employed routinely across the natural sciences to reduce the dimensionality of data sets so they can be visualized, inspected and, in some cases, analysed mathematically. However, these methods are not the only procedures available for the task of dimensionality reduction (DR) and, for many purposes, may not be the most appropriate choices. Among the newer crop of DR alternatives are autoencoders, t-Distributed Stochastic Neighbor Embedding (t-SNE) and Uniform Manifold Approximation and Projection (UMap) all of which operate on the same types of data accepted by PCA, PCoord and MDS methods, but have been designed specifically to provide accurate depictions of both linear and non-linear patterns of variation in reduced-

dimension spaces. In order to test the applicability of these newer DR methods for use in morphological disparity studies, suites of morphometric, character state and image data from example microfossil, invertebrate macrofossil and vertebrate fossil samples were subjected to parallel PCA and UMap procedures. In each case patterns of morphological similarity and difference were revealed by UMap analysis that were not present in the low-dimensional PCA ordination results; patterns that could imply very different assessments of the morphological disparity history for these groups is applied to a larger sample. In particular, UMap reveals the clustered character of similar morphologies to any extent not matched by linear or Euclidean rank order-procedures. The ability to portray both linear and non-linear patterns of similarity and difference that exist in high-dimensional morphological data accurately in low-dimensional spaces is a necessary requirement for morphological disparity studies. This requirement cannot be met by ordination spaces determined from linear eigenanalysis and ranked Euclidean distance-based methods, but can be delivered, for morphological disparity analyses as well as in many other paleobiological contexts, via the use of newer DR procedures.

## QUANTIFYING ECOSYSTEM STRUCTURE USING BIOVOLUME OF BENTHIC MARINE INVERTEBRATES DURING THE LATE PALEOZOIC ICE AGE

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The Late Paleozoic Ice Age, a glacial interval spanning the late Devonian to the Permian, was an interval of rapid climatic changes coinciding with the formation of the supercontinent of Pangaea. During this time, initial rapid cooling followed by repeated glacial-interglacial cycles resulted in environmental stresses that are thought to have favored generalist taxa over more specialized provincial genera in the marine realm. While it has long been postulated that this climactic cycling led to decelerated speciation and extinction rates globally, previous research into marine community composition focused heavily on single clades where individuals are easily quantified, such as the brachiopods, and exploration of whole community structure was limited. Counts of individuals for crinoids and bryozoans, in particular, are often difficult due to *post mortem* disarticulation and a colonial lifestyle, respectively. The aim of this study is to quantify the benthic community composition and biomineral productivity of the Pennsylvanian-aged benthic community represented within the Keechi Creek Shale member of the Mineral Wells Formation in Palo Pinto County, Texas. Specimens were sieved from a random subsample of an ecological bulk sample taken *in situ* from the outcrop. Specimens >5 mm were selected for analysis. Taxa were identified to the genus level and classified into distinct ecoguilds based on mobility, substrate tiering, and locomotion by referencing paleoecological assignments from Paleobiology Database (paleobiodb.org). Biovolume estimates are calculated using fossil mass and volume to account for skeletal productivity of the community, serving as a proxy for the occupation of the various ecoguilds and trophic levels of an ecosystem. Minimum number of individual (MNI) counts were taken for solitary organisms (with the exception of crinoid columnals), to avoid overestimation of individual organism occurrence. The composition of the subsample was dominated by crinoid columnals and brachiopod valves and contained a total of 6 identified genera across 101 specimens. Crinoids accounted for 59.44% of total biovolume and brachiopods were 19.49%. A comparison of ecosystem structure and diversity between the two metrics shows that the biovolume metric allows for a more holistic quantitative treatment of the paleoecological data from these bulk samples. Future work will involve extraction of contemporaneous bulk samples along a bathymetric gradient within the Permian Basin, as well as geographically proximal deposits representing equivalent environments across the Late Paleozoic Ice Age interval. These samples allow for assessments of the degree of ecosystem heterogeneity and the impact of the Late Paleozoic Ice Age's effects on benthic communities across the region.

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## FUNCTIONAL MORPHOLOGY OF ASYMMETRICAL ROOTS IN THE LOWER MOLARS OF JURASSIC DRYOLESTOIDEAN MAMMALS AND THEIR BIOMECHANICAL IMPLICATIONS

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The tooth roots of the postcanine teeth of mammals transformed during their evolution from cynodonts. Mammals and their mammaliaform relatives are characterized by apomorphic root structures where the molariform postcanines have fully divided double roots. By contrast, non-mammaliaform cynodonts mostly have a plesiomorphic root structure where the postcanines have a single, undivided root. Mammalian tooth roots serve mechanical and sensory functions during occlusion by resisting forces on the tooth crown and relaying sensory information via the periodontal ligaments to the brain. Some workers have hypothesized that a fully divided double root system, as seen in the earliest mammaliaforms, would confer a mechanical advantage by reducing the stress at the crown-root junction, over the undivided postcanine roots of cynodonts. However, the functional difference between the fully divided and symmetrical (equal-sized) double roots in the molariforms of mammals and the undivided root of

the postcanines in cynodonts has not been fully explored. Moreover, it is also unknown if differences in shape and size of the divided roots result in any changes to the biomechanical function for the teeth of Mesozoic mammals. Here, we are studying the influence of tooth root shape on biomechanical function in dryolestoideans: a diverse stem lineage leading to crown therians (marsupials and placentals) with a global geographic distribution known mostly from the Jurassic and Cretaceous. While dryolestoidean mammals have conserved molar crown morphology, their lower molar roots show a striking disparity of shape and size between more basal taxa and the more derived subclade of Dryolestidae. Stemward placed dryolestoideans have more symmetrical, equal-sized double roots in their lower molars, like other mammaliaforms, while species of the more derived family Dryolestidae have a distinct asymmetrical shape in which the anterior (mesial) root is extremely enlarged, spatulate in shape, and envelopes a shorter and thinner cylindrical distal root. Using this comparative framework, we qualitatively and quantitatively assess the influence of tooth root shape on the biomechanical function using 3D FEA modeling. We aim to test if placement of the enlarged and thicker anterior root below the principle cusps forming the trigonid provides greater stability during occlusion. Furthermore, we discuss the diversity of tooth root morphologies found in the early mammal fossil record and their relationship to functional crown diversity.

## A NEW, NEARLY COMPLETE SPECIMEN OF *ALNASHETRI CERROPOLICIENSIS* SHEDS LIGHT ON THE COMPLEX EVOLUTIONARY HISTORY OF ALVAREZSAUROIDEA

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Alvarezsauroidea is a specialized clade of theropods with a complicated taxonomic history. Originally interpreted as flightless stem birds, their phylogenetic position within Maniraptoriformes is debated, and they are the only theropod lineage besides birds to exhibit evolutionary miniaturization. In addition to small body size (< 5 kg), late diverging parvicursorine members of the clade are characterized by short, massive forelimbs adapted for digging, sensory adaptations observed in nocturnal birds, and have been interpreted as myrmecophagous. The alvarezsauroid fossil record is patchy with most species found in the Late Cretaceous of Asia and South America. Only Asian taxa preserve significant cranial remains. Here we present a subadult specimen of *Alnashetri cerropoliciensis* from desertic facies of the Campanas Formation at La Buitrera, Argentina, representing the most complete South American alvarezsauroid. It preserves most of the skull, the entire presacral vertebral column, and nearly complete girdles and limbs. Phylogenetic analysis posits *Alnashetri* as an early branching alvarezsauroid patristically removed from other South American taxa despite their geographic and stratigraphic proximity. *Alnashetri* lacks a number of synapomorphies of the more exclusive clade Alvarezsauridae, which includes all other South American taxa, such as cervical ball and socket joints, a biconvex dorsal vertebra, short stocky humerus, and hypertrophied olecranon process. Indeed, we recover the geologically older Chinese taxa *Bannykus* and *Xiyunykus* as closer to the remaining South American alvarezsaurids, implying a Jurassic divergence for *Alnashetri*. This long ghost lineage underscores that the fossil record of Alvarezsauroidea is undersampled prior to the Late Cretaceous. A survey of fragmentary theropod fossils from North America and Europe allowed us to identify two historically unrecognized alvarezsaurid taxa within this gap, supporting a wider ancestral range for the clade with the disjunct Late Cretaceous distribution resulting from regional extirpation coupled with preservation and collection biases. With an estimated body mass of ~2 kg, *Alnashetri* is among the smaller alvarezsauroids. Reconstruction of body mass evolution shows that *Alnashetri* evolved small body size independently from the miniaturization of later-diverging parvicursorines, which is hypothesized to be tied to myrmecophagy as evinced by their short, massive forelimbs adapted for digging and their dentition. Forelimb modification in *Alnashetri* is only incipient, and the forelimb is proportionately longer even than in large, early branching alvarezsauroids like *Haplocheirus*. Our analysis reveals that evolutionary miniaturization in alvarezsauroids occurred at least twice and was not solely tied to forelimb modifications as fossorial adaptations as was previously suggested, but may have evolved in response to differing selective pressures and ecological conditions.

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## DID THE DECCAN VOLCANIC EVENT CAUSE BIOTIC STRESS AND EXTINCTIONS OF LATEST CRETACEOUS PLANKTONIC FORAMINIFERA?

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Abrupt mass extinctions of ~75% of plant and animal species, including >90% of planktonic foraminifera species, mark the Cretaceous-Paleogene (K/Pg) boundary 66 million years ago. There is broad consensus that an asteroid impact at the Chicxulub crater on the Yucatan Peninsula triggered the extinctions. Still, some researchers consider the eruption of the Deccan Traps (west-central India), especially an event starting ~250 kyr before the end of the Cretaceous, as a contributory, if not the primary, cause for the terminal Cretaceous extinctions. Our study investigates the Deccan hypothesis for K/Pg extinctions by analyzing changes in planktonic foraminiferal species distributions, stable isotopes ($d^{18}O$ and $d^{13}C$), and test sizes (i.e., the "Lilliput Effect") during the last 500 k.y. of the Cretaceous from deep-sea sites at high (ODP Holes 689B, 690C, southern South Atlantic; IODP Hole 1579D, Agulhas Plateau, SW Indian Ocean) and low (ODP Hole 1049C, Blake Plateau, western Atlantic) latitudes. Samples from Holes 690C and 1049C record no significant changes in species abundance or diversity across the Deccan Event. Further, only a small reduction in test sizes (and in only four out of ten species measured) is observed within the Deccan interval. Test sizes recover before the end of the Cretaceous, with eight out of ten species reaching their largest size following the event. High latitude sites record poleward expansion followed by equatorward contraction of the geographic range of the thermophilic biserial planktonic species *Pseudotexularia elegans*; this migration is attributed to $CO_2$ outgassing and global warming associated with the Deccan eruptions. Oxygen isotope analyses from Hole 690C also reveal a brief warming coincident with the Deccan Event, followed by a return to pre-event temperatures before the asteroid impact. In short, while we found environmental and biological shifts likely forced by Deccan volcanism, no shifts continue through the latest Cretaceous suggesting the bolide impact is indeed the cause of the K/Pg extinctions. New $d^{18}O$ and $d^{13}C$ data and test size measurements across the Deccan warming event at high latitude sites 689 and 1579 will provide additional information on the environmental and biotic consequences of the latest Cretaceous Deccan Traps volcanic eruptions.

## THE IMPACT OF MOUNTAIN BUILDING ON BIODIVERSITY OF SMALL TO MEDIUM SIZED TERRESTRIAL MAMMALS IN DEEP TIME

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Small- to medium-sized terrestrial mammals present high biodiversity in montane regions today and major biological turnovers in tectonically active and topographically complex regions in the fossil record over the Cenozoic. However, since the fossil record is primarily located at depositional basins and often does not record biodiversity in higher elevation, erosional portions of the mountain range landscape, it is not clear whether the high biodiversity of terrestrial mammals in mountain ranges today is the result of long term (106–107 yrs) tectonically-driven mountain building or geologically recent (102–105 yrs) climatic and biological forcings acting upon the existing mountain range topography. Here, we address this knowledge gap by using a coupled landscape-biological evolution model and a novel speciation algorithm, to simulate diversification in an uplifting erosional mountain range with subsiding depositional basins over twenty million years. Our simulations show that (1) the total number of species in depositional basins and the high erosion mountain range systematically increase with the magnitude and pace of mountain building when topography and net diversification rate reach equilibria; and, (2) species richness is highest and concentrated at mid-elevations with increased magnitude and pace of mountain building. These results are consistent with empirical observations of paleo and modern biodiversity patterns in mountain ranges today, suggesting that (1) the fossil record in depositional basins of mountain ranges can be used to infer biodiversity changes in deep time, and that (2) the high biodiversity in mountain ranges today is significantly influenced by long-term landscape dynamics.

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## PROLONGED ANOXIA ACROSS THE TOARCIAN OCEANIC ANOXIC EVENT (T-OAE) WITHIN THE EUROPEAN EPICONTINENTAL SEAWAY

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The Early Jurassic Toarcian Oceanic Anoxic Event or T-OAE (~183 Ma) represents an episode of severe environmental change that was associated with elevated marine extinction rates, disruptions to the carbon cycle, and marine deoxygenation. The stratigraphic interval assigned to the T-OAE, was originally identified using the occurrence of organic-rich marine and lacustrine strata globally. However, these strata are known to be deposited under a variety of water column redox conditions. Therefore, the precise geographic and temporal extent of marine anoxia related to the T-OAE, remains an open question. Here, we present a large iron speciation dataset that presents new and published data from nine localities within the European Epicontinental Seaway (EES) that represent some of the most extensively studied Toarcian successions containing organic-rich strata. These

data suggest water column anoxia in this region developed well before, and persisted well after, the intervals commonly attributed to the T-OAE. However, euxinic conditions (sulfide-rich water columns) were more common in the stratigraphic interval traditional attributed to the event. Local factors that controlled primary productivity and the supply of oxygen, iron, and sulfate likely affected where and when anoxia and euxinia developed within the EES. However, our data when combined with other global and local redox proxy data, suggest that global climatic changes were an overriding control on the conditions that promoted the widespread deoxygenation and the development of anoxia on a global scale across much of the Toarcian.

## FOLLOW THE ENERGY: VIEWING MACROEVOLUTIONARY CHANGE THROUGH THE LENS OF TROPHIC ENERGY FLUXES, THAT IS, THROUGH THE LENS TROPHIC POWER

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All species belong to ecosystems, knitted together by the flow of energy which typically enters in the form of sunlight to then flow through the various trophic levels. Energy use is conditional on the availability of needed co-occurring resources, for example, nitrogen, phosphorous, and water, and on appropriate physical conditions, for example, suitable temperatures and oxygen levels. Here I develop a framework for understanding macroevolutionary change centered on this lens of ecosystem energy flow. For the study of mass extinctions, the focus on physical conditions inimical to life are often sufficient for developing powerful hypotheses, but given that life has survived all physical perturbations, following the energy should be of value in understanding the nature and pace of recovery. My hope is that this framework will help unite the wide range of approaches used to assess biodiversity change, from taxonomic analysis, morphological, ecological, and phylogenetic disparity analysis, to the use of ecological tools, for example Ecological Niche Models and food web analysis, to the application of Earth System models, which enable the modeling of the ecological consequences of environmental change, for example, via the metabolic index. Using the lens of organismal power means analyzing phenotypic attributes relevant to the acquisition and deployment of power. Analysis through the lens of ecological power leads to predictions about how change in energy flow ramifies through ecosystems, e.g., the prediction that indirect effects and mutualisms increase with increased ecosystem size, which in turn suggests that the analysis of extinction should be progressively more difficult the larger the ecosystem. Applying the lens of power challenges us to develop measures of the strength of these indirect effects and mutualisms, and to focus on developing predictions for what happens not only when power increases, but also when it decreases, for example, with the emergence of isoëtalean-based floras in the wake of the end-Permian mass extinction.

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## TRACES OF ECOLOGICAL RECOVERY IN PALEOCENE FRESHWATER ECOSYSTEMS AT CORRAL BLUFFS (DENVER BASIN), COLORADO

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The end-Cretaceous bolide impact changed the trajectory of the evolutionary tree of life, resulting in a radical shift in terrestrial ecosystems from dinosaur- to mammal-dominated communities. An exceptional record of this post-catastrophe renewal is preserved at Corral Bluffs, Colorado, where strata representing mountain-proximal terrestrial and freshwater ecosystems span the first million years after the end-Cretaceous mass extinction. Although body fossil, floral, and insect-herbivory records from these strata have been reported, trace fossils representing plants, invertebrates, and vertebrates in sediments have not yet been described. Here we report a suite of trace fossils from this succession, including traces that exemplify adaptations related to the K-Pg ecological recovery. Plants are represented by root traces, with the most distinctive those of palms, which are evident as clustered and minute (2–5 mm wide) subvertical tubes in crevasse-splay facies. Invertebrate burrows include locally abundant I- and J-shaped vertical burrows (mostly *Skolithos* isp.) in rippled crevasse-splay sandstones, as well as horizontal meniscate burrows (*Taenidium* and *Scoyenia* isp.) in floodplain facies. These vertical and horizontal burrows likely represent freshwater benthic insects behaving as suspension feeders and deposit feeders, respectively. Presumed vertebrate trace fossils are quite varied and prominent. Among these are 8 cm wide and 23–27 cm long subvertical burrows resembling amphibian estivation burrows (*Torridorefugium* isp.) in floodplain facies, as well as 40–48 cm wide and 12–32 cm deep, sand-filled, and vase-like depressions in channel-margin facies similar to modern reptilian hole nests, such as those made by extant freshwater turtles and crocodilians. Shallow but broad depressions preserved on channel-sandstone bases may represent amphibian or crocodilian body pits made in adjacent floodplains. Overall, invertebrate burrows point toward previously undocumented feeding and dwelling behaviors of infaunal invertebrates in these ecosystems,

as well as possible estivation or other forms of sheltering in vertebrates, and underground nesting.These trace fossil assemblages thus provide us with new insights on organismal behaviors and adaptations in freshwater-related ecosystems in the earliest Paleocene of the Denver Basin following a global reset of such environments.

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## ANACHRONISTIC FACIES (WRINKLE STRUCTURES) IN THE AFTERMATH OF THE PLIENSBACHIAN-TOARCIAN EXTINCTION, MOROCCO

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Mass extinctions have unique and profound effects on ecosystems; for example, 'disaster forms,' such as wrinkle structures (or runzelmarken), are often found within anachronistic facies during extreme events. Wrinkle structures (irregular, millimeter-to-centimeter scale ridges or pits) are microbially induced sedimentary structures on bedding planes and are attributed to microbial mats or microbial aggregates. They are commonly preserved in the Precambrian but are rare in modern marine subtidal environments as macrofauna destroy the microbial mats before they lithify. Wrinkle structures and other anachronistic facies have been reported from the aftermath of several mass extinctions, such as the Early Triassic wrinkle marks following the end-Permian mass extinction and the Hettangian wrinkle structures following the end-Triassic mass extinction. It is posited that these extinctions were so severe that the dearth of grazing macrofauna and bioturbators allowed wrinkle structures to be preserved in normal marine environments. Here, we document Early Jurassic wrinkle structures following the Pliensbachian/Toarcian extinction within turbidites of the Tagoudite Formation (Dadès Valley, Central High Atlas Mountains); notably, these are the first wrinkle structures reported from this extinction event. In this region of Morocco, there were thriving carbonate ecosystems during the late Pliensbachian (e.g., coral reefs, lithiotid biostromes). Shortly after the stage boundary, climatic changes from dry to humid conditions resulted in an influx of terrestrial material that poisoned the carbonate platform, resulting in a carbonate crisis and marine extinction. The Tagoudite Formation was deposited in the aftermath of this biotic collapse, and wrinkle structures are found on bedding planes of rippled sandstones within the delta front deposits that prograded into the basin (earliest Toarcian). In the Tafraout Formation, above the turbidites, carbonate communities show evidence of biotic recovery from the Pliensbachian/Toarcian extinction, including the recovery of lithiotid biostromes and eventually coral reefs. Wrinkle structures have long been recognized as anachronistic facies indicative of severe biotic depletion and therefore, we suggest that the Tagoudite Formation wrinkle structures mark an interval of extreme stress for this early Toarcian marine community. They are also only the third example of Phanerozoic extinctions leading to such anachronistic facies (end-Permian, end Triassic, and now the Pliensbachian/Toarcian event). Therefore, either the Pliensbachian/Toarcian extinction in Morocco resulted in community collapse on par with the biggest extinctions of the Phanerozoic or wrinkle structures are an extinction hallmark that are more common than previously assumed.

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## "REEF SURVIVOR": A NEW BOARD GAME DESIGNED TO TEACH COLLEGE AND UNIVERSITY UNDERGRADUATE STUDENTS ABOUT REEF ECOLOGY, EVOLUTION, AND EXTINCTION

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Educational geoscience games have been increasing in popularity because they promote learning through amusement and encourage students to engage with both the topical material and each other. Here we present a new board game, "Reef Survivor," and its use as an instructional tool in undergraduate classes; we will also present modifications for high schools, middle schools, and coastal communities. The educational objective is to teach players about ecology, evolution, and environmental perturbations, while the gameplay objective is to build a resilient reef ecosystem. Through collaborative and competitive gameplay, students learn about evolution mechanics—mutation, migration, and natural selection—as well as ecology and how reefs survive natural disasters. The game blends informed decision-making with chance

to encourage students to learn and model complex Earth systems and evolutionary processes. Students choose their environment and reef community, whereas chance influences mutations and disasters. The game was incorporated in undergraduate classroom activities in 2021 and 2022 at 20 colleges and universities, mostly U.S. public institutions. Students were enthusiastic about the game, with two-thirds saying they would rather play the game than have a normal lab. Notably, students said playing with a peer helped them learn better. When undergraduate student gameplay was evaluated, observers noted higher instances of cooperative learning during team play (e.g., strategizing, group processing, and positive interdependence). Working together may support connections to the material and other students, as well as, encouraging engaged learning and decreasing cognitive load. Although learning gains (based on pre- and post-lab assessments) were not statistically significant during the first deployment (online, 1 institution), they improved substantially when refined and played in person. Ultimately, the learning gains were positive, with statistically significant positive learning gains by the final semester of assessment (15 institutions). A print-and-play version of the game (doi: 10.18738/T8/S3KWT7), onboarding and follow-up assignments, and suggested extension activities will be presented as well as modifications for time, course objective, and educational level.

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## QUANTITATIVE ANALYSIS OF IGUANID PALATAL TEETH WITH IMPLICATIONS FOR INFERRING DIETS OF EARLY AMNIOTES

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The evolution of herbivory in early amniotes marks an important transition in the history of life. Early synapsid and diapsid herbivores, like the synapsid *Edaphosaurus novomexicanus* or the stem reptile *Oryporan insolitus*, possess extensive fields of palatal denticles but the role of the palatal dentition in oral food processing is unclear. Today, modern mammalian herbivores possess no palatal dentition and instead use complex cheek teeth to orally process their food. Extant squamates, however, possess palatal teeth, thereby representing the only living amniote clade in which the relationship between palatal dentitions, and details of oral processing, can be observed. The morphology and function of squamate palatal dentitions are relatively understudied, and this poses a challenge when attempting to untangle the functional and evolutionary history of these structures. With few exceptions, all snakes possess palatal teeth, but these teeth are long and recurved, and specialized for the mechanism by which snakes swallow large prey—a function that is unlikely for the palatal teeth of fossil amniotes. Among non-snake squamates, palatal teeth are largely absent from more basal clades but can be found in the following families: Gerrhosauridae, Scincidae, Teiidae, Gymnophthalmidae, Lacertidae, Helodermatidae, Anguidae, Shinisauridae, Lanthanotidae, Tropiduridae, Iguanidae, Leiocephalidae, Crotaphytidae, Polychrotidae, Hoplocercidae, Opluridae, Leiosauridae, Liolaemidae, Corytophanidae, and Dactyloidae. Further, lizards exhibit a diversity of dietary ecologies, including carnivory, herbivory, insectivory, omnivory, and durophagy. Although none of these diets outright lack taxa with palatal dentitions, palatal teeth are less common among hypercarnivorous lizards like some varanids. The iguanids (iguanas and chuckwallas, and their fossil kin) are notable for being nearly exclusively herbivorous. Additionally, iguanids possess a variety of palatal tooth morphologies and organizations that vary ontogenetically as well as intra- and interspecifically among adults. Prior characterization of this diversity, though, has been limited to qualitative observations. For the first time, I quantify the diversity of palatal tooth morphology and organization in extant iguanids using a combination of tooth complexity measures and traditional and landmark-based geometric morphometrics. The complexity and organization of palatal dentitions group largely by diet: general herbivory, frugivory, folivory, algivory, florivory, and omnivory. For example, large numbers of sharp, conical palatal teeth correlate with high-fiber plant diets. Our findings demonstrate that palatal teeth are sufficient osteological correlates for inferring diet in extant iguanids, with the potential for expansion to include other lizard groups. Furthermore, this work validates the use of palatal teeth for inferring dietary ecology in fossil taxa.

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## DIETARY GENERALISM OF PLEISTOCENE COYOTES FROM THE MCKITTRICK AND RANCHO LA BREA ASPHALT SEEPS, SOUTHERN CALIFORNIA, U.S.A.

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The consequences of the terminal Pleistocene extinctions have cascaded down to modern ecosystems: large predators like dire wolves (*Aenocyon* (formerly *Canis*) *dirus*) went extinct at the end of the last Ice Age, while smaller canids including coyotes (*Canis latrans*) survived to the present-day. An oft-cited hypothesis for this differential survival is that generalist

coyotes could switch food sources when prey became endangered. Here, to test this hypothesis of generalism, we analyzed body size and dietary ecomorphology in coyotes from the Pleistocene-age McKittrick asphalt seeps on the southern end of the Central Valley of California, comparing them to the same species preserved at the Rancho La Brea (RLB) asphalt seeps in Los Angeles. McKittrick's arid inland environment likely hosted a less abundant and/or diverse prey set than the verdurous coastal environment of RLB; therefore, we predicted that McKittrick coyotes would be smaller, with more specialist traits than McKittrick. We examined McKittrick coyotes (122 lower jaw elements) at the University of California Museum of Paleontology, Berkeley, CA, and RLB coyotes (42 lower jaws) from three deposits (Pleistocene: Pits 4 and 13; Holocene: Pit 10) at the La Brea Tar Pits & Museum, Los Angeles, CA. We collected 15 linear measurements of the jaws and teeth and combined six of these into three indices reflecting dietary function: relative blade length, relative lower molar grinding area, and relative jaw depth. Inter-deposit comparisons at RLB show that, based on the length of the lower carnassial (m1L) as a body-size proxy, Pleistocene coyotes were larger than Holocene, supporting previous work. Among Pleistocene deposits, McKittrick m1L was larger and jaws were deeper than in their coastal counterparts (especially Pit 4), although other size metrics overlapped. Larger body size at McKittrick may be the result of a cooler climate; alternatively, limited prey may have led to more competition between canids, favoring larger size and deeper jaws for competitive advantage. Coyote grinding area was smaller at McKittrick than Pleistocene RLB, although other functional indices were similar; smaller grinding area with no corresponding decrease in blade length supports decreased ability to chew tough matter but not necessarily greater ability to slice meat. Coyotes are more variable in multiple traits at McKittrick than RLB, suggesting generalist feeding across the population; however, McKittrick simply may span more broadly across time than individual RLB deposits. In several metrics, McKittrick coyotes overlap with Pit 13, the RLB deposit where dire wolves exhibited heavy tooth wear and fracture; concurrent tooth-wear work will help evaluate the possibility of tough times at McKittrick. As poor preservation at McKittrick limited our data, ongoing work includes measuring more intact specimens to improve understanding of the dietary habits that allowed coyotes to thrive to the present.

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## THROUGH THE SIEVE AND THE ACID BATH: SAMPLE PREPARATION AND TAPHONOMIC BIASES OF SMALL SHELLY FAUNAS FROM THE CAMBRIAN (SERIES 2: STAGE 3) OF SOUTH AUSTRALIA

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Our perception of the fossil record is only as good as the window through which we view it. In the case of microfossils, the window is frequently clouded by the inability to readily view these faunas without the assistance of chemical, and often destructive, methods of extraction. The traditional method of extracting microfossils from limestone involves acid maceration, wherein faunas possessing insoluble hard parts or having been secondarily replaced can be separated from the host matrix. As this preparation method selectively removes the calcareous constituent of the fauna, there is an inherent bias imposed on the faunal constituent represented in acid residues. Despite this, there have been few efforts to quantify the degree of bias and how that might impact paleoecological interpretations. In this study, eleven samples from a measured stratigraphic section intersecting the Mernmerna Formation (Cambrian Series 2, Stage 3) of the Ikara-Flinders Ranges, South Australia were investigated for their small shelly faunal content by pairing thin sections and acid extracted components. Using a combination of point counting and segmentation methods, including thresholding and trainable machine learning algorithms, small shelly fauna were differentiated based on both their higher order taxonomic affinity and mineralogic composition. This data will then be compared to the abundance of taxa recovered from acid residues using the same variables. This comparison will bring to light the extent to which these extraction methods impact our view of these earliest biomineralized microfossil assemblages and the assumptions that need to be considered for further paleoecological and biostratigraphic analyses. In the future, this can be further applied to other locations and time periods, helping to reveal potential biases introduced by such methods and assist in evaluating how appropriate those methods may be for certain facies and faunal assemblages.

## DIGITIZING THE FIELD MUSEUM'S FOSSIL INVERTEBRATE COLLECTION USING UNDERGRADUATE INTERNS AND IMLS FUNDED GRANTS

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The Field Museum of Natural History's fossil invertebrate collection was started in 1893 and has specimens from every continent and every geologic period from the Ediacaran to the Quaternary. However, ~80% of the collection is focused on Paleozoic fossils from the Midwest and Great Lakes Region. The collection is arranged by geologic period and then systematically by major taxonomic groups. Collection highlights include Mazon Creek, Silurian reef, Falls of the Ohio, and Ordovician echinoderms. In the 1996 survey of

invertebrate fossil collections (Allmon & White) the Field Museum listed 320,000 specimen lots. Over the last 28 years the collection has grown by 11% to 336,315 lots. Since 2009 the average number of days per year that professionals are visiting the collection is 26. The average number of loans per year is 17. Digitization started in the 1980's with an NSF grant resulting in ~30,000 Mazon Creek fossils being digitized. In the 1990's and 2000's there were several attempts to obtain funding to digitize the entire collection, but resulted in only part of the type, figured, and referred collection being digitized. In 2009 a collection survey was conducted. Specimen lots were graded based on their condition and how much data were associated with them. Predicated on this survey, 180,000 specimen lots were identified as priorities to be digitized. Since this survey, there have been 10 successful digitization projects including: cephalopod type collection, 1893 World's Columbian Exposition specimens, Mazon Creek type collection, IMLS Silurian reef digitization grant, WIS Thomas V. Testa collection, Tully monster specimens, IMLS Ordovician digitization grant, WIS James and Sylvia Konecny Mazon Creek collection, WIS James and Sylvia Konecny Paleozoic collection, and IMLS Devonian digitization grant (currently in year 1 of 3). WIS projects are Women in Science digitization projects funded by the Field Museum Women's Board. IMLS projects are digitization projects funded by the Institute of Museum and Library Services, Museum for America grants—all three projects have been in partnership with the Milwaukee Public Museum. These projects all involve undergraduate interns going drawer by drawer through the collection, photographing the specimens and labels, and entering the data into our database. This has resulted in over 55,000 specimen database records. As of February 2024, there are currently 95,660 fossil invertebrate specimen records in our database and over half of these were entered by interns and volunteers. Initially, there were no images in our database. Through these projects we have added over 92,000 images to our database. Looking towards the future, we hope to continue our digitization efforts with projects on the Mississippian; Cambrian; Pennsylvanian; and the type, figured, and referred collection and we are starting to add 3D photogrammetry models.

## THE EYES HAVE IT: OCULAR THERMOREGULATION IN BIRDS AND ITS INVERSE CORRELATION WITH OSTEOARTHRITIS

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Optical illusions once led orbital roof phenomena to be misdiagnosed as pores and as bone marrow hyperplasia-exposed trabeculae. Subsequent studies revealed them to be vascular channels and suggested the presence of a vascular plexus in selected groups across phylogeny. Such plexuses, recognized on parietal surfaces of Suidae, Tayassidae and Tapiridae, identify the presence of a countercurrent heat exchange mechanism. Bony imprints of vascular structures have also been noted in the superior aspect of the orbital roof in select mammals. Preliminary studies revealed similar patterns in birds. Birds occupy a remarkable cacophony of ecological niches, ranging from terrestrial to high altitude (e.g., flying over the Himalayan Mountains), the extreme heat of deserts, to the sub-zero temperatures at 20,000 feet. Thermal extremes represented by their various habitats provide an opportunity to assess the potential significance of vascular plexuses for protection of the contents of the orbit against environmental extremes. The ectocranial parietal and orbital surfaces of bird skulls were examined by epi-microscopy at 50–200x magnification in the collection of the Ohio Wesleyan University. Comparative study analyzed orbital roof alterations in 25 avian species, representing thirteen orders, 16 families sampled to date. We tested whether prevalence of orbital plexus correlates with geography, costal versus interior distribution, habitual altitude, climate (desert versus wetlands, rain forest versus savannah), routine temperature exposure, population density, group size, greater contact with soil, slower host life history, increased ranging, dietary factors (position in the food chain [prey versus predator] and character of diet), body mass and susceptibility to osteoarthritis. Presence of orbital plexus-correlates were not limited to a single order, and their presence was neither uniform within orders, nor within families. Preliminary results suggest the phenomenon is phylogenetically diverse, as well as unrelated to geography, habitat character (e.g., climate, including temperature, altitude, arboreal versus terrestrial), position in food chain and dietary choices, size, habitat altitude, geography, population density, group size, greater contact with soil, slower host life history, increased ranging. Susceptibility to osteoarthritis was inversely proportional to presence of orbital plexus correlates ($p = 0.0294$). In contrast to the generally inverse relationship of mass to osteoarthritis susceptibility in birds, no correlation was identified with respect to orbital plexus findings. Hypothetically, the role of an orbital plexus is likely modulate circa-orbital temperatures for protection of and perhaps for optimization of ocular function. Given the lack of correlation with environmental parameters and inverse relationship to osteoarthritis, it is suspected that a behavioral exploration is likely and a subject for future investigation.

## NEW COLLECTIONS, INTRASPECIFIC VARIATION, AND PALEOGEOGRAPHY LEAD TO REVISED TAXONOMY AND SPECIATION OF LATE PLEISTOCENE GROUND SLOTHS (MAMMALIA: PILOSA) IN HISPANIOLA

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Hispaniola has a rich karst geology that has preserved snapshots of life on the islands, spanning from the Pleistocene to the present, and of which fossil sloths play a significant role. The earliest published work on the cave faunas began in the 1920's, focusing on sites in Haiti. Representation for the Dominican Republic came later in the 1960–70s but was sparse and reflective of the greater importance placed on archeological work at those sites. Renewed collections were made from numerous sites in Haiti during the late 1970s but publication for much of material was greatly delayed. The past two decades have seen new paleontological explorations of the south central and eastern parts of Hispaniola, producing collections of specimens in excellent states of preservation and composed of numerous individuals per locality for the varied taxa. This newer and vaster sloth material now gives rise to a previously unavailable range of morphological variation across the breadth of Hispaniola, and subsequently opens up new research avenues. One study exploring the intraspecific variation revealed evidence of a sexual size dimorphism consistent at sites across the island and for multiple genera. Additionally, the study revealed a larger size difference within *Parocnus* that led to the creation of a new species, *P. dominicanus*, and placed the former taxon *Megalocnus zile* as a junior synonym of *P. serus*. Unlike studies for other species of the Greater Antilles, there was not supported evidence of differences attributable to the paleo islands of the formerly divided Hispaniola but that may be an artifact of discrepancies in the current taxonomic assignments for the sloth genera and species. More recent study sites from eastern Hispaniola presents novel individuals initially assigned to Neocnus but are challenging the current taxon in multiple ways. One individual exhibits an array of characters that are a mix of those indicative of *Neocnus* and *Acratocnus*, as well as some novel character states that differentiate from both of those genera. Another set of *Neocnus*-like individuals exhibit an anteriorly fused jugal along with a complete zygomatic arch, which is an entirely novel character amongst all sloths. As Caribbean sloths are proposed to have migrated north across the Lesser Antilles and then westward across the Greater Antilles, these new finds may represent early speciation events related to the island hopping but also to the topographical and isolating effects of the changing sea levels and tectonics from the Miocene to the late Pleistocene. As such, these specimens represent new species, and possibly new genera, with close but unclear relationships to those sloth species previously established in the western (Haitian) side of the island, and to those recognized from Puerto Rico.

## THE END-TRIASSIC ENIGMA: LONG-TERM OXYGEN LOSS AND ENVIRONMENTAL DESTABILIZATION PRECEDED THE END-TRIASSIC MASS EXTINCTION

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The end-Triassic mass extinction (ETME) occurred ~201 million years ago and is thought to have resulted from a series of environmental changes triggered by the emplacement of the Central Atlantic Magmatic Province (CAMP). Despite being one of the most significant extinction events to occur in the past ~540 million years, environmental change leading to the ETME and preceding CAMP eruptions is not well understood. Specifically, the role of environmental change in driving the extinction remains unresolved due to both spatial and temporal biases within the existing geochemical records. Here, we present nitrogen isotope ($\delta^{15}N$) and iron speciation data from McCarthy Formation at Grotto Creek—a sedimentary sequence representative of a deep ocean setting within the Panthalassa, or Paleo-Pacific Ocean—spanning the upper Norian (Triassic) into the lower Hettangian (Jurassic; ~215 to 198 million years ago). We observe pronounced shifts in the marine nitrogen cycle and upper water column redox, manifesting as a 3 ‰ positive $\delta^{15}N$ excursion that peaks around the Norian-Rhaetian boundary (NRB; ~208.5 Ma). Iron speciation data throughout this interval reveal predominantly anoxic conditions with occasional episodes of euxinia in the local bottom waters. We propose that the combination of this positive $\delta^{15}N$ excursion and iron speciation data from the Grotto Creek Section reflects progressive deoxygenation of the local/regional upper water column, contemporaneously with expansion of the equatorial oxygen minimum zone (OMZ). The expansion of the OMZ would have been enhanced by denitrification (i.e., the reduction of nitrate with organic carbon) in the upper water column resulting in $^{14}N$-depleted organic matter. Our findings indicate that decreased marine oxygen preceded the onset of the ETME interval by at least ~8 Ma and coincided with commensurate redox fluctuations, in-sync with initial declines in biodiversity, and carbon cycle perturbations observed within the Panthalassa. Collectively, this evidence suggests that low-oxygen conditions began to intensify in the region prior to CAMP emplacement. Although the specific driver(s) for this earlier environmental decline remain unknown, this older event likely set the stage for the subsequent biotic and environmental devastation associated with the ETME.

## THE ELEPHANT IN THE ROOM—THE NON-PROFESSIONAL SIDE OF PALEONTOLOGY

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"Paleontological resources" means many things. Fossil collections are resources, true—but so are collection housing, knowledge sharing, information, manpower, funding, localities, specimen identification, preparation, curation—all the things that go into what makes paleontology tick in the professional world. However, there are two sides to paleontology, and no contemplation of paleontological resources would be complete without considering the non-professional side of the equation. Whether it's an individual collector; a fossil club or society; a fossil park; a pay-to-play site or a fossil dealer—all have their respective impact and all should be acknowledged as resources. Consider that individual collectors locate new sites, host professionals at sites only they may have access to, find scientifically relevant specimens and donate them, create personal collections—some as extensive as any museum, allow professionals access to their collections, collaborate with professionals on projects—frequently supplying expertise they alone possess, collaborate with professionals on peer reviewed papers and sometimes publish on their own. One need only look at the accomplishments of the Paleontological Society Strimple Award winners to understand how important this sector of the non-professional community is to the advancement of paleontology. Fossil clubs/societies are the face of paleontology in their communities, do extensive paleo outreach, require members to abide by safe and ethical collecting rules, collaborate with professionals on projects—supplying unique site or specimen expertise, manpower and more, volunteer countless hours at museums and/or universities, offer funds for professional research through scholarships and grants, publish outstanding identification guides and material. Fossil Clubs/Societies are a hugely overlooked paleontological resource, one that could be leveraged far better by the professional community. Fossil parks, pay-to-play sites and yes, even fossil dealers make valuable contributions as well and must be taken into account. This talk will explore my personal experience with all of them—over my 60 years of involvement with the professional and non-professional communities. You may find the results surprising.

## FOSSIL CLUBS—PAST, PRESENT AND FUTURE? THE 10,000 FT VIEW

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Humans have been "collecting" fossils since the stone age, and doubtless will continue doing so far into the future. What social constructs evolve around this have, and will change with time, but our fascination with fossils will remain. We have always been drawn to relics from the past, fossils among them—but surprisingly, the Science of Paleontology is a relatively young one—only being "official" since the late 18th century. Prior to that, everyone playing with fossils was an "amateur". Think on that a minute. Fossil clubs (clubs and societies are basically the same) are an even more recent construct. Anytime you get enough amateur/avocational paleontologists all rumbling around the same area, they are bound to get together—and when they do—a club is born. The earliest fossil clubs seem to have been offshoots of museums and mineral clubs, or were created to support museums, parks or national monuments—and several early clubs encompassed all the earth sciences—not just paleontology. The Dry Dredgers, founded in 1942, is the oldest "fossil club" created by amateurs still in existence today. An explosion of these kinds of organizations happened in the 1970s and 80s resulting in the majority of the 50+ such groups in existence today. Young enough that their founding members may still be around today or have only recently left us. While all clubs are remarkably similar in their love of paleontology, no 2 are alike. They are all comprised of an eclectic group of individuals, whose personalities and expertise frequently define the "personality" and direction of the organization. All clubs exist to go collecting in the field and all share the desire to get together and talk about fossils with each other (at meetings) and in the community (in the form of outreach). Most are 501 (c) (3) organizations with by-laws & a mission statement, an ethics policy, liability insurance, elected officers (and a board of directors), a website and maybe social media. Most also give out grants, scholarships and/or donations. Many are affiliated with a museum or university and probably have an academic advisor. Some branch out into publishing—newsletters, articles, papers (some peer-reviewed) & books (generally on identification). Some are big on members volunteering time at their local museum or university or in the field to aid professionals on scientific projects. Each club has their own unique "take" on how to best express their collective love of paleontology. Ten years ago, I gave my first talk on Fossil Clubs at NAPC in a talk entitled "The Purpose and Function of Fossil Clubs—a Personal Perspective." How have things changed in the decade since I gave that talk and what do I foresee for the future, given our changing times and challenges? I'll draw on my 50 years of membership in multiple clubs from coast to coast to ponder that.

## PUTTING ALGAE IN EDIACARAN ECOSYSTEMS

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Fossils of multicellular algae are present among Ediacaran deposits of the earliest macroscopic metazoan communities, termed the Ediacara Biota (575–542 mya). Ediacaran algae

are underrepresented in community-level analyses of these first ecosystems in part because of their relatively poor preservation compared to co-occurring metazoan fossils. These algae were composed of low relief filaments that preserve faintly compared to metazoans, and algae commonly disarticulate during burial while metazoans typically remain intact. This is the case for algae preserved in Ediacara Member deposits found in the Flinders Ranges area of South Australia. These deposits house abundant algal and metazoan fossils together and are renowned for the snapshot preservation of individual, in situ, ecosystems as casts and molds on discrete, non-amalgamated bedding planes resulting from mat-mediated preservation. Fossil algae are only found within the shallow water Oscillation Rippled Sandstone facies of the Ediacara Member, but they are found on at least 16 of the 24 beds excavated from this facies. Ten beds preserve only a few ($n < 5$) specimens, but six beds preserve relatively abundant algal populations with two bed communities dominated by algae. Where algae are relatively abundant, their density ranges from approximately 3–30 specimens per square meter and their spatial distribution displays statistical patterns of aggregation. Populations of relatively abundant algae are also associated with both high mat maturity and community diversity, suggesting that algae may be more prominent in well-established ecosystems. Recent work has resolved the complicated taphonomy of these organisms, allowing them to be incorporated into ecosystem-scale analyses of the Ediacara Biota including tests of association between algae and metazoan taxa, size classes, life mode, and feeding mode. Such methods are employed in this study to determine the role of algae in shaping these early ecosystems.

## TWO-PHOTON FLUORESCENCE MICROSCOPY PROVIDES EVIDENCE OF SUBERIN PRESERVATION IN FOSSIL BARK OF THE MONKEYHAIR TREE FROM THE EOCENE GEISELTAL FOSSIL LAGERSTÄTTE

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Fossil remains of the monkeyhair tree, *Coumaxylon hartigii*, from the Eocene Geiseltal lignites in Germany, commonly occur as mats of preserved laticifers surrounded by a dark, rough outer layer. Based on gross morphology, this outer layer has commonly been interpreted as preserved bark, which is strikingly rare in the fossil record. Bark is distinct from other plant tissues in that it contains abundant suberin, a complex biopolymer, so identifying suberin in these remains would confirm their interpretation as bark. Here we apply two-photon microspectroscopy, using an excitation wavelength of 790 nm, to these fossils to see if they exhibit characteristic suberin autofluorescence. We focus on three distinct samples: untreated material from the outermost layer of the fossil monkeyhair tree; a "desuberized" portion of the outermost fossil layer (residue after suberin hydrolysis and extraction of constituents); and Recent *Quercus suber* bark as a control sample. In addition, we use a previously published fluorescence emission spectrum of pure suberin, also excited at 760 nm using two-photon fluorescence microscopy, for comparison. We fit the average spectrum of the untreated fossil material with three different "theoretical" models: (a) a model consisting of the spectrum of the desuberized fossil alone; (b) a model consisting of a weighted sum between the desuberized fossil's spectrum with the average spectrum measured from the control sample of *Q. suber* bark, and (c) a model consisting of the weighted sum of the desuberized fossil spectrum with the previously reported suberin emission spectrum. The fitted curves are assessed based on their residual sum of squared differences, which were 5.4 for model (a), 1.3 for model (b), and 1.0 for model (c). Including an element of suberin fluorescence into the model (either the spectrum of *Q. suber* bark or pure suberin) results in better fittings than the model which excluded suberin, indicating that the fossil material likely contains an appreciable amount of suberin. This study therefore supports the identification of the outer layer of the monkeyhair fossils as bark. Furthermore, a wide variety of plant tissues fluoresce, and the results of this study suggest that two-photon fluorescence microscopy could be a powerful non-destructive tool for identifying remnants of original tissues in fossil plants.

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## UPDATE ON THE EXTINCT SLOTH *NOHOCHICHAK* AND ITS RELATIONSHIP TO PLEISTOCENE SLOTH DIVERSITY OF THE YUCATAN REGION

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The exploration of caves and cenotes, both submerged and dry, in the Yucatan has resulted in the recovery of a diverse Pleistocene vertebrate fauna including previously unknown sloth taxa, particularly of megalonychid sloths. Many of these new taxa are based on only a few parts of the skeleton, so determining their phylogenetic relationships is problematic.

One of these taxa is *Nohochichak xibalbahkah* first recovered from the immense natural trap, Hoyo Negro in Outland Cave, Quintana Roo, México and is currently the only known location for the taxon. While the initial description was based on a lower jaw and an edentulous rostrum of the skull, ongoing work in Hoyo Negro has subsequently yielded a complete skull along with most of the skeleton of a single individual from the same area as the type. To date this is the only essentially complete skeleton of a sloth recovered from the region. The recovery of a complete skull significantly increased the number of available cranial characters thus permitting a reexamination of the phylogenetic relationship of *Nohochichak* to other megalonychids not only in the Yucatan, but also in North, Central and South America as well as the Caribbean Islands. The updated character set confirms *Nohochichak* was part of an endemic radiation of megalonychid sloths in the northern part of the Neotropics and represents a distinct clade from other megalonychids in temperate North America, South America, and the Caribbean. As all current records of megalonychid sloths in this region are middle to late Pleistocene in age it is not yet possible to date the origin of this radiation, but this clade appears to be related to *Zacatzontli tecolotlanensis* currently known from a lower jaw from the late Hemphillian of Jalisco, México. This suggests that during the early stages of the Great American Biotic Interchange there were two separate dispersal events of megalonychid sloths in the Hemphillian, an earlier one represented by a clade including *Pliometanastes* and *Megalonyx* and a later one by *Zacatzontli* which may have given rise to the Neotropical sloths present in the Yucatan. It is also possible that the Pleistocene sloths in the Yucatan represent a third and younger dispersal event. Whereas *Nohochichak* appears to be the largest species of sloth from the Yucatan based on the currently available specimens, *Xibalbaonyx oviceps* may have been equally large or larger. The skull of the type of *Xibalbaonyx* is from a large juvenile so the adult may have been significantly larger. Based on the femur length of the single known skeleton of *Nohochichak* the estimated body mass of an adult is about 987 kg so somewhat smaller than the body mass estimates of late Pleistocene *Megalonyx jeffersonii* which is about 1295 kg.

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## *EREMOTHERIUM* BONES AND THE CENOTE OF DOOM: ADVENTURES IN UNDERWATER PALEONTOLOGY

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Cara Blanca in Belize is a system of 25 lakes and water-filled karstic sinkholes or cenotes formed in Cretaceous limestone in a forested tropical landscape. The presence today of perennial water which typically lasts during prolonged droughts serves as a modern analog for the role of these water sources in this seasonally arid region during the Pleistocene. During the Pleistocene the Central American lowlands were increasingly cool and arid from Interstadial Stage 3 (~36 to 24 ka) through Glacial Stage 2 (~24 to 13 ka). During Glacial Stage 2 (Last Glacial Maximum, LGM) sea level was 110 meters lower than today with lake levels and the water table of the Yucatan at their lowest leaving much of the Yucatan including the Cara Blanca area desiccated, and making cenotes an important resource for megafauna seeking water and exposing the ledge at 17.3 m. Recent diving expeditions in Pool 1, the deepest of the cenotes at approximately 62 m. yielded megafaunal remains embedded in clay deposited on a ledge along the wall of the cenote at 17.3 m. Multiple remains of the giant ground sloth, *Eremotherium laurillardi*, are preserved in a 5.1-m-thick clay layer on the ledge. An isolated molariform of the sloth was recovered for stable isotope analysis. Sloth teeth are hypselodont and ever-growing, so changes in the $^{18}O/^{16}O$ ratio concentrations along the length of the tooth can be indicative of seasonal changes in temperature and/or the amount of precipitation as isotope data roughly reflects the $d^{18}O$ values of water consumed. Complementing the oxygen isotope data, variation in $d^{13}C$ along the length of the tooth records seasonal changes in the sloth's diet. and the degree to which its diet varied seasonally. The radiocarbon age of the sloth tooth dates to 26,975 ± 120 cal BP, the earliest stages of the LGM. The oxygen isotope pattern in the *Eremotherium* tooth indicates two short wet seasons separated by a prolonged dry season. Based on skeletal morphology, it has been suggested *Eremotherium* was primarily a browser, rather than a mixed feeder. The $d^{13}C$ values of -6.8‰ indicate a mixed diet in the Belize sloth. As the sloth remains date to a period of increasing aridity during the Pleistocene, the isotopic analyses show how *E. laurillardi* was adapted to a seasonally variable climate. Entrapment in the cenote probably occurred while accessing water during severe dry events. During the brief wet seasons, the sloths may have taken advantage of relatively more palatable C4 vegetation that was likely more abundant due to both low $CO_2$ levels during the LGM and more arid conditions locally. *E. laurillardi* did not consume foliage from a dense canopy forest and appears to have been adapted to more open habitats and not closed canopy forest.

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## PLEISTOCENE DISRUPTION OF TRAIT-ENVIRONMENT RELATIONSHIPS INFORMS THE FUTURE CONSERVATION OF AFRICAN MEGAFAUNA

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A crucial challenge in ecological research is predicting tipping points that lead to the deterioration of ecosystem function. This can be addressed using an ecometric framework, which examines the alignment of community functional traits with environmental conditions. Mismatches between ecometric trait distributions and their environments can indicate functional loss within a community. Ecometrics has been underutilized for addressing fundamental ecological questions. However, as trait and environmental data have become more accessible, ecometric methods development has proliferated. We adapt ecometric methods to evaluate whether biodiversity losses since 7.5 Ma were coincident with disruptions to the functional link between communities of herbivorous, eastern African megafauna and their environments (i.e., functional trait-environment relationships) and evaluate potential future disruptions of ecometric relationships in Africa given projected climate change. Mammalian megafauna have been critical to the functioning of Earth's biosphere for millions of years. However, since the Plio-Pleistocene, herbivore taxonomic and functional diversity began to decline as open grassland habitats emerged, persisted, and expanded. In the mid-Pleistocene, grassland expansion intensified and Acheulean hominin tools emerged. We find that it was at this time that phylogenetic diversity declined and the trait-environment relationships of herbivore communities shifted significantly. Our results demonstrate the varying implications of different losses in megafaunal biodiversity. Only the losses that occurred since the environmental and anthropogenic changes of the Pleistocene were coincident with a disturbance to trait-environment function. Such a disturbance is projected to occur in even greater magnitude in the future, as climate change and human impacts intensify. Using the ecometric model of modern megafaunal communities in Africa, we then identified communities whose trait-environment relationships will be disrupted under projected climate change. Over 50% of communities exhibit weak future ecometric relationships with respect to at least one trait, putting them at risk of depleted ecological function. The species comprising these communities will need to shift across space so that trait-environment relationships remain undisturbed. We therefore evaluate the landscape connectivity across Africa and identify regions where these community reconfigurations will be disrupted. Many communities that are at risk occur in low-connectivity regions, like the Sahel. Conservation efforts that focus on movement routes between these communities will be critical if megafauna are to persist and continue providing essential ecological functions.

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## THE SIGNIFICANCE OF ENCRUSTING TAXA AND BORING ICHNOTAXA ON MARINE BIVALVES IN THE MIOCENE, SHALLOW MARINE CALVERT AND CHOPTANK FORMATIONS, CALVERT CLIFFS, MARYLAND

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Fossil molluscs are common in the Miocene marine strata of coastal Maryland. Molluscs are particularly diverse and abundant in four densely-packed shell beds referred to as Shattuck zones (SZ) 10 and 14 (Calvert Formation) and in SZ 17 and 19 (Choptank Formation), each previously interpreted as the stratigraphically condensed record of a marine transgression. Although the taxonomy of the molluscan fauna is well-established, the occurrence of borers and encrusters has been minimally documented. The species composition, life habits and relative abundances of these foulers provides valuable evidence about the dynamics of sediment accumulation. This study compares and contrasts the encrusters and boring ichnofauna of SZ 14 and 17 at the famous Parker Creek locality. SZ 14 is dominated by abundant, commonly articulated scallops, whose shells support sparse traces and rare barnacle basal attachment plates. SZ 17 contrasts markedly, preserving a more diverse array of bivalve and gastropod taxa which are characterized by diverse and abundant encrusting taxa and boring ichnotaxa. Barnacles are numerous and diverse (6 species). Bryozoans and juvenile ostreid valves occur attached to both the inner and outer surfaces of many shells. The boring ichnofauna in SZ 17 includes traces emplaced by polychaetes, sponges, bivalves, octopods, gastropods, marine fungi and cyanobacteria. Many of these traces occur on both the inner and outer surfaces of the shells, implying that some traces were postmortem and that shells resided near the sediment-water interface (SWI) long enough to permit colonization, maturation, and in some instances perhaps, ecological succession. This set of foulers

includes traces of both marine predators and encrusters that colonized the shell both before the basibiont died as well as after the shells became empty and disarticulated. Differences in the diversity of the basibionts and in the proportion and abundance of foulers between the two horizons implies strong differences in paleoecological conditions and sediment dynamics during condensation. We interpret that, at Parker Creek, SZ 14 was deposited under deeper water conditions, with more frequent and persistent deposition of mud and rare post mortem exhumation/exposure of shells at the SWI, thus leaving insufficient time for encrusting and boring organisms to colonize the shells. The dynamics of sedimentation during this interval thus likely entailed only brief and/or infrequent exposure of shells at the SWI, with some short-term depositional events entombing still-articulated scallops. In contrast, the greater diversity and frequency of foulers on mollusks from SZ 17, as well as their occurrence on both internal and external shell surfaces, suggest more shell-gravel-like conditions at the sediment-water interface, or at the least more frequent burial-exhumation cycles of shells, consistent with slow sediment accumulation in shallower waters.

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## FOSSIL POINT OREGON; NEW FOSSILS, OLD FOSSILS REVISITED, AND POSSIBLE CASCADIA TSUNAMI DEPOSITS

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On the outskirts of Coos Bay Oregon sits the aptly named Fossil Point locality. Records of Neogene marine mammal fossils and copious marine invertebrates date back to the late 1800s, with the name Fossil Point appearing on maps from the 1890s. The same maps also note the presence of three distinct geologic units exposed in the narrow band of coastline. Capping the wave-cut terrace is poorly consolidated beach gravel from uplift of terraces along the south coast, with previous authors proposing this terrace dates from roughly 100–150 ka. Underlying this, and forming the current wave-cut platform is the Empire Formation. Broken into two units, the Empire Fm proper and the Coos Conglomerate, only exposed at Fossil Point, both producing vertebrate and invertebrate fossils forming the basis of previous geochronology. Despite the long history of collection very limited published material exists and no detailed work on the stratigraphic relationships, age, or depositional environment exists. I am reexamining existing unpublished fossils from all three units, newly discovered material from the Coos Conglomerate and Empire, as well as looking at the geologic units themselves to better reconstruct the timing and setting for the units. The Empire includes several complete cetacean skulls and associated postcrania, a walrus, a basking shark, crabs, clams and scallops, gastropods, brachiopods and sand dollars. Unfortunately, many of these specimens were collected or described in the early 1900s and have received little subsequent attention. I report on a previously undescribed walrus mandible (*Odobenus rosmarus*) from the capping Pleistocene gravel accompanied by new stratigraphic and structural work assigning the terrace to the slightly younger 80 ka Whiskey Run Terrace. This assignment is of potential importance in that despite the younger date this would still make the mandible the oldest modern walrus from the PNW. I also propose that the Coos Conglomerate unit is not in fact part of the Empire Formation. The Coos Conglomerate is deeply incised into the Empire and includes concretions from the Empire reworked into the unit that are up to 2 m in length indicating an unconformable relationship between the two. Using updated biostratigraphy as well as new paleomagnetic work, I retain the assignment of the Empire to the latest Miocene, but suggest the Coos Conglomerate is Pliocene to even early Pleistocene in age and likely represents a tsunami deposit from a proximal Cascadia megathrust earthquake event. In the Coos Conglomerate I propose that both a newly discovered whale specimen and the previously published basking shark are contained in concretions from the Empire formation, and thus the previous older age assignment, whereas the gastropods and new urchin from the Coos Conglomerate represent a better biostratigraphic and paleoecological indicator.

## *PALEODICTYON*, MICROBURROWS, AND THE ORIGIN OF ANIMALS

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Two related conundra loom large for future advance in both paleontology and sedimentology. The first involves the interpretation of the putative trace fossil *Paleodictyon*. The second relates to the interpretation of Tonian carbonate sedimentary structures that have recently been suggested to be animalian in origin. *Paleodictyon* is likely formed by a metazoan with a very ancient lineage that existed long before the beginning of the Cambrian. Recent evidence and interpretations suggest that Tonian and later carbonate sedimentary structures are may in fact be products of the same metazoan lineage that produces *Paleodictyon*. This mysterious lineage (evidently still alive today in the deep sea, yet currently unidentified) lacks, as far as we know, a body fossil record. This may be the case because the animals lack robust cuticle that could easily fossilize. Ichnofossils in nautiloid chamber fill sediment, ranging from the Paleozoic to Cenozoic, show characteristic features that suggest that they may also be products of this same lineage.

## DENTAL COMPLEXITY DISPARITY OF LATE TRIASSIC REPTILES APPROACHES THAT OF EXTANT LEPIDOSAURIA

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The Triassic Period was a transformative interval in the history of tetrapod evolution, when the survivors of the end-Permian mass extinction recovered, diversified, and radiated into novel ecological roles. All major tetrapod clades in terrestrial environments today originated during the Triassic (e.g., lissamphibians, mammaliforms, lepidosaurs, turtles, crocodylomorphs, and dinosaurs), as well as many lineages that ultimately went extinct by the end of the period. Recent discoveries demonstrate exceptional Triassic tetrapod diversity with disparate tooth shapes. These taxa have revised our understanding of the diversification and phylogenetic relationships of these groups, but many aspects about their ecology remain poorly understood. In particular, the ecological role these groups occupied and potential dietary overlap between now extinct and living groups remain unresolved. To address these, we used micro-CT scans of 17 Late Triassic reptile taxa to create 3D surface models of dentitions, resulting in a broad sample of both living and now extinct major groups. Using the orientation patch count rotated (OPCR) method, we quantified phenotypic tooth shape to directly compare the dental complexity of extinct groups to each other and extant taxa. The recovered dental complexities vary considerably (OPCRavg 8.5–23.45 patches per tooth). *Trilophosaurus buettneri* had the highest average dental complexity in sampled taxa, driven by multiple prominent cusps. *Revueltosaurus callenderi*, isolated teeth referred to *Revueltosaurus*, and the silesaurid *Kwanasaurus williamparkeri* exhibit teeth that rival the complexities of *Trilophosaurus buettneri*. Both small- (e.g., the lepidosauromorph *Vinitasaura lizae*) and large-bodied (e.g., the phytosaur *Wannia scurriensis*) taxa exhibit the other extreme (~10 patches per tooth), with simple conically-shaped teeth. Between these end members fall a variety of early lepidosaurs, *Puercosuchus*, lagerpetids, and dinosaurs. The range of dental complexities largely matches sampled extant lepidosaurs. Only some iguanids (*Cyclura cornuta*) and teiids (*Dicrodon guttulatum*) surpass *Trilophosaurus* in OPCRavg values. Sampled early lepidosaurs (i.e., *Diphydontosaurus*, *Vinitasaura lizae*, eusphenodontian) display simple teeth suggestive of an invertebrate-based diet. In this dataset, the sampled clades that exhibit dental complexities that suggest specialized carnivory or herbivory go extinct by the end of the Triassic (e.g., silesaurids and trilophosaurids), whereas taxa with OPCR values that indicate less specialized diets (such as insectivory or omnivory) endure into the Jurassic Period (e.g., lepidosaurs). These results suggest that less specialized diets may have been one factor that enabled survival of the end-Triassic mass extinction.

## INTEGRATING DATA FROM EXTANT AND EXTINCT SPECIES FOR THE UNDERSTANDING THE EVOLUTIONARY DYNAMICS OF SQUIRREL TOOTH MORPHOLOGY IN RELATION TO DIET

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Combining data from extinct and extant species is essential for the understanding of the ecological evolution of lineages. Considering both sources of data, we studied how and when squirrels (Sciuridae, Rodentia) adapted to new diets. Since most squirrels' fossil record consists of isolated teeth, we focused our study on the fourth lower premolar (p4). We employed two different methodological approaches, geometric morphometrics and Elliptic Fourier analyses, to quantify the outline of the p4 in occlusal view. Based on the relationship between tooth morphology and dietary preferences in extant squirrels, we inferred the diets of extinct species. We obtained similar dietary inferences with both geometric morphometrics and Elliptic Fourier analyses. Combining the resulting inferences for extinct species with a phylogenetic ancestral reconstruction of diets for extant squirrels, we discussed the timing of morphological adaptation to new diets. This allowed us to identify potential drivers of squirrel morphological evolution in the context of past climatic changes. Our results demonstrate that p4 morphology is conserved across evolutionary history for most lineages. However, certain lineages experienced changes in tooth morphology due to adaptations to demanding diets, often influenced by climatic factors. Phylogenetic ancestral state estimation yielded a primitive diet of seeds and nuts, with transitions to specialized

frugivory, folivory, or insectivory in tree squirrels, and diets including grasses in ground squirrels. Dietary preferences of extinct species, inferred from tooth morphology, indicated that crushing was required since the origin of this clade and throughout most of its evolution, and it was not until the Late Miocene that North American marmots included grass in their diets. Subsequently, other North American ground squirrels (*Cynomys*, *Spermophilus*, and *Urocitellus*) adopted diets including both seeds and grasses during the Pliocene and Pleistocene. Major changes in p4 shape were associated with the inclusion of grass in their diets, presumably as an adaptive response to the expansion of grasslands in North America. In contrast, the rest of the dietary transitions were not associated with tooth shape change, probably because the ancestral shape allows for processing a wide variety of food and most species in the family have broad diets. This study sheds light on the macroevolutionary evolution of squirrels and reinforces the utility of tooth morphology in inferring the diets of extinct mammalian species.

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## A FRESH LOOK AT A VERY OLD SPECIMEN: VISUALIZING THE ANATOMY OF *TETRACERATOPS INSIGNIS* (SYNAPSIDA, EUPELYCOSAURIA) WITH µCT

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Tetraceratops insignis is an enigmatic early Permian synapsid, known only from a single skull collected by Charles Sternberg in Baylor County, TX in 1897. Little documentation from its discovery survives, but its locality, Big Wichita River, is reported to be well-prospected, with vertebrate material exceedingly rare. It originates from the Lower Clear Fork Formation which is Kungurian in age. This skull is ca. ten cm in length and is mostly complete—but is also flattened diagonally and partially crushed. The severity of damage has prevented decisive interpretation of its anatomy, obscuring the phylogenetic affinity of *Tetraceratops* and leading to decades of debate over whether it is a therapsid. If true, *Tetraceratops* would be the only therapsid of lower Permian origin and would thus abridge the ghost lineage that occludes the origins of Therapsida. However, debates about the relationships of this taxon have historically taken precedence over analysis of the specimen itself. Thus, the morphology of *Tetraceratops*—which is highly dissimilar to its better-known contemporaries (e.g., *Dimetrodon*, *Ophiacodon*)—is relatively understudied. Its most notable features include the bony bosses or 'horns,' on the premaxillae, prefrontals, and angular. The bony ornamentation and degree of ossification suggest a mature individual, but the orbits are unusually large for an adult. The maxilla and dentary bear enlarged caniniform teeth, well differentiated from the slender, peg-like posterior dentition, but the degree of supracaniniform buttressing is superficially obscured by the premaxillary horn. There appears to be a ventral keel on the angular, potentially a homologue of the reflected lamina of the angular. Damage to the tooth crowns prevents dietary inferences beyond faunivory, but the orientation of the first tooth root within the dentary is unusual for a pelycosaur and almost incisor-like in its protrusion. The profile of the rostrum besides the bony ornamentation is short and round, again somewhat unusual for a faunivorous pelycosaur, and the anterior part of the mandible is narrow and delicate in comparison with the rest of the skull. These traits allude to an unusual specialist whose morphological uniqueness may be driven by yet-unknown functional demands. µCT scanning of the specimen provides new details of its anatomy. Segmentation and reconstruction has yielded new insights into problematic aspects of the specimen —particularly in the posterior cranium, which is badly broken, with the identities of its elements long disputed. The trabecular structure is slightly varied in its structure and orientation in each piece, which informs both relative position and hints at the direction of muscular loading. Clarifying the identity, position, and muscle attachment sites of these broken pieces of the squamosal, jugal, and quadrate via their internal morphology will shed light on past hypotheses about phylogenetically informative characters in this region.

## A MAMMOTH DIET: UNDERSTANDING ECOLOGY AND BEHAVIOR OF *MAMMUTHUS PRIMIGENIUS* TO UNDERSTAND CAUSES AND CONSEQUENCES OF ITS EXTINCTION

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Understanding the biology of extinct species is pivotal to understanding causes and consequence of past extinctions events and ecological upheavals. The woolly mammoth (*Mammuthus primigenius*), despite surviving multiple glacial/interglacial cycles and having a range encompassing 3 continents during the glacial periods, disappeared from Earth during the last 10,000 years. The ultimate causes of its extinction are still debated, as is its role in Arctic ecosystem—an obligate dweller of steppe-like environments dictated by cold, arid glacial conditions, or a keystone species able to

shape Arctic ecosystems making them more productive and resilient? This, together with the availability of recent, well-preserved subfossil specimens, makes the woolly mammoth a target for paleontologist, paleoecologists, ecosystem ecologists and, more recently, de-extinction advocates. Despite this fact, key elements of the woolly mammoth's biology are still unclear—including its diet. Our knowledge of mammoth diet comes mainly from studies on stable isotopes (which paint a general picture of dietary preference among plant groups, but lack taxonomic and temporal resolution) and gut contents from frozen carcasses (which are rare and can suffer of the "last supper" effect—the last meal of an animal might not be representative of its diet). Coprolites allow for high taxonomic resolution of diet without incurring biases of the gut content. Despite some mammoth coprolites having been found in permafrost, so fare they have been a rare occurrence. To understand the woolly mammoth diet, we studied a novel dataset of 50 coprolites from Yakutia (Siberia, Western Beringia), collected from permafrost deposits between 2012 and 2019. Radiocarbon dating showed that the coprolites cluster among two periods: before ~42,000 years BP and between 30,000 and 20,000 years BP, two time intervals climatically different. We analyzed their content with a multiproxy approach, including microfossils (pollen, spores, phytoliths), macrofossils and ancient DNA. The results picture the woolly mammoth as an adaptable species, feeding on a variety of plants including shrubs (*Salix*), forbs (*Asteraceae*, *Fabaceae*, *Plantaginaceae*) and grasses (*Poaceae*), also including taxa that are considered toxic for extant herbivores (*Ranunculaceae*). Our data points at a seasonal preference in the selection of food items, with grasses becoming more abundant during the least productive part of the year and forbs being preferred during summer months. We also didn't observe a significant change in the composition of the diet and the pollen spectra across the two time periods represented in the coprolites. This gives credit to the hypothesis that the mammoth steppe was not only driven by climate, but biotic interactions (including the activities of woolly mammoths) were likely playing a role in its persistence across diverse climatic conditions.

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## EVERYTHING OLD IS NEW AGAIN: STRATIGRAPHIC REVISIONS AND SURVEY OF NEARLY 100 YEARS OF WORK ON THE EARLY MIOCENE RUSINGA AND MFANGANO ISLANDS, LAKE VICTORIA, KENYA

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Louis Leakey started working on Rusinga Island in 1931, setting off near-continuous paleontological and geological studies on both it and the neighboring Mfangano Island. While initial work revealed fossils important for understanding hominoid evolution, and later studies led to insights about floral and faunal evolution in eastern Africa during the early Neogene, and nearly 100 years later, important discoveries are still happening on these islands. Recent fieldwork has clarified the stratigraphy on Rusinga Island and solidified the ideas first put forth by John Van Couvering in 1972. This new (old) stratigraphic column includes the Kiahera Formation as the oldest units on the island, followed by the Rusinga Agglomerate, Hiwegi Formation, Kulu Formation, Kiangata Agglomerate, and finally the Lunene Lavas. All these formations were deposited after the Kisingiri Volcano began erupting, and they record quiescence and activity of the volcano through time, as well as the subsequent changing landscape. Our new stratigraphic column also formally named the members of the Kiahera Formation, something that had never been done over the previous decades. These new members include the Nyamita Spring Member, Ukowe Member, and Rondo Member. Very preliminary work on the neighboring Mfangano Island suggests the occurrence of the entire stratigraphic series found on Rusinga as well as older units, which are informally named the Makira Series. The fauna from the Makira Series has important differences from those found on Rusinga Island, which might be due to its older age or nuanced paleotopography. These new discoveries suggests that the next 100 years of learning the lessons of Rusinga Island might best be done through systematic, careful work on Mfangano Island, and through analysis of the understudied, fossiliferous Kiahera Formation on both Rusinga and Mfangano.

Funding source: The Leakey Foundation

## LOWER ACTINOPTERYGIAN FISHES FROM THE UPPER PENNSYLVANIAN HAMILTON QUARRY, A KONSERVAT-LAGERSTÄTTE IN SOUTHEASTERN KANSAS, U.S.A.

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The Upper Pennsylvanian (Virgilian) Hamilton Quarry in southeastern Kansas (U.S.A.) is known as a Konservat-Lagerstätte because of the abundance and exceptional preservation of aquatic and terrestrial vertebrates, invertebrates, and plants recovered from this site. Lower actinopterygian fishes are included in the Hamilton Quarry fauna and while they are not the most numerous or diverse vertebrates from this locality, they are represented by three-dimensionally preserved articulated to partially articulated specimens. The 3D nature of the preservation makes the actinopterygians from this site particularly important. Currently, there is no consensus on the relationships of lower actinopterygians, a problem that is partially attributed to the need for detailed descriptions and redescriptions of well-preserved taxa as well as deeper investigations into morphological characters that are included in phylogenetic analyses. Hamilton Quarry actinopterygians have been previously investigated in a dissertation, but taxa have not yet been formally described. Some of the Hamilton Quarry fishes, including two acid-prepared specimens that preserve three-dimensional views of the skull bones, scales, and vertebral elements, were designated in this unpublished dissertation as belonging to a new genus and species. These specimens are reexamined and presented here. This includes a reinvestigation of the dermal bones of the skull, dentition, and vertebral elements. Additionally, an undescribed specimen from the Hamilton Quarry is presented and compared to the specimens of the previously proposed new genus and species from this locality. This new specimen, also acid-prepared and showing three-dimensional views of structures, preserves information on the dermal skull bones in the circumorbital series, cheek, operculogular apparatus, and shoulder girdle, as well as details regarding dentition and fin supports. The examined lower actinopterygians from the Hamilton Quarry are compared to each other as well as other lower actinopterygians. Shared amongst the Hamilton Quarry fishes is a prominent ovoid-shaped jugal that is different from the crescent-shaped jugal seen in the majority of lower actinopterygians. The presence of this distinctive jugal suggests a possible close relationship between these Hamilton specimens while also distinguishing them from the majority of other lower actinopterygians. The examined Hamilton Quarry specimens do otherwise show differences from each other in regards to features of the teeth, supracleithrum, branchiostegal rays, and suborbital bones, suggesting that they represent separate and distinct taxa. The two specimens presented here may represent two new species within a new genus and an increase in the actinopterygian diversity recovered from the Hamilton Lagerstätte.

## COMPARATIVE ICHNOLOGICAL ANALYSIS OF THE PALEOCENE-EOCENE THERMAL MAXIMUM: GOING FROM SHALLOW TO DEEP MARINE SETTINGS AT THE PYRENEAN BASIN, SPAIN

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The Paleocene-Eocene Thermal Maximum (PETM) represents a significant climatic and environmental occurrence approximately 56 million years ago. It is marked by a substantial increase in global temperatures (4–8ºC) and widespread alterations in the environment. These changes encompass ocean acidification, rising sea levels, an intensified hydrological cycle, and the migration and extinction of various species. During the early Paleogene, the Pyrenean Basin was a deep-water gulf opening towards the Bay of Biscay (Spain) in the west and rimmed by shallow-marine carbonates. Here we conduct an comparative ichnological analysis between two sections with contrasting environments: 1) The Zumaia section, a deep-sea section with middle-lower bathyal paleo-depths (Pujalte et al., 2015); and 2) The Campo section, an open shallow marine section in a carbonate ramp where a regression occurs contemporary with PETM development, up to the paralic zone, and then a transgression take it back to a ramp (Li et al., 2021). At the Zumaia section a fully established burrowing community is evident in the sediments before the PETM, suggesting the presence of oxygen-rich conditions and typical availability of benthic food. However, as the PETM unfolded the disappearance of the previous burrowing community. After the PETM, the burrowing community recovered gradually and slowly, in a delayed return to pre-PETM environmental conditions (Rodríguez-Tovar et al., 2011). At the Campo section, a well-developed burrowing community is recognized before the PETM. However, the bioturbation intensity slightly decrease before the PETM, probable related with the registered pre-onset excursion. The PETM produce the disappearance of the burrowing community, probably related with the sea level rise. Nevertheless, before the PETM ended, the burrowing community was recovered. Thus, the burrowing community was reestablished even before the $d^{13}C$ excursion finishes. The comparative ichnological analysis highlights the different effect of the PETM on the tracemaker benthic communities, even at regional scales (i.e., within the same basin). Given that periods of warmer conditions (e.g., PETM, MECO) have been proposed as analogs for how seafloor communities will fare under future climate perturbations, understanding the spatial and temporal variations of these events is crucial for environmental predictions at the benthic realm.

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## RESURRECTING THE SILURIAN TRILOBITES OF THE CENTRAL UNITED STATES; NEW LIFE FOR OLD COLLECTIONS

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Beginning in the 1840s, numerous trilobites were described from the Silurian rocks of the central United States. As one of the country's most extensive Silurian trilobite biotas, it has had an essential role in describing related taxa worldwide. James Hall initiated the study of these fossils after establishing his Niagara Group in New York. Interested in extending the geographic range of Niagara Group rocks, Hall found similar trilobites in Wisconsin, Illinois, Indiana, and Iowa, along with many new taxa. While later authors such as Stuart Weller and Percy Raymond continued to describe additional trilobites from these rocks, there has been little work on most Midwestern "Niagara" taxa since the 1920s. Problems in studying these fossils include a reliance on old collections along with limited documentation of their systematics, biostratigraphy, paleoecology, taphonomy, and preservation. During the last fifty years, the authors have made extensive new, well-documented collections and examined all old and largely unstudied existing collections of these fossils. As a result, we have been able to determine the characteristics of individual taxa, place them in a precise stratigraphic and geographic framework, recognize ecologic associations, differentiate between behavioral and taphonomic controls on preservation and diversity, along with identifying climatic parameters influencing the evolution and extinction of these taxa. Specifically, we have determined that these trilobites are not members of a single "Niagara biota." They represent several temporally and environmentally constrained distinct associations that do not range through the entire "Niagara" but occur at specific time intervals within Llandovery through Ludlow strata. These associations occur in specific environments, such as reefs, which have the highest recorded diversity of Silurian reef-related trilobites worldwide, while others are found in shelf regions of time-equivalent carbonate or clastic rocks. Taphonomic processes dramatically impact the character of trilobite associations found in reefs, providing critical information on depositional conditions in these environments. Behavioral features related to molting affect the character of non-reef and reef associations, which help define depositional conditions in shelf areas. Integrated studies of sequence stratigraphy, chemostratigraphy, lithostratigraphy, and biostratigraphy document repetitive and pervasive extinction events of taxa and associations occurring during glacial-eustatic sea level changes. For example, extinction events happen in the early phases of transgressive episodes, as do examples of exceptional preservation. Silurian trilobite extinction and evolution events mirror those occurring at mid-late Cambrian and early Ordovician Biomere boundaries. This suggests that eustatically driven, repetitive, large-scale, extinction events may be typical of trilobites and other organisms during much of the early Paleozoic.

## THE FUTURE OF SMALL MUSEUM PALEONTOLOGICAL RESOURCES AND THE WEIS EARTH SCIENCE MUSEUM

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Small regional museums have long been an important resource for North American paleontological research. They date back to the early 19th century before the concept of modern museums housing research collections existed. Previously, a few wealthy individuals assembled their own private natural history collections while others acquired curiosities to use in for-profit "museums" or touring exhibitions. As paleontology and other natural history subjects became formal disciplines, the need to house specimens collected for research or education led to the establishment of more formal collections and museums. By the end of the century, institutions, including universities, scientific academies, government surveys, and municipal public museums, provided a broad range of repositories for housing fossils. During the 20th century, many of these institutions closed or ended their museum interests, divesting themselves of collections and sometimes creating orphan or lost collections. Even today, some major museums house their own "lost collections." However, many small regional museums remain, although they are frequently poorly funded and can only store their collections. Despite these trends, many of these institutions can be a source of important research material regardless of their current state of operations. Some contain type and figured specimens, or documented collections used in published research. They might also contain unstudied material from classic localities or those no longer available for sampling on a local or regional scale. Specimens important in the history of science through association with noteworthy ideas, individuals, organizations, or events may also exist. Other non-museum local or regional collections could also have research potential. This could include university geology departments that have thesis collections that are commonly well documented or collections and field notes resulting from faculty research. Despite limited funding, some small local museums have succeeded without formal associations with other institutions. An example of a new small regional museum actively working to assemble research collections is the Weis Earth Science Museum (WESM), which opened in 2002. Its focus, established by its founding director Joanne Kluessendorf, is the geologic and mining history of Wisconsin and surrounding states. It is developing a comprehensive collection of fossils, rocks, and minerals limited to that region. A primary museum goal through active research is to identify localities and create collections of regional specimens poorly represented in other institutions. Although housed in a "new" purposely designed building, the WESM routinely faces issues shared with many other small institutions, such as limited funding, storage space, lab space, and trained staff. Despite these issues, the museum maintains an active program of collection expansion and care.

## NEW TETRAPOD TRACKWAYS IN THE COCONINO SANDSTONE, GRAND CANYON NATIONAL PARK, ARIZONA

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The behavior of early Permian tetrapods is not well understood, however the ichnological record can provide evidence for it. The Coconino Sandstone (southwestern United States) preserves many tetrapod tracks made by amniote and anamniote vertebrates including the youngest record of the ichnogenus *Ichniotherium*. Trackways of *Ichniotherium sphaerodactylum* have been previously identified from loose Coconino blocks and some poorly preserved in situ tracks just below the South Rim of Grand Canyon National Park (GRCA) and along the Mogollon Rim in Northern Arizona. Here, we introduce a new, significant locality in a Coconino Sandstone outcropping below the North Rim at GRCA that contains at least 15 trackways preserved in situ on a 20° foreset surface of an eolian dune and may belong to the ichnogenus *Ichniotherium*. The Coconino Sandstone was deposited as an eolian desert erg during the early Permian (Kungurian: Cisuralian) and crops out in Southwestern United States. At GRCA, the Coconino Sandstone is often exposed as sheer cliffs containing large-scale crossbedding and sits between the underlying Permian Hermit Formation and overlying Permian Toroweap Formation. In some areas, the Coconino Sandstone may contain rare interdunal deposits. Vertebrate ichnogenera reported in this unit includes *Amphisauropus*, cf. *Dromopus*, cf. *Erpetopus*, *Ichniotherium*, *Tambachichnium*, *Varanopus*, and other undetermined tracks. An 84-meter-thick stratigraphic section was measured at the new locality. 15 trackways were documented on five different horizons near the middle of the full section. Loose blocks of Coconino Sandstone containing tracks preserved as natural casts were also documented and matched up to the in situ trackway molds. One of these loose blocks containing trackway casts was collected for further analysis. Three separate photogrammetry models showing elevation range were created where the majority of trackways are present. Trackway lengths were measured, with the longest being 5.1 meters and the shortest being 1.2 meters. These trackways show typical features of upslope locomotion, such as very short pace, low asymmetry, deeper expulsion rims proximally and sliding traces parallel to the direction of progression. The trackways generally are parallel to each other and go in the same direction, with minimal overlap. Since this is observed on the same surfaces, this can potentially indicate aggregation behavior. The morphology of these tracks is similar to *Ichniotherium*, in which case the number of parallel trackways present on this outcrop may indicate herding behavior of diadectomorph reptiliomorphs, which has not been previously reported and acquires an important meaning in consideration of its occurrence in deserts, being the diadectomorphs anamniotes.

Funding source: Grand Canyon National Park

## PROBABLE IMPACT ORIGIN OF COINCIDENT EXTINCTIONS AMONG CONODONTS, TRILOBITES, AND BRACHIOPODS, TOP OF SYMPHYSURINID BIOMERE, EARLY ORDOVICIAN, HOUSE RANGE, IBEX AREA, WEST-CENTRAL UTAH

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Phanerozoic extinctions include the trilobite biomere boundaries in the Cambrian and earliest Ordovician; the cause(s) of the extinctions are unknown. Biomeres are biostratigraphic units of stage magnitude with boundaries at abrupt extinctions of species, genera, and families. Six Cambrian and earliest Ordovician biomeres have been identified. The top two also have important conodont and phosphatic brachiopod extinctions in the same interval. The youngest biomere extinction, top of the Symphysurinid Biomere, is at the top of the House Limestone at the Lava Dam North section, southern House Range, Ibex Area, Utah. That extinction defines the Laurentian Skullrockian/Stairsian Stage boundary. Extinctions in the three faunal groups occur in the same interval but are manifested differently, from abrupt to gradual. Common genera of the biomere, e.g., *Symphysurina*, *Bellefontia*, and *Xenostegium* disappeared abruptly and were replaced by *Paraplethopeltis*, followed by a second extinction and replacement by *Leiostegium* and *Kainella*. Conodonts in this interval are abundant, diverse, and include *Cordylodus*, *Acanthodus*, *Polycostatus*, *Rossodus*, *Laurentoscandodus*, *Aloxoconus*, and others. Extinctions began at the lower trilobite extinction but are spaced gradually through several meters of strata. The 180 m House Limestone is entirely limestone except for a peculiar thin, brown dolostone right where extinctions began. Fourteen of Furnish's 1938 species disappeared within this extinction at the top of the Zone. Taxa known from other parts of the world appeared in the extinction interval, including one from Sweden named by Lindström. The overlying 100 m of the Fillmore Formation are assigned to the Low Diversity Interval, which has low conodont abundance. Phosphatic brachiopods recovered from conodont samples document the extinction of 3 taxa at the second trilobite extinction; four new taxa appeared in the highest beds of the *R. manitouensis* Zone. A $^{13}C$ profile has an abrupt ~2 per mil positive shift that began at the brown

dolostone bed and coincides with the onset of extinctions. The profile gradually shifted back to the negative through ~40 m in the Low Diversity Interval before reaching stable values. A 255 m drill core in NW Australia includes nearly all the Lower Ordovician and contains 7 volcanic ashes. U-Pb zircon dates range from 479.4 to 470.2 Ma. The Early Ordovician was divided into 1 Ma intervals. Conodonts from the core delineated Australian Early Ordovician zones that were correlated to Baltoscandia, S. China, and N. America (Utah). The Carswell Impact Structure in Saskatchewan is ~50 km in diameter. Some breccia is cemented by authigenic K-Feldspar that yielded an $^{40}Ar$-$^{39}Ar$ date of 481.5 ± 0.8 Ma. That date plots on the Australian chronology near the top of the Utah *R. manitouensis* Zone, where extinctions began. Fallout and tsunamis from that impact are probable causes of these extinctions. More geochemistry is needed.

## GAPS IN THE FOSSIL RECORD PROVIDE NEW INSIGHT INTO MAMMOTH EXTINCTION DYNAMICS

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When and why did mammoths go extinct? Did their populations fail catastrophically, or languish over time before finally disappearing? Did mammoth extinctions around the world follow the same trajectories, or were there regional differences? While these are basic questions, answering them with any degree of certainty has proven challenging. The late Pleistocene fossil record is an unusually rich resource for studying extinction dynamics because individual specimens can generally be directly radiocarbon dated. While this provides opportunities for pinpointing extinction timing with high precision, such high-resolution time series data may also be sensitive to a variety of geological, taphonomic, and biological factors, such as changes in preservation potential due to shifts in climate, depositional setting, and/or population size. While such factors may be particularly challenging to differentiate using regional- to continental-scale data, highly fossiliferous late Pleistocene records can provide relatively geographically (and thus climatically and environmentally) constrained fossil time series. Using published time-series of radiocarbon dated mammoth specimens within regions across North America and Eurasia, we combine the temporal distribution of specimen ages with the distribution and size of temporal gaps between dated specimens to test for shifts in population trajectories through time consistent with (1) protracted population decline, or (2) abrupt loss. We do this separately for mainland populations and Arctic island populations (where mammoths persisted for millennia following mainland extinctions and where there are no indications of human co-occurrence). We find that sampling can be excellent during mammoth extinction intervals. For example, in northern North America, gap sizes during extinction are consistent with average gap sizes across the time-series, which is inconsistent with mammoth populations dwindling slowly over millennia. However, elsewhere (e.g., St. Paul Island) gap size increases during extinction and, in the absence of a sedimentological explanation for this increase, suggests that the fossil record records a dwindling population. The late Pleistocene fossil record offers important opportunities for evaluating drivers of extinction. While the fossils themselves tell much of the story, gaps in the fossil record can be equally revealing for evaluating species' demographic histories.

## A NEW REPORT ON FLORA AND FAUNA FROM THE MIDDLE PENNSYLVANIAN "STANLEY CEMETARY" LOCALITY IN SOUTHERN INDIANA, A LITTLE-KNOWN LAGGERSTÄTTE FROM A MAZON CREEK-LIKE ENVIRONMENT

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One of the most famous fossil localities in the Midwest is the Mazon Creek in Illinois, a lagerstätte representing part of the coastline that circled the marine basin the Lower Midwest was during the Pennsylvanian. However, it's not the only such locality; and others have been woefully understudied. We report here on another from Indiana, known as "Stanley Cemetery" in the literature. An initial survey of its flora and a summary which also mentioned the presence of a few animals have been published, but otherwise it has only appeared in a few brief mentions. A collection donated to Indiana University and a visit to private land adjacent to the cemetery have revealed much more biodiversity than has previously been suggested. Additionally, the landowner's knowledge of the fossils and the history of the mines they came from provide previously absent stratigraphic context. Nodules containing fossils have historically been collected from piles left by the mines, with fine-scale stratigraphic information impossible to determine. But in an "island" of unmined beds present on his property, nodules can be found *in situ*. We report here on the specimens identified so far. In addition to increasing the alpha-level diversity of the previously-reported flora and updating it to reflect more recent taxonomic opinions, we have identified multiple animal clades including: holothurians, crustaceans, bivalves, annelids, cnidarians, fish, a scorpion, and an early coleoid.

## INCREASING THE ACCESSIBILITY AND DISCOVERABILITY OF THE NATIONAL FOSSIL COLLECTIONS AT THE SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY

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The Smithsonian National Museum of Natural History contains one of the largest fossil collections in the world with over 44 million specimens. Though the Department of Paleobiology (NMNH Paleo) was only founded in 1963, the Smithsonian has been collecting fossils since the 1840s. Some of our significant holdings include invertebrate, plant, and vertebrate fossils collected by the United States Geological Survey, the Cushman foraminifera collection, the LaCoe collection of Carboniferous flora, and the first major collection of Burgess Shale fossils. Given our diverse holdings, NMNH Paleo has been a major resource for paleontological research worldwide. Over the decades, the way research is conducted has changed significantly with new scientific discoveries and technological advances. For example, ecological studies may include datasets of several taxa from multiple institutions downloaded from an online data aggregator and 3D imaging has shed new light on morphological analyses. In order to keep up with the paleontological research community, museums have also needed to shift operational strategies and change how specimens and their data are managed. NMNH Paleo is actively striving to make our collections more accessible and discoverable to researchers. In the last decade we have revised data workflows and guidelines to better standardize our data in our collections management system and mobilize it through data aggregators. We regularly generate and manage 3D imaging data and promote open-access use of our data and digital media. The changes we've been making are not limited to data management and extend to the physical care of our collections as well. NMNH Paleo is undergoing the first major reorganization of the fossil collections in over 50 years to increase the physical accessibility of our specimens and better align with current taxonomic and stratigraphic knowledge. Though NMNH Paleo has seen much growth we are not without our setbacks. A constant decline of collections staff in the last decade has inhibited our ability to engage with the research community. As research needs grow and change, we aim to improve the discoverability of our data and physical specimens in order to continue to facilitate access to the collections for researchers in new ways. With this presentation, we hope to invite new engagement with our fellow collections and research communities in this endeavor to cultivate the Smithsonian fossil collections as a major resource in paleontology.

## LEAF EPIDERMAL CELLS RECORD THE CANOPY RESPONSE TO CHANGING CLIMATE DURING THE LATE PALEOCENE TO EARLY EOCENE IN THE BIGHORN BASIN, WY

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Canopy structure—the openness of a canopy—is a critical component of ecosystems. Changes in canopy structure play a role in ecological interactions (e.g., productivity, landscape stability, the composition of faunal communities, and mammal evolution) and can influence the Earth's climate (e.g., albedo, hydrological and carbon cycling). Despite being a vital component of terrestrial ecosystems, deficiencies in existing proxy methods have necessitated higher-resolution analyses of canopy structure throughout deep time. Here, we study the relationship between canopy structure and climate change during the late Paleocene-early Eocene (~59–53 Ma) in the Bighorn Basin, Wyoming. This interval may provide good analogs for future climate change as Earth transitioned from a 'warmhouse' to a 'hothouse' punctuated by several hyperthermals with elevated atmospheric $CO_2$ levels. We used a new canopy structure proxy based on leaf epidermal cell morphology to reconstruct leaf area index, a measure of canopy density (LAI; foliage area ($m^2$)/area of ground ($m^2$)). Our preliminary results find an ~51% decrease in LAI from the late Paleocene to the Paleocene-Eocene Thermal Maximum (PETM) hyperthermal (Paleocene, 2.47 $m^2/m^2$; PETM, 1.20 $m^2/m^2$) and an increase in LAI to 3.92 $m^2/m^2$ within the PETM recovery interval. LAI subsequently decreases during the Early Eocene Climatic Optimum (EECO, 1.70 $m^2/m^2$). A decrease in LAI during the PETM and EECO is coincident with evidence for increased mean annual temperature and increased water stress within the BHB. Importantly, our results provide a new lens to evaluate the changes in flora and fauna and may provide insight into current and future ecosystem change. Future work will focus on reconstructing LAI in the Bighorn Basin during ETM2 and the early Eocene cool period to provide a more complete analysis of the impact of climate change on forest canopy structure.

## VARIATIONS IN DENSITY DEPENDENT PROCESSES IN EARLY EDIACARAN COMMUNITIES

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The Ediacaran strata of Newfoundland, Canada (580–560 Ma) record some of the first animal communities. The in situ preservation of these sessile organisms means that the positions and sizes of specimens on the bedding planes encapsulates their life-histories, enabling spatial analyses to reconstruct their ecological dynamics. However, it is not known how the ecological dynamics of individual outcrops vary across large spatial scales. Fortunately, the E and G surfaces at Mistaken Point, Newfoundland (~565 Ma) outcrop at multiple locations, providing the opportunity to compare ecological dynamics between communities separated by large spatial scales (~800 m) between outcrops. In this study, we collected data from two outcrops each of E and G surfaces using a combination of laser-line probe, LiDAR and photogrammetry. We mapped out the G surface Queens (hereafter Gully G) over 7.78 $m^2$, finding 9 frondose taxa within 158 specimens, G surface Watern Cove East (hereafter Slopey G) across 154 $m^2$, finding 19 frondose taxa within 1320 specimens and E Surface Watern Cove West (hereafter Watern Cove) across 15.45 $m^2$, finding 11 frondose taxa across 734 specimens. We compared the Watern Cove E surface with previously collected data from E surface Yale (hereafter E surface), which had 2977 specimens over 85.42 $m^2$. The two G outcrops exhibited remarkably similar community compositions, both dominated by *Bradgatia* with high proportions of frondose rangeomorphs and arboreomorphs. In contrast, the proportions between the E surfaces were notably different, with Watern Cove showing higher proportions of *Fractofusus* and *Bradgatia* and lower proportions of frondose taxa. Only *Bradgatia* (G) and *Fractofusus* (E) populations occurred in sufficient numbers to enable spatial pattern comparisons. We quantified the spatial distributions using spatial point process analyses, finding for E surface the Fractofusus populations showed significantly similar spatial patterns, which indicated reproductive events. In contrast, on G surface, the *Bradgatia* populations show remarkably different underlying processes, with the Slopey G population showing reproductive clusters on a background environmental heterogeneity whereas the Gully G population shows spatial segregation so indicates intra-specific competition. The Slopey G *Bradgatia* have a much lower density than those on Gully G, suggesting that the increased density leads to competition due to insufficient resources to maintain this higher density. In modern benthic communities, increased population densities can occur within communities, when different areas are subject to different flow regimes, so increased nutrient flux. These results suggest that the Ediacaran communities of Mistaken Point show ecological variability over spatial scales, but the impact of this variability depends on the life-history traits, such as reproductive mode.

## STRATIGRAPHIC CONTROLS ON THE LATE SERPUKHOVIAN (MISSISSIPPIAN, CARBONIFEROUS) MASS EXTINCTION EVENT

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Clusters of fossil last occurrences are used to delineate extinction horizons. These clusters, however, are controlled by the structure of the stratigraphic record, such that clusters are typically found below stratigraphic horizons that mark major changes in facies (relative water depth), such as flooding surfaces and subaerial unconformities. As such, the structure of the stratigraphic record could potentially influence how extinction events are interpreted from field observations. The late Serpukhovian (late Mississippian) mass extinction event is the seventh largest of the Phanerozoic with 26–28% genera extinction. This extinction event occurred during the onset of the Late Paleozoic Ice Age during a time of high-frequency and high-amplitude glacioeustasy. Field-based studies from the North America craton, demonstrate that uppermost Serpukhovian marine invertebrates track their preferred habitats, with overall richness patterns remaining stable across the Serpukhovian-Bashkirian boundary (uppermost Mississippian–lowermost Pennsylvanian). These studies reveal evidence against an extinction event during the upper Serpukhovian, with observed taxonomic turnover principally attributed to extirpation and facies preservation, but not true extinction. Here we provide further insight into the late Serpukhovian extinction event by documenting brachiopod assemblages across the mid-Carboniferous global boundary stratotype section and point (GSSP) at Arrow Canyon in southern Nevada. A combination of facies analysis and multivariate quantitative methods from field observations and previously collected, unpublished material was used to document taxonomic composition between the upper Serpukhovian Indian Springs Formation and the uppermost Serpukhovian to lowermost Bashkirian section of the Bird Spring Formation. Results show an overall increase in genera richness throughout the uppermost Serpukhovian and across the boundary into the lowermost Bashkirian where richness peaks. Additionally, 19% of Serpukhovian genera are not present in the Bashkirian of Arrow Canyon. However, global stratigraphic ranges reveal that all but two Serpukhovian genera persisted into the Bashkirian, with some genera even occurring higher in the unstudied section at Arrow Canyon. Multivariate analysis reveals similar taxonomic composition between Serpukhovian and Bashkirian assemblages, with a notable gradient driven by differences in lithology and water depth. These results further suggest a lack of a late Serpukhovian extinction event in North America and highlight how working with the structure of the stratigraphic record can untangle biological signals from stratigraphic patterns.

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## ITERATIVE ORIGINS OF EURYPTERID GIGANTISM WERE DECOUPLED FROM ECOLOGICAL AND ENVIRONMENTAL FACTORS

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Eurypterids are a diverse clade of extinct chelicerates that inhabited freshwater and marine environments in the Paleozoic. One of their most striking features is their gigantism: body sizes in excess of 1 meter evolved multiple times independently, producing some of the largest arthropods known. While several explanations have been proposed for the evolution of giant sizes, including predator-prey interactions, changing oxygen and temperature levels, habitat and osmoregulation, these hypotheses have yet to be tested using model-based approaches. We compile phylogenetic and comparative data sets encompassing 138 eurypterid taxa, and explore the drivers of eurypterid gigantism using a suite of phylogenetic comparative methods. By inferring a novel tip-dated phylogenetic framework for the clade, we shed light on the evolution of body size and the history of habitat transitions. At the same time, we find no evidence that the evolution of gigantism was driven by either temperature or oxygen levels, nor that it was coupled with the invasion of land. While these factors might have played a role within smaller clades, they were not universal determinants. It is likely that intrinsic factors played a larger role in determining the iterative origins of eurypterid gigantism than previously recognized.

## REVIEW AND UPDATE OF THE FOSSIL HISTORY OF BILLFISHES (ISTIOPHORIFORMES, XIPHIOIDEI)

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The billfishes of the suborder Xiphioidei (Istiophoriformes) are instantly recognizable acanthomorph teleosts, bearing fused premaxillae forming an elongate non-protrusible rostrum (i.e., the "bill"), small rasp-like teeth, and long fusiform bodies. Extant billfishes are split into two families, Istiophoridae (the marlins, sailfishes, and spearfishes) and Xiphiidae (the swordfish), and range from the middle Miocene to the present. The late Paleocene family Hemingwayidae is the earliest taxon recognized as belonging to Xiphioidei; there are two other families of billfishes, Palaeorhynchidae and Blochidae, that range in age from the early Eocene to early Miocene but are of unclear relationship to the Xiphioidei. Fierstine's 2006 publication on the fossil history of Xiphioidei has been instrumental to billfish paleontology in part because of its review of the group's taxonomy. Recent and ongoing research has contributed significant new systematic and biogeographic knowledge about the group by adding observations from fossil assemblages in Asia, Oceania, and South America. In this presentation we will examine recent advancements in the field, provide an overview of billfish fossils and fossil site locations, and further review the literature of the fossil record of xiphiioid fishes.

## BISEXUAL CLIMBERS OF ARACEAE IN DEEP TIME: A REEXAMINATION OF *ARTHMIOCARPUS HESPERUS* FROM THE LATE CRETACEOUS OF SOUTH DAKOTA

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The study and re-evaluation of Cretaceous fossil plants offers insights to the early evolution of angiosperms prior to the establishment of modern ecosystems. Araceae display significant eco-morphological diversity (e.g., geophytes, climbers, epiphytes, helophytes, and free-floating aquatics), with their fossil record dating back to the Early Cretaceous (110 to 120 Ma). However, confidently assigned aroid fossils before the Cretaceous-Paleogene (K-Pg) mass extinction are limited to early divergent lineages (Orontioideae and Lemnoideae), hindering our understanding of the historical evolution of aroid subfamilies over deep time. This study focuses on *Arthmiocarpus hesperus* (Wieland) Delevoryas, a permineralized fossil from the Late Cretaceous Fox Hills Sandstone of South Dakota. Previously classified as a drupe from the fig family (Moraceae), it exhibits features consistent with Araceae. Through thin-sectioning and X-ray micro-computed tomography (μCT), we conducted a detailed examination resulting in 3D reconstructions of the seed and characterizing structures in multiple planes of section. Furthermore, we created a de novo character database by analyzing 300 species of fruits with μCT for fruit, seed and embryo morphology. This process resolved conflicting interpretations of fruit-seed morphology and anatomy, allowing us to identify additional characters useful for refining taxonomic affinities.The helically arranged sessile berries on a central spadix confirm affinities to Araceae, and features of the fruits and seeds such as berries with fibrous pericarp and stylar region, thick stylar region, a smooth seed coat, and a monocotyledonous L-shaped embryo suggest

it is most closely related to members within the subfamily Monsteroideae. However, *Arthmiocarpus* presents a unique set of characters that differentiates it from extant and extinct members of Araceae. This investigation exemplifies how the subfamilies of extant angiosperms were integral components of Cretaceous ecosystems prior to the K-Pg mass extinction, contributing to the establishment of modern ecosystems.

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## PALEONTOLOGICAL COLLECTIONS AT THE NORTH CAROLINA MUSEUM OF NATURAL SCIENCES: IMPROVEMENT AND EXPANSION OVER THE LAST DECADE

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The paleontological collections of the North Carolina Museum of Natural Sciences (Raleigh) house moderately-sized, yet rapidly growing and scientifically significant, collections of plant, invertebrate, and vertebrate fossils. At present, the collections hold over 170,000 cataloged specimens with vertebrate fossils representing 61% of the total collection, invertebrate fossils representing 35.5%, and plants representing 3.5%. Of particular note are North Carolina specimens of Ediacaran invertebrates, Mesozoic and Cenozoic molluscs and echinoderms, Triassic and Cretaceous vertebrates and plants, and Miocene-Pliocene marine vertebrates. Here we present an overview of the state of the collection including its geographic, geochronologic, and taxonomic breadth; current and recent areas of collection growth; improvements to curatorial and data standards; and conservation of at-risk specimens. Major improvements to the collections were aided by a National Science Foundation Collections in Support of Biological Research (NSF CSBR) grant awarded in 2016. This grant provided the means to inventory and rehouse the entire collection from deteriorating wooden cabinetry to museum-grade steel cabinets and implement strict use of archival materials for storage of cataloged specimens. Furthermore, all specimen data were audited for consistency and migrated from the antiquated Microsoft Access database to Specify. More recently, the museum has received several notable donations, including absorbing the sizable historical paleontological collection of the University of North Carolina—Chapel Hill. Efforts are underway to increase the useability and visibility of the collections (e.g., through retroactive geolocation and specimen imaging) in tandem with rebounding post-pandemic visitation of external researchers, though obstacles such as coarse historical data remain.

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## WILDCAT SKELETONS FROM NATURAL BRIDGE CAVERNS OFFER INSIGHTS INTO THE DIVERSITY OF SMALL FELINES IN THE LATE QUATERNARY OF TEXAS

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Small cats (Felinae) are poorly represented in the fossil record and the resulting gaps in knowledge obscure the evolution of extant forms and changes in diversity across time. Historical data indicate that felines were more widespread and abundant in North America at the start of the 20th century and have since experienced range contractions and extirpation. We know the causes of those changes, primarily anthropogenic habitat loss and extermination campaigns. Yet, we lack the fossil data necessary for interpreting those recent changes in a broader natural history context. Bobcat (*Lynx rufus*), jaguarundi (*Puma yagouaroundi*), and margay (*Leopardus wiedii*) were documented in Texas in the early 20th century. The historic presence of jaguarundi is poorly understood and the occurrence of margay is questionable. Surprisingly, fossils and trace fossils preserved in Natural Bridge Caverns (NBC), a show cave on the Edwards Plateau of Texas, may hold the clearest evidence yet of the late Quaternary diversity of small felines. A partial skeleton of a small feline collected in 1963 from The Dungeon, a pit room deep within the cave, was subsequently interpreted as a margay. That skeleton was the basis for reinterpreting *Felis amnicola*, a purported extinct species from the late Pleistocene, as an extinct form of margay (*L. wiedii amnicola* or *L. amnicola*). If correct, the skeleton from The Dungeon would be the most complete example of *L. amnicola* or fossil *L. wiedii*. Yet, the same skeleton has been interpreted as bobcat and jaguarundi and there is no evidence of the geologic age of the skeleton. Recent exploration in NBC led to the discovery and sampling of more of the skeleton from The Dungeon, the skeleton of a second individual from a neighboring pit room (Inferno Room), and ancient small feline tracks in clay lining the passage between the two chambers. I am testing hypotheses about the taxonomic identity of the skeletons using morphological traits purported to be diagnostic in combination with sequence data from aDNA. If successful, those analyses should be capable of addressing broader questions about the correspondence between morphology and species boundaries. Extracts obtained from bone freshly collected from The Dungeon appear to contain endogenous aDNA, but analysis was so far hampered by low abundance and the presence of contamination. Efforts to recover endogenous aDNA from the skeleton from Inferno Room failed. That biomolecular preservation is mirrored in results from radiocarbon analyses. Elements from Inferno

Room lacked collagen and failed to produce an age, while one sample from The Dungeon contained sufficient collagen and produced a late Pleistocene age of between 12,470 and 10,780 cal. yrs BP (95.4% probability). Those data document the age of the small felines of NBC for the first time. Molecular and morphological analyses are ongoing.

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## THE MIDDLE-LATE MIOCENE SIWALIK MAMMAL RECORD AND DYNAMIC PALEOCOMMUNITIES OF THE POTWAR PLATEAU, PAKISTAN

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Long fossiliferous sequences offer opportunity to evaluate the relative roles of abiotic and biotic processes on faunal evolution. Situated in the northwest corner of the Indian subcontinent, the Potwar Plateau region of Pakistan is the western edge of the Siwalik Hills, a belt of sedimentary rocks that extends more than 2000 km along the southern border of the Himalayas. In the Potwar, the nearly continuous Early Miocene to Pleistocene fluvial sediment record has been a focus of research for 50 years by members of the Harvard-Geological Survey of Pakistan project. Here we present an overview of the Middle and Late Miocene Siwalik vertebrate fauna between 14 and 7 Ma and highlight features of mammalian paleocommunity structure and change during this seven million-year interval. The physical setting for the fauna is an expansive alluvial plain with perennial and seasonal rivers and streams, and floodplain surfaces supporting abundant vegetation. The predominantly forest and woodland habitats of the Middle Miocene become primarily open woodland and grassland habitats in the very Late Miocene. With excellent chronostratigraphic control of most fossil localities we create a series of paleocommunities with 100 ky resolution, recognizing that these are more analogous to regional faunas (metacommunities) than to neo-communities, and that some species may never have overlapped temporally even if recorded in the same 100 ky interval. Excluding carnivorans and bats, the mammalian fauna is species rich with over 80 species present in the late Middle Miocene. Faunal change is variable within and asynchronous between small- (< 1 kg), large- (1–800 kg) and mega- (>800 kg) mammal guilds. Small mammals decline in species richness over time while large mammals fluctuate. Megaherbivore rhinocerotids and proboscideans have very high species richness in the Middle to Late Miocene, with up to nine species documented in a single fossil locality, and up to 18 species in a 100 ky paleocommunity. At the family level, species richness and relative specimen abundance do not always mirror one another. To examine the tempo and mode of species first occurrences in the Potwar, we categorize newly occurring species as either immigrants (usually the first occurrence of a genus or family) or endemic originations (first occurrence of new species within genera already documented in the metacommunity). Incumbent species and genera show some selective advantage over immigrant species. Most species documented in only one 100 ky paleocommunity are immigrants; however, some immigrants, such as equids, become very successful as assessed by both relative abundance and ubiquity on the landscape. Future work will extend comparisons to other terrestrial Miocene fossil sequences to address questions of paleobiodiversity and biogeography on continental scales.

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## IDENTIFYING A SPRUCE REFUGIUM IN ALASKA, U.S.A. USING MONTE CARLO STATISTICAL METHODS

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When a population is threatened by adverse environmental conditions, refugia can provide a means for maintaining local biodiversity. Consequently, refugia are of interest both to paleontologists, who study refugia to understand species survivorship during mass extinctions, and conservation biologists, who study refugia to guide policymakers in establishing nature reserves. Refugia are classically defined as localities that shelter a species from extinction during ecological crises; however, some previous work has argued that post-crisis re-expansion should be a defining characteristic of refugia, distinguishing them from refugial traps or relict populations. This study aims to expand on this definition by creating a computational model that identifies cases of re-expansion and calculates the probability of re-expansion occurring as a non-random event. To test the effectiveness of this computational model, the geographic range of spruce was reconstructed over the past 20 kyr using pollen preserved in lake cores from northern Alaska, U.S.A. Lake core data were

procured from the online Neotoma database and organized into 500-year time bins. To identify possible refugia, two curves were generated for the dataset: the first curve was the number of localities with available data for a given time bin, and the second curve was the number of localities with spruce present for said time bin. The curves were visually inspected, and if spruce declined then rebounded substantially relative to the available data, a Monte Carlo simulation was performed. The simulation generated a random number representing the prevalence of spruce, between zero and the number of localities for which data were available, and calculated the probability of simulated curves matching the parameters of the observed decline and rebound over 100,000 iterations. Finally, an animated heat map visualizing changes in plant distributions over the past 20 ka was generated to identify which localities were likely to have been refugia. Spruce mirrored the availability of the data until approximately 14.0–13.0 ka, when it declined from 11 localities to five. Spruce persisted in 3–5 localities until approximately 9.5–9.0 ka, when it increased back to 11 localities and resumed mirroring the data availability. A Monte Carlo simulation found that the observed pattern (i.e., declining from 11 localities to five, persisting in five localities or less for 3.5 kyr, then re-expanding to 11 localities) was significantly different from a randomly generated pattern ($n = 100{,}000$, $\alpha = 0.05$, $p = 0.003$). On the heat map, one locality, which remained populated throughout the decline, apparently served as a centre for re-expansion following the Pleistocene-Holocene transition, indicating that it was likely a refugium. Using these methods to identify refugia, followed by independent paleoenvironmental analysis, will allow for a more nuanced understanding of species survivorship during ecological crises.

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## A LIVE-DEAD STUDY OF TAXONOMIC AND FUNCTIONAL DIVERSITY IN GREAT BASIN SMALL MAMMALS

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To fully comprehend the full extent of effect that modern climate change has had on terrestrial ecosystems today, it is essential to understand whether they have shifted away from baseline states in the recent past. Comparisons between living, modern dead, and Holocene fossil assemblages can tell us this; however, live-dead studies in terrestrial systems are underutilized. In the western Great Basin of North America, there are a number of archaeological deposits within caves that contain vast faunal archives. Small mammal remains from these deposits are tools for paleoenvironmental and paleoecological reconstruction, but our understanding of the fidelity between living and dead small mammal communities found within and around these deposits is minimal. Depositionally, these caves are more complex than raptor roosts or woodrat middens alone, as skeletal material has entered these records through multiple taphonomic pathways, including via human activity. Here I present a live-dead taphonomic study of small mammals from an archaeological context in which I quantify the taxonomic and functional diversity of living populations, modern death assemblages, and late Holocene fossil assemblages at two Great Basin sites, the Paisley and Connley Caves in south central Oregon. The caves in question hold the record of the first people to arrive to the landscape ~16,000 years ago. Their archaeological and megafaunal records have been well documented, but the less charismatic small mammals have not been given the attention they deserve, despite the fact that they make for excellent ecological indicators (due to their limited home ranges, short generations, and tight habitat associations). Thus far, I have found that modern death assemblages (swept from cave floors in 2023) are similar in species richness to snapshot trapping surveys also from 2023. Late Holocene deposits, however, are more species rich. As such, Jaccard similarity declines from ~0.63 between modern live to modern dead comparisons to ~0.47 between modern live to late Holocene comparisons and ~0.50 between modern dead to late Holocene comparisons. In comparing the timeframes, ~83% of trapped species were also found in the modern death assemblage, while ~75% of trapped species were found in the late Holocene deposits. However, only ~56% of species present in the late Holocene are still present today. Future work will include quantifying the functional ecological impact of the taxonomic changes through time, and the degree to which these changes may have been caused by climatic factors, taphonomic factors, and/or possible human activities.

## A MULTIPROXY APPROACH TO CHARACTERIZING THE ECOLOGY OF THE EARLIEST KNOWN CROWN PRIMATE FROM THE BIGHORN BASIN, WY

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A suite of morphological traits characterizing crown primates has been interpreted through a variety of adaptive 'primate origins hypotheses' (POH) for the Order based primarily on observations of the morphology and behavior of living primates. Focus among POH is given to dietary habits, locomotor strategies, and the visual system. A heavily forested environment during the emergence of these traits is universally assumed, since most extant primates are arboreal and inhabit tropical, densely canopied biomes. Specimens of *Teilhardina brandti* represent the oldest fossil material confidently assigned to crown Primates and provide a direct means to test POH and associated models of primate trait evolution. Recent collecting from strata associated with the Paleocene-Eocene Thermal Maximum (PETM) in the Bighorn Basin, WY (~56 Ma), has produced >400 dental and postcranial specimens of *T. brandti*, previously known from only a few dozen specimens. The PETM was a rapid global climate event with warming of ~5 °C associated with increased aridification and intensified rainfall before a return to cooler, wetter conditions. Collaboration among paleontologists, stable isotope geochemists, and sedimentary geologists has produced a well-resolved stratigraphy that permits a detailed characterization of the environment that *T. brandti* inhabited during the PETM. Quantifying the molar occlusal surface in *T. brandti* via dental topographic analysis indicates similarity with extant primate omnivores with diverse dietary repertoires but precludes specialization for efficiently consuming insects. The pes of *T. brandti* is long, primarily through elongation of the elements distal to the crurotarsal joint such as the cuboid and metatarsals, and capable of producing powerful leaping through increased overall acceleration distance. The PETM paleoflora has a lower average leaf area index and distinctive morphotypes compared to adjacent intervals, similar to those of modern dry tropical forests. Stable carbon isotopes from mammalian tooth enamel show no evidence for a closed canopy understory marked by negative outliers, indicating an open or frequently gapped canopy structure. While the dental and postcranial morphology of *T. brandti* thus conforms to the expectations of some POH, these traits are not associated with the arboreal niche thought to drive their adaptive significance. The ecology of *T. brandti* fits better with that of modern dwarf lemurs or galagos—primates that can occasionally be found in dry tropical forests and open, savannah-like habitats and are recognized among living primates as being unusually ecologically flexible. While dwarf lemur and galago edge populations that persist in challenging environments are not the inspiration for POH, they represent strong model organisms for *T. brandti*, which must have survived varying biomes while migrating across high latitude land bridges and during the climatological shifts of the PETM.

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## BETTER NOW THAN NEVER: CATALOGUING A COLLECTION AFTER 188 YEARS

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The Paleontology Collection at the New York State Museum was established in 1836. Our collections house an estimated 750,000 specimens including all fossil faunal and floral elements except for the Pleistocene vertebrates. Type specimens and those that have been designated as appropriate for exhibit (E specimens) each have a unique number that is recorded in the Museum-wide database. Most of the rest of the collection is catalogued using the locality-register system and the specimens are stored in either the Paleontology Stratigraphic Collection, which contains a mix of taxa, or in stratigraphically arranged collections for each taxonomic group. These stratigraphically stored specimens were historically deemed less important than the type and E collections, and the physical condition of the specimens themselves and their housing and associated labels has suffered over time. For example, at some time in the past, the collection was stored in a building with a coal-fired furnace, which led to coal dust marring some labels beyond legibility. The move of the collection to its current building also caused confusion. For example, frequently a single specimen from a different locality will have "jumped" from one tray to another. In other cases, labels appear to be in the wrong tray or drawer. Due to the current condition of the stratigraphically stored specimens, we have decided to undertake not only its cataloging, but also its rehousing in archival materials, including trays with higher sides to prevent the "jumping" problem in any future moves. The goal of this project is three-fold. First it is imperative to halt the deterioration of collection, which is being accomplished by rehousing the specimens and labels. Secondly, all data associated with the specimens is being recorded digitally in a searchable format. Lastly, we will make the information accessible to researchers, artists, educators, and the general public, except for specific locality data that will be released on an individual basis. During this poster session, the author will be available to discuss cataloguing and rehousing and will have the digital catalogue so far to answer questions about specific holdings.

## A NEW RADIODONT WITH A SPECIALIZED POSTERIOR TAGMA FROM THE BURGESS SHALE EXEMPLIFIES EARLY PLASTICITY IN ARTHROPOD SEGMENTATION

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Much of the diversity in euarthropod form is the result of differences in the number and differentiation of segments. By contrast, their closest extant relatives, onychophorans and tardigrades, have highly conserved patterns of segment differentiation and less variation in segment count. Fossil evidence to date has suggested that the earliest-diverging arthropods, the radiodonts, exhibited a more limited range of segmentation patterns, more similar to the situations in onychophorans and tardigrades than in euarthropods. Known mature radiodonts had segment numbers restricted between 14 and 22 and a conserved body plan characterized by an anteriormost feeding appendage pair, a series of trunk segments with lateral flaps and gills serving roles in locomotion and respiration, and, typically, one to three pairs of posterior blade-like appendages aiding with maneuvering. We present a new radiodont arthropod from the Cambrian (Wuliuan) Burgess Shale that considerably expands known diversity in radiodont segmentation. The new species exhibits a maximum of 28 or 29 segments, the highest number reported for any radiodont. The head is about one sixth the total body length and is likely composed of two segments. The first segment supports the lateral eyes, unpaired median eye, and elliptical ocular sclerite. The second segment gives rise to the frontal appendages, which are characterized by a row of 6 slender, curving endites with bifid tips. The remaining segments, in the trunk region, bear lateral flaps and bands of gill lamellae, but are differentiated into two main batches, or tagmata. The anterior trunk is composed of 10 segments. Flap size is small anteriorly, but increases to one third of total body width by segment 6, decreasing slightly thereafter. These flaps are inferred to have been the primary locomotory organs. The posterior trunk consists of 16 or 17 segments that are sharply differentiated from those of the anterior trunk tagma. These segments exhibit extreme size reduction and bear tightly spaced gills. The reduced flaps were presumably too small to have played a significant role in swimming. Instead, we infer a specialization of the posterior trunk for respiration. Such posterior regionalization is unique among radiodonts, but comparable examples exist in euarthropod groups such as the chelicerate opisthosoma, malacostracan pleon, and insect abdomen. This finding demonstrates that radiodont segment number and differentiation were more plastic than previously appreciated. Taken together with the segmental variation exhibited by diverse Cambrian euarthropods, this suggests that an increase in plasticity was associated with the origin of the arthropod clade. In the case of the new species, this enabled evolution of functional specialization of posterior segments which was later repeatedly converged on by other groups of arthropods.

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## ADVANCING HIGH-RESOLUTION TRAIT EXTRACTION IN THREE-DIMENSIONAL BIOLOGICAL IMAGES THROUGH DEEP LEARNING

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Three-dimensional imaging techniques, such as x-ray micro-computed tomography (micro-CT), have revolutionized the examination of internal and external structures in diverse biological specimens. Despite their unprecedented resolution and visualization capabilities, manual segmentation for feature extraction presents significant challenges, particularly with increasing trait complexity. Deep learning methods, notably convolutional neural networks (CNNs), offer a promising solution for automating image segmentation and enhancing our comprehension of biological systems. In this study, we employ CNNs to extract volumetric data from a comprehensive dataset of 1886 CT-scanned specimens of planktonic foraminifera, representing multiple species within the *Menardella* lineage. Through this analysis, we evaluate the efficacy of deep learning in enabling larger sample sizes and extracting more relevant traits across various taxa. Our results demonstrate that deep learning facilitates accurate and reproducible outcomes while enhancing scalability for generating precise volumetric and shape data for both internal and external structures. Consequently, we not only enable comparative analyses across numerous individuals but also expand the scope of inquiry to encompass fundamental biological, paleontological, and oceanographic processes. Specifically, we elucidate how trait function relates to broader evolutionary implications, exploring the translation of individual-level variation into evolutionary dynamics above the species level. By shedding light on these intricate relationships, our study underscores the utility of deep learning techniques for high-resolution trait extraction in three-dimensional biological imaging. In conclusion, this research not only advances methodological capabilities but also contributes to theoretical insights in evolutionary biology and paleontology.

## PREDATOR-PREY DYNAMICS OF DIRE WOLVES AND THEIR PREY IN THE CONTEXT OF CHANGING CLIMATE, LATE PLEISTOCENE-EARLY HOLOCENE, CUTLER HAMMOCK SITE, FLORIDA, U.S.A.

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The Cutler Hammock site, a sinkhole-fill deposit in Miami-Dade County, Florida, includes an assemblage of dire wolves (*Aenocyon dirus dirus*) and inferred prey taxa, many of which became extinct in the Quaternary Land Mammal Extinction Event. To test changes in both predator-prey and ecosystem dynamics, teeth of dire wolves and inferred herbivorous prey were sampled for $\delta^{13}C$ and $\delta^{18}O$. $\delta^{13}C$ was used to infer dietary preference, and $\delta^{18}O$ was used to infer paleotemperature and aridity. *Odocoileus virginianus*, *Mylohyus fossilis*, and *Platygonus compressus* consumed mainly $C_3$ vegetation; whereas *Bison*, *Equus ferus fraternus*, *Hemiauchenia macrocephala*, and *Mammuthus columbi* ingested mainly $C_4$ grasses. $\delta^{13}C$ values in dire wolf teeth suggest a change through time, and mixing models were used to infer the proportions of $C_3$ to $C_4$ herbivorous prey. In the lower and middle study intervals (Upper Pleistocene-Lower Holocene), dire wolves had a diverse diet of herbivorous prey, consuming mainly $C_3$ feeders. In the Early Holocene dire wolves shifted to a diet of mostly $C^4$ feeders. $\delta^{18}O$ values in herbivore teeth suggest that the Late Pleistocene was relatively warm and arid; the Late Pleistocene-Early Holocene was relatively cooler and humid; and later in the Early Holocene the climate was warm and arid. Remains and artifacts of *Homo sapiens* co-occur with dire wolves and their prey at Cutler Hammock. Based on previously published $^{14}C$ dates on charcoal from Cutler Hammock, we infer that dire wolves and some of their prey species survived until about 9,810 b2k (Early Holocene) in south Florida.

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## RECONSTRUCTING THE CLIMATE AND ECOLOGY OF AN EARLY MIOCENE TROPICAL FOREST ON THE FLANKS OF THE TINDERET VOLCANO, NYANZA PROVINCE, WESTERN KENYA

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Eastern African terrestrial ecosystems in the Early Miocene are characterized by habitat heterogeneity resulting from local rifting, climate variation, and biogeography. These dynamic landscapes profoundly influenced the evolutionary trajectories of hominoids and other mammals. In western Kenya, a collection of Early Miocene fossil-rich sites (ca. 20 Ma) proximate to the extinct Tinderet Volcano, offers a unique window into understanding habitat preferences and ecological drivers to the evolution of hominoids. Here, we present data from one of the sites, Koru 16, with evidence of remarkably preserved fossil fauna, fossil leaves, tree stump casts, and paleosols, to provide invaluable insights into the ancient ecological dynamics of the region. We use multiple proxies to reconstruct the paleoclimate and paleoecology of the Koru 16 site. The lithofacies of the Koru 16 area are characterized as interbedded ash and weakly developed paleosols indicating episodic landscape disturbance from eruptions of the volcano followed by intervals of stability. Paleosol features together with paleoclimate estimates using two models based on elemental weathering (RF-MAP and PPM) indicate warm and wet conditions. More than 1000 fossil leaves collected from two stratigraphic locations at Koru 16 yielded seventeen morphotypes which were identified across both localities and displaying different distributions of morphotypes between them. The average leaf size of morphotypes form both localities is mesophyll to megaphyll and mean annual precipitation estimates using multiple leaf physiognomic methods indicate >2000 mm/yr. Leaf lifespan estimates derived from the leaf mass per area (MA) proxy suggest that the site was predominantly characterized by evergreen taxa, with limited deciduous taxa. The distribution of MA is consistent with tropical rainforests and tropical seasonal forests in equatorial Africa, indicating similarities in leaf characteristics and ecological patterns. Tree stump casts corroborate this observation, as they indicate an open forest, with density similar to modern tropical forests that support large-bodied primates. The fauna includes a medium-sized pythonid, and at least two species of apes, along with other mammalian taxa typical for the early Miocene. Our comprehensive paleoclimate and paleoecological analyses suggest that the Koru 16 site was very warm and wet, which is a climate conducive for a tropical seasonal forest transitioning into a rainforest biome. This environmental reconstruction underscores the broad distribution of Early Miocene apes in a variety of habitats, and calls into question a recent hypothesis that apes only lived in environments with a significant open component.

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## HYDRODYNAMICS OF NON-UNIFORM, DISARTICULATED CRINOID GRAINS AND THEIR RELEVANCE TO THE MISSISSIPPIAN ROCK RECORD

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Crinoids, popularly named sea lilies, are marine animals belonging to the phylum Echinodermata. They are filter feeders living at the sea floor, today found at depths below 100 m. During their time of peak abundance in the Early Mississippian, stalked crinoids thrived in both shallow- and deep-water environments. The skeletal remains of crinoid stems represent some of the most abundant macrofossils in Middle to Late Paleozoic carbonate rocks. Due to the non-uniform shapes of disarticulated crinoid grains (ranging from rods to discoids), high intraskeletal porosity and relatively low density, their hydrodynamic behavior is poorly understood. This research aims to investigate the hydrodynamic behavior of crinoid grains. Physical experiments using modern crinoid specimens demonstrate how the organism dissociates into individual ossicles and pluricolumnals. From this, the grain-size distribution of a single organism is obtained. Additional experiments look into the hydrodynamic aspects of crinoid grains. Investigated parameters include settling velocity, entrainment threshold, and transport behavior as bedload and suspended load. The results from hydrodynamic behavior of crinoids in controlled experiments are upscaled to bed-scale and basin-scale flow-event processes. For the upscaling, two crinoid-rich formations are investigated to allow for a comprehensive analysis of the relationship between crinoid grain-to-flow interactions and deposits. This provides insight into the redistribution of crinoidal debris, thereby evaluating the large-scale architectures generated. The first study area comprises the Mississippian Fort Payne Formation, Tennessee, which was selected due to the abundance of crinoidal sediment deposited on a distally-steepened carbonate ramp with the presence of large-scale crinoidal bedforms. The second study area encompasses the Mississippian Lake Valley Formation in the Sacramento Mountains, New Mexico, characterized by the presence of crinoid-covered Waulsortian mounds blanketed by distal crinoid-rich carbonate submarine fan facies. These two locations will highlight the mechanisms of transport and deposition specific to crinoid skeletal debris, which is strongly influenced by their low density and broad distribution of grain shape and size. Outcomes of this research are expected to have profound implications on one of the most abundant macrofossils in the Paleozoic, and their role in the sedimentary record. Understanding the unique distribution of crinoid grain shapes and their behavior in (gravity) flows will lead to more accurate assessments of basin-fill history, hydrocarbon exploration, mineral exploitation, climate indicators, and the nature of these exceptional organisms.

## CONSERVATION PALEOBIOLOGY IN THE CARIBBEAN: HOW FOSSILS CAN HELP US SAVE THE REGION'S LAST SURVIVING MAMMALS

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The Caribbean experienced the largest postglacial losses of mammals globally during the Holocene, with a pronounced spike in extinctions following the arrival of European land use practices and commensal species. Investigations of the Late Quaternary fossil record have been crucial in accurately describing the evolutionary processes that unfolded in the archipelago and in documenting what components of ecosystems have been lost. Current taxonomic classifications place this overall extinction toll at upwards of 90 nonvolant mammal species. These extinctions unfolded in two waves: larger species such as sloths and monkeys disappeared following initial human settlement ~6,000 years ago, whereas smaller species, mostly rodents and eulipotyphlan 'insectivores,' disappeared after 1500 CE. These size-biased extinction events were linked to differences in intrinsic versus extrinsic risk and thus provide important parallels for categorizing the drivers of mammal endangerment today. How can paleontologists contribute to the development of evidence-based conservation practices for the few remaining extant Caribbean mammals? We will review the current Red List status of these surviving species as assessed by the International Union for the Conservation of Nature (IUCN)'s Small Mammal Specialist Group, encompassing the updated rankings of 12 formally assessed species across the orders Rodentia and Eulipotyphla and representing a range of both downlisted and uplisted taxa. We will discuss how paleontological datasets can be used to contextualize assessments of extinction risk (IUCN Red List) as well as population recovery (IUCN Green List). Because these species coexisted with and were often harvested by Indigenous peoples, it is imperative that the archaeological record is incorporated to holistically assess the anthropogenic conditions under which these species have persisted. We will showcase examples of how fossil records have contributed to discussions of Hispaniolan Solenodon (*Solenodon paradoxus*) and Bahamian Hutia (*Geocapromys ingrahami*) conservation and consider how coupled fossil and paleoenvironmental datasets can inform rewilding dialogues. While focused on the Caribbean, the approaches and perspectives shared here are broadly applicable to other island systems worldwide.

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## LATITUDINAL GRADIENT CONTROL ON EARLY PALEOZOIC BIODIVERSITY AND ECOSYSTEM FUNCTIONING

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Marine communities exhibit variation in species richness at global and provincial scales. The decline in diversity from equatorial to polar regions (latitudinal diversity gradient, LDG) is one of the most pervasive patterns in modern ecosystem. Although recognized for more than two centuries, the underlying mechanisms responsible for elevated low-latitude richness remain unclear. Deriving LDG patterns in deep time can help us understand how biodiversity is generated and maintained, as well as how species composition and biodiversity responded to major extinction events. Here we use fossil occurrences data documented in the Paleobiology, Geobiodiversity, and PhytoPal databases, to derive LDG patterns from the Cambrian to the Silurian among different geographic regions and trophic communities to elucidate ecological and environmental drivers of biogeographic changes over the early Paleozoic. To further explore the functional consequences of the changes in diversity and faunal composition along latitudinal gradient, we classified taxa into different ecological groups based on their functional traits. By dissecting diversity dynamics along ecological and latitudinal gradients, we aim to find key controls on variation in geographic distribution of biodiversity in early Paleozoic marine ecosystem. We used Scotese's modeled sea-surface temperature for long-term variation in climate during the early Paleozoic. By resolving data into 24 stage-level time slices and 5° palaeolatitudinal bands at genus level, we find that (1) the strength of LDG increased form the Cambrian to the Silurian, (2) the strength of LDG varied with trophic level, (3) the LDG of phytoplankton is decoupled from that of consumers, and (4) diversity peak shift slowly southward with a steady cooling trend occurred throughout the end of Ordovician.

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## REBUILDING PARTNERSHIPS FOR THE CARE OF FEDERAL PALEONTOLOGICAL RESOURCES AT THE SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY

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The Department of Paleobiology at the Smithsonian National Museum of Natural History (NMNH Paleo) is a longtime collaborator with federal partners in shared stewardship of paleontological resources. Notably, the federal status of the Smithsonian Institution can result in some differences in functionality from fellow repositories of these resources. However, we still face similar challenges in our shared work to preserve and enable enhanced access for research to these paleontological resources in alignment with federal regulations and documentation needs. Over the last decade, changes in staff, research needs, types of requests, and federal regulations have impacted how NMNH Paleo operates in this space. These shifts have emphasized a necessary evaluation of our procedures and capacity. This time of adjustment has also presented an opportunity to restructure and re-establish our partnerships with public land managers and researchers. In addition, we have seen an increased need to coordinate with our peers managing similar collections to establish shared practices where possible. This presentation will be a re-introduction to the national fossil collection at the Smithsonian and will outline the current status and ongoing work for improving physical and digital documentation, care, and accessibility of paleontological resources in the NMNH Paleo collections. We will share the efforts of NMNH Paleo to identify our internal priorities and protocols and how that work can guide our renewed engagement and collaboration with non-federal repositories, public land managers, and researchers working with federal paleontological resources. Our aim is to open doors and build shared understanding that will be mutually beneficial for NMNH Paleo and all stakeholders in this community.

## VERTEBRATE PALEONTOLOGY COLLECTIONS AT THE FLORIDA MUSEUM OF NATURAL HISTORY, UNIVERSITY OF FLORIDA

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In 1977 the Division of Vertebrate Paleontology (VP) at the Florida State Museum (by 1988 = Florida Museum of Natural History; FLMNH) housed a total of ~25,000 cataloged fossil specimens/lots. Since then, full-time staff salaried through the University of Florida (UF) in VP has included 2 faculty-curators, a collections manager, a preparator, and later the addition of a specialist focused on microvertebrate fossils. Current personnel also include 7 temporary staff, ~20 collection and lab volunteers, and ~200 volunteers per field season. In 1977 the collection footprint was ~5,000 square feet (not counting labs and offices). Presently, the VP collection footprint has doubled to ~10,000 square feet in two separate buildings with >554,000 specimens/lots cataloged. Hundreds of plaster jackets are unprepared and kept in another off-site

building, and many specimens are part of the Florida Fossil Hall on permanent exhibit. Since 1977, over 800 publications by internal and external researchers have used specimens from the collection, and 160 holo- and paratypes have been added. Major externally funded digitization efforts have contributed to increased numbers of cataloged specimens in our Specify database, and many 2D and 3D images and models are freely available. The FLMNH is designated by the Florida Legislature as the official state repository for vertebrate fossils and treated by UF as a separate unit on campus, with the FLMNH director having Dean-level status and VP curators as faculty with tenure in the FLMNH Department of Natural History. The faculty teach and have graduate status through affiliate departments at UF (e.g., Anthropology, Biology, and Geology) with 33 master's and 32 doctorate degrees awarded to VP graduate students since 1977. The annual operating state budget for VP is very limited and only covers basic curatorial and lab supplies. All other collections, lab, and field-related resources and salaries for temporary staff are funded through donations and external grants. FLMNH VP manages the Florida Fossil Permit Program which allows the public to collect vertebrate fossils found on state land, report their discoveries, and, if not requested, keep them for personal use. The FLMNH VP division has prospered from strong museum leadership that values research-driven collections growth, a genuine commitment to formal and informal science education, and always looking for new ways to broaden impact through novel outreach initiatives. Substantial growth of the VP collections comes from working with volunteers in the field and labs and significant donations from amateur fossil collectors. While FLMNH staff and resources have modestly increased over the decades, relationships, trust, and reliance on the amateur paleontology community, donors, and highly skilled volunteers has grown immensely. The VP collection has flourished thanks to the museum working with and being available to external researchers and the surrounding community.

## PRESERVATION POTENTIALS, SKELETAL ARCHITECTURES AND THE SEDIMENTARY RECORD OF NEARSHORE REGULAR ECHINOIDS

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In recent sediments and in the fossil record, echinoids are preserved along a taphonomic gradient ranging from whole skeletons with associated appendages, complete tests, articulated and single plates to highly fragmented remains. The degree of preservation along this gradient dictates their recognition and subsequent inclusion in studies concerning diversity, environmental reconstructions and conservation ecology among others. Although shallow water regular echinoid taxa are well known with respect to their morphology, environmental distributions and population ecologies, studies on their taphonomy are scarce. In general, regular echinoids are prone to disarticulation into separate plates after death, while near-shore environments with often rocky substrates in high energy settings are not conducive to skeletal preservation. In this study, the preservation potentials of three Mediterranean near-shore, regular echinoids from Sardinia from recent marine settings and Pleistocene fossil localities of similar sedimentary environments are compared. The differential effects of varying skeletal morphologies as well as a wide range of both biotic and abiotic taphonomic processes including predation, fragmentation and encrustation are taken into account. Methods include CT and REM analysis as well as fragmentation experiments. The results show important differences in test architecture especially along plate margins that can affect preservation. Fragmentation experiments shows specific breakage patterns along and across plate boundaries. Echinoid remnants from both recent and fossil environments show characteristic distributions with respect to plate and size distributions.

## ECOSYSTEM ENGINEERING THROUGH TIME: THE ROLE OF POST-PALEOZOIC DETRITIVORES IN PEATLANDS

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Decomposition rates observed in modern peat-accumulating wetlands, or peatlands, may be dependent on the depositional environment. In coastal peatlands during the Pennsylvanian, peat accumulated in siliciclastic settings; however, analogous peats in modern mangroves rarely form in such environments. Today, mangrove peat mostly accumulates in carbonate settings, which have low rates of sediment accumulation compared to siliciclastic settings. Moreover, the evolution of new detritivore groups in post-Paleozoic peatlands may further the divide in peat accumulation rates between siliciclastic and carbonate settings. Detritivores have played a pivotal role in ecosystem engineering within peatlands throughout geological history, significantly contributing to the decomposition of organic matter and nutrient cycling. In addition to numerous evolutionary changes within the composition of peatland ecosystems, the appearances of new detritivore groups

highlight the evolutionary dynamics of ecosystem engineering processes, which are in turn are reflected in the taphonomic characteristics of preserved peats. Increased detritivory observed in modern peats may explain smaller peat particles and lower percentages of leaf litter and other aerial plant organs, such as propagules, when compared to permineralized Paleozoic peats in coal-balls. In the absence of highly diversified detritivore groups, myriapods may have been key detritivores in terrestrial Paleozoic peatlands. Micro-arthropods, such as collembolans and oribatid mites, also contributed to peat decomposition by breaking down fine organic material and enhancing microbial activity; these groups are present in Carboniferous and modern peatlands. In post-Pennsylvanian peatlands, detritivores such as beetles, termites, and flies have emerged as key contributors to the rapid decomposition of peat. Similarly, in modern coastal swamps, termites, ocypodid and sesarmid crabs, and pulmonate snails are crucial in accelerating peat decomposition. These organisms play a significant role in breaking down organic matter through various mechanisms, such as burrowing into the substrate (crabs), tunneling and consuming wood (termites), and direct consumption of leaves and propagules (pulmonate snails and sesarmid crabs). While herbivory might have been uncommon in Paleozoic peatlands, it now plays a prominent role, potentially accelerating leaf litter decay once leaves fall to the substrate. However, inundated swales observed in modern peat-accumulating basin mangroves may restrict access of detritivores from litterfall, allowing for longer residence times for standing leaf litter and leaf mat formation in coastal environments.

## GLASS HOUSES: POTENTIAL COMMENSALISM BETWEEN A CRINOID AND HEXACTINELLID SPONGE FROM THE UPPER DEVONIAN OF PENNSYLVANIA

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Understanding interactions between organisms is vital for understanding the history of life, but these interactions are seldom documented by the fossil record. A Famennian (Late Devonian) crinoid preserved inside a hexactinellid sponge from the collections of the State Museum of Pennsylvania provides evidence of potential commensalism. The specimen was collected prior to 1882 by the Second Pennsylvania Geological Survey near Warren, Pennsylvania. The crinoid is preserved as an external mold, surrounded by an internal mold of the sponge's skeleton. The high quality of preservation of the crinoid and its stem curvature suggest that it lived anchored inside the sponge, rather than having been washed in. A latex mold of the crinoid impression provided a clearer view of the calyx, which aided in assigning the crinoid to Monobathrida; the sponge had previously been identified as *Dictyophyton* but likely belongs to genus *Calathospongia*. Another *Calathospongia* specimen described by Caster in the 1930s from a nearby locality contained a brittle star impression, bolstering the case that echinoderms and hexactinellids may have lived symbiotically during the Late Devonian. Modern mutualistic interactions between crustaceans and Venus' flower baskets (*Euplectella aspergillum*) can serve as helpful analogs in exploring the ecological implications of such symbiosis during the Late Devonian, a time of considerable global change in marine ecosystems.

## EVOLUTION OF DEVELOPMENT ON MICRO- AND MACROEVOLUTIONARY TIMESCALES IN MURINE RODENTS OF SOUTHWEST AUSTRALIA

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Development plays an integral role in the production of phenotypic variation made available to natural selection. Developmentally biased variation of, and covariation between, traits within a species may therefore constrain the direction of phenotypic evolution that the species can achieve, a phenomenon known as developmental constraint. However, the degree to which developmental bias influences evolution is still incompletely understood. Significant uncertainty lies in the timescales over which a given developmental bias persists: the rate at which the structure of developmentally controlled trait (co)variation itself evolves ultimately determines the duration of the evolutionary constraint. Here, I explore this issue by utilizing an abundant (sub)fossil record of murine rodents from cave deposits in west-central Western Australia and the Nullarbor Plain of southern Australia. The stratified cave deposits are used to determine patterns of developmental constraint on mandible morphology for a series of horizons through a time of profound post-Pleistocene climatic change. Using the tools of geometric morphometrics, comparisons can be made within and between species, among horizons, and across geographic locations. This sheds light on the lability of developmental bias, and the role of such bias as a constraint on micro- and macroevolutionary timescales. With appropriate taphonomic consideration, cave deposits may represent a rich and largely untapped resource for the study of the evolution of development in a variety of terrestrial clades.

## ATTACK OF THE CRABS: PREDATION TRACES INDICATING A SUCCESSFUL ATTACK

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Previous attempts to analyze crushing predation on shells in the fossil record have mostly been limited to repair scars (traces

of failed attacks), leaving successful attacks overlooked and mortality estimates incomplete. This approach assumes that most kills due to crushing result in the total fragmentation of the shell. Consequently, some researchers have attempted to identify fragments from predation as a means of capturing information on kills. However, some durophagous predator-prey systems may produce characteristic traces on shells (rather than just fragments) indicative of successful attacks. Using in-lab predation experiments, we assessed the predatory capabilities of red rock crabs (*Cancer productus*) preying upon a common prey-item, the littleneck clam (*Leukoma staminea*), and explored predation traces after successful attacks. Both species are common taxa in Pacific Northwest intertidal zones and have been found dating back to the Pleistocene. Red rock crabs (muscle bundle height ranging from 22.17–40.36 mm; average = 34.09 mm) and bivalves were collected from Bamfield Inlet, British Columbia, Canada, and the clams were separated into 4 size categories: 11–18 $cm^3$, 18–22 $cm^3$, 22–28 $cm^3$, and 28–38 $cm^3$. Experiments were performed in a circular sea table 125.7 cm in diameter and 68.6 cm deep under red light. In each trial, four bivalves (one from each size category to ensure a constant distribution of sizes between trials) were placed in a 2x2 grid and presented to one crab; the trial continued for 30 minutes or until the crab successfully killed a clam. There were 16 trials in which crabs attempted to take a clam. With one exception, all crabs were able to crush a clam successfully, regardless of clam size. Crab chelae size is related to the size of the crab and larger muscle bundles indicate greater strength. There was a statistically significant relationship between muscle bundle height and grappling time ($r^2 = 0.44$; $p = 0.005$) with a decrease in grappling time as the muscle bundles get larger. Many of the predation traces produced by red rock crabs during the experiments are a direct match to those found in the field, even though these are examples of successful predation. Therefore, these traces can potentially be found in the fossil record and attributed to predation rather than taphonomy. Identifying examples of successful predation in the fossil record would, along with repair scars, provide more complete evidence for a durophagous predator-prey system.

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## WHAT'S IN THE TRUNK: BIASED TRUNK SHAPE EVOLUTION IN TRILOBITES

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Trilobites are an iconic group of extinct arthropods represented in the fossil record by over 22,000 named species. The trilobite lineage existed for ~270 million years, during which the 'trilobed' body plan, from which the trilobites derive their name, remained largely consistent. The shape of the trilobite thorax and pygidium (the post-cephalic regions collectively called the trunk) are determined by the relative sizes of their component segments—which were added sequentially to the body over post-embryonic ontogeny. Of course, modifications within this plan were achieved, mostly through changes in segment patterning, e.g., relative segment size, number of segments, reallocation of segments to different regions. Trunk shape had much functional and ecological significance to trilobites as it would have directly influenced behaviours such as locomotion and enrolment, while having an important relationship with the hydrodynamic profile of the animal. Yet, trilobites show distinct biases in segment size patterning and allocation that could have produced long-term bias in body shape evolution. Owing to a lack of phylogenies at higher taxonomic scales, phylogenetic comparative studies of trait evolution in trilobites have been sparse, but here, we quantify and examine the evolution of trunk shape on a newly constructed comprehensive tip-dated phylogeny covering two orders and ~130 million years. We test for biases in morphospace occupation throughout the long evolutionary history of these groups and examine the influence of possible developmental biases resulting from the segmentation process. To do this, we took a geometric morphometric approach and collected landmark data for the trunk of 34 species on the phylogeny with sufficient articulated material to do so. We then constructed a phylomorphospace to examine biases in morphospace occupation over the phylogeny, and further analysed disparity through time and rates of evolution. Preliminary analysis indicates a shift in mean body shape from the Cambrian to post-Cambrian but without associated change in the amount of disparity or rate of evolution along branches.

Funding source: Paleontological Society Graduate Student research award

## VIRTUAL PALEOBIOLOGY: WALCOTT'S *BROOKSELLA ALTERNATA* AFFINITY RESOLVED THROUGH A COMBINATION OF CLASSIC AND MICRO-CT IMAGING TECHNIQUES

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First described as a medusoid jellyfish, the "star-shaped" *Brooksella alternata* from the Conasauga Formation Lagerstätten, Southeastern U.S.A., was variously reconsidered as algae, feeding traces, gas bubbles, and most recently

hexactinellid sponges. To resolve this enduring controversy of identification, we applied classical paleontological techniques supplemented with high precision microCT analysis to more fully determine the composition and fine internal structure of *Brooksella* and co-occurring siliceous concretions. Here, we present morphological, chemical, and structural data of *Brooksella* to evaluate its hexactinellid affinities, as well as whether it could be a trace fossil or pseudofossil. External and cross-sectional surfaces along with thin sections provided initial information about the composition and interior structure of *Brooksella*, including diagenetic alteration and the presence of interior voids and tubes. X-ray computed tomography (CT) and especially micro-CT imaging revealed the complex 3D internal features, particularly of those voids and tubes of both *Brooksella* and co-occurring siliceous concretions which were not visible using the classic approaches. These analyses revealed no evidence that *Brooksella* is a hexactinellid sponge or a trace fossil. Although internally *Brooksella* contains abundant voids and variously orientated tubes consistent with multiple burrowing or bioeroding organisms, these structures have no relation to *Brooksella*'s external lobe-like morphology. Furthermore, *Brooksella* has no pattern of growth comparable to the linear growth of early Paleozoic hexactinellids; rather, its growth is similar to syndepositional concretions. Lastly, *Brooksella*, except for its lobes and occasional central depression, is no different in microstructure to the silica concretions of the Conasauga Formation, strongly indicating it is a morphologically unusual endmember of the silica concretions of the formation. These findings highlight the importance of combining classic with new techniques to reveal affinities for enigmatic early to middle Cambrian fossils; using the full range of techniques is essential to address ambiguous material from that Period. This presentation is based on research presented in https://doi.org/10.7717/peerj.14796

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## PROBLEMS AND SOLUTIONS FOR USING CALCIUM ISOTOPE RATIOS OF TEETH AS A PROXY FOR DINOSAUR PALEOECOLOGY

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Accurate interpretations of animal paleoecology are incredibly important for understanding evolution. One approach to inferring vertebrate diet and ecology involves measuring stable isotope ratios of fossil tooth enamel. Dental proxies rely on the observation that isotope ratios of food and water ingested by an animal are preserved in the animal's enamel. While carbon and oxygen isotope ratios of tooth enamel are well understood and commonly used for paleoecological studies, calcium isotope ratios ($d^{44}Ca$) are a novel proxy to infer diet and niche partitioning; $d^{44}Ca$ has the potential to be an excellent proxy, especially for rare specimens, due to its resistance to diagenesis and small sample size (100 µg material) required for analysis. Here we report on our investigation of $d^{44}Ca$ systematics of Jurassic dinosaur teeth. One of the most interesting observations is that $d^{44}Ca$ of enamel can vary by up to ~0.4‰ within an individual tooth. Intra-tooth variation is rarely reported for Ca isotopes, despite being frequently utilized in C and O for studies of seasonal ecological differences in both mammals and dinosaurs. This variation calls into question the conclusions of previous work which has distinguished chemical niches between species by 0.1–0.9‰. If $d^{44}Ca$ can vary by 0.4‰ within a single tooth, then inferring dietary differences between species with $d^{44}Ca$ differences of less than <0.4‰ based on single $d^{44}Ca$ measurements is unreliable, at best. Instead, we recommend sampling Ca at multiple locations along the tooth growth axis, so that $d^{44}Ca$ analysis can encompass some of the variation found within individual teeth. Possible explanations of intra-tooth variations in $d^{44}Ca$ include seasonal changes in diet (e.g., plant type or plant part), seasonal changes in physiology, episodic ecophysiological stress, or sampling issues like dentine contamination. Even small contamination can drastically alter the $d^{44}Ca$ values, thus researchers should ensure that the weight percent Ca in their sampled material is between 30% and 40%, as Ca should be 39 wt% in bioapatite. Here we will present a new sampling/analytical protocol that will allow us to understand dietary differences between species. More precise data may also allow us to study seasonal changes in the ecological habits of individual animals similar to changes seen in other isotope systems. When combined with intra-tooth data from other isotopic systems such as carbon and oxygen, calcium isotope ratios of dinosaur tooth enamel have tremendous potential to expand our knowledge of Mesozoic paleoecology and paleoenvironments.

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## REVISITING THE FOSSIL HERBIVORE ENAMEL ISOTOPES FROM LAETOLI, TANZANIA: INSIGHTS INTO THE PALEOECOLOGY OF *AUSTRALOPITHECUS AFARENSIS*

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Mosaic environments, typically viewed as habitats comprised of forested to open grassland components, have been critical to the evolution of our lineage, providing early hominins access to variable open habitat resources and diverse landscapes to navigate. Characterizing these types of environments in the fossil record has been a challenge in identifying potential environmental and climatic drivers of hominin evolution. In this regard, the Plio-Pleistocene fossil site of Laetoli, Tanzania, is of particular interest as it has yielded specimens of *Australopithecus afarensis* fossils, variable sets of hominin footprint trails, and a diverse faunal assemblage. Although earlier paleoecological reconstructions converged on open savanna ecosystems, subsequent research has revealed more complex, heterogeneous ecosystems that included wooded microhabitats. These latter reconstructions have been used to argue both that *A. afarensis* was a eurytopic species and that Laetoli may have been a somewhat marginal habitat for *A. afarensis* relative to sites such as Hadar and Dikika where specimens of *A. afarensis* are notably more abundant within the faunal assemblages. Investigations into the fossil faunal communities at Laetoli have considered ungulate taxonomic diversity, mesowear, and stable isotopic analyses of herbivore enamel ($\delta^{13}C_{enamel}$) and found unusually high diversity and strong evidence for mixed feeding. A dominance of mixed feeding strategies within the fossil assemblages, unlike modern communities, has also been central to the argument that environments at Laetoli may not have modern analogs. In this study, we compare community patterns over time from fossil assemblages derived from the Upper Laetoli Beds (~3.8–3.7 Ma) and the Ndolanya Beds (~3.58 and 2.66 Ma) at Laetoli with an expanded modern ungulate enamel isotope dataset from across eastern Africa. We also apply recently developed analytical methods to previous fossil enamel collections from Laetoli, including the use of isotope data to characterize "niche space" and the application of multivariate analyses identifying underlying similarities between fossil assemblages and modern communities. Expanding on past studies, our results provide additional insights into the nature of shifting mosaic environments at Laetoli through time. Ultimately, our findings highlight the ways that environmental diversity and heterogeneity are compressed in enamel isotopic records, particularly in the "mixed-feeding" space, but also elucidate the importance of corroborative lines of evidence including phytolith and pollen data for interpreting enamel isotopic spectra and reconstruct landscapes that may be unlike any modern environments.

## PERSISTENT ECOLOGICAL DIVERSITY OF MARINE TAXA THROUGH THE HISTORY OF ANIMAL LIFE

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Why are some clades ecologically mundane and others diverse? The answer to this question is of major importance in understanding the causes and limits to evolutionary innovation, but requires an objective means to measure ecological diversity in the first place. Here, I use updated codings of ecological life habits for all known Phanerozoic marine animal genera, using a standardized ecospace framework to rank major animal taxa (phyla and classes) according to their ecological (functional) diversity. Ecological diversity is evaluated using two measures: ecological richness (the number of unique life habits) and disparity (mean Euclidean distance). Mollusks have remained the ecologically most diverse animal phylum since their origin, followed by echinoderms and arthropods. Cnidarians and chordates have intermediate ecological diversity, followed by brachiopods, with bryozoans and sponges ecologically least diverse. Classes within these phyla parallel these rankings, with gastropods, echinoids, bivalves, and trilobites the most diverse. Cephalopods, crinoids, and perhaps actinopterygian fishes are ecologically rich but with low disparity. Ostracods and perhaps marine mammals are more disparate than expected given their richness. These rankings are robust to sensitivity analyses, are generally unchanged since the origins of each taxon, and immutable to major extinction events. These patterns suggest limits to ecological innovation are largely set during the origins of major clades, implying deep phylogenetic constraints in evolutionary novelty.

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## EVOLUTION AND ENVIRONMENT OF CARIBBEAN COASTAL ECOSYSTEMS

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Isolation of the Caribbean Sea from the tropical Eastern Pacific by uplift of the Isthmus of Panama in the late Pliocene was associated with major, taxonomically-variable, shifts in Caribbean biotic composition and extinction, but inferred causes of these biological changes have remained elusive. We addressed this through falsifiable hypotheses about how independently determined historical changes in oceanographic conditions may have been responsible. The most striking environmental change was a sharp decline in upwelling intensity as measured from decreases in intra-annual fluctuations in temperature and consequently in planktonic productivity. We then hypothesized three general categories of biological response based upon observed differences in natural history between the oceans today. These include changes in feeding ecology, life histories, and habitats. As expected, suspension feeders and predators became rarer as upwelling declined.

However, predicted increases in benthic productivity by reef corals and benthic algae were drawn out over more than 1 Myr as seagrass and coral reef habitats proliferated; a shift that was itself driven by declining upwelling. Similar time lags occurred for predicted shifts in reproductive life history characteristics of bivalves, gastropods, and bryozoans. Examination of the spatial variability of biotic change helps to understand the time lags. Many older species characteristic of times before environmental conditions had changed tended to hang on in progressively smaller proportions of locations until they became extinct as expected from metapopulation theory and the concept of extinction debt. Faunal turnover may not occur until a million or more years after the environmental changes ultimately responsible.

## UNCOVERING THE PAST: UTILIZING INVERTEBRATE SUB-FOSSIL ASSEMBLAGES FROM BELIZEAN LAGOONAL REEFS TO DETERMINE DRIVERS AND TIMING FOR CARIBBEAN REEF ECOSYSTEM DECLINE

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The health of Caribbean coral reef ecosystems has rapidly declined in recent decades due to climate change and local human stressors. Although we have robust data sets following the onset of large-scale monitoring in the late 1970s, less is known about reef health before this time. Furthermore, the majority of this monitoring work has focused on organisms like corals, parrotfish, and echinoderms; much less is known about how changing environments are reflected in other important coral reef community members (e.g., molluscs). Reef matrix cores can help fill this knowledge gap, as they provide records of reef communities and environments over the past centuries to millennia, prior to large-scale human disturbance. To obtain a more accurate baseline of reef ecosystem structure and functioning and to track ecosystem change over the past one and a half millennia, we assessed changes in the taxonomic and functional group composition of sub-fossil assemblages of bivalves, gastropods, and urchins preserved in 3.5 m-long cores from three reefs within the central lagoon of Belize. Bivalve and gastropod composition was assessed via relative abundance of shells, while urchin composition was assessed via the accumulation rate of spines measured by weight. These cores record a shift in the dominant substrate relationship in bivalves from epifaunal to infaunal over time, which becomes most prominent in the late 1800's, indicating a loss of hard substrate (i.e., live coral). Additionally, this epifaunal decline coincides with an increase in seagrass indicating gastropods (e.g., *Cerithium spp.*). In contrast, urchin composition shows little change through time, with the currently-common *Echinometra* spp. dominating throughout the cores. Finally, the loss of epifaunal bivalves and increase in seagrass indicating gastropods occur in tandem with a decline in the abundance of large (>2 mm) coral fragments in the cores; this shift suggests a loss of coral and/or declines in coral growth in this region of Belize since the latter half of the 19th century. These trends mirror those that have been previously observed from reef matrix cores from Caribbean Panama, as well as Belizean vertebrate assemblages, suggesting region-wide declines in reef environmental conditions and ecosystems during the Late Holocene.

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## GROWING UP IN THE GRÈS À VOLTZIA: ONTOGENY IN *LIMULITELLA BRONNI*

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Horseshoe crabs (Class Xiphosura) are often invoked as unchanging relics of a bygone era due to their seeming morphological immutability over geological timescales. Investigation of their 480 million year long fossil record, however, reveals a more complex evolutionary history shaped by environmental and developmental factors. Previous work elucidating macroevolutionary dynamics in Xiphosura has identified heterochronic trends within two lineages that also occupy nonmarine environments, Belinurina and Austrolimulidae. As heterochrony is defined as a change in developmental timing, characterizing ontogeny within a lineage is key to pinpointing where developmental changes occur. Additionally, interpreting fossils with an ontogenetic lens is essential to proper species delineation, phylogenetic analyses, and understanding organismal life history. Of the two clades that display aberrant, heterochronic morphologies, only Belinurina has been subjected to extensive ontogenetic study. Here, we present the results of a preliminary examination of the austrolimulid *Limulitella bronni* material from the Triassic Grès à Voltzia formation. Morphological variation is quantified using linear and geometric morphometric datasets, alongside qualitative observational data. We identify two morphotypes, each comprised of material from multiple developmental stages.

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## FOSSILS FROM THE MIDDLE CAMBRIAN OF SOUTHWESTERN MONTANA IN A STRATIGRAPHIC CONTEXT

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The middle Cambrian Flathead Sandstone, Wolsey Shale, and Meagher Limestone are exposed throughout southwestern and central Montana. This succession is Wuliuan (509–504.5 Ma) in age, and spans the *Albertella*, *Glossopleura*, and *Ehmaniella* trilobite biozones. Despite being coeval and proximate to the Burgess Shale, relatively few paleontological studies have been conducted on these units. Each formation contains variable depositional settings spanning both carbonate and siliciclastic environments (e.g., tidal flat, shoreface, shelf, deep-subtidal). It has been recognized that fossil preservation in these units is highly variable and the controlling processes are not well understood. Some areas with soft-bodied preservation would be classified as a Tier 3 Burgess Shale Type deposit, while others preserve no fossil material. This variation has been previously explained as a biologic signal with organisms only living in their preferred environments, or as a taphonomic process where organisms are preserved only where environmental conditions allow. New stratigraphic sections and fossil assemblages from the Big Belt Mountains and Bridger Range in southwestern Montana can shed light on how preservation changes with geographic location and depositional settings. There are multiple observed taphonomic modes in these units, with the most abundant material coming from near the Wolsey Shale-Meagher Limestone contact. With this new stratigraphic framework, we can better understand the distribution of fossil materials in the formations, and whether variable preservation represents taphonomic processes, ecophysiological constraints, or other processes.

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## ARE THE FOOD WEB PROPERTIES STABLE THROUGH A MASS EXTINCTION EVENT?

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Food webs describe the flow of nutrients and energy among diverse, co-occurring species in a community. They provide a useful quantitative framework for assessing ecological complexity and ecosystem responses to disturbance. While the effects of perturbations on communities have been studied extensively in extant ecosystems, not much has been done for paleoecological systems, especially during mass extinction events. Here we used a highly detailed food web analysis to assess how the end-Triassic mass extinction event, the four larger mass extinction (201.5 mya), modulated the ecological complexity and trophic structure of marine ecosystems. We built a Triassic-Jurassic food web dataset that includes 3150 marine taxa restricted to deposits in Europe spanning from the Rhaetian to Sinemurian [~15.6 my]. Trophic roles and the likely trophic relationships between taxa were assigned by autoecological analysis and from literature searches, which was used to generate pre- (Raethian), during (Hettangian), and post-extinction (Sinemurian) food webs. The structure and complexity of these webs were analysed at two levels: At macro-level, which analysed the degree distributions of whole-network, and at specific-level; which focus on the network structure properties (e.g., number of links, connectance, proportion of predator, diet discontinuity, etc.). We found different structural changes in the food webs across the extinction event at specific level. Species richness drops 35% at the regional scale from the Rhaetian to Hettangian and increases 30% during the Sinemurian. Connectance decreased by 30% from Rhaetian to Hettangian, while increasing only 9% during the Sinemurian. The number of links per species decreased 23% during the extinction but exhibited slow recovery (1%) during the Sinemurian. Higher diet discontinuity (87%) and low similarity is observed during the Hettangian relative to pre-extinction and recovery stages (10%). Alternatively, during the extinction event the generality (number of prey per consumer) increased 30%, while the mean chain length, the intraguild predation, and the fraction of intermediate species (species that have both predators and prey) decreased significantly (27%) suggesting a diffusive effect across the ecological network, which could be related with their extinctive mechanism. However, once we account for the changes in the size and complexity of the webs, only a few aspects of the trophic organization changed significantly across the extinction event, and the webs display a universal concave down decreasing degree distribution (in log-log scale) like other paleo and extant food webs. This suggests that the trophic organization of food webs is stable across the Phanerozoic, regardless of the drastic effect of the mass extinctions like the end-Triassic that temporarily reduced ecological diversity and complexity.

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## ISOTOPIC NICHE SPACE: ASSESSING A NEW WAY TO LOOK AT HOMININ NICHE DYNAMICS AT HADAR AND WORANSO MILLE

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Stable isotopes are widely used to evaluate hominin diet and environment, but few studies use isotope distributions to quantify hominin niche space. Isotopic niche space analysis, which considers the spatial statistics of isotopic enamel data in bivariate plots, can be used to evaluate the breadth and overlap of isotopic niches among taxa, while controlling for sample size. We used this approach to evaluate isotopic niches among hominins (*A.afarensis* and Woranso Mille hominins undifferentiated) and associated mammal families (Cercopithecidae, Bovidae, Suidae, Equidae) from adjacent sites, Hadar and Woranso Mille (WM), using published enamel carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope data. At WM, we found that Bovidae and Cercopithecidae families occupied overlapping but larger isotopic niche space than the WM hominins. In contrast, at Hadar, we find minimal isotopic niche overlap (20%) between *A.afarensis* and all associated fauna. This suggests that hominins at Hadar occupied a distinct isotopic niche from their associated fauna than the hominins at WM. We observe these differences, even with the limitations of analysis which requires a minimum sample size of 10, forcing our analysis to combine samples that represent multiple depositional environments, different temporal ranges, and varying species compositions. Future work will increase sample sizes to allow for binning data at higher taxonomic resolution, from discrete time intervals, and depositional contexts.

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## POTENTIAL SOURCES OF COMMUNITY COMPOSITION CHANGE IN THE CLOVERLY FORMATION AND SYKES MOUNTAIN FORMATION OF WYOMING, U.S.A.

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A key issue in stratigraphic paleobiology is whether stratigraphic changes in community composition result from changing species abundance and ecological structure over time or from sampling across different facies along a stable ecological gradient. Recent numerical models suggest that changes in accommodation produce predictable stratigraphic changes in species composition, even when the species pool and regional ecological gradients are unchanged. In the case of transgression on a passive margin, strata would be expected to record a transition from inland to coastal communities, resulting in a considerable change in local community composition. To account for this possibility, species occurrence data should be analyzed in the context of a sequence-stratigraphic model. The Early Cretaceous Cloverly Formation and Sykes Mountain Formation in the Bighorn Basin of Wyoming host uncommon microvertebrate bone beds and well-preserved macroflora across a nonmarine–marine succession. This transition consists of three previously unrecognized unconformity-bounded depositional sequences. Sequence 1 contains high accommodation lacustrine deposits and poorly-drained paleosols of the Little Sheep Mudstone Member. Sequence 2 contains low accommodation amalgamated channels and well-drained paleosols. Sequence 3 records increasing accommodation as valley fills and poorly-drained paleosols of the Greybull Interval pass upwards into paralic deposits and then backstepping shallow marine deposits of the Sykes Mountain Formation. Stratigraphic ranges of vertebrates suggest an upwards loss in species richness, with predominantly crocodilian and turtle taxa near the top of the Greybull Interval. In addition, the formation records the Lower Cretaceous gymnosperm–angiosperm transition, with no evidence of angiosperms from the Little Sheep Mudstone Member but uncommon occurrences in the Greybull Interval. Although analyses of the vertebrate fauna are ongoing, ordination of the flora with NMS shows two distinct groups of samples, corresponding to sequence 1 and sequence 3, and species scores separate into a gymnosperm-dominant group and an angiosperm-dominant group. This change in community composition between sequence 1 and sequence 3 could result from three influences: 1) basin-scale species extirpation, immigration, and origination, 2) the temporal vacuity represented by the unconformities, and 3) ecological gradients in landscape position. The presence of at least two previously unrecognized unconformities emphasizes the need for better chronostratigraphic constraints on the duration of the hiatuses between the three Cloverly depositional sequences. Understanding the array of ecological and stratigraphic controls that may contribute to community composition shifts allows us to ask more focused and informed questions about changes in the fossil record.

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## BODY SIZE & *BASSARISCUS*

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Small carnivoran taxa are often differentiated, at least in part, by size. For example, several species of the procyonid *Bassariscus* include relative body size as a component of their diagnosis, including the small species *Bassariscus parvus* and *Bassariscus minimus* and the large *Bassariscus rexroadensis*. Despite the importance of size to small carnivoran paleobiology and taxonomy, few proxies for body mass are widely applied, by far the most prominent being the length of the lower carnassial. Furthermore, these proxies have generally been identified using a data set incorporating taxonomically and morphologically diverse taxa. We gathered dental measurements for specimens of extant musteloids with known body mass to identify reliable, taxon-specific proxies for size. Surprisingly, our results suggest that other teeth, particularly the fourth lower premolar, are far better body mass proxies than the lower carnassial. The teeth we identified as reliable predictors of size include not only lower dentition, but upper molars, premolars, and even canines, meaning that we can expand reconstructions of body size in extinct musteloids to include specimens in which the mandible is not preserved. We applied our findings to *Bassariscus* to test whether species previously distinguished by size remain significantly different from one another after including a larger fossil sample. We included fossils of a putative new species of *Bassariscus* from the Miocene Dalles Group of Oregon that, qualitatively, appears to be larger than even *B. rexroadensis*. While this comparison supports the suggestion that the Oregon specimens represent a new, large species, size differences between many *Bassariscus* species are less pronounced than had previously been thought. This underscores the importance of caution when diagnosing species based on size, but we hope that the development of taxon-specific body size proxies will pave the way towards more robust analyses of macroevolutionary trends in body size evolution and population-level patterns of body mass in certain extinct carnivoran species.

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## PLIOCENE-PLEISTOCENE CAPROMYINE RODENTS FROM CUBA: BRIDGING A GAP IN THE CARIBBEAN'S LAND VERTEBRATE PALEONTOLOGICAL RECORD

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Despite advances in Caribbean paleontology, Cuba's late Pliocene to early Pleistocene terrestrial vertebrate diversity remains underexplored, particularly for capromyid rodents and other land vertebrates. This study unveils new vertebrate fossils from the El Abra Formation in Matanzas, Western Cuba, marking the first documentation of capromyine rodents from this period, alongside an associated biota including plants, manta rays, sharks, barracudas, and bony fishes. These findings significantly enhance the Cuban terrestrial vertebrate fossil record, contributing to our understanding of the region's paleoecology and biogeography. Systematic excavations have yielded a diverse collection of vertebrate fossils, alongside incidental discoveries of flora and marine species, revealing a dynamic ecosystem during this transitional epoch. Our multidisciplinary approach, integrating stratigraphy, geochronology, paleoecology, and comparative anatomy, aims to place these findings within a broader evolutionary context, shedding light on patterns of vertebrate dispersal and diversification. The El Abra discoveries underscore its potential as a crucial site for future paleontological research, promising to advance our knowledge of Caribbean terrestrial vertebrate evolution. This study not only fills a significant gap in the fossil record but also sets a new trajectory for paleontological exploration in the region, highlighting the complexity of Caribbean faunal history.

## TERRESTRIAL POSITIONAL BEHAVIOR OF WILD *PONGO PYGMAEUS*: IMPLICATIONS FOR THE ORIGINS OF BIPEDALISM

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Although bipedalism has afforded the human lineage unparalleled capacities, the context of its emergence remains an enigma. The critical time interval in the late Miocene is not well represented in the hominoid fossil record, but three potentially bipedal genera have been recovered: *Sahelanthropus* (~7 Ma, Chad), *Orrorin* (6 Ma, Kenya), and *Ardipithecus* (4.4 Ma, Ethiopia). However, due to limited data, there is currently a lack of consensus on the reconstructions of their paleoecology, making inferences concerning the circumstances leading to bipedalism in the hominin lineage difficult to assess. Living apes have served as comparative models to test hypotheses concerning the ecological, social, and environmental forces that may have driven the reliance on this positional behavior in early hominins. The African apes, particularly chimpanzees, have been the primary focus in this

line of research due to their close phylogenetic relationship to humans and the frequency of their terrestrial travel. However, it has also been suggested that highly arboreal orangutans may be a relevant taxon for reconstructing the conditions associated with incipient bipedality due to their use of human-like fully extended hips and knees while navigating compliant arboreal supports. Their use of bipedal positional behavior while on the ground, however, has only recently been possible to study in the wild through the use of camera traps. Over a five year period, footage of terrestrial *Pongo pygmaeus* was captured in Gunung Palung National Park, West Kalimantan, Indonesia. 100 instances were analyzed for positional behavior, revealing that orangutans maintain the extended hip and knee during terrestrial bouts of bipedality in 82% of cases. The frequency of bipedal locomotion was found to be similar terrestrially (10%) to what has been observed arboreally (8%). Furthermore, when stationary, orangutans were orthograde more often than not and stood both bipedally and monopedally. Thus, the arboreally-adapted morphology of *Pongo pygmaeus* is also compatible with terrestrial orthograde. In addition, the kinematic execution of bipedality is more similar to that of humans than that observed in the African apes. These findings reaffirm the potential for an arboreal evolutionary pathway to more committed bipedality in hominins and may serve to recalibrate hypotheses concerning its origins. Advancing these debates requires combining neontological and paleontological datasets, which, in the latter case, will depend on more detailed, multiproxy reconstructions of the paleoecology of hominin sites during the late Miocene.

## EFFECTS OF CLIMATIC WARMING ON MOLLUSCAN ABUNDANCE AND COMMUNITY STRUCTURE DURING THE MID-PLIOCENE WARM PERIOD

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The Mid-Pliocene Warm Period, or MPWP, occurred 3.3–3 Ma, and provides a glimpse into a period of climatic change that is analogous to modern day warming trends. This interval of warming is represented in southeastern Virginia by the highly fossiliferous Yorktown Formation (4.9–2.8 Ma). The goal of this research is to determine how the MPWP affected molluscan abundance and community structure, with a deeper examination of a subset of economically valuable genera. The Yorktown Formation is composed of four members, three of which were deposited in similar environments, making it possible to sample molluscan fauna before, during, and after the MPWP. Museum collections and field samples were assessed from the Sunken Meadow, Rushmere, and Moore House Members. Bulk field samples were sieved and sorted, and all specimens were identified down to the lowest taxonomic level possible. Minimum number of individuals was quantified for each species by counting the number of identifiable hinges and dividing by two for bivalves and counting the higher number of either apices or apertures for gastropods. Abundance data were analyzed using ordination, including non-metric multidimensional scaling (nMDS) to assess differences in taxonomic composition and community structure across the MPWP. Preliminary results indicate a significant variation in response to the warming and cooling phases of the MPWP. During the warming, species such as *Cyclocardia granulata* and *Hiatella arctica*, declined markedly in abundance, while other taxa, such as *Crepidula*, *Noetia incile*, and *Chama congregata* increased. The period of cooling that followed was marked by decreased abundance in *Chama congregata*, *Noetia incile*, and *Striarca centaria*. Species that responded positively in abundance to the cooling event included slipper shells such as *Crepidula plana*, *Crepidula fornicata*, and *Bostrycapulus aculeatus*. It should be noted that some genera, including *Chesapecten*, remained abundant regardless of climate trends. Economically valuable species also varied in their responses. *Mercenaria campechiensis* responded favorably to the warming, while *Spisula (Hemimactra) confraga* increased in abundance across the cooling. There is stability in genus level abundance in other cases, like *Ostrea*. The fossil record across the MPWP preserved the molluscan biological response in terms of abundance and community structure to a period of warming that parallels current global warming patterns.

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## ANATOMY, PRESERVATION AND EVOLUTIONARY SIGNIFICANCE OF THE CENTRAL NERVOUS SYSTEM IN AN ORDOVICIAN TRILOBITE

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Trilobites represent a major and iconic group of Paleozoic arthropods with a lengthy evolutionary history, diverse morphologies and widespread distribution around the world. Despite their substantial abundance, both in the conventional fossil record and in sites of exceptional preservation, key aspects of trilobite internal anatomy remain enigmatic, such as the organization of their central nervous system. Here, we present the first direct evidence for central nervous system preservation in a trilobite based on a unique specimen of the phacopid *Anacheirurus adserai* from the Lower Ordovician Fezouata Shale biota of Morocco. The brain shows distinct neuromeres, including the proto- and deutocerebrum, as well

as a well-defined stomodeal foramen that would accommodate the foregut. Posteriorly, we identify the presence of two additional ganglia, which correspond to the post-oral tritocerebrum and the anterior portion of the ventral nerve cord. Elemental analyses indicate that the central nervous system is replicated by framboidal iron oxides with traces of organic carbon, making it directly similar to the taphonomic mode seen in early Cambrian Chengjiang fossils with neurological preservation. Comparisons with the exceptionally preserved digestive tract of *A. adserai* allows us to discard alternative morphological interpretations. The overall morphology of the brain and nerve cord of *A. adserai* suggest that trilobites represent stem-group mandibulates, as opposed to their traditionally proposed affinity as early chelicerates.

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## THE EVOLUTIONARY SIGNIFICANCE AND PRESERVATION OF FOSSILIZED CENTRAL NERVOUS SYSTEMS IN CAMBRIAN METAZOANS

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Sites of exceptional preservation provide unparalleled insights into the anatomy of extinct animals beyond the capabilities of the conventional shelly fossil record, and can contain delicate structures such as eyes, guts and legs. Although it has been widely assumed that metazoan neurological structures such a brains or nerve cords are too labile for the process of fossilization, there is growing evidence of preserved central nervous systems in extinct organisms up to 518 million years old. Paleoneuroanatomical remains are restricted to Burgess Shale-type sites with exceptional preservation for the Cambrian Period. They are typically recognizable as organic carbon compressions with occasional iron oxide replacement, and have been recorded in phylogenetically distant groups including early branching metazoans and bilaterians. In this talk we will address the impact of paleoneuroanatomical data for resolving the phylogenetic affinities of Cambrian taxa, examine the processes controlling the global spatiotemporal distribution of fossilized nervous systems, and explore patterns of mosaic evolution and secondary simplification in deep time as informed by comparative neuroanatomy between extant and extinct species.

## SKELETAL ORGANISATION, COMPOSITION AND CONTROLLED BIOMINERALIZATION OF EDIACARAN *CORUMBELLA WERNERI*

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Biomineralization in Metazoa was a key evolutionary novelty to the development of biomineralized skeletons, that have enhanced the protection against predators, favoured ecological strategies, and changed the sedimentary record and geochemical cycles. The record of biomineralizing metazoans begins in the terminal Ediacaran, with the appearing of skeletal tubular taxa. However, much uncertainty remains as to the primary mineralogy, biological control in biomineralization, and biological affinities of these taxa. Here, we investigate the biomineralization of *Corumbella werneri* (Tamengo Formation, Corumba Group, MS, Brazil; ca. 555–542 million years old), a fossil with debated composition, morphology, and affinity. We employ a multi-technical approach, using light petrography, cathodoluminescence, electron microscopy techniques (SEM/EDS, EBSD, EPMA), micro-Raman spectroscopy, and synchrotron-based X-ray microtomographic imaging. We show that *Corumbella* had a calcareous skeleton with primary aragonitic composition (aragonite relicts in neomorphic calcite and elevated strontium concentration) and a possible laminar microstructure, formed by an organic matrix embedding crystals with a consistent crystallographic orientation. The skeleton had a bi-layered construction of imbricated plates and rings (sclerites), yielding a cataphract organisation. Taken together, these lines of evidence support controlled biomineralization for *Corumbella*. Our new morphological reconstruction questions previous proposals of an affinity to cnidarians or to sinotubulitids, alternatively showing a new possibility of affinity to early Cambrian cataphract bilaterians and taxa with contentious affinities.

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## POSSIBLE ADAPTIVE CHELONIVORY IN UINTAN CROCODYLOIDS FROM WESTERN NORTH AMERICA

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Large-bodied crocodyloids of the Eocene Western Interior of North America—notably "*Crocodylus*" *affinis* and *Brachyuranochampsa eversolei*—were comparable in size to large species of extant Crocodylus, and like them, were probably apex predators with generalized diets, being perhaps most similar in size and habitat to the extant Nile crocodile (*Crocodylus niloticus*). However, several lines of evidence suggest that chelonians (turtles) may have played a more significant role in the diets of these Eocene crocodyloids than in the diets of extant crocodilians. Crocodilian bite marks on Uintan turtle shell fragments confirm that turtles were at least a portion of the diet of Uintan-aged crocodilians. Furthermore, wear patterns on the teeth of multiple specimens of Uintan crocodyloids are consistent with frequent durophagy. The teeth of these specimens generally have noticeably more robust crowns, and preliminary dimensional analysis of the teeth of specimens from the Uinta Formation of Utah, shows a mild trend in the Eocene crocodyloids having slightly lower crown height ratios, i.e., proportionally shorter/stouter crowns, than the extant Nile crocodile teeth to which they were compared. This is most pronounced in the middle portion of the jaw, and particularly in the maxilla. Analysis of additional specimens, both extant and from the Eocene, may shine additional light on these preliminary comparisons, either refuting or confirming such a difference. Based on the current data, it does appear that the teeth of North American Eocene crocodyloids are generally more robust than their modern counterparts, which may be evidence of adaptive chelonivory. This is not to say that these crocodyloids were turtle specialists; like extant crocodilians, they would have been opportunistic generalists, preying on whatever animals they could catch and subdue; however, the most common potential prey in these crocodyloids' environments appears to have been medium-large sized chelonians, the Uinta Formation being noted as especially turtle-rich, thus it follows that these predators would have been well-adapted for tackling this most readily available source of food, a food source of which most mammalian predators likely weren't well-equipped to take full advantage. This strong predator-prey association between crocodyloids and chelonians likely lasted until the end of the Uintan NALMA, after which both crocodilians and many chelonians appear to decline in North America, most notably with crocodilians disappearing from the North American Western Interior, and baenid turtles going extinct entirely.

## VERTEBRATE PALEONTOLOGY OF PLEISTOCENE SITES IN BELIZE

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Preliminary findings from this study serve as a review of paleontological research conducted in Belize. The nature of paleontology as a science is multi-disciplinary and can take many forms especially during its inception in developing countries such as Belize. By highlighting the paleontological findings from this country and the contributions scientists have made thus far, fundamental gaps in knowledge become apparent. The earliest use of paleontology in Belize is documented as early as 1952 during the first industrial oil explorations of British Honduras (Belize). Geologic surveys conducted at the time relied on the fossils found across the country to estimate the age of geological formations. In the 2000s and 2010s archaeologists and cavers working in Belize came across fossils of extinct Pleistocene species that have led to remarkable scientific discoveries. There are approximately 14 locations known to produce Pleistocene fossils in Belize so far. These sites include caves, sink holes, rivers, and gravel pits. The location and current state of some of these sites are presently understudied. Therefore, revisiting each location to photograph, map, and document the geology associated with the fossils is requisite. At least 27 vertebrate taxa across 12 families are known thus far, the majority of which are presently extinct or extirpated. The current knowledge on the fossils of Belize is drawn from inferences using regional information and smaller well studied areas of the country. It is expected that the fossil record in Belize could potentially yield similar fossil taxa that have been found in other parts of Central America and southern Mexico. Expected taxa not yet found in Belize include Canidae and Toxodontidae. Microfossil studies haven't been conducted yet and will likely produce fossils from various small mammals, birds, reptiles, amphibians, and fish. The results from this study describe the substantial on-going natural processes in the changes of ecosystems and the ecology of species in Belize. Furthermore, this research demonstrates the universal value of protecting sites containing fossils from the point of view of conservation paleobiology. As paleontology continues to develop in Belize, these new and exciting findings can help to enhance Belize's understating and awareness of the Earth's natural heritage. Connecting humans to the past through natural history can be used as a catalyst for improving Belizean led initiatives to safe guard paleontological resources through policy and public engagement.

## CONODONT COLOR ALTERATION INDEX REFERENCE SETS: HISTORIC ICONS AND ANITA (EPSTEIN) HARRIS LEGACY

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The landmark Epstein et al. (1977) conodont color alteration index (CAI) paper and chart demonstrated that the change in color of conodont elements was the result of thermal alteration of organic material preserved within the apatite crystal matrix of the conodont in a continuum from light amber, CAI 1, unaltered below 60 degrees C, to black, CAI 5, at approximately 300 degrees C. This was accomplished by comparison of unaltered conodont material experimentally heated under controlled temperature conditions compared to conodonts recovered in the field, where darker conodonts essentially came from deeper burial and orogenic regions. A subsequent study documented the color change of conodont elements from black to clear as all of the organic material was volatized at increasing temperature from approximately 400 degrees to 700 degrees (Rejebian et al., 1987). These works added another geothermometer to the geological tool kit, especially as the thermal alteration of conodonts corresponded to the thermal generation of hydrocarbons and metamorphic grade. Anita Harris produced conodont color alteration comparison cards containing reference materials spanning Cambrian to Triassic samples that have numerous representatives of CAI 1–8. The cards personally made by Harris, utilizing conodont collections from across North America, as well as lab heated specimens, were numbered and distributed to colleagues in the U.S.A. and internationally. The whereabouts of cards 1, 3, 6, 9, and 12 are known to me. As these are important reference standards of the conodont trade, my goal is to find all of the cards and track their location and keepers.

## THE DEVONIAN-CARBONIFEROUS DIVERSITY OF CLAM SHRIMP (CRUSTACEA: BRANCHIOPODA: LAEVICAUDATA, SPINICAUDATA, CYCLESTHERIDA): A PRELIMINARY REPORT

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The taxonomy of fossil clam shrimp (a group of three taxa previously referred to as the paraphyletic taxon 'Conchostraca') is a mess—a reflection of the different taxonomic systems that emerged during the Cold War. As a result, we lack a clear understanding of their diversity and evolutionary trajectory from their emergence in the Devonian to today. Their unusual mode of reproduction, utilizing cysts that can withstand unfavorable conditions in a dormant state, has some interesting implications for survivorship during mass extinctions. To better understand their evolution, we have begun the creation of a clam shrimp taxonomic database. This database utilizes the most complete collection of publications containing records of fossil clam shrimp in existence (approaching 1,300 publications). Of particular interest is tracking the jarring higher-level taxonomic shifts that occur between the taxonomic systems; as a result, the initial phase of database construction has taken place outside of the esteemed Paleobiology Database. Initial work focused on the early record of clam shrimp in the Devonian and Carboniferous. Thus far, we have documented 230 species names that are used in regards to Devonian-Carboniferous specimens. These range from names referenced only in a single paper and ignored after, to names that invoke modern species in the Paleozoic. Though the database does not yet take taxonomic synonyms into account, this is a surprising high level of diversity for the early phase of clam shrimp evolution. One particular challenge is that a high proportion of the publications are written in non-English languages. This has necessitated employment of optical character recognition and Google Translate to read the article. Many paleontologists in previous generations implicitly ignored publications in different languages. With this technology, there is no longer any excuse to ignore these bodies of work.

## DIGGING ONLINE AND PARTNERING WITH PALEONTOLOGISTS TO DISCOVER NEW SPECIES AND PREHISTORIC BEHAVIOR

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Digging in the digital world presents an intriguing new way to make important paleontological discoveries. As an amateur scientist, I have been exploring eBay and other websites to find new species as well as prehistoric behaviors preserved as fossils. When I discover one of these specimens for sale online, I contact a scientist who may be interested in describing the find. So far, I've bought and donated over 70 fossils, including new species of fish, wasps, ants, flies, mites and beetles, as well as several specimens exhibiting reproductive and other behaviors. I've partnered with numerous paleontologists from around the world to document these fascinating discoveries, and I continue to look for more scientists interested in this work. They need only tell me the types of species or behaviors they study, and I'll email them if I locate a relevant fossil for sale online. If they agree it's scientifically important, I will buy the fossil and donate it to a museum. Together, we can prevent these rare fossils from disappearing into private collections while adding them to the scientific record.

## WHAT IS THE FUNCTIONAL EQUIVALENT OF A MAMMOTH?

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Rewilding with functional equivalents emphasizes the conservation of ecological function rather than rigid taxonomic correctness. Although Pleistocene rewilding is an unlikely solution to conservation issues, it has nevertheless stimulated discussion on the ecological function of extinct megafauna. In addition to characterizing the diversity of biotic interactions that are now absent from most terrestrial systems, detailed understanding of the functional ecology of these species provides valuable insight into the processes that lead to their extinction. However, assigning ecological function, such as dietary type, to a species that is only known from its fossil record can be challenging. Despite having evolved adaptations enabling the consumption of grass (e.g., extreme hypsodonty), mammoth (*Mammuthus*) were widespread across many environments with variable diets ranging from mixed-feeding to grazing. Here, we use ecological niche modeling (in Maxent) to aid in the interpretation of differing dietary behavior across the geographic distribution of *M. columbi* from the last glacial maximum (~26 ka) to the terminal Pleistocene (11.7 ka). Maxent models were trained using directly dated *M. columbi* occurrences from the literature and Paleoclim climate reconstructions. With this model, we mapped likelihood of occurrence across geographic regions over time. We used these mapped regions to provide a spatially explicit context for interpreting data from two widely used dietary proxies. The first, stable isotope analysis (SIA) of $\delta^{13}C$ from tooth enamel, identifies whether diets consist of C3, C4, or mixed resources. The second, dental microwear texture analysis (DMTA), uses scale-sensitive fractal analysis of tooth wear to characterize the texture of recently consumed foods. For a frame of reference, we compare mammoth DMTA values with those from a known population of *Loxodonta africana*. We then asked, "What is the ecological function of a mammoth?" We find that some generalities can be made for *M. columbi*—they are mixed-feeders with a preference for grass. However, dietary behaviors vary broadly across the species' distribution and can be locally specialized. Importantly, while *M. columbi* exhibits wide species-level breadth in DMTA characteristics, many fossil localities have variation that is similar to or lower than our known reference sample. We believe the approach we present can be useful for understanding patterns of end Pleistocene extinctions in a spatially explicit way as regional extirpation chronologies improve. We find that the localized ecological role of mammoth is context specific, and this is the scale at which most conservation interventions occur. It could, therefore, be challenging to match the ecological function of *M. columbi* with a modern analogue. This further emphasizes the need to conserve the biodiversity and ecological function that exists today.

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## VOMERONASAL ADAPTATIONS RESPONSIBLE FOR UNIQUE PALATAL MORPHOLOGY IN ENDOTHIODONT DICYNODONTS (THERAPSIDA, ANOMODONTIA)

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Secondary palates are a common feature among neotherapsids. A robust secondary palate formed by contributions of the premaxilla and maxillae is a characteristic feature of dicynodonts. This structure appears very early in the evolution of the group in close association with the evolution of the dicynodont beak and is thought to have contributed to their success as the most diverse and abundant terrestrial herbivores in the late Permian and early Triassic. Endothiodontia, a clade of morphologically disparate non-bidentalian dicynodonts, deviate from this general trend, showing a stark reduction in the palatal shelves, resulting in a superficially primitive anteriorly-extended choana. As this represents (to our knowledge) the only case of a definitive loss of a complete secondary palate, we compared the anatomy of the secondary palate and nasal passage in endothiodonts and in other dicynodonts using μCT. We show that the choanal space in dicynodonts preserves traces of two parallel structures: the passage of the choanal tube (nasopharynx) and the vomeronasal organ. The latter is located along the anteroventral margin of the choanal tube and is apparent as a distinct fossa formed by the maxilla and vomer. In most dicynodonts, the vomeronasal fossa is a long, thin posteroventrally-directed tube that opens into the palatal surface through a small notch on the anterior margin of the choana. In the endothiodonts *Endothiodon* and *Abajudon*, the vomeronasal canal is short and wide, with a diameter approximately half that of the choanal tube. CT scans show that the vomeronasal canal exhibits a typical dicynodont organization in juvenile *Endothiodon* but grows allometrically to produce the unique adult morphology. We hypothesize that the apparent reduction of the secondary palate in *Endothiodon* is a consequence of increased reliance on chemosensory roles of the vomeronasal organ around the transition to adulthood, coincident with a possible dietary shift previously documented from both morphology and isotope geochemistry. More broadly, this suggests that the constraints of palatal development and geometry may have imposed strict tradeoffs between reliance on chemosensory cues and functional benefits of the secondary palate within therapsids more generally.

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## MACROEVOLUTIONARY AND PHYLOGENETIC CONSEQUENCES OF STABLE MORPHOLOGICAL POLYMORPHISM IN THE FOSSIL RECORD

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Morphological polymorphism is ubiquitous in the fossil record. Virtually all fossil lineages display population-level variation, some of which is maintained over millions of years. In this talk, I will examine how polymorphisms maintained throughout the duration of fossil lineages is inherited across incipient daughter species. Applying models of morphological evolution that account for intra-specific polymorphism alongside models of stratigraphic sampling, I explore how long-maintained polymorphisms have shaped macroevolutionary dynamics and phylogenetic patterns in two genera of fossil echinoderms.

## A COLLABORATIVE MODEL FOR RECOVERING LOST HISTORIC PALEONTOLOGICAL LOCALITIES AND FOSSIL PROVENIENCE ON FEDERAL LANDS

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Although legacy paleontological collections associated with federally managed lands are vital resources for scientific research and heritage preservation, many historic museum specimens lack provenience data. Missing or insufficient stratigraphic and chronological context can pose a major barrier to researchers working for and partnering with federal agencies. We present a collaborative model for a management program that addresses this issue to ultimately enhance the scientific and educational value of these nonrenewable resources. This project is ongoing and is facilitated by an interdisciplinary team of National Park Service staff, partners, and amateur paleontologists at Tule Springs Fossil Beds National Monument (TUSK) in Southern Nevada. For over 100 years, scientists have led expeditions to what is now TUSK, generating several legacy Pleistocene paleontological collections curated at federal repositories across North America. TUSK has developed an effective protocol for 1) rediscovering historic paleontological localities, 2) redocumenting these sites using modern best practices, and 3) recovering missing provenience data for historic paleontological collections. To date, we have successfully redocumented six historic paleontological localities originally excavated in 1933, 1955, 1956, and 1962-1963. Because these sites are historic, they are managed as both paleontological and cultural resources. These localities are rediscovered in the field using historic photos compiled from archive searches and original publications. TUSK completed contemporary locality documentation forms for each site to consolidate historic data, photographs, and maps using current best practices, including cross-referencing archeological resource data. Geospatial data and repeat photography are also utilized to connect original and updated documentation of each site. Diagnostic fossils within TUSK legacy collections that previously lacked provenience data have been cross-referenced with historic photos and archives to recover this critical context. There are limitations to this protocol; it is time-consuming to complete this work, and sometimes archives become lost or destroyed. Nevertheless, we have found that the possibilities of this work far exceed the limitations. Results of this project successfully justified federal natural resources funding for a complete excavation and curation of one of these six historic paleontological sites. Redocumentation of these once-lost historic sites also opens the door for further research, including updated geochronology and stratigraphic analysis. With adequate support, this methodology could be adopted at other federal sites that preserve long histories of paleontological research. This methodology helps to fulfill our obligations to manage federal paleontological resources using scientific principles and expertise, as well as preserve natural heritage and the history of paleontology on federal lands.

## TESTING CHEMICAL-AIDED DISAGGREGATION OF THE SILICA FORMATION'S (MIDDLE DEVONIAN) FOSSILIFEROUS SHALE

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The Silica Formation (Middle Devonian) exposed in southern Michigan and northern Ohio is a well-known, fossiliferous formation that yields a rich and diverse assemblage of micro- and macro-marine invertebrates. The fossils of the Silica Formation have been sampled and studied for over 90 years and it continues to be a unit of interest to amateur and professional paleontologists. This research investigates the use of various chemical treatments to disaggregate the fossil-rich shales of the Silica Formation. Previous researchers used a chemical surfactant called 'Quaternary-O' or 'Miramine,' but neither product is currently commercially available. We are interested in identifying a chemical that will significantly reduce (>70%) the fine-grained matrix in bulk samples and increase workflow productivity when studying macro-invertebrate fossils. We bulk sampled 170 kg of Silica

Formation's shale from spoil piles in the Martin-Marietta Quarry south of Ann Arbor, MI. This bulk sample was initially screen-washed in water using nested screens of #20 (0.841 mm openings) and #32 mesh (0.500 mm openings), resulting in a reduction of matrix by 23–40%. Subsequent washes in water were found to further reduce the matrix by less than 10%. We tested subsequent washes in water against chemical treatments to study how they aided in the consistent reduction of matrix without negatively impacting the fossil. The following chemicals were selected based on recommendations from the literature and/or similarity in chemical structure to Quaternary-O: Dimethyl Sulfoxide (100% conc.), Hydrogen Peroxide (3% conc.), Acetic Acid (6% conc.), Hydrochloric Acid (3% conc.), and Benzenesulfonic Acid or Biosoft S-101 (2%–50% conc.). Testing is ongoing, but the chemicals tried so far have only reduced bulk samples by 12–44%. Further testing will include heat-aided disaggregation and the use of sodium hexametaphosphate (Calgon). Because we are aiming to find a methodology that reduces bulk samples by over 70%, we are not currently recommending a chemical treatment over screen washing in water due to the added cost and time in processing bulk samples.

## THE POTENTIAL OF UNASSUMING FOSSILS: ASSESSING THE TAXONOMIC UTILITY OF OSTEODERM MORPHOLOGY IN ARCHOSAURIA

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Preservation bias plays a major role in our understanding of the geologic past. Robust skeletal elements have more fossilization potential, which can lead to an over-representation of these elements in the rock record. Osteoderms (bony plates found in the skin of multiple vertebrate groups) are one such example—they are found in abundance in the fossil record, but are considered less taxonomically useful in isolation compared to other skeletal elements. The degree to which osteoderm morphology is influenced by evolutionary history versus non-phylogenetic factors (e.g., ecology, function, body-size) is not well known. For this study, a survey of osteoderm morphology was conducted using simple linear measurements (e.g., length, width, thickness) to describe overall osteoderm shape within Archosauria. Archosaurs (and outgroups in Archosauromorpha) were chosen for this study in part due to the dichotomy in osteoderm presence between pseudosuchian and avemetatarsalian archosaurs. Most lineages within Pseudosuchia retained osteoderms from the ancestral archosaur condition, whereas the avemetatarsalian lineage lost osteoderms early in their evolutionary history, only to re-evolve them later in several clades. Taxa surveyed include isolated osteoderms from the earliest non-crocodylomorph pseudosuchians, and non-archosaurian Archosauromorpha—specifically the aetosaurs *Stagonolepis* (14), *Scutarx* (2), *Calyptosuchus* (1) and *Paratypothorax* (5), the aetosauriform *Revueltosaurus* (28), the phytosaur *Leptosuchus* (9), and the archosauriform *Vancleavea* (10), as well as a number of unknown phytosaur (47) and aetosaur (2) taxa. Results show that osteoderm morphologies exhibit the most variance within their anterior-posterior length, followed by the anterior-posterior length of the osteoderm keel. Anterior-posterior length is relatively conserved within clades, whereas lateral width is more homoplastic. Conservation of the anterior-posterior length may relate to a one-to-one correspondence between osteoderms and vertebrae in these groups, and may not be conserved in groups that do not have a one-to-one correspondence of osteoderms and vertebrae. In PCA morphospace, aetosaurian and phytosaurian osteoderms take up a large area of morphospace, though rarely overlap. *Revueltosaurus* and *Vancleavea* osteoderms take up a much smaller morphospace, but sit between and span both aetosaur and phytosaur morphospace. Expanding this dataset crownward within the evolutionary tree of Archosauria is necessary to determine overall levels of phylogenetic signal in osteoderm morphology, and the accuracy and limits of taxonomic identification from isolated or fragmentary osteoderms.

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## DETERMINING THE LIFE AND FEEDING MODES OF EARLY ARTHROPODS USING COMPUTATIONAL FLUID DYNAMICS

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Accurately determining the life and feeding modes of extinct animals is critical for reconstructing extinct ecosystems, resolving the complexity of trophic systems, and integrating the evolution of metazoans within the broader biosphere. Reconstructing the life mode of early arthropods is particularly important for understanding the evolution of these systems during the early Palaeozoic, due to the diversity, disparity, and range of life and feeding modes occupied by this phylum. Here we combine three dimensional reconstructions of Cambrian arthropods, constructed using Blender from fossils preserved in multiple orientations, with computational fluid dynamics, in order to test life and feeding modes for extinct Cambrian arthropods known from Burgess Shale-type deposits. Specifically, we consider whether three taxa *Fibulacaris*, *Odaraia*, and *Clypecaris* swam and fed inverted. An inverted lifestyle has been proposed for the former two,

while the third was included for comparison. These taxa are compared to a modern analogue, the fairy shrimp, and two hypotheses are considered: (1) taxa which swam inverted will generate more lift in an inverted posture than when dorsal-surface up; (2) taxa which swam inverted will direct more particles between their carapace valves in an inverted posture than when dorsal-surface up. Results supported inverted swimming in *Fibulacaris*, as it performed better in terms of both hydrodynamics and feeding when inverted. The results for *Odaraia* and *Clypecaris* did not provide strong support for inverted swimming. Results were consistent across multiple swimming speeds and particle sizes. Importantly, the use of virtual paleobiology enabled the robust testing of life and feeding modes of Cambrian arthropods, demonstrating that an array of autecologies were operational 500 million years ago, shortly after the diversification of arthropods in benthic ecosystems.

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## NICHE PARTITIONING AMONG MIDDLE MIOCENE SIWALIK PRIMATES FROM RAMNAGAR (J&K), INDIA

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Fossil primate intra-tooth stable carbon and oxygen isotope analyses offer insights into past seasonal variations in diet and ecology. While Late Miocene Siwalik apes *Sivapithecus* and *Indopithecus*, and sivaladapids (*Sivaladapis*) have been studied for their diet and ecology based on dental enamel stable isotope and microwear analyses, Middle Miocene Siwalik primate teeth are yet to be analysed for their diet and ecology. Ramnagar, a Middle Miocene (~14–11.4 Ma) Siwalik locality in India, has yielded the apes *Sivapithecus indicus* and *Kapi ramnagarensis*, along with the sivaladapids *Sivaladapis* and *Ramadapis*. We carried out intra-tooth $d^{13}C$ and $d^{18}O$ analyses of *Sivapithecus indicus*, the stem gibbon *Kapi ramnagarensis*, and *Ramadapis sahnii* from two contemporary sites (Rashole and Sunetar-2) of Ramnagar using a LA-IRMS to reconstruct their diet and habitat. One tooth of *S. indicus* from Thaplal, lying 85 m above Sunetar-2 was also analysed using the same method. To compare, we also sampled teeth of extant gibbons (*Hoolock*, *Symphalangus*, *Nomascus* and *Hylobates*) and a loris (*Nycticebus*) to understand the niche partitioning among modern primates. Our preliminary results indicate that Ramnagar *S. indicus*, with high $d^{13}C$ diet and $d^{18}O$ values relative to those of other pongines, was primarily an arboreal frugivore and folivore, feeding higher up in the canopy of a woodland/forest (no closed canopy). The Late Miocene *Sivapithecus* (Siwaliks of Pakistan) and *Khoratpithecus ayeyarwadyensis* (from Thailand) lived in relatively denser and more seasonal (likely monsoonal) forests. The Late Miocene *Sivapithecus* likely derived its food from even higher up in the canopy, as compared to the Middle Miocene Ramnagar *S. indicus*. The habitat of Ramnagar *S. indicus* was significantly different from the dense closed canopy rainforests of extant and extinct Pongo and the giant Pleistocene ape *Gigantopithecus*. The small bodied ape *Kapi ramnagarensis*, unlike most modern gibbons (*Hoolock*, *Symphalangus* and *Hylobates*), occupied less dense forest but ventured like them into higher canopy areas for feeding probably more on leaves than on ripe fruits (most similar in isotope values to *Nomascus*). The sivaladapid *Ramadapis sahnii*, on the other hand, exploited highly $d^{18}O$ enriched leaves of higher up in the canopy of open forest, differing significantly from the Late Miocene *Sivaladapis nagrii* and the extant loris *Nycticebus*, who occupied lower parts of denser forests. Overall, the primates suggest a more open forested/woodland environment at Ramnagar in the Middle Miocene, with all primate taxa relatively high in the canopy. *Sivapithecus indicus* was likely the most frugivorous and lower in canopy, but still more of a mixed-feeder compared to *Sivapithecus* in the Late Miocene. *Kapi ramnagarensis* was also likely a mixed-feeder, foraging a bit higher in the canopy, and the folivorous sivaladapid *Ramadapis sahnii* appears to have fed highest in the canopy among the primates analyzed here.

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## VALENTINIAN ECOSPACE, ENVIRONMENTAL AFFINITIES, AND THE ORDOVICIAN RADIATION OF BRACHIOPODS

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A fundamental question in paleobiology is how ecospace is

filled as clades diversify. Jim Valentine addressed this question with a model of ecospace based on a dual taxonomic and ecologic hierarchy. He based his ecospace on Hutchinson's niche concept, but extended it to higher taxa. Simply put, Valentine argued that the Hutchinsonian niche of a genus is composed of the niches of its constituent species, and the niche of a family is composed of the niches of its constituent genera, and so on up the taxonomic hierarchy. We present analyses to show that environmental affinities can be used to build a multidimensional Valentinian ecospace and we apply it to clade diversification in the early Paleozoic. We illustrate this approach by looking at how brachiopod orders fill ecospace during the Ordovician radiation. We evaluate three processes by which higher taxa move through ecospace: (i) movement of multiple genera into a new region of ecospace (niche expansion), (ii) movement of a small number of genera into new regions of ecospace that then diversify (adaptive radiation followed by niche conservatism), and (iii) selective extinction of genera in a limited region of ecospace. To test for these processes, we use brachiopod occurrences from the Paleobiology Database to calculate environmental affinities for lithology, latitude, water depth, and grainsize in seven well-sampled brachiopod orders. We use the log-odds ratio of occurrence counts as our affinity metric. Multivariate analysis of the environmental affinities indicates that lithology and latitude are most important in explaining the environmental distribution of these orders through the Ordovician. Although the proportion of genera with carbonate affinities shifts over time from a little over sixty percent in the early Ordovician to a little less than forty percent in the late Ordovician, the affinities of individual genera do not show strong directional shifts. Thus, niche expansion of individual genera did not drive the shift of brachiopods into siliciclastic environments. Instead, the expansion into siliciclastic habitats was driven by higher diversification rates in siliciclastic environments and selective extinction of genera with carbonate affinities in the late Ordovician. We argue that analyses of multivariate ecospaces based on environmental affinities can be applied broadly to better understand the environmental drivers of diversification.

## THE GIGANTIC EGG CAME FIRST: A STATE-FEDERAL PARTNERSHIP USING CUTTING-EDGE SCANNING AND 3D PRINTING TECHNOLOGY FOR A MAJOR EXHIBITION

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The 'mid-Cretaceous' (Aptian-Santonian) is a relatively undersampled and understudied interval in the succession of terrestrial ecosystems preserved in western North America. This is especially true of the beginnings of the Late Cretaceous Period (Cenomanian Stage), when there is turnover amongst North American vertebrate clades and global climate heads into the Cretaceous Thermal Maximum. Cenomanian vertebrate body fossils are known from the Mussentuchit Member of the Cedar Mountain Formation (Utah) and the Wayan-Vaughn Assemblage (WVA) shared across the Wayan Formation (Idaho) and the Vaughn Member of the Blackleaf Formation (Montana). The WVA is unique in its preservation of an upland environment where high energy fluvial deposits contain fragmentary remains of a diverse fauna and flora. As of 2024 the Wayan vertebrate body fossil record consists of semionotiform fishes, multituberculate mammals, turtles, terrestrial and aquatic crocodyliforms, theropod dinosaurs, including a small-bodied tyrannosauroid, and diverse ornithischians, including the common burrowing taxon *Oryctodromeus cubicularis*, as well as eggs and ubiquitous eggshell of the caenagnathid oviraptorosaur ootaxon *Macroelongatoolithus carlylei*. The Wayan outcrops are entirely within lands administered by the Caribou-Targhee National Forest (USDA Forest Service); the Idaho Museum of Natural History partnered with the Forest Service to open our major exhibition "Dinosaurs from the Mountain" (DftM) in October, 2023 and develop associated programming. DftM is built around USDA specimens, and we pushed the limits of our 3D printing to give the visitor a paleontologist's appreciation of this fragmentary record. The centerpiece is North America's only mount of a *Gigantoraptor*-grade caenagnathid oviraptorosaur, standing 2.5 m tall and 4 m long. The skeleton was digitally sculpted bone-by-bone in a polygonal modeling program, based on comparative material and the literature, and 3D printed using plastic filament material in-house, with an armature completed at the Idaho State University College of Technology. We are completing a full digitization of the Wayan collections using a coordinate measuring laser line probe scanner. The rollout of educational materials has seen youth engagement for the IMNH rise to 138% of pre-exhibit levels, year-over-year. Three education traveling kits containing 3D replicas of USFS fossils have been assembled for IMNH and K-12 educator use, with further kits in development for USFS staff. Using program evaluation rubrics developed at the IMNH based on Bloom's Taxonomy (an educational rigor framework), the kits have had an average program quality of 85% in the first two months of use, showing that 3D printed specimens can be effective and engaging in classroom outreach, especially for a state's only dinosaur-aged fauna.

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## MODERN BIOLOGICAL DIVERSITY GRADIENTS AND THEIR IMPLICATIONS FOR THE FOSSIL RECORD: A CASE STUDY IN NORTH AMERICAN RODENTS

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Diversity gradients record changes in biological diversity and are often driven by geographic and environmental variables. In particular, species richness has been shown to correlate closely with various climatic and topographic factors in modern assemblages, which is apparent across taxonomic groups, geographic settings, and time periods. Much of the study of biological gradients is centered around taxonomic species richness. However, diversity is made up of many attributes beyond taxonomic, including genetic, ecological, and morphological aspects, which can reveal important insights about the processes that drive the spatial distribution of diversity. In this study, we explore the relationship between taxonomic diversity, morphological diversity, and latitude, along with indicators of climate and topographic complexity to discern the roles that these variables play in the distribution of modern biodiversity. We do this by investigating the distribution of species richness, body mass, and morphological diversity in extant rodents at 10,000 equidistant sampling points across North America. We examine the relationship between these biodiversity measures and mean annual temperature, annual precipitation, altitude (a proxy for topographic relief), and latitude. We find that the strongest correlations lie between species richness and mean annual temperature, as well as between species richness and altitude. Weaker yet statistically significant correlations exist between both morphological diversity with mean annual temperature and average body mass with mean annual temperature. Notably, the removal of localities with the smallest average body masses considerably strengthens the relationship between body mass and the climatic variables, suggesting that sites with small average body sizes may be driven by separate processes. Furthermore, we make comparisons to Miocene-aged fossil occurrences and determine whether these same relationships exist in the deep past. Our findings suggest that when compared to taxonomic richness, body mass and morphological disparity have a weaker relationship with climatic and topographic variables. This result is consistent with past findings that taxonomic diversity may be driven by distinct processes from morphological diversity, and that these two aspects of diversity may respond differently to environmental change.

## HYDRODYNAMIC INSIGHTS INTO THE PALAEOBIOLOGY OF THE EDIACARAN RANGEOMORPH *FRACTOFUSUS MISRAI*

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The Ediacaran of Newfoundland preserves some of the oldest complex macroscopic communities several of which are dominated by the fractal-like rangeomorph genus *Fractofusus*. Here we use computational fluid dynamics and a detailed reconstruction of *Fractofusus misrai* to document hydrodynamic phenomena associated with this sediment-reclining organism that: are relevant to interpreting feeding strategies; explain the recently documented rheotropic growth oblique to currents; and provide insights into their impact on the Ediacaran seafloor. Obliquely oriented *Fractofusus* are common, probably representing a compromise between maximized aspect ratio and minimization of drag. We document a long wake in the lee of *Fractofusus*, demonstrating for the first time that reclining Rangeomorpha had potential to modify sedimentation patterns on the ancient seafloor possibly serving as ecosystem engineers. Flow patterns on the upper surface of *Fractofusus* are consistent with the collection of dissolved organic matter as well as gas exchange.

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## THE ASAPHID TRILOBITE GENERA *TRIGONOCERCA* AND *TRIGONOCERCELLA* FROM THE EARLY ORDOVICIAN OF THE GREAT BASIN, WESTERN U.S.A.

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Asaphidae Burmeister, 1845 is the most species-rich trilobite family of the Ordovician, with 146 genera and 754 species described. The family is characterized by an hourglass shaped cranidium, a relatively dorsoventrally flattened cephalon and pygidium, the presence of eight thoracic segments, a sub-triangular pygidium, and a forked hypostome. Despite its great diversity, asaphid taxonomy is among the least understood of all post-Cambrian trilobites. Taxonomic problems stem from the effaced dorsal features and the conservative body plan of the group. The asaphid genera *Trigonocerca* Ross, 1951 and *Trigonocercella* Hintze 1953 are known from the Early Ordovician of the Great Basin. Both genera are found in the Pogonip Group, in the Ibex area (western Utah). However, no taxonomic work has been done on these asaphids since the original work on the sections in the 1950s. The diagnoses of *Trigonocerca* and *Trigonocercella* species are challenging, owing the subtle morphological characters that differentiate

them. The species *Trigonocerca typica* Ross, 1951exemplifies problems with species diagnoses in either genera genera. In the past, *T. typica* defined the base of the Blackhillsian Stage (Floian), however recent studies proved the misidentification of the species and its stratigraphic range. In order to understand the diversity and the stratigraphic range of both genera, a reassessment of *Trigonocerca* and *Trigonocercella* is needed. New silicified material provides new information about the dorsal and ventral morphology necessary to provide an accurate diagnosis of each species. Here a taxonomic study of *Trigonocerca* and *Trigonocercella* is carried out using new material sampled from the Ibex area. As a preliminary result, three *Trigonocerca* and two *Trigonocercella* species are defined: *Trigonocerca typica* (Tulean), *Trigonocerca vasta* n. sp. (Blackhillsian), *Trigoncerca piochensis* Hintze, 1953 (Blackhillsian), *Trigonocercella acuta* Hintze, 1953 (Blackhillsian) and *Trigonocercella obtusa* n. sp. (Blackhillsian). In addition, older material (*Heckethornia bowiei* Zone, Tulean) displays several morphological differences with the younger species (e.g., pre-occipital node, shape of the hypostome, outline of the pygidium, definition of the axial furrow in the pygidium, posterior pygidial spine). The morphological evidence suggests that this new species from the *Heckethornia bowiei* Zone belongs to a new genus closely related to *Trigonocerca* and *Trigonocercella*.

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## PALEOENVIRONMENTAL RECONSTRUCTION OF A SUBAQUATIC CAVE IN WESTERN CUBA CONTAINING EXTINCT SLOTH REMAINS

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Submerged caves are potentially rich but relatively untapped sources of paleontological, paleoenvironmental, and archaeological data. The purpose of this study is to undertake a paleohydrological and paleoecological reconstruction of an underwater cave, Cueva Chicharrones, in Matanzas, Cuba, containing the fossilized remains of at least three extinct sloths. Technical cave divers collected sediment cores from within the cave, which were studied for grain size, seeds, ostracods, and pollen, and which were dated by radiocarbon and luminescence methods. The chronology of the sediments and the resulting paleohydrological reconstruction, based on the interpretation of the sedimentary facies, help to constrain the timing of water level changes in the cave, which appear to be driven by a combination of relative sea level and regional climatic variability. Specifically, the results indicate that the cave was likely dry prior to 7000 cal yr BP, and was flooded by 6500 cal yr BP (a time consistent with humid conditions in much of the northern Caribbean). Then, water levels decreased between 6500 and 2000 cal yr BP, when regional climate was drier, and increased around 1000 cal yr BP, due to a shift to a more humid climate. The seeds found in some of the cores consist of the genera *Ficus*, *Cecropia*, and *Solanum* and may have been deposited by frugivorous bats, although the possibility of transport by storm water cannot be ruled out. The pollen data are consistent with the information derived from the seeds, and indicate that pollen spectra variability was probably driven by changes in water level, environmental and climatic conditions, and possibly bat activity. This study is the first of its kind from a submerged cave in Cuba and highlights the potential of underwater caves as archives of regional paleoclimatic and relative sea level data. In addition, given the presence of abundant vertebrate fossils present in the cave, our work will provide important context for the study of these remains and help inform on Caribbean paleoecology and paleontology.

## EXPLORING THE STABILIZING POTENTIAL OF AMMONOID CONCH ORNAMENTATION WITH 3D PRINTING, 3D MOTION TRACKING, AND PARTICLE IMAGE VELOCIMETRY

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Many shell-bearing organisms underwent morphological changes during the Mesozoic Marine Revolution. During this time, various taxa experienced escalation, demonstrating patterns of increasing shell thickness and other anti-predatory features (i.e., ornamentation intensity). Ammonoid cephalopods display a remarkable variety of ornamentation patterns, which have been documented to increase in coarseness throughout the Mesozoic. However, most of these patterns lack a clear defensive role. Alternatively, these patterns could have had fundamental consequences for the swimming capabilities of these near-neutrally buoyant animals. We explored the hydromechanical properties of conch ornamentation using theoretical morphologies falling on a continuum of increasing

coarseness. These virtual models were 3D-printed with an adjustable buoyancy chamber and counterweight system, allowing the buoyancy and mass distribution of their living counterparts to be matched. Therefore, these models behave as the living animals in water and experience the same restoring torques when rotated away from their equilibrium orientations. Three-dimensional motion tracking reveals that coarser ornamentation patterns substantially attenuate rocking compared to fine or smooth patterns. The physical mechanisms for this trend were explored with Particle Image Velocimetry (PIV), an optical measurement technique used to visualize and quantify fluid flow velocities. This technique involves illuminating particles within the fluid with a laser sheet and capturing images to analyze their displacement over time, providing detailed insights into the fluid's motion characteristics. The smooth model shears the proximal fluid, causing it to travel in the direction of rocking. In contrast, coarser ornamentation disrupts the direction of the sheared fluid while shedding vortical structures that reverse direction and destructively interact. The fluid dynamics that attenuate rocking motion would have had important implications for the life habits and ecological roles of ammonoid cephalopods. Coarser ornamentation patterns are found more often in a region of their morphospace with moderate to low hydrostatic stability. Therefore, a hydrodynamic stability mechanism offered by second-order conch features (ornamentation) could have compensated for the physical attributes of first-order conch coiling. This higher hydrodynamic stability would have counteracted the rocking produced by jetting, improving directional motility. We also use computational fluid dynamics simulations to explore the hydrodynamic influence of conch ornamentation during linear movement. Our experiments demonstrate that ammonoid conch disparity during the Mesozoic may represent complex adaptive compromises between several hydromechanical factors, among others.

## ISOTOPIC SIGNATURES OF PALEOPHYSIOLOGY—A TOOL FOR PALEONTOLOGISTS?

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Bivalve fossils are ubiquitous in the rock record and are used in a myriad of ways, both paleontological and paleoclimatological, to better understand the ancient world. Extinct species are defined primarily by the shape of key shell features and how these vary over time and space. Although form alone can reveal a surprising amount of information about the lifestyle of an organism, the lack of preservation of soft tissues in the rock record hampers interpretations of paleophysiology. Here we propose a new way of looking at the isotopic composition of bivalve shell carbonate that can reveal information about internal body processes and mechanisms of shell formation. Bivalves grow their shells in 2-3 layers whose isotopic compositions can differ—the outer layers grow from the outer extrapallial fluid which usually approximates surrounding seawater, and the inner layer grows from the inner extrapallial fluid which is seawater modified by body processes. Differences in the stable ($\delta^{18}O$, $\delta^{13}C$) and clumped ($\Delta_{47}$, $\Delta_{48}$) isotopic compositions of the inner and outer layers, which we term biologically-driven isotopic fractionations (BioDIFs), are therefore a manifestation of these body processes. We have documented BioDIFs of varying magnitude and direction in an array of modern and fossil species and have linked certain signatures with hypothetical precipitation mechanisms. In this talk, we will present these modern and fossil studies, share what we have learned so far about how certain signatures are conserved across species, genera, environments, and geologic intervals. We will paint an (admittedly optimistic) picture of how BioDIFs could be used by paleontologists to explore evolutionary relationships and individual species traits in the Cenozoic and Mesozoic at least, as well as teach us about precipitation mechanisms employed by modern species.

## MORPHOSPACE OCCUPATION AND BIOMECHANICAL PERFORMANCE OF THE PERIGNATHIC GIRDLE IN JAWED ECHINOIDS

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Anatomical structures and behaviors associated with feeding strategies are strongly acted upon by selective pressures, as these morphologies interact directly with an organism's environment and have significant influence on fitness and survival. Innovations in feeding structures and associated feeding behaviors have been suggested to underlie major adaptive radiations and expansion into new niche spaces across several different clades. In addition to establishing occupation and evolution through morphospace of feeding structures, the associated biomechanical performance of these structures can be quantified for a more holistic exploration of evolution across adaptive landscapes. Here, we present a preliminary analysis of the morpho-functional landscape of the perignathic girdle, the skeletal support structure of the jaw apparatus in crown group jawed echinoids. We implement 3D geometric morphometric techniques, using a combination of anatomical landmarks and surface semi-landmarks, to explore phylo-morphospace of taxonomically and ecologically distinct girdle shapes. We compare biomechanical performance using the distribution of stress along different girdle shapes resulting from simulated applied muscle forces using finite element methods. Finally, we explore ecological breadth of echinoid groups as related to the biomechanical performance of their perignathic girdle shape. We demonstrate notable differences in distribution of

stress among girdle shapes and find convergence of girdle morphology in phylogenetically distinct lineages. Weak trends are observed with girdle biomechanical performance and ecological breadth, with 'weaker' girdles associated with echinoids that are more environmentally restricted. Results from this pilot dataset highlight the need for a continued comprehensive exploration of the role of perignathic girdle evolution, function, and performance in the post-Paleozoic evolution of crown group echinoids.

## INCORPORATING LOCAL COMMUNITY PRIORITIES INTO CONSERVATION PALEOBIOLOGY RESEARCH: A CASE STUDY IN VELONDRIAKE, SOUTHWEST MADAGASCAR

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In Madagascar, three of six endemic baobab tree species (genus *Adansonia*) are classified by the IUCN as Endangered or Near Threatened, with almost all species experiencing population declines. The extinctions and extirpations of these keystone species will be to the detriment of other inhabitants of Malagasy dry forest ecosystems as well as the communities that rely on these trees for various resources. Thus, it is critical to identify and address issues that hinder baobab seed dispersal and subsequent seedling establishment. In this study, we used Accelerator Mass Spectrometry (AMS) radiocarbon dating and baobab age estimation models to determine when past periods of poor baobab seedling survival occurred across Velondriake, Southwest Madagascar, to temporally correlate intervals of poor baobab recruitment with potential contributing factors (e.g., periods of socio-political turmoil that greatly restrict human landscape mobility). Crucially, this study's research questions and priorities were developed in collaboration with local community members in Velondriake. In this presentation, we will focus on the challenges and successes of our ongoing collaboration—including but not limited to power imbalances that exist as legacies of scientific colonialism; the value assigned to "personal communications" from a non-scientist by peer-reviewed journals and more broadly, academic communities; and mismatches between the slower speed of research and the immediate desire of the community for conservation. Finally, we urge future researchers to further advance the field of conservation paleobiology by creating interdisciplinary research teams and by including local communities in research design from project conception.

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## STORYTELLING WITH THE PAST AS A PERSUASIVE TOOL FOR CONSERVATION

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Storytelling is a powerful tool used by conservation scientists to engage with diverse audiences. Stories can persuade individuals and communities to adopt specific beliefs or behaviors by establishing mental imagery and an emotional connection. Here, we argue that conservation storytelling can be more persuasive when longer-term perspectives from geohistorical records—such as sediment cores and fossils—are incorporated. By restoring one's environmental memory, the past can provide richer context, which may help avoid a shifted baseline mindset and motivate both individuals and communities towards achieving specific conservation goals. Although persuasion requires several ethical considerations, collaboration with local stakeholders and practicing reflexivity throughout the strategic communication process can produce a compelling story that maintains a storyteller's credibility and trust. Conservation paleobiology has focused largely on enhancing modern conservation by providing policy-relevant specimens and datasets, but there is also untapped potential in the stories our science reveals that have yet to be told.

## A COMBINED STRATIGRAPHIC AND ICHNOLOGICAL APPROACH TO RECONSTRUCTING THE EVOLUTION OF THE SEDIMENTARY MIXED LAYER IN THE DEVONIAN OF THE APPALACHIAN BASIN

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Burrowing and sediment-mixing animals—bioturbators—are today one of the foremost groups of ecosystem engineers, whose activities strongly shape surrounding ecosystems and environments. Intense sediment mixing by bioturbating

organisms produces the sedimentary mixed layer, which in modern oceans consists of, on average, ten centimeters of fluid-rich, homogenized sediments. Previous work has revealed that the development of a deep mixed layer lagged significantly behind the rise of other forms of bioturbation, and that mixed layer depths remained well below those of modern oceans through at least the Silurian. The advent of modern-style sediment mixing in ancient oceans would have substantially shaped the biological and chemical character of the seafloor, increasing infaunal tiering, shifting epifaunal community composition, and changing nutrient cycling; thus, constraining the evolutionary development of the sedimentary mixed layer is critical to deciphering the ecological and environmental changes brought about by intensifying bioturbation. Here we present a field- and core-based stratigraphic exploration of bioturbation intensity in Devonian and Carboniferous successions of the Appalachian Basin. Our focus on this interval provides a window into the relationship between the sedimentary mixed layer, bioturbation intensity, and the diversification of "biological bulldozers," deposit-feeding animals that are among the most efficient and extensive bioturbators in modern oceans. Fifteen outcrops and three cores from the northern and central Appalachian Basin were sampled for this study, comprising fourteen sedimentary units ranging in age from Lower Devonian to Mississippian and including ~350 meters of strata logged at the centimeter to decimeter scale. Devonian sedimentary units throughout the Appalachian Basin are generally characterized by intensive bedding plane-parallel bioturbation, with abundant and diverse horizontal trace fossil assemblages reaching centimeter-scale diameters. High-fidelity preservation of many of these traces suggest that seafloor sediments were commonly firm at the depth of burrow emplacement. Despite the presence of centimeter-deep vertical burrows and high ichnofabric index (ii) values in some beds, ii was low on average and vertical burrowing relatively sparse. Additionally, thin sandstone event beds are commonly preserved in many of these Devonian units, implying a lack of intensive mixing that would have homogenized bed junctions. We observe these trends during background (non-extinction) time intervals containing normal marine conditions. These data suggest that despite proposed Devonian radiations in bulldozing taxa, mixed layer depths in a range of shallow marine settings of the Appalachian Basin remained relatively shallow during this interval, with implications for our understanding of middle Paleozoic seafloor ecology and geochemistry.

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## CRETACEOUS MICROBIAL ACTIVITY PRESERVED IN THE CARBON STABLE ISOTOPE COMPOSITIONS OF HERBIVOROUS DINOSAUR COPROLITES

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Fossilized feces, or coprolites, provide unique records of the diets of extinct organisms and offer the opportunity to investigate the role of microbes in the utilization and fossilization of fecal material. Previous studies have analyzed $\delta^{13}C$ stable isotopes of organic matter in coprolites, but few studies have focused on coprolite carbonate $\delta^{13}C$ and the role of microbes in these recorded isotopic signatures. This study focuses on the $\delta^{13}C$ in two coeval Cretaceous assemblages of calcareous herbivorous dinosaur coprolites with similar contents; one from the Two Medicine Formation of Montana and another from the Kaiparowits Formation of Utah. We found that while $\delta^{13}C$ values of organic carbon in kerogen extracted from the coprolites are consistent with tissues from plants with C3 photosynthesis, carbonate $\delta^{13}C$ values in these specimens are highly variable depending upon where carbonate was sampled in the heterogeneous coprolites. These variable values likely reflect differences in rates of microbial metabolism. The obtained carbonate $\delta^{13}C$ values were used to estimate microbial respiration rates recorded during the coprolite mineralization process using a paleosol carbonate formation model adapted from Cerling (1984). To provide baseline estimates of microbial respiration rates in coeval paleosols, we used our adapted model to interpret $\delta^{13}C$ values of paleosols from previous studies. The estimated microbial respiration rates from the coprolite carbonate $\delta^{13}C$ values were generally higher than the rates of coeval paleosol carbonates interpreted through our model. Furthermore, the estimated microbial respiration rates in the coprolites overlapped with the range of modern fecal respiration rates found in the literature. This suggests that the coprolite $\delta^{13}C$ values capture ancient fecal respiration rates that are comparable to those in modern feces, indicating significant microbial activity and $CO_2$ production. As such, this study supports that microbes likely provided a major $CO_2$ source that was incorporated into calcium carbonate during the mineralization of the feces. Moreover, the variable $\delta^{13}C$ values could reflect differences in the susceptibility of different organic materials to microbial degradation. This work demonstrates that $\delta^{13}C$ analysis of coprolite carbonates offers a novel way to study ancient fecal microbiomes and diagenesis. This approach is currently underutilized in coprolite research and can provide informative value beyond what organic matter $\delta^{13}C$ analysis of coprolites can tell us about ancient diets.

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## NO MORE MONKEYS JUMPING INTO THE BED: FIRST ORDER CONTROLS ON THE FOSSIL RECORD OF PRIMATES

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Severe data comparison issues make it difficult to contrast the ongoing Sixth Extinction with extinctions in the geologic record. The approach adopted here is to predict what the modern biota will look like in the far future. There are currently 522 species of primates, comprising 8.7% of mammal species. Of the primate species, 235 are in the highest threat categories of the IUCN. Integrating data from paleontological databases with information on ecology, biogeography, and life history characteristics of contemporary primates, demonstrates strong taphonomic biases related to taxonomy, body size, range, habitat, and geography. Only about 11% (58) of living primate species have a Quaternary fossil record, including just 27 of the most threatened. Hominidae are well-represented, probably due to intense investigator interest, comprising 43% of primate occurrences. The Neotropical record is particularly poor, with only four of the 179 species of extant Ceboidea (New World monkeys) being found as fossils (12 occurrences). In contrast, 27 of 160 species of Cercopithecoidea (Old World monkeys) are in the record, with 359 occurrences (46% of all primate occurrences). Species of primates found as fossils have significantly larger body mass, range area, and habitat breadth than those that are not. Primates living in forest habitats are greatly underrepresented, while those occurring in areas with human disturbance are overrepresented. A major first order control is the presence of caves and other karst sites, with 62% of Quaternary mammals being found in karst sites. The lack of primate fossils in South America may be largely due to the sparse distribution of karst. The erosion of karst over time implies a large lost primate fossil record.

## THE LATE PLEISTOCENE FOSSILS OF THE WOLF (*CANIS* SP.)

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Descriptions of a mummified remains of the head and part of the neck of a wolf (*Canis* sp.), found in August 2018 on the bank of the Tirekhtyakh River (Yakutia), are given. The preservation of the find (soft tissues, hair, muscle tissue, and skin) allows us to determine the color of the hair and its length in different parts of the head and neck. In addition, it was possible to measure the skull without violating the integrity of the object and while maintaining its attractiveness using computed tomography and 3D visualization programs. According to the results of our research, the separation of the head from the body occurred under the influence of permafrost. No traces of the influence of an ancient person or any animal on the sample were found. Judging by the size and degree of abrasion of the exposed teeth, as well as by the ratio of the total width and the width of the pulp cavity of the upper canine, the individual age of the studied sample is from 1 to 1.5 years. The absolute age of the find corresponds to the Karginskii time of the Late Pleistocene.

## CHANGES IN ABYSSAL BENTHIC FORAMINIFERAL ASSEMBLAGES IN THE WESTERN NORTH ATLANTIC DURING THE LAST 3 MILLION YEARS (BERMUDA RISE, ODP SITE 1063)

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We examined benthic foraminifera assemblages in sediments deposited during the last 3 million years at ODP Site 1063 on the northeastern flank of the Bermuda Rise (4,600 m) to identify long-term paleoenvironmental changes in this part of the North Atlantic. The rise is a sediment drift produced by advection of clay and silt by deep recirculating gyres, which supply terrigenous material from northern sources and result in high sedimentation rates (up to 200 cm/k.y.). Based on the benthic foraminiferal faunas, it is possible to propose a subdivision of the recovered succession into three main intervals, with boundaries that correlate with significant climatic changes. The upper interval (A), from the top of the well to approximately 150–160 mcd, corresponds to the late Pleistocene and is characterized by a high frequency of *Epistominella exigua* as well as marked variations in the benthic assemblage correlated with the large glacial-interglacial cycles that characterize this time interval. Interval B, between approximately 160 and 320 mcd (Late Pliocene and early Pleistocene), is marked by the abundant presence of *O. umbonatus* and *N. umbonifera*, along with *G. subglobosa*. Interval C, between approximately 320 mcd and the well's bottom (Middle to Upper Pliocene, between ca. 3.4 and 2.0 Ma), is characterized by a lower content of benthic foraminifera which are poorly preserved. *N. umbonifera* dominates the associations. Two intense dissolution events were identified at approximately 175 meters below sea level (around 0.9 Ma) and around 0.4 Ma.

## THE ASSEMBLY OF NEW WORLD CAT COMMUNITIES: ECOMETRICS AND NEOGENE LOCOMOTOR TRAIT TURNOVER

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Felids possess some of the highest ankle gear ratios of extant Carnivora, which facilitates leaping, sprinting, ambush predation, and scansorial lifestyles. In today's North American carnivoran communities, the high gear ratio of cats contributes to an overall high ecometric average for this trait and contributes strongly to ecometric disparity in local communities. But felids were late additions arriving from Eurasia about 17 Ma at the end of the "cat gap." Today's carnivorans have ankle gear ratios that range from 1.08 in ursids to 1.46 in felids. When cats first entered North American communities in the Miocene they did not occupy high gear ratio niches and, in fact, occupied some of the lowest gear ratio niches during the Barstovian, Clarendonian, and Hemphillian. A major restructuring of gear ratio distributions in North American carnivoran communities occurred during the Blancan that appears to have resulted from clade sorting processes involving the selective loss of low gear ratio groups, favoring high gear ratio subclades in both Felidae and Canidae. Subsequent evolution within these clades produced the high gear ratios that are found in felids today, indicating that the specialized leaping (and possibly extreme scansorial or ambush behaviors) are largely a Quaternary phenomenon.

## HOOKING ELEMENTARY STUDENTS INTO A LOVE OF SCIENCE WITH FOSSILS

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Elementary teachers are trained to be "experts" in all science topics covered in grades one through six, with only one course of science teacher preparation during undergraduate training. Teacher preparation classes focus on the teaching strategies and processes and do not go into depth in any one content area. Many teachers find themselves with a cursory overview of all topics in science and lack the content knowledge to deliver meaningful instruction. This talk will discuss a 3rd-grade teacher's quest to bring meaningful and hands-on experiences to her elementary students as well as educate herself in the field of paleontology. From creating their own "fossils," 3D printing replicas, virtual visits, sharing actual fossils, "racing" dinosaurs and searching real matrix, students are transported into the field, enriching the textbook instruction and inspiring the next generation of paleontologists with meaningful experiences. These activities provide elementary students the ability to master three of the third grade Next Generation Science Standards (NGSS): "Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago (3-LS4-1), Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all (3-LS4-3), and Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change (3-LS4-4)." End-of-unit assessments indicate students have mastered the content core concepts, but the true outcomes are immeasurable: positive attitude, appreciation and curiosity. Even the students who do not wish to pursue a career in science develop a new appreciation for the work involved in collecting and preparing specimens for all to enjoy in museums, and are inspired to become community scientists themselves.

## SCANNING ELECTRON MICROSCOPE INVESTIGATION INTO THE PRESERVATION OF THE "TULLY MONSTER"

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The Tully Monster, *Tullimonstrum gregarium*, is an extinct animal known only from the ~308.6 Mazon Creek Fossil site in Illinois, U.S.A. The fossilization processes at the Mazon Creek are complex and not yet fully understood. Here we use a scanning electron microscope (SEM) equipped with an energy-dispersive X-Ray spectrometer (EDS) for imaging and elemental analysis of the tissue preservation of 17 Tully Monster fossils from the Field Museum of Natural History. All specimens have exceptional 3D preservation of the eyebar and related morphological features. This study confirms previous results that oblate and cylindrical melanosomes, arranged in distinct layers, are ubiquitous within well-preserved, dark-colored eyes. Both morphologies of melanosomes have a carbon signature consistent with melanin preservation. Well-preserved eyes also commonly have lenses visible as white or light-colored circles which, based on backscatter images of mineral structures and EDS element maps, are preserved in kaolinite. The texture of the body is largely indistinguishable from that of the concretion itselfnd both appear as a mixture of small siderite crystals and small clay particles under SEM. However, small (~10 μm) patches of amorphous carbon are fairly common in all body regions, either embedded or partially embedded in the siderite matrix; similar carbon patches were not observed outside the body in the concretion itself. In addition, some of the more robust features (with 3D preservation) of the Tully Monster contain small (0.05–50 μm in size) grains with an elemental composition dominated by phosphorus and calcium. Some of the larger phosphorous and calcium pieces have a texture characteristic of cartilage, supporting the previous interpretation that the eybar and 3D preserved features in the Tully Monster reflect originally tough cartilaginous composition. The 3D structures also contained accumulations of a bladed mineral in several of the fossils imaged for this study. These areas are distinct from the matrix under backscatter electron imaging (BSE) and are strongly

associated with a calcium elemental signature, suggesting they may be bladed calcite. Their bladed form appears to be recrystallized, and these regions also have an associated carbon signal when analyzed with EDS. Collectively, these findings provide more insight into the Tully Monster's anatomy and preservation while also providing support for previous studies on the Tully Monster's anatomy and biochemical preservation.

## A NEW CARNIVORAMORPHAN FROM THE EOCENE FRIARS FORMATION OF SOUTHERN CALIFORNIA

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The early evolution of carnivoramorphans during the Eocene represents a watershed moment in mammalian evolution, which influenced the structuring of mammalian communities in subsequent epochs. A better understanding of the diversity and ecosystem roles of stem-carnivorans is important to reconstructing the ecosystem structure of Paleogene terrestrial communities in the North Hemisphere and the origin of living Carnivora. The dynamically shifting middle Eocene biosphere, with changing global temperatures and regionally widespread alterations in tree-cover and faunal composition, including the first appearances of crown Carnivora, makes this a key period in the Eocene–Oligocene biotic transition. We report a new genus of non-carnivoran carnivoramorphan from the middle Eocene of San Diego, California, which adds to this growing body of knowledge. The new fossil, SDSNH 49600, was discovered by paleontologist Bradford Riney during mitigation work in the middle Eocene (early Uintan age) Friars Formation. Three to five million years older than other carnivoramorphan-containing rock units in southern California, the Friars Fm. provides context for the better sampled late Uintan-to-Duchesnean faunas. SDSNH 49600 comprises a skull with largely complete dentition, cervical vertebrae, including atlas and axis, and metapodials. Compared to those of earlier carnivoramorphans, the dentition of this short-snouted, roughly raccoon-sized carnivore is characterized by robust premolars and reduced molar grinding surfaces that suggests a mesocarnivorous diet. Preliminary phylogenetic analysis of 47 carnivoramorphans, including both stem and early crown Carnivora, resulted in the placement of SDSNH 49600 outside the crown group, and as the earliest diverging member of a clade containing five other middle Eocene taxa, including *Neovulpavus*. Although this is a primarily North American clade, it contains "*Miacis*" *lushiensis* from China, augmenting the growing evidence for substantial circum-Pacific interchange between Asian and North American mammalian carnivore assemblages during the middle Eocene. The recognition of a new mid-sized, mesocarnivorous carnivoramorphan strengthens the gradual middle-Eocene trend of increasing carnivory among North American carnivoramorphans and contributes to clarifying the geographic tapestry of early carnivoramorphan evolution.

## BALANCING TRADE-OFFS IN SALIENCY, CREDIBILITY, AND LEGITIMACY IN CONSERVATION PALEOBIOLOGY: A CASE STUDY FROM LONG ISLAND SOUND

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Integrating geohistorical data into conservation management is a challenge, particularly as researchers often lack the training to navigate the boundary between science and management. Facilitating effective interactions between researchers and resource managers requires developing and maintaining three key attributes: credibility (scientific quality and validity), saliency (relevance and timeliness to management needs), and legitimacy (fairness and transparency). However, maintaining the appropriate balance between these attributes may necessitate trade-offs. In this presentation, we explore trade-offs, such as the complexity-clarity trade-off—communicating uncertainty versus simple and concise messages—and the speed-quality trade-off—timely results versus exhaustive quality assessments—using our work on constructing geohistorical baselines of ecological quality in Long Island Sound, NY, CT in support of the Sound's Comprehensive Conservation Management Plan. We share our lessons learned from interacting with local managers and provide advice for facilitating effective interactions.

## MORPHOMETRICS OF CONOSTICHOID BURROWS WITH BIOCLASTIC INFILL FROM THE SILURIAN OF SOUTHERN INDIANA

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The plug-shaped burrow *Conostichus* is well-studied from siliciclastic facies, being characterized by longitudinal constrictions and an apical disk with 12 lobes. However, little is known about the morphology of *Conostichus* and similar (conostichoid) burrows in settings where fine siliciclastic

sediment is not the primary infilling material. Herein, we describe the results of morphometric analysis of conostichoid burrows from the middle Silurian (Wenlock: Sheinwoodian) Massie Formation of southeastern Indiana that were passively infilled with bioclastic sediments. A sample of 200 burrows was collected and 11 measurements were collected for each specimen, including maximum and minimum dimensions of the upper conical region and the apical disk; degree of eccentricity (ovality) of the upper region and apical disk, and ratios between these values; maximum thickness; maximum and minimum steepness of walls; and degree of asymmetry in wall steepness. Univariate analyses show that burrows are variable in size but very weakly ovoid in both the upper and apical regions, with similar values of eccentricity between the upper and apical portions of the burrow. The sample shows weak asymmetry with respect to wall steepness. Bivariate analyses show that burrow depth is the attribute that correlates with other properties most strongly: it shows an unsurprising positive relationship with maximum widths of both the upper and apical regions and a negative relationship with wall asymmetry. Other bivariate data show that, in general, larger burrows tend to be more symmetrical, both with respect to upper and apical dimensions and vertical wall angles. In contrast, the smaller burrows display greater variability and are more asymmetrical in both plan and cross-sectional views. It is probable that smaller tracemakers (most likely solitary polypoid cnidarians) were more strongly affected and/or had their burrows more strongly modified by surficial phenomena such as current strength and direction, and may have initially constructed non-vertical burrows. Larger burrows are more idealized and symmetrical, more accurately reflecting the shape and preferred orientation of the tracemaking organism. Future work will focus on comparisons between these patterns and those collected from burrows associated with other infilling materials, including siliciclastic and micritic sediments.

## BRINGING THE HERMIT OUT OF HIDING: A REINVESTIGATION OF THE PERMIAN HERMIT FLORA IN GRAND CANYON NATIONAL PARK AFTER NEARLY A CENTURY IN OBSCURITY

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The early Permian Hermit Formation bears abundant plant fossils, tetrapod tracks, and invertebrate burrows, as well as rare meganisopterid wings, and is a significant paleontological resource in Grand Canyon National Park (GRCA), AZ, U.S.A. One of few paleobotanical studies of the Hermit is the 1929 David White monograph that describes the composition of the floral assemblage and its depositional environment. White assigned the specimens to 35 species, including 3 novel genera and 25 novel species. Later reclassifications suggested that White over-split the taxa in this deposit, but a thorough reevaluation is long overdue. Herein, we present our ongoing reinvestigation of the flora and depositional environment of the Hermit Fm. We imaged and measured specimens from White's original collections at the Smithsonian National Museum of Natural History and other specimens at the GRCA Museum Collection and the Museum of Northern Arizona. Stratigraphic sections were measured in GRCA, and multiple unpublished sections from GRCA archives were geolocated and drafted. Detrital zircon samples were collected from the top of the underlying Esplanade Sandstone, throughout the Hermit Fm., and the base of the overlying Coconino Sandstone for laser ablation inductively coupled plasma mass spectrometry and isotope dilution thermal ionization mass spectrometry. Several new fossiliferous localities were discovered in GRCA and ~300 additional plant fossils were documented, including multiple *in-situ* specimens. The Hermit flora exhibits low diversity, dominated by pteridosperms (*Supaia* and callipterids) and walchian conifers, with lesser *Sphenophyllum* and rare Taeniopterid elements. Plants are preserved as impressions in red-brown siltstone to very fine-grained sandstone in association with tetrapod tracks, invertebrate burrows, mud cracks, and *Rivularites*. Fossils are restricted to the lowermost strata of the Hermit Fm. and are typically concentrated in paleovalleys carved into the underlying unit. Organic material is generally absent, although scanning electron microscopy has revealed the presence of carbonaceous flecks in one pteridosperm. Hitherto unknown is that the Hermit flora is remarkable for its record of the 3D structure of the plants preserved upright, and in life position. *Supaia* fronds attached to branches and vertical in-situ *Sphenophyllum* specimens exposed in cross-section shed new light on the architecture of these taxa and their density. We interpret the depositional environment as an arid low-gradient fluvial system, as evidenced by the stratigraphy and floral assemblage. The Hermit Fm. is the western-most Permian tropical flora of Pangea and fits the trend shown by other floras of increasing aridity to the west. Additionally, the mixing of xeromorphic taxa (*Supaia*, walchian conifers) and hydromorphic taxa (*Sphenophyllum*) is in line with recent studies implicating a climate-based floral model over the classic upland vs. lowland model.

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## DEVELOPMENT OF A HIGH-THROUGHPUT FOSSIL POLLEN ANALYSIS PIPELINE

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The open-world describes uncontrolled operational environments in machine learning. It stands in contrast to classic supervised learning, where all the test classes are known and have been introduced in training. Fossil pollen analysis represents a paleontological example of an open-world problem. Specimens often represent new, undiscovered species. Abundances naturally follow a long-tailed distribution, so many taxa are rare and training examples are consequently unbalanced. Images of the same taxon can vary widely, depending on the microscope, magnification, orientation, degree of preservation, and imaging or preparation techniques. Developing machine learning models that can generalize across the range of variability in pollen diversity, abundance, preservation, preparation, and imaging requires adopting workflows that can succeed in open-world environments. The first step in an automated fossil pollen analysis is the accurate, consistent detection of pollen on a microscope slide. Palynological material can be imaged quickly and efficiently with slide scanning microscopes. These scans capture the entirety of a pollen slide—both the area of a coverslip and multiple focal planes—producing a fully three-dimensional representation of the pollen sample with a full complement of morphological detail for classification. However, pollen specimens need to be detected within these scans and set apart from other organic debris. We use ResNet34 architecture as the backbone of our detection model and build a decoder on top of this backbone. The addition of the decoder configured the output from the model as a detection map, with each pixel approximating a confidence score for predicted pollen detection. We next cluster pollen detection results using semi-supervised and transfer learning approaches. This allows us to efficiently produce training and validation data for pollen classification models. We experiment with k-means clustering and continual learning to fine-tune supervised models previously trained on pollen specimens from modern reference material and airborne pollen traps. Experts are then able to vet and label clusters to provide feedback for further fine-tuning of the detection model and the construction of classification models. Developing fully automated detection pipelines requires adapting models to the uncertainties inherent to open-world problems. By incorporating fine-tuning and continual learning with expert feedback, we are developing robust, generalized detection models that can be applied to a wide range of palynomorphs collected from microscope images.

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## THE SIWALIK GROUP RECORD AND THE EXPANSION OF $C_4$ VEGETATION IN THE MIOCENE

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It was 35 years ago this year (2024) that the evidence for a dramatic late Miocene expansion of C4 vegetation was first published. This evidence first came from the carbon isotopic values of carbonates and organic matter recorded in buried paleosols of Siwalik Group sediments spectacularly exposed in the Himalayan foreland of northern Pakistan. Subsequent research showed the late Miocene C4 expansion to be global through the low to middle latitudes and not just local. This required global explanations such as a drop in atmospheric $pCO_2$ (which favors C4 metabolism in plants) or global aridification, but the exact cause is still debated. The oxygen isotopic composition of paleosol carbonates also increased in the late Miocene across the northern Indian sub-continent, in probable concert with several indicators of increasing aridity. How this change in climate may have affected the rise of C4 plants is also still unclear. The conversion of floodplain vegetation from C3 plants (forest?) to C4 grasses occurred over 4 Ma (~8–4 Ma), with mixed contemporaneous habitats recorded in pedogenic carbonates during this transition. This vegetation change had a profound impact on ecosystem dynamics and fauna. Fire frequency apparently increased, and a major turnover among floodplain dwelling mammals at this time was accompanied near complete shift to C4 diet. The increase of C4 plant biomass also altered the carbon isotopic composition of riverine aquatic habitats, and ground water as deep as a kilometer beneath the surface. The rise in C4 plants has also been implicated in affecting the carbon isotopic value of the oceans in the late Miocene, which, if true, may offer the clearest picture of the global pace of C4 plant expansion during this time. The large isotope difference between C3 and C4 plants also allows many paleontological hypotheses concerning diet change to be tested in the Plio-Pleistocene. In many cases, the isotope shift from C3-browse to C4-grass occurs earlier than previously identified in morphological change, and in some cases a completely different diet is suggested by the isotope data. Thus, the C3-C4 system has become an important tool for paleontological diet reconstructions as well as landscape reconstructions.

## A PALEONTOLOGICAL GOLDMINE: EDUCATION AND RESEARCH FUNDING OPPORTUNITIES THROUGH THE NATIONAL SCIENCE FOUNDATION

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Paleontology provides an understanding of how organisms and their surroundings evolved across geologic time and has aided in important societal endeavors: dinosaur walking mechanics to improve robotics and paleoclimate-organismal research to improve forecasting of anthropogenic climate change impacts. However, the paleontology pipeline—from K-12 education, to undergraduate, graduate, post-doctoral, faculty, and other professional opportunities—is narrowing and leaking. The value of our contributions to society is seemingly less clear to non-paleontologists, thus funds to support paleontological activities and positions decrease. Data from the American Geosciences Institute (AGI) documents a 32% decrease from 1999 to 2023 in the number of geoscience faculty positions in US institutions that record paleontology as a primary research or teaching specialty. Paleontologist representation of the earth science community decreased from 2012 (7.23%) to 2019 (6.84%). To address this leaky pipeline, we investigated research and education opportunities sponsored by the National Science Foundation (NSF) to discover which programs align with paleontology and how well-utilized they are by paleontologists. The sole research opportunity for undergraduates is the REU (Research Experience for Undergraduates), which is widely underrepresented for paleontology. As of 2016 there is only one paleontology REU despite a 2023 total financial year projection of $84 million. Paleontology graduate students are annually awarded the Graduate Research Fellowship (GRFP) to conduct their doctoral work, notably with 130 recipients across the last thirty years (1992–2022). The Non-Academic Research Internships for Graduate Students (INTERN) program is not well-accessed by current paleontology graduate students; those who pursue INTERN will translate their professional/research skills to future non-academic employment opportunities. Although fewer postdoctoral-fellow specific opportunities exist through NSF, paleontology postdocs are regularly awarded the Earth Sciences Postdoctoral Fellowship: eight awards in the last four years alone. For academic faculty, a wide range of funding sources exist within NSF apart from Sedimentary Geology & Paleobiology (SGP) funding (66% are recent paleontology awards): Geoinformatics (GI; 25%), Arctic Natural Sciences (ANS; 5%), and Frontier Research in Earth Sciences (FRES; 36%). The Faculty Early Career Development (CAREER) and Grant Opportunities for Academic Liaison with Industry (GOALI) programs are key underutilized opportunities for paleontologists to establish themselves as educational/research leaders and to promote relevance in society, respectively. As a community, it is incumbent upon us to acknowledge the domino-effect of decline and devise a plan of action to slow, stop, and reverse a disturbing trend. Taking greater advantage of the opportunities available at NSF would be a step in the right direction.

Funding source: The Paleontological Society and American Geosciences Institute

## PRELIMINARY INSIGHTS INTO MARINE GASTROPOD PRECIPITATION KINETICS FROM DUAL CLUMPED ISOTOPES (Δ47/Δ48)

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Gastropods are an interesting paleontological archive as they are the most diverse class within the mollusk phylum, live in diverse habitats, and are highly abundant in the fossil record (Cambrian to the present). Although it comes at an energetic cost, shell formation is essential for gastropod mollusks, with shells primarily serving as protection against predators. However, how gastropods precipitate their shells, including whether this is done via precipitation close to isotopic equilibrium or biologically driven disequilibrium precipitation, is not yet understood. A new tool has emerged that may allow us to better understand precipitation of biogenic carbonates broadly: dual clumped isotopes. Although clumped isotopes have primarily been used for paleothermometry on biogenic carbonates (Δ47), recent studies have shown that dual clumped isotopes (Δ47/Δ48) can be used to screen for equilibrium vs. disequilibrium precipitation. This method has been successfully applied to corals, brachiopods, and other biogenic carbonates that precipitate out of isotopic equilibrium and has shed light on their precipitation kinetics. In this study, we survey 12 modern marine gastropods species across 8 genera, taking seasonally targeted Δ47/Δ48 measurements to determine if they precipitate in equilibrium (i.e., can directly reconstruct paleotemperatures) or out of equilibrium (i.e., biologically driven kinetic fractionation during precipitation). We find that some gastropods precipitate in isotopic equilibrium while others do not, with disequilibrium signatures clustering along phylogenetic lines. *Conus* sp., conchs (*Strombus*), and whelks (*Austrofusus*, *Busycon*/*Sinistrofulgur*) appear to precipitate in isotopic equilibrium. Disequilibrium signatures are clustered between gastropods within the Trochoidea superfamily (*Megastraea*, *Cittarium*) and between the closely related *Turritella* and Campanile

genera, suggesting that their precipitation mechanisms are more complicated than previously thought. We can use this methodological approach on ancient taxa to identify where certain precipitation mechanisms diverged in the evolutionary tree. Similar future studies sampling a wider range of species and families can hopefully lead to a better understanding of gastropod shell formation processes today and through geologic time.

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## QUANTIFYING WEAR IN ORNITHOPOD AND CERATOPSIAN DENTAL BATTERIES

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In contrast to the other major dinosaur clades, Ornithischia was uniquely constrained to herbivory from the outset of its evolution. Two ornithischian lineages, Ornithopoda and Ceratopsia, would independently, and in gradual fashion, converge on a dental innovation termed the "dental battery": a mosaic of hundreds of densely packed, constantly replacing and uniformly wearing teeth; with species like *Edmontosaurus* holding the record for highest tooth count among all terrestrial vertebrates. The perennial herbivory of Ornithischia means that the masticatory apparatus was responding solely to its ability to process vegetation. This means that the dental system provides a stable locus for evaluating the presence or absence of a 'key innovation' in Ornithischia: did evolution of the dental battery "unlock" the ability for early hadrosaurs and ceratopsians to radiate into larger bodied, ecologically prominent forms? Or did large body sizes in these lineages provide the impetus to increase the efficiency of the dental system? How much more efficient were dental batteries than their simpler precursors? Is the dental battery even an efficient structure? With emphasis on the dental battery, here we present a novel method for quantifying the wear and efficiency of ornithischian dentition that we dub the Dinosaur Macrowear Metric (DMM), and present preliminary results for species that span the body mass ranges and evolutionary histories of ornithopods and ceratopsians. DMM is inspired by the qualitative mesowear analyses of mammalian dental systems, but leverages reptilian polyphyodonty to acquire quantitative measurements. Specifically, we quantify the amount of worn tooth material at each tooth position in a dentary by retrofitting an unworn crown to each erupted one and subtracting the non-overlapping volume. We then sum those values across the tooth row, dividing by the total surface area of wear facets to calculate the DMM score. Our preliminary data support a correlation between high DMM values and increasing body size. We will also use this proxy to investigate the ability to consume bulk fodder, thought to be a prerequisite of evolving large body size, and to elucidate the role dentition may have had on shaping competition between and within ornithischian lineages like it did for mammals during the Cenozoic.

**WITHDRAWN**

## STORING RADIOACTIVE FOSSILS SAFELY, A CASE STUDY FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT

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Hagerman Fossil Beds National Monument (HAFO) is known to produce Pliocene fossils that emit high levels of radon, a colorless, odorless, cancer-causing gas. Any levels above 4 pCi/L require mitigation according to the Environmental Protection Agency. Fossils have been excavated from the Hagerman area since the late 1920s and are housed in museums and universities around the world. Radon poses special considerations for storage and handling of not only HAFO's collection, but for many other collections and fossil beds as well. This case study provides examples of user-friendly methods for testing radon levels emitted by fossils, and sample procedures developed to make it safe to handle, work around, and study radon-emitting fossils. It describes the methods and technologies used to measure radon levels and offers solutions for mitigating exposure to radon gas and particulates. Experiments conducted over the course of several months aimed to answer the following and develop improved protocols for the building and storage cabinets: 1) What are the baseline radon averages? 2) What are the most effective mitigation strategies? New protocols successfully reduced average daily radon concentrations to safe levels with minimal labor. Collected data also helped establish a project for the design of a new Energy Recovery Ventilation system for improved energy efficiency.

## NEW INFORMATION ON THE XENACANTHIFORM SHARK IN THE MALERI FORMATION, UPPER TRIASSIC OF INDIA: PALEOHISTOTLOGICAL APPROACH AND FAUNAL ASSOCIATION INDICATE SOME PALEOBIOLOGICAL AND PALEOECOLOGICAL INSIGHTS

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The UpperTriassic Maleri Fomation of India contains many teeth cusp or multiple single cusps that are represented by the Xenacanthiform shark taxa. The Xenacanthiforms are very widespread as they encountered in the whole part of the Pangea during Carnian and Rhetian stage of the Upper Triassic including Europe (Germany, Spain, Czech Republic), North America (Alabama, Arizona, Texas) and South America (Brazil).However, Mesozoic Forms are only encountered in Europe, North America (Texas) and India and it's represented by One of the Family of Xenacanthidae in Asia. Recent and complete survey of *Mooreodontus* from the Tiki Formation, India (Bhat et al., 2018) with histological insights has helped to determine species assignment of the multiple cusps encountered in the Maleri Formation. Smooth lateral edges and fine or no vertical striations on the cusps suggest that these Maleri specimens belong to Moreodontus indicus (Jain, 1980), but new materials of multiple xenacanthiform dental single cups could have potential information to determine the life style of the Indian form: potamodromous and piscivorous are resulted from a new survey of the morphological cusp features and its faunal association. In addition, description of isolated teeth with cups made by Jain in combination with the study of the ten tooth examination characters according to the data of cladistic analysis (Soler-Gijon, 1997), with a partial histological study have concluded that the diplodonty could summarize its paleobiology (Sankey et al., 2008).

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## LARGE DEBRIS IN PALEOZOIC AND MODERN PEAT

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Permineralized peat in Pennsylvanian and earliest Permian coal balls records processes of decomposition in ancient coastal wetlands. Compared to modern peat, ancient peat has more leaves and other aerial debris and fewer small particles (= 100 μm). Moreover, coal balls can contain very large pieces of debris. For example, some mid-Moscovian coal balls contain single pieces of cordaitean wood up to 130 mm in size, measured perpendicular to bedding. These differences point to slower rates of decomposition in ancient peat swamps than at present. In modern peat, particle size is an indicator of decomposition. However, meaningful comparisons of particle size in ancient and modern peat require comparable sample sizes and similar approaches to measuring particles. We determined the particle size distribution of plant debris in Pennsylvanian peat by making cellulose acetate peels of coal balls cut perpendicular to the bedding plane. On each peel, we drew a line perpendicular to the bedding plane and measured the height of each piece of debris that touched it. Most data on peat particle size in modern coastal wetlands come from Cohen's work on freshwater and marine peats from the Florida Everglades and the freshwater peats from the Okefenokee Swamp. Cohen, whose original research focus was the peat-to-coal transition, used paraffin impregnation to prepare microtome thin-sections of small peat samples, usually 1 to 1.5 $cm^2$. Cohen tracked two particle size categories, framework particles = 100 μm in one dimension, and matrix particles <100 μm in all dimensions. However, the small size of Cohen's peat samples excluded large particles. Furthermore, the paraffin impregnation technique is not suited to sampling large, hard particles, such as wood and bark. To determine the particle size distribution of large debris in

mangrove peat, we collected three short peat cores (150 mm in diameter, 150 mm deep) from fringe and basin mangroves in Barnes Sound, Florida. To extract large debris, we divided cores into thirds (50 mm each) and disaggregated the peat. Most large debris consisted of aerenchymatous roots that were compressed perpendicular to the bedding plane and had an ellipsoidal cross-section. If the short axis of the ellipsoid was >3 mm, we included the debris in the large debris sample. In addition to aerial roots, we also encountered *Rhizophora* (red mangrove) bark and propagules. We found few pieces of wood and no buried leaves. Results indicate that the largest debris in our modern mangrove peat cores is 35 mm in size perpendicular to the bedding plane, The average size of large debris in the three cores was 7 to 8 mm, measured perpendicular to bedding. Our preliminary data suggest Pennsylvanian coal-ball peat has larger particles than modern mangrove peat. Particle size may enable us to track relative rates of terrestrial decomposition in Paleozoic peat.

## WE SHOULD COLLABORATE

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Paleontology, as a discipline, is often taught in Earth science departments. And, as long as people are fascinated by ancient life, paleontology will be part of College and University curricula. However, as Universities and Colleges change to meet the challenges of global environmental change and the energy transition, the role of paleontologists in Earth science education and research will change. Some parts of the equation are easier to predict than others—the application of micropaleontology to biostratigraphy for purpose of hydrocarbon exploration will probably diminish. On the other hand, studies of ancient diversity and ecosystem change associated with environmental drivers will probably grow. I look forward to conservation paleontology becoming a recognized specialty in Ecology Departments. Professional societies associated with traditional Earth sciences are already feeling the pinch—as the average age of members rises and the number of members drops. I am happy to say membership in the Paleontological Society is holding steady and even rising—and we have been able to maintain a healthy mix of early, middle and late career members. Our journals, Paleobiology and the Journal of Paleontology are thriving. Nonetheless paleontology as a field faces its own set of challenges. Museums, funded by fixed-income endowments, face increasing costs, putting irreplaceable paleontological research collections at risk. Databases, that were funded with great enthusiasm at their inception, struggle to identify sources of continuing funding. These are not easy problems to solve. My purpose today is to take a first step towards collaborating with our sister paleontological societies to collaborate in seeking solutions. We share a common interest in fostering the careers of young paleontologists, maintaining access to field sites on federal land, in safeguarding University and Museum collections, rescuing orphan collections and in maintaining paleontological databases. NAPC is a celebration of all disciplines paleontological. Let's take this opportunity to start talking to each other about maintaining the critical infrastructure of our field.

## TIME ON THE GROUND IN THE HIMALAYAN MOLASSE SEDIMENTS; OBSERVATIONS FROM KHAUR TO KASHMIR

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In the late 1970's through 1990's, research in the central Potwar Plateau focused on the Khaur Anticline and surrounding areas was coordinated by Yale University (later transferred to Harvard) in collaboration with the Geological Survey of Pakistan. Simultaneously, research on the eastern Potwar Plateau and Kashmir was coordinated by Dartmouth College in collaboration with the Centre for Excellence in Geology at Peshawar University. The Yale group focused mostly on Miocene strata of the Chinji, Nagri, and Dhok Pathan formations. The Dartmouth group focused largely on the latest Miocene and Plio-Pleistocene Dhok Pathan and Soan formations as well as the Karewa Group in Kashmir. Both groups recognized strong structural and possibly climatic controls on lithofacies, with many of the traditional formation boundaries being diachronous. Recognition that the same polarity reversal signals that allowed the dating of ocean basins could be used to date these fluvial strata provided the key to calibrating the history of mammalian evolution and the concurrent geomorphic evolution of the region. Calibrated paleomagnetic records derived from many tens of kilometers of measured sections are catalogued in a website at Siwalikstratigraphy.org. The recognition that strike lines visible on Google Earth are essentially isochronous markers allows time maps to be created, permitting calibration of the fossil record. These patterns also offer the opportunity to define the evolution of deformation and facies-change patterns. The onset of deformation and the tapestry of fluvial pathways and facies tracts can be shown to be controlled by evolving compressional landforms. These include folding and faulting along individual anticlines, broad scale deformation of the Salt Range and Potwar Plateau, and the development of the large-scale Kashmir and Peshawar piggy-back basins. These deductions rest on simple facies analysis, paleocurrent measurements, and sandstone composition studies that offer fruitful research avenues for students and researchers interested in the Siwaliks to carry these observations to a more refined level, using field-based approaches.

## TWO EPISODES OF DEFORMATION AND SEDIMENTATION IN THE LARAMIDE BIGHORN BASIN, WYOMING

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The Bighorn Basin is part of a flock of basement-bounded basins that formed on the shattered Cretaceous foreland between New Mexico and Montana (Dickinson et al., 1988). The onset of basin subsidence and adjacent mountain uplift is diachronous across this region. For example, the Denver Basin developed about 68 million years ago, while the Bighorn Basin dates to 66 million years ago. The synorogenic Laramide basin-fill of the Bighorn Basin can be divided into two pulses or depositional episodes (deposodes of Galloway, 2011). Onset of basin subsidence and accumulation of the Fort Union Formation is heralded by the dispersal of far-derived conglomerates at the dawn if the Paleocene. These are spawned across a xenoconformity (senso Carroll, 2017). It may not be coincidental that the largest seismic pulse to ever pass through these rocks occurred at this same time. Eleven million years later at about 55.5 MY, a second pulse of deformation uplifted and warped the southwestern basin margin. Again, an apron of far-derived conglomerates spread across the basin, this time perhaps largely recycled from the first pulse. This event, at the dawn of the Eocene, is perhaps coincidental with the PETM climate change event and is largely characterized by the accumulation of the Willwood Formation. The tectonic signal is strong and recalibrates the proximal fluvial facies in the basin. The climatic signal, while pronounced in the fauna and flora, is only weakly manifest in the stratigraphic record. The biological record and the stratigraphic record are not directly linked.

## VERTEBRATE PALEONTOLOGY RESEARCH IN PAKISTAN: HISTORY, PRESENT, AND THE FUTURE

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The Neogene Siwalik rocks forming the southern foothills of the Himalayas have been known for their rich vertebrate fauna since the early 1800s. The Potwar Plateau (eastern Pakistan) is the most intensively studied region because of its vast exposures and rich vertebrate fauna, mostly mammalian fossils. However, vertebrate paleontology and allied subjects have generally been neglected in Pakistani universities and geological organizations. The three notable exceptions are the Geological Survey of Pakistan (GSP), the Institute of Zoology, Punjab University (Lahore), and the Pakistan Museum of Natural History (Islamabad). The Geological Survey of Pakistan (GSP) has emphasized and promoted paleontological research since its inception in August 1947. The research remained focused mainly on molluscan and foraminiferal paleontology, as there was some expertise available within the GSP. To fast-track and diversify paleontological research with well-qualified professionals, the GSP encouraged foreign collaborative research programs with established foreign institutions. There were two main objectives of such collaborations; first to develop indigenous expertise through active participation, and second to build useful fossil reference collections. The vertebrate paleontology discipline which had been neglected got a surprise boost when two collaborative projects were initiated with Yale (later with Harvard) University in 1973 and with Howard University (in association with Utrecht University) in 1974 for Neogene Siwalik paleontology and stratigraphy of the Indus Basin. Later, in 1980, the GSP entered a collaboration with University of Michigan for Eocene mammal studies from the Middle and Upper Indus Basins. All the joint field activities became innocent victims of the global political conditions around 2001–2002. At the same time, the GSP had to divert all its human and financial resources to geological mapping and mineral explorations, curtailing basic research programs to a minimum. However, circumstances have changed, and vertebrate paleontology research programs are being initiated again. GSP has reactivated the vertebrate paleontology program and recently has established a modestly equipped Vertebrate Paleontology Research Center (VPRC) at its Northern Regional Office in Islamabad. The priority agenda is to establish well-curated fossil reference collections as our partners are returning the fossil loans previously borrowed for research. GSP also has plans to involve other Pakistani institutions in joint research and continued education programs. The GSP is committed to encouraging foreign collaboration for field-based research programs and will have open-door access for all scientists to their fossil collections. We present here a synopsis of the status of vertebrate paleontology to date in Pakistan with details of the GSP plans for its revival.

## THERMAL PREFERENCES CORRESPOND TO ESCALATORY REGIONAL SPECIES RESPONSES DURING EARLY JURASSIC CLIMATE CHANGE

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Marine assemblages are expected to undergo substantial

reorganization under anthropogenic climate change but some species may be better situated to track their preferred conditions. Assemblage vulnerability can thus be indicated by change relative to the thermal niches of its component species. However, the link between species vulnerability based on their thermal niche and their extinction risk is unclear and cannot yet be tested with modern species since widespread climate-driven extinctions are not yet manifest, only extirpations. To address this gap, we inferred fossil brachiopod, bivalve, and gastropod species' thermal niches based on their observed distributions on paleoclimate maps over hyperthermal pulses in the Late Pliensbachian to Early Toarcian. We show that species extirpated from fossil invertebrate assemblages after warming, and moreso those species that went extinct, were most likely from the pool of species that were above their thermal optima, in contrast to species immigrating into an assemblage. This statistical tendency increased with magnitude of regional warming, and for brachiopods relative to bivalves. We explore the potential meanings of these relationships for analogous modern regions under climate change.

## FIELD TRIP IN THE MUSEUM: A NEW DINOSAUR BONEBED FROM NIOBRARA COUNTY, WYOMING

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In 2018, a re-evaluation of the stomach content in the *Edmontosaurus* mummy (SMF-R-4050) on exhibition at the Senckenberg Nature Museum in Frankfurt was reinterpreted as plant material deposited long after the death of the specimen. This finding motivated SMF to organize several prospections and excavations in Wyoming, United States, during the summers of 2018 and 2019. In August 2019, a new dinosaur bone bed was located in Niobrara County. The outcrop consisted of several horizontal facies of mudstone, coal, and sandstone. The excavation was part of an experimental exhibition project to show visitors palaeontologists working on site. In total, sixteen blocks with a surface of 20 $m^2$ and a thickness of 60 to 80 cm were removed from the locality and shipped to Frankfurt, Germany. In this contribution, we describe the stratigraphy, fauna, flora and palaeoenvironment of the outcrop. Furthermore, we discuss the advantages and disadvantages of doing this type of collection work by bringing the field to the museum and doing the fieldwork in the museum. The mudstone layer yielded remains of dinosaurs, mostly appendicular elements from *Edmontosaurus*, and macroflora, whereas the sandstone is richer in vertebrate microfossils, macroflora (leaves), amber and calcified wood. The most diverse layer is the sandstone, whereas the mudstone contains most of the macroflora, including seeds. The sandstone and mudstone layers are separated by a limonite layer that contained mostly hadrosaur tendon fragments, teeth, turtle shells and an assortment of microvertebrate fossils. In total, the outcrop has yielded ornithischians (53.72% of the identified remains), theropods (16.07%), crocodiles (5.45%), turtles (3.59%), amphibians (0.21%), and fish (4.96%); 16% of the remains are unidentifiable fragments. The material is, in general, disarticulated but very well preserved, with *Edmontosaurus* cranial elements being ubiquitous elements in the sandstone. Several other dinosaur taxa have been found represented in the sandstone, namely teeth of *Tyrannosaurus*, *Pectinodon*, and *Triceratops*, and caudal vertebrae of dromaeosaurid, pachycephalosaurid, and ankylosaurid, hadrosaurid dinosaurs. The sandstone has also yielded a mammalian mandible and multituberculate teeth. Some bones in both layers show evidence of transport, others have a thin iron hydroxide layer covering, and most of them have good preservation, suggesting a continuous deposition of sediments in a subtropical environment. Although most of the fauna in the sandstone indicates a freshwater environment, several scales from cartilaginous fish suggest some marine influence. The underlying mudstone layers, where most of the macroflora has been found, suggest a more terrestrial environment covered by a dense, subtropical forest dominated by deciduous trees that experienced frequent wildfires. We propose here that the blocks represent the changes from a large fluvial system to a meander belt.

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## EXPLORING THE MORPHOMETRIC IMPLICATIONS OF THE LOSS OF RESPIRATORY STRUCTURES IN PLEUROCYSTITID ECHINODERMS

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Blastozoan echinoderms have traditionally been classified on the basis of distinctive respiratory structures. However, these structures are extremely evolutionarily plastic and variable across the phylum. Pleurocystitid echinoderms, such as *Pleurocystites*, have distinctive respiratory pectinirhombs that grow allometrically with overall body size and may account for approximately half of the respiratory needs of the individual. However, these pectinirhombs are subsequently lost in the closely related and co-occurring pleurocystitid *Amecystis*. To explore the morphometric, ecologic, and

physiologic impacts of the loss of respiratory structures we examined a collection of *Pleurocystites* and *Amecystis* from the Late Ordovician Brechin Lagerstätte of Southern Ontario. We compared plate shape and variability using outline analysis between the two genera on five homologous plates with and without pectinirhombs located across the theca. We hypothesize that *Amecystis* could have a greater variability in plate shape due to the lack of pectinirhombs as a control on morphology. Alternatively, *Pleurocystites* could potentially have a greater amount of plate variability related to the presence of pectinirhombs producing more complicated plate boundaries. Our preliminary results show that the shape of individual plates are distinctive between the two genera even with consistent thecal architecture. However, the variance in plate shape is much higher in *Amecystis* than in *Pleurocystites*, suggesting that the presence of pectinirhombs acts as a control on plate morphology. This effect is likely amplified given the pectinirhombs cross plate boundaries requiring a more stereotypical shape to retain alignment of the external respiratory slits. Despite the strong allometric relationship between pectinirhombs and body size in *Pleurocystites*, the loss of these respiratory structures in *Amecystis* did not seem to negatively affect growth given a significantly larger average body size in the latter genus (~17% larger). Therefore, these respiratory structures could represent a remnant adaptation of lower oxygen conditions that has little selective advantage in their current environment. Despite a similar morphology and ecology, a larger body size, and an increase in morphologic flexibility, *Amecystis* is dramatically less abundant within the Brechin Lagerstätte. This difference in abundance could be linked to the loss of respiratory structures either by lowering rates of respiration that in turn lower reproductive rates regardless of individual physiological needs or the respiratory structures played a reproductive role as has been proposed in other blastozoan echinoderms. Overall, this model system shows the inherent complexity between physiology, morphology, evolution, and community structure.

## BAT GUANO RECORDS OF PAST CLIMATE AND ENVIRONMENT FROM SOUTHWEST VIRGINIA: EXCAVATING THE FORGOTTEN GRASSLANDS OF THE SOUTH

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The antiquity of grassland ecosystems in the southeastern United States is evident in both the high degree of endemism and enormous species richness documented in remnant southern Appalachian communities. The conservation of these ecologically valuable but oft dismissed habitats depends on understanding how and why they have expanded and contracted over time and especially which factors contribute to their maintenance. Pleistocene and Holocene paleoenvironmental records are limited in the Appalachian Mountains due to the scarcity of lakes, but bat guano deposits are relatively abundant in the limestone karst terrain of the Valley and Ridge Province of southern Appalachia. These deposits archive significant information about past landscapes and climate; in addition to trapping pollen grains and macrocharcoal, insectivorous bat guano captures information about past vegetation ($d^{13}C$) and precipitation ($d^{2}H$ and potentially $d^{15}N$). We investigated the paleoenvironmental history in southwest Virginia by collecting two guano cores from limestone caves in Giles County, VA: (A) a 170-cm core that dates from ~5300–1200 cal yrs BP and (B) a 50-cm core that dates from ~33,000–26,000 cal yrs BP. Isotope results show clear trends of increasing $d^{15}N$ values and decreasing $d^{13}C$ values from deep in core A toward the surface. Higher $d^{13}C$ values deep in the core likely indicate a greater prevalence of $C_4$ grassland vegetation on the landscape in the past, which could be linked to drier climate, indigenous burning, or both. Forthcoming macrocharcoal data will help to contextualize the relationship between fire and grassland prevalence. Ongoing study of the older core B will provide insights on late Pleistocene climate.

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## RECONSTRUCTING PAST GROUNDWATER LEVELS IN HOYO NEGRO, SAC ACTUN CAVE SYSTEM, QUINTANA ROO, MEXICO

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Reconstructing past groundwater levels in karstic caves is important for understanding taphonomy, faunal access and the availability/quality of freshwater during the Pleistocene/Holocene. In the anchialine cave systems of the Yucatan Peninsula, aquifer flooding history largely follows sea-level, but there are departures from this trend that might be local or regional in extent. At the beginning of the research in Hoyo Negro, there was considerable debate about the presence of water at the bottom of the pit (~40 to 45 m depth) because sea-level would have been at a lower elevation during the Late Pleistocene. The taphonomy of the skeletal remains both human and animal indicate they remained submerged in

groundwater. Our research over the past 10+ yrs has focused on establishing water level indicators in the cave systems of Quintana Roo. Sediment deposition within these cave systems is not great in extent (time and space) and behaves differently than surficial systems. Because these sedimentary deposits are ephemeral in time and space, it requires a variety of novel proxies for establishing the presence of water. We will discuss the various water level indicators including biological, sedimentological, and geochemical evidence and their limitations in terms of age and elevation with a focus on Hoyo Negro in the Sac Actun Cave System. The indicators include calcite raft deposits, microfossils (ostracods, testate amoebae, foraminifera, and diatoms), sediment accumulations and their structure (e.g., mud cracks), speleothems and microbialites. The impetus for this research was to: 1) establish flooding history to account for water at the bottom of the pit in Hoyo Negro at the end of the Pleistocene, 2) determine when the upper cave passages became flooded cutting off human and faunal access, and 3) provide evidence on groundwater quality and its relationship with climate change (wet and dry periods).

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## AN AGGREGATE OF YOUNG, SKELETALLY IMMATURE AETOSAURS (ARCHOSAURIA: PSEUDOSUCHIA) FROM THE LATE TRIASSIC DOCKUM GROUP (OTISCHALKIAN) OF TEXAS

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The fossil record of archosaurs currently extends back into the Early Triassic. This clade has a fossiliferous record spanning the entire Mesozoic. In-ovo embryos, nests, neonates, and hatchlings are well represented in terrestrial Jurassic and Cretaceous strata but are mostly restricted to dinosaurs. Skeletally immature archosaurs are sparse in the Triassic Period. Currently, no egg-bearing archosaur nests or embryos are documented from that period. When present, neonates and hatchlings are typically documented based on limited fragmentary elements intermixed with larger specimens. Currently, the only exception is a cluster of articulated hatchlings (n = 24) of the aetosaur *Aetosaurus ferratus* (SMNS 5770) from the Late Triassic (mid-Norian) Lowenstein Formation in Germany. That clutch is indicative of gregarious behavior in hatchling aetosaurs and possibly represents nesting behavior. If so, SMNS 5770 possibly represents the oldest evidence of nesting among archosaurs and likely the only documentation from the Triassic Period. Here, we present a cluster of skeletally immature individuals (TMM 31100-1336) referrable to the aetosaur *Coahomoasuchus kahleorum* from the Otis Chalk localities within the Late Triassic (late Carnian-early Norian) Dockum Group of Texas. This cluster preserves 3–4 individuals, including a three-dimensionally well-preserved skull and two partial skeletons. Taxonomic identity and skeletal proxies such as the presence of un-coossified neurocentral sutures of the vertebrae, small body size, loosely articulated skulls, and porous nature of the bones, indicate that these individuals are young, skeletally immature juveniles possibly representing hatchlings based on comparisons with SMNS 5770. The degree of ossification and preservation of these individuals brings to question the behavior and development of aetosaurs, and more broadly speaking, basal archosaurs. TMM 31100-1336 and SMNS 5770 indicate that aetosaurs exhibited well ossified osteoderms early in development, and were likely ossified to some degree at birth. This is unlike modern crocodilians which exhibit a delayed ossification of their osteoderms after hatching. Additionally, the articulated nature and association of these individuals suggests that TMM 31100-1336 was likely preserved within an enclosed area, possibly a burrow, that resulted in partial intermixing of the bones and 3-dimensional preservation of the skull and associated carapace.

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## MULTIVARIATE FUNCTIONAL ADAPTIVE LANDSCAPES AND HOW WE MAKE THEM

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Recently it was demonstrated that a 'functional adaptive landscape' can be estimated by iteratively weighting and combining performance surfaces until a solution is found that maximizes the height at which empirical data points rest on the combined surface. This functional adaptive landscape can be used to predict the evolutionary trajectories lineages would take under selection for the combination of functions considered. This approach has piqued interest in the paleontological community because adaptive landscapes can now be readily computed directly from phenotypic data. Applications include work addressing major evolutionary transformations in the fossil record, such as the water-land transition in tetrapods and the 'lateral-to-sagittal' model of mammalian vertebral evolution. However, the choice of method used to compute performance surfaces has not been consistent across analyses, nor have the implementations of the likelihood equation that computes support for the many possible topologies. Here, we demonstrate that these inconsistencies can have appreciable consequences on the topology of the resulting adaptive landscapes, potentially leading to scenarios where different interpretations about the evolutionary history of a clade can be drawn from the same input data. Methods to construct performance surfaces can be broadly grouped into two categories: 1) methods that make no a priori assumption of topology before interpolation

(e.g., Kriging, spline interpolations), but run the risk of overfitting and producing unrealistically rugged topologies; and 2) methods that are constrained to certain topologies (e.g., polynomial regression, normal surfaces) but are less sensitive to error and have certain favorable properties due to the underlying mathematical functions defining the surface. One of these 'constrained' surface-construction methods, quadratic regression, is highlighted for its cohesion with evolutionary quantitative genetics and selection theory. Lastly, we demonstrate that fully multivariate adaptive landscapes are tenable for these 'constrained' surface methods, allowing paleontologists to realize the multidimensional adaptive landscape envisioned by G.G. Simpson.

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## BUILDING AND STEWARDING VERTEBRATE FOSSIL COLLECTIONS HELD IN PUBLIC TRUST: 150 YEARS OF SCIENTIFIC INQUIRY AT THE YALE PEABODY MUSEUM

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The Yale Peabody Museum was first established in 1866 and houses one of the oldest significant vertebrate fossil collections in North America. Benjamin Silliman was foundational in building Yale's principal collection of minerals in the early 1800's. A few decades later, Othniel Charles Marsh petitioned his uncle George Peabody to fund the Yale Peabody Museum. Expeditions to Paleozoic, Mesozoic, and Cenozoic deposits throughout North America rapidly built the museum's holdings of fossil fishes, amphibians, reptiles, birds, and mammals. In 1906 Richard Swann Lull continued a vibrant collecting program while overseeing the museum's relocation and expansion. Despite delays to construction by the onset of World War I, the new Peabody Museum was dedicated in 1925. Collections grew in volume and scope via the efforts of G. Edward Lewis and Joseph T. Gregory. In subsequent years, materials were added from the Ordovician, Devonian, Carboniferous, Permian, and Triassic periods of North America by faculty curators, students, and affiliates. Collections from outside North America were built by G. Edward Lewis from expeditions to the Siwaliks of northern India and Pakistan in the 1930's and by Elwyn L. Simons' field work to the Fayum region of Egypt in the 1960's. Under John Ostrom's leadership in 1985, the vertebrate fossil collections from Princeton University were acquired, thereby adding over 20,000 cataloged specimens, including a notable South American fauna. Collection growth in recent decades is shaped by research interests in functional morphology and systematics, especially faunal turnover at the Cretaceous-Paleogene boundary, and vertebrate development at the origins of extant radiations. Most recently, the Yale Peabody Museum closed for a large-scale renovation project in 2020 to build new collections storage rooms, laboratories, conservation workrooms, classrooms, and exhibitions. The stewardship of historical collections is layered by the efforts of collection care workers over the decades and constrained by environmental factors and equitable access to resources. Nonetheless, each collection care worker contributes to the metanarrative of a specimen's history through their approach to stewardship and care. The management of our resources, staffing, and time matters. Identifying projects that are attainable and equipping workers, especially emerging professionals, with the tools and training to accomplish curation tasks is essential. How we as a community approach our research questions and methods informs the way we prospect, identify, collect, prepare, treat, sample, digitize, document, label, house, move, track, and increase access to collections and their associated data. A collections management philosophy that values attentiveness to detail, consistency of approach, transparent documentation, retention of institutional knowledge, and professional development of the team is paramount to sustaining the future of primary scientific data.

## A NEW LUOLISHANIID FROM THE EARLY ORDOVICIAN AND THE AUTECOLOGY OF SUSPENSION-FEEDING LOBOPODIANS

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Lobopodians are a diverse clade of soft-bodied, vermiform marine invertebrates crucial to understanding panarthropod evolution in deep time. We describe a new luolishaniid lobopodian from the early Ordovician Fezouata Shale biota of Morocco with adaptations for suspension feeding. The Fezouata Shale luolishaniid features at least nine relatively robust and annulated limb pairs. The anterior-most five limb pairs are elongated with setiform structures emerging from either side of the limb in a chevron pattern. The remaining posterior limb pairs are shorter and likely end in a terminal claw. The Fezouata Shale lobopodian extends the evolutionary history of luolishaniids, previously only known from early and mid-Cambrian deposits in North America, South China, and South Australia. We also explore the autecological implications of the suspension feeding morphology of all described luolishaniid taxa. Luolishaniids sifted particles and organisms out of the water column that are on the larger end of the micro-planktonic spectrum (20–200 μm) and on the smaller end of the meso-plankton spectrum (200 μm–20 mm). We find a statistically significant, positive relationship between luolishaniid maximum body size and setae mesh size, suggesting that larger luolishaniids specialized on meso-plankton while smaller taxa specialized on micro-plankton.

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## BENTHIC FORAMINIFERA CAN PROVIDE A SURROGATE FOR MARINE ECOSYSTEM BIOGEOGRAPHY

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Benthic foraminifera are marine protists with an extensive fossil record throughout marine and coastal environments making them key proxies for past environmental conditions. Examining their modern biogeography and the environmental controls on their present-day distribution will allow us to quantitatively calibrate the environmental meaning of foraminiferal faunas. Furthermore, comparing the biogeographic structure of modern foraminifera to provincial schemes for marine metazoans allows us to test the hypothesis that the distribution of benthic foraminifera reflect the larger marine ecosystem. Here, we use georeferenced occurrence data from the Smithsonian Contributions to Marine Sciences to estimate species geographic ranges with a range-through approach informed by the bathymetric profile of each species. We then used the bathymetry-informed range-through polygons to infer the occurrence of species within an equal area spatial grid across Atlantic, Pacific, and Arctic Ocean regions adjacent to North and Central America. Species richness at the grid-cell level was best modeled by a multiple regression with temperature and water depth as predictor variables whereas other environmental factors (salinity, pH, dissolved oxygen, latitude, and primary productivity) had limited explanatory power. These insights into the relationships between benthic foraminiferal distributions and environmental variables enhance their utility as paleoenvironmental proxies and help us understand the historical drivers of their modern biogeography. Further, we propose biogeographic units (BUs) analogous to provinces for benthic foraminifera derived from a cluster analysis of species occurrences. The resulting spatial structure is similar to existing provincial schemes based primarily on metazoans; indeed, benthic foraminiferal occurrences are able to predict grid-cell assignment to existing provinces with >80% accuracy. Thus, the more readily preserved benthic foraminiferal faunas can be used as a surrogate to understand the paleobiogeography of marine faunas in a broad sense through the fossil record where other taxa are not as well recorded.

## FOSSIL SQUAMATES OF PEDERNALES PROVINCE, DOMINICAN REPUBLIC: NOVEL RECORD OF HUMAN-INDUCED EXTINCTION AND EXTIRPATION

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Hispaniola, currently split between the Dominican Republic and Haiti, is the second largest island in the Caribbean and is a hotspot of squamate biodiversity (~184 species), yet little is known about their fossil record and how it relates to the present. Previous studies on mammalian communities suggest that many rodent species go extinct after human arrival (~7,000 Y.B.P.), most significantly after European colonization (~530 Y.B.P.). Similar human-correlated extinctions have been noted in sloth, primate, and bird taxa, all occurring within the last 5,000 years. More recently, agricultural and industrial land use has resulted in a rapid loss of original forest, with a nearly 98% loss in Haiti, and a 70% loss in the Dominican Republic. Pedernales Province in the D.R., has much of its original forest cover, yet fossil squamates from this region have not been documented. Our study of Holocene dry cave fossil sites and a new archeological site located in Pedernales allows for evaluation of extinction in squamates in an area where deforestation is not a primary concern. Using dentigerous elements, several genera of squamates (*Ameiva*, *Anolis*, *Celestus*, *Cyclura*, *Leiocephalus*, and geckos) were identified. We recorded their abundance at each depth within the cave deposit, and found *Anolis*, *Celestus*, and geckos to be the most common fossils. From this collection we discovered two new species of *Celestus*, a new species of gecko, and revised the taxonomy of *Leiocephalus*. One of the newly identified large *Celestus* species, originally only known from fossils, was later discovered in a separate cave as a living specimen.These results suggest that deforestation is not the only driver of extinction in the D.R., and that even in well preserved areas, extinction of small taxa is happening. Additionally, some cryptic taxa may be unrecognized. The arrival of domesticated animals and associated pests (e.g., mice, rats, etc.), likely had a dramatic influence on these extinctions, as well as human predation, first reported here. Further radiocarbon and geochemical sampling of these herpetofaunal fossils will help assess hypotheses related to timing and drivers of extinction, and such trends can inform modern conservation efforts as to which taxa are most at risk.

## DOCUMENTING LIZARD FAUNAS ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN, WYOMING

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The Paleocene-Eocene Thermal Maximum (PETM, 56 Ma) was an interval of global warming with temperatures rising ~5 °C resulting from a rapid release of greenhouse gasses into the atmosphere. Most past studies of terrestrial faunal response to the PETM have focused on mammals, showing decreased body size, increased first appearances and species richness, and changes in trophic structure. However, the fossil record of small-bodied non-mammalian vertebrates including lizards (Squamata) just before the PETM in the latest Paleocene (Cf-3), during the PETM (Wa-M, Wa-0, Wa-R), and directly after the PETM (Wa-1) has been limited by sampling and research focus. A notable exception comes from a previously published Wa-0 lizard fauna derived from a single screenwashed locality (Castle Gardens) in the southern Bighorn Basin (BHB). That study suggested an increase in species richness compared to the Paleocene, with persistence of some Paleocene taxa alongside taxa considered intracontinental immigrants from lower latitudes of North America during the PETM. Comparisons to a later-occurring BHB lizard assemblage (Wa-5) showed a mixed pattern of taxa that first appeared in the PETM, suggesting persistence of some taxa in the BHB, but not others (e.g., amphisbaenian?*Anniealexandria gansi*, anguids?*Eodiploglossus*?and?*Apodosauriscus*, and a xantusiid related to?*Lepidophyma*). To test these patterns, we studied 7 new lizard fossil assemblages from the BHB derived from intensive screenwashing efforts in strata just underlying, during, and overlaying the PETM. Our pre-PETM microsite from the latest Paleocene (upper Cf-3) is still the focus of screenwashing efforts, but has already yielded ~30 diagnostic specimens that are mostly attributable to the family Anguidae. Three PETM microsites from lower Wa-0 (similar level as Castle Gardens) and later Wa-0 support previous results with an increase in squamate species richness, immigrant taxa appearing at the start of the PETM, and persistence of these taxa through the duration of the PETM. Wa-0 squamate taxa include specimens tentatively belonging to Anguidae, Iguanidae, Amphisbaenia, and Varanidae, including five distinct genera. Post-PETM microsites from Wa-1 and Wa-2 exhibit similar faunas, both to each other and to those from Wa-0. An exception is the appearance of a large-bodied amphisbaenian in Wa-1 assigned to the genus *Spathorhynchus*, which is likely more fossorial than others described from this genus. Large glyptosaurine anguids are the only taxa that range fully through the interval (Cf-3, Wa-0, Wa-1, Wa-2) with many diagnostic osteoderms found at all sites. Starting in Wa-0, the lizard communities are relatively more diverse and remain so through Wa-1 and Wa-2, with *Spathorhynchus* representing the only post-PETM immigrant. While further comparative work is needed, many of these taxa appear morphologically similar to those described from previously published Wa-5 localities.

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## FIRST CRANIUM OF THE ENIGMATIC ARCHAIC UNGULATE MAMMAL '*CARCINODON*' IN THE DENVER BASIN, COLORADO, PROMPTS REEVALUATION OF THAT GENUS

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Archaic ungulates (i.e., 'condylarths') epitomize the ascendancy of mammals in the aftermath of the Cretaceous-Paleogene (K-Pg) mass extinction due to abundance and diversity in the early Paleocene. Nonetheless, their taxonomy is problematic due to their generally fragmentary fossil record, which comprises mostly isolated teeth and jaw fragments, and their broadly similar and plesiomorphic dental morphologies. Recently, in early Paleocene exposures in the Denver Basin just east of Colorado Springs, Colorado (Corral Bluffs), exceptionally preserved mammal skulls have been discovered, providing fresh insights into the taxonomy and paleobiology of early archaic ungulates. Here we report the discovery of a mammalian cranium that is almost complete, with a maxilla including almost all premolars and all molars on both sides (DMNH EPV.132501). We assign this skull to '*Carcinodon*' based on (1) P3 length exceeding its width, (2) P3 protocone being absent, and (3) P4 parastylar lobes being buccolingually narrow and roughly parallel, thus representing the first occurrence of that genus in the Denver Basin. The upper dentition closely resembles that of *'Carcinodon' olearyi* based on the: (1) prominent hypocones on M1–M2, (2) prominent lingual cingulum continuous with precingulum and hypocone shelf on M1–M3, (3) metacone shifted lingually relative to the paracone on M2–M3, (4) similar size (M2 length = 6.10 mm), (5) hypocone extends lingually past the protocone apex on M1, and (6) parastylar lobe on M3 extends much farther buccally relative to the metastylar lobe. Species of *'Carcinodon'* have been variably placed in the genera *Chriacus*, *Baioconodon*, and *Oxyclaenus*, all of which exhibit relatively plesiomorphic dentitions. Nevertheless, our study of the nearly complete dentition of *'C.' olearyi* supports the hypothesis that *'Carcinodon'* is polyphyletic. As such, we propose that *'C.' olearyi* and *'C.' antiquus* represent a new genus separate from genotypic species, *C. simplex*, that is phylogenetically basal to *Oxyclaenus*, *Eoconodon*, and *Triisodon*, and all of their descendants. Recognition of this new genus clarifies phylogenetic relationships among early

Paleocene 'arctocyonids.' Further, DMNH EPV.132501 represents the first cranial remains of this taxon and for any other 'oxyclaenid-like' archaic ungulate. Study of its cranial anatomy is ongoing, but will hopefully illuminate cranial autapomorphies that help further differentiate early archaic ungulates.

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## RECENT ADVANCES IN VISUAL ANALYTICS AND VIRTUAL ACCESS TO SUBMERGED LATE PLEISTOCENE AND EARLY HOLOCENE FAUNAL DEPOSITS IN THE SUBMERGED CAVES OF THE YUCATAN PENINSULA

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The submerged cave systems of the eastern Yucatan Peninsula, Mexico, provide access to well preserved late Pleistocene and Early Holocene deposits that reveal a wealth of information about the paleobiogeography of the region. Ongoing interdisciplinary research efforts aim to identify and reconstruct the processes that have formed and transformed these subterranean sites over millennia. In addition to ongoing studies involving evidence of human activity, human skeletal remains, and diverse assemblages of Pleistocene-Holocene fauna and botanical deposits, the development of digital workflows enables virtual access to remote sites. Rather than functioning as static 3D models, multimodal and multiresolution digital twins enable virtual taphonomic analyses across scales—allowing domain experts to annotate, segment, extract, measure, and compare, while taking advantage of the complementary surface or volumetric views afforded by each imaging modality. Additionally, native image files corresponding to point regions can be readily and simultaneously consulted as users virtually access the caves. The interactive, point-based visual analytics workflow has proven to be especially empowering for researchers unable to otherwise physically access deep and remote underwater sites. In practice, team researchers have used the models to select specimens for recovery, collaboratively plan the recovery process, and design and develop custom recovery hardware and techniques without ever seeing the deposits in person.

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## DIVERSIFICATION OF JAW GEOMETRY DURING THE INITIAL RADIATION OF LOBE-FINNED FISHES (OSTEICHTHYES: SARCOPTERYGII)

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The origin of crown sarcopterygians around 420 Ma precedes the emergence of major lineage specializations, including contrasts relating to morphology of the feeding apparatus. Key examples include dental plates in lungfishes, reduction of marginal jaw bones in coelacanths, and elaboration of fangs in a variety of porolepiforms and tetrapodomorphs. Such putative ecological divergence, alongside evidence that individual lineages show high rates of evolutionary change early in their history, mark this event as a possible episode of adaptive radiation. Here, we explicitly test this hypothesis using mandibles as a taphonomically robust, taxonomically diagnostic trait intimately associated with ecology. We assembled a dataset of 70 three-dimensionally preserved jaws of total-group Sarcopterygii obtained by CT scanning or photogrammetry. Most are dipnomorphs or tetrapodomorph fishes, plus a smaller sample of stem sarcopterygians and taxa of less certain placement. We developed a landmarking scheme of 6 fixed landmarks and 8 curves with sliding semilandmarks capturing overall jaw shape and orientation, including aspects of the glenoid and adductor fossa. We paired these data with a composite phylogenetic tree with branch durations informed by the ages of fossil tips. We examined the fit of three basic models of trait evolution to these shape data in a multivariate framework: Brownian motion (BM; diffusive evolution at a constant rate), early burst (EB; diffusive evolution with a declining rate over time, corresponding to theoretical predictions for adaptive radiation), and Ornstein-Uhlenbeck (OU; constant rates of change with a central tendency limiting

the accumulation of variation over time). Our results indicate that EB is the best-supported model for jaw shape evolution for the clade, with groups such as dipnomorphs fitting this pattern more markedly than other groups. This corroborates our hypothesis and implies that high initial rates of phenotypic evolution complemented the extensive exploration of jaw shape space early in the history of lobe-finned fishes.

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## NO TAXONOMIC OR ECOLOGICAL RESPONSE TO GLOBAL CLIMATE EVENTS IN THE LATE MAASTRICHTIAN OWL CREEK FORMATION

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The Owl Creek Type Section, Mississippi, records a portion of the last 350 ka of the Late Maastrichtian stage which concludes with the end-Cretaceous extinction event, 66 Mya. During the last 300 ka of the Maastrichtian, global temperatures increased and decreased by ~2 ˚C, likely caused by a major pulse of Deccan volcanism. Due to these recorded global climate changes, we hypothesize that the Owl Creek Type Section will record a portion of this temperature increase and subsequent decrease. As a result of climate change, we anticipate a decrease in diversity and body volume of marine invertebrates, and an increase in abundance of low activity-level invertebrate fauna, similar to the ecological impacts observed in response to climate warming following other large igneous provinces in the geologic record. The Owl Creek Type Section has been the topic of extensive taxonomic, biostratigraphic, and functional ecological studies in the Maastrichtian. This study is the first to explore temporal trends in the exposed 9 m thick Maastrichtian section by systematically gathering bulk samples at a 0.5 m resolution. For each sample, species level identification was made for all invertebrates, functional ecological guild assignments were made, and size dimensions were used to approximate shell volume as a proxy for body size. Metabolic expenditure was estimated from shell size and metabolic rates from modern families. The Owl Creek Formation contains a diverse mollusk fauna dominated by suspension feeding, facultatively mobile bivalves, gastropods, scaphopods and nektonic, carnivorous cephalopods expressing similar abundances of ecological guild classifications to previous studies of Maastrichtian shallow marine deposits from the Gulf Coastal Plain. Preliminary observations indicate a lack of directional change in species richness and diversity, proportional abundances of functional guild occupation, body size, mean metabolic rate, and mean activity quotient. Δ47-based paleotemperature reconstructions collected from benthic and nektobenthic organisms show non-directional temperature variability (mean = 22.9 ˚C, range of 19.2 ˚C to 26.5 ˚C, mean = 22.4 ˚C, range of 17.9 ˚C to 26.5 ˚C respectively) whereas nearshore organisms show a warming of 6.7 ˚C followed by a decrease of 6.6 ˚C up the section. The lack of directional taxonomic and ecological change, yet evidence of temperature change, in the Owl Creek Formation suggests either that Deccan warming was not recorded in the exposed section, that the equatorial position of the Mississippi Embayment limited the impact of global-scale climate change or that the shallow marine shelf was buffered against global-scale climate change. The observed background variability evident in this section may be indicative of evolutionary stasis in this portion of the Gulf Coastal Plain. This would allow the Owl Creek Type Section to be invaluable as a baseline for future Gulf Coastal Plain comparative studies.

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## NEW INFORMATION ON THE UPPER ORDOVICIAN (KATIAN) CRINOID FAUNA FROM SARDINIA, ITALY

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The Late Ordovician was a crucial time in the evolution of stalked echinoderms with the origination of several major Paleozoic clades, significant climatic and environmental shifts, biogeographic dispersals, and a dramatic expansion of both morphological and taxonomic diversity. Our understanding of this interval is primarily based on assemblages from Laurentia, thus, information from other paleocontinents is needed to form a global perspective. The crinoid fauna from High-Latitude Perigondwanan Sardinia, Italy can help address this Laurentian bias and provide a key biogeographical intermediary between paleocontinents. The Portixeddu Formation fauna contains a diverse stalked echinoderm assemblage of hemicosmitoids, coronoids, diploporitans, glyptocystitoids, echinosphaeritids, and crinoids. Articulated crinoids are preserved as external molds within siltstones contained in small obrution deposits. The assemblages contain a high diversity compared to that of others in the Katian of Gondwana, including four species of

diplobathrid camerates, one species of cladid, and five species of disparids. In addition, most taxa are represented by a single specimen, suggesting that a much higher overall diversity fauna would be recovered with additional sampling. The crinoid taxa include representatives from the Anthacocrinidae, Dendrocrinidae, Tetragonocrinidae, and Myelodactylidae. This assemblage includes taxa that are endemic to Laurentia and Gondwana, suggesting an assemblage that bridges the two paleocontinents. Considering the high-level of diversity within the limited sample and the paleogeographic importance, the Portixeddu fauna needs further study.

## DIVERGENT EVOLUTIONARY HISTORIES OF AXIAL SKELETAL COMPLEXITY BETWEEN REPTILES AND MAMMALS

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A highly complex axial skeleton, composed of morphologically heterogeneous elements divided into discrete morphological and functional regions, has long been considered unique to crown mammals. The evolution of axial skeletal complexity has historically been interpreted as a linear increase in regionalization and heterogeneity leading to mammals. However, skeletal complexity and diversity remain unknown for the majority of tetrapod clades, as do the potential relationships to function, ecology, and development. We combined 3D geometric morphometrics with maximum likelihood model testing to determine the degree of regionalization and heterogeneity within the vertebral column of 96 taxa across Pan-Reptilia, Pan-Mammalia, and Crown Lissamphibia. We tested competing hypotheses regarding axial skeletal evolution across Amniota, and determined the relationships between axial skeleton diversity, phylogeny, body size, and ecology using phylogenetic comparative methods, evolutionary modelling, and the integration of recent and fossil data. We do not recover evidence of a uniquely complex axial skeleton in mammals. Instead, we model four regions in all mammals and in every principal clade of reptile, regardless of body size or ecology. Across Reptilia we find that most of the diversity in intracolumnar heterogeneity is directly linked to body size; larger reptiles have more heterogeneous axial skeletons than smaller taxa, whereas no such relationship is recovered across pan-Mammalia. Lepidosaurs are relatively smaller-bodied and have relatively homogenous axial skeletons, pseudosuchians are larger and have moderately heterogeneous anatomies, and the largest sampled reptiles across Ornithodira have the most heterogeneous vertebral columns. We suggest that at larger body sizes biomechanical stresses on the axial skeleton are larger and more heterogeneously distributed along the vertebral column, therefore increasing overall vertebral complexity. Volant birds are the only reptiles that have more complex vertebral anatomies than expected based on body size alone. In birds and mammals vertebral heterogeneity is related to respiratory and locomotory specialization, which is maintained even at small body sizes. The evolutionary history of axial skeletal complexity across Amniota reflects the differential presence or absence of functional constraint. The lack of such constraint in most reptiles may have facilitated morphological plasticity that contributes to a remarkable diversity of ecology, function and form through deep and shallow time.

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## IDENTIFYING FLORISSANT LEAF FOSSILS TO FAMILY USING DEEP NEURAL NETWORKS

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Isolated leaves dominate the angiosperm fossil record, but correctly identifying them remains one of the most challenging problems in paleobotany. The same issues impede both human and artificial intelligence, especially extreme visual variation and incompleteness resulting from taphonomy and the lack of vetted leaf fossils for most plant families. Here, we take a strategic approach by testing a single, well-studied fossil site to minimize taphonomic variation, namely Florissant Fossil Beds National Monument, late Eocene of Colorado. The fossil-image dataset from Florissant, amassed by Herbert W. Meyer et al., is probably the largest of its kind. Wilf et al. (2021, PhytoKeys) made available a subset used here of 3,200 Florissant images vetted to 23 families, of which 19 had sample sizes of at least five specimens, along with 30,252 images of vetted cleared (and x-rayed) leaves, including 4,076 newly added samples from the National Museum of Nature and Science (Ibaraki, Japan). To address the issue of fossil-sample scarcity, we used generative AI to augment the existing datasets of extant leaves with synthetic, highly photorealistic fossil counterparts, enhancing the familial diversity of images analyzable as fossils. We segmented the images to reduce biases from features such as annotations and rulers. For training, we used the 23 families from the Florissant collection, along with a selection of specimens from the cleared leaves dataset (140 families with at least 25 images each) and their corresponding synthetic fossils. We used a transformer based architecture (BEIT) with a custom training objective function. For evaluation, we used a leave-one-out approach, where for each of the 19 Florissant families we provided only synthetic fossils for the out family and tested

on all the real samples for that family, achieving 75% top-5 accuracy on family identification. This demonstrated that the synthetic fossils have potential to bridge the gap for real fossil images. In a less conservative scenario, we performed 10-fold cross validation with a 90-10 split on real fossils, achieving 87% top-5 accuracy. Using all training resources, including 140 families of cleared leaves, their derived synthetic fossils, and all real fossils, the overall top-5, leave-one-out accuracy for identifying Florissant leaves from 19 families was 75% (vs. 3% for chance). We will demo a tool for uploading fossil leaf images and receiving probability-ranked family classifications and visual feedback in the form of heatmaps and family-level visual concepts. We will also provide machine identifications and heatmaps for thousands of additional Florissant leaves that are not confidently placed in a botanical family, providing novel input for paleobotanists. Future work will address the challenges of variation at additional fossil sites that are not as well sampled as Florissant.

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## TESTING THE FUNCTIONALITY OF TRAITS: INSIGHTS INTO EXTINCTION SELECTIVITY PATTERNS OF LATE CENOZOIC MOLLUSKS

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The influence of functional traits on species survivorship has been evaluated in various contexts in both modern and ancient ecosystems, but an important direction for research is to integrate datasets that include both extinct and extant taxa. This approach can provide a more reliable understanding of the effects of functional traits on macroecological and macroevolutionary dynamics. Knowledge of the links between organismal traits and survivorship is crucial for developing accurate predictive models of extinction risk. Here we test the impact of numerous functional traits on the survival and extinction of species through time, using bivalve and gastropod species from the rich fossil record of the western Atlantic over the last ~3 million years, along with the associated extant biota. Analyses use datasets that encompass 12 biological and ecological traits including life habit, feeding behavior, and basal metabolic rate (BMR), for 114 species from 36 families. Traits were identified and measured from specimens in the collections of the Paleontological Research Institution, Florida Museum of Natural History, and University of Kansas, as well as surveys of the literature and online databases such as the Neogene Marine Biota of Tropical America (NMITA) and The Paleobiology Database (PBDB). Preliminary results from the binary logistic regression models were developed using data for the three traits shared across both clades: life habit; shell composition; and BMR. They indicate an effect of life habit (e.g., infaunal, semi-infaunal, or epifaunal) on survival (whether the species is extinct or extant). On average, when the entire dataset is analyzed, the odds of epifaunal species surviving during the time interval considered are ~80% lower relative to infaunal species. In addition, when only bivalve species are considered, we found consistent evidence of this effect of life habit on extinction selectivity. However, when only gastropod species are included in our models, analyzes show no evidence of an effect of either life habit or BMR on survival. Shell composition was not considered as a predictor by our model selection algorithm, which could indicate that, overall, there is no discernible difference between the shell compositions of extinct and extant taxa, and therefore no real effect of this trait on survival of these species. The relative importance of life habit as a predictor of extinction in bivalve species could also involve possible relationships between this trait and higher hierarchical level features. For instance, there might be a relationship between life habit and dispersal capabilities of organisms within species. This in turn would be related to their geographic range, which has a very well-established relationship with extinction risk.

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## USING MACHINE LEARNING TO STUDY CHANGES IN THE LATITUDINAL DISTRIBUTION OF TERRESTRIAL PLANTS BETWEEN THE LATE PALEOCENE AND EARLY EOCENE IN NORTH AMERICA

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The Paleocene-Eocene interval (60–49 Ma) is an excellent time period to study greenhouse climate because it includes

examples of a relatively cool greenhouse climate (mid-to-late Paleocene), the warmest global climate of the Cenozoic (Early Eocene Climatic Optimum or EECO) when mean surface temperature was 10–20 °C warmer than preindustrial levels, and short-lived hyperthermal events like the PETM and ETM2. Previous palaeobotanical studies suggest that plant ranges moved across North America in response to both long-term and short-term global warming, with thermophilic plants extending ranges northward during warming phases and retreating southward during cooling. Most of these studies, however, have used information from very few sites. Palynology has the potential to provide the most temporally continuous and geographically extensive record of terrestrial vegetation. However, pollen identification is time-consuming, and specimen identification is limited by the expertise of the palynologist. Automatized methods, such as convolutional neural networks have shown the potential to speed the workflow of palynological analyses by increasing the efficiency of pollen detection and classification, thus substantially increasing the data that can be collected. To have a better understanding of climate distribution across North America, we describe geographic patterns of floral composition, comparing the late Paleocene cool greenhouse (60–56 Ma) with the EECO hot greenhouse (53–49 Ma). Our research relies on an extensive palynological sample set that is part of the US Geological Survey (USGS) Denver palynological collection, recently donated to the Smithsonian. The 200 samples analyzed are from 28 states from Alaska to Mississippi and provide the largest and densest plant fossil record for North America ever assembled for a pre-Quaternary time interval. We are using a combination of two methods: a digital pathology slide scanning microscope, which allows the imaging of complete microscope pollen samples at more than 20 axial focal planes to capture the three-dimensional data from whole palynological samples; and machine learning models to detect and classify pollen grains. This will be the first of its kind continental-scale integrated "big data" set for paleoclimate and floristics in deep time. The results of this study will be used to test climatic simulations for the Paleocene and Eocene of North America proposed by the Community Earth System models (CESM).

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## MODELING ECOLOGICAL DYNAMICS ON GEOLOGICAL TIMESCALES: CHANGING COMPOSITION, STRUCTURE AND COMPLEXITY OF LATE CRETACEOUS HELL CREEK COMMUNITIES

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The composition, structure and complexity of biological communities are altered by changes of species composition through processes of origination, extinction and migration. Changing composition causes the addition and removal of evolutionary innovations and adaptations, species functions, and biotic interactions. A major goal of systems paleoecology is to understand the impacts that these changes may have on the stability of communities, meaning their resistance to and resilience against perturbations on ecological timescales, and their persistence on evolutionary and geological timescales. Furthermore, whereas properties such as resilience emerge from species dynamics, those properties in turn exert top-down influence and feedback to species dynamics and evolutionary trajectories. An increased understanding of these complex processes must incorporate models that connect community structure and change on geological timescales to contemporary ecological dynamics. Here we report on work on the Late Cretaceous communities of the Hell Creek Formation. We undertook a comprehensive reconstruction of terrestrial and aquatic Hell Creek biota, assigning more than 1,200 observed or modeled species, including plants, invertebrates and vertebrates, to 64 functional trophic guilds. The formation is divisible into three broadly recognized sub-units (~300 kyr each), and the biota was therefore divided into the lower, middle and upper Hell Creek paleocommunities (LHC, MHC and UHC, respectively). UHC is the richest community, including 466 species in contrast to LHC and MHC (420 and 416, respectively). It differed significantly in its food web structure, having greater evenness, link density, connectance and energy flow pathways, but a lower index for potential percolation of perturbations. It also had significantly higher ranges of network trophic position and species maximum chain lengths. These structural differences are accounted for almost entirely by increased richness in several non-megafuanal guilds, including "Very Small Terrestrial Omnivores," "Very Small Terrestrial Faunivores" and "Very Small Endothermic Terrestrial Omnivores," and the introduction of two new guilds, "Small Terrestrial Carnivores" and "Medium Volant Carnivores." Conventional ecological theory suggests that such increases of richness and complexity would cause increased sensitivity and instability of the community. Preliminary modeling of predator-prey dynamics of these guilds, however, which are all connected in a sub-network within the larger community, indicates otherwise, with UHC model communities having overall greater population abundances, and possibly greater resilience to perturbation. We hypothesize that prolonged Late Cretaceous environmental changes and taxonomic turnover may have driven increasing ecosystem resilience.

## REASSESSMENT OF THE TAXONOMIC RECORD OF LUNGFISH (SARCOPTERYGII: DIPNOI) IN THE LATE TRIASSIC OF THE UNITED STATES

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Fossil dipnoans (lungfish) in the post-Paleozoic are mostly represented by isolated tooth plates due to reduced skeletal ossification in the Mesozoic. As a result, taxonomic assignments from the Triassic-onward are often based on tooth plates due to the relative lack of cranial material. These assignments are based on characters such as the number, size, and shape of the ridges and intervening furrows, and the angles that define these features. However, ontogenetic change, positional variation, and wear facets complicate these assessments. In the Triassic of North America, *Arganodus* has long been considered the sole genus represented on the mainland continent, with various occurrences documented in the Chinle/Dockum and more recently in the Newark Supergroup, partially assigned as *Asiatoceratodus*. The Homestead (HS) Site at Garita Creek is a new Late Triassic (Norian, ~215 Ma) microvertebrate assemblage within the Garita Creek Formation of the Chinle Group, located in east-central New Mexico. The HS yields numerous diagnostic tetrapod fossils, along with many osteichthyans, most diagnostic of which are 18 complete lungfish tooth plates and dozens of fragments. Additionally, the Late Triassic (Norian, ~225 Ma) Moncure microvertebrate assemblage in the Cumnock Formation of the Newark Supergroup, located in central North Carolina, has yielded the first published dipnoans of the Newark. Both sites contain various lungfish tooth plates previously assigned to *Arganodus*. We analyze the 18 HS tooth plates, along with 14 from the Moncure locality, using principal component and linear discriminant analyses to determine separation among the specimens and test our taxonomic hypotheses. Using a set of five anchor points, placed on the mesiointernal corner and distal ends of the ridges, we measure the ridge angles of the plates for use in these analyses (ABC, $C_1BC_P$, $C_2BC_P$, $C_3BC_P$). We find that two morphologies are present at both localities: an *Arganodus*-like morph, and a *Ptychoceratodus*-like morph. The synonymy of *Arganodus* and *Asiatoceratodus* has been heavily contested, though our analyses show that *Asiatoceratodus* aligns with the *Arganodus*-like morph. *Arganodus* and *Ptychoceratodus* are closely related genera, and share many overlapping characters in their tooth plates. The main feature that distinguishes the two are the number of ridges, with *Arganodus* having 6–7 (splenial) and 6–8 (palatal), and *Ptychoceratodus* having 4–6 (splenial) and 5–6 (palatal). There is one documented occurrence of *Ptychoceratodus* in the Late Triassic of Greenland, though it is younger than both HS and Moncure. It has been proposed that *Ptychoceratodus* first arrived in Greenland after transitioning over from Europe, but its presence in the Newark suggests they had already transitioned into southern Appalachia, later expanding into the western U.S.A., coexisting with *Arganodus* on at least three modern continents during the Triassic.

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## DISKS AND DYSOXIA: INVESTIGATING POTENTIAL RELATIONSHIPS BETWEEN REDOX CONDITIONS AND SOFT-BODIED PRESERVATION FROM THE MIDDLE DEVONIAN (GIVETIAN) APPALACHIAN BASIN

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The preservation of soft-bodied fossils is rare in the geologic record, often requiring unique environmental conditions. Although several factors may be responsible for the preserving of such forms, reduced oxygen availability has been linked to Lagerstätte deposits. Several instances of soft-bodied fossilization have been reported, but understudied, throughout the Middle and Late Devonian Appalachian Basin. This time interval and region are well-known for prolonged intervals of anoxia, linked to major extinction events. Here, we investigate enigmatic soft-bodied discoidal fossils from three localities from the Middle Devonian (Givetian) of upstate New York. These disks occur in an otherwise fossil barren interval, devoid of typical Devonian shelled taxa, suggesting a possible transition from redox conditions more typical of Phanerozoic oceans to the settings that promoted exceptional fossilization. As these fossils occur in black shales, geochemical proxy data, including Fe speciation and redox-sensitive trace element concentrations (e.g., Mo, Mn, and V), will be incorporated to better constrain local oxygen availability and the role such conditions played in extraordinary preservation. Combining both paleontological and geochemical data allows for a more comprehensive interpretation of the local redox conditions during this interval. Thus far, the data suggest a dynamic redox history that potentially aided in the preservation of soft-bodied forms. Importantly, the spatiotemporal distribution of these enigmatic fossilized disks suggests that oxygen stress was widespread in the Appalachian Basin before the more well-known 'anoxic events' associated with global declines in diversity during the Late Devonian—thus a potential precursor.

## *GONDOLELLA* SPECIES OF THE UPPER SALESVILLE FORMATION, PALO PINTO COUNTY, TEXAS

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Conodont biostratigraphy in the Middle-Upper Pennsylvanian boundary interval is focused on idiognathodid conodonts. Other genera are understudied and have suffered from confusing taxonomic histories. 612 $P_1$-elements of the genus *Gondolella* were recovered from the upper Salesville Formation and over 100 specimens of these elements were imaged with an SEM. Variation in $P_1$-elements of both platformed and naked (non-platformed) species was assessed. Species groups were established and compared to previous taxonomic classifications. The species *Gondolella sublanceolata*, *G. bella*, *G. denuda*, and *G. magna* were recovered, with *G. sublanceolata* being the dominant species. *Gondolella bella* and the naked species *G. denuda* were common throughout. *Gondolella magna* was the least common in the collection. Small sample sizes limited the ability of previous authors to properly assess ontogenic variation within species groups that led to large-scale clumping or extraordinary splitting of species. Revision of platformed species was required. Various authors and researchers have attributed unornamented platforms (lacking transverse ridges) to juvenile forms or even to wear of the platform surface. The smallest specimens do exhibit smooth platforms; however, the large collection showed that smooth forms persist into adult sizes. Specimens with smooth platforms were remarkably uniform in other platform characteristics and belong to the species *G. bella*. High magnification investigation of smooth and ridged platform surfaces yielded no evidence of differential wear. Specimens with well-developed transverse ridges were split among two species based on overall platform shape. Specimens of *G. sublanceolata* have a boat-shaped platform where the dorsal third to half of the platform maintains a uniform width before rapidly tapering to blade. Specimens of *G. magna* are widest at the dorsal margin and taper uniformly to the blade, giving the platform an elongate triangular shape. In all cases, transverse ridges become more developed and margins more crenulate in adult forms. Bifurcation of transverse ridges along with development of scalloped margins occurs in the largest forms and the dorsal margins tend to become squared off in larger specimens. A caudal accessory lobe may develop on the dorso-caudal margin of *G. magna*. Small numbers of specimens have been consistently recorded with secondary cusps dorsal to the primary cusp in both naked and platformed species. The presence of a secondary cusp, adjacent to the primary functional surface of the element, indicates low functional significance. The persistence of this characteristic implies an important evolutionary relationship to ancestral forms with a true dorsal process. Specimens with secondary cusps should be classified and reported as morphotypes of their species. Examples of species exhibiting this morphotype in the upper Salesville Formation include *G. denuda* and *G. sublanceolata*.

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## MIOCENE APES FROM THE LOTHIDOK FORMATION, KENYA

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Most of the Early Miocene record of hominoids comes from the Tinderet and Kisingiri localities in Western Kenya. Mounting evidence from there and elsewhere suggests that much of the taxonomic and adaptive diversity of apes from this time is still to be discovered. Aimed at expanding our knowledge of early apes, the West Turkana Miocene Project (WTMP) has since 2008 carried out paleontological research in the Early and Middle Miocene sediments of the Lothidok Formation exposed to the West of Lake Turkana in Northern Kenya. Since the 1980s, three species of hominoids have been known from the lower Lothidok Fm and are not found at the western Kenya sites: *Afropithecus turkanensis*, *Turkanapithecus kalakolensis*, and *Simiolus enjiessi*. While the first two are known from fairly complete facial specimens, all three are otherwise poorly represented. Our growing collection of hominoid material from these localities suggests that their taxonomic diversity may be greater than previously documented. It also sheds light on the taxonomic position of *Turkanapithecus*, and the positional behavior of *Simiolus*. Now known from unworn molars, *Turkanapithecus* is clearly a member of the Nyanzapithecinae, as previously inferred from badly worn and damaged specimens. The forelimbs of *Simiolus* possess a combination of traits not previously seen in Early Miocene apes.

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## CRANIAL CHANNELS AND SUPRA-PARIETAL VASCULAR PLEXUSES: IMPLICATIONS FOR BRAIN THERMOREGULATION IN MAMMALIAN CARNIVORES

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The significance of cranial surface alterations has been a matter or controversy for the past half century. At one time attributed to iron deficiency, the more likely physiological rather than pathological significance of at least some has more recently been established. Studies of artiodactyls and perissodactyls revealed the presence of supra-parietal vascular plexuses, whose function appears attributable to thermoregulation. Such would explain the evolutionary development of a countercurrent vascular system in ungulates, but what of carnivores? While survival (escape effort) overrides the impulse to maintain brain temperature below critical values in terrestrial prey animals, predator survival is not dependent upon the success of a single hunt. Heat accumulation has been correlated with and is likely the proximal physiologic factor responsible for termination of pursuit by predatory carnivores. This has been observed in species occurring from the high arctic to rain forests to deserts. Thermal extremes in various habitats provide an opportunity to assess the significance of cranial channels and supra-parietal vascular plexuses for brain thermoregulation. Presence of parietal channels and vascular plexus-correlates were assessed in a diffuse selection of Canidae, Felidae, Hyaenidae and Ursidae, noting environmental and behavioral correlates. Vascular branching patterns were observed in all examined members of the genera *Canis* (*familiaris* and *latrans*, excepted), *Cerdocyon*, *Lycalopex (vetulus*, excepted*)*, *Lycaon*, *Otocyon*, *Speothos*, *Crocuta a*nd *Hyaena*, absent in *Chrysocyon*, *Nyctereutes*, *and Melursus*, and variable in *Dusicyon* and *Vulpes*, *Leopardus*, *Lynx*, *Panthera*, *Prionailurus* and *Ursus*. Vascular plexus-correlates were present in all examined members of the genera *Acinonyx*, *Herpailurus*, *Lynx*, *Neofelis*, *Panthera*, *Cerdocyon*, *Chrysocyon*, *Lycalopex*, *Lycaon*, *Otocyon*, *Urocyon*, *Otocyon*, *Speothos*, *Ailuropoda*, and *Hyaena*, absent in *Catopuma*, *Otocolobus*, *Dusicyon Nyctereutes*, *Tremarctos*, *Melursus*, *Crocuta and Proteles*, with variable presence among species of *Caracal*, *Felis*, *Leopardus*, *Prionailurus*, *Canis*, *Vulpes* and *Ursus*, both recent and fossil. Vascular plexus-correlates were found among carnivores in hot dry, hot humid, arctic, as well as temperate habitats, with no obvious preference. There was no identifiable relationship to continent, elevation, or any particular terrestrial biome type. Ectocranial parietal vascular channels represent a phenomenon independent in derivation from vascular plexus-correlates (Chi square = 0.0002, n.s.). Notably, a vascular plexus-correlate was present in *Acinonyx*, but surface vascular channels were not. The presence of a vascular plexus does not appear to be a determinant of resistance to thermal challenges. A role for the surface vascular imprint pattern merits further attention.

## "A STRIKING PATTERN OF INCREMENTAL LAMINATION": GROWTH INCREMENTS IN VERTEBRATE TISSUES

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In the early 1980s, Dan Fisher initiated what would become some of the most detailed work on the lives of individual fossil organisms in the field of paleontology when he used growth increments in mastodon tusks to determine seasons of death and test a hypothesis of scavenging vs. human hunting. The scope has since expanded to include analyses of both tusk growth and composition (e.g., isotopes, trace elements, hormones) to provide deeper insights into the lives of these animals. Here, we trace the history of growth-increment analyses in vertebrates and examine the variation in annual growth series in a variety of taxa and tissues. While the study of tree rings goes back at least to Leonardo da Vinci, documented identification of growth increments in vertebrate tissues and their use to infer animal ages occurred only after the development of microscopes. Initial research into vertebrate growth increments focused on fish scales, and efforts to tie variation in increment magnitude to the life histories of fishes began in the late 1800s and early 1900s, with studies noting phenomena such as increases in salmon scale growth rates that coincided with freshwater emigration. Research on growth increments in reptiles began by the 1930s, and these researchers attributed variation in increment magnitudes to environment and nutrition. Mammalian growth increment research is an interesting case of "fossils first," with H.F. Osborn suggesting that periradicular bands in mastodon tusks might be useful for age determination in 1910. However, it seems that his hypothesis went untested in modern mammals for decades. Growth increment analysis in mammals is generally considered to have started in the 1950s, when wildlife biologists determined that periradicular bands and growth lines in dentin from marked, known-age seals were annual and reflective of seasonal variation in nutritional status. Given that studies across vertebrate taxa suggest factors such as climate and nutrition influence the magnitude of annual increments, observations on the variation in degree of influence are of interest. In many cases, the data required to test the influence of a particular climate or productivity measure on increment magnitude do not exist, but we can adopt the concept of "sensitivity" from Douglass and the field of dendrochronology to assess the degree to which animals are affected by environmental variation. Mean sensitivity is a measure of year-to-year variability in growth series that is dependent on standard deviation and autocorrelation. This measure has long been used in dendrochronology, and although its utility over other measures has been debated, it remains a somewhat intuitive gauge of year-to-year variation often reported in earlier work. We employ this measure and others to compare the variability of annual growth structures across a selection of vertebrates.

## SCREENWASHING FOR VERTEBRATE MICROFOSSILS IN LATE MIDDLE EOCENE STRATA OF THE DUCHESNE RIVER FORMATION, UINTA BASIN, UTAH

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The Uinta Basin, Utah contains both the Uinta and Duchesne River Formations, which comprise a stratigraphic sequence spanning ~7.8 million years (45.8–38 Ma) and are the type formations for the Uintan and Duchesnean North American Land Mammal Ages (NALMAs). Historically, late Uintan (Ui2–Ui3 biochrons) faunas have been studied in detail. Over the past 30 years, surface collection of mammal fossils from these biochrons were the primary focus of study, with one exception: the screenwashing project at the WU-26 locality yielding 545 microfossils from the Ui3 biochron. The Uinta Basin Project now aims to construct a high-resolution stratigraphic section to document faunal change over the Uintan-Duchesnean transition, an interval that we have shown records the last Eocene hyperthermal event, the Middle Eocene Climatic Optimum (MECO; 41.5–40 Ma). In order to best capture the vertebrate response to the MECO event, we began screenwashing efforts in the Duchesne River Formation, which is known to yield few microfossils. During the 2022–2023 field seasons, we sampled mudstone and claystone sediments from 22 localities, primarily in the Duchesne River Formation. These localities bracket or are known to record the MECO event. Matrix was first screenwashed in 20 and 30 mesh nested boxes in the field; the remaining concentrate was then further washed in 20, 30, and 50 mesh sieves in the lab. A team of undergraduates picked through the finer grained 30 and 50 mesh concentrate under a dissecting microscope to identify microfossils. The coarser grained, 20 mesh concentrate underwent a chemical soak (hydrogen peroxide and mineral spirits) to further crack the clay before picking. Mammal, reptile, and fish specimens (N = 152) were identified from 12 localities. While most specimens were fragments of bones, 38 teeth or tooth fragments were found, including 18 cheek teeth and 11 incisors. Rodent teeth were the most commonly identified, with eight assigned to the genus *Metanoiamys*. Other taxa include *Protadjidaumo* and a possible marsupial. These results indicate we were successful in establishing a productive screenwashing methodology and identifying vertebrate microfossil localities in the Duchesne River Formation. Thus, we will continue these screenwashing efforts to further expand the microfossil collection and better capture the impact of the MECO on Duchesnean faunas.

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## DESCRIPTION OF A SPADEFISH (ACANTHOMORPHA: EPHIPPIDAE) FROM PAKISTAN AND ITS IMPLICATIONS FOR MARINE FISH BIOGEOGRAPHY IN THE PALEOGENE

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Ephippidae (spadefishes) is a clade of marine fishes containing 15 extant species divided among 8 genera. Found on coral reefs and in open waters worldwide, ephippids are laterally compressed fishes with small, non-protrusive mouths and often bear striking, dark vertical bars of pigmentation on their flanks. Articulated remains of putative ephippids derive almost exclusively from the early Eocene (Ypresian, ca. 49 Ma) deposits of Bolca, Italy, and include two extinct genera: *Eoplatax* and *Archaephippus*. Today the greatest diversity of extant spadefish species is in the Indo-West Pacific, yet there are no known fossil ephippid remains from this region. Here we report the first fossil spadefish from the Indo-Pacific, from the middle Eocene (Lutetian, ca. 47 Ma) Habib Rahi Formation of western Pakistan. Preserved as an impression on a limestone slab, this single articulated individual does not preserve definitive synapomorphies of ephippids, such as the branchial skeleton, dentition, and pelvic girdle. However, intact portions of the skeleton correspond closely to the anatomy of *Eoplatax* from Bolca. Major similarities include a nearly circular body, greatly elongated dorsal- and anal-fin rays, and a very deep caudal peduncle. The discovery of an *Eoplatax*-like fossil in the middle Eocene of Pakistan could have important implications for marine fish biogeography in the Paleogene. At this time, Indo-Pakistan is thought to have been outside the margins of an ancient biodiversity hotspot centered in the West Tethys. The presence of similar faunal elements in the ancient Indo-Pacific can help to constrain models of shifting biodiversity hotspots during the Cenozoic. Such hotspot migration is supported by fossil evidence as well as patterns of relationships among some extant groups. Integration of putative fossil ephippids, including the new form from Pakistan, into a phylogenetic framework with living examples will be critical for determining what—if any—bearing spadefishes might have on these broad biogeographic questions.

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## INVENTORY OF EAR STONES: DATABASE OF OTOLITHS THROUGHOUT THE CENOZOIC

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Otoliths, aragonitic growing structures found in the inner ear of teleost fishes, provide a unique tool for reconstructing past fish faunas, their evolution, and paleobiogeography. Due to their high preservation potential, small size, and robust structure, otoliths can be collected systematically via bulk sampling of poorly consolidated sediments. Furthermore, the morphology of otoliths is diagnostic, permitting consistent taxonomic identifications. Formal analyses comparing living to fossil assemblages are not yet available; however, the composition of recent or geologically young otolith accumulations reflects the fish assemblage of their modern communities. This suggests fossil otolith assemblages might accurately capture the diversity of ancient faunas. Although the otolith record shares geographical biases with the fossil record more broadly, the greater abundance of fossil otoliths means this record provides a more complete geographic picture than the sparse record of articulated fish skeletons. Here, we have created an online database of compiled fossil otolith literature throughout the Cenozoic, incorporating information on lithology, locality, geological age, and taxonomy. Over 50 reports were synthesized, yielding a database of over 100,000 otoliths from over 100 unique fossil localities. This database can be used for future research to understand the spatiotemporal distribution of marine fishes throughout the Cenozoic.

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## EVOLUTION OF PROBOSCIDEAN DENTAL FUNCTIONAL TRAITS—HOW ARE THEY RELATED TO VEGETATION AND CLIMATE?

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Proboscideans have been the largest herbivorous terrestrial mammals on most continents since their dispersal out of Africa during the early Neogene, and they have had a profound ecological role as keystone megaherbivores since then interacting with their environment and other mammals, including humans. On the other hand, they were ecologically versatile and non-selective feeders, and their diets and adaptations have tracked changes in climate and vegetation through time. We explored the evolution of proboscidean dental traits in East Africa during the last 26 million years in relation to climatic aridification and changes in diet and local vegetation patterns. We show that some proboscideans started to adapt to locally grass-rich environments in East Africa first by changing their behavior and starting to feed more on grasses. This happened in some lineages of proboscideans, such as choerolophodonts, much earlier than has been thought until now, during the Early and Middle Miocene, in parts of East Africa where the environments where locally more grass-dominated than in the surrounding areas. Also, around 7 million years ago in the lake Turkana region, increasingly grass-rich diets of the earliest true elephants were associated with dryer and more grass-rich savanna environments than elsewhere in East Africa, supporting the hypothesis of such regions as "species-factories." During the Early and Middle Miocene choerolophodont proboscideans were able to shift to more grass-rich diets with relatively modest changes in the morphology of their teeth. Our results suggest that aridification of climate in East Africa during the last 10 million years was the major driving factor that led to the evolution of multi-ridged, high-crowned teeth in true elephants to increase functional durability and shearing efficiency of the teeth. Moreover, we show that the major evolutionary changes in these traits happened in steps following the strongest peaks of aridification. This supports earlier suggestions that adaptive traits in organisms are adaptations to extreme rather than average environmental conditions. We also show that the drastic increase in loph count was enabled only after proboscideans evolved a specialized propalineal (front-aft) chewing between 10 and 8 million years ago. Alongside the aridification of climate, an important factor contributing to the evolution of elephant teeth during the last 7 million years was the spread of grass-dominated savannas in East Africa, favouring elephant species with highly durable, multi-ridged teeth, such as species in the genera *Elephas* and *Palaeoloxodon*. However, the rapid fluctuations of climate during the last ca. 300,000 years could have been challenging on grassland environments, which could explain why those previously successful grazing-adapted lineages of elephants eventually went extinct, while the less specialized and dietarily more flexible modern elephants survived.

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## A PEIROSAURID CROCODYLIFORM FROM THE UPPER CRETACEOUS (CENOMANIAN) BAHARIYA FORMATION OF THE BAHARIYA OASIS, WESTERN DESERT, EGYPT

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The Upper Cretaceous (Cenomanian) Bahariya Formation of the Bahariya Oasis in the Egyptian Western Desert has yielded a diverse assemblage of non-avian dinosaurs. Crocodyliforms, however, are less speciose, being represented to date by only three valid taxa: the notosuchian *Libycosuchus brevirostris* and the neosuchians *Stomatosuchus inermis* and *Aegyptosuchus peyeri*. Here we report an isolated partial right dentary of a medium- to large-bodied peirosaurid crocodyliform from the Bahariya Formation, collected by the Mansoura University Vertebrate Paleontology Center (MUVP). The new specimen exhibits several features consistent with placement in Peirosauridae, a Gondwanan Cretaceous mesoeucrocodylian clade not previously reported from northeastern Africa. Peirosaurid synapomorphies include a wide divergence angle (48°) of the mandibular rami, a sinusoidal dorsal margin of the dentary comprising two distinct waves, and a mediolaterally compressed dentary with a vertical ventrolateral surface anterior to the mandibular fenestra. Additionally, the anteriormost alveoli are strongly procumbent, and the dentary is concave lateral to alveoli 6/7 and 8/9 for the reception of two enlarged maxillary teeth. Dentary teeth 1, 4, and 11 are enlarged, and the dentary crowns are conical and triangular in labial view with a gently curved apex. Phylogenetic analysis recovers the Bahariya form within Peirosauridae, in a clade that also includes *Miadanasuchus oblita* from the Maastrichtian of Madagascar and *Barrosasuchus neuquenianus* from the Santonian of Argentina. This clade is supported by unambiguous synapomorphies, including a dentary symphysis that is U-shaped in ventral view and smoothly curving anteriorly and an elongate, anteroposteriorly shallow concavity lateral to teeth 5–10 on the lateral surface of the dentary to receive an enlarged premaxillary tooth. Moreover, the three taxa lack a 'peg' at the posterior edge of the mandibular symphysis. MUVP 523 therefore represents the first unquestionable peirosaurid from Egypt and northeastern Africa more generally. The new specimen augments the crocodyliform assemblage of the Bahariya Formation, and when considered in tandem with taxa from northwestern Africa, demonstrates the wide geographic distribution of Peirosauridae across northern Africa during the 'middle' Cretaceous.

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## MAMMAL COMMUNITY EVOLUTION THROUGH THE CENOZOIC OF OREGON WAS DRIVEN BY CLIMATE CHANGES AND GEOLOGIC INFLUENCES

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The incredible paleontological and geological records of the John Day and Crooked River basins of Oregon document evolution in faunas and floras through nearly 50 million years of time. A well-dated sequence of strata, with over 40 dated tuffs and lava flows, and thousands of fossil specimens provide an excellent chronology of environmental changes through time. Studies of paleosols, paleobotanical records, isotopic analyses, and recent ecometric analyses also provide independent evidence of climate and habitat changes through the sequence. Multiproxy data reveal trends of cooling and aridification of the region starting in the early Oligocene, which correspond with opening of habitats. During the Middle Miocene Climatic Optimum, which is attributable to the Columbia River Basalt Group (flood basalts), evidence from multiple proxies indicates the region had warmer and more humid conditions. The John Day and Crooked River basins include fossil mammal assemblages from the middle Eocene through the late Miocene. While completeness of assemblages varies, these basins include taxa from every North American Land Mammal age from the Uintan to Hemphillian, except the Clarendonian. We analyzed 18 fossil mammal assemblages using community structure analysis, including 284 mammal taxa coded into tooth crown height and locomotor categories using data from the NOW Database. The relative abundances of crown heights, locomotion, and patterns of species richness within clades were: 1) compared across assemblages; and 2) compared to independent records of paleoclimate and habitat conditions. Mammal communities in Oregon show clear shifts that correspond to the timing of climate and habitat changes in the region. After the Eocene-Oligocene transition, small ungulates became less common, rodents and lagomorphs shifted to be dominated by taxa with higher-crowned teeth, and the earliest cursorial rabbits and burrowing rodents appeared. Through the late Oligocene and early Miocene, high-crowned and cursorial ungulates appeared, as did running-adapted carnivorans and saltatory rodents. At that time, open habitat specialists became more common, while forest-dependent groups declined. In the early and middle Miocene, low-crowned browsing herbivores and arboreal mammals were still common, but open habitat specialist cursorial ungulates and burrowing rodents diversified greatly, possibly attributable

to massive volcanic activity in the region at the time. Late Miocene assemblages have predominantly high-crowned taxa in both large and small herbivorous mammals, similar to species living in the Columbia Plateau today. Overall, detailed records in Oregon reveal dynamic mammal community evolution driven by changes in climate and geologic influences.

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## NEW CARNIVORAN FOSSILS OF THE NATURAL TRAP HOYO NEGRO, FROM A SUBMERGED CAVE IN THE YUCATAN PENINSULA OF MEXICO

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The natural trap Hoyo Negro, preserved within the Sac Actun cave system in Quintana Roo, Mexico, records a rich and exceptionally well-preserved late Pleistocene fauna. The ursid *Arctotherium wingei* and canid *Protocyon troglodytes*, both previously thought to be restricted to South America, were recently described from the site. *Smilodon fatalis* has also been noted in previous studies of Hoyo Negro. Here, we report several additional carnivorans from Hoyo Negro, which include three felids (*Puma concolor*, *Leopardus pardalis*, *L. wiedii*), one procyonid (*Nasua narica*), and two mephitids (*Spilogale yucatanensis*, *Conepatus semistriatus*). These species are represented by well-preserved fossil specimens, with nearly complete skulls and dentition represented for each taxon. The skull of *S. yucatanensis* is particularly interesting, as it displays lesions that are evidence of frontal sinus damage due to nematode parasites. Of the Hoyo Negro species, puma, margay, coati, and spotted skunk had previously been recorded from Cueva de Loltun in the Yucatan, but the hog-nosed skunk (*C. semistriatus*) is the first fossil record from this region. The presence of multiple extant carnivorans that currently occur in the Yucatan (puma, ocelot, margay, coati, hog-nosed skunk, spotted skunk) suggests these species have existed within their current ranges for thousands of years, and may have co-occurred in the Pleistocene with a diverse array of larger extinct carnivorans. It is important to note that though these fossils were all recovered from the floor of Hoyo Negro, they may not be contemporaneous, and instead may have lived and died thousands of years apart. Fossils reported here raise the number of carnivorans known from the site to 9 species, and highlight the extraordinary opportunity these submerged Yucatan caves have to preserve and reveal the history of life in the region, with great potential for even more discoveries in the future.

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## SPATIAL DIVISION OF REPRODUCTIVE LABOR IN THE BRYOZOAN *PARASMITTINA AREOLATA* AND IMPLICATIONS FOR INTERPRETING THE CHEILOSTOME FOSSIL RECORD

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Colonial organisms benefit from optimizing the division of labor amongst individuals in a colony. For colony organization to evolve, individuals need developmental plasticity that is heritable. Bryozoans, a phylum of colonial marine invertebrate, are an excellent system in which to study the long-term evolution of polymorphic traits. The cheilostome order of bryozoans have polymorphic larval brood chambers known as ovicells, and the density of ovicells on a colony is a proxy for number of offspring and therefore fitness. However, our understanding of how and why ovicells are spatially arranged in living bryozoan colonies remains incomplete, hampering our ability to make interpretations of their fossil record. Newly automated digital light microscopy allows us to now image and map ovicells across entire bryozoan colonies. We take advantage of a previous experiment in which *Parasmittina areolata* was bred in a controlled laboratory setting to study ovicell arrangement and its heritability across a population of complete bryozoan colony specimens. We find the distribution of ovicells on a colony is nonrandom. Ovicells are clustered; as distance from an ovicell increases, the density of other ovicells decreases by 27% per mm. No aspects of ovicell arrangement are more similar between parents and offspring than between unrelated colonies. We subset our colonies to simulate fossil fragments and test whether the common practice of measuring ovicell density from fragments is an accurate and precise measure of ovicell density on an entire colony. When 1-10% of the colony is sampled, 92% of ovicell density estimates are more than two binomial standard errors from the true value. When 90-99% of the colony is sampled, 19% of ovicell density estimates are similarly imprecise. Therefore, when estimating ovicell density for a fossil population, the large uncertainty in the estimate should be calculated based on the observed variance between colony fragments caused by ovicell clustering.

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## LIVE-DEAD DATA FROM BENTHIC MARINE SURVEYS OF THE EASTERN GULF OF MEXICO REVEAL POSSIBLE RANGE CONTRACTION IN AN IUCN RED LIST CONE SNAIL

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For over a century, anthropogenic pressures have caused declines in coastal marine habitat function and biodiversity of the Gulf of Mexico. Existing baseline data, however, extend back only a few decades, emphasizing the need for longer-term perspectives. Molluscs from a recent dredge survey of the entire West Florida shelf include shells from $^{14}$C- and amino acid racemization-calibrated taphonomic grades (live; grade I, decades; grade II, centuries to millennia), making them a valuable resource for documenting such long-term differences in the region. In this study, we use this survey collection to model changes in density distributions of a vulnerable IUCN Red List cone snail, *Conus anabathrum* over time. *Conus anabathrum* live and dead records in the survey dataset are rare, comprising just 150 out of more than 28 thousand individual gastropods (0.005%) and 32 out of 230 total station occurrences (14%). Occurrences of dead grade II shells ranged from shallow (4 m) to the outer shelf depths (91 m), with the highest counts and station densities at lower latitudes west of the Everglades. Most (89%) of the total occurrences recorded for *C. anabathrum* are dead shells, demonstrating the value of dead shells for assessing the long-term distributions of rare species. However, younger grade I and live records were almost entirely restricted to shallower inshore waters less than 20 m depth. This observation matches historical trends for the species in presence-only records from museum collections, which suggests that the pattern is real. This project is part of a larger transdisciplinary, collaborative effort with Florida Fish and Wildlife to assess threatened species for management and policy decisions.

## PROBOSCIDEANS OF THE SIWALIKS: A WORLD LIKE NO OTHER

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The Siwalik Group of the Potwar Plateau, Pakistan comprises an extensive Early–Late Miocene succession of terrestrial fossil beds dated with remarkable precision between ca. 18 and 6 Ma. These beds are organized into superposed formations: Kamlial, ca. 18–14.3 Ma; Chinji, 14.3–11.2 Ma; Nagri, 11.2–10.1 Ma; Dhok Pathan, 10.1–3.5 Ma. Nearby sedimentary deposits extend the fossil record of these and related beds from the late Oligocene to the early Pleistocene. Successions of mammalian fossil assemblages are highly diverse and abundant, reflecting great heterogeneity of subtropical habitats, and increasing importance of C4 grasses in the Late Miocene onward. Proboscideans are speciose and fossil-rich in the Potwar Plateau sequence, consisting of deinotheres, choerolophodonts, amebelodonts, gomphotheriines, tetralophodonts, stegolophodonts, and anancine gomphotheres. The current project taxonomically identifies the proboscidean fossils from the Potwar Plateau and places them in geological, ecological, and temporal contexts. Biogeographic study indicates derivations of Siwalik species from disparate regions of the Old World, but migration patterns may have been circuitous and are difficult to decipher. Dental isotopic and microwear analyses suggest that these proboscideans were either leaf browsers/partly frugivorous, such as deinotheres and mammutids, or mixed feeders incorporating some C3 or C4 grasses into their diets (Dhok Pathan stegolophodonts, gomphotheriines, amebelodonts). Taxonomic investigation of the site sample shows that deinotheres are represented by *Prodeinotherium* in the Kamlial and Chinji fms. (18–11.7 Ma) and *Deinotherium* in the Chinji to Dhok Pathan fms. (13.5-8.1 Ma; an earlier appearance and demise of the genus than in Africa, and possibly locally evolved); mammutids by *Zygolophodon* in the Chinji Fm. (13.8–12.4 Ma); choerolophs by primitive *Afrochoerodon* in the Kamlial and *Choerolophodon* in the Chinji through Dhok Pathan fms. (14.1–7.4 Ma); gomphotheriines by *Gomphotherium* in the Chinji (13.9–11.4 Ma); amebelodonts by *Protanancus* in the Chinji and Dhok Pathan fms. (14.0–6.5 Ma) and a shovel-tusker (?*Konobelodon*) in the Dhok Pathan Fm. (8.7 Ma); tetralophodonts by *Paratetralophodon* (8.7–7.4 Ma); and rare anancines by *Anancus* at 8.9 Ma in the Dhok Pathan Fm. *Stegolophodon* species sort into a primitive-advanced series ("groups 1–6") from the mid-Chinji Fm. at 13.7 Ma to the Dhok Pathan Fm. at 7.4 Ma, indicating several migrations from Asia. Coexistence of multiple proboscideans throughout the Siwalik sequence, alongside other megaherbivores, reveals ecosystems unlike those observed in modern times, of astonishing carrying capacity. Survey of collections from the Indian Siwaliks shows that proboscidean diversity was even greater than estimated from the Potwar Plateau sample, raising questions of how to reconstruct biotic interactions in these ancient communities.

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## WINNERS AND LOSERS IN AFRO-ARABIAN PROBOSCIDEAN EVOLUTION

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Proboscideans are the oldest continuously represented eutherian mammals in Afro-Arabia, with a fossil record extending to 60 Ma. Taxonomically depauperate since the end of the late Pleistocene, in prior intervals they were more speciose and phylogenetically diverse. Most major proboscidean evolutionary episodes occurred in Afro-Arabia, including their origins, initial succession of plesielephantiforms, derivation of barytheres, deinotheres, and moeritheres, origination and diversification of elephantimorphs into gomphotheres and mastodons, and first appearance of elephants. For their first ~30 Myr, proboscideans were isolated in 'Island Afro-Arabia'; consequently, all Eurasian and North and Central American proboscideans have ancestries linked to the continent prior to emigration events after the onset of the Neogene. The current study chronologically traces morphological and behavioral *adaptations*, and climatic, tectonic, biogeographic, and ecological *contexts* of Afro-Arabian proboscideans over this 60-million-year interval, to investigate selective drivers of origination, success, adaptive radiation, and extinction of major taxa that comprise significant phylogenetic episodes. The project is based on comprehensive comparative morphological analyses of fossil and extant Afro-Arabian proboscideans. *Features* of study include degree of cranial configuration; dental formula; degree of lophodonty; expression of cementodonty; number and hypsodonty of molar loph(id)s or lamellae; development and placement of accessory conules; arrangement of half-loph(id)s; tusk development; mechanisms of cheek tooth emergence and deployment; and occlusal evidence for chewing mechanics and diet. Seven *episodes* are highlighted as especially significant: (1) Origin and initial succession of plesielephantimorphs (Paleocene, Eocene); (2) first occurrence of elephantiform-like taxa and moeritheres (Eocene); (3) origin and diversification of barytheres and deinotheres (Eocene, Oligocene); (4) appearance and divergence of early elephantiforms (Oligocene); (5) origin of elephantimorphs and division into Elephantida and Mammutida (Oligocene); (6) diversification of Elephantida (gomphothere radiation; Miocene); and (7) origin and ecological dominance of elephants (Miocene). The components/mechanisms of *evolutionary novelties* associated with these episodes are elucidated, such as hypertrophy and functional specialization of anterior dentition; gigantism and graviportal postcrania; increased complexity of occlusal characters; horizontal tooth displacement; conversion of loph(id)s into lamellae; cranial reconfigurations; and adoption of proal shearing mastication. The study illustrates how the interplay between these morphological innovations and their selective drivers winnowed 'losers' from 'winners' in major episodes of Afro-Arabian proboscidean evolution.

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## COSPLAY FOR SCIENCE: AN AMBITIOUS CROSSOVER OF POP CULTURE AND SCIENCE EDUCATION

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In a world of instant information and digital media, science educators and scientists working to educate the public continue to be plagued by an onslaught of well-meaning misinformation and targeted anti-science sentiments. Running parallel to that, pop culture media is often the first exposure for many to scientific concepts but rarely aid in developing critical thinking skills or bettering audience's perceptions of science. Traditional learning settings, such as classrooms, tend to focus on memorization for practical examinations and rarely address topics such as media literacy. Informal learning environments, such as natural history museums, provide opportunities for counteracting such activities, yet these settings can only be effective if audiences willingly participate. This is most often not the case as such informal settings are self-selecting in their audience or inaccessible to some audiences. To effectively educate audiences and shift perceptions of science, scientists, science communicators, and educators must extend their reach beyond "traditional" techniques and settings and work with pop culture and media. The Cosplay for Science (C4S) Initiative was founded in order to do just that. By utilizing a framework that combines storytelling, pedagogical practices, and scientific evaluation with pop culture and cosplay, the C4S initiative works to educate audiences on the science concepts woven into well-loved pop culture stories, increase media literacy, and shift perceptions of scientists and STEAM in general into the positive. In order to reach wide audiences, the C4S Initiative mainly operates at pop culture events such as comic cons, through themed pop-up museums and science-themed panels. For example, the concepts of planetary geology, paleontology, and evolutionary biology within the Star Wars universe explained through the use of museum specimens. To understand the potential for science learning with comic con attendees, we used the two-pronged conceptual framework of effective framing and narrative structuring to delineate aspects of educative science communication efforts used by cosplaying scientists. In addition, the C4S Initiative is collaborating with educational institutions and professors to develop curriculum that educate college students in specific scientific concepts while also training them in effective science communication. Overall, the Cosplay for Science Initiative's innovative approach to education is an example of how modern scientists and educators can use pop culture and digital media to science's benefit and to the benefit of audiences.

## BIVALVES FROM THE NEOGENE DEPOSITS OF ALGERIA (SYSTEMATIC & PALEOENVIRONMENTS)

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Negoene deposits of the northwest of Algeria have yielded rich and high diversified malacofauna. However, more than 60 taxa have been identified in several facies, belonging to the Upper Tortonian, Messinian and Pliocene outcrops. Pectinidae and Ostreidae are the most common groups. Shells have shown mostly a good state of preservation and their size could be more important in reef limestone. Neogene bivalves fauna have characterized variable environments : outershelf deep mud, innershelf reef limestone and onshore sands. Keywords : bivalves, Neogene, Algeria, Pectinidae, Ostreidae, shell preservation, environment.

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## BIOLOGICAL MEANING IN THE RISE AND FALL OF FOSSIL SPECIES

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Many fossil species show a characteristic rise and fall in their global ecological footprint—their occupancy—over their lifespans. Despite much analysis of these patterns over the last few decades, there is little consensus yet as to the biological meaning of the rise and fall of species, and whether and how it differs from expectations under possible null models. Here we develop and test an approach which uses ecological neutral theory to cut to the heart of the issue: a neutral model for the abundance of fossil species is contrasted with a model in which individuals of younger species are fitter than those of older ones. Model comparison with AIC shows decisive support for the non-neutral model in a dataset of species occupancy trajectories among planktonic foraminiferans: younger species do tend to expand, and older ones tend to decline. We use the non-neutral model to predict extinction probabilities based on species age and abundance. This model may explain the relatively unique positive relationship between species age and extinction risk in foraminiferans. Long-term occupancy trajectories predicted under the non-neutral model are strikingly different from neutral trajectories, but correspond to only a tiny mean fitness difference between old and young species which would be challenging to detect in empirical populations. The rise and fall of species is unlikely to be a statistical artifact but is rather a genuine biological phenomenon in need of explaining.

## UNCOVERING, CONSERVING, AND INCREASING ACCESS TO FEDERAL PALEONTOLOGICAL RESOURCES AT MUSEUM OF THE ROCKIES

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Museum of the Rockies (MOR) is a repository for federal paleontological resources from multiple land management agencies in the northern Rocky Mountains region. Renowned vertebrate specimens, including the *Allosaurus* "Big Al" (MOR 693), *Tyrannosaurus* "B-Rex" (MOR 1125), and *Triceratops* "Yoshi's Trike" (MOR 3027), are just some of the scientifically significant fossils collected from federal lands that continue to shape our understanding of paleobiology. An estimated 250,000 federal fossils are cared for in the MOR collections, with ongoing fieldwork continually adding to this number. MOR provides hands-on training for students working with fossils throughout the entire process of paleontology, from discovery in the field, to detailed preparation and histological processing in the laboratory, curation and cataloging in the collections, and active research projects. Federal fossils are also the subject of educational and outreach initiatives. Over the years, the MOR Paleontology Collections have been updated and expanded with support from federal partners, allowing for the addition of archival cabinets, trays, and pallet racking systems. This has expedited development of a new holotype room to increase security for exemplar specimens. Support from federal partners has also funded student interns working to identify and catalogue specimens. Currently, MOR staff are reorganizing the fossils in the Paleontology Collections according to land management agency, locality, taxonomy, and anatomy. Data are also being transferred to a relational database with the goal of making the collection searchable online. These steps will facilitate specimen tracking and increase accessibility. Through partnerships with federal agencies, MOR continues to work to ensure public fossils remain an accessible and continual source of new discoveries.

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## USING THE FUNCTIONAL TRAITS OF SMALL MAMMALS TO ESTIMATE PAST ENVIRONMENTS AT NATURAL TRAP CAVE, WYOMING

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Functional ecology, the study of how functional traits relate to specific ecological processes and the environment, has been an informative method to understand community dynamics of past and present ecosystems. The use of functional traits in ecological studies has become widespread because trait-based approaches are better at predicting ecosystem functioning than taxonomic approaches alone. Strong correlations between functional traits and various aspects of climate and the environment including temperature, precipitation, nutrient cycling, primary productivity, and openness have been found in a variety of study systems. As functional traits are tied to a taxon's ability to interact with its environment, and are correlated with modern environmental variables, we can use functional traits preserved in the fossil record to estimate these aspects of past environments. Recent work has highlighted the importance of considering biases in sampling efforts and the nonrandom distribution of traits within a community, which may skew paleoenvironmental estimates derived from community-averaged trait values. Here, we use abundance-weighted functional traits of the small mammal (rodent and leporid) community at Natural Trap Cave (NTC) over the last 25,000 years to estimate past environmental variables. NTC is a 24.5 m deep karst sinkhole located at the base of the Bighorn Mountain range in Wyoming, U.S.A. An exceptional fossil record of microfaunal remains comes from well-stratified layers in the cave stretching back before the end-Pleistocene megafauna extinction, up until a few hundred years ago. We calculated the relative abundances of the small mammal community (< 1 kg) across three time periods: the Late Pleistocene (LP), Middle Holocene (MH), and Late Holocene (LH). We focused on functional traits, including tooth crown height, body mass, diet, and locomotor pattern, to make inferences about how the environment around NTC changed through time. We found an increase in the abundance of high crowned teeth and cursoriality (running) from the LP (40%, 10%) to the MH (78%, 44%) and LH (76%, 41%) indicating a shift to a more open and arid environment. The percentage of plant consumption also increases from the LP (41%) to the MH (74%) and LH (76%), with a simultaneous decrease in the percentage of invertebrate and seed consumption (25% and 19% respectively in the LP; 10.5% and 9% in the MH; 9.2% and 8% in the LH), all indicating open habitats. We also note an increase in community body size into the Holocene, largely driven by an increase in leporid abundance, which is potentially the result of ecological release from the megafauna extinction. Through abundance-weighted function trait values, we can parse out rarer traits from more common traits to understand the dynamics of functional niches. We are also able to generate more nuanced interpretations of past environments by using the morphology of taxa that were directly interacting with their local ecosystem.

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## *CELTIS* ENDOCARP BOUND ORGANIC MATTER $\Delta^{15}N$: A POTENTIAL PALEOCLIMATE PROXY

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*Celtis* (common name Hackberry) is an extant genus of plant that is quite unique in creating an aragonite shell (endocarp) around the seed within a fruit. Because mineralized *Celtis* endocarps are often preserved in fossil material, they have received attention as a potential paleoclimate archive. Carbonate clumped isotopes and oxygen isotopes have been shown to record growing season temperatures. Here, we explore another isotope system in hackberry endocarps that may preserve paleoclimate information, the nitrogen isotopic composition of endocarp-bound organic matter ($\delta^{15}N_{EBOM}$). As a *Celtis* endocarp mineralizes within a fleshy fruit, small amounts of nitrogen containing organic material become trapped within the aragonite matrix. In the modern environment, correlations have been observed between the $\delta^{15}N$ of other plant material and environmental variables like mean annual temperature (MAT) and mean annual precipitation (MAP). In this work, we investigate the use of $\delta^{15}N_{EBOM}$ for paleoclimate reconstructions with a suite of modern endocarps from a MAT and MAP range across North America. We present preliminary analyses of fossil endocarps from the Holocene of Pennsylvania and the Paleocene Eocene Thermal Maximum (PETM) of the Bighorn Basin. To remove any exogenous organics from fossil material and measure the biomineral-native nitrogen, we use an intense chemical cleaning and the oxidation-denitrifier method for nanomole-level nitrogen isotopic analysis In modern North American *Celtis* endocarps, we find correlations between $\delta^{15}N_{EBOM}$ and MAP, vapor pressure deficit (VPD), and a measure of seasonality. Future work will bolster our modern ground truthing by expanding the MAT, MAP, and seasonality ranges with endocarps from new sites. We also investigate the impact of the recrystallization of aragonite to calcite on $\delta^{15}N_{EBOM}$. Aragonite is metastable and commonly recrystallizes to calcite in the fossil record. If recrystallization does not affect $\delta^{15}N_{EBOM}$ and robust relationships exist between $\delta^{15}N_{EBOM}$ and climate variables over a larger modern climate range, this proxy holds promise for application to periods of particular interest with abundant *Celtis* endocarp fossils like the PETM.

## THE ANATOMY OF A MASS EXTINCTION: COMPARING THE PRESENT WITH THE PAST

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All of Earth's past mass extinctions hold one factor in common: a rapid loss of biodiversity over a geologically brief interval of time. Present-day rates of species loss, if calculated for time intervals comparable to past extinction intervals, estimate that the current mass extinction will fall within or even exceed past species-level estimates for mass extinctions. Published and calculated estimates for extinction rates since AD 1500 indicate that, if rates are unchecked and are kept constant, global species loss will approach 50% by 69,000 years from now (at a 0.5% species extinction rate) to 3,250 years from now (at a 10% species extinction rate). Lag times of continued environmental stress that precede post-mass extinction recovery, and the recovery interval itself, vary in length among Earth's past mass extinctions. For the present biodiversity crisis, no matter the magnitude of an ensuing mass extinction, the global environment will need to recover before diversification can take place. Lag and recovery intervals will depend on human activity: in the best-case scenario, if anthropogenic factors like greenhouse emissions and habitat destruction cease and even reverse in the near future, the present biodiversity crisis may be truncated before it becomes a mass extinction and lag and recovery times will be accordingly short. If, instead, anthropogenic deterioration of the Earth's systems continues, the process of environmental recovery and re-diversification will be dependent on the cessation of human impacts and proportional to the magnitude of the crisis. The one positive aspect of the present biodiversity crisis is that all human-caused environmental deterioration is controllable and reversable; the present-day biodiversity crisis is not facing a geologically-caused, ongoing environmental crisis, like the emissions from a large igneous province or an oncoming and inevitable ice age. As extinction scientists, in facing the present global biodiversity crisis, we have the advantage of the vast natural laboratory of Earth's history to find solutions that could decrease the magnitude of the future mass extinction. The anthropogenic drive behind the current mass extinction is unique in Earth's history, but many of the human-caused environmental and biodiversity crises have analogs in past mass extinctions. Some analogs are direct comparisons between the past and present, like rapid warming, habitat loss, and range shifts. Some problems that appear unique to the modern crisis may still have a relevant correspondence in the past, like particulate pollution, decline in top predators, and marine dead zones. Similarly, there are many potential solutions to extinction survivorship that can be found in past mass extinctions and that are relevant, even essential, to helping solve present-day biodiversity crises.

## TRENDS IN BIOSTROME-OFF BIOSTROME PALEONTOLOGY, SEDIMENTOLOGY, AND DIAGENESIS IN THE WATERWAYS FORMATION (LATE DEVONIAN) FROM ALBERTA, CANADA

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A coral-stromatoporoid biostrome in the Moberly Member of the Waterways Formation is a conspicuous and traceable bed in the Devonian strata that underlie the Cretaceous McMurray Formation oil sands in northeastern Alberta. Outcrop and core investigations reveal facies transitions from the coral-stromatoporoid biostrome into an off-biostrome, diverse shallow benthic fauna, in the following steps: (1.) The biostrome bears abundant fragments of branching corals and bulbous and laminar stromatoporoids. Laminar stromatoporoids in life position cement rudstone-grainstone beds of coral fragments and other fossils. In thin section, remnants of radial-fibrous cement indicate partial early cementation. Corals and patches of skeletal sand were recrystallized but stromatoporoids were only lightly altered. Porosity is conspicuous because of bitumen staining. (2.) A possible transition from the biostrome (1) into the brachiopod bank (3) was observed at one outcrop, although this fauna may also represent an embayment of off-biostrome environment similar to (6). The fossil assemblage is abundant but often fragmentary brachiopods, crinoids, molluscs, corals, and stromatoporoids in a wackestone to packstone matrix. No fossils are in life position. Recrystallization of fossils and matrix was minimal. (3.) The brachiopod "bank" is a rudstone of close-packed brachiopod shells with stromatoporoids up to 0.5 m in diameter in life position. Stromatoporoids were heavily bored. In thin section, the matrix is variably a packstone to grainstone of skeletal debris and subordinate micrite. Stromatoporoids and brachiopod shells are mostly unaltered but some micrite patches were recrystallized. Most porosity was filled with calcite spar. (4.) The brachiopod bank is unchanged but stromatoporoids are no longer in life position; they are toppled and often broken. This facies is present for one outcrop. (5.) No data exists in the few km distance between the brachiopod bank (4) and the off-biostrome, diverse fauna (6). (6.) The fauna of the off-biostrome, shallow benthos is abundant brachiopods, crinoids, molluscs, corals, and bulbous stromatoporoids in a Thalassinoides-bioturbated micritic matrix. No fossils are in life position. Sclerobionts encrusted some brachiopods. The matrix is micritic and recrystallization is minimal, save for proximity to joints that bear evidence of past hydrothermal fluids. Observed porosity is low but some Thalassinoides burrow fills were partially altered, indicating that they were permeable conduits for fluid flow. In conclusion, the transition from coral-stromatoporoid biostrome to off-biostrome diverse fauna follows a trend from high-energy, littoral swash zone to a sub-littoral, lower energy muddy substrate. Early cementation, high porosity,

and recrystallization is substantial in the biostrome and minor in the off-biostrome high diversity facies.

## DIVERSITY OF FEEDING STRUCTURES IN HETEROSTRACAN FISH

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The evolution of jaws is a key innovation in vertebrate history and their dominance in past and present ecosystems has long been attributed to the re-engineering of the head to support feeding and ventilation. In contrast, the extant jawless vertebrates, represented by parasitic lampreys and scavenging hagfish (the cyclostomes), comprise a miniscule proportion of vertebrate diversity. Assumed to be 'primitive,' jawless vertebrates had a much greater significance prior to the end-Devonian when a broad array of jawless taxa, generally referred to as the ostracoderms, were highly successful and co-existed with jawed vertebrates for over 100 million years. They are known from a wide range of body types and diversified into a range of marine and fluvial environments. The reasons for their initial success are poorly understood: the temporal and phylogenetic distance between the ostracoderms and the extant cyclostomes makes comparisons of feeding mechanisms problematic. Using computed tomography imaging and 3D visualisation methods, we have studied a number of heterostracan specimens (one of the most diverse and abundant ostracoderm groups), documenting the diverse array of feeding structures present in the group. These reveal a number of hitherto undescribed features of the heterostracan oral region, which, together with published work, provide insight and constraints on functional models for these feeding apparatuses. The position of the mouth itself varies considerably in the group, from ventral, terminal and dorsal locations, and this is also mirrored in variations in the structure of the lower 'lip' (including multiple finger-like projections, or large single plates, or an absence of specialised and differentiated oral plates). Across the range of taxa studied, movement of the oral plates and hence opening of the mouth appears to have been limited, primarily moderating the oral gape. This finding rules out a number of scenarios, most notably a pseudo-bite function, and lends support to previous interpretations that at least some heterostracans were predominately suspension feeders.

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## EXCEPTIONAL RECORDS OF EXTINCT CARNIVORANS (*ARCTOTHERIUM*, *PROTOCYON*, AND *SMILODON*) FROM SUBMERGED CAVES OF THE YUCATAN PENINSULA, MEXICO

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The Pleistocene fossil record of southeastern Mexico and Central America has been sparse until recent years. This shift in the known record occurred as divers increased exploration of submerged caves and cenotes in the Yucatan and began reporting large bones. Of these discoveries, one site in particular is noteworthy for its extensive, diverse, and exquisitely preserved accumulation of vertebrates: the natural trap Hoyo Negro (HN). This pit trap is located at the intersection of three horizontal passages within the Sac Actun cave system of Quintana Roo, Mexico. To date, we have discovered a wide variety of extant and extinct mammals in this pit, including bat, gomphothere, giant ground sloths, tapir, peccary, skunks, coati, canid, short-faced bear, margay, ocelot, puma, and sabertooth cat. Here we report on remains of the extinct carnivorans from HN and associated upper passages. These include the short-faced bear *Arctotherium*, canid *Protocyon*, and sabertooth *Smilodon*. The most abundant large mammal from HN is the bear, *Arctotherium wingei*, with nine individuals discovered. Prior to this, *Arctotherium* was only known from South America, with *A. wingei* represented by fragmentary remains only. We have now collected four bear crania and abundant postcrania from HN, representing the most extensive collection of *Arctotherium* known, and the only relatively complete skeleton of *A. wingei*. Since this discovery, *A. wingei* has also been identified from other caves in the Yucatan region, including other submerged caves in Mexico, and a dry cave in Belize. In addition, a calcified bear trackway in one of the upper passages of Sac Actun may represent the first tracks for this genus. Like *Arctotherium*, the canid *Protocyon* was only known from South America prior to

HN. Unlike *Arctotherium*, *Protocyon* hasn't been documented from any other sites north of South America. The species represented at HN is *P. troglodytes*, with three individuals, and includes two complete crania, one partial cranium, and an assortment of postcrania. Interestingly, the bear and canid specimens evince notable variation in their dentition that will be important for ongoing phylogenetic work. In contrast to the ursid and canid, the sabertooth felid *Smilodon* is well known from both the United States and South America. However, this genus is poorly known in the vast area between these regions, with only fragmentary specimens reported. Four *Smilodon* individuals are recorded within HN, and two are documented from upper passages. The most complete individual has an intact skull, and is identified as *S. fatalis*. Since the taxon is poorly represented from Mexico and Central America, this occurrence fills a geographic gap in the fossil record. Like other animals trapped in HN, these carnivorans may have entered the cave for denning or in search of fresh water. However, it is also possible that they were attracted to the sounds and smells of dying or dead animals trapped in Hoyo Negro.

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## DIETARY CHANGE ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE MESONYCHID *DISSACUS PRAENUNTIUS* THROUGH DENTAL MICROWEAR TEXTURE ANALYSIS

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Mesonychids were among the earliest large-bodied faunivorous mammals in early Cenozoic ecosystems. A prevalent taxon in the Paleocene and Eocene of North America was the jackal sized *Dissacus*, with remains spanning the Torrejonian to Wasatchian North American Land Mammal Ages in the Bighorn Basin of Wyoming. The species *Dissacus praenuntius* is of particular interest as it spans the Paleocene-Eocene Thermal Maximum (PETM), a period of rapid onset climate change. Global temperatures rose 5–8 degrees Celcius over a few thousand years, remained elevated for tens of thousands of years, and returned to pre-PETM temperatures after a total duration of ~200,000 years. Along with several other taxa, *D. praenuntius* has been shown to have decreased in body mass across the PETM. Previous dietary reconstructions of mesonychids have been based on dental morphology, patterns of Hunter-Schreger Bands, and orientation patch counts. We investigated dietary change in this taxon across the PETM using dental microwear texture analysis. Our analysis finds that dental microwear differs significantly between *D. praenuntius* living prior to, during, and after the PETM. Differences in complexity and anisotropy suggest that PETM *D. praenuntius* consumed more brittle, less tough objects than those living during the latest Paleocene and early Eocene. This may indicate individuals living during the PETM consumed smaller, bonier prey, had later access to carcasses, or were more heavily reliant on hard fruits. These results suggest that changes in diet not only accompanied body mass reduction but may have contributed to it as well. Alternatively, higher complexity may reflect greater loads of exogenous grit mastication during the PETM. We show a potential connection between body mass reduction and dietary change in a faunivorous mammal coinciding with rapid climatic warming, providing a potential model for mammalian dietary change in response to current and future global warming.

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## STRATIGRAPHIC PALEOBIOLOGY IN THE LATE SILURIAN AND EARLY DEVONIAN OF CENTRAL NEVADA: PUTTING OLD DATA TO NEW USES

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Body size has predictable relationships with environmental conditions that reflect ecological, physiological, and life history processes. Despite predictions about how body size should change with environment, there are few paleontological studies that have evaluated change in body size within particular clades and in a specific stratigraphic context, and even fewer that have placed body size trends within sequence stratigraphic architecture. During the Devonian, brachiopod adult body size peaked—is this a true evolutionary pattern or a product of sampling? To determine if brachiopod body size reflects adaptation to changing environmental conditions, we have placed our research plans within an existing regional framework. An extensive research program led by M.A. Murphy, A.J. Boucot, and J.G. Johnson in the second half of the 20th century developed a comprehensive biostratigraphic and paleoecological assessment of the Silurian/Devonian carbonate sequence in Central Nevada. Multiple field seasons in this region produced an abundance of sedimentological data, stratigraphic measurements, and well-preserved fossils (at least a dozen sections and over 100 brachiopod species), most of which have not been examined in this century. This wealth of remarkably detailed and largely untouched paleontological

and stratigraphic knowledge provides opportunities to apply new methods to reanalyze data, reexamine specimens, and remeasure sections. In updating the interpretations of this region, we will determine sequence stratigraphic architecture and describe how brachiopod faunal composition and body size change within a facies model. Combining these results with our ongoing phylogenetic analyses of these taxa will illustrate how studies from this region might scale up and compare to global brachiopod evolutionary trends. Extensive lithostratigraphic and biostratigraphic data exist for much of North America, and most of these sections have not been re-examined since sequence stratigraphy was developed. In particular, stratigraphic studies with associated paleontological monographs on specimens that are reposited in museum collections are worth revisiting, especially for regions where regulations make additional collecting difficult. These older studies serve as a wealth of data that can fuel stratigraphic paleobiology research for many decades hence. In particular, hypotheses of morphological and evolutionary change within sequence stratigraphic architecture are typically limited by the availability of intact and well-preserved fossil material. By examining species descriptions in monographs and their associated specimens in a museum collection, we can leverage these detailed observations of what was found to ask questions about how occurrences change across depositional environments. For example in the Silurian/Devonian of Central Nevada, we ask if small body size is widespread throughout continental margin environments or restricted to a particular facies.

## THE RISE OF ARBORESCENT LYCOPHYTES AS KEYSTONE SPECIES

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The diversification and spread of arborescent lycophytes in the Mississippian had a major impact for the Earth System. Initially in the Tournaisian and early Viséan these plants played a minor role in a range of lowland ecosystems from lowland floodplains to disturbed volcanogenic settings. As such they may be considered keystone species in that their impact upon communities or ecosystems is large. In particular several factors potentially led to these plants becoming dominant in wetland ecosystems and hence provided a major impact upon the Earth System as a whole. The first was the development of a stigmarian rooting system that allowed the plants to live in wetland setting where their fast determinate growth and cheap construction allowed rapid drawdown of carbon dioxide from the atmosphere. The burial of the resulting organic sediments—peats, further influenced this atmospheric change. At the same time extensive development of lycophyte dominated peats in the mid to late Mississippian allowed for an increase in atmospheric oxygen levels. This in turn would have led to increased wildfire activity. The ability for arborescent lycophyte vegetation to survive fire may be the result of continuous leaf abscission from the trunk and the ability of the plant to photosynthesise through stomata on the trunks thereby reducing the ladder fuels and preventing crown fire development. This set the scene for the dominance of these plants in the following Pennsylvanian.

## NEW INFORMATION ON THE BRAIN CAVITY AND INNER EAR OF PACHYRHINOSAURUS LAKUSTAI BASED ON CT SCANNING AND 3D VISUALIZATION

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In recent decades, advances in computed tomographic (CT) scanning and three-dimensional (3D) visualization technology such as 3D Slicer have broadened the capabilities of paleontological research, providing a window into the internal structures of fossilized remains. This form of study is particularly useful for visualizing internal cranial features, which often cannot be physically observed without damaging remains. Rendering 3D images of a skull's interior enables the reconstruction of cerebral structures, and the neurology of present-day organisms can provide a basis for formulating hypotheses about the neural anatomy and function of extinct ones. The focus of this study is a complete, isolated, and relatively un-deformed braincase of an adult individual of the centrosaurine ceratopsid dinosaur *Pachyrhinosaurus lakustai* (UALVP 54444), collected from the Wapiti Formation of northern Alberta in 2011, and CT scanned at the University of Alberta Hospital in Edmonton in May 2023. The specimen currently resides at the Philip J. Currie Dinosaur Museum and has not been formally described since its excavation. A 2008 study by Witmer and Ridgely is currently the only published description of the braincase of *P. lakustai*. The specimen they described (TMP 1989.55.1243) is highly taphonomically deformed and belongs to an unusually small individual, potentially a sub-adult. This project aims to provide a description of UALVP 54444, compare its features to those of TMP 1989.55.1243 and other previously described ceratopsid braincases, and provide new ethological and ontogenetic insights. Relative to TMP 1989.55.1243, UALVP 54444 shows evidence of a more robust cerebral

hemisphere and better-developed optic nerves. The olfactory bulb of *P. lakustai* appears to be modestly developed even by ornithischian standards, but nevertheless larger than in the presumably less social chasmosaurines. The relative sizes of certain nerve and brain structures may hold implications for how neurology impacts the inference of sociality in centrosaurines, as opposed to chasmosaurines. Current data and assessments on the structure of the brain, cranial nerves, inner ear, and encephalic vasculature in UALVP 54444 are presented based on CT scanning of the braincase followed by 3D visualization in the program 3D Slicer.

Funding source: Funding for CT Scanning at University of Alberta Hospital was provided by Dr. Corwin Sullivan at the University of Alberta's Dinosaur Lab.

## RELATIVELY SIMPLE DENTAL COMPLEXITY SUGGESTS A GENERALIST DIET FOR THE LATE JURASSIC RHYNCHOCEPHALIAN *OPISTHIAS*

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The Upper Jurassic Morrison Formation is known for its remarkable diversity of large-bodied dinosaurs, but increased sampling has also revealed an exceptional array of microvertebrates. The Fruita Paleontological Area, in particular, has yielded small-bodied mammals, crocodylomorphs, and lepidosaurs, permitting a better understanding of the diversity and ecology of this fauna. The rhynchocephalian *Opisthias* sp. is a relatively common taxon at this site and is known from dozens of isolated jaw elements allowing for a nuanced interpretation of dental morphology and feeding ecology. The high number of specimens permitted us to test the hypothesis that dental morphology and complexity would be relatively low in this group, a pattern observed in the living representative of the rhynchocephalian clade, *Sphenodon punctatus*. To accomplish this, we micro-CT scanned 15 dentigerous elements, most of which are identified as *Opisthias* sp. from the Fruita Paleontological Area. Using the Orientation Patch Count Rotated (OPCR) method, we quantified the dental complexity of the preserved teeth. OPCR is a measure of phenotypic tooth complexity and allows for the direct comparison of tooth shape, even in specimens lacking homologous landmarks. Previous studies established correlations between diet and dental complexity in extant saurians, permitting the reconstruction of dietary ecology in extinct taxa. We find that average tooth complexities of measured individuals are relatively low (average OPCR varies between 10.5–15.5 patches per tooth). In some specimens, high complexities may be attributable to either dental wear or taphonomic damage, but this is currently equivocal. Dental complexity disparity is low compared to contemporaneous ornithischian dinosaurs but resembles that of theropods and sauropods that lived during the Late Jurassic. The individual tooth OPCR disparity and average OPCR values for fossil jaws are nearly identical to the extant *Sphenodon punctatus*, despite noteworthy differences in tooth shape. Compared to sampled extant amniotes, the OPCR values fall into an intermediate region where mostly dietary generalists are represented, including *Sphenodon punctatus*. This supports previous qualitative hypotheses that supposed an omnivorous or insectivorous diet for *Opisthias*. This dietary ecology, however, differs from hypothesized diets of other Late Jurassic rhynchocephalians (e.g., *Eilenodon robustus*, *Oenosaurus muehlheimensis*) and supports the hypothesis that Late Jurassic rhynchocephalians exhibited a much broader ecological diversity than is observed today.

## THE TIDES THAT BIND: CORRELATIONS BETWEEN ROCKS, FOSSILS, AND TRANSGRESSION-REGRESSION CYCLES AT THE DAWN OF ANIMAL LIFE

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The oldest known fossils of complex, macroscopic organisms, including some of the oldest agreed-upon metazoans, are found in rocks of Ediacaran age (635–538.8 Ma) and are often referred to as the Ediacaran biota. Trends in Ediacaran fossil occurrences show that they first occur in mid-Ediacaran strata, increase in diversity during the mid-late Ediacaran, and decline in the late Ediacaran. The disappearance of the Ediacaran biota in terminal Ediacaran strata is followed by the Cambrian radiation of animals, which kicks off the diversification of the Phanerozoic's 'visible life.' The apparent origins and decline of the Ediacaran biota remain enigmatic, though many hypotheses provide potential explanations, including, but not limited to: changing ocean redox states, biotic replacement by Cambrian-type fauna, mass extinction during the terminal Ediacaran, and preservation bias in the Ediacaran fossil record. Increasing recovery and description of the Ediacaran rock record since its addition to the Geologic Time Scale nearly two decades ago has enabled quantitative analyses of fossil occurrences that have previously only been feasible for Phanerozoic datasets. Here we present a quantitative analysis of comprehensive North American Ediacaran-Cambrian rock and fossil records from Macrostrat and the Paleobiology Database. Marine sedimentary rock quantity increases by over a factor of five from the latest Ediacaran to the end of the Cambrian. Fossil quantities of the Ediacaran and Cambrian have strong positive correlations with marine sedimentary rock area and volume ($r_s > 0.8$), a phenomenon that is well-characterized in the Phanerozoic geologic record. However, Ediacaran fossil quantities are distinctly lower when compared

to the Cambrian, even when normalized by the quantity of preserved marine rock. Although some aspects of these results are expected of a fossil preservation sampling bias, combined they indicate that transgression-regression-driven changes in marine shelf area coincide with Ediacaran and Cambrian macroevolutionary patterns, providing a sedimentary rock-based perspective on the first 150 million years of animal diversification.

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## LIFE HISTORIES IN THE HISTORY OF LIFE: A BIOGRAPHICAL APPROACH TO PALEONTOLOGY

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This talk celebrates the pioneering work of University of Michigan paleontologist Daniel Fisher from the perspective of a historian of science and the environment. Inspired by Earth System scientists' models of global environmental catastrophe, luminaries of "planetary history" proclaim the collapse of the divide separating natural and human history and, simultaneously, define the planetary scale as incommensurable with experience. Fisher's approach to Earth history offers an alternative perspective. From life histories recorded in the tusks of mastodons and mammoths, he investigates the drivers of species extinction at the end of the Ice Age. This presentation reconstructs the disciplinary and personal history that led to Fisher's innovative methods. It juxtaposes his mammalian life histories to his advisor Stephen Jay Gould's and graduate school peer Jack Sepkoski's investigations of species extinction through a "natural history of data" to assess Fisher's place in the "paleobiological revolution." The scalar perspective that emerges from the interaction of extinct proboscidean biographies and a scientific career offers a planetary imaginary individuals may relate to.

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## THE ORIENTATION OF THE QUADRATE BONE COEVOLVED WITH JOINT REACTION FORCE DURING CROCODILE EVOLUTION

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The quadrate bone serves as a pivotal component within the skeletal structure of nonmammalian vertebrates, pivotal for its role in withstanding joint reaction forces (JRF). Some scholars have postulated a connection between the orientation of the quadrate bone and the broader muscle anatomy, thereby suggesting an implication for JRF. In this study, we rigorously examine the enduring hypothesis linking quadrate orientation to JRF orientation, focusing on the suchian lineage leading to extant Crocodylia. The transformation of the skull observed in crocodylians stands as a hallmark event in vertebrate evolution, with the quadrate bone playing a central role. Employing intricate three-dimensional biomechanical modeling techniques, we estimate JRF in a selection of eleven fossil and extant suchians, juxtaposing these findings with quadrate orientation. Utilizing the cross product of orientation vectors, we quantitatively assess the similarity in orientation and reveal a tight correlation between the angle of the quadrate in the sagittal plane and the associated JRF. These findings underscore a coordinated evolutionary trajectory between JRF and quadrate anatomy during suchian evolution, offering a structured framework for analyzing evolutionary shifts in joint anatomy and biomechanics.

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## TAXONOMIC REASSESSMENT OF *CLOUDINA?* FROM THE TAYLOR FORMATION, ANTARCTICA

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Fossils represented as *Cloudina?* were reported in the Antarctic Taylor Formation by Yochelson and Stump in 1977. Their assessment presented thin sections of specimens derived from an oolitic limestone breccia. Notably, one thin section contained a single presumed trilobite fragment, leading the authors to attribute the materials to the early Cambrian. The remaining fossil materials were characterized as tubes of varying preservational quality, likely overprinted by recrystallization. The structure of tubular fossils, as viewed in thin section, appeared bilayerd, showing a thicker outer layer surrounding a thinner, darker, inner layer, enveloping the innermost lumen or cavity of the tube. While one specimen was reported to have two layers, it lacked other identifying features, such as the characteristic nested structure typical of *Cloudina*. The authors acknowledged the dissimilarity of their specimens to those reported from Namibia by G.J.B.

Germs but noted similarities to *Cloudina borrelloi* from the San Juan Province, Argentina described by Yochelson and Herrera in 1974. This led the authors to cautiously identify their Antarctic specimens as *Cloudina?*, though subsequent reports expressed skepticism about placing the Argentinian materials within the *Cloudina* genus, suggesting a more plausible association with *Salterella* or *Acuticloudina.* Based on this single report, Ediacaran paleontologists have often, but tenuously, expanded the geographic distribution of *Cloudina* to include Antarctica. As the International Commission on Stratigraphy's Ediacaran Subcommission has defined the use of Ediacaran tubicolus organisms, including all plausible designations of *Cloudina*, as the leading index fossil group for placement of the terminal Ediacaran stage, this long-overdue reexamination is both timely and important for gaining a clearer picture of the cosmopolitan nature of this genus. Our initial analysis shows that these tubicolus taxa are single-walled, non-nested, and smooth-walled, gently tapering, conical tubes. Herein, we aim to reevaluate the taxonomy of these fossils using modern microanalysis and high-resolution photography to shed light on their potential phylogeny and evaluate their role in the broader context of late Ediacaran to early Cambrian tubular fossils.

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## REEVALUATION OF AGNOSTOID ARTHROPOD MORPHOLOGY AND REASSESSMENT OF TRILOBITE AFFINITY USING SILICIFIED SPECIMENS FROM THE GREAT BASIN

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Agnostoids are an extinct group of blind, cosmopolitan, benthic arthropods which are known from the early Cambrian through the Late Ordovician. Although agnostoids are some of the most common Cambrian fossils and are important biostratigraphic indices with widespread use, the group continues to be shrouded in disagreement over their phylogenetic affinities, namely their potential relationship to trilobites and position on the arthropod evolutionary tree. While traditionally considered trilobites, agnostoids lack a number of significant trilobite features (such as a calcified protaspid larval stage, facial sutures, and a rostral plate) and also substantially differ from trilobites in their appendage placement and structure, lack of a transitory pygidium, differences in thoracic articulation, and differences in the relationship between pairs of appendages and thoracic tergites due to each of their two thoracic tergites not representing individual true metameric body segments. These significant morphological differences that set agnostoids apart from trilobites are well supported, with some having been continually described in agnostoid literature since the mid-19th century. Such differences have often been overlooked, overridden, or mischaracterized in phylogenetic analyses, resulting in the classification of agnostoids within Trilobita being upheld. To address this matter, secondarily silicified agnostoid specimens have been collected from the Marjuman (Miaolingian; Guzhangian) Lincoln Peak Formation at a locality near Cleve Creek, northwest Schell Creek Range, eastern Nevada. Well preserved silicified agnostoid specimens representing at least six genera (*Acmarhachis*, *Clavagnostus*, *Kormagnostus*, *Lejopyge*, *Oedorhachis*, and *Proagnostus*) were freed from their host limestone using hydrochloric acid digestion. These specimens provide ample new supporting data, including rich ontogenetic material, that demonstrates important agnostoid-specific morphological characters. On silicified juvenile agnostoid pygidia, both thoracic tergites are shown to differentiate and subsequently be released from the same position on the anterior end of the incipient pygidial shield, in stark contrast to the transitory pygidium of trilobites in which thoracic tergites are produced in a posterior generative zone and then work their way anteriorly through the whole pygidium until being released. In addition, articulated (enrolled) silicified specimens ranging from the earliest ontogenetic stage through holaspids demonstrate the unique lack of an articulating half-ring between the cephalon and thorax in agnostoids. This indicates that agnostoids do not share the same type of thoracic articulation as trilobites. Reconsideration of agnostoid hard parts does not support recent codings of putative dorsal exoskeleton synapomorphies shared with trilobites, but instead suggest that agnostoids are not ingroup Trilobita.

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## EXPLORING RATES OF CHANGE AND MODES OF EVOLUTION IN BLASTOZOAN ECHINODERMS

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Studies assessing shifts in rates and modes of anatomical evolution have been a critical component of paleobiology for nearly half a century. However, many fossil groups lack a rigorous phylogenetic framework to assess rates of character change and modes of evolution in an iterative and repeatable manner. Blastozoans, a diverse, globally distributed, and morphologically disparate clade of Paleozoic echinoderms, are one such group with few phylogenetic frameworks. Recently, advances have been made in understanding

echinoderm homologies, allowing for the development of more reliable character states, and therefore, the development of phylogenetic frameworks upon which to test hypotheses of rates and modes of character evolution. Herein, we focus on three groups of blastozoans: diploporans (Ordovician–Devonian), paracrinoids (Ordovician), and eublastoids (Silurian–Permian) that have had recently published phylogenetic hypotheses. We evaluate character group evolution within and across each of these groups, using time-stratified phylogenetic trees. We also consider character group rates of change in context with major climatic and biotic shifts (e.g., the Late Ordovician Mass Extinction), and explore possible relationships between different character groups to understand if rate shifts in some character groups might trigger rate shifts in others. We use reversible jump Markov Chain Monte Carlo (rjMCMC) model averaging to test these hypotheses. Characters were partitioned into categories (e.g., feeding characters or attachment characters). rjMCMC allows for the testing of different combinations of functional group partitions and assesses support for which sets of characters are evolving according to similar mechanisms and to co-fit other model components (such as the fossilized birth-death tree model) at the same time. This is a more computationally tractable approach than previous more iterative methods utilizing the stepping stone analyses.This work provides the first exploration of this framework to fossil organisms and provides new insights into the connections between different character groups' evolutionary patterns within extinct echinoderms. Initial results indicate that each of the three groups of blastozoans favor distinct models of evolution and rate shifts.

## CHARACTERIZING SOFT TISSUE PRESERVATION IN MAZON CREEK (PALEOZOIC; PENNSYLVANIAN) AMPHIBAMIFORMS (TEMNOSPONDYLI; AMPHIBAMIFORMES)

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The Mazon Creek fossil assemblage is a Pennsylvanian age (309–307 mya) Lagerstätte notable for the exceptional preservation of plants and soft-bodied animals within siderite concretions. This site preserves a shallow marine, nearshore paleoenvironment with high terrestrial input. Within this assemblage are two distinct faunal horizons: the Essex biota, a more offshore component primarily preserving marine organisms, and the Braidwood biota, a more nearshore component preserving plants, freshwater fish, and terrestrial organisms. Included among the terrestrial fauna of Mazon Creek are members of the temnospondyl clade Amphibamiformes—largely represented at the site by the species *Amphibamus grandiceps*. Many adult and larval stage (tadpole) amphibamids at the site have been assigned to this taxon. The purpose of this study was to characterize soft tissue preservation across the bodies of five amphibamid specimens at varying ontogenetic stages: two tadpoles and three adults. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) were used in tandem to examine the topography and mineralogy of specific anatomical structures. Siderite was responsible for the preservation of most non-skeletal regions of the body. Pyrite, a common precipitate found in many Mazon Creek fossils, was not observed in high concentrations within any samples. Clay interpreted as kaolinite was largely responsible for infilling molds of bony tissue structures in adult specimens. Potassium-bearing clay was also intermittently observed. Fossilized melanosomes and melanosome molds were distributed within the eyes and body of both tadpoles but were not observed in the three adult specimens examined. Strong carbonaceous signatures found in conjunction with these melanosomes suggested preservation of original melanin. These melanosomes exhibited distinct morphologies depending on where in the body they were observed, indicating differential function as in modern tetrapods. Structures resembling glandular skin were observed on one adult specimen which, upon closer examination, had carbon and phosphate signatures consistent with the preservation of original bone. Adult specimens also preserved teeth as both molds and casts, in addition to dorsal and ventral dermal armor. The manner of preservation varied ontogenetically across adult and larval specimens. Specifically, melanosomes were not observed in any adult specimen, indicating either a lack of pigmentation in life or an ontogeny-specific fossilization trajectory inconsistent with the preservation of melanosomes. These results help showcase the high fidelity of fossilization at the Mazon Creek and highlight the critical role ontogeny plays in understanding the taphonomy and preservation of animals at this site.

## VERTEBRATE PALEONTOLOGICAL RESOURCES FROM LOWER CARBONIFEROUS ROCKS OF THE HOOSIER AND SHAWNEE NATIONAL FORESTS (USA: ILLINOIS AND INDIANA)

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The eastern United States is home to the earliest significant fossil discoveries in North America, yet fossil vertebrates in

the U.S. are often associated only with western states in the public consciousness. Western fossils have also historically dominated research and promotion of paleontological resources on U.S. federal lands. Field work in the east is challenged by vegetation, rapid urban development, and orogenic and glacial processes which can obscure or erase geologic history. Charismatic megafauna are also rarer. Despite these obstacles, recent major discoveries of Paleozoic vertebrates in National Park Service lands are bringing this half of the continent back into focus, particularly Middle–Late Mississippian (Meramecian–Chesterian or Visean–Serpukhovian) rocks in Mammoth Cave National Park. The United States Forest Service manages two large tracts of land where similar research and promotion can be conducted. The Hoosier National Forest in Indiana contains the Osagean (late Tournaisian–Visean) Borden Group from which fish fossils such as paleonisciform fishes and teeth from the large-bodied chondrichthyan apex predator *Saivodus striatus* have recently been recovered. The younger Glen Dean Limestone on the Shawnee National Forest in southernmost Illinois has produced *Petrodus*-type chondrichthyan denticles as well. Elsewhere in the Illinois Basin, the non-marine rocks of the late Chesterian Stage that fall within the Shawnee National Forest's boundaries, but are not themselves federally owned, have produced the remains of early tetrapods, rhizodontids, and hybodontiform chondrichthyans. The Chesterian (late Visean–Serpukhovian) Illinois faunas are similar to those from the slightly older Buffalo Wallow Formation in western Kentucky and the much older Bluefield Formation of eastern and north-central West Virginia of the Appalachian Basin (while the most productive historic locality at Greer is closed, newer localities are emerging). While these latter three are not on federal lands, their proximity to the proclamation boundaries of federal forests with underexplored, but extensive outcroppings is promising. These sites suggest the enormous research potential of federal lands in the eastern United States in the realm of vertebrate paleontology. When combined with the recent discoveries at Mammoth Cave, there is ample opportunity for greatly expanding our understanding of marine and non-marine fossil vertebrates throughout the Mississippian Period of the eastern U.S. For example, the recently investigated Goreville locality, less than 500 m from the Shawnee National Forest, indicates that early-tetrapod bearing strata from this time preserve taxa that are unknown to science, biodiverse in terms of their vertebrates, and laterally continuous across wide swaths of public and private land in the region.

## NEW POSTCRANIAL FOSSILS OF A *PROCONSUL MAJOR* RADIOHUMERAL JOINT FROM THE EARLY MIOCENE SITE COMPLEX NAPAK, UGANDA

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An associated proximal radius and distal humerus (UMP NAPCC 06'1431/1432) were recovered from the 20 Ma fossil site complex Napak, Uganda. These fossils represent the first radiohumeral joint ascribed to the stem hominoid *Proconsul major*. *P. major* is a taxon of considerable interest because it possessed a gorilla-sized body but retained an inferred primitive morphology that together may have compromised arboreal abilities present in living apes including acrobatic climbing and suspension. The radiohumeral joint possesses a spherical capitulum on the humerus and a well-developed lateral lip on the radial head, a combination of traits that lacks modern primate analogs. To determine functional affinities, the new specimens were compared using multidimensional analyses and linear models to a large sample of extant anthropoid primates that vary in body size and locomotor and postural modes. A distance matrix was used to calculate the degree of dissimilarity in 3D space (Euclidean distance) between the new radiohumeral joint and those of 12 genera of anthropoid primates using indices calculated from linear measurements. Results demonstrate that the elbow of *P. major* shares more affinities with taxa practicing varying locomotor modes, including small suspensory apes and arboreal and terrestrial monkeys, but shares less affinities with the great apes. Nonetheless, the spherical capitulum and asymmetric radial head may have facilitated fluid movement in pronation and supination, but still provided the enhanced stability needed during pronated flexion, the critical weight-bearing position for above-branch quadrupeds. A body size estimate of 65 kg based on the surface area of the radial head using linear regressions exceeds those of living monkeys and matches those of great apes. The overall similarity of the joint complex to extant arboreal taxa suggests *P. major* may have navigated arboreal contexts despite its large size, but presumably using generalized quadrupedalism at slower speeds, unlike the active vertical climbing and suspension of living great apes.

## DIVERSITY-INDEPENDENT FUSULINID DIVERSIFICATION PATTERN DURING THE LATE PALEOZOIC ICE AGE EXPOSED BY A HIGH-TEMPORAL-RESOLUTION SPECIES RICHNESS ANALYSIS

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Fusulinids, as the first recorded larger benthic foraminiferal group, emerged in the Early Carboniferous and thrived in the Late Carboniferous to the end of Middle Permian. Their most significant diversification episode occurred during

the Late Carboniferous to earliest Permian, dominating the Carboniferous to earliest Permian Biodiversification Event (CPBE) and coinciding with the peak of the Late Paleozoic Ice Age. Here, a newly established high-temporal-resolution species richness curve has revealed details of this process. The curve cumulates 1391 fusulinid species from 293 published stratigraphic sections worldwide with the Constrained Optimization method and presents their species richness change at an average time resolution around 40 kyr. The change was paced by long-term astronomical forcing, including ~1.0–1.2 myr obliquity and ~2.1 myr eccentricity cycles. After those cycles were removed, a long-term exponential increase of the species richness can be recognized during the Carboniferous to the Early Permian, spanning ~38 myr. During the Moscovian to Kasimovian, this increasing trend was interrupted by the doubled to tripled high extinction rates but rebounded to the original increase pattern in the Gzhelian. This trend kept until the species richness reached the climax in the Asselian of the Early Permian. The combination of high extinction rate and low origination rate of species richness in Sakmarian to Artinskian resulted in the largest drop for fusulinid species richness and it never recovered since then. After a diversification plateau through the Middle Permian, fusulinid species richness dropped again and the fauna fully collapsed finally in the end-Permian mass extinction event. The diversity-independent exponential increase of fusulinid species richness expanding as long as 38-myr displays no equilibrium on the species richness, origination rate and extinction rate, revealing an unconstrained species radiation for the firstly evolved larger benthic foraminifera during a relatively cool environment.

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## A RE-EVALUATION OF THE SUPPOSED OCCURRENCE OF THE EXTANT NOTOSTRACAN SPECIES, *TRIOPS CANCRIFORMIS*, IN THE TRIASSIC OF VIRGINIA

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The branchiopod crustacean species, *Triops cancriformis* (Bosc, 1801), enjoys the label "living fossil" on the basis of its cosmetic similarities to a number of Paleozoic fossils. This label is misleading because it implies that cosmetic similarity equates to morphological synonymity. Genetic and now paleontological evidence coalesce to challenge the "living fossil" designation: instead, they reinforce the genetic and anatomical improbability that *T. cancriformis* existed during the Triassic. Twelve North American fossils collected from the Culpeper Basin of the Bull Run Formation, belonging to the Newark Supergroup, were identified as *T. cancriformis* upon their collection (Gore, 1986). Recent work by Geyer and colleagues (in submission) suggests that these specimens and others from Europe are, instead, members of the extinct genus *Apudites* Schimper, 1853. This created a conundrum: are the Virginian specimens representatives of the type species, *Apudites antiquus* Schimper, 1853 or a new species? Based on a unique style of insertion for the caudal furca, the Virginia specimens are interpreted as a previously unrecognized species of *Apudites*.

## MAMMOTH TUSK CT-DERIVED REPRODUCTIVE LIFE HISTORIES FROM EASTERN SIBERIA AND THE CONSERVATION BIOLOGY OF ELEPHANTS

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Woolly mammoths went extinct in the face of mounting pressure from human populations and environmental changes—the same threats faced by elephants today. Reproductive rates generally increase when harvest lowers population densities, and fall when unfavorable environmental conditions reduce available resources; these reproductive rates, in part, determine the demographics of populations as they approach extinction. We created a series of population models with varying mortality and reproductive rates over a 35,000 yr period (reflecting the approximate span between the earliest carbon dates at ~45 ka through mainland Siberian mammoth extinction at ~10 ka). Modeled populations did not go extinct over this interval unless mortality was high (above levels observed in living elephant populations) or female pregnancies were infrequent (1 calf per 10 years—a rate lower than in most elephant populations). Considering maximum and minimum reproductive rates in models under different stressors, we examined a sample of 15 female and 5 male mainland mammoth tusks from northeastern Siberia to recover records of growth and interpret aspects of life history. Computed tomography (CT) of these tusks permitted measurement of annual growth increments bounded by regular, conspicuous changes in radiodensity. Measurements

of annual increment dimensions cyclically decreased and then increased over multiple ~5 yr periods in adult female tusks, likely reflecting changes in tusk growth rate caused by reproductive episodes, as closely related living elephant females tend to become pregnant around once every five years. Though these results are preliminary, the calving intervals found in this sample are considerably shorter than those in modeled mammoth populations that went extinct without human hunting. Our results are therefore consistent with modeled extinction scenarios that include human hunting, and inconsistent with those that include only environmental change. Larger sample sizes could help reconstruct geographic patterns of mammoth population decline and permit comparison of extinction causes between populations across their range—critical for understanding the extent to which different stressors contributed to the extinction of the species as a whole. Our results offer a promising path forward for paleontological research on not only mammoths, but also other proboscidean species, many of which went extinct under circumstances similar to those experienced by mammoths. Furthermore, studies of larger samples of fossil proboscideans could show how reproductive rates fluctuate through time and space in association with changing conditions. A more thorough understanding of these fluctuations and their causes will help construct more accurate predictive models for endangered elephant populations, and ultimately contribute to their conservation.

## INVESTIGATING THE IMPACT OF PALEOBIOLOGY OUTREACH ON ATTITUDES ABOUT FOSSILS AND LIVING APE CONSERVATION IN UGANDA

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Apes, from unique Miocene fossil taxa to endangered chimpanzees and gorillas today, have lived in Uganda for over 20 million years. Uganda thus offers a special setting for synergistic research and education on living and fossil apes that can inform and promote conservation. The "Apes of Uganda" Exhibition and Outreach Project is a collaboration between the Uganda National Museum and anthropologists at the University of Michigan. The project features a museum exhibit for the general public in the capital, Kampala, and an outreach program targeting rural schoolchildren living near national parks far from the capital. The exhibit and outreach program shared information about ape evolution, the lives of chimpanzees and gorillas, and the importance of conserving fossil sites and national parks, with three aims: enhancing science education for schoolchildren; introducing paleontological and neontological research on Uganda's apes to the public; and cultivating positive attitudes toward primate conservation. The museum exhibit launched in February, 2023, and has been visited by over 200,000 people, mostly schoolchildren from Kampala. In July and August of 2023, the outreach program visited 18 schools and ~1,600 students living near conservation units with chimpanzees and gorillas. Using a single survey instrument to collect data from some museum visitors (n = 89), and a similar before- and after-survey of student participants in the outreach program (n = 983), we evaluated the effects of the project on understanding of extinct fossil and endangered living apes, as well as how this understanding might relate to attitudes about conservation. Responses suggest that the outreach program strengthened feelings of connectedness to nature and positive attitudes towards ape conservation. Overall, respondents also indicated a better understanding of fossil and modern apes and the plight facing endangered chimpanzees and gorillas. However, while results indicate that describing fossils and past extinctions can increase awareness of risks faced by today's endangered species, it can also desensitize some learners to future extinction. Many responses to questions about evolution, extinction, and fossils suggested a disconnect between local language and the terminology used by researchers to describe concepts central to both paleontology and conservation. This work highlights the potential positive effects of outreach about both fossils and modern conservation, and provides a framework for the creation of future assessments. However, it also exposes some of the biggest challenges for conservation biologists and paleontologists in communicating their work to local audiences in different cultural and linguistic contexts. This emphasizes the continued need not only for high-quality scientific outreach, but also for more social sciences research into attitudes about conservation, fossils, and how paleontology can be used as part of the conservation toolkit.

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## AMATEUR CONTRIBUTIONS TO PALEONTOLOGY: A MIDWESTERNER'S EXPERIENCE

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This presentation aims to detail several anecdotes highlighting my experience as an avocational paleontologist in the midwest. Through this talk I will demonstrate using multiple personal examples how amateurs can contribute to academic paleontology. Several key experiences will be discussed: The discovery of a new late Hirnantian rock unit equivalent to the Centerville Formation of Ohio and an associated low-diversity echinoderm fauna helps shed light on community recovery following the first major pulse of the end-Ordovician extinction and adds to our knowledge of the late Hirnantian–Rhuddanian Edgewood–Cathay fauna. Additionally my experiences opening a dig site within the Edwardsville Formation will be discussed wherein several rare, scientifically significant specimens were discovered. The Edwardsville Formation is well studied with respect to its echinoderm fauna, but despite this fact a new site I discovered in Monroe County, Indiana, has yielded a new species of batocrinid, a new rhodocrinitid occurrence, and two specimens of the unusual crinoid species *Atelestocrinus baumilleri*. Several other paleontological contributions will be mentioned: The discovery of a new nucleocrinid blastoid out of the Devonian Boyle Formation of Kentucky, the latest occurrence of *Carpenteroblastus* sp. from the Meramecian Ramp Creek Formation of Indiana, and the discovery of a new undescribed possibly archeocrinid crinoid from the early Hirnantian Cape Girardeau Formation of Missouri. With this talk I aim to demonstrate the strong part amateurs can play in paleontology and why it is important for professional and academic paleontologists to collaborate with and foster growth of this demographic.

## INSPIRING PUBLIC ENTRY INTO AVOCATIONAL PALEONTOLOGY: IMPEDIMENTS AND INITIATIVES

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Informal interviews and conversations with avocational paleontologists and academic paleontologists alike revealed several commonalities regarding amateurs' perceived barriers to entry and deeper engagement with the field as a whole. For many respondents the common attitude was that collecting often preceded intellectual engagement with paleontology. Given that prevailing attitude, the most significant and often repeated factor acting to keep amateurs from engaging with paleontology as both a science and hobby was a lack of access to high-quality fossil collecting localities and a lack of variety within sites that are accessible. Lack of site access stems from several factors, including (1) hesitancy from property owners/managers to allow collecting at sites due to liability concerns, (2) depreciation of sites due to slumping and foliage overgrowth, (3) "playing out" of sites due to either limited extent of exposure or patchiness of fossil occurrence beyond the area of a given exposure, and (4) legislation that either deliberately or as a matter of course restricts fossil collecting within a given jurisdiction. Each of the aforementioned factors works independently to bottleneck amateur entry into avocational paleontology. This talk aims to discuss workarounds and initiatives for potentially overcoming the previously mentioned barriers. Specific initiatives include (a) facilitating the practice of trucking fossiliferous rock from quarries to local parks or privately owned grounds to be used as small-scale fossil parks, (b) petitioning local governments or governmental bodies such as the state Department of Natural Resources or Army Corps of Engineers to loosen restrictions on collecting within specific sites where small-scale collecting would not result in wider problems, (c) working with academic paleontologists and quarry managers to grant limited access to otherwise restricted sites for vetted amateurs, and (d) educating 'bought-in' amateurs on the prospects of leasing sites to overcome private property owners' liability concerns. Several ongoing attempts at putting these initiatives into practice will be discussed: In progress attempts to establish a fossil park in the town of Saint Paul, Indiana, and working with the Indiana Department of Natural Resources to loosen restrictions on fossil collecting at Edwardsville Formation exposures at Lake Monroe, Indiana. Ultimately the purpose of this talk is to start a dialogue on what options are available for avocationals and academics alike with respect to lack of access to collecting localities.

## ADVANCING CONSERVATION PALEOBIOLOGY THROUGH ECOMETRICS: INTEGRATING FUNCTIONAL TRAITS AND ENVIRONMENTS OF PAST, PRESENT, AND FUTURE FAUNAS

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Conservation paleobiology relies on the long-term understanding of biological patterns and processes for informed management and conservation decisions. Functional traits provide a valuable method for studying biodiversity across spatiotemporal scales because traits are largely independent of taxonomy. We use ecometrics, or the study of functional trait-environment relationships at the community level, to generate spatiotemporal knowledge of relationships between faunal communities and the environments in which they live. Here, we discuss previous ecometric studies and future directions of expanding this approach. Building upon earlier work on carnivorans, we established an ecometric relationship between calcaneal gear ratio and environment in global artiodactyl communities. Gear ratio is functionally related to locomotion, and in modern artiodactyl communities,

gear ratio correctly estimated vegetation cover (65% of communities) and precipitation (83% of communities). We used this ecometric relationship to illustrate precipitation trends in six protected areas of Kenya between two time periods (1896–1950) and (1950–2013). Next, we expanded this model by integrating gear ratio across trophic levels to increase the accuracy of vegetation cover estimates. With this model, we used the gear ratio of artiodactyls and carnivorans to more accurately estimate vegetation cover across 81% of global communities. We applied this new model to five North American fossil sites (<5000 years old) and generated paleoenvironmental estimates. In ecometric studies, the next steps will include further taxonomic and trait integration to build more informative models, application of these models to deeper time fossil sites, and predictions of future community traits using climate projections. A new study investigates the past, present, and future mammal communities and associated environmental changes in a single geographic area by using existing models and developing new ecometric models. We further resolve the mammal communities preserved at four paleontological sites of different ages (<200,000 years old) and incorporate survey data of the modern mammal community. Future climate projections will enable estimates of community traits that might be well-suited under different climate change scenarios. We will combine all time points to develop a trajectory of the changes that occurred in the past and anticipate the changes that might occur in the future. By integrating past, present, and future fauna, results of this work will advance the field of conservation paleobiology from conceptual to applicable.

## UPCYCLING PLASTIC WASTE TO MODEL DANGERS OF THE SIXTH EXTINCTION: VICTIMS OF THE "BIG 5" SEEN THROUGH THE TRASH OF TODAY

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The sixth extinction is a problem our planet faces and communicating the all encompassing impacts of such a disaster on biodiversity can be difficult. This project aims to create models of charismatic species from previous extinctions using plastic and other material waste, prevalent in our current environment, as a means to tell stories about ancient life that once lived as well as modern biota at risk due to current human impacts. This form of scientific communication seeks to provide a clearer picture of the dangers presently impacting wildlife by specifically highlighting their ancestors through upcycled artistic works. This project uses an alternative medium to communicate an important message and exemplifies the integration of art into science as promoted by STEAM. These models will serve as exhibits in collaboration with Fernbank Science Center for Earth Day and as part of outreach events for Atlanta Science Festival, facilitating science communication and promoting awareness of both paleontological history and contemporary environmental challenges. By constructing representations of past species by relying on modern-day single-use materials, the project seeks to draw parallels between historical extinction events and present-day threats to biodiversity. For instance, a model of an extinct dinosaur made from plastic containers symbolizes the environmental dangers faced by their living descendants in speaking to the impact that pollution and habitat destruction have had on birds. Five models will be created to represent each of the major mass extinctions in the fossil record with all examples connected to modern fauna and relevant threats to these groups. Through this interdisciplinary approach, the project endeavors to evoke a vivid portrayal of the interconnectedness between past and present extinctions, highlighting the urgent need for conservation efforts and sustainable practices to mitigate the effects of the ongoing sixth extinction. Ultimately, it aims to foster a deeper understanding of the complex dynamics driving biodiversity loss and inspire action towards safeguarding Earth's ecosystems for future generations.

## AN EXCEPTIONAL MAMMAL LOCALITY FROM THE FIRST ~28 KYRS AFTER THE CRETACEOUS-PALEOGENE MASS EXTINCTION IN NORTHEASTERN MONTANA WITH LANCIAN-ASPECT 'DEAD CLADES WALKING'

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The impact of the Cretaceous/Paleogene (K/Pg) mass extinction event (66.052 Ma) on mammalian evolution is best known from the Western Interior of North America, particularly the Hell Creek region of the western Williston Basin, northeastern Montana. However, the 'early disaster' subphase of faunal recovery, spanning the first ~28 kyr after the K/Pg event, remains poorly understood. Here we provide updated biostratigraphic and lithostratigraphic context for the Constenius Locality, an extremely productive vertebrate microfossil site within a sandstone channel from the lowermost Fort Union Fm (Tullock Mbr), just above the uppermost Hell Creek Formation. We hypothesize that the channel was

deposited between equivalents of the Iridium Z coal (IrZ) at the K/Pg boundary and the McGuire Creek coal (MCZ; 66.024 Ma). The mammalian local fauna (>400 specimens from at least 16 morphospecies) includes multituberculates (*Cimexomys*, *Mesodma*, *Stygimys*, *Valenopsalis*), metatherians (*Thylacodon*), and eutherians (*Baioconodon*, *Mimatuta*, *Procerberus*, *Protungulatum*, *Oxyprimus*) typical of the Pu1 interval zone of the Puercan North American Land Mammal Age (NALMA; ~66.052–65.820 Ma). We have also identified metatherian 'dead clades walking' (e.g., *Alphadon*, *Pediomys*) characteristic of the preceding Lancian NALMA (~69–66.052 Ma), as well as new cimolestid and leptictid morphs resembling Lancian taxa. Constenius resembles Z-Line Quarry, another Williston Basin 'early disaster' local fauna constrained between the IrZ and MCZ coals, in being depauperate and uneven compared to pre-extinction and 'recovery' faunas, and in bearing metatherian 'dead clades walking.' However, the Constenius local fauna is noticeably richer than Z-Line and represented by more complete elements (e.g., dentulous jaws), particularly of multituberculate and eutherian 'immigrant taxa' more common in 'late disaster' Pu1 local faunas. Additional geochronological and lithostratigraphic work is underway to further bracket the age of the Constenius channel and to rule out reworking as explanation for the Lancian-aspect mammals, and phylogenetic morphometric analyses are underway to clarify taxonomic identifications. Overall, the taxonomic composition of the Constenius local fauna corroborates previous hypotheses of a relatively rapid turnover of North American mammalian communities across the K/Pg boundary. Compositional differences between Constenius and Z-Line may indicate regional heterogeneity in faunal recovery within the Williston Basin.

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## ANALYTICAL PALEOBIOLOGY RELIES ON ACCURATE TAXONOMIC DESCRIPTIONS: AN EMPHASIS ON PALEOBOTANY

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Ever since the publication of the Red Queen hypothesis by Van Valen in 1971, paleontology has evolved increasingly from a specimen-based descriptive field to an analytical "big data" science in which individual studies analyze up to hundreds of localities, thousands of taxa, and millions of specimens within a single publication. Because the invertebrate fossil record is taphonomically more prolific than that of other groups, vertebrate paleontology and paleobotany have lagged behind invertebrate paleontology, but in time, the plant fossil record has been the target of analytical work on extinction dynamics, global paleoclimate and carbon dioxide levels, vegetation structure, and more. Across all fields of paleontology, many have noted that these synthetic studies all depend on one thing: accurate alpha taxonomic descriptions of the what, the where, and the when that supply the raw data for more inclusive work, with efforts to revise Sepkoski's compendium and similar revisions dating back to the 2000s and earlier. Within paleobotany, questions of the veracity of past monographs are asked so often that it has generally precluded efforts to conduct large, analytical studies. Fortunately, new systems and databases of identifying fossil plants are being constructed. Historically, botanists have relied on reproductive structures to describe plant taxa due to rampant convergent evolution characterizing vegetative structures, but paleobotanists more often work with vegetative structures because leaves make up the bulk of plant fossils. Yet, fruits and seeds do represent important components of many fossil floras, and like their living counterparts, tend to be more useful for taxonomic identifications than vegetative anatomy. As such, thus databasing and methods of identification of plant fossils are sorely needed in order to expand the botanical side of "big data" paleobiology. Journal editors, hiring and tenure committees, and funding agencies alike should value both descriptive and analytical science.

## THE ORIGIN OF ANIMALS FROM A UNICELLULAR PERSPECTIVE

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Metazoans appear to have evolved and diversified during an ~200 million year window (around 800–600 mya) during the Neoproterozoic Era. At this time, much of the Earth system was in flux—it included 70 million years of the global Snowball Earth glaciations, a massive influx of sediment and nutrients, and the rise of atmospheric oxygen. All of these have been proposed to be the cause of animal multicellularity but we do not know which, if any, of these earth system changes were important for the origin multicellularity. A unicellular prospect may help identify what was important for the origins of animals. The ecological changes that come with multicellularity involve changes in the dominant physics that the organisms experience. Here I explore what ecologically important shifts in physics occur due to the environmental changes occurring in the Neoproterozoic. Using the choanoflagellate Salpingoeca rosetta, I quantify how motility, feeding rates, and temperature-metabolic scaling, change as a function of temperature and viscosity and how their observed biology compares with a general mechanistic theory that shows how multicellularity can generate ecological advantages in high seawater viscosity. This work provides some clues and testable hypotheses for how animal evolution

could have proceeded during the time after their origin but prior to their fossil record.

## SEA SHELLS THROUGH TIME: ABUNDANCE AND DISTRIBUTION OF MARINE SKELETAL BIOMASS ACROSS THE PHANEROZOIC

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Organismal abundance is as important as diversity in the collective ecological functions by which complex life has shaped our planet's biogeochemistry and habitability across space and time. The diversity histories of marine animals, algae, and foraminifera are well characterized and provide the foundation for our understanding of major evolutionary events from the Cambrian Explosion to the Big Five mass extinctions and their recoveries, but the abundance histories of these groups remain poorly documented. Local snapshots across major extinction events suggest substantial declines in skeleton production associated with these biodiversity catastrophes, lasting as much as a few million years. However, Phanerozoic background values and trends away from these critical intervals have yet to be assessed. Consequently, it is unclear whether modern levels of skeleton production were reached early in the Paleozoic or only quite recently and whether there were other major trends in skeletal production away from the major mass extinction events. To develop a direct, quantitative record of skeletal abundance across geologic time, and thereby assess the potential controls on the abundance of skeletal organisms, we compiled compositional data from marine carbonate sediments deposited across the Phanerozoic. Compositional data from marine carbonates are in the form of point counts from petrographic thin sections of carbonate rocks. The point count data used in this study were compiled from published literature as well as new samples counted for the purpose of this study. We chose carbonate sediments because the precipitation of carbonate sediments in the marine realm has been a continuous phenomenon since the late Archean and, therefore, does not require skeletal biomineralization to occur. In fact, consistent with our data, much carbonate sediment is non-skeletal even on the modern seafloor. Depositional environments can be determined by sedimentary structures independent of skeletal grains and can be used to assess variation in skeletal content after controlling for depositional setting. The database consists of 7683 thin sections with each thin section having counts ranging from 200–500 points. This amounts to more than 1.4 million counted points for the entire dataset. We observe a secular increase in the abundance of skeletonized taxa from the Cambrian to present. Beyond this first-order trend, the abundance patterns capture key biotic transitions in the marine realm, including an increase in abundance across the Great Ordovician Biodiversification Event and decreases across the Late Devonian, end-Permian and end-Triassic mass extinctions. Abundance trends are consistent across platforms and ramps, shallower and deeper environments, and lower versus higher latitudes. Overall patterns closely resemble the taxonomic diversity of marine invertebrates across time, indicating a close coupling between abundance and diversity over geological time scales.

## IMPACT OF THE EARLY JURASSIC EXTINCTION (PLIENSBACHIAN-TOARCIAN STAGES) ON THE FUNCTIONAL DIVERSITY OF MARINE MACROFAUNAL COMMUNITIES

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The Pliensbachian/Toarcian boundary event (~184.2 million years ago) and the Toarcian Oceanic Anoxic Event (TOAE, ~183 million years ago) represent two of the most severe environmental perturbations of the Early Jurassic Epoch, leading to marine ecosystem disruption and biotic crises. Previous work on the Early Jurassic biotic crises has regarded warming-induced anoxia as the primary driver for the extinctions, and the two events (i.e., the stage boundary and early Toarcian) are often considered to be causally linked. Recent studies, however, show elevated extinction rates in well-oxygenated basins, such as the Iberian Basin in Spain, and the High Atlas Basin in Morocco. Furthermore, subtle differences in environmental conditions (such as, warming or eutrophication) between the two events have been identified at multiple localities. So far, there have been no quantitative studies on the Early Jurassic macrofauna from Morocco; thus, the extinction dynamics (e.g., ecosystem functioning and recovery), as well as the exact causes of the extinctions in the marine level-bottom communities in this low latitude locality, remain unclear. In this study, we report the occurrences of

late Pliensbachian-Toarcian marine invertebrate taxa from the Central High Atlas Basin of Morocco and their associated functional groups. We collected macrofaunal samples from the late Pliensbachian- Toarcian strata, capturing the boundary event and the TOAE, followed by taxonomic identification and functional group assignment. Assessing functional diversity (i.e., how organisms operate in a community) provides data about how marine communities changed in response to environmental stressors (e.g., increased temperature or eutrophication) and what factors dictated survival versus extinction. The functional groups of the macrofauna are documented based on their inferred lifestyle, and niches assigned using the Bambachian ecospace model. Preliminary results show that bivalves are the most functionally diverse, with eight different functional groups. Unattached epifaunal carnivores and unattached deep-infaunal suspension feeders cross the stage boundary event but disappear at the onset of the TOAE. Similarly, the facultatively-unattached, epifaunal, suspension feeders appear after the onset of the TOAE, while byssate epifaunal suspension feeders are present throughout the late Pliensbachian–Toarcian interval. The differential survival of functional groups is likely due to the causal mechanisms of the two events. This new paleontological data from tropical, shallow-water macrofaunal communities is critical to our understanding of the extinctions across these two events because most of the comparable data has been collected from deeper-water, extratropical shales. In addition, this study provides important data about the patterns of biotic change in tropical marine communities and how these communities recovered from significant global events like those we are facing now.

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## MODELLING THE LIFE-ENVIRONMENT INTERFACE IN ANCIENT SHELF SEAS

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The co-evolution of life and environment is a dynamic system of feedbacks. In ancient ocean shelf seas, evolving biota and redox conditions created biogeochemical feedbacks that are hypothesized to have permanently shifted the redox state of the ocean. As early animal radiations into new ecospace gave rise to increasing ecological complexity, these feedbacks grew into stable ecological networks robust to perturbations—but which could collapse in times of environmental stress when perturbation thresholds were exceeded. Connecting the localized, short timescale, matter and energy flow through ecological networks to global Earth system cycles over geological timescales is a particular modelling challenge. When modelling at geological timescales, smaller scale processes are taken to be in steady state and abstracted out. However, when the small-scale feedbacks at the life-environment interface compound directionally, the assumption of steady state is violated and the very dynamics leading to long-term ecosystem evolution can be left out of models. We introduce a 1D biogeochemical column model of an ocean shelf sea in the PALEO modelling framework to explore the compounding interactions between ecology and environment. The model captures the biogeochemistry and dynamics of the shelf sea and uses networks of ecological functions to represent key functional groups in early ecological networks. The model demonstrates that ecological processes and nutrient cycling can be modeled together at the finest scales, while being computationally viable over timescales required to balance geochemical cycles in the ocean and sediment. Ongoing work integrating this model with data from critical time intervals of radiation and environmental stress and extinction in the Phanerozoic ocean will provide specific hypotheses for the feedback relationship between environmental change and ecological expansion and collapse, in particular with regard to anoxia. It is anticipated that model outcomes will yield insight into ecosystem functioning and stability, or conditions necessary to stability, during such critical intervals.

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## GEOCHEMICAL BIOSIGNATURES OF MICROBIALITES: ANALOGOUS FOR EARLY EARTH AND ASTROBIOLOGY

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While fossil records are unambiguous records of life, unambiguous fossils are not produced by the microbial communities that have been the prevalent form of life on Earth, and the only form for much of its history. Interpreting the evidence of life without fossils relies on other perspectives, such as geochemical biosignatures which are chemical, isotopic or mineralogic patterns that could only have been produced by life. This includes biomarker molecules that can be attributed to a specific biological source, patterns of isotopic distributions that can be uniquely attributed to the activities of life or patterns in mineralogic structure, chemistry or isotopic compositions that record the direct or indirect influence of life. Geochemical biosignatures are used across Earth and Environmental sciences to elucidate the activities of modern microbial communities, for interpretation of the geologic record of early life on Earth, and as one of the primary foundations for the search for life beyond the Earth in the field of Astrobiology. Critical to the latter application is the ability

to distinguish between biosigantures and signatures produced by abiological systems, abiosignatures. Microbialites can represent both morphological and geochemical biosignatures of life. Our research in Pavilion Lake, BC, Canada demonstrated that not only were the unique morphologies of the microbialites there associated with abundant microbial communities, but that there were isotopic biosignatures of photosynthetic influence being recorded in the microbialite carbonates. The extent of this signature was based on differences to the isotopic signature expected for abiotic precipitation and related to light exposure, and supported the hypothesis that cyanobacterial growth toward the light was responsible for the microbialtie morphology. However, this isotopic biosignature was overprinted within the microbialite structures apparently due to further carbonate precipitation driven by heterotrophic metabolisms. The multiple lines of evidence required to identify a biosignature in the Pavilion Lake microbialites, and the observation that it can be overprinted, illustrate the challenges faced in the search for life beyond the Earth. However, with mechanistic understanding of the formation and preservation of biosignatures, we have the capability to address that most fundamental question of whether we are alone in our solar system.

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## THE EVAPORATION SENSITIVITY OF LARGE-BODIED NORTH AMERICAN MAMMALIAN HERBIVORES

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One of the most pressing ongoing threats to modern mammalian communities is increasing periods of aridity under climate change. Changes in water availability can affect community compositions based on species-specific responses to aridity. We can track the influence of aridity on organisms via oxygen-18 isotope enrichment in body water and mineralized tissues. As aridity increases, so does evapotranspiration, which preferentially evaporates $^{16}O$ and concentrates $^{18}O$ in plant water. When herbivores consume these plants, their tooth enamel becomes similarly $^{18}O$-enriched. Ungulates have been categorized into two functional groups based on their sensitivity to aridity: evaporation-sensitive (ES) and evaporation-insensitive (EI). Taxa that are classified as ES typically obtain much of their water from plants; therefore, as aridity increases, their d18Oenamel values tend to increase. In contrast, taxa classified as EI obligatorily consume surface water, and so their $d^{18}O_{enamel}$ values tend to remain constant under all environmental conditions and strongly correlate with precipitation $d^{18}O$ values. While this offset in $d^{18}O$ values between ES and EI taxa is robust, the magnitude of the isotopic signal incorporated into herbivorous mammals can be confounded by species-specific physiologies that aid in body water conservation. Our goal is to elucidate the role that physiology plays in changing community assemblages as a response to increased aridification, and determine how we can use stable isotope geochemistry as a proxy to better evaluate this relationship. While the interplay of aridity, physiology, and $d^{18}O_{enamel}$ is well understood in African herbivores, there is a dearth of knowledge about the relationship between these variables in North American taxa. This is due, in part, to the absence of EI taxa among North American herbivores, such as proboscideans in African communities. Currently, this means that paleontological North American studies are restricted to mammoth sites that are likely to have high water availability and, therefore, be buffered from the effects of aridification. Our analysis aims to scale modern North American large-bodied herbivores along the spectrum of evaporation sensitivity and use these results to identify an appropriate baseline for paleontological surface waters. We ground truth this analysis using a steady-state mass balance model of oxygen isotope fluxes in body water to differentiate the influence of environmental and physiological factors on $d^{18}O_{enamel}$. For example, we find that a North American taxon considered to be water-dependent, Bison bison, still exhibits evaporation sensitivity even in environments where water is abundantly available, with $d^{18}O_{enamel}$ values that display a broad breadth of variation. Understanding how species-specific physiologies influence $d^{18}O_{enamel}$ values can be useful in interpreting past responses to aridification and in making informed predictions for future large herbivore conservation.

## THE THEORETICAL SIDE OF CONSERVATION PALEOBIOLOGY: A PERSPECTIVE FROM THE PALEOSYNTHESIS PROJECT

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Conservation paleobiology is at a crossroads, wrestling with the duality of being an interdisciplinary field with theoretical underpinnings and aspirations of being applied. The applied component of conservation paleobiology is undoubtedly important; however, recent work suggests that almost 90% of research falling under this disciplinary umbrella remains theoretical. For the field to grow and reach its full potential, it may be beneficial to evaluate and reflect on the value of these theoretical contributions and what they bring to the field. Through the lens of the PaleoSynthesis Project, which has had engagement from hundreds of paleontologists around the

world, I will offer a perspective on common themes expressed about conservation-related topics. These themes include issues pertaining to (i) data collection, aggregation, and citation, (ii) establishing theory that bridges spatiotemporal scales, and (iii) methodological advances to apply new technology and computing capacity. A comprehensive theoretical foundation will support continued advancement of academic and applied conservation paleobiology.

Funding source: Volkswagen Foundation

## CLUMPED ISOTOPE THERMOMETRY OF PALEOCENE TO EOCENE HYPERTHERMAL EVENTS IN THE BIGHORN BASIN, WY—EVOLUTION OF A TOOL AND A RECORD

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The Early Eocene was the warmest time of the Cenozoic, and was characterized by rapid global warming events, termed hyperthermals, that increased temperatures rapidly (~10,000 years or less) above the already warm climate of the time. Often studied as potential analogs for modern global warming, significantly more is known about the temperature response during these events in the ocean than on land. The Bighorn Basin in Wyoming preserves the best characterized terrestrial record of this generally warm time and three of these hyperthermals: the Paleocene-Eocene Thermal Maximum (PETM), ETM2 and H2. The abundant paleosol carbonates that span the latest Paleocene to Early Eocene also made these deposits an early target for carbonate clumped isotope thermometry. The earliest clumped isotope results—from 2013—yielded variable and warm temperatures (26–45 degrees C) that matched the pattern of change seen in mean annual temperature (MAT) estimates made from leaf margin analysis (LMA). These results were interpreted as summer temperatures, possibly amplified by radiant heating of the soils, and were used to argue that seasonal range of temperatures in this region and time were not reduced, as had been previously argued. Since 2013, however, both analytical methods and our understanding of soil carbonate formation in different soil types has evolved. Three critical things have changed that are important for both generating and interpreting this original record as well as our in-progress higher temporal resolution records through the PETM, ETM2 and H2. First, there is a now a community accepted suite of carbonate standards and data reduction procedures that are and should be used to produce clumped isotope values that are comparable and reproducible between labs. Second, there is now a temperature calibration that utilized these best practices that is significantly higher precision than the original calibration. Together, these have reduced clumped isotope temperatures so that many from the Bighorn Basin resemble LMA MAT estimates. Lastly, some samples from the hyperthermal datasets were affected by an unknown contaminant that created mass interference during the isotope measurements, resulting in artificially high and variable temperature estimates compared to uncontaminated samples. As a result of all of these issues, we have been reanalyzing ETM2 and H2 samples to bring these data into alignment with current best practices and to better identify samples affected by contaminants. In this presentation we will discuss effects of these updates on magnitudes of terrestrial temperature for ETH2 and H2 (originally about 10 degrees C in the old dataset), and compare these data to a high-resolution clumped isotope temperature record developed for the PETM in the Bighorn Basin.

## FROM EXTIRPATION TO EXTINCTION: HOLOCENE RANGE COLLAPSE OF THE GREAT AUK (*PINGUINUS IMPENNIS*)

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Investigating the process of species range collapse is crucial for understanding the drivers of population decline and permits us to explore the ecological and anthropogenic contexts in which extinction occurs. We apply a conservation paleobiology lens to reconstruct spatiotemporal dynamics of range collapse for the extinct Great Auk (Alcidae: *Pinguinus impennis*), a large flightless seabird once found across the North Atlantic that was last sighted in 1844 CE. Seabirds are at an elevated extinction risk, with 97 (28% of all extant seabirds) species globally threatened today. Investigating the Great Auk's extinction may help inform conservation strategies for extant seabirds in decline. While most studies have been conducted on the Great Auk's eastern range, little is known about its western range. To determine extinction timing across its entire range, including the overlooked North-West Atlantic region, we surveyed the literature comprehensively to compile a dataset of 142 auk-associated (134) and direct (8) radiocarbon dates on auk bone. To account for differences in stratigraphic control and sampling material, we developed a standardized ranking scheme and assigned quality scores to all dates based on associative strength, reliability of the material dated, and the dating method used. We further accounted for variability in sample size across sites by thinning our dataset, omitting loosely associated dates, and combining dates from the same strata with RCombine in OxCal. As the last appearance is

unlikely to represent the last live individual, we applied a Gaussian-resampled, inverse-weighted McInerny (GRIWM) model to estimate extinction timing for different populations. We repeated this process for the 94 unique sighting dates we compiled, ranked from one to three, with one representing an expert sighting and three an unconfirmed sighting. Using the GRIWM radiocarbon and Solow & Beet sighting models, we compared extinction timing results between data types and populations to reveal extinction patterns. All radiocarbon-based extinction estimates were earlier than the confirmed capture date of 1844 CE, suggesting that there are few radiocarbon dates on geologically recent Holocene material to assess when extirpation occurred for various populations, including the Gulf of Maine. We estimated sighting-based extinction for the North-West Atlantic population ~1825 CE, 35 years before the North-East Atlantic population. However, the extinction date of the North-West population is less certain. The Great Auk's extinction continues a pattern of anthropogenically-driven Holocene extinctions and demonstrates the necessity of studying extinction over this period to understand human-animal interactions. Our research provides new insights into the Great Auk's range collapse and illustrates how diverse data types can be combined and considered for more robust extinction models.

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## MORPHOLOGICAL, PHYLOGENETIC AND ECOLOGICAL ASSESSMENT OF A NEW SPECIES OF GEOMORPHA FROM THE PAWNEE CREEK FORMATION, COLORADO

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The Geomyoidea are a group of rodents endemic to North America that exhibit great ecological diversity today as well as throughout their fossil record. However, less is known about the diversifications and ecologies of early geomyoids and stem taxa (together part of Geomorpha). Here, we present a new genus and species of Geomorpha from Hemingfordian-aged deposits of the Pawnee Creek Formation in Colorado. The specimen includes a partial skull, complete upper and lower dentitions, as well as several fragments of limbs and vertebrae, notably a complete right astragalus. Distinguishing features of the new fossil include its large size in comparison to many other stem geomyoids, the presence of frontal foramina and a supraorbital bony flange, the inflation of both the mastoid and auditory bulla, and the coronoid process of the dentary ascending at the middle of the m2. The upper premolars are larger than the molars and have a paracone and elongated protocone. On the lower premolars, the metaconid is connected to the protoconid. In order to effectively place this specimen within Geomorpha, we built upon a previously established matrix for this clade, assembling an updated matrix of 119 characters and 55 OTUs. Our phylogenetic analysis makes use of a backbone tree based on molecular data to constrain relationships and character evolution. We find the new fossil to be the sister taxon to the genus *Trogomys*. These taxa are stem geomyoids along with *Harrymys* and *Proharrymys*. To assess the systematic capability of our new character matrix, we performed a saturation analysis and calculated Gower's pairwise dissimilarities among all characters. Our results show high dissimilarity amongst characters, supporting the ability of our matrix to shed light on the relationships within Geomorpha. In addition to exploring their systematics, the new fossil enables an investigation of the locomotion of stem geomyoids. Indeed, we used measurements of the astragalus of the new fossil as well as the astragali of nine other geomorph taxa to undertake several morphometric analyses. The new fossil is categorized as semi-fossorial, the same locomotory mode as several other stem geomyoids. Future work adding morphological characters, likely focusing on the dentition, as well as Bayesian inference work will help further resolve the diversification of geomorph rodents and, along with additional ecomorphological analyses, reveal the patterns and processes of the diversification of one of the most species-rich and ecologically diverse rodent clades in North America.

## CRANIAL ONTOGENY IN THE EARLY CRETACEOUS CERATOPSIAN DINOSAUR *PSITTACOSAURUS LUJIATUNENSIS*: INTRASPECIFIC VARIATION BY AGE AND TAXONOMIC IMPLICATIONS

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Before using ontogenetically variable character data and character scorings from immature individuals in maturity assessment and taxonomy of fossils, character state changes across ontogeny should first be evaluated at the species level. *Psittacosaurus* is one of the best-sampled dinosaur genera in the fossil record and the most speciose genus of dinosaur, with ten species currently accepted as valid. Histological data for *Psittacosaurus* specimens from China, Mongolia, and Russia have been reported, showing different life history strategies for each analyzed species. However, no study has yet comprehensively examined changes in character states

or evaluated characters specific to an ontogenetic stage. Here we examined the post-hatchling variation of *Psittacosaurus lujiatunensis* based on 30 three-dimensionally preserved complete skulls, of which 16 have associated long bone histology data. The specimens are all from the Lujiatun Unit (Barremian, Early Cretaceous) of the lowermost Yixian Formation in Liaoning Province, northeast China. Taphonomic effects were accounted for when identifying and scoring variation. Taphonomic processes inferred from articulated skeletons support the presence of only a single species of *Psittacosaurus* in the Lujiatun bed, with other proposed Lujiatun species exhibiting different skull morphology due to diagenetic deformation. Based on histological ages, specimens range from less than a year old to fully mature individuals more than ten years old. As previously reported, commonly used body measurements are strongly correlated with age. The efficacy of size-independent character changes for assessing maturity and assigning a specimen to an ontogenetic stage was tested by treating the ontogenetic hierarchy as a form of phylogenetic hierarchy (cladistic ontogeny). We built a character matrix of ontogenetically variable characters of the skull defined as binary or multistate transformation series. The matrix was analyzed with TNT, recovering a strict consensus tree (i.e., ontogram). The consensus ontogram is poorly resolved indicating prevalent intraspecific variation, and is incongruent with the ontogenetic sequence of specimens based on age and size rankings. Although some histologically supported age groups cluster in the ontogram, others are separated by varying patristic distances. Some trait combinations proposed as diagnostic of different *Psittacosaurus* species are in fact observed across the growth series of *P. lujiatunensis*, meriting a revision of *Psittacosaurus* diversity and evolutionary patterns.

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## BIAS IN MORPHOLOGICAL DISPARITY STUDIES I: CHARACTERIZATION OF THE PHENOTYPE

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Morphological disparity studies have been an important palaeobiological research program since the 1980s. Yet, no consensus has emerged regarding how best to characterize the morphologies of different fossil groups, portray these morphologies in multivariate spaces, or compare the distribution of taxa within such spaces across time intervals. As a result, no consensus has been reached regarding what morphological disparity tells us about the history of life. The most important aspect of any disparity study is the transformation of complex fossil geometries into analyzable data. Disparity data come in two forms: direct morphometric measurements and text-based descriptions. Logically, representations derived from these sources should be roughly equivalent since they are merely different ways of describing the same characteristics. However, few empirical tests of this assumption have been made. To explore whether disparity ordinations derived from text-based descriptions are consistent with those derived from morphometric measurements and/or from a quantitative comparison of the images themselves, data were collected for three fossil groups: microfossils (planktonic foraminifera), invertebrate macrofossils (gastropods and trilobites) and fossil vertebrates (amphibians). Text-based data were coded numerically and all three datasets used to construct linear multivariate ordination spaces for comparison. Multidimensional analyses and statistical tests were then preformed to determine whether the resulting ordinations exhibit comparable patterns of similarity and/or distinction. In an associated study we also investigated the degree to which expert-assessed text-based character-state assignments were consistent with morphometric and image-based assessments of the same morphological characteristics. Our results demonstrate that linear ordinations of different representations of the same specimen sets are inconsistent with one another for all fossil-group datasets examined. Disparity results of important cranidium characters of Tremadocian trilobites exhibited particularly different disparity patterns. Our results suggest that text-based descriptions have inherent limitations in terms of accurately and consistently characterizing complex fossil forms. Results from morphometric measurements and direct image-based assessments were much closer to one another than either was to text-based character ordinations. These results have important implications for future disparity studies. Geometric morphometric data represent forms more accurately and consistently than text-based character-state descriptions. However, direct analysis of images may be an acceptable alternative for geometries that are difficult to characterize morphometrically. Regardless, disparity results derived from text-based descriptions and morphometric measurements should not be compared, or considered comparable, in terms of their ability to represent patterns of morphological disparity.

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## LESSONS FROM THE PAST: INSIGHTS FROM LATE PLEISTOCENE MARINE INVASIONS INTO SOUTHERN CALIFORNIA

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Marine ecosystems are highly vulnerable to severe threats induced by human activity and climate change. Coastal systems are rapidly warming, which is causing species to relocate in order to adapt to changes in their ecology, behavior, and physiology. This shift in species distribution alters biodiversity patterns, and therefore, it is important to implement effective conservation measures to mitigate potential ecosystem losses. The sedimentary record of Southern California marine terraces preserves evidence of the profound paleoclimatic shifts that took place during the Quaternary. Fossil faunas associated with these sediments are often described as thermally anomalous assemblages, where constituent species are found outside their modern-day biogeographic range. These may also be referred to as extralimital species or local invasives and can serve as potential indicators of species migration during glacial-interglacial cycles. Our research aims to identify those local invasives while assessing their spatial distribution to recognize which coastal landscapes were more prone to shaping invasion success during the late Pleistocene. This requires a more refined assessment of the modern distribution, habitat requirements, and other ecological characteristics of these species. Our preliminary results indicate that in the late Pleistocene of southern California (~850 spp.), approximately 20% of the molluscan species can be classified as local invasives. However, around 50% of these occurrences are recorded less than 1° of latitude beyond their modern range. The spatial pattern of invasion reveals a higher likelihood of finding invasive species in sheltered areas of coastal basins compared to ocean-facing shorelines. Taken together, past and present molluscan communities of Southern California are highly dynamic, shifting composition in response to climatic fluctuations, although these anomalous assemblages are not distributed evenly throughout the region. A next step in this research is better characterizing the ecological traits associated with invasiveness. Late Pleistocene community dynamics offer important insights into potential future species migrations under warming conditions. Novel community compositions are to be expected, and particular coastal habitats will be more vulnerable to invasion.

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## TRAIT-BASED PALEONTOLOGICAL NICHE PREDICTION RECOVERS EXTINCT ECOLOGICAL BREADTH OF THE EARLIEST SPECIALIZED ANT PREDATORS

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Paleoecological estimation is fundamental to the reconstruction of evolutionary and environmental histories. The ant fossil record preserves a range of species in three-dimensional fidelity and chronicles faunal turnover across the Cretaceous and Cenozoic. Taxonomically rich and ecologically diverse, ants are an exemplar system to test new methods of paleoecological estimation in evaluating hypotheses. We apply a broad extant ecomorphological dataset to evaluate random forest machine learning classification in predicting the total ecological breadth of extinct and enigmatic hell ants. In contrast to previous hypotheses of extinction-prone arboreality, we find that hell ants were primarily leaf litter or ground-nesting and foraging predators, and by comparing ecospace occupation of hell ants and their extant analogs, we recover a signature of ecomorphological turnover across temporally and phylogenetically distinct lineages on opposing sides of the Cretaceous-Paleogene boundary. This paleoecological predictive framework is applicable across lineages and may provide new avenues for testing hypotheses over deep time.

## INTO- OR OUT-OF-INDIA? EARLY EOCENE POLLEN AND MACROFOSSILS FROM THE GHAZIJ FORMATION IN BALOCHISTAN, PAKISTAN TEST LONG-STANDING BIOGEOGRAPHIC HYPOTHESES

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The early Cenozoic collision of the Indo-Pakistan Tectonic Plate into Asia and resulting biotic exchange hypothetically contributed to the immense biodiversity of modern South and Southeast Asia. Proposed out-of-India plant lineages include Dipterocarpaceae, *Durio*, *Alangium*, *Barringtonia*, and *Ctenolophon*. However, pollen and macrofossil data with robust age constraints from pre-interchange Indo-Pakistan are rare, limiting support for these hypotheses. Additionally, diverse mammalian assemblages from the early Eocene (ca. 54–50 Ma) Ghazij Formation in Balochistan, Pakistan, on the northwestern plate margin, previously showed a

contrasting into-India dispersal pattern. The endemic faunas of the middle Ghazij were replaced by Holarctic taxa, found in the upper Ghazij, as the collision progressed. Here, we present a preliminary report on the first plant macrofossils and palynofloras from the Ghazij Formation, collected from the same biostratigraphically and magnetostratigraphically-constrained sequence as the mammalian faunas. The 39 palynological samples were collected directly from the paleomagnetic sample splits through the lower, middle, and upper Ghazij. The macrofossils (15 sites, ca. 390 specimens) were concentrated in the upper Ghazij Formation These fossil sites, sampled in 2000, are no longer accessible due to regional conflict. The palynofloras indicate an environmental transition from coastal or nearshore marine settings, to freshwater and coastal palm swamps, coastal peatlands, and increasingly terrestrial ecosystems that retain minor marine influence. Diverse dinoflagellate cyst fossils, including Apectodinium homomorphum, Areosphaeridium ebdonii, Areosphaeridium diktyoplokum, and ?Eatonicysta ursulae reaffirm the early Eocene age of the formation. Notable palynomorphs recovered include *Nypa*, *Barringtonia*, Euphorbiaceae, Ericaceae, Chloranthaceae, Fabaceae, Meliaceae, Moraceae, Dipterocarpaceae, and *Alangium* in the middle and lower Ghazij; and *Salvinia*, *Nypa*, *Croton*, Malvaceae, Polygonaceae, and Onagraceae from the upper Ghazij. Unexpectedly well-preserved, reworked palynomorphs from the Ghazij samples also provide insight into the vegetation history of NW Indo-Pakistan during the Permo-Triassic and Late Jurassic–Cretaceous. The leaf flora (ca. 30 species) is dominated by a probable Sapindales morphotype and multiple Fabaceae morphotypes, as well as Salvinia leaves, several palm morphotypes, Araceae, and possible *Calophyllum*. These fossil data provide abundant new information for paleoenvironmental reconstructions of the Ghazij mammal faunas. The presence of several hypothesized out-of-India taxa in the lower and middle Ghazij Formation (Dipterocarpaceae, Alangium, Barringtonia), from a time of limited mammalian interchange with Asia as recorded in the same formation, supports the prior hypothesis that these plant taxa were present in India before the main phases of the Asian collision and associated biotic exchange.

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## BASELINES, BIODIVERSITY, AND BASIN INFILL: USING PALEOLIMNOLOGY TO INFORM MANAGEMENT PRACTICES AND CONSERVATION EFFORTS

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Paleolimnology has a rich history of being used to reconstruct past environments and climates. Recently, the field has turned its attention to better contextualizing the impact of human activity on watersheds and aquatic ecosystems. Here, we present three case studies from a suite of lakes that illustrate how information gleaned from lacustrine sedimentary archives can be useful in achieving management aims while broadening our understanding of aquatic system dynamics prior to the availability of monitoring data. For each lake, we highlight how our research has developed in partnership with local and/or federal agencies to better understand baseline ecosystem conditions before, during, and after the onset of rapid anthropogenic changes. West Lake Okoboji is a mesotrophic lake located in Iowa (USA), and has been impacted by intensive land use change, primarily driven by land conversion to agriculture. In cooperation with the Iowa Department of Natural Resources, we have been using the lake's sedimentary archives to better understand the spatial and temporal variability of sedimentation rates and lake productivity. Results from this research will be used to develop models of sediment infill of the lake basin and lake-wide productivity, focusing on algal community dynamics prior to and after zebra mussel invasion. Western Lake Erie (USA, Canada) has had a similar history of eutrophication and biological invasions by multiple introduced species. Here, our research is focused on the impact of acidification, temperature, alkalinity, and nutrients on the development and succession of harmful algal blooms. In collaboration with and through funding from NOAA, we are coupling experiments with archival sedimentary DNA analyses to characterize the activity and presence of inorganic carbon uptake enzymes and cyanotoxin production genes to determine the influence of multiple stressors on phytoplankton community structure. Using Holocene sediments from Lake Tanganyika, we are exploring the response of the aquatic food web to past warming as an analog for future climate change. The riparian nations of Lake Tanganyika (Burundi, Democratic Republic of Congo, Tanzania, and Zambia) rely on the lake's fisheries as a primary protein source, yet a combination of overfishing and climate change has led to decreasing fish stocks. Here, we are teamed with the Tanzania Fisheries Research Institute (TAFIRI), a public institution under the Ministry of Livestock and Fisheries, and the Lake Tanganyika Authority to provide workshops for the next generation of African Great Lakes scientists on the techniques (e.g., sedimentology, stratigraphy, micropaleontology, and genomics) our research team is using to evaluate the impact of warming on the structural and functional biodiversity of food webs within Lake Tanganyika. Our conclusion includes a vision for the future of integrating paleolimnological research with management priorities and conservation goals.

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## *WHERE THE WILD THINGS WERE*: AN ONLINE, INTERACTIVE, AND ACCESSIBLE ATLAS OF ANIMAL LOSSES FROM THE PLEISTOCENE TO TODAY

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Since the Pleistocene, over half of all large animals have become extinct. These losses have transcended prehistoric, recent, and modern times—accelerating respectively. To highlight these losses as a whole, we aimed to create a pilot version of *Where the Wild Things Were*: an interactive web atlas of charismatic animal losses from the Pleistocene to today. Through this, we sought to: 1) Create a unique resource that instills a sense of awe and place in the public via connections between Quaternary vertebrate paleontology and the present, and 2) Use that sense of awe and place to promote paleontology literacy and conservation engagement (e.g., inspiring Earth science and conservation careers) through the link between Quaternary animal losses and the world today. This resultant pilot version includes ArcGIS StoryMap entries on charismatic megafauna—including wooly mammoths (*Mammuthus primigenius*), Columbian mammoths (*M. columbi*), jaguars (*Panthera onca*), American lions (*P. atrox*), and saber-toothed cats (*Smilodon fatalis*) of the United States. We include information about these species' natural histories, historic ranges, extinction hypotheses, and connections to modern analogs using maps we created with data from paleontological and neontological databases. This comes along with Creative-Commons-licensed images and videos—plus hyperlinks to peer-reviewed publications and relevant conservation organizations. By evoking connections to these animal losses through a sense of place, we hope to intrigue, evoke, and inspire users for effective conservation action.

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## A NEW SPECIES OF *SAURICHTHYS* (ACTINOPTERYGII) FROM THE DOCKUM GROUP OF TEXAS (LATE TRIASSIC, ?EARLY NORIAN) HIGHLIGHTS THE UNEVEN TEMPO OF THE EVOLUTION OF SPECIALIZED JAW MORPHOLOGIES

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The Triassic Period saw major shifts in the composition of vertebrate assemblages towards groups that are critical components of extant ecosystems. For instance, the composition of Late Triassic ray-finned fish (Actinopterygii) marine assemblages transitioned from stem-group "paleoniscoids" to primarily neopterygians, which today include ~35,000 species. Late Triassic marine assemblages show that neopterygian diversification centered on species with short, thick jaws analogous to extant taxa with powerful, force-specialized bites. Late Triassic continental ecosystems from the western United States provide an opportunity to compare actinopterygian evolution in marine and freshwater environments. We describe isolated teeth and rostral fragments of a new species of the "paleoniscoid" ray-finned fish *Saurichthys* from newly discovered microvertebrate sites in the Late Triassic (?early Norian) Boren Ranch beds (Dockum Group) of Texas. The occurrences of *Saurichthys* in the Dockum Group and previous reports in the Chinle Formation expand the geographic and environmental range of the taxon outside of the marine northwestern Tethys in the Norian. The Dockum taxon possesses a fused, elongate rostropremaxillary element that is unique to *Saurichthys* among ray-finned fishes. The Dockum taxon is distinct from *Saurichthys* documented from the Late Triassic (Norian) Chinle Formation of Arizona in lacking prominent, dorsal-ventral ridges along the lateral surface of the oral margin of the rostropremaxilla. The independently evolved elongate jaws of *Saurichthys* indicate convergence on living ray-finned fishes with lengthened jaws. The closing mechanics of extremely elongate jaws in ray-finned fishes shows specialization for jaw closing velocity at the expense of force, seen in species that ambush prey with rapid strikes. Therefore, the novel *Saurichthys* likely occupied a rapid jaw closure predatory role, like *Saurichthys* from contemporary marine assemblages in Europe. Our finding indicates that Late Triassic "paleoniscoids" continued to occupy jaw velocity specialized predatory roles in both marine and freshwater environments even as neopterygians diversified in jaw force specialized roles. There are no documented neopterygians with extremely elongate jaws in the fossil record until the Middle Jurassic. The apparent disjunct timing of the evolution of force and velocity specialized jaws in neopterygians implies that the initial ecological diversification of the clade that occupies ~50% of extant vertebrate diversity proceeded unevenly through the roles they occupy today.

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## THE GREAT ORDOVICIAN BIODIVERSIFICATION EVENT HAD NO EXTERNAL CAUSE BUT WAS SIMPLY THE RESULT OF MANY NEW HIGHER TAXA RADIATING AT THEIR INTRINSIC RATES

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The large increase for marine taxa known as The Great Ordovician Biodiversification Event (GOBE) has been discussed by more than 100 authors and attracted numerous suggestions for causation. Although these efforts have spanned nearly three decades, no widely accepted explanation for an external cause has emerged. I've produced an alternative hypothesis which postulates that there was no external cause for the GOBE: It was simply composed of radiations that occurred at normal rates for numerous taxa originating as part of the initial diversification of marine life. Cambrian radiations accomplished less because evolutionary "experimentation" led to many early extinctions, and four mass extinctions set back diversification. I've tested my hypothesis for eight major GOBE participants: crinoids, corals, brachiopods, trilobites, bryozoans, bivalves, gastropods, and nautiloids. Adaptive radiations entail exponential increase, for which rates can be calculated from the length of the interval involved and the original and final number of genera. From this I calculate a doubling time to use because it's more tangible than a rate. My test compares the doubling times for the various GOBE taxa with doubling times for the same taxa or, in a few cases very closely related ones, for radiations that occurred before or after the GOBE. The two sets of doubling times turn out to be quite similar. Thus, the GOBE rates represent nothing more than intrinsic rates of radiation for taxa, and my hypothesis is supported. The reason that no one has found an external cause for the GOBE is that there wasn't one.

## PALEOECOLOGY AND PALEOENVIRONMENTS OF OLIGO-MIOCENE DESMOSTYLIANS FROM THE STRAIT OF JUAN DE FUCA

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Desmostylians were an important and frequently enigmatic component of marine faunas in the Oligocene and Miocene Epochs and have been found across the North Pacific. Despite their importance and their relatively rich fossil record many questions remain about their paleobiology. Paleoenvironmental reconstructions of desmostylian localities could shed light on their behavior and ecology by indicating habitat preference. The Oligocene Pysht (Olympic Peninsula, Washington) and Sooke (Vancouver Island, British Columbia) Formations provide an excellent opportunity to undertake such reconstructions. At least two species of desmostylian have been recovered from these formations: *Behemotops proteus* and *Cornwallius sookensis*. A third genus may be present as well. Many Pysht and Sooke Formation localities are on public lands and are easily accessible for sedimentological observations. Fossils of marine invertebrates are abundant from both formations, providing multiple paleoenvironmental proxies. We combined qualitative observations of lithology and sedimentary structures from sites along the Strait of Juan de Fuca with quantitative comparisons of localities based on previously collected invertebrate fossils. Field observations suggest that the Sooke Formation preserves highly variable environments whereas the Pysht Formation was deposited almost entirely in deeper water habitats. This is supported by cluster analyses that reveal a high degree of similarity between Pysht Formation localities. Cluster analysis tentatively supports a higher degree of environmental heterogeneity in the Sooke Formation, but a larger fossil sample is required. The two positively identified species of desmostylian from the formations seem to be associated with different environments. *Behemotops* fossils were uncovered exclusively from deeper water sediments while *Cornwallius* specimens were found at sites deposited in shallower water. This observation supports morphology-based suggestions that *Behemotops* was a more active swimmer and more fully marine than many other desmostylians. Systematic collection of fossils will help further clarify the Oligocene environments of the Strait of Juan de Fuca.

## MID-HIGH LATITUDE FOREST EXPANSIONS ACROSS THE EARLY EOCENE CLIMATIC OPTIMUM IN SOUTH AMERICA: PHYTOLITH RECORDS FROM THE SAN JORGE BASIN OF ARGENTINE PATAGONIA

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Cenozoic temperatures and pCO2 levels reached a maximum during the Early Eocene Climatic Optimum (EECO), during which temperature latitude gradients were significantly shallower than today. In response, global vegetation reconstruction models based on paleofloral records broadly suggest the expansion of tropical or mixed tropical-temperate forests to mid-high latitudes and evergreen floras in polar latitudes. However, global and regional models show significant discrepancies regarding South American vegetation responses during this interval, especially in mid-

high latitudes. The lack of congruence is likely due to limited records compared to Northern Hemisphere coverage. At the extremes, models suggest either the expansion of tropical rainforest or arid savannah/steppe floras to mid-high latitudes during the EECO. Paleofloras from Argentine Patagonia show the presence of warm, equable climates with abundant rainfall during the EECO before a palynological turnover, suggesting cooler and drier conditions in the mid-late Eocene. Phytoliths—silica particles deposited in or around plant cells—are a tool for reconstructing vegetation structure in deep time, discerning between closed forests or open savannah/woodland habitats. Testing previous models, we present a regional study of phytolith records across the late Paleocene—middle to late Eocene interval in the San Jorge Basin of Argentine Patagonia. Our analyses show the predominance of palm-dominated phytolith assemblages before and after the EECO and a significant increase in forest indicators (e.g., dicot trees) relative to palm phytoliths during the EECO. Combined with other paleobotanical and geochemical data, we interpret this pattern as a spread of woody dicot-dominated forests during the early Eocene, followed by a shift towards a palm-dominated shrubland in the mid-late Eocene. We find no evidence of savannah-like conditions; grass phytoliths in our samples are rare and represent groups currently occupying the forest understory. Phytolith assemblages across the EECO in Patagonia are consistent with other regional paleobotanical records showing expansive forest vegetation across this interval.

## DIGGING FOR TRILOBITES, SCIENCE EDUCATION, AND LONG-TERM SUSTAINABILITY AT PENN DIXIE FOSSIL PARK IN BUFFALO, NY

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Near the eastern shores of Lake Erie sits a former shale quarry once operated by the now-defunct Pennsylvania-Dixie Cement Company. The shale's high calcite content, resulting from biogenic processes typical of shallow marine environments, made it ideal for use in manufacturing Portland cement. Of little use to the cement company were abundant Devonian Hamilton Group fossils (Givetian Stage, 387.7–382.7 MYA), which included well-preserved clusters of *Eldredgeops* trilobites. The 100-acre quarry was abandoned in the 1970s, leading to two decades of blight as it became filled with illegally dumped trash, stolen vehicles, and vandal activity. Tires outnumbered trilobites until the early 1990s when community advocates blocked a proposed plan to develop the former quarry into a waste transfer station. Advocates joined forces with avocational and professional paleontologists, lobbying for permanent preservation of the quarry. In 1993, a nonprofit was formed; in 1995 a portion of the former quarry was deeded to the nonprofit for purposes of science education and tourism. Following cleanup efforts, visitors were able to safely collect fossils under volunteer guidance. Today, Penn Dixie welcomes 17,000 local and international visitors yearly. The park is a popular location for K-12 field trips, and with the help of state and local government grants numerous capital improvements are underway. Increasing revenue from programming currently supports 25 employees. Penn Dixie's first holotype specimen (solutan carpoid) was discovered in 2023, leading to significant press coverage and opportunities for additional study and exploration at the park.

Funding source: Erie County and Town of Hamburg, NY

## EARLY JURASSIC REEF COLLAPSE AND RECOVERY: HOW KILL MECHANISMS SHIFTED REEF REGIMES

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Mass extinctions in the early Mesozoic were foundational to the development of modern marine communities, especially coral reefs. One of the most severe reef collapses of the Phanerozoic is associated with two consecutive extinctions in the Early Jurassic: the Pliensbachian/Toarcian (Pl/To) boundary event and the Toarcian Oceanic Anoxic event (T-OAE), which are only separated by about 1 million years. Current research on the effects of shallow-water reef ecosystems during these extinctions lacks the stratigraphic and paleontological resolution necessary to either quantify the ecological changes caused by the extinctions or determine how specific extinction drivers (e.g., nutrient influx, ocean acidification, sea-level change) influenced ecological shifts. This study uses fossil data to reconstruct the ecology of reefs from intervals before, between, and after these two events to identify variability in how taxa responded to each extinction. We then used this data to determine if those differences could be explained by differing extinction drivers in each event. These reefs grew in tropical carbonate settings in the Central Atlas Rift Basin, Morocco; an interval uniquely expanded, enabling us to thoroughly sample reefal units from multiple locations, chronostratigraphic units, facies, and stages of reef growth, from across the Lower Jurassic. A quantitative point count analysis of more than 250 thin sections provides data for an assessment of the specific structural and ecological changes that occurred as reefs evolved across the Pl/To and

the T-OAE. Occurrence and percent composition data are used to quantify the differences in reef facies between extinctions. During the Pliensbachian, lithiotid bivalve reefs grew in lagoonal environments and coral, sponge, and microbialite reefs grew on the platform edge. A large influx of nutrients and siliciclastics just after the Pliensbachian/Toarcian boundary caused a severe extinction in reef ecosystems. In the earliest Toarcian, lithiotid bivalves recovered more rapidly than other reef builders, which led to a shift in reef type to predominantly lithiotid bivalve biostromes immediately following the recovery of the carbonate factory. Coral, sponge, and microbial reefs were slower to recover from the Pl/To but were beginning to recover just before the T-OAE. The environmental changes associated with the T-OAE, such as siliciclastic influx and potentially ocean acidification, resulted in the extinction of the lithiotids; in contrast, corals, sponges, and microbialites recovered quickly, and coral, sponge, and microbialite-dominated reefs returned to the platform, but in deeper environments than in the Pliensbachian. That corals were more effected by the nutrient influx associated with the Pl/To and lithiotids were more effected by the acidification associated with the T-OAE gives us insight into how a variety of reef ecosystems may respond to the anthropogenic climate changes facing reefs today.

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## BIOTIC RESPONSES TO ENVIRONMENTAL CHANGE IN A RESTRICTED BASIN: A MACROEVOLUTIONARY AND PALEOECOLOGICAL EXAMINATION OF THE LATE NEOGENE SAN JOAQUIN SEAWAY, CALIFORNIA

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Epicontinental seaways are of very limited extent at present, but are prominent in the marine stratigraphic and fossil record. Characterized by restricted, often dynamic environments and limited genetic exchange with open marine populations, epicontinental seaways can serve as mesocosms for studying ecological and evolutionary responses of marine biota to environmental forcings. The San Joaquin Seaway was a silled marginal basin that covered large areas of the present-day San Joaquin and Salinas valleys in central-southern California during the Late Miocene and Pliocene. The seaway was initially connected to the open ocean by two straits, and became progressively more restricted through the Pliocene due to a combination of tectonic closure and eustatic sea level fall. In the Coalinga Anticline-Kettleman Hills area, ~2.5 km of often richly fossiliferous sediments of the Santa Margarita, Jacalitos, San Joaquin, Etchegoin, and Tulare formations record evidence of multiple invasion, extirpation, speciation, and extinction pulses. Throughout the Pliocene, species endemic to the San Joaquin Basin account for typically ~20% of bivalve species and ~50% of gastropod species, providing an opportunity to contrast macroevolutionary patterns in endemic and nonendemic lineages. Previous work has recognized seven distinct pulses of last occurrences and hypothesized that they were driven by changes in salinity, temperature, and productivity. My dissertation will build on this work to (1) elucidate the traits that influenced extinction/extirpation versus survival of mollusk species throughout the history of the seaway, (2) examine the effects of invasions, extinctions, and changing environmental conditions on the trophic and energetic structure of benthic communities, and (3) investigate the morphological evolution of select mollusk lineages within the San Joaquin Seaway and in the adjacent open Pacific.

## LOST DIGGING MODES OF Z: RECONSTRUCTING FOSSORIAL FUNCTION AND EXTINCT DIGGING STRATEGIES IN FOSSIL MAMMALS USING A COMPREHENSIVE MORPHOMETRIC FRAMEWORK

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Fossoriality has evolved across various mammal clades, and several digging modes (i.e., scratch, chisel-tooth, head-lift, hook-and-pull, humeral rotation) are observed in extant mammals. It is well known that general fossorial adaptations are reflected in skeletal morphology, but broad quantitative investigations of traits closely associated with fossorial specialization and digging mode are lacking, particularly in taxa that use multiple digging modes. Numerous extinct mammals show evidence of fossoriality, whether by being preserved in burrows (e.g., *Palaeocastor*) or exhibiting skeletal traits comparable to modern fossors (e.g., *Pseudochrysochloris*). However, degree of fossorial specialization and digging mode usage in fossil mammals remain poorly understood. Furthermore, given how strongly environmental pressures and ancestral morphologies differ across clades and time bins, it is likely that at least some fossil mammal taxa engaged in extinct, or "lost," digging modes that are no longer represented in the modern biota. Developing indices of digging mode using extant mammals, then applying them to fossil taxa, can provide valuable insight into mammalian fossoriality in deep time. Here, I collected digging mode data (e.g., from behavioral/kinematic studies; for extant taxa only) and morphological data from 166 extant mammal species representing 13 orders and 203 fossil mammal species representing 17 orders. Morphometric data

included dimensions of the humerus, ulna, femur, cranium, olecranon process, deltopectoral crest, metacarpals, and terminal phalanges; incisor procumbency angle; occiput height and angle; and nasofrontal suture complexity. Analysis of 389 rodent specimens representing 151 species (79 extant, 72 fossil) suggested that nasofrontal suture complexity, occiput angle, and procumbency angle are effective metrics for inferring digging mode. Notable results of discriminant function analysis of extant and fossil taxa included that different *Palaeocastor* species used different digging modes, that rhizomyids and a castorid converged on similar usage of both head-lift and chisel-tooth digging, and that *Epigaulus hatcheri* may have engaged in chisel-tooth digging. Additionally, several fossil taxa, including *Protoptychus*, *Castoroides*, and *Ernanodon*, consistently occupied sections of morphospace distinct from any modern species, suggesting that these taxa may have used extinct digging modes or otherwise represented fossorial ecomorphotypes no longer present in modern assemblages. Examining the morphological markers and phylogenetic distributions of such extinct digging modes can illuminate how ancient fossorial mammals interacted with their environments (behaviorally, functionally, and ecologically) in ways that cannot be observed in the present day.

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## TO FUSE OR NOT TO FUSE: DRIVERS OF SYMPHYSEAL FUSION IN WHALES

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In mammals, the mandibular symphysis is where left and right mandibles meet anteriorly, forming the lower jaw. The extent to which the left and right mandibles connect varies widely across different mammal species, with union of the mandibles ranging from completely unfused and kinetic (e.g., anteaters) to completely fused and immobile (e.g., hominids). This range of fusion is observed in cetaceans, the group that includes whales, dolphins, and porpoises. For example, early whale-like ancestors and modern toothed whales exhibit some degree of fusion (i.e., bony connection or complete fusion at the symphysis). Baleen whales, however, have a non-sutured, unfused condition that is thought to accommodate filter feeding and feeding at lower trophic levels. Thus, diverse anatomical form at the mandibular symphysis may represent diverse feeding ecologies across Cetacea. Understanding the link between the degree of fusion at the mandibular symphysis and the broader ecology of cetaceans requires a comprehensive study that examines this trait across the entire lineage. This study (1) documents and describes the diversity of symphyseal fusion and elongation across Cetacea and (2) performs an ancestral state reconstruction. We predict that the degree of fusion will more strongly correspond to feeding ecology than family group, and our preliminary results suggest that tighter fusion correlates with a more elongated symphysis. The results of this study will provide insight into what drives symphyseal fusion in whales, as well as how symphyseal morphology relates to feeding ecology in an aquatic environment.

## COMPETITION AND THE END OF THE LINE: WHAT STEAM LOCOMOTIVES CAN TELL US ABOUT CLADE REPLACEMENT IN THE FOSSIL RECORD

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Evidence for competitive exclusion at the macroevolutionary scale—often referred to as clade replacement—can be elusive. Reasons for this include the difficulty of distinguishing competitive interactions in fossil time-series, and an absence of abiotic constancy at any point in the geological past, limiting the number of available examples of clade replacement that can be definitively upheld. We propose resolving this impasse requires an outside-the-box approach. We first identify four desiderata needed to establish a definitive case of competitive exclusion: (i) functional trait data relevant to survival of individuals within the extinct clade can be quantified; (ii) direct competitors have been identified that overlap spatially, temporally and in resource requirements; (iii) a complete time series exists for the extinct clade, and ages of first appearance for putative competitors are known; and (iv) non-competitive factors cannot explain the extinction. Identifying fossil clades that meet all these criteria ranges from difficult to impossible, challenging the prospect of establishing the relative frequency of clade replacement with any certainty. Still, because neither competition nor extinction are confined to biology, there exist analogous study systems that fit our criteria and can be examined to understand what clade replacement would look like in the fossil record, if it ever happened. One excellent example of a known competition-facilitated extinction is the end of the steam locomotive (SL) as an economically successful means of transport. Through detailed analysis of variation in tractive effort, a trait that captures almost all of SL function, we find patterns of functional trait change for SLs applicable to recognizing clade replacement in fossil time-series. These include evidence of an immediate directional response associated with the first appearance of a direct

competitor, with subsequent competitors further reducing the realized niche of SLs, until extinction was inevitable. Notably, in the case of SLs, phenomena akin to abiotic factors can be excluded. Our results demonstrate how interspecific competition can lead to extinction, but that extinction only occurs when niche overlap between an incumbent and its competitors is near absolute *and* where the incumbent cannot transition to a new adaptive zone. We propose our findings provide the basis for a new approach, largely free of prior assumptions, to analyze putative examples of clade replacement in the fossil record. Functional trait data should be preferred (as opposed to diversity data), and, when the full spectrum of variation for trait values are considered, there exist specific patterns that signify an adaptive response, show when structural limits are reached, and indicate when the end is nigh. Excluding abiotic factors will, however, likely remain a sticking point to identifying macroevolutionary examples of competitive exclusion.

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## FOSSIL BOBCATS: A LENS TOWARD UNDERSTANDING RESILIENCE TO ANTHROPOGENIC CHANGE

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With the extirpation of larger carnivores due to human activity, mesocarnivores (small mammalian carnivores) assume the role of apex predators in many communities today. One such mesocarnivore is the bobcat (*Lynx rufus*), a medium-sized felid that resides in canyons as well as large cities. In southern California, bobcats occur as fossils in the Pleistocene to Holocene-age Rancho La Brea (RLB) asphalt seeps in Los Angeles (LA) and are still extant. We hypothesize that large-scale ecological and environmental change at the end of the last Ice Age ca. 11,700 years ago impacted bobcat ecology and behavior, producing morphological differences between fossil and modern representatives. In this study, we compare linear caliper measurements of crania and post-crania of RLB bobcats at the La Brea Tar Pits & Museum (141 specimens) and historically collected southern California bobcats (primarily from LA and Kern counties; 45 individuals) at the Natural History Museum of LA County. We find that fossil bobcats had significantly longer upper fourth premolars and deeper jaws than modern bobcats; they also had marginally wider lower fourth premolars, larger lower carnassials, and longer lower carnassial blade lengths, potentially enabling feeding on larger prey. However, post-cranial raw measurements and most indices of ecological function do not differ significantly between fossil and modern bobcats, suggesting minimal differences in locomotor mode. Among modern bobcats, Kern specimens had larger jaws and smaller premolar functional indices than LA specimens, suggesting differences in feeding, but other functional differences were insignificant. The reductions in tooth size suggest smaller body size in modern populations, which generally could have resulted from the end-Pleistocene disappearance of large predators like the saber-tooth cat that might have compelled larger body size in bobcats for competitive advantage ("top-down"). Alternatively, climate and vegetation shifts that also marked the Pleistocene-Holocene boundary may have affected the bobcat's small-mammal prey, ultimately impacting the bobcat ("bottom-up"). Morphological change also may have occurred through phenomena like Bergmann's Rule: cold climates, as during the Last Glacial Maximum approximately 20,000 years ago, may correlate with large body size. Concurrent stable isotope work will provide complementary evidence of bobcat resource use; as well, to supplement the linear-morphometric dataset, we are conducting three-dimensional geometric morphometrics on postcranial remains. Having prevailed through megafaunal extinction and environmental transition over tens of thousands of years, bobcats offer continuity in the southern California landscape. Their morphological and habitual adaptation offers lessons for understanding how Ice Age survivors demonstrate resilience to both natural and anthropogenic change, providing valuable perspectives for their conservation even in urban environments.

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## LOCOMOTOR MODULES AND THE EVOLUTION OF FLIGHT IN BIRDS, BATS AND PTEROSAURS

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Among vertebrate taxa that evolved powered flight, pterosaurs and bats retained a hand with some grasping function, whereas this capability was lost early in the evolution of birds. In bats the pollex is free of the wing membrane, and may be used to grip substrates (e.g., branches) or manipulate food items. The pterosaur manus includes three free digits in addition to the wing finger, and the free digits appear well adapted to gripping. Birds evolved from among non-avian pennaraptoran theropods, which were bipedal and equipped with a clawed, tridactyl manus well suited for seizing prey. This type of prehensile manus remained intact as part of the wing in the basalmost birds, such as *Archaeopteryx* and *Jeholornis*, but in the basal pygostylian *Confuciusornis* the second digit shows features, including robustness of the proximal phalanx and reduction of the claw, that suggest compromised grasping function and an increased role in supporting the primary flight

feathers. In subsequent evolution on the line to crown birds the manus rapidly became further consolidated and the third digit reduced and clawless, though even modern birds may have one or two small claws on each hand. Various evidence, particularly from the proportions of the pedal digits, the curvature of the pedal claws, and the presence in many cases of large "hind wings" that would have interfered with terrestrial locomotion, suggests that early birds and some related non-avian pennaraptorans were predominantly arboreal. The prehensile hands of these taxa may then have been used for gripping branches and climbing, as well as for predation. However, the hands of potentially volant and arboreal non-pygostylian pennaraptorans do not appear more strongly adapted for grasping than those of their clearly flightless and terrestrial relatives, lacking conspicuously greater relative elongation of either the phalanges in general or the penultimate phalanges in particular. Any arboreal capability of the manus was thus based on exaptation of ancestral grasping function, without evident enhancement. The forelimbs and legs of birds form distinct locomotor modules, the former functioning in flight and the latter in perching and terrestrial locomotion. In most theropods the forelimbs were used for non-locomotor behaviours, but the arboreal hypothesis of avian origins implies that the forelimbs and hindlimbs became partly integrated into a single locomotor module used in climbing, only to be decoupled as the manus lost its grasping function and became increasingly specialised for flight. Pterosaurs may also have evolved from bipedal ancestors, but their case integration of both limb pairs into a single module used for a variety of locomotor behaviours was evidently never disrupted, given attachment of the wing membrane to the hindlimb. Whatever the ancestral condition of bats, locomotor integration of the forelimbs and hindlimbs became the permanent condition in this group as well.

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## COMPARING THE TAXONOMIC AND FUNCTIONAL TURNOVERS OF BENTHIC FORAMINIFERA ACROSS THE K-PG AND THE EOCENE-OLIGOCENE

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Modern marine ecosystems are the result of gradual faunal turnovers occurring over millions of years and sudden changes due to mass extinctions. However, focus is generally given to understanding the ecological and environmental drivers of the impacts of mass extinctions. Meanwhile, the drivers of slower turnover events and how they factor into building modern ecosystems remains poorly explored. Disentangling taxonomic and ecological turnover allows for researchers to study the severity of a particular event in a changing global ecosystem structure. Benthic foraminifera are an ideal group for comparing the impacts of mass extinctions and turnover events because they have a rich, global fossil record and are well studied such that we can relate their morphology to environmental factors, and, thus, test whether turnover events select against species with particular ecological roles. Previous research has revealed that benthic foraminifera experienced very little functional turnover across the end-Cretaceous Mass Extinction (K-Pg) but did experience significant functional turnover across the Eocene-Oligocene (E/O) boundary. Although some studies show there was preferential survivorship of some ecological groups following the K-Pg, eventual recovery of the faunas were ecologically similar to late-Cretaceous faunal assemblages suggesting no long-term ecological impact of the event. In contrast, previous studies show that the E/O turnover marked a significant shift in marine ecosystem ecology, perhaps linked to the establishment of strong benthic-pelagic coupling seen in modern oceans. Here I examine functional turnover in benthic foraminifera using a global compilation of faunal census records that cross these significant events. Preliminary results suggest that morphotypes and chamber arrangements associated with low oxygen conditions decline in abundance after the E/O turnover, but no functional response appears to occur after the K-Pg given that the relative abundance of morphological groups is similar before and after the event. This implies that despite the dramatic extinction event at the end-Cretaceous, there was little to no net change in benthic ecosystem structure post-recovery. Meanwhile, the shift in morphology seen after the E/O implies a better ventilated ocean, most likely caused by a cooling climate and glaciation in Antarctica. By furthering our understanding of how past turnover events have shaped modern ecosystems, researchers will be better equipped to predict how anthropogenic influences could shape future ecosystems.

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## A LATE MISSISSIPPIAN TURNOVER IN NORTH AMERICAN OPHIUROID FAUNAS

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New methodologies to identify ophiuroid taxa from isolated

lateral arm plates (LAPs) have revolutionized how we view Late Paleozoic brittle star faunas. Previous studies overlooked the bulk of Late Paleozoic ophiuroid diversity because they focused on incidental finds of articulated skeletons, thus missing all the taxa that were too fragile or too small to be readily preserved. Recently, a coarse survey of Late Paleozoic, North American brittle star faunas from the Tournaisian through Artinskian was conducted that show surprising abundance and diversity, as well as dramatic temporal shifts in clade-level abundances among the main brittle star lineages. Whereas brittle stars were previously considered rare and with low species richness during the Late Paleozoic, they are, in fact, commonly abundant and highly diverse faunal components. Early Mississippian faunas are richly diverse with a wealth of stenuroids, protasterids, furcasterids, cheiropterasterids and modern-clade ophiuroids. Although data are still sparse, it appears that no one clade is dominant over another and there is modest diversity in each ranging from 1–3 species per clade, depending on the fauna. This pattern continues through the Viséan where taxa are generically similar to these earlier faunas. By the Serpukhovian (Pitkin Fauna), a dramatic shift occurs in relative abundances. A few common components of earlier Mississippian faunas, notably *Onychaster*, disappear, and instead of a relatively even faunal abundance among the main brittle-star clades, we see an overwhelming shift to modern-clade brittle star domination. This trend is apparent in Early Pennsylvanian faunas, though poorly-sampled, and diversification of modern-clade brittle stars is apparent. By the Kasimovian, we see a striking diversification of modern types with some faunas having as many as six co-occurring genera. While archaic clades are still present, they remain in relatively low abundance. This trend continues into the Permian, but by the Artinskian, a single locality (the Elm Creek Fauna) stands out as a depauperate fauna, dominated by a modern-clade ophioscolecid, which is a rare component of slightly younger faunas, rather than more typical plesiomorphic modern taxa. These shifts in ophiuroid abundance are similar to faunal transitions seen in Late Paleozoic crinoid faunas that were linked to environmental change. Early Mississippian carbonate ramps favored non-eucladid crinoids and archaic brittle stars in greenhouse conditions. Late Mississippian icehouse conditions, in turn, favored eucladid crinoids (the stem lineage from which modern crinoids evolved) and stem lineage modern clade ophiuroids. In both cases the cyclic sedimentation derived from glacial cycles promoted diversification of these taxa and set the stage for the modern fauna some 75 million years before the Permian Mass Extinction.

## SPATIOTEMPORAL DISTRIBUTION AND MORPHOLOGICAL DIVERSITY OF CAMBRIAN ENIGMA WIWAXIA: NEW INSIGHTS FROM SOUTH CHINA

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Soft-bodied *Wiwaxia* stands as an iconic Cambrian enigma, recognized by its densely arranged dorsal imbricated sclerites. Despite its prevalence in the fossil record, the scarcity of articulated specimens leading to persistent uncertainties regarding its biological attribution and evolutionary relationships have fueled ongoing investigations. This study presents an additional articulated specimen and isolated sclerites from the Cambrian Stage 4 Douposi Formation in Yunnan Province, South China, representing a new species—*Wiwaxia douposiensis* sp. nov. The newly described materials, originating from a potential new Cambrian Konservat-Lagerstätte, exhibit typical Burgess Shale-type preservation. They unveil a distinctive two-order rib pattern and aspect ratios of sclerites, establishing a morphological bridge between known species. The temporal and spatial distribution of *Wiwaxia* suggests a potential origination centered in South China, with an expanding pattern from shallow to deep waters and from warm-humid to dry-cold climates during the Cambrian Age 4 to Drumian. Statistical and phylogenetic analyses highlight the dual aspects of conservative aspect ratios in sclerites, and morphological variations observed at both the species and intra-species levels within *Wiwaxia*.

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## A REVIEW OF THE GLOBAL RECORD OF THE EDIACARAN TUBULAR MORPHOTYPE

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The Ediacaran tubular morphogroup has compelling links to metazoan phyla, occurs globally, and is the most commonly occurring morphogroup in the Nama Assemblage (~550–538 Ma) of the Ediacara Biota. However, tubular taxa of the older White Sea Assemblage (~558–550 Ma) are comparatively understudied despite their high abundance and potential to contextualize the high diversity of tubular organisms in the Nama Assemblage, which is critical for determining the scale of the purported radiation of tubular taxa in the Nama Assemblage and for understanding their role in Earth's earliest complex communities. This is further complicated by a mass extinction occurring between the White Sea and the Nama assemblages. To test whether the radiation of tubular organisms in the Nama Assemblage represents a true increase in diversity, we constructed a database of all non-biomineral Ediacaran tubular taxa. Synthesis of the database informs the proposal of three new form-based subgroupings

including tubiform, conotubular, and ovatubular taxa. Further, it reveals that tubular organisms are represented by the same number of genera in the White Sea and the Nama assemblages, demonstrating that the number of non-biomineral tubular genera did not increase across the White Sea-Nama transition. However, the variability of the original compositions of tubular organisms in the Nama Assemblage is found to increase. Thus, a tubular form is shown to have been a common solution to multicellularity prior to the Nama Assemblage, but understanding of the Nama Assemblage as a period of increased tubular complexity is upheld.

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## EFFECTS OF TEMPERATURE, ARIDITY, AND PLANT STOICHIOMETRY ON INSECT HERBIVORY: LESSONS FROM THE PAST AND THE PRESENT

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The influence of climate on deep-time plant–insect interactions is becoming increasingly well-known, with temperature likely playing a critical role. Previous work also hypothesizes the importance of climate-mediated plant stoichiometry and aridity on these interactions. In our modern climate, all three factors are shifting at an unprecedented rate with uncertain consequences for biodiversity. To determine the effects of temperature, stoichiometry, and aridity on insect herbivory in the context of climate change, we compare insect herbivory in 39 fossil floras (focusing on eight floras around a previous hyperthermal event) with herbivory in modern floral assemblages. Our analyses reveal that temperature was positively associated with past herbivory, specifically during geologically rapid climate change. Within the same ecosystem, $N_2$-fixing plants experienced elevated herbivory compared to non-$N_2$-fixing plants with compensatory feeding driving feeding on non-$N_2$-fixers. When comparing similar ecosystems that varied in their aridity, insect herbivory was greater in the arid environments. Compared to deep-time environments, herbivory frequency is higher today, suggesting that effects of anthropogenic warming, or other anthropogenic factors, uniquely impact plant–insect interactions. The work presented here fills a much-needed knowledge gap that addresses multiple aspects of climate change while also contextualizing the impact of modern anthropogenic change on Earth's most diverse interactions.

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## REVISING AND UPDATING QUATERNARY $^{14}C$ CHRONOLOGIES IN THE NEOTOMA PALEOECOLOGY DATABASE FOR COMMUNITY PALEOECOLOGY

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Community paleoecology is a potentially powerful approach for understanding the stability of ecological communities during long-term climate shifts like the Pleistocene-Holocene transition, but it requires the capacity to accurately estimate species co-occurrences across space and time based on the fossil record. The Neotoma Paleoecology Database (www.neotomadb.org) is an open paleodata resource that stores assemblage-level information for Quaternary fossil localities, each of which is associated with spatial and temporal information. However, the temporal information associated with many vertebrate fossil localities is outdated, limiting the scope of paleoecological inferences. For example, many of the age estimates for localities are based on uncalibrated radiocarbon dates, which makes it difficult to compare ecological patterns among sites or with other proxies. We are reassessing and updating the radiocarbon-based age estimates in Neotoma for all late Quaternary small mammal fossil collections in North America, in order to make a consistent and updated set of age ranges available for paleoecological studies, including our own trait-based study of small mammal community assembly. Neotoma contains at least 5500 geochronological dates from about 1300 collections, 95% of which are uncalibrated radiocarbon dates. We have added to this at least 570 new dates from existing sites and 200 dates from new sites by comparison with the Canadian Archeological Radiocarbon Database (www.canadianarchaeology.ca), as well as additional dates from the xDD corpus (xdd.wisc.edu). We use OxCal to calibrate all the radiocarbon dates from each analysis unit based on the most recent calibration curve (IntCal20), combine all the analysis units from the collection,

incorporate any non-radiocarbon geochronologic ages, and compute the posterior probability distributions of the maximum and minimum age boundaries for the collection, as well as any internal age boundaries for the analysis units. The medians of these age boundary distributions are then designated as the maximum and minimum age estimates for the collection (the "chronology"). The precision and accuracy of each date was assessed based on the nature of the material dated, the precision of the date, and the strength of its association with the vertebrate remains, and where possible we generated an additional chronology based only on high-quality dates. Once fully developed, the new chronologies will be uploaded and made publicly available in the Neotoma database.

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## FINE-SCALE FOOD WEB MODELING FOR SHALLOW MARINE ECOSYSTEMS

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Food web models have enormous capacity to identify deeper interactions in ecosystems and predict responses to environmental perturbations, but a limiting factor to their application to marine paleoecology is differential preservation of fossil taxa in common shallow marine depositional environments. Food web models generally draw from many taxon-specific publications from large (basin-scale) regions. While this approach allows for a broad view of global ocean structure, it may be difficult to apply these concepts to smaller regions. Here, we explore how food web models differ at a finer scale, in a shallow marine ecosystem of the Late Triassic with robust geochemical and sequence stratigraphic control, including shelly macrofossils and microfossils extracted from sedimentary matrix material. The inclusion of microfossils filled many trophic levels that would not be recognized by only macrofossil assemblages (mainly bivalves, gastropods, cephalopods, and brachiopods), including such biosedimentary additions as protists, sponges, echinoderms, ostracods, and vertebrates. We also assess variation of food web link density, connectance, and several aspects of trophic diversity and similarity. This work further refines food web modeling approaches in marine paleoecology, clarifying the roles of geographic scale, sampling effort, and mineralogy.

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## CLIMATE CHANGE IMPACTS ON ENDEMIC SPECIES IN THE CENTRAL PART OF MOROCCO: *ARGANIA SPINOSA* AS A CASE STUDY

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Current research places a pivotal focus on understanding the impact of climate change on key climatic parameters, particularly temperature and precipitation. These elements directly connect to vegetation, agriculture, and the livelihoods of individuals, emphasising the crucial nature of this research. The investigation utilises modern pollen analysis as an environmental indicator, to understand the intricate relationships between pollen distribution, current vegetation, and climate change factors in central Morocco. The case study aims to provide valuable insight into the profound impacts of climate change on endemic species with a specific focus on the argan tree (*Argania spinosa*). The analysis reveals a complex interplay of climatic factors influencing surface pollen distribution. Severe drought, desertification and soil degradation have altered vegetation composition across the investigated area, identifying a shift towards steppe vegetation dominated by Cichoroideae, Poaceae, and Cyperaceae. Different clusters based on pollen assemblages reflect diverse plant communities influenced by varying climate types from semi-arid to desertic conditions. Furthermore, the study focused on the degradation of the argan tree, a key endemic species in the region, caused by climate change and human activities such as overgrazing and deforestation. The argan tree with ecological, botanical, economic, and social importance, faces challenges from prolonged drought, rising population pressure and expanding pastoral activities.

## TRILOBITES BURROWING, WALKING, AND FEEDING IN TIDAL FLATS OF THE LATE ORDOVICIAN SEQUATCHIE FORMATION OF GEORGIA, U.S.A.

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The Sequatchie Formation in the southern Appalachians is composed of marginal to shallow-marine facies dominated by clastic facies, with trace fossils in most beds. The formation is completely exposed in the U.S. Interstate Highway 75 cut near Ringgold, Georgia, where its lowermost part, the Ringgold Member, consists of interbedded hematitic sandstones and mudstones. No macrofauna has been discovered except in marine-transitional beds, where brachiopods, bryozoans, and molluscans of low diversity occur; a few thin limestone beds have yielded ostracodes. In the 1970s to 90s, Rindsberg and Martin studied Ringgold Member trace fossils, identifying abundant burrows that they eventually attributed to small-bodied trilobites. In this study, we reexamine these trace fossils to test that hypothesis with new digital tools, while also quantifying traits and clarifying relationships of these trace fossils to their tidal-flat environments. Descriptions and measurements for this study were taken from dislodged boulders of Ringgold Member sandstones at its type section. Digital photos of bedding planes were processed with Reality Capture™ 1.3 photogrammetry software, to render digital 3D models of each specimen. ImageJ™ software was then applied to bedding planes to measure and otherwise quantify burrow abundances and burrow cross-sections, while also analyzing the burrows' proximity to physical sedimentary structures, such as desiccation cracks. Most trace fossils are *Taenidium*, with a few associated *Rusophycus* and *Diplichnites*, accompanied by desiccation cracks, wrinkle marks, low-amplitude ripple marks, and minute horizontal and vertical burrows. Specimens of *Taenidium* are meniscate (backfilled) burrows with both horizontal and vertical components, commonly intersecting bedding planes with circular to elliptical cross-sections. Backfills include 1–2 mm thick and 1–5 mm wide clay clasts, indicating that burrowers dug through fine-grained laminae without digesting them. Burrow cross-section areas are variable, with burrows on two bedding planes having means of $1.9 \pm 1.6$ cm$^2$ (n = 31) and $0.8 \pm 0.7$ cm$^2$ (n = 11), suggesting either multiple growth stages or more than one species of tracemakers. We interpret *Taenidium* as burrows made by small, short-bodied trilobites burrowing either to feed or seek prey on and in tidal-flat sediments. *Rusophycus* and *Diplichnites* show directions of movement toward or away from burrows, with fine details likely preserved by microbial mats. Desiccation cracks are cross-cut by multiple burrows in places, suggesting that trilobites actively sought these areas, whether for organic detritus or to hunt smaller infauna. Hematitic sandstones and mudstones in the Ringgold Member further indicate these tidal flats were well-oxygenated environments. Although trilobites are normally regarded as solely marine fauna, their presence in these tidal-flat facies indicate adaptations to marginal-marine conditions.

## ECOMORPHOLOGICAL COMPARISON OF FOSSIL COYOTES AT THE MCKITTRICK AND RANCHO LA BREA ASPHALT SEEPS USING TWO-DIMENSIONAL GEOMETRIC MORPHOMETRICS OF THE LOWER JAW

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In the Pleistocene epoch, today's coyotes (*Canis latrans*) shared the landscape with a larger, now-extinct canid predator, dire wolves (*Aenocyon* (formerly *Canis*) *dirus*). Both species are preserved together at multiple localities, including two asphaltic sites in California, U.S.A.: Rancho La Brea (RLB), in Los Angeles; and McKittrick 200 km northwest. We compared canids between these two sites to study how their ecomorphology may vary with ecological and environmental differences. Inland McKittrick was drier than coastal RLB; the two sites also differed in flora and fauna. Based on the literature, we hypothesized that a generalist diet facilitated coyote survival, while a specialist diet contributed to dire wolf extinction. We predicted that, at both sites, dire wolves would have larger teeth and deeper jaws as they preyed on large herbivores; coyotes would be smaller, able to feed on a broader diet. We photographed canid dentaries from McKittrick at the University of California Museum of Paleontology, Berkeley, and from RLB at the La Brea Tar Pits & Museum in Los Angeles, California. While our McKittrick sample (coyote $n = 9$, dire wolf $n = 7$) was in one depositional category, our RLB sample (coyote $n = 30$, dire wolf $n = 24$) came from four deposits: Pits 3, 4, and 13, all Pleistocene; and Pit 10, Holocene. We analyzed the images using geometric morphometrics in the R geomorph package to examine shape and size differences between species and localities. The posterior dentary was fragmented in nearly 50% of McKittrick specimens; therefore, we focused data collection on nine landmarks on the horizontal ramus. Because we find differences between McKittrick and RLB in coyote jaws but not dire wolf jaws, we focus the remaining analyses on coyotes. Coyote jaw shape differs between McKittrick and each of the three sampled RLB deposits, remaining significant when we exclude Holocene Pit 10. McKittrick coyote jaws appear deeper though not necessarily longer than at RLB; this jaw shape could potentially crush hard matter including but not limited to bone, possibly aiding response to nutrient stress or prey limitation at McKittrick. However, in centroid size—a proxy for jaw size—coyotes from Pit 10 are distinct from RLB Pleistocene deposits, but McKittrick coyote jaws overlap all RLB deposits including Pit 10. This lack of significant size difference may be due to McKittrick chronologically spanning the sampled RLB deposits; a radiocarbon chronology in progress should enable testing of this hypothesis in the future.

While differences are marginal, coyote jaws tend to be smaller at McKittrick than Pleistocene RLB: a trend opposite from concurrent work showing larger teeth in McKittrick than RLB coyotes. This observation echoes earlier research that found coyote jaws and teeth decoupled in the late Pleistocene, likely a microevolutionary signal as coyotes transitioned into smaller body size and different prey in the Holocene.

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## THE ROLE OF MARINE SILICA CYCLING IN DRIVING THE EXCEPTIONAL FOSSILIZATION OF EARTH'S EARLIEST ANIMAL COMMUNITIES

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The enigmatic fossils of the Ediacara Biota, preserved in upper Ediacaran strata around the world, record the emergence and radiation of complex multicellular, macroscopic life. Ediacara fossil assemblages are dominated by soft-bodied organisms that are predominantly exceptionally preserved as casts and molds in sandstones in what has been termed "Ediacara-style" fossilization. One of the longest-standing debates in early animal life history revolves around the nature of this extraordinary mode of fossilization. Resolving the drivers of Ediacara-style fossilization is essential to robustly reconstruct the affinities, community structure and habitats of these ancient organisms; gauge the fidelity of the Precambrian fossil record; and evaluate competing hypotheses for drivers of Ediacara radiation and extinction. Petrographic, paleontological and geochemical evidence from a range of sandstone-hosted Ediacara-style fossil assemblages of Ediacaran and Cambrian age indicates that these fossils are commonly associated with pervasive early diagenetic silica cements. Prior to the Phanerozoic radiation of silica-biomineralizing organisms, elevated seawater silica levels may have driven extensive early diagenetic silica cementation of decaying macroorganism carcasses, facilitating their exceptional moldic fossilization. Moreover, Ediacara-style assemblages commonly include microbially mediated sedimentary structures, formed through the hydrodynamic disruption and burial of organically bound seafloor sediments, that likewise record early diagenetic silicification. Taphonomic experiments conducted under conditions analogous to Ediacaran seawater suggest that the presence of silica-reactive hydroxyl, carboxyl, amino and phosphoryl functional groups in the organic substrates provided by buried macroorganism carcasses and microbial matgrounds permitted these systems to overcome kinetic barriers to silica precipitation, and thereby fostered silicification in upper seafloor sediments even under silica-undersaturated conditions. More broadly, these coupled fossil-based and experimental observations indicate that the Ediacara seafloor was shaped by dynamic environmental and preservational processes linked to Neoproterozoic and early Paleozoic seawater chemistry and substrate character.

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## TRACKING TAXONOMIC AND FUNCTIONAL DIVERSITY OF SMALL MAMMALS ACROSS 17,000 YEARS OF CULTURAL AND ENVIRONMENTAL CHANGE AT THE PAISLEY CAVES, OREGON

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The end of the Pleistocene captures the first intersection of climate change and human impacts on wild ecosystems in North America, resulting in the well-known demise of mammalian megafauna and a cascade of continent-wide ecological transformations. Less well known is how the rise of humans and loss of megafauna affected the diversity and function of communities of the smallest small-bodied survivors. Here, we examine the taxonomic and functional diversity dynamics of small mammals across this tumultuous time, and how these dynamics compare to the transition this community underwent historically from European contact to today. Our study system is Oregon's Summer Lake Basin, as recorded by the deposits preserved in the Paisley Caves, a world-famous pre-Clovis archaeological record spanning the last ~17,000 years. To date, we have identified ca. 2000 small mammal specimens from 32 species. All species are extant, thus we described species with respect to their ecological functional roles using a mix of categorical and mensural traits that are available in the published literature and online databases. The resulting trait space captures aspects of space utilization (e.g., range size, dispersal), body size, diet, habitat preference, activity patterns, and hibernation/torpor. For both taxonomic and functional richness comparisons across time, we standardized samples by coverage via Shareholder Quorum Subsampling. Despite stability in taxonomic richness across the Pleistocene-Holocene transition, we detect functional richness loss within the small mammals from the late Pleistocene into the Bølling-Allerod, yet no change from the Bølling-Allerod into the Younger Dryas, despite a similar amount of taxonomic turnover across time steps. It is noteworthy that this loss of functionally unique small mammals precedes the loss of Pleistocene megafauna from the record by ~2,000 years. Functional richness rebounds in the Late Holocene to near Pleistocene levels, however this does not represent a refilling of previously lost functional space, but rather the addition of new species into existing functional space. The late Holocene rise in functional richness coincides with a period of climatic instability, specifically the onset of

severe megadroughts and an uptick in utilization of the caves by people. The species present during this period indicate the most diverse mosaic of habitats available on the landscape relative to any of the preceding time periods. Both taxonomic and functional richness are reduced in this desert ecosystem today relative to its late Holocene baseline. Future work will focus on disentangling the direct and indirect effects of environmental change, megafaunal loss, and human activities on small mammal biodiversity in the Summer Lake basin, including the degree to which today's depressed richness is due to differences in time averaging across time periods or the result of a recently shifted baseline.

## DIVERSITY UP MOUNTAINS: QUANTIFYING THE ROLE OF CANYON GEOMORPHOLOGY ON ELEVATIONAL DIVERSITY GRADIENTS

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How and why biodiversity varies through time remains a central question in paleobiology and is directly related to how and why biodiversity varies across space at any given moment. The study of modern elevation gradients has become a popular means by which to investigate patterns of biodiversity and underlying causes. Given the pervasiveness of the species-area relationship, it is not surprising that area effects have been suggested to influence patterns of species richness across elevation through a variety of mechanisms including resource and/or habitat heterogeneity, colonization and extinction processes, sampling effects, and the indirect effect of regional area on local richness (the echo effect). The interplay between such factors and the geomorphology of the landscape, however, has been relatively neglected, despite clear links between topographic complexity and diversity across continents and taxa. Thus, understanding these links in modern landscapes will allow us to refine our estimates of how and where biodiversity highs may have come and gone in the past as dynamic landscapes responded to climate and tectonics. Here, we investigate the role of geomorphology in shaping elevational diversity in small mammals along two local canyons in the Great Basin's Ruby Mountains and Toiyabe Range. Specifically, we incorporate measurements of topographic relief, canyon width, hypsometry, and surface roughness into a multi-model analysis that also includes the more traditional ecological predictor variables of habitat heterogeneity, productivity, temperature, and precipitation. In doing so, we uncover a strong role for geological surface process measures as drivers of elevational gradients in species richness in these canyons today, which implies they were also important in shaping diversity across landscapes in the past. Our findings suggest integration between ecology and geology can advance our understanding of the role of dynamic topography in the generation and maintenance of biodiversity.

## MOLLUSK METABOLIC ENERGY EXPENDITURES FROM SHELL VOLUME AND FUNCTIONAL ECOLOGY INDICATE A PRODUCTIVE POST-IMPACT PALEOCENE SHALLOW MARINE ECOSYSTEM

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Insights into how ecosystems respond to sudden and dramatic changes in the environment can result from the study of invertebrate marine macrofossils at the Cretaceous-Paleogene Boundary (KPB, 66 Mya). The KPB fossil record from Malvern AR is a geographic window to the northernmost extent of the US Gulf Coastal Plain (GCP) embayment. Sedimentological, geochemical, taxonomic, and ecological comparisons are made from pre- and post-extinction assemblages to test for; 1. Body size and metabolic energy expenditure values consistent with sufficient post-impact primary productivity to drive shallow marine ecosystem recovery, 2. A period of ecological instability (flux ecosystem) during the recovery prior to establishing a more diverse and evenly occupied functional ecological guild space, 3. Similarity of the shallow marine ecosystem recovery in the north-central GCP to that of more southern KPB locations. Bulk samples were collected at 0.5-meter intervals below and above the KPB from 13 m of section. Biostratigraphic data constrains the section to the late Maastrichtian and Danian. Pre- and post- impact samples were compared for taxonomic diversity, functional ecology, shell volume, and estimated metabolic energy. Comparison with well-documented KPB sections from Texas and Mississippi allow us to test for geographic and environmental differences in taxonomic and ecological effects.The Cretaceous mollusk assemblage is characterized by diverse, mobile infaunal deposit and suspension feeders with low shell volume and a mean 0.149 W/g metabolic energy expenditure. The initial Danian shallow marine mollusk assemblage is a low-diversity disaster fauna dominated by epifaunal, suspension-feeding oysters but with greater shell volume yielding a larger metabolic energy expenditure estimate for the Danian assemblage (0.6 W/g). Stratigraphically higher Danian samples fluctuate between an

oyster-dominated faunal association and an opportunist fauna of motile, infaunal, deposit feeding nuculanid bivalves which are also larger and would expend more average energy (0.65 W/g) than their Cretaceous counterparts. Oyster-dominated and deposit-feeding assemblages have been reported during ecosystem restructuring at other GCP sites but are likely driven at this locality by interfingering marginal marine facies. The precise timing of the fluctuations between faunal associations in the Danian is unknown due to the absence of diagnostic index fossils. Danian mollusk assemblages with larger shell volume and more active ecological roles are suggestive of a rebound in primary productivity in the photic zone and/or increased nutrient levels delivered by terrestrial run-off. Despite a return to pre-extinction proportional abundance in ecological modes of life and greater average metabolic energy expenditure, taxonomic diversity remains below pre-extinction levels providing weak support for a possible flux ecosystem in the shallow marine Danian recovery.

## THE IDENTITY OF A HISTORIC MOUNTED DICYNODONT SKELETON AT THE FIELD MUSEUM

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‘Cryptodonts’ are a grouping of late Permian dicynodont therapsids typically distinguished by a prominent postcaniniform crest on the maxilla and ornamentation in the form of well-developed nasal bosses and ridges present on the anterior, dorsal, and/or palatal portions of the snout. Some cryptodonts, including *Aulacephalodon bainii*, *Odontocyclops whaitsi*, and *Rhachiocephalus magnus*, were the largest dicynodonts, and indeed among the largest terrestrial animals, of the late Permian. However, ‘cryptodont’ alpha taxonomy is in need of revision and their phylogenetic position within dicynodonts is unclear. FMNH UC 1532 is a large dicynodont skeleton from the late Permian *Cistecephalus* Assemblage Zone of the South African Karoo Basin, currently on display at the Field Museum in Chicago. Despite the presence of both cranial and postcranial elements and the specimen’s high public profile as part of a major museum exhibition, it has a convoluted taxonomic history and is rarely mentioned in the literature. FMNH UC 1532 was first given a full description in 1938 and referred to *Aulacephalodon peavoti*, a taxonomic assignment reflected in its current exhibit label. The holotype specimen of *A. peavoti* is partially lost, and the material that has been located is identical to *A. bainii*, making this taxon’s validity dubious. Our reevaluation of FMNH UC 1532 reveals no synapomorphies for the highly ornamented clade Geikiidae, such as a naso-frontal ridge, and numerous other differences from *A. bainii* in cranial and postcranial morphology, including the presence of well-developed postcaniniform crests, widely-exposed unfused postfrontals, a humerus with less strongly developed deltopectoral crest or epicondyle, and a lack of tusks or squamosal bosses. The skull morphology of FMNH UC 1532 is more congruent with a position in Rhachiocephalidae, but the intertemporal skull roof and humeral morphology of this specimen differ from those of *Kitchinganomodon* and *Rhachiocephalus*. The skull of FMNH UC 1532 is most consistent with the holotype of *Kitchingia planifrons*, a taxon known from a single specimen and previously considered a junior synonym of *R. magnus*. These specimens differ from *R. magnus* in bearing a shallow labial fossa, a broad intertemporal skull roof not abutted by the postorbitals, a posteriorly placed pineal foramen surrounded by a boss that is not anteriorly directed, and a more posteriorly-located crista oesophagea of the pterygoid. Phylogenetic analysis supports referral of FMNH UC 1532 to *K. planifrons* and recognition of this taxon as a distinct species of basal rhachiocephalid. Large-bodied ornamented dicynodonts other than *Aulacephalodon* are relatively rare in the Karoo Basin, and recognition of *Kitchingia planifrons* as a distinct taxon adds to our understanding of their diversity in the *Cistecephalus* Assemblage Zone fauna.

Funding source: Idaho State University

## A SHORT-LIVED BURST OF ABERRANT POLYMORPHISM IN PLIOCENE POPULATIONS OF *GLYCYMERIS AMERICANA* (BIVALVIA: ARCOIDA), CONSISTENT WITH EXPRESSION OF A TRANSPOSABLE ELEMENT IN ITS GENOME, ASSOCIATED WITH RAPID ENVIRONMENTAL CHANGE IN THE WESTERN ATLANTIC

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*Glycymeris americana* lives today on the continental shelf off the southeastern U.S.A. It appeared first in the early Pliocene. Direct antecedents occur in mid-Miocene and latest Oligocene strata, so the lineage endured for up to 25 Myr. Shells of *G. americana* are variable in form and adult size, especially on different substrates. During the mid-Piacenzian warm period, variants with striking patterns of aberrant shell sculpture appeared in populations of *G. americana*. These variants occur together with normal shells in faunas that were contemporaneous, within limits of correlation, from North Carolina to south Florida. They occur in sands and shell beds deposited during a major transgression attributed to a high glacio-eustatic sea level. The aberrant shells bear oblique or irregularly concentric folds or ridges, largely affecting only the outer shell layer. Four distinct variants are recognized: ($M_1$) oblique dorsal rugae, variable in number and amplitude, just posterior or less often anterior of the umbo; ($M_2$) more

extensive anterior and posterior rugae, diverging from a medial area of the shell without rugae; ($M_3$) irregularly concentric rugae extending across the entire shell, which is long relative to its height; ($M_4$) irregularly concentric rugae on juvenile shells which are suppressed in adults that revert to the normal shell shape. These variants occur in varying frequencies among populations. No such aberrant shell morphotypes have been found in later Pliocene, Pleistocene or living populations of *G. americana*. David Nicol cited the occurrence of $M_1$ together with wildtype shells ($M_0$) as evidence of genetic polymorphism in *G. americana*. Later he described $M_2$ as a distinct species. Discovery of $M_0$, $M_1$ and $M_3$ in the same shell bed led to consideration of a model based on a single mutation with different expressions in homozygotes and heterozygotes, incorporating pleiotropic and ecophenotypic effects, but this did not satisfactorily explain all the variants. Now, recognition of high frequencies at which transposable elements occur among living bivalves; the kinds of disruptive influence they exert on patterns of development, often with repression of their effects; the fact that they proliferate most readily under environmental stress; and that their negative influences commonly cause them to be vulnerable to extinction, suggest that a transposable element was responsible for just such a set of outcomes in these Pliocene populations. This proliferation of aberrant shell forms in *G. americana* coincides with the occurrence of unusual morphologies in other taxa in the same faunas. Ocean temperatures off the southeastern United States increased sharply at this time and ranges of subtropical taxa extended further north than at any other time in the Neogene. These events appear to have been prompted by changes in ocean circulation, nutrient availability, and other environmental effects arising from late stages of closure of the Isthmus of Panama.

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## TROPHIC STRUCTURE CHANGES IN NEOGENE GASTROPODS FROM THE SOUTHWESTERN CARIBBEAN

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Understanding the mechanisms by which the physical environment impacts biological communities assists how we decipher and predict system function in our rapidly changing world. One way to explore these mechanisms is to study the response of ancient communities to past physical system changes. In the Neogene western Caribbean, environmental change led to restructuring of older communities and emergence of the modern Caribbean fauna. While previous workers have detailed the response of many groups to the environmental changes associated with the closure of the Isthmus of Panama, including corals, bryozoans, and bivalves, changes in the gastropod community are less understood. Here, we quantify relative abundances of gastropod trophic groups across seventy bulk sampling locations in Panama and Costa Rica. Samples ranged in age from 11 million years to ~7000 yrs. We identified individual specimens to the genus level, and then assigned each genus to a trophic group based on diet, mobility, and relationship to the substrate as defined in the Neogene Marine Biota of Tropical America (NMITA) database. Previous work on gastropod ecology suggests that declines in abundance of carnivores and suspension feeding gastropods are expected over time, as productivity decreased in the Caribbean. Our data supports this hypothesis. Developing a strong understanding of changes in these regional communities can help contribute to understanding of mechanisms that link operations of environmental and biological changes.

## OTHER STRATIGRAPHIES, OTHER NARRATIVES: EXPLORING POST HUMAN METHODOLOGIES IN PALEOBIOLOGY EDUCATION

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Scientific research, inclusive of paleobiology, conducted in the US context necessitates connection to the benefit of wider society. One way to connect scientific research to broader communities is through education in informal contexts, such as museums, libraries, and aquariums. This presentation follows the connections found across feminist, post-human literature to paleobiology education in these informal teaching settings. How do we move from these esoteric academic theories into something that has practical application for the classroom setting? One possible model to connect these seemingly disparate disciplines is using rephotography, which imposes images from the present upon images of the past. This is a way of acknowledging intertwined histories in the environments which we are studying, and the layers (physical and otherwise) that exist within the context of the classroom setting.

## FUNCTIONAL FORM OF SPECIES-TIME RELATIONSHIP IS NOT POWER-LAW IN MOST LONG TIMESERIES

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With increasing time span, the number of species observed in a community increases in a pattern known as the species-time relationship (STR). The main functional form of STRs, in analogy to the better studied species area relationship (SAR), is thought to be a power-law function. A power law functional form means that the proportional increase in species richness is scale-invariant, implying that the dynamics observed on one scale can be extrapolated to other scales. However, it has proven difficult to distinguish between power law and other functional forms in time series of limited duration (i.e., decadal scale). Here, we provide a data-dense test of the functional form of species-time relationships across timescales ranging from a few years to a few millions of years by combining ~2,500 ecological time series with ~1,700 fossil time series (Biodeeptime database). We find a large variability in the functional form of STRs, with most time series (>~70%) not obeying the expectation of scale invariance of species turnover. Instead, STRs predominantly decelerate and are best fit by logarithmic or exponential functions (60%). Support for power-law models declines with increasing duration of time series from nearly equal support for logarithmic and power-law models at time scales of less than a century to nearly double the support for logarithmic models on timescales of millennia or longer. We show that these patterns are unlikely to be generated by sampling incompleteness or by correlated changes in temporal grain and resolution. Instead, we hypothesize that the shifting importance of different underlying ecological and evolutionary processes with timescale results in species-time relationships that change over time.

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## NEW INSIGHTS INTO THE ORIGIN OF THE GALAPAGOS TORTOISES WITH A TIP-DATED ANALYSIS OF TESTUDINIDAE

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The giant tortoises of the Galapagos Archipelago influenced Darwin's early thinking on transmutation and now constitute a famous example of island-based speciation and evolutionary dynamics. Questions regarding their evolutionary origin still exist and include whether their giant size evolved before or after the lineage arrived in the Galapagos from the South American continent. Here we present new evidence supporting the 'before' hypothesis based on previously reported fossil specimens from the late Pleistocene of Ecuador. Despite the isolated and fragmentary nature of these tortoise fossils, phylogenetically informative features are preserved. A tip-dated phylogenetic analysis recovers the Ecuador form as the sister taxon to the Galapagos lineage, thus supporting the existence of a closely related, giant tortoise population at approximately the same time and place that the Humboldt Current is thought to have carried the ancestral Galapagos tortoise to the archipelago. The phylogeny also raises the possibility that the same evolution of continental gigantism also facilitated the dispersal of South American tortoises into the Caribbean Basin where they diversified before succumbing to Holocene extinction.

## TAPHONOMY AND TIME-AVERAGING: A COMPARATIVE ANALYSIS OF ECHINOIDS AND MOLLUSKS

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Skeletal remains of marine invertebrates represent geohistorical data that conservation paleobiologists can utilize to interpret pre-anthropogenic states of marine faunal associations. This knowledge could then be used to aid the conservation and restoration efforts of modern ecosystems. However, differences in the skeletal robustness of organisms can lead to differential preservation and affect their susceptibility to time-averaging. In this study, we attempt to quantify a likely taphonomic bias between echinoids and mollusks, which we hypothesize results in lower preservation of whole echinoid tests relative to whole mollusk shells (H1) but similar preservation between the fragments of both groups (H2). We also hypothesize that time-averaging scale is a function of preservation potential, and thus, age mixing and post-mortem survival times should be low for whole echinoid tests, high for whole mollusk shells, and highest in echinoid/mollusk fragments (H3). To test these hypotheses, we collected live and skeletal material from SCUBA sourced sediment samples taken from the marine, soft bottom habitats of three localities along the Florida coast (Cedar Key, CK; Florida Keys, FK; and Carrabelle, CB). Samples were taken at the sediment surface (0–10 cm depth) and subsurface (30–40 cm depth) to compare preservation and time-averaging patterns between the benthic surface and the base of the Taphonomic Active Zone. All echinoid/mollusk skeletal material was classified into three categories: (1) Live-collected, (2) Whole-dead, and (3) Fragments. Counts and total weights were then measured for echinoids/mollusks in each category. Some whole dead and fragmentary specimens were randomly selected for $C^{14}$ dating to quantify time-averaging by taxon, fragmentation state, and sample type. Based on preliminary data, all posited hypotheses seem to be supported in all samples across all localities. Whole echinoid tests were rarer than whole mollusk shells in terms of relative frequencies (CK: 0.64% vs. 22.05%; FK: 0.16% vs. 11.85%; CB: 0.06% vs. 22.22%). Fragments of echinoids seemed to preserve at least as well as mollusks relative to their respective total remains (CK: 97.53% vs. 75.84%; FK: 96.14% vs. 87.91%; CB: 78.66% vs. 75.01%). Radiocarbon age distributions based on 191 CK specimens indicated that whole echinoid tests undergo sub-centennial time-averaging whereas whole mollusk shells are time-averaged over multi-centennial time scales [median: 61 yrs (echinoids) vs. 397 yrs (mollusks); IQR: 27 yrs vs. 720 yrs]. Echinoid/mollusk fragments were time-averaged over millennial time scales and displayed similar levels of age mixing [median: 1636 yrs (echinoids) vs. 1062 (mollusks)]; IQR: 2214 yrs vs. 1540 yrs). These results indicate that complete specimens of mollusks and echinoids differ in completeness as well as resolution and thus should not be analyzed jointly. Fragmentary material shows similar completeness and resolution and may be used for this purpose.

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## EARLY MIOCENE BIOMARKER RECORDS FROM TURKANA PALEONTOLOGICAL SITES

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The geologic and paleontologic records of the Turkana Basin are an exceptional archive for studying the evolution and ecology of large mammals and hominoids. Turkana's central location within the East African Rift System led to widespread volcanism throughout the Neogene, yielding more exposure and dateable material than most other early hominoid study areas. The combination of this favorable geology and an abundant fossil record have positioned Turkana as a cornerstone of hominoid evolutionary research for the better part of a century. However, the majority of paleoenvironmental reconstructions for the basin have focused on the Plio-Pleistocene, and further Miocene records are needed to better contextualize how environmental change impacted the region's fauna. The need for more Miocene reconstructions is particularly acute given discrepancies between regional and local records. Regional-scale studies demonstrate that plant communities were C3-dominated until ~10 Ma in eastern Africa, however, site-specific studies have recently indicated the local presence of C4 plants as far back as the Early Miocene at Moroto, Uganda. Here, we further investigate the ecology of the Turkana Basin using plant wax *n*-alkanes—molecular remains of past vegetation. These biomarkers are analyzed for their carbon and hydrogen isotopic signatures, yielding insight into local plant communities and hydrology. We present new $\delta^{13}C$ and $\delta D$ measurements from the localities of Buluk (~16.7 Ma), Loperot (17 Ma) and Locherangan (~17.5 Ma). Collectively these sites have produced important cercopithecoid (e.g., *Noropithecus bulukensis*) and hominoid (e.g., *Afropithecus turkanensis*, *Limnopithecus legetet*, and *Rangwapithecus gordoni*) fossils, and the close temporal relationship of these sites allows us to compare habitat ecology within a short time

window. Preliminary results from Buluk indicate exceptional biomarker preservation, yielding high fidelity $\delta^{13}C$ records of a purely C3 ecosystem, in accordance with tooth enamel data indicating C3 diets but in contrast to previously published soil carbonate $\delta^{13}C$ data. Such exceptional preservation at Buluk has, in some cases, allowed for δD reconstructions, which are the first of their kind for terrestrial studies of this age in eastern Africa. Loperot and Locherangan results are forthcoming, but initial sample screening from the LpM4 stratigraphic section (extended by the Turkana Miocene Project in 2022 and 2023) appears promising. New biomarker records for the sites of Loperot and Locherangan, and an expanded biomarker record for Buluk, will enhance understanding of the Turkana Basin's ecological history, and the habitats of early hominoids in the Early Miocene.

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## THE COLLECTED PALEONTOLOGICAL HERITAGE OF THE NATIONAL PARK SERVICE

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The various units of the National Park Service (NPS) collectively contain paleontological resources recording close to 1.5 billion years of the history of life on Earth. To date, 286 NPS units and affiliated areas are known to have some type of paleontological resources. Fossils have been collected from many of these units and are now reposited at a variety of within-NPS and outside repositories. As of the end of 2023, the NPS manages 1,472,794 paleontological specimens. An inventory of institutions with NPS fossils was initiated as part of a general synthesis of NPS paleontological data. Making a comprehensive inventory of non-NPS institutions with fossils from NPS units is challenging, especially when considering pre-NPS collections from areas now in NPS units; scientific collecting in some well-known areas goes back to the early 19th century or even farther. Our inventory has been based on references in the literature (particularly type and figured specimens), museum databases, and correspondence. Approximately 195 external institutions and eight multi-park NPS collection facilities are thought to maintain specimens collected in nearly 190 NPS units. These facilities are located in 45 states, the District of Columbia, and ten foreign countries on four continents. We expect that we have missed some collections, particularly small and/or unpublicized collections. Furthermore, based on the history of paleontology, it would not be surprising to find certain types of fossils from current NPS lands almost anywhere (e.g., wood from Petrified Forest NP or vertebrate material from Badlands NP). We also know of 28 other collections that have since been moved or lost, and it is likely that some of the smaller collections listed as active have also been transferred to other institutions. Small institutions are most liable to send collections elsewhere, but even large collections have been moved (e.g., Princeton University or the U.S. Geological Survey collections). The repositories with the broadest collections from NPS lands are for the most part predictable based on history, and include the U.S. National Museum of Natural History, the University of California Museum of Paleontology, the Peabody Museum of Natural History, the University of Kansas, and the Natural History Museum of Los Angeles County, all of which maintain fossils from at least 20 NPS units. We continue to work to maintain and improve this inventory, to keep track of collected resources, improve management of uncollected resources, and collate more comprehensive information on NPS paleontological resources.

## A NEW HIGHLY DIVERSE ASSEMBLAGE OF ORGANICALLY PRESERVED VASE-SHAPED MICROFOSSILS

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Vase shaped microfossils (VSMs) are hemispherical to tear-shaped tests that are globally distributed in late Tonian rocks and thought to be related to modern arcellinid (Amoebozoa) testate amoebae. Most VSMs are preserved as mineralized casts and molds; however, VSMs from the lower Walcott Member of the <770–730 Ma Chuar Group, Grand Canyon, Arizona, are preserved organically. Based on preliminary investigation, we have identified at least 19 species in this assemblage, nine of which are new. New species include a curved test with bumps along the surface resembling a pickle, spherical tests with triangular apertures, tests with slit-shaped apertures, and tests possessing tentacle-like structures around the aperture. Additionally, this investigation revealed previously unknown microstructural details, such as plywood-like layers, small pores, and dimples in the test wall along with some bulbous collar structures we tentatively interpret as preserved soft parts. Many of the species in this assemblage have similar test profiles and are mainly differentiated by aperture shape or by external text features like bumps or spines. Unfortunately these structures are unidentifiable in many angles of thin sections, which means several shapes of test previously understood to be unique in thin sections are no longer sufficiently diagnostic of their species. Newly discovered structures like slit shaped apertures could indicate that some of these VSMs were exposed to a desiccating environment. This along with the presence of apparent scratches could indicate some of the tests may have originated from a terrestrial environment—consistent with the habitats of modern arcellinids—and were transported to marine sediment. Several species possess traits unknown in the modern group such as multiple layered tests and apertures surrounded by tentacle-like structures. We interpret these taxa to be stem arcellinids that evolved their own distinctive traits.

Our new data adds to the 19 species already described, for a total of 28 species of VSMs, recording an extraordinary diversification of amoebozoan testate amoebae in late Tonian environments.

## CHANGES IN MARINE FOOD WEB STRUCTURE AND THE CONSEQUENCES OF INVASIVE SPECIES DURING THE LATE ORDOVICIAN

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Understanding how the complexity observed in nature is able to persist is one of the fundamental goals of ecology. The fossil record provides unique insights into ecosystem structure and functioning through time, yet the mechanisms and underlying principles governing community organization remain poorly understood. Here we examine the evolution of shallow marine ecosystems in response to invasion using food webs. Shallow marine food webs from the Late Ordovician (Katian, U.S.A.) were compared before, during, and after the Richmondian Invasion, a well-documented influx of invasive species preserved in the Cincinnati Series. Invasions are thought to trigger significant ecosystem restructuring and major changes in energy transfer pathways, such as patterns of interactions and the distribution of taxa among trophic levels. Food webs were thus examined prior to the invasion, and compared with the arrival, establishment, and integration phases to identify changes in structure and functioning. After the integration phase of the invasion, the number of guilds with sparse resource links (fewer than 5 resource types) dropped by ~33%, suggesting that a smaller proportion of the community may have consisted of more specialized species with potentially narrower dietary breadths relative to the pre-invasion community. Three guilds also had notably broader dietary breadths, likely as invading species forged new consumer-resource links with other species in the recipient region. Overall, guilds at nearly all trophic positions were linked with more resources in communities after the establishment of invaders. In addition, 7 new functional groups were present in the established community, which also had the greatest number of guilds overall, nearly double that of the pre-invasion community. These results are consistent with the differential survival of generalist taxa found in previous work, and suggest that this led to community wide structural changes in responses to invasion, which has important implications for predicting the long-term effects of modern invasions.

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## NEOGENE ECOSYSTEMS AND MAMMAL DIETS IN EAST AFRICA

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Biomarker records from deep sea cores document dramatic terrestrial ecosystem change that swept across much of Africa during the late Neogene (~10 Ma), when the primary spread of $C_4$ grasslands began, culminating in the modern savanna ecosystems that characterize much of sub-Saharan Africa today. Tooth enamel records from terrestrial archives in eastern Africa show that many large herbivores began to shift their diets towards $C_4$ vegetation (e.g., tropical grasses) at 10 Ma, concurrent with the primary spread of grassy ecosystems. Recent isotopic and phytolith data show that $C_4$ vegetation was present locally prior to 10 Ma and as early as ~21 Ma in eastern Africa, which has major implications for our understanding of climatic drivers of vegetation change and the evolution of mammals, including primates and early humans. A relatively understudied dimension of these early Neogene ecosystems is the diet of large herbivores. If $C_4$ vegetation comprised a significant proportion of early Neogene biomass, it is reasonable to assume herbivores would eat it. Here, we evaluate the diets of early Neogene large herbivores through stable isotope analysis of ~650 fossil teeth from seven fossil sites in the Turkana Basin ranging in age from 29 to ~5 Ma. We also compiled ~850 previously published enamel isotope data from other sites in Africa spanning 37 to 5 Ma. For samples older than 10 Ma, 98% indicate $C_3$-dominated diets with the remaining 2% of samples indicating possible minor amounts (up to ~10%) of $C_4$ vegetation in herbivore diets. We find no evidence of $C_4$-dominated diets. This result raises the question about how we define the ecological significance of vegetation in past ecosystems as $C_4$ was present in the early Miocene but has yet to be shown as a dietary resource for any large mammal. Finally, the new enamel isotope dataset also enables finer scale investigations of dietary niche-partitioning, body water variations, and hydroclimate at and between fossil sites.

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## THE SIGNIFICANCE OF THE SIWALIKS IN EVOLUTIONARY, ECOLOGICAL, AND EARTH HISTORY

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The Siwalik deposits consist of millions of years of stacked flood plain deposits that have been exhumed at the doorstep of the Himalayas. The exposed Neogene to Pleistocene sequence, which stretches across Pakistan, India, Nepal and Bhutan, contains vertebrate fossil, geological, and paleobotanical records that together tell a remarkable story of earth and evolutionary history. The most remarkable story from the Siwaliks is the late Miocene establishment and expansion of $C_4$ grassy ecosystems and the well-documented mammalian faunal change that accompanied it. The magnitude of the late Miocene ecological and faunal change in the Siwaliks makes it unique among late Cenozoic records of earth history. For this reason, the Siwaliks have served as a testbed for evolutionary and ecological theory that has produced numerous pioneering studies. For example, the first studies to characterize the spatial and temporal dynamics of grassland expansion using carbon and oxygen isotopes in pedogenic carbonates were in the Potwar Plateau region. Long-term erosion of the Himalayan foreland by the Indus and Ganges-Brahmaputra river systems built massive sedimentary fans in the Indian Ocean. Studies of sediment from deep sea cores drilled in these distal fans were the first to demonstrate distal carbon isotope records from organic matter and plant wax biomarkers faithfully record the $C_4$ expansion seen in Siwalik deposits. This finding opened doors for future studies using deep sea records to produce regional to continental scale records of $C_4$ grassland expansion in North America, Africa, and Australia. Back on land, pioneering isotopic analysis of carbon and oxygen isotopes in fossil tooth enamel in the early 1990s demonstrated that dietary and faunal change went hand in hand. This was followed by comprehensive isotopic analysis across taxonomic groups that explored differential diet change among mammal lineages during the $C_4$ expansion in the Siwaliks. The ecological or climatic cause(s) of the late Miocene to Pliocene expansion of $C_4$ grasses around the world remains unsolved. Here again, the rich Siwalik record provides a testbed for evaluating the competing roles of $CO_2$, fire, hydroclimate, and herbivory. Recent pioneering organic geochemical studies on terrestrial deposits and deep see cores point to important roles of fire and hydroclimate for $C_4$ expansion in the region. These results are supported by integrated and detailed reviews of existing paleofloral and enamel oxygen isotope records. The ultimate driver for these changes remains enigmatic, although global late-Miocene cooling and, perhaps, atmospheric $CO_2$ decline, likely played a role.

## SPINELESS WONDERS: A HISTORY OF THE INVERTEBRATE PALEONTOLOGY COLLECTIONS AT YALE PEABODY MUSEUM

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While the Yale Peabody Museum itself did not exist as an entity until 1866, the collections that are its core have been on campus much longer. Yale College had a cabinet of natural wonders dating back to the American Revolution. This "Cabinet of Yale College" had been housed in multiple places around campus prior to the construction of the Peabody Museum. Some of the earliest collections came from exchanges between Benjamin Silliman and Gideon Mantell. It wasn't until 1876 when the first Peabody Museum building opened that the museum had both its own identity and space. The appointment of Charles Beecher in 1888 gave the invertebrate paleontology collection its first dedicated staff member. Under Beecher the collections continued to grow with multiple accessions from Syria, Lebanon, and Palestine. O. C. Marsh and Benjamin Silliman purchased fossils from famous European dealers including A. Krantz, L. Saemann, J. Lommel, F. Krantz, and R. F. Damon. Extensive Paleozoic collections primarily from North America were either purchased or collected and then donated by Frank Howe Bradley. Marsh also used his allowance from his uncle, George Peabody, to buy collections from prominent amateur collectors including many crinoid specimens from Crawfordsville collected by Bassett & Hovey. By the late 1860s, fossils from the American West were being shipped back to Yale by train. Marsh's dinosaurs are the most well-known, but the invertebrate paleontology division received extensive collections of Western Interior Seaway specimens. Charles Schuchert took over the division in 1904, bringing with him an extensive collection of brachiopods that he continued to expand over his lifetime. Schuchert purchased many collectors' collections from his own funds to add to the museum, significantly increasing the Paleozoic holdings. In 1917, the original Peabody building was demolished, and the collections were stashed around campus in anticipation of a new building. World War I delayed the construction, and it wasn't until 1926 that the current building opened. Students and the public now had a grand space to view some of the collections. The highlight of the museum was Marsh's dinosaur hall, but an extensive invertebrate hall was also built highlighting the diversity of invertebrates through geologic time. Graduate student dissertation collections significantly grew the collections throughout the twentieth century. Significant additions in the last quarter century include the Samuel J. Ciurca Eurypterid collection, an Early Ordovician Fezouata Formation lagerstätte collection, the CLIMAP collection of foraminifera slides and vials, and an incredibly diverse collection of Green River Formation insects. Many fossils are on display in the newly renovated Yale Peabody Museum which reopened in April of 2024.

## DIVING THROUGH SHALLOW AND DEEP TIME: UNRAVELING THE (PALEO)ECOLOGY AND ECOMORPHOLOGY OF MARINE CARNIVOROUS MAMMALS

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As large-bodied carnivores, pinnipeds (seals, fur seals, sea lions, and walruses) play an essential role in the structure and function of marine ecosystems through consumer-prey interactions. However, the mechanisms underlying these diverse strategies and how they have evolved and influenced their community structure over the past ~30 million years remain poorly understood. Using novel museum specimen-based datasets and combining comparative anatomy, ecomorphometrics, and biogeochemical analyses of extinct and living pinnipeds, my research examines the foraging ecology and niche partitioning of living and fossil pinnipeds, providing a deep-time perspective on their (paleo)biology. I will show how differences in body size and skull morphology contribute to resource partitioning among co-occurring eared seals inhabiting the northeastern Pacific Ocean. Yet the mechanisms controlling body size and feeding ecomorphology in extant and extinct pinnipeds (and likely other marine predators) may be more complex than traditionally accepted narratives involving direct functional trade-offs between cranial morphology and feeding performance. I will discuss how density-dependent sexual selection can drive changes in the body size and biomechanical properties of pinniped foraging morphology, which in turn may affect their performance, confounding (paleo)biological interpretations based solely on morphology. Despite having a globally distributed fossil record, little is known about the macroecological changes associated with the land-sea transition of pinnipeds and how and when modern foraging strategies and community structure evolved. Based on published and original stable carbon and oxygen isotope compositions of tooth enamel from fossil pinnipeds and coeval marine and terrestrial mammals, I will show that fossil pinniped assemblages from the east and west coasts of North America had foraging and niche partitioning patterns analogous to those described in modern communities (i.e., with co-occurring nearshore, offshore, and alternative foraging). These results suggest that resource partitioning emerged early in the evolution of pinnipeds and likely contributed to the structure of their communities over geologic time. Collectively, these research examples demonstrate how the use of complementary frameworks that integrate living and fossil taxa can advance our understanding of the (paleo) biology and ecology of carnivores across multiple temporal and spatial scales.

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## DEVELOPING PROCEDURES FOR THE MIGRATION OF LEGACY PALEONTOLOGICAL LOCALITIES INTO THE BUREAU OF LAND MANAGEMENT'S RECREATION AND PERMIT TRACKING ONLINE REPORTING (RAPTOR) PALEONTOLOGICAL LOCALITIES DATABASE

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The University of Colorado Museum of Natural History (CUMNH) is collaborating with the Bureau of Land Management (BLM) New Mexico State Office to georeference and map CUMNH paleontological localities on or near BLM lands. Once completed, the locality data will be migrated to BLM's newly created Recreation and Permit Tracking Online Reporting (RAPTOR) paleontology locality database. The RAPTOR database will centralize and standardize BLM locality data, helping BLM make more informed decisions on the care, management, and conservation of paleontological resources found on their lands. First, localities are georeferenced to provide a consistent and standard set of geographic coordinates. Current and historic land ownership records are used to verify BLM or other landowners for the locality through time. Any localities collected when BLM did not manage the land are not shared with the BLM. Once georeferenced and landownership is verified, the localities are mapped into an ArcGIS Pro geodatabase structured using BLM's RAPTOR paleontology locality database schema. A digital copy of the locality form and a specimen list are attached to a locality's ArcGIS Pro record, which then serves as a one-stop shop for the original and georeferenced locality data, specimens collected, and other data not part of the RAPTOR database. The locality data and attachments are then shared with the BLM New Mexico State Office via ArcGIS Pro. Challenges encountered primarily related to paucity or vagueness of data of the legacy localities and the determination of land ownership. Localities lacking data were shelved until more data for the locality is found. BLM's Surface Land Management Agency GIS layer and General Land Office records website, which are used to verify land ownership through time, are not intuitive, contain data inconsistencies, or are not usable for some states, thereby increasing the time needed or making it nearly impossible to verify land ownership. Using state or county level land office records or working with BLM personnel on unclear General Land Office records may create a better procedure for land ownership verification. When developed, the CUMNH would like to use the app version of the RAPTOR database to ground truth the localities and refine the locality data even further. The project is providing valuable, hands-on training to CUMNH students whose career goals are to work in museums or other institutions that house paleontological resources. Ultimately, this project is helping the CUMNH resolve data errors and

refine the data for its localities, making them more useful for researchers and the BLM.

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## PHYLOGENY AND EVOLUTIONARY MODULARITY OF A TRILOBITE FAMILY OVER THE ORDOVICIAN RADIATION

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Animals are organized in packages. These packages, or modules, are composed of traits that evolve semi-independently such that change in one module does not necessarily beget change in another. At the macroevolutionary level, this decoupling and relaxation of evolutionary constraints is thought to promote evolvability. Thus, it is thought that modularity facilitates rapid diversification in diverse evolutionary directions, the hallmark of an adaptive radiation, as evolutionary rates among modules can vary along phylogenetic branches. Trilobites provide an unmatched fossil record, due to their biomineralized exoskeleton, to test the long-term relationship between macroevolutionary diversification and modularity. Specifically, modularity in the trilobite cephalon (head) is of interest due to it being a complex structure composed of several fused segments which served multiple functions. The trilobite family Pterygometopidae well-expresses this segmentation of the head and radiated during the Middle and Late Ordovician of Baltica, Avalonia, Laurentia, and Siberia. This group is traditionally comprised of four subfamilies with strong biogeographic signal; however, relationships between and within subfamilies remain unresolved. To address questions regarding the relationship between macroevolution and modularity, phylogenetic relationships must first be resolved in this trilobite group. To do so, we constructed a comprehensive character matrix comprising >240 discrete and meristic characters. Analyses include taxa from all 36 genera assigned to Pterygometopidae and include Ordovician exemplars from families within the suborder Phacopina. We ran Bayesian phylogenetic analyses to produce trees that co-estimate topology and evolutionary rates using the fossilized birth-death model. We then quantified the 3D morphology of the trilobite head using high-density geometric morphometrics for exemplar taxa within Pterygometopidae to identify the structure and degree of modularity of the trilobite head in this group. We found that phylogenetic relationships between subfamilies are largely consistent with hypothesized relationships proposed in past studies of this family notably with the subfamily Pterygometopinae being paraphyletic. The structure of modularity at the family level is similar to what is observed at the species level with the eyes and frontmost part of the head forming a single module. Phylogenetic comparative methods indicate that evolutionary rate varies by module and show a positive relationship between disparity and rate of evolution at the subfamily level.

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## CAMBRIAN REEFS PROVIDED A FOUNDATION FOR THE CAMBRIAN EXPLOSION: EVIDENCE FROM SMALL SHELLY FOSSIL ASSEMBLAGES FROM YUKON, CANADA

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In the early Cambrian, the stage was set for the first major diversification of animal life. Suggested drivers of this radiation include biological (e.g., HOX genes), ecological (e.g., predation and the evolution of biomineralization), and environmental factors (e.g., temperature, oxygen, and nutrient supplies), but the interplay of these factors and their implications for the Cambrian Explosion remain poorly understood. Here I describe two phosphatized fossil assemblages from Yukon, Canada that preserve this burst of diversity. These assemblages are from the Ingta and Sekwi formations, representing deposition in a slope environment, where dead organisms were washed in from shallower water and accumulated. This deeper water setting provided the geochemical conditions for the fossils to be preserved in calcium phosphate (phosphatization). This taphonomic mode can preserve intricate detail and even nonbiomineralized tissues, providing a unique glimpse at the early Cambrian biota. The Ingta Formation is earliest Cambrian in age and contains an assemblage of predominately tubular epifaunal organisms, as well as phosphatized embryos. This low-diversity assemblage is dominated by the early Cambrian index fossil *Anabarites trisulcatus*. The Sekwi Formation is late early Cambrian in age and records a diverse fauna including the earliest reef builders, archaeocyaths and chancelloriid sponges, as well as a diverse shelly fauna including trilobites, brachiopods, early mollusks, and a variety of enigmatic metazoans. Together, these assemblages record the explosion of animal diversity during the early Cambrian. The establishment of reefs likely played a key role in this diversity increase through ecological engineering, or creating new habitats and niches for animals to explore.

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## VERTEBRATE PALEONTOLOGY IN PUERTO RICO: PAST, PRESENT AND FUTURE DIRECTIONS

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The island of Puerto Rico, located in the northeastern Caribbean, has a complex geologic history tied to the development of the Caribbean Plate. This history combined with its rich biodiversity places Puerto Rico as a perfect study case for unraveling the mechanisms of evolution in tropical islands, integrating climatic, biogeographic, and geologic events. A thorough understanding of the regional fossil record, which greatly depends on research and collection efforts, is imperative to characterize the factors that shaped the past and present biodiversity of Puerto Rico. Here, we provide a synopsis of paleontological work in Puerto Rico over the last 112 years (1911–2023) together with current and new discoveries in order to discern trends and patterns and highlight areas in need of focus. Paleontological discoveries during the first part of the 1900's were largely the result of the New York Academy of Sciences Scientific Survey of Puerto Rico and the Virgin Islands. This period witnessed the description of multiple species of mammals and birds, primarily from Quaternary cave deposits, mirroring similar discoveries across the region. Vertebrates from older deposits were described in the works of Narciso Rabell Cabrero, considered by many as the first Puerto Rican paleontologist. This trend continued well into the early 1980's with works focusing mainly on Quaternary terrestrial vertebrates, with further descriptions of mammals, birds, and the first comprehensive review of the herpetofauna. Renewed interest in the vertebrate fauna of the region sparked a new era of research beginning in the late 1980's. This included efforts to study the Quaternary fauna, but also a search for their origins in Paleogene deposits. This further fueled and inspired a generation of works by Puerto Rican paleontologists in collaboration with international researchers during the following decades and into the present. As a result, the last 23 years has seen an improved understanding of the origins of the terrestrial vertebrates (e.g., frogs, rodents), new additions to the marine vertebrate assemblages (e.g., crocodylians, sirenians), refined morphological data and new occurrence records. These advances were further enhanced by improved chronostratigraphy and radiometric dating. However, persistent challenges include helicopter science, limited rock exposures, funding shortages and a dearth of local institutional support. The absence of a local natural history museum to properly house and preserve collections, and provide opportunities for capacity building in paleontology for students remains a pressing concern. Notwithstanding, a renewed interest in Caribbean paleontology has brought researchers back to Puerto Rico, resulting in substantial scientific growth led by local and external collaborative teams in the last 20 years. Continuing this trend will be instrumental towards further enhancing our understanding of the past and present diversity of the region.

## A LATE CRETACEOUS CROCODYLIAN (*DOLICHOCHAMPSA MINIMA*) PROVIDES INSIGHTS INTO THE EARLY EVOLUTIONARY AND PALEOBIOGEOGRAPHIC HISTORY OF GAVIALINAE

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Several Late Cretaceous species have been proposed as among the earliest gavialoids, including 'thoracosaurs' from North America, *Ocepesuchus eoafricanus* from Africa, and *Dolichochampsa minima* from South America. However, the exact evolutionary connections of these Late Cretaceous species to gavialoids are still debated. Consequently, the origins of Gavialoidea in terms of both geographical location (Laurasia vs. Gondwana) and time period (Cretaceous vs. Miocene) remain uncertain. In this study, we present new findings of the Late Cretaceous (73–69 million years ago) *Dolichochampsa* from the upper section of the El Molino Formation in Bolivia. This discovery provides crucial anatomical insights that help clarify the evolutionary relationships of early gavialoids. Through a phylogenetic analysis using an updated morphological character dataset, we find *Dolichochampsa* to be nested within Gavialinae, a subgroup that includes crown-group gharials. However, other proposed gavialoids are found outside the group. *Ocepesuchus* is resolved within alligatorids, and 'thoracosaurs' are situated outside the crown-group Crocodylia. The inferred phylogenetic position of *Dolichochampsa* within Gavialinae suggests a possible origin of the group in Gondwana, with subsequent trans-oceanic dispersals during the Late Cretaceous to other continents, and potential dispersals to South America from the Tethys

region during the late Paleogene–Eocene. This discovery highlights the importance of including the fossil record in phylogenetic analyses to elucidate the complex evolutionary and paleobiogeographic histories of modern species.

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## TRACKING THE IMPACT OF THE K/PG ON PELAGIC SHARK DIVERSITY USING DERMAL DENTICLES

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Sharks are ecosystem engineers, and interpreting trends for how sharks have responded to past extinctions has predictive potential for the current declining in shark populations today. Shark scales, also called dermal denticles, preserved in the marine fossil record can be used to reconstruct trends in open ocean shark abundances and diversity. Dermal denticles have distinct morphologies which can be quantified using a character coding scheme, and can record changes in shark diversity through time, such as a major extinction 19 Ma (e.g., Sibert and Rubin 2021). The Cretaceous-Paleogene Mass Extinction (K/Pg), 66 Ma, caused serious environmental perturbations such as forest fires, loss in primary production and ocean acidification. There is evidence of a 30% extinction in coastal sharks (e.g., Kriwet and Benton), but there is not yet a record on the impact of the K/Pg on open ocean sharks. Here we present preliminary results of a multi-site study of denticle diversity across the K/Pg boundary at three deep-sea drilling sites: Deep Sea Drilling Project (DSDP) Site 386 in the North Atlantic, Ocean Drilling Program (ODP) in Site 1209 in the Central Pacific, and ODP Site 1262 in the South Atlantic. Nearly 1000 denticles across the boundary were coded on a standardized morphometric character coding scheme, and morphological dissimilarity was assessed using the R Package ichthyoliths, and placed within the context of sediment geochemistry-based paleoproxy reconstructions. Preliminary data suggests that sharks were resilient to the K/Pg with less than 50% loss, and unlike the open ocean fish tooth microfossil record from these sites there is no major diversification in sharks following the extinction. These results suggest that the evolutionary forces on sharks following the K/Pg were distinct from those acting on the fish, indicating a decoupling of evolutionary dynamics in marine vertebrate consumers in the aftermath of the K/Pg Extinction.

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## POLYPHYLY AND EVOLUTION IN ANAZYGID BRACHIOPODS: A TALE OF MORPHOLOGICAL OVERLAP AND DISPERSAL EVENTS (ATRYPIDA: ANAZYGINAE AND CATAZYGINAE)

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Speciation events drive diversification, but ecological and biogeographic constraints moderate the speciation process itself. Generating well-constrained species-level phylogenetic hypotheses to investigate speciation processes and facilitators can provide key data on links between biogeography, ecology, and diversification dynamics. The Ordovician epicontinental seas in eastern Laurentia provided an excellent setting in which to examine the effects of sea-level fluctuations, shifting climatic conditions, and active tectonism on the evolution of the shelly benthos. During the Ordovician, the brachiopod order Atrypida originated and diversified extensively, evolving novelties such as skeletal-supported lophophores. However, speciation patterns and evolutionary drivers within two widely distributed atrypid subfamilies, Anazyginae (*Anazyga* + *Zygospira*) and Catazyginae (*Catazyga*) remain poorly known. Herein, we develop a robust phylogenetic framework for these clades and use that framework to evaluate speciation processes and facilitators during the Late Ordovician. Morphological character data, including 29 external characters, were collected from literature and museum collections for a focal group of 20 species, seven recently reviewed *Zygospira* species, six *Anazyga* species, and seven Catazyga species. These data were analyzed in RevBayes, via the morphological model (Mk Model) of character evolution and fossilized-birth-death process (FBD), where evolutionary relationships and rates of extinction, origination, and differential sampling are simultaneously estimated over a clade's history. Speciation mode and biogeographic patterns for the maximum posterior probability phylogeny were then analyzed using BioGeoBears, through the likelihood-based models: (1) Dispersal-Extinction cladogenesis (DEC), (2) DIVALIKE, and (3) BayArea. Primary results include (1) species attributed to the three traditionally named genera do not form monophyletic groups; (2) there is consistency in key morphological traits, such as the number of shell ribs or spiralia whorls within the traditional genera, but also substantial morphological overlap; (3) biogeographic shifts comprising an increase in the number of dispersal episodes relative to vicariance occur associated with increases in sea level and associated establishment of basinal connections within Laurentia that occur after the GOBE interval; and (4) changes in speciation and extinction rates are associated

with major geological events, such as the Great Ordovician Biodiversification Event and the Late Ordovician Mass Extinction. Combining phylogenetic and biogeographic analyses of the Atrypida provides essential information for understanding the impacts of geological and biotic changes influencing the evolution and ecology of the shelly benthos across the Middle and Upper Ordovician in Laurentia during a time of major environmental and ecological shifts.

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## A NEW GLIMPSE INTO THE ANCIENT DIVERSITY OF HISPANIOLA: FAUNAL CHANGE AND ASSEMBLY OF MODERN CARIBBEAN BIODIVERSITY

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The fossil record can provide direct evidence for how modern and past terrestrial biodiversity originated and accumulated over time and space. This is of particular interest in regions with high species richness and endemism threatened by extinction today, as these vulnerable ecosystems are often considered the result of evolutionary processes operating over long-time scales. Oceanic islands provide unique insight to tempo and mode of evolution in relatively closed ecosystems with low immigration rates and high in situ species origination. Classic studies on extant vertebrates in the Caribbean region suggested that the islands have not only acted as museums that retain representatives of ancient lineages, but also were centers of large endemic radiations. While the late Quaternary terrestrial fossil record of the archipelago is well known and documents significant extinctions and extirpations associated with the arrival of humans in the region, the pre-Quaternary record is relatively limited. Even with this limited record, it is clear that a significant portion of extant and recently extinct Caribbean taxa (e.g., lizards in the genera *Anolis* and *Sphaerodactylus*, frogs of the genus *Eleutherodactylus*, sloths, primates, and caviomorph rodents) were already in the Caribbean by the early Miocene, while a few other clades colonized the islands and became extinct before the Quaternary. Recent fieldwork in two Late Miocene-Early Pliocene (7.14–4.57 mya) fossil rich localities in northeast Hispaniola has revealed the presence of a unique and distinct terrestrial faunal assemblage. At least 14 vertebrate taxa were collected including a sloth, two rodents, a sirenian, a pelomedusoide turtle, a gharial, several indeterminate teleosts, four elasmobranchs as well as the first confirmed records of a caiman, sebecosuchian, and siluriform in the Caribbean islands. Fossil invertebrates including terrestrial and brackish water mollusks were also recovered in the stratigraphy, suggesting that the vertebrate bonebed was deposited in a salty marsh paleoenvironment which developed with varying degrees of open sea influence. While a previous study on sloth fossils from these localities suggested affinities to taxa from Cuba, at least six other vertebrate taxa correspond to groups that have no recent fossil record and are no longer present in the region today. The disappearance of these groups, particularly the predator guild between the Late Pliocene and Pleistocene not only suggests substantial changes to terrestrial ecosystems in Hispaniola, but that assembly of modern biodiversity was in part likely the result of post Pliocene radiations and colonization.

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## MARINE MOLLUSCAN COMMUNITIES OF THE PLIO-PLEISTOCENE NASHUA FORMATION FROM MULTIPLE LOCALITIES IN NORTH-CENTRAL FLORIDA

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Various researchers have examined western Atlantic molluscan communities from the Carolinas and southern Florida as part of an effort to better understand extinction episodes across the Plio-Pleistocene. Limited work has been done on assemblages near the biogeographic boundary between the Carolinian and Gulf Provinces in northern Florida, but fossiliferous deposits of the Nashua Formation provide an opportunity to contribute new data from that understudied region. Initial work focused on samples collected from spoil piles in 2018 from East Coast Aggregates near Hastings, FL. More recently, in 2022, in situ samples were retrieved from the quarry wall

at Buck Hammock Materials near Deer Park, FL. Students in Principles of Paleontology classes at Georgia State University in 2018, 2021, and 2023 have been sorting and studying specimens from these localities as part of their course-based undergraduate research experiences. Other students have additionally contributed to processing samples as part of a high school internship and an M.S. capstone project in the Conservation Paleobiology lab at GSU. So far, ~24,500 shells have been identified comprising ~6,500 specimens from spoil piles at East Coast Aggregates and an additional ~18,000 specimens from Buck Hammock Materials representing assemblages from both the lower and upper sections of the quarry wall. Sample processing included sieving (>5 mm shells retained) and classification to genus with paleoecological analyses focused on diversity, abundance, life modes, predation, bioerosion, shell size, and preservational quality. Rare, small, and heavily fragmented shells are still being examined. Throughout all samples, bivalves dominate the assemblages, and *Mulinia* is by far the most abundant genus. Depending on the sample and location, other common genera include *Anadara*, *Diplodonta*, *Donax*, *Spisula*, and an array of lucinids and corbulids. For gastropods, *Crepidula* is present across nearly all samples but is more frequently observed at Buck Hammock Materials. Other gastropod genera such as *Conus*, *Oliva*, *Olivella*, *Prunum*, and *Terebra* are often additionally reported but vary in presence and abundance by location. Drilling predation is consistently documented but is usually recorded at lower percentages. Ongoing work from multiple localities will continue to refine our understanding of paleocommunities from the Nashua Formation and how they fit into the broader context of change in these marine molluscan assemblages during the Plio-Pleistocene.

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## PALEONTOLOGY IN THE PARKS FELLOWSHIPS: A PROGRESS UPDATE ON THE NATIONAL PARK SERVICE AND PALEONTOLOGICAL SOCIETY COLLABORATIVE PROGRAM

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The National Park Service (NPS), Paleontological Society (PS), and Society of Vertebrate Paleontology signed a Memorandum of Understanding (MOU) in 2018 to enhance the study and stewardship of paleontological resources in the NPS. Ongoing collaboration between the NPS and PS following the MOU led to conceptualization of the jointly sponsored Paleontology in the Parks Fellowship Program beginning in late 2020. Pilot projects and support for the new initiative began in 2021 with a full program launch in 2022. Goals of the fellowship program are to provide student-mentor pairs opportunities to collaborate with the NPS on paleontology projects. Paleontological resources are known from 286 NPS units with specimens recorded in situ, museum collections, and cultural contexts. These fossils extend over 1.4 billion years of Earth history and are represented by microfossils, invertebrates, vertebrates, plants, and ichnofossils. Studying the distribution, scope, significance, and management of these non-renewable resources is critical for their preservation and in communicating their scientific value to the public. The model of this fellowship program leverages the expertise of mentors in helping to address needs of the NPS and offers students a chance to learn, bring new ideas, and contribute to NPS projects. Students in the program additionally engage in activities to foster their professional growth such as participating on panels, doing education/outreach, and/or presenting their work to a variety of audiences. Pilot projects that helped shape the development of the program included park-specific inventories at Vicksburg Military National Park (VICK) and Gulf Islands National Seashore (GUIS) and production of a Spanish-language version of the NPS Junior Paleontologist activity booklet. Projects in progress include a) study of fossils in coastal park settings, b) inventories of NPS paleobotanical resources for the Paleozoic, Mesozoic, and Cenozoic, c) projects in development at the intersection of art and paleontology, and d) a program assistant position to support an array of projects in the NPS Paleontology Program. Twelve students and nine mentors from 10 different institutions have participated in the program to date. Products have included NPS public and sensitive version inventory reports for GUIS and VICK as well as publications about findings for these parks that focused on the history of paleontology in/around VICK and new documentation of many chondrichthyan and other vertebrate fossils at GUIS. The Spanish-language version of the NPS Junior Paleontologist activity booklet debuted on National Fossil Day 2023. Two articles featuring a series of projects from the program were published online in the Paleontology Park News including highlights of Cenozoic floras in Alaskan parks. Numerous presentations led by students and/or mentors have been additionally shared at a variety of regional and national conferences since the start of the program.

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## SUSTAINED WORK BREAKS NEW GROUND: EVOLUTIONARY RESEARCH FRONTIERS IN THE BIGHORN BASIN

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Over a century of collecting in the Paleogene record of the Bighorn Basin (BHB), Wyoming has yielded important discoveries about faunal and floral turnover in the Paleogene, the tempo and mode of evolution, and biotic response to global climate change. In particular, significant work in the basin has gone into documenting the brief ~200,000 year record of the Paleocene-Eocene Thermal Maximum (PETM). Here we illustrate how additional collecting in the last 20 years, building off this century of work, has made it possible to tackle central evolutionary questions that are challenging to address with the terrestrial fossil record. Continuing BHB fieldwork is developing a study system that serves as a vital "middle ground" between microevolutionary and macroevolutionary records. This middle ground is critical because the emergent properties of macroevolutionary patterns are difficult to relate directly to microevolutionary processes. Explaining the former through appeal to the latter is difficult in part because most microevolutionary sequences range up to $10^2$ years, but macroevolutionary sequences commonly have a resolution of at least $10^6$ years. The solution must involve empirical tests of evolution at critical intermediate timescales ($10^3$–$10^5$ years)—the temporal resolution being developed in BHB records of the PETM. Developing such a middle ground requires multiple lines of paleontological and geological research, including: (1) large sample sizes of focal organisms, which we have gained through intensive, long-term collecting, including screenwashing, of terrestrial vertebrates; (2) faunally independent characterizations of the paleoenvironment, which we have obtained through geological and paleofloral data collected by collaborators; (3) a high-resolution stratigraphic framework integrating these records, which we have been developing for our field area since 2001; (4) revisiting of assumptions and interpretive models that work well at a macroevolutionary scale, but break down as records approach microevolutionary timescales. Use of these four fundamental advances has produced new insights about the evolutionary patterns of vertebrates in response to climate change. More detailed application of 3D morphometric methods and better characterization of within-species variation has led us to overturn some previous hypotheses of anagenesis. We are starting to disentangle ultimate and proximate drivers of climate change, with implications for interpreting both community and within-lineage turnover. We have begun investigating the potential role that untested phenomena such as phenotypic plasticity may play in long-term response to climate change. Overall, sustained focus on a local record from one particular interval can produce new opportunities for paleontology to contribute to evolutionary theory.

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## SEAWATER SULFATE AND SEDIMENTARY IRON (OXYHYDR)OXIDE CONCENTRATIONS AS TAPHONOMIC CONSTRAINTS ON SOFT TISSUE PRESERVATION BY PYRITE

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The mechanisms behind Ediacaran-style exceptional preservation of soft tissues are contentious. A popular taphonomic model for the preservation of Ediacaran soft tissues involves formation of a pyrite 'death mask,' a mechanism supported by petrological data from multiple localities globally. Surficial iron staining of many Ediacaran fossil-bearing bedding planes provides ambiguous further evidence of the possible presence of pyrite prior to meteoric weathering. Here, we explore how seawater sulfate and sedimentary iron (oxyhydr)oxide concentrations affect the taphonomic trajectory of anemone carcasses during decay. Employing a novel stabilisation protocol in taphonomic experiments, which allows us to consolidate taphonomic experiments via solvent replacement and Paraloid B72 resin impregnation, we show a strong link between sulfate concentration and the extent of iron remobilisation around a buried carcass. The results imply that sedimentary oxidised iron can buffer the system against severely reducing conditions, accelerating the rate of decay substantially. Additionally, we record decay-associated sedimentary structures generated in vitro that suggest a plausible taphonomic continuum between anthozoan-grade animals and some discoidal taphomorphs. Our results demonstrate that Ediacaran-style fossilization may have required a specific range of sedimentary iron composition and/or concentration, limiting the range of environmental conditions wherein fossilization could occur before decay.

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## AN EXOGENOUS ENZYMATIC CONTROL ON SOFT-TISSUE PRESERVATION IN THE EARLY ANIMAL FOSSIL RECORD

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While it is commonly held that the fossil record improves towards the present, exceptional preservation of soft tissues was at its peak in the late Ediacaran and early Paleozoic and diminishes towards the modern day. Although a wide range of environmental drivers behind this decline have been implicated, the impact of microbial enzymes on the longevity of soft tissues buried within sediment has been largely overlooked. Collagen is a key structural biopolymer, present in essentially all metazoans, responsible for maintaining soft tissue integrity. Collagen can theoretically persist in the absence of collagenases (collagen-degrading enzymes) for millennia, yet it disintegrates within hours of exposure to collagenase. As such, the presence of collagenases should considerably decrease the persistence of animal soft tissues in the taphonomically active zone. Here, we reconcile protein trees with a time-calibrated phylogeny to show that the dominant microbial collagenases (U32 and M9 collagenases) were exclusively possessed by obligate anaerobes prior to 1 Ga, before proliferating via lateral gene transfer to obligate aerobes in the terminal Neoproterozoic and Phanerozoic. For much of the Neoproterozoic, collagen degradation was therefore controlled by anaerobes, delaying the onset of collagen degradation until complete anoxia was established, and thus permitting the collagen scaffolds of carcasses to remain intact and available for mineralization for considerable periods of time. The timing of acquisition of collagenase-encoding genes by obligately aerobic microorganisms coincides with the closure of several taphonomic windows for exceptional soft tissue preservation. We propose that a major driver for exceptional preservation in the Ediacaran was the absence of a broad consortium of aerobic, collagen-degrading microorganisms. Furthermore, we propose that this model may limit the preservation potential of aspiculate sponge-grade and stem-animal lineages, imparting a major taphonomic bias to the fossil record.

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## MACROEVOLUTIONARY MOUSE, PHYLOGENETIC MOUSETRAP: THE BROAD IMPLICATIONS OF EARLY BURSTS

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A common pattern revealed by studies of morphological disparity is for disparity to be unusually high early in clade histories. A common explanation for such Early Bursts is that rates of anatomical change were unusually high early in a clade's history. which in turn might reflect filling of relatively empty ecospace and/or the reorganization of developmental linkages among characters. However, the ramifications of Early Bursts transcend these important theoretical issues. Early Bursts represent an alternative to the standard clock models that quantitative phylogenetic analyses use to generate the likelihoods of divergences, and thus the apparent timing of diversification times. This means that our ability to model and potentially control for Early Bursts can have important ramifications for tree-based assessments of the timing of major radiations relative to other events. Early Bursts represent a relaxed clock model allowing rates to vary over at tree. However, there are several ways we could model this, including: 1) declining rates over time that are shared among contemporaneous branches; 2) uncorrelated relaxed clock with a declining central tendency but lognormal distribution of rates among contemporaneous branches; and, 3) autocorrelated relaxed clocks in which we see parallel trends towards decreasing rates across branches contemporaneous branches. An additional challenge for fitting Early Burst models relative to other clock models is that the strongest predictions concern the earliest history of the clade. Bayesian phylogenetic analyses consider alternative origination, extinction and sampling rates that generate prior probabilities on tree-shapes, including divergence times. However, if origination, extinction and sampling rates are assessed solely based on the analyzed taxa, then it might be too easy to allow for deep divergences that allow disparity without Early Bursts. If so, then external data both sampling and diversification controls might be needed. Alternatively, analyses could be expanded to include extended outgroups that would restrict plausible origination, extinction and sampling rates within the clade of interest, with the Early Burst now representing an increase in rates of change followed by a decrease. Because rates of origination often are relatively high early in clade histories, whether change is independent of cladogenesis becomes another important consideration as punctuated change coupled with elevated rates of cladogenesis will increase rates of change per million years even if frequencies of change per cladogenetic event remain constant. Here, we will dissect different ways to model Early Bursts in Bayesian phylogenetics and in efforts to both better understand what drives sudden increases in disparity and also to safeguard against those sudden increases interfering with our ability to study other aspects of macroevolution.

## DECIPHERING DESMOCERATOIDEA (AMMONOIDEA) TURNOVER RATES DURING CENOMANIAN-TURONIAN OCEAN ANOXIC EVENT 2 USING BAYESIAN AND PARSIMONY-BASED PHYLOGENETIC APPROACHES

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The Cenomanian-Turonian (C-T) interval of the Late Cretaceous was a time of environmental perturbation, particularly within marine ecosystems. Ocean Anoxic Event 2, or OAE2, occurred during this time (around 93.9 million years ago) and is characterized by a high amount of organic carbon sequestration, deposition of black shales, and expansion of the oxygen minimum zone. Sea surface temperatures were the highest they have been in the last 120 million years, reaching over 30? around certain parts of the equator. This event varied by region in its intensity, as demonstrated by previous research. A significant number of marine invertebrates went extinct during this period, especially ammonoids and foraminifera. One ammonoid superfamily that survived this extinction event is the cosmopolitan Desmoceratoidea. Until now, the effects of OAE2 on this superfamily were not well understood. I used both parsimony-based and Bayesian phylogenetic approaches to assess turnover through the C-T interval in this superfamily. In doing so, I developed the first quantitative species-level phylogenetic dataset for Desmoceratoidea. Parsimony-based analyses show that most genera do not form monophyletic clades. Some genera, such as Damesites, Puzosia, and Lewesiceras, have species scattered throughout the tree. Other genera overlap and show many similarities, like Beudanticeras and Desmoceras. The parsimony-based analyses could not provide adequate resolution to assess evolutionary relationships or turnover dynamics during the C-T interval. A Bayesian phylogenetic approach offers more promise in rigorously testing hypotheses about rates of turnover in Desmoceratoidea. Results of Bayesian analyses (in process) and interpretations of C-T turnover patterns will be presented. I will also discuss implications for revising desmoceratoid taxonomy. This study provides insight from a cosmopolitan ammonoid clade's perspective into a critical interval in Earth history.

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## COMBINED STABLE O, CA, AND SR ISOTOPE RECORDS REVEAL COCCOLITHOPHORE FEEDBACKS ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM

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Multiple studies have attributed the Paleocene-Eocene Thermal Maximum (PETM, ca. 56 Ma) to eruption of the North Atlantic Igneous Province (NAIP). The release of volcanic $CO_2$ increased temperature and caused ocean acidification (OA). A global negative carbon isotope excursion (CIE) preserved in the carbonate rock record provides evidence for the injection of isotopically light carbon into the surface carbon cycle. IODP Expedition 378 recently recovered a continuous deep-sea pelagic core at Site U1553 (southern Campbell Plateau, South Pacific Ocean) spanning the PETM. Here, we apply high-precision stable calcium and strontium isotope measurements ($\delta^{44/40}$Ca and $\delta^{88/86}$Sr) to Site U1553 bulk samples, which predominantly comprise nannofossil calcite. The novel "$\delta^{44/40}$Ca-$\delta^{88/86}$Sr multi-proxy" is sensitive to multiple mechanisms, including kinetic isotope effects imparted by carbonate mineral formation and biological cycling. We also generated $\delta^{13}$C, $\delta^{18}$O, and Sr/Ca records to provide a chronostratigraphic framework, locate the P/E boundary, and reconstruct paleo-temperature conditions in the high-latitude South Pacific region. The new Site U1553 $\delta^{44/40}$Ca record fully mimics multiple previously published PETM foraminiferal $\delta^{44/40}$Ca records, including a distinctive positive excursion spanning the CIE. $\delta^{44/40}$Ca and $\delta^{88/86}$Sr values strongly correlate with a slope of -0.30. This slope is similar in magnitude but opposite in sign compared to kinetic mass-dependent fractionation during inorganic calcite precipitation. However, $\delta^{88/86}$Sr and $\delta^{18}$O values positively correlate with a slope of 0.08, which parallels the slope detected in coccolithophore culturing studies. No diagenetic mechanisms have been identified that can produce these patterns. Rather, the results show that higher temperatures and OA stimulated coccolithophore photosynthetic growth while impairing calcification. Our dataset also identifies pre-onset excursions (POEs), which portend biocalcification stress prior to the PETM. Changes to the biological pump implied by the $\delta^{44/40}$Ca-$\delta^{88/86}$Sr multi-proxy could have shifted the partitioning of $CO_2$ between the atmosphere and surface ocean, altered bottom water geochemistry, and contributed to the decline of benthic foraminiferal taxa during the PETM. For the first time, we illustrate how the $\delta^{44/40}$Ca-$\delta^{88/86}$Sr multi-proxy can trace temperature, as well as calcification and photosynthetic growth rates, in coccolith-dominated facies.

## BIOGEOGRAPHY AND ISOTOPE ECOLOGY OF EXTANT HERBIVOROUS ARTIODACTYLS, WITH IMPLICATIONS FOR PALEOECOLOGY

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Reconstructing the diets of herbivorous mammals in the fossil record relies on a thorough understanding of their dietary ecology in relation to environmental gradients, morphological traits, and carbon-isotope values in modern ecosystems. We analyzed these topics for a wide range of extant artiodactyl species. Our results show that species with different ecological traits (feeding categories and body size classes) have markedly different geographic patterns of presence, absence, and richness hotspots. The high artiodactyl richness in Africa is achieved by accommodation of more ecological traits as well as more coexisting species with the same traits. Species with different ecological traits also have different sizes and ranges of climate envelope. Dietary extremes (frugivores and obligate grazers) occur in the most restricted climatic conditions, occurring in regions with warm climates and no prolonged dry season. Seasonal extremes of temperature (mean temperature of the coldest month) and rainfall (maximum monthly precipitation) are the most important climatic predictors of artiodactyl richness patterns. The artiodactyl herbivore dietary spectrum is expressed through a wide range of $\delta^{13}C_{diet}$ values inferred from tooth enamel composition, with the most depleted mean value in frugivores and the most enriched in obligate grazers. In general, grazing species have a broader range of isotope values than browsing species, suggesting a wider dietary niche breadth. Notably, variable grazers exhibit a bimodal distribution of $\delta^{13}C_{diet}$ values, with North American and Asian taxa consuming $C_3$ diets and African taxa consuming $C_4$ diets, reflecting the amount of $C_4$ vegetation in the environment. Variation in $\delta^{13}C_{diet}$ values also occurs among terrestrial ecoregions and artiodactyl clades, and they are correlated with hypsodonty index, body mass, and mandibular shape. Taken together, these findings support use of the more detailed dietary classification in the study of large herbivorous mammals. Identifying frugivory and obligate grazing, especially, will inform paleoenvironmental studies. Determining variation in $\delta^{13}C_{diet}$ values in different feeding categories and lineages will help refine paleoecological and paleoenvironmental reconstructions from the rich fossil record of artiodactyls. In addition, this work highlights the importance of integrating different types of data in (paleo) ecological research.

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## EXCEPTIONAL PRESERVATION OF REPRODUCTIVE ORGANS AND GIANT SPERM IN THE CRETACEOUS OSTRACODS

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The bivalved crustacean ostracods have the richest fossil record of any arthropod group and display complex reproductive strategies contributing to their evolutionary success. Sexual reproduction involving giant sperm, shared by three superfamilies of living ostracod crustaceans, is among the most fascinating behaviours. However, the origin and evolution of this reproductive mechanism has remained largely unexplored because fossil preservation of such features is extremely rare. Here, we report exceptionally preserved ostracods with soft parts (appendages and reproductive organs) in a single piece of mid-Cretaceous Kachin amber (approximately 100 Myr old). The ostracod assemblage is composed of 39 individuals. Thirty-one individuals belong to a new species and genus, *Myanmarcypris hui* gen. et sp. nov., exhibiting an ontogenetic sequence from juveniles to adults (male and female). Seven individuals are assigned to a new species and genus *Electrocypria burmitei* gen. et sp. nov. and one to *Sanyuania* sp. Our micro-CT reconstruction provides direct evidence of the male clasper, sperm pumps (Zenker organs), hemipenes, eggs and female seminal receptacles with giant sperm. Our results reveal that the reproduction behavioural repertoire, which is associated with considerable morphological adaptations, has remained unchanged over at least 100 million years—a paramount example of evolutionary stasis. These results also double the age of the oldest unequivocal fossil animal sperm. This discovery highlights the capacity of amber to document invertebrate soft parts that are rarely recorded by other depositional environments. We further describe taphonomic traits indicating that the studied ostracods were quickly surrounded by resin and instantly immobilized. The palaeoenvironment is considered to be a vegetated brackish (mesohaline-oligohaline) lagoon.

The amber piece on which we here report was collected in 2016 and has been deposited in the Lingpoge Amber Museum (Shanghai) since January 2017, before the Myanmar military closed the Kachin amber mining in November 2017. The fossils acquired by the Lingpoge Amber Museum were collected in full compliance with the laws of Myanmar and China including Regulation on the Protection of Fossils of China. To avoid any confusion and misunderstanding, we declare that the amber reported in this study is not involved in armed conflict and ethnic strife in Myanmar.

## BIOCALCIFICATION CRISIS INDICATED BY STABLE CA AND SR ISOTOPES DURING OAE1A

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Large Igneous Province eruptions are expected to trigger biocalcification crises via numerous local-to-global scale mechanisms. The Aptian nannoconid crisis, which correlates with emplacement of the Ontong Java Plateau (OJP) and Ocean Anoxic Event 1a (OAE1a, ~120 Ma), may represent one such example. As Ca and stable Sr isotope fractionations are both senstive to carbonate precipitation rate, linking the Ca and stable Sr isotopes together ("the d44/40Ca-d88/86Sr multi-proxy") can help resolve the origin of their variabilities and thus offer potential to detect biocalcification fluctuations in the rock record. In this talk, we present high-precision TIMS d44/40Ca, d88/86Sr, and 87Sr/86Sr records for Hole 866A of ODP Leg 143 drilled in Resolution Guyot, mid-Pacific. The samples span from the Barremian (~127 Ma) to the Albian (~100 Ma). 87Sr/86Sr ratios gradually decrease from ~0.70750 to ~0.70727, in agreement with the global record. d44/40Ca and d88/86Sr values range from -0.74‰ to -1.07‰ and 0.25‰ to 0.37‰, respectively. The d44/40Ca and d88/86Sr secular trends differ from the 87Sr/86Sr record, but mimic each other. d44/40Ca and [Sr], as well as d44/40Ca and d88/86Sr, strongly correlate and yield slopes expected for kinetic isotope effect. These results indicate that variable mass-dependent fractionation, triggered by changing seawater carbonate chemistry, regulated the isotopic relationship between carbonates and seawater. Positive d44/40Ca and d88/86Sr shifts within the OAE1a interval are consistent with reduced biocalcification rates. The data support a causal connection between eruption of the OJP and the Aptian nannoconid crisis.

## FOSSILS OF AN ENDANGERED, ENDEMIC, GIANT DIPTEROCARP TREE UNLOCK A HISTORICAL PORTAL INTO BORNEO'S VANISHING RAINFORESTS

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The tropical island of Borneo is recognized for its extraordinary biodiversity, endemism, and biogeographic significance. However, Borneo faces severe anthropogenic pressures from extensive deforestation and expansion of agriculture, especially in its lowland regions. Borneo's vanishing peat swamps are critical habitats that host many endemic and endangered plant species and function as significant carbon sinks. Preserving these habitats and their species against extinction is a widely acknowledged conservation priority, but paleobotanical evidence of their evolutionary history from Borneo and the broader Southeast Asian tropics remains extremely scarce, limiting insights into the origin and antiquity of the representative plant groups and threatened living forests. In a recent paper on the first fossil floras from Brunei Darussalam, a sultanate on Borneo's north coast, Wilf et al. (2022) recognized abundant leaf compressions of *Dryobalanops*, a dipterocarp genus with seven species of giant trees endemic to West Malesia. These fossils constituted more than three-quarters of all plant fossils at the Plio-Pleistocene Kampong Lugu fossil site, which was interpreted as an ancient analog to the region's extant coastal peat swamps dominated by dipterocarps. However, the fossils were identified based only on leaf architecture; additional evidence is required to confirm their distinction from a long list of genera with similar leaves and further clarify their relationship with living species. Here, we present the exceptionally preserved in-situ cuticular micromorphology of these fossils, exhibiting diagnostic epidermal and stomatal features of modern *Dryobalanops* (areolae encircling numerous stomata, cyclocytic stomatal complexes, giant stomata on secondary-intersecondary veins, and prevalence of circular hair bases). Qualitative and quantitative comparisons of micromorphology and leaf architecture (shape ovate-lanceolate, size microphyll, apex acuminate, secondary veins numerous and closely spaced, alternating with intersecondary veins, tertiary veins reticulate and forming areolae) indicate remarkable similarity to the living species *D. rappa*, an IUCN red-listed Endangered species that still forms monodominant stands today, constituting the major component of extensive peat swamps of Brunei and Malaysian Borneo. We assign the fossils to *D. rappa*, providing the first definitive non-wood fossil record of *Dryobalanops* and the world's first macrofossil evidence of a living, endangered tropical tree species. Carbon-rich peat swamp forests with monodominant *D. rappa*in northwest Borneo date back to at least the Pliocene, identifying several World Heritage outstanding universal values for this imperiled ecosystem. This work opens new conservation opportunities by using fossil records to inform heritage values based on the antiquity of endangered species and their associated threatened habitats.

## QUANTITATIVE ICHNOLOGY: LINKING PALAEOBIOLOGY AND ENVIRONMENTAL CONDITIONS WITH TRACE FOSSIL MORPHOLOGY

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Locomotory trace fossils can provide unique insights into the evolutionary history of animals, shedding light on the behaviors, mobility patterns, and body plans of their extinct trace makers. Their significance is particularly pronounced for understanding the divergence of early animals during the Ediacaran–Cambrian, when the body fossil record can be patchy and incomplete. Most contemporary trace fossil studies rely predominantly on subjective descriptions, which are less precise and repeatable than quantitative, objective interpretations. Challenges in studying trace fossils include the absence of a direct correlation between trace fossils and their creators, uncertainty regarding the validity of ichnotaxonomic classification, and difficulties in quantitatively assessing the mobility and sensory capabilities of the trace makers. In this study, we used a suite of mathematical metrics and concepts such as the frequency spectrum, bandwidth, autocorrelation, smoothness (in epsilon-delta definition), minimal radius of curvatures, and kurtosis of turning angles to re-evaluate typical simple horizontal trace fossils, along with the traces left by putative modern analogues. Additionally, we used numerical simulations to reproduce foraging trajectories under different movement speeds, body sizes, food densities, sensory ranges and substrates. The results allow us to use dimensionless numbers to quantitatively link biological and environmental signals with the aforementioned mathematical metrics. This approach can be used to determine the putative identity or anatomy of the trace maker. Furthermore, by calibrating the mobility capabilities of trace makers, our findings suggest that the roots of the Cambrian Explosion can be traced back at least as far back as 543 million years ago. This work offers the potential to transform our understanding of trace fossils, providing a more nuanced perspective on the evolution of early animal life.

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## ISOTOPIC EVIDENCE REVEALS LIMITED MOBILITY IN THE SHORT-LEGGED RHINOCEROS *TELEOCERAS MAJOR* AT ASHFALL FOSSIL BEDS, U.S.A.

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We use carbon (C), oxygen (O), and strontium (Sr) isotopes to evaluate multiple types of mobility in *Teleoceras major* from Ashfall Fossil Beds, Nebraska. Ashfall is a mid-Miocene (ca. 12 Ma) site that preserves hundreds of *T. major* skeletons in a volcanic ash-filled watering hole. This *Laggerstätte* provides a temporal "snapshot" of *T. major* population dynamics and allows us to test three possible types of mobility: (1) sex-specific (male) ontogenetic dispersal; (2) seasonal migration; and (3) retreat to a refugium in response to the catastrophic volcanic event. To test for dispersal, we bulk sampled lower m2's and m3's from five males and eight females; m2's formed after weaning but before cow-calf separation, while m3's formed between cow-calf separation and sexual maturity. To test for seasonal migration, we serially sampled m2's and m3's from two males and two females. Lastly, we compared isotope data for *T. major* with other ungulates from Ashfall to detect possible perimortem mobility and niche partitioning. We found only one significant isotopic shift between bulk-sampled m2's and m3's for either sex: C isotopes for female m2's were ca. 0.5‰ higher than female m3's. This is too small of a difference to worry about confidently assign a single driver. There were also no significant isotopic differences between sexes for either m2's or m3's. Oxygen isotopes oscillated by ca. 2‰ for all serially sampled teeth, which likely reflects seasonal climate fluctuations. In contrast, the range in C isotopes was <1‰, and the range in Sr isotopes was within analytical uncertainty (±0.00003). Finally, O and Sr isotopes distinguish *T. major* from co-occurring ungulates, especially horses. Combined, these results suggest that the sampled *T. major* individuals were local to Ashfall throughout their lives. They did not arrive from elsewhere (due to ontogenetic dispersal or catastrophe), nor did they seasonally migrate. To avoid inbreeding and intraspecific competition, individuals may have socially (rather than spatially) dispersed among co-occurring groups. Small but significant isotopic differences among ungulates indicate niche partitioning; *Teleoceras major* at Ashfall likely inhabited wet habitats. Modern rhinoceros species rely on mud wallows for thermoregulation and social interactions, and *T. major* may have been restricted to wet habitats for similar biological or social reasons.

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## ENDOCRANIAL DEVELOPMENT IN NON-AVIAN DINOSAURS REVEALS AN ONTOGENETIC BRAIN TRAJECTORY DISTINCT FROM EXTANT ARCHOSAURS

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Modern birds possess highly encephalized brains that evolved from non-avian dinosaurs. Evolutionary shifts in developmental timing, namely juvenilization of adult phenotypes, have been proposed as a driver of head evolution along the dinosaur-bird transition, including brain morphology. Testing this hypothesis requires a sufficient developmental sampling of brain morphology in non-avian dinosaurs. In this study, we harness, for the first time, brain endocasts of a postnatal growth series of the ornithischian dinosaur *Psittacosaurus* and several other immature and mature non-avian dinosaurs to investigate how evolutionary changes to brain development are implicated in the origin of the avian brain. Using three-dimensional characterization of neuroanatomical shape across archosaur reptiles, we demonstrate that (i) the brain of non-avian dinosaurs underwent a distinct developmental trajectory compared to alligators and crown birds; (ii) ornithischian and non-avialan theropod dinosaurs shared a similar developmental trajectory, suggesting that their derived trajectory evolved in their common ancestor; and (iii) the evolutionary shift in developmental trajectories is partly consistent with paedomorphosis underlying overall brain shape evolution along the dinosaur-bird transition; however, the heterochronic signal is not uniform across time and neuroanatomical region suggesting a highly mosaic acquisition of the avian brain form.

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## DO CHANGES IN SPAWNING SEASON OF *CHIONE SP.* FACTOR INTO SURVIVORSHIP THROUGH THE PLIO-PLEISTOCENE MOLLUSCAN EXTINCTION?

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A regional extinction event covering the Late Pliocene to the Middle Pleistocene in Florida led to mass faunal turnover within marine mollusk populations, though the exact cause of this turnover remains unconfirmed. Cooling ocean temperatures are often cited as the leading cause, but changing mean temperatures may not be the most influential factor in terms of survivorship. It may have been more important to an individual species whether its thermal tolerances were exceeded during seasonal temperature extremes, which would also have changed along with the mean climate. Subannual $\delta^{18}O$ records can indicate what time of year mollusks spawn, grow, pause growth, and ultimately die, leaving behind a record of physiology and thermal tolerance in their shell material. We collected bulk samples from 22 horizons at Florida Shell Quarry near Charlotte County, Florida from the Caloosahatchee, Bermont, and Fort Thompson Formations. We separated out over 1000 valves of *Chione sp.* including both *C. erosa* (found in older units) and *C. elevata* (found in younger units). *C. elevata* supposedly succeeded *C. erosa* around the time of the Caloosahatchee and Bermont Formations. We measured shell dimensions and generated isotope profiles for 6 or more shells from each unit. In this presentation, I will compare shell size and growth rates across the two species and three formations. I will use $\delta^{18}O$ profiles to determine the season of spawning and compare this across species and formation. I will also use $\delta^{18}O$ to determine and identify changes in seasonal temperature extremes through the section. Climate-driven extinctions are often discussed in terms of changes in mean climate, but individual species may be more sensitive to changes in temperature during key times of year, such as during spawning seasons. Determining the relationship between physiology, climate change, and survivorship could help explain why certain taxa persisted during this regional mass extinction when others did not and could indicate which modern bivalve species are more or less vulnerable to today's rapidly changing climate.

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## EVOLUTIONARY PATTERNS IN THE COMPOSITION OF THE TETRAPOD LOWER JAW

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Tetrapods (limbed vertebrates) are a diverse clade that originated around 390Ma following the water-to-land transition, and are seen today in over 30,000 species of amphibians, reptiles and birds, and mammals. The primary function of the lower jaw, feeding, has remained the same across all tetrapods, in spite of substantial morphological and functional evolution. We wanted to quantify how the composition of the jaw changed throughout Tetrapoda. The earliest tetrapods had up to twelve elements comprising their mandible and functional teeth across up to five of those elements, whereas living mammals have only retained one element with a single short tooth row or no teeth at all. We coded the presence or absence of mandibular elements for over 3000 tetrapod species, representing family level sampling across Tetrapoda where possible. We also coded the presence and absence of teeth on variably tooth-bearing elements, and other

variable characters such as the presence or absence of a beak or a mandibular fenestra. We found that early canalisation is the prevailing theme of mandibular evolution across Tetrapoda, although the routes to this vary between major clades. Losses of elements are ubiquitous, but there are also multiple gains across the tree. Tooth-bearing elements have unilaterally decreased, resulting in simpler dental compositions towards extant tetrapods. Our results demonstrate that the mandible has undergone significant compositional evolution over the last ~390 million years, experiencing much higher diversity in the early evolution of Tetrapoda, and successively adapting towards an overall simplified mandibular composition seen across living tetrapods.

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## "PSYCHO" ECHINOID SPINES—EVOLUTION THROUGH SPINE MORPHOSPACE IN CROWN GROUP CIDAROID ECHINOIDS

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Crown group cidaroid echinoids display a variety of spine morphologies and ornamentation thought to have developed as adaptive evolutionary responses to selective pressures such as predation, commensalism, or shelter availability. As spines tend to interact directly with the echinoid's environment, it stands to reason that spine shape is ecologically meaningful, and that the diversity of spines shapes observed across the fossil record of crown group echinoids tracks the ecological evolution of the group. To quantify morphological trends in cidaroid echinoid spine shape, we implement 2D geometric morphometric analysis of spine outlines to track the occupation of spine morphospace through time and across cidaroid echinoid clades. Four anatomical landmarks and 250 semi-landmarks were used to capture complexly shaped cidaroid spine outlines in the basal Psychocidaridae with a fossil record spanning the Jurassic to Holocene. Variability in the extent of morphospace occupation can be seen between forms during the Jurassic–Cretaceous, Danian, and post-Danian taxa, with Danian taxa exhibiting the least shape variability. Extinction of taxa and changes in selective pressures following the K-Pg mass extinction, such as predation and environmental stability, are likely the causes of this constriction of spine shape variability. The single extant psychocidarid taxon included in this study displays ornamentation most similar to other living cidaroids, like the distantly related and derived genera *Prionocidaris* and *Goniocidaris*, suggesting a convergence and constriction of spine shapes in the recent evolutionary history of the Cidaroida. Alongside the diversification in morphologies is the diversification in ornamentation in which the extant pyschocidarid falls. Some ornamentation types are more commonly found on specific spine morphologies, displaying a potential connection between the two. Further work is necessary to elucidate the likely selective pressures that have resulted in these trends in cidaroid spine shape and the trend in ornamentation.

## AN EMERGING PERSPECTIVE ON MAMMALIAN EVOLUTION ACROSS THE CRETACEOUS-PALEOGENE BOUNDARY IN THE BIGHORN BASIN (WYOMING, U.S.A.)

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The Western Interior of North America provides the richest record of mammalian evolution leading up to and across the Cretaceous-Paleogene (K-Pg) boundary (ca. 66 Ma), but that record is drawn from a mosaic of depositional basins and paleogeographic settings. Individual regions within the Western Interior rarely yield a stratigraphic succession of K-Pg mammalian assemblages that exceeds a temporal window of five million years. The Bighorn Basin (BHB) of northwestern Wyoming, however, captures approximately 30 million years of nearly continuous continental deposition spanning at least the middle Campanian through the lower Eocene (ca. 80–50 Ma), and mammal-bearing bonebeds have been found from every formation spanning that interval. Nonetheless, compared to the extremely rich Paleocene–Eocene (P–E) record from the Fort Union and Willwood formations, the more scarce and fragmentary mammalian fossils from the Upper Cretaceous have received far less attention. Here we report our recent efforts to grow the Upper Cretaceous mammalian fossil record in the BHB and, like has been done with the P–E assemblages, place those bonebeds within a highly resolved paleoenvironmental and chronostratigraphic context. To date, our team has discovered > 50 new, rich microfossil bonebeds from the 'Mesaverde' (mid–late Campanian), Meeteetse (early Maastrichtian), and Lance (late Maastrichtian) formations, mostly from the northern BHB. Screenwashing and collecting from these localities has only just begun, but we already have a stratigraphic succession of two or more localities per formation that are yielding a relatively high abundance of mammalian fossils. Our complementary sedimentological and stratigraphic work is revealing the depositional environments that typify Upper Cretaceous strata and their lateral variability in the

BHB. For example, whereas 'Mesaverde'–Lance sections to the west are mostly non-marine and sandstone-rich, those to the east exhibit prolonged marine sedimentation overlain by mostly continental mudstones and coals. Although much of our chronostratigraphic data are pending analysis, geochemical analyses of bulk-sediment samples spanning the uppermost Lance and lowermost Fort Union formations at Polecat Bench and Elk Basin have yielded iridium anomalies (0.5–1.5 ppb) at the Lance-Fort Union contact (i.e., the 'Z coal'). This is the first evidence of a true K-Pg boundary preserved in the BHB and supports our interpretation that continental deposition was largely uninterrupted from the Upper Cretaceous through lower Eocene in portions of the BHB. In sum, the BHB is an exceptional natural laboratory in which hypotheses about the role that vegetation, landscape, and climate change play in shaping the macroevolutionary trajectory of mammals (and other terrestrial vertebrates) can be tested empirically with high stratigraphic resolution and geographic fidelity through the last ~15 Ma of the Cretaceous and first ~15 Ma of the Paleogene.

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## ON THE ROLE OF TECTONICS IN STIMULATING THE CRETACEOUS DIVERSIFICATION OF MAMMALS

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Mammals rose to prominence in terrestrial ecosystems after the Cretaceous–Paleogene mass extinction, but the mammalian lineages characteristic of Paleogene faunas began their evolutionary and ecological diversification in the Late Cretaceous, stimulated by the rise of angiosperms (flowering plants) according to the preeminent hypothesis. The Cretaceous rise of mammals is part of a larger expansion in biodiversity on land that has been termed the Cretaceous (or Angiosperm) Terrestrial Revolution, but the mechanisms underlying its initiation remain opaque. Here, we review data from the fossil and rock records of western North America—due to its relatively continuous fossil record and complete chronology of mountain-building events—to explore the role that tectonism might have played in catalyzing the rise of modern-aspect terrestrial biodiversity, especially that of mammals and angiosperms. We highlight that accelerated increases in mammal and angiosperm species richness in the Late Cretaceous, ca. 100–75 Ma, track the acceleration of tectonic processes that formed the North American Cordillera and occurred during the 'middle-Cretaceous greenhouse' climate. This rapid increase in both mammal and angiosperm diversity also occurred during the zenith of Western Interior Seaway transgression, a period when the availability of lowland habitats was at its minimum, and oscillatory transgression-regression cycles would have frequently forced upland range shifts among lowland populations. These changes to both landscapes and climates have all been linked to an abrupt, global tectonic-plate 'reorganization' that occurred ca. 100 Ma. That mammals and angiosperms both increased in species richness during this interval does not appear to be a taphonomic artifact—some of the largest spikes in diversity occur when the available mammal-bearing fossil localities are sparse. Noting that mountainous regions are engines for generating biodiversity, especially in warm climates, we propose that the Cretaceous/Angiosperm Terrestrial Revolution was ultimately catalyzed by accelerated tectonism and enhanced via cascading changes to landscapes and climate. In the fossil record of individual basins across western North America, we predict that (1) increases in mammalian diversity through the Late Cretaceous should be positively correlated with rates of tectonic uplift, (2) the diversity of mountain-proximal mammalian assemblages should exceed that of coeval mountain-distal assemblages, and (3) endemism should increase from the latest Cretaceous to early Paleogene as Laramide mountain belts fragmented the Western Interior. Empirical tests of these predictions will require increased fossil collecting in under-sampled regions and time intervals, description and systematic study of existing collections, and basin-scale integration of geological and paleontological data.

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## XENARTHRAN MORPHOLOGICAL DISPARITY AND IMPLICATIONS FOR CINGULATE TAXONOMY

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Xenarthra is one of four superorders of placental mammals and is composed of two orders: Cingulata (armadillos, pampatheres, and glyptodonts) and Pilosa (sloths and anteaters). The extant diversity of xenarthrans (14 genera and 30 species) is far surpassed by the diversity of extinct representatives. Recent molecular phylogenetic analyses have called into question traditional taxonomic arrangements of cingulates and have proposed dividing the group into two major clades: Dasypodidae, consisting solely of *Dasypus* spp., and Chlamyphoridae, including all other extant armadillos plus extinct glyptodonts (traditionally recognized as a separate family). This proposal has been criticized for lumping most cingulate morphological diversity into a single

family (Chlamyphoridae), in stark contrast to its sister-group, Pilosa, which includes seven family-level groups. An alternative taxonomic scheme for cingulates would recognize four families of extant armadillos plus Glyptodontidae (and several other extinct families). In order to test the idea that the morphological diversity (= disparity) of these two groups is similar, we quantified the disparity of cingulates and pilosans. Morphology was quantified using 15 multistate craniodental, postcranial, and dermal armor characters, focusing on features likely to reflect ecological/functional adaptations. We coded eight extant and fourteen extinct xenarthrans at the genus level, including 10 cingulates and 12 pilosans, and analyzed the matrix via two correspondence analyses in PAST. Disparity was measured as the area occupied by each clade in a plot of the first two axes from this analysis, which together accounted for 61.4% of the total variation in the analysis comparing cingulates to pilosans and 69.4% of variation in the analysis comparing folivorans to cingulates. Overall, disparity of cingulates was less than that of pilosans but greater than that of sloths. Sloths (folivorans) are currently divided among seven highly disparate families, implying that a similar number of families should be recognized among cingulates. That would not be the case if the recent Dasypodidae-Chlamyphoridae classification were followed. Recognizing greater familial diversity among cingulates would also result in family-level divergence dates comparable to those of other mammal groups. To our knowledge, this is the first study to quantify morphology of xenarthrans in order to compare disparities of different clades.

## PALEOTEMPERATURE RECONSTRUCTION USING ISOTOPIC ANALYSIS ON LIVE, DEAD, AND FOSSIL GASTROPODS FROM THE WAKULLA RIVER IN FLORIDA

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Freshwater fluvial ecosystems in Florida are increasingly threatened by human impacts and environmental changes. These rivers contain live, dead, and fossil molluscan assemblages that document a record of past and current environmental conditions. In this study, we collected fossil (*in situ* from underwater riverbank sediments), death (loose shell accumulations), and live (living individuals) assemblage specimens of the gastropod *Elimia floridensis* from the Wakulla River in Florida to reconstruct water paleotemperatures since the late Pleistocene. We analyzed 45 samples from 38 specimens representing multiple sites along the headspring and river and across the three assemblage types. Specimens were processed for shell $\delta^{18}O$ and $\delta^{13}C$ isotopic values. These values reflect environmental conditions at the time of shell formation and may act as a proxy for temperature changes of the Wakulla River through time. Results show strong isotopic agreement among live assemblage specimens, recording lower $\delta^{18}O$ and $\delta^{13}C$ values. Fossil specimens also tend to cluster in agreement, though at relatively higher values of both $\delta^{18}O$ and $\delta^{13}C$ than live specimens. Death assemblage specimens exhibit a wide range of values with some specimens isotopically similar to fossil, some similar to live, and many intermediate between the two. These $\delta^{18}O$ values suggest water temperature of the Wakulla has warmed since the late Pleistocene (average 15.9 °C) compared to today (average 23.1 °C). Modern water temperatures derived from live-collected shell isotopic values are similar to water temperatures measured directly from the river. The more complete understanding of water paleotemperature history of the Wakulla River documented in this study will allow for comparisons of ecological trends such as predation intensity, taphonomic preservation, and community restructuring with environmental changes experienced at this freshwater ecosystem. These trends may then allow us to make targeted estimates of future impacts with increasingly warmer water temperatures.

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## PALEOZOIC EVOLUTION OF THE MARINE LATITUDINAL DIVERSITY GRADIENT REGULATED BY PLATE TECTONICS, CLIMATE CHANGE AND GENUS-SPECIFIC TRAITS

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The origin, maintenance, and history of the latitudinal diversity gradient (LDG) remain disputed: what are its features and what does it tell us? Several hypotheses have been proposed for the factors that might regulate the LDG, among which climatic, geographical and biological explanations are prominent. In this study, global genus-level fossil data of marine invertebrates were analyzed to assess LDG patterns during the Paleozoic. Our refined dataset, after cleaning, included approximately half a million occurrence records from 18,234 genera across 85,259 fossil collections. To mitigate spatiotemporal sampling biases, we utilized a novel minimum spanning tree spatial subsampling technique,

employing moving equal-area hexagonal regions, along with shareholder quorum subsampling and rarefaction methods. This methodology allowed for a more accurate representation of biodiversity patterns by minimizing the impact of uneven sampling effort over space and time. We then applied shape analysis to identify substantial variation in the shape of the LDG across the Paleozoic. The dynamic nature of this variation was quantified by focusing on three LDG characteristics (peak diversity location, gradient steepness, peak distribution) and seven ecospace categories. Our shape analysis results showed that the LDG evolved from unimodal in the Cambrian, through bimodal and flat during the GOBE, and fluctuated with climatic shifts and mass extinctions across the rest of the Paleozoic. Moreover, six specific ecological-driver hypotheses were tested by comparing variation in LDG shape with time-series data of both abiotic (plate tectonics and climate change) and biotic (genus-specific traits) proxies. These results suggested that secular variation in marine shelf distribution and magnitude of temperature changes exerted a dominant influence on LDG peak location through time. In particular, variation in global average temperature (GAT) exhibited the strongest correlation with LDG-peak geometry (unimodal/bimodal), suggesting the operation of genus-energy constraints. Furthermore, correlations between latitudinal ranges of genera and LDG-peak geometry indicated that a broader average latitudinal range of genera corresponds to a bimodal LDG. The influence of various biotic factors was also evident, especially genus-specific traits such as broader geographical distributions and greater ecological adaptability (as inferred by Earth System Modeling) being linked to higher variance in LDG distributions. Overall, these results revealed the significant and multifaceted roles of both abiotic and biotic factors in shaping LDG. Our findings demonstrated that the marine LDG gradient, as a fundamental pattern of biodiversity on Earth, is intricately linked to plate tectonics, environmental changes and genus-specific traits, providing insights into the phased changes of LDG over long timescales and their driving factors.

## ARIDIFICATION AND FAUNAL ADAPTATIONS IN RESPONSE TO EAST AFRICAN MIOCENE UPLIFT

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Hominid evolution in Late Miocene is linked to a transition from forested ecosystems to grasslands in Central and East Africa. This ecological shift has been attributed to a major reorganisation of the African hydroclimate during the Miocene. A pivotal factor in this transition is the uplift of the East African Dome, particularly the Ethiopian Highlands, which played a crucial role in altering the regional climate. This would have been a catalyzing factor in the shift towards a grassland-dominated landscape and the aridification of East Africa. While several studies have acknowledged this connection, the detailed temporal evolution of the climate in response to the uplift remains largely unclear. To address this knowledge gap, we use the Earth System Model EC-Earth3 to simulate the Miocene at key time slices (5, 15 and 25 Ma). To capture and explain the climatic effects of the East African uplift, we modify the topographic boundary conditions for the region according to data derived from geophysical modelling. The changed topography leads to a redistribution of precipitation, especially in the 15 and 25 Ma time slices. Our findings indicate that higher elevations in East Africa significantly reduce orographic precipitation, leading to a drier interior of the African continent. Moreover, by elevating pCO2 to Early Miocene levels, our model successfully simulated a forest-covered African landscape as suggested by proxy records. Interestingly, our simulations consistently depict a green East Africa until the Late Miocene, indicating that the uplift of East Africa was a major driver of the region's aridification. We found that a lower topography in East African not only alters regional atmospheric dynamics but also impacts the Arabian Sea, including a weakening of the Hadley Cell over Africa. We further find that topography is a key factor impacting precipitation distribution across Africa, with CO2 changes amplifying this effect. However, the emergence of grasslands cannot be attributed to topographic changes alone, it also requires increased levels of pCO2. Studies of faunal adaptations and change in the Miocene of Africa have largely been site-specfic, i.e., focusing on local environmental conditions. Therefore, broader conclusions linking faunal change to uplift-induced environmental changes are challenging to establish. However, recent studies highlight a shift in faunal composition, particularly among Carnivora (more open habitat forms) and Bovidae (more grazers), between the Kenyan sites of Maboko (ca. 14.8 Ma) and Fort Ternan (13.7 Ma), which coincides with the mid-Miocene Climatic Transition and the onset of climate change just at the time when uplift-mediated climate change had begun to take effect.

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## AN INTRODUCTION TO THE HILL ANNEX PALEONTOLOGY PROJECT: A NEW RESEARCH PROGRAM EXAMINING THE CRETACEOUS SYSTEMS OF THE MINNESOTA REGION

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The Hill Annex Paleontology Project is an 11-year-old research project focused on the Late Cretaceous systems of the Minnesota region. During this period, transgressions of the Western Interior Seaway flooded Minnesota from the west, which resulted in fluvial and coastal, as well as off-shore marine deposits. The majority of known rock exposures are concentrated along two main areas: tributaries along the Minnesota River valley in the southern portion of the state (Windrow Formation) and open pit iron mines in the north central region (Coleraine Formation). A wide suite of flora and fauna are represented in the collections from more than a dozen field sites, where biostratigraphic markers indicate a Cenomanian timeframe. Although Cretaceous fossils in the region were first reported more than 130 years ago, little research has delved into a full description of either formation or the full suite of their fossil diversity. Prior to the transgression of the Western Interior Seaway, Minnesota would have been a primarily terrestrial environment, evidenced by fossil plants represented by leaves, cones and wood pieces, as well as at least one dinosaur remain. Seaway incursion brought new coastal marine environments with many marine taxa, including molluscs such as ammonites, oysters, clams, mussels, gastropods, limpets and tusk shells; unidentified crustacean remains; and vertebrates including cartilaginous (sharks and rays) and bony fishes as well as crocodiles, turtles, and plesiosaurs. Trace fossils of borings, burrows, coprolites and wave ripples have also been collected. The Project was founded in 2015 by volunteers at the Science Museum of Minnesota under the direction of paleontology staff, and since 2021, it is hosted by the Minnesota Discovery Center in Chisholm, Minnesota, along the Mesabi Iron Range. This new host has started a full paleontology program with funding to support a full-time researcher as well as a lab space with collection storage. Hill Annex Paleontology Project, having started as a volunteer initiative, maintains a robust volunteer program, where an adult "field crew" provide extensive hours toward field sessions, laboratory duties and inventory. Opportunities exist for participation in public events, exhibitions, outreach programming and research. While the tries to maintain about 40% of its time commitments to outreach and engagement activities, it has striven to expand and diversify its research team over the last two years.

## FORELAND BASIN FORMATION, ENVIRONMENTAL CHANGE AND TRILOBITE DISTRIBUTION, LATE ORDOVICIAN OF EASTERN LAURENTIA

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Trilobite distribution, abundance and diversity in the Late Ordovician (Sandbian–Katian) of Laurentia are influenced by environmental changes associated with the Taconic Orogeny. Establishment and infilling of the Taconic Foreland basin led to profound changes in the distribution of lithofacies across the eastern half of the continent, including a shift from "tropical" to "cool water" carbonates, which are reflected in trilobite biofacies. In the late Sandbian, mid-continent regions such as Oklahoma, and foreland basin regions share similar deep-water faunas, dominated by raphiophorid and isoteline trilobites. Later, in the Katian, regions in the mid-continent have a relatively continuous record of carbonate deposition, and diverse platformal biofacies that pass down-ramp into deeper subtidal, low-diversity cryptolithine faunas. In the foreland basin, cryptolithine biofacies became widespread in the Katian, and expanded geographically as the clastic wedge prograded westward. Sedimentary evidence indicates that cryptolithines have a broader bathymetric range in the foreland basin and emerged at least locally into shallow subtidal, storm-influenced settings. Up-ramp, around the margins of the basin in such regions as southern Ontario, more diverse biofacies lack cryptolithines and share taxa with mid-continent faunas. In general, trilobite diversity drops sharply in the foreland basin, and trilobite genera are regionally extirpated. However, none become extinct globally, and there is no appreciable loss of diversity in regions outside the basin. The absence of a major trilobite extinction in response to regional environmental change in the Sandbian–Katian boundary interval stands in sharp contrast to the well-known "biomere" events of the Cambrian and Early Ordovician. This may point to changes in the "rules" of trilobite extinction in the Late Ordovician.

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## A TALE OF TWO LAGERSTÄTTEN: SIMILARITIES AND DIFFERENCES BETWEEN THE SILURIAN ERAMOSA FORMATION AND BRANDON BRIDGE FORMATION OF NORTH AMERICA

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The middle Silurian (Wenlock; Sheinwoodian) Eramosa Formation (Ontario, Canada) represents a near-shore environment during the critical transition in earth history of major terrestrial colonization by multi-cellular life. Within

the Bruce Peninsula, the Eramosa Formation contains a Lagerstätte preserving both biomineralized and soft-bodied taxa. Deposited on the rim of the intra-cratonic Michigan Basin, the Eramosa Lagerstätte contains chordates (heterostracan fish, articulated conodonts), arthropods (trilobites, eurypterids, scorpions, phyllocarids, ostracods), echinoderms (ophiuroids, crinoids, lepidocentrid echinoids), lobopodians, brachiopods, cephalopods, polychaetes, and dasyclad algae. However, Lagerstätten, while sites of exceptional preservation, are not free from biases that impact interpretation (e.g., paleo-environmental, taphonomic, and anthropogenic biases). The Eramosa Formation is most often compared to the Waukesha Biota (Llandovery, Telychian) of the Brandon Bridge Formation in Wisconsin, U.S.A. However, the presence of several localities, shelly marine fauna, and additional preservation modes within the Eramosa separate it from the Waukesha. The main forms of preservation in the Eramosa are phosphatization, carbonaceous compressions, and molds/casts. Preservation is controlled geographically, with authigenic phosphatization being more common in the Wiarton locality than in Hepworth or Park Head localities. The presence of microbially induced sedimentary structures (MISS) at Wiarton support a microbially-mediated preservation pathway inducing phosphatization, similar to the preservation pathway from the Waukesha Biota. However, the Eramosa and Waukesha differ in depositional environment and biotic composition. While often grouped together, these differences highlight how each Lagerstätte is unique, even within Lagerstätten 'types.' The different depositional environments, biases, and modes of preservation are discussed, and placed within a wider view of Silurian Lagerstätten.

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## INTERPRETATION OF EOLIAN ICHNOFOSSILS USING NEOICHNOLOGY OF DESERT ARTHROPODS

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Inland eolian settings provide few body fossils with which to interpret their ancient ecosystems, leaving the bulk of interpretations to be based on ichnofossils. While some of these ichnofossils, in particular vertebrate tracks, are relatively simple to interpret, there remain many ambiguous subsurface bioturbation structures that are not well understood. Arthropods are the most common bioturbators in modern eolian environments, which suggests that they are the most likely producers of these structures. Recent neoichnological experimentation has been able to bridge the gap of understanding between observed behaviors, environmental conditions, and the three-dimensional morphology of burrows produced by different continental animals. Most eolian ichnofossils are only expressed in two-dimensions, however, and were likely produced in loose substrates that do not conform to these recent experimental designs. This study examined the activities, behaviors, and resulting two-dimensional biofabrics produced by six arthropod species, *Hogna lenta* (a wolf spider), *Orthoporus ornatus* (brown desert millipede), *Galeodes arabs* (Egyptian camel spider), *Smeringurus mesaensis* (dune scorpion), *Stenopelmatus fuscus* (a Jerusalem cricket), and *Eleodes armata* (a tenebrionid beetle), in loose sandy sediment of varying compositions and moisture levels. The relative proportion and distribution of sand, silt, clay and organic matter were varied from pure sand, layers of each component, and a homogenized mixture of all three components. Sediment moisture content varied in ranges from 0–5%, 8–12%, and 15–25% by volume. Throughout the experiments, structures produced by the arthropods were photographed and described both qualitatively and quantitatively. Active substrate disturbance activities and associated behaviors were observed and recorded. Biogenic fabrics from each trial were compared among all six species and the different sediment conditions (sediment moisture and composition). Biogenic structures produced in these experiments were compared to indistinct burrows and biofabrics from Mesozoic eolianites including the Cretaceous Mulichinco Formation in Argentina, and Early Jurassic Entrada, Navajo, and Nugget Sandstones in the southwestern United States to help with the interpretation of potential tracemakers, associated behaviors, and environmental conditions. Identifying the varying behaviors and organisms that produce biogenic structures will aid in future interpretation of cryptic bioturbation in eolian deposits.

## ADVANCING COMMUNITY COLLEGE EDUCATION AND STUDENT SUCCESS (ACCESS) AT THE UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY: SEVEN YEARS OF EXPANDING ACCESS AND BUILDING NEW PARTNERSHIPS OPPORTUNITIES

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Advancing Community College Education and Student Success (ACCESS) is a collaborative partnership between the University of California Museum of Paleontology (UCMP) and community colleges. In the beginning of the program in 2017, the program featured specimen-based lab courses utilizing fossils from the UCMP collections. Largely led by graduate students, community college students and their instructors would spend a lab period on the UC Berkeley

campus participating in a custom-built laboratory class session to address specific course goals. Beginning in 2020 the COVID-19 pandemic created unique obstacles for the program, our partners, and our ability to accommodate a diverse body of students with differing needs. To meet the needs of our partner institutions during the pandemic, we shifted our focus to the development of online paleobiology and geoscience experiences to provide an alternative to the in-person ACCESS labs. The adaptation of the ACCESS labs to a digital format during this phase allowed us to utilize a wider range of resources including three-dimensional models of fossils, online databases, and virtual interactive tools. Incorporating these resources into the online ACCESS labs led to a new suite of lessons in collaboration with our partners. The inclusion of databases and interactive tools in these online labs placed a greater emphasis on scientific inquiry, data collection, and hypothesis testing by focusing on phenomena throughout Earth history. Over this period the ACCESS program grew the network of community college instructors across the country and in 2022 we reached an audience of approximately 1,000 students across more than a dozen states. We therefore saw the need to focus on providing year-long support for community college instructors. The Professional Learning Community (PLC) that resulted from this need helped participants transform and sustain their shifts in teaching practices, and during a 2 year period we prioritized the integration of active learning and inquiry-based instructional practices into ACCESS resources. PLC participants applied Model-Based Inquiry (MBI) and a range of student-centered, inclusive practices resulting in the next iteration of ACCESS resources. In the current phase of the ACCESS program graduate students are developing new learning units for the ACCESS program and employing MBI teaching practices. Graduate students are also monitoring community college student engagement by implementing the practices during in-person campus visits which will resume this year, in addition to supervised summer research experiences in the UCMP for community college students. In the multiple phases of the ACCESS program over a seven year period, we have gained a better understanding of how to leverage communities of educators, inclusive teaching strategies, and student interest to support and sustain opportunities to increase engagement in paleobiology and geoscience for community college students.

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## DOCUMENTING THE EARLY CONIACIAN *PEDIASTRUM* ACME BIO-EVENT IN A THIRD SECTION FROM THE NUMANHA FORMATION, YOLA BASIN, NIGERIA

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The Yola Basin in the Northern Benue Trough is an up-and-coming petroleum province with the potential to become a vital source of energy and production for Nigeria. The Upper Cretaceous succession of the Yola Basin has been under study, with the intent to characterize and identify its hydrocarbon source potential and the amount of organic matter present. The stratigraphy of the Yola Basin is poorly understood, especially in reference to bio-stratigraphic markers. In previous palynological studies of two sections from the Numanha Formation, the *Pediastrum* Acme Bio-event has been identified and well established as an easy to recognize marker horizon. The present study documents the *Pediastrum* Acme Bio-event in a third section (NL8) from the Numanha Formation, further confirming its basin-wide presence. The event was identified by counting the palynomorph grains from 18 outcrop samples, which represent a 34 m section. The *Pediastrum* Acme Bio-event was found in sample 11 at approximately 21 m from the base of the section. The NL8 section differs significantly from the other two previously studied sections in that it has an extremely low presence of *Pediastrum*.

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## THE PALEOHISTOLOGY OF VERTEBRATE WATER-TO-LAND TRANSITIONS: INSIGHTS FROM COMPARATIVE SALAMANDER BONE HISTOLOGY

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The transition from water-bound fish with fins to terrestrial tetrapods with limbs is one of the most consequential transitions in vertebrate evolution. As a result, considerable effort has been placed on describing the gross morphological transformation of Devonian and Carboniferous fossils. By contrast, changes to the bony microanatomy remain poorly sampled. Given such data have the potential to inform the ecological and physiological expansion of vertebrate life onto land, it is critical to include paleohistology as a line of evidence to inform the biology of early tetrapods. However, a modern histological framework is required for robust interpretations of the fossil material. Salamanders have long been considered a modern analogue for early tetrapods, yet

their bone histology, especially through their metamorphic stages, is poorly known. Here, we report on ontogenetic series of three groups of salamanders–axolotls, eastern newts, and tiger salamanders–all of which vary in their interactions in the aquatic and terrestrial spheres throughout ontogeny. Femora from these salamander groups were micro-CT scanned and subsequently thin-sectioned and stained using modern histological techniques from both fresh and whole preserved specimens. Both transverse mid-diaphyseal and longitudinal epiphyseal sections were examined. Our results reveal that the strongest predictor of terrestrial behavior is the development of trabecular bone in the femur, especially in the epiphyses. Additionally, we find that cartilage remains a significant component of salamander cortical and trabecular bone even in established terrestrial adults. These findings are critical for interpreting how current and future sampling of early tetrapod bone histology relates to their ontogenetic stage and habitat. Our study suggests that, in an ontogenetic framework, epiphyseal trabeculae-building is a line of evidence that should be considered when assessing terrestriality. Further, the presence of cartilage in cortical and trabecular bone does not disqualify a tetrapod from being an adult or interacting with the terrestrial landscape. Together, our study establishes an experimentally-tested framework for how ontogeny and habitat may influence the bone histology of amphibious tetrapods and, as a result, can help inform paleohistological interpretations of the tetrapod transition to land.

## ANTARCTICA'S EARLIEST CENOZOIC GLACIAL COMMUNITIES

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The sea floor (benthic realm) is the most biodiverse part of the modern-day Southern Ocean. It is unique compared to the rest of the world, being dominated by immobile suspension-feeding creatures. Benthic communities elsewhere normally have large numbers of burrowing organisms, and mobile predators and prey. Many Antarctic benthic organisms are stationary; therefore, they are vulnerable to activities such as fishing and the invasion of predatory groups due to climate change or human introduction. How the biodiversity and stability of modern Southern Ocean benthic ecosystems is maintained today is unknown. We are studying the evolution of Southern Ocean communities to identify the conditions under which they evolved and give an indication of environmental conditions which are necessary for their maintenance. Antarctica's earliest known Cenozoic glacial communities are from King George Island (northwest tip of Antarctic Peninsula 61.9°S). The geological formations on this island provide a unique window into Southern Ocean glacial sea floor communities ~ 26 Ma (Oligocene). Glacial evidence comes from the presence of dropstones, striated rocks, and diamictites. Communities are dominated by epifaunal suspension feeding organisms. Pectenid bivalves and brachiopods occur in large aggregations in shallow water deposits. There are very few predatory groups preserved. This research forms part of a larger effort to document community change under different temperature regimes through the Cenozoic in order to understand the evolution of modern Antarctic communities. This will increase ability to predict the effects of anthropogenic climate change on these unique communities.

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## COMBINED MICRO-COMPUTED TOMOGRAPHY AND SERIAL STABLE ISOTOPE ANALYSES OF GROUND SLOTHS FROM CENOTE HOYO NEGRO (QUINTANA ROO, MEXICO)

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Serial analyses of stable isotope systems in incrementally forming tooth enamel have yielded seasonally resolved, highly detailed information about mammal diet and behavior. Similar analyses of ground sloths have been hampered by the absence of enamel in their dentition. This study used micro-computed tomography to characterize diagensis and growth in sloth teeth. These data were used to select appropriate specimens for serial stable isotope analyses of CO3 and PO4 from sloth orthodentine. Four teeth from taxonomically different sloth individuals were included in this study, *Nothrotheriops*, *Nohochichak*, cf. *Xibalbaonyx* and a mylodont sloth of unknown affiliation. Each molariform tooth was u-CT scanned at 15–20 um voxel resolution. Two specimens showed extensive post-depositional mineralization and were not further sampled for serial isotope analyses. Two specimens exhibited well-preserved growth structures, including patterned distribution of microanatomical features such as microtubules. Vertical clustering of large-diameter microtubules is inferred to represent periods of rapid growth (e.g., wet season). Serial samples of the inner and outer orthodentine in the mylodont and *Nothrotheriops* molariforms were acquired. Each sample was split for isotopic analyses of the CO3 and PO4 fractions. Non-linear differences in the δ18O of paired CO3 and PO4 fractions suggest diagenetic alteration of CO3 throughout both teeth. Therefore, δ18O (CO3) and δ13C (CO3) should be interpreted cautiously. A single oscillation in δ18O (PO4) was found in the mylodont molariform growth series. This oscillation does not correspond

to inferred micro-anatomical measures of tooth growth, and shifts in the timing of this change between inner and outer orthodentine suggests complex, wave-like secondary mineralization of dentin in sloth teeth.

## WE THOUGHT WE KNEW YOU: EVOLVING PERSPECTIVES ON THE ORIGINS, BIOGEOGRAPHY, AND MORPHOLOGY OF THE AMERICAN MASTODON, *MAMMUT AMERICANUM*

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*Mammut americanum*, the American Mastodon, has deep roots in the study of North American vertebrate paleontology. Historically, it has been documented from Alaska to Honduras and across the coterminous United States, Canada, and Mexico. However, recent work has highlighted variability within this population, suggesting at least two, perhaps as many as five, genetically distinct populations are extant during the Pleistocene. This presentation will review the current status of Pleistocene *Mammut* in North America with special attention paid to the current status of *M. americanum. Mammut americanum* was first described by Kerr (1792) on the basis of material from Big Bone Lick, Kentucky housed in the Muséum national d'Histoire naturelle. Although collected by Baron de Longueuil in 1739–40, subsequent work at this locality has documented a wide range of late Quaternary megafauna dating from 12.7 ka to 25 ka deposited in Ohio River slackwater deposits. Although genomic analyses of *M. americanum* from BBL have not yet been performed, they are centrally located within the Great Lakes region and roughly contemporaneous with Clade G mammutids. Measurements of major limb elements indicate *M. americanum* from the Great Lakes is generally larger in size than *M. pacificus*. Molars are typically wider relative to their length (i.e., lower L:W) when compared to other *Mammut* populations. We also note differences in loph(id) thickness that may have utility to distinguish between different *Mammut*. Mandibular tusks are sometimes present, but vary in their mode of presentation. Analyses of microwear and stable isotopes in Great Lakes mastodons indicate a diet dominated by C3 browse. However, there is significant, under-appreciated variability within this category. Robust Maxent niche models of M. americanum distributions during the Bolling-Allerod are tightly constrained to the Great Lakes region. A genus-level niche model of the last interglacial reflects known phylogeographic variation in North American Mammut. At the current time, it is unclear whether these models reflect the limited geographic distribution of well-dated animals or is a function of deeper ecological differences in terminal Pleistocene mammutids in North America.

## COMPUTATIONAL APPROACHES TO CHEMICAL DATA REVEAL THE FIDELITY OF MOLECULAR BIOSIGNATURES THROUGH TIME AND SPACE

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Recent conceptual progress on the chemical transformation of biomolecules during fossilization has drawn attention to preserved carbonaceous remains as an underexplored resource of molecular biological information. The molecular makeup of fossils sampled across the tree of Life has been demonstrated to preserve original signals encoding biomineralization, tissue identity, metabolic capacity, and organismal relationships, each corresponding to related chemical signals in modern organismal samples. While such molecular information has the potential to aid in resolving major questions on the origin(s) and evolution of Life on Earth and eslewhere in the solar system, it is yet unknown how the fidelity of these four molecular biosignatures changes through geological time and with elevated pressure- and temperature-metamorphism of fossils. Here, I employ a diversity of statistical tools to systematically quantify the fidelity (= prediction accuracy) of the biomineralization, tissue identity, metabolic capacity, and relationship signals detected for a spectroscopic training data set of n > 200 modern organismal samples, carbonaceous fossils spanning across the tree of Life (Biota) and ranging in age from Pre-Cambrian to Recent, and organic-rich meteorites—representing an abiogenic, yet complex organic, outgroup to Life as we know it—from the asteroid belt and Mars. Chemical fingerprints were collected over the organic fingerprint region (500–2000 1/cm) via complementary Raman and Fourier-Transform Infrared spectroscopy, and established geochemical proxies were utilized to constrain for individual samples the peak pressure (P; sp2/sp3 C) and temperature (T; R1 ratio) conditions experienced during diagenesis (and/or impact). Simultaneously, changes in the signal abundance of diagnostic molecular heterogeneities are traced in an integrated experimental organic P/T phase space, in order to determine minimum thresholds for high-fidelity biosignature detection. The four biosignatures show different degradation rates of encoded biological information, correlated with the P-/T-stability of their diagnostic molecular features: peak P- and T-alterations determine the nature of the non-linear loss functions of different types of biosignatures. Notably, time does not have a major impact on biosignature

fidelity. Biomineralization and tissue identity signals are most resistant to P-/T-alteration, yielding a high prediction accuracy even in Pre-Cambrian carbonaceous compression fossils (P > 0.2 GPa, T > 200°C). Elevated P-/T-conditions have a substantially stronger impact on molecular metabolic and phylogenetic signals. The individual strengths and limitations of each biosignature are showcased with examples from the diverse array of analyzed fossils. Molecular biosignatures preserve paleobiological information in deepest time and, thus, represent a powerful tool in addressing fundamental questions on the origin(s) and evolution of Life on Earth and beyond.

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## BONE DISTRIBUTION, LOAD PATHS, AND A NEW FRAMEWORK OF MANDIBLE FUNCTION FOR RECONSTRUCTING OF MAMMALIAN JAW EVOLUTION

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Understanding the function of osteological features is key to reconstructing behaviors and ecology of fossil animals. While the architecture and distribution of bony material has historically been linked to trajectories of biomechanical loads, methodological and imaging limitations have hindered comprehensive mapping of the distribution of bony material to locations of load transfer, and loading patterns have not been studied in fossils. Here we employ a novel load path analysis, in conjunction with Finite Element Analysis (FEA), to quantify sites of high force transfer (load paths) in a wide array of extant mammal jaws, with a further aim to study load paths of fossil mammals in near future. Our sample of extant mammals include *Didelphis*, *Canis*, *Panthera*, *Rattus*, *Tupaia*, and *Pan*. Using measurements of cortical bone thickness at predefined sections along the mandible, we tested for relationships between the position of the load path and cortical bone thickness in the mandibular ramus. We found that load paths are consistently located on the surface ridges corresponding to thickened cortical bone in the mandible. In all taxa sampled here this relationship was statistically significant. These analyses provide novel insights into the variation of the mandibular ramus observed in mammals, revealing new patterns of jaw form and function, useful for reconstructing the functional evolution of early mammals.

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## INTEGRATING FOSSIL DATA IMPROVES PREDICTIONS OF FUTURE HABITAT FOR KEY CARIBBEAN REEF CORALS

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Global warming and human impacts continue to be devastating for coral reef systems, which are home to some of the most diverse ecosystems on the planet. To mitigate the effects of changing climates, it is important to understand how these threats impact the ecology of important coral species in the Caribbean (i.e., *Acropora cervicornis*, *Acropora palmata*, *Agaricia agaricites*, *Porites asteroides*, *Orbicella annularis*). Here we utilized PaleoEcological Niche Models (PaleoENMs) to assess the spatiotemporal distribution of suitable habitat for these species through the last 21,000 years. Climate data for the Last Glacial Maximum (LGM), mid-Holocene, and modern ocean was derived from Bio-ORACLE and MARSPEC; PaleoENMs were trained in each time bin for spatiotemporal comparison. Future predictions of suitable habitat change were derived from projects of models trained using modern-ocean data and the training dataset of all time periods combined. Representative Concentration Pathways (RCP) 2.6, 4.5, 6.0, and 8.5 future climate predictions were used for these projections. With this framework, we tested a) how niche occupancy changed through time (environmental space), and b) how suitable habitat location and size may shift in the future (geographic space consequences). Overall, coral habitat in the Caribbean is predicted to decrease significantly under future climate projections from all climate scenarios and training datasets. Models trained on modern coral occurrences predict the highest loss of suitable habitat, suggesting that the integration of fossil data and environments expands model predictions of the fundamental niche and therefore provides a potentially more accurate picture of the fate of Caribbean coral ecosystems in our near future.

## RECONSTRUCTING DEPOSITIONAL PATTERNS OF THE SIWALIK FLUVIAL SYSTEMS, CHINJI AND NAGRI FORMATIONS, POTWAR PLATEAU, PAKISTAN

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The Siwaliks were deposited by large distributive fluvial systems (DFS), each fanning away from entrance points pinned at the uplifting mountain front (much like the rivers

in the modern Ganga Basin). Huge exposures in the Potwar Plateau of Pakistan allow the architecture of these fluvial deposits to be documented to provide detailed interpretations of the evolving fluvial paleoenvironments. Evidence that the major rivers had braided patterns is indicated by the relatively large number of channel fills within channel belt deposits exposed perpendicular to paleoflow, abundant evidence for channel bar deposit superposition due to channel switching, local evidence for mid-channel bars, the dominance of coarse-grained channel fills, and low paleocurrent variation. Overbank deposits record subdued alluvial ridges (thickness generally less than 20% of channel depth) that extend only a few kilometers away from the channel belts. Away from the major rivers, minor channel systems were more ephemeral, seasonally ponded areas were common, and many paleosols display vertic structures and thick calcrete horizons characteristic of dryland soils. The deposits suggest strong seasonal changes comparable to monsoonal variations in the modern Ganga basin river systems. In the Chinji village area, the vertical transition between the Chinji and Nagri Formations (each kilometer-thick units) record the lateral displacement of a smaller DFS by a larger system. The main river channel deposits are only 5 to 15 m thick within the Chinji Formation but are up to 30 m thick within the Nagri Formation. Paleochannel reconstructions of the Chinji Formation rivers indicate that individual channel segments were 80–200 m wide, 4–13 m deep, had bend wavelengths of 1.6–2 km, and discharges of 400–800 $m^3/s$. Full channel belt widths (1–2 km) estimated from exposures perpendicular to paleoflow, and evidence for 2–3 coeval channels within channel belts, indicate full river discharges of 1500–2000 $m^3/s$. Larger channel segments reconstructed from the Nagri Formation were 200–400 m wide, 15–30 m deep, 3–5 km bend wavelengths, and discharges of 3000–5000 $m^3/s$. As Nagri Formation river systems were also clearly braided, full river dimensions and discharge estimates are probably at least a factor of two greater than for individual channel segments (i.e., order of 10,000 $m^3/s$). Within formations, channel belt deposits are not randomly stacked within overbank successions but rather are more abundant along some stratigraphic intervals than others. Similarly, the character of the overbank deposits varies upsection, including the abundance of minor sandstones and the thickness of deposits between well-developed paleosol horizons. These smaller-scale (tens to 100 meter thick) intraformational variations may record shorter-term changes in river water and sediment from the mountains relative to rates of basin subsidence or may reflect lateral shifts in the locus of deposition across the basin.

## INTEGRATING MICROVERTEBRATE FOSSILS AND MOLECULAR PHYLOGENIES TO BETTER UNDERSTAND THE DIVERSITY DYNAMICS OF FRESHWATER FISH ACROSS THE K/PG MASS EXTINCTION EVENT

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Isolated and fragmentary microvertebrate fossils present many of the same challenges and opportunities as those non-vertebrate groups historically discussed as microfossils. These fossils offer the benefit of relative abundance and high stratigraphic resolution but are difficult to study using increasingly powerful phylogenetic approaches given the relative paucity of character data. This combination of potential and limitation compels creative thinking to insure all relevant data are brought to bear on critical questions. Here, we present an integrated approach to an understudied and poorly understood assemblage of microvertebrate fossils—those documenting the diversity of freshwater actinopterygian fish across the Cretaceous/Paleogene (K/Pg) mass extinction event. In contrast to marine lineages, which are generally characterized by extinction of large, predatory forms and post-K/Pg morphological diversification of some major clades, the event is thought to have had little impact on freshwater diversity. But to what degree does this disparity reflect preservational biases rather than biological realities? We set out to test the stability hypothesis for freshwater fish across the K/Pg using a multi-pronged approach that considers both molecular sequences of extant species and the microfossils that compose the majority of K/Pg freshwater fish collections. We used a broadly sampled, time-calibrated molecular phylogeny of actinopterygian diversity to explicitly search for post-extinction spikes in diversification that would signal a significant K/Pg influence. Our microfossil analysis used morphotypes of isolated vertebral centra recovered from freshwater sediments. The analysis is an important step forward in that the specimens are from West Bijou, Denver Basin, Colorado, a unique locality with a well-documented K/Pg boundary containing primary markers of the asteroid impact and a precise chronostratigraphic framework thanks to abundant U-Pb-dated ash beds and high-resolution magnetostratigraphy. Our analyses suggest that the stability hypothesis has merit, but there were drops in community diversity at West Bijou that suggest a heterogenous landscape of extinction intensity. Understanding of the actinopterygian skeleton and its variational dynamics still lies below the level needed to fully realize the heuristic potential of the freshwater fossil record. This form of integrative analysis is motivational as it demonstrates what meeting this potential could mean for our understanding of the modern biota and its deep history.

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## JAMES PARKINSON: NEGLECTED PALEONTOLOGY PIONEER

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James Parkinson (1755–1824) was an English surgeon best known today as the namesake for Parkinson's Disease. He was also a prolific and perceptive paleontologist who wrote four volumes on fossils that were widely used in his time. Parkinson was respected by the prominent geologists of that era, being one of the founding members of the Geological Society of London. He has been neglected in modern histories of paleontology, however. We believe this is likely because his work came amidst the revolutionary geological contributions of James Hutton, William Smith and Charles Lyell, his early insistence on a Biblical framework for fossil occurrences, and the fact that the "shaking palsy" he described in 1817 was later named after him, dominating his posthumous reputation. Parkinson's early career was marked by progressive politics (which put him at mortal risk after the French Revolution) and his practice of medicine (he was known at the time as the "madhouse doctor" for his work with the mentally impaired). Inspired by his visits to growing natural history cabinets of contemporaries, Parkinson began to accumulate fossils for his own museum in his home in Shoreditch, England. Dissatisfied with the current literature on fossils, he published a three-volume work titled "Organic Remains of a Former World" (1804–1811). His subtitle to these volumes was "An Examination of the Mineralized Remains of the Vegetables and Animals of the Antediluvian World," showing his original intention to place fossils in the context of Noah's Flood. The illustrations in these volumes were exceptionally detailed, so much so that they were used decades later in other paleontological works, especially by Gideon Mantell. Parkinson's "Remains" volumes were more than picture books or identification guides. He meticulously described morphology and interpreted the functional morphology of his fossils, summarizing the current paleontological literature. He was especially interested in fossil crinoids ("stone lilies"). He was the first to correctly orient crinoids with the holdfast at the base and calyx with arms at the top. Desiring to make the current literature on fossils more accessible to the public, Parkinson published in 1822 "Outlines of Oryctology." In it he fully embraces J.S. Miller's seminal 1821 work on crinoids. In the introduction to his book, Parkinson showed his struggles with harmonizing the fossil record with the Biblical accounts of creation and Noah's Flood. He wrote that "circumstances will be observed apparently contradictory to the Mosaic account," but, nevertheless will "serve to establish it as the revealed history of creation." Parkinson recognized the stratigraphic value of fossils, using them to correlate strata in the London Basin with equivalent units in France. Parkinson died in 1824 after a stroke. His reputation as a prominent paleontologist continued for many years until his work was eclipsed by the non-biblical paradigms of the mid-19th century.

## A NEW KURMADEMYDINE TURTLE (PLEURODIRA: BOTHREMYDIDAE) FROM THE CRETACEOUS-PALEOGENE INTERTRAPPEANS OF UPPARHATTI (KARNATAKA STATE), INDIA

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The timing and duration of physical connections during Indo-Pakistan's progressive disengagement with Gondwanan landmasses during the late Mesozoic and its engagement with the Asia in early Cenozoic are expected to have profoundly influenced its terrestrial vertebrate fauna as well as that of neighboring landmasses. Most paleocoastline reconstructions predict a phase of geographic isolation for Indo-Pakistan that may have lasted for tens of millions of years during the transitional period from the Late Cretaceous to early Paleogene. Somewhat surprisingly, however, many of the terrestrial vertebrates known from that time period in India and Pakistan are not endemic but show biotic connections to species from other Gondwanan landmasses, such as Madagascar, South America, and Africa. Thus far, only one terrestrial vertebrate clade is hypothesized to be endemic to Indo-Pakistan during the late Mesozoic–early Cenozoic: Kurmademydinae, the side-necked turtle clade that includes three genera known from skulls from the Late Cretaceous of southern and central India (*Kurmademys*, *Jainemys*) and the Paleocene of central India (*Sankuchemys*). Here we report on the discovery of a beautifully preserved, complete skull of a side-necked turtle from "intertrappean" horizons in Karnataka State that are latest Cretaceous to earliest Paleogene in age. The specimen was found in association with numerous partial and complete turtle shells that are as yet unprepared. The skull is approximately 6.5 cm long and characterized by double triturating surface on the maxilla and a well-marked pterygoideus fossa. These and other features suggest it is a new species with close affinities with *Kurmademys*, *Jainemys*, and *Sankuchemys* within Kurmademydinae, broadening the spatiotemporal distribution of this endemic clade.

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## AN EVOLUTIONARY DWARF TITANOSAUR (DINOSAURIA: SAUROPODA) FROM THE UPPER CRETACEOUS (MAASTRICHTIAN) OF AFRO-ARABIA

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Paleontological exploration of uppermost Cretaceous horizons of central, southern, and western Jordan by a joint Natural Resources Authority–Yarmouk University–University of Michigan team discovered important new localities that preserve excellent fossil vertebrate remains. These fossils open a window into the last chapter in the Mesozoic history of Afro-Arabia, which has remained poorly understood. Despite a relatively rich Early Cretaceous and Cenomanian terrestrial vertebrate record, especially in the Sahara, latest Cretaceous localities remain undersampled in Afro-Arabia compared to neighboring Gondwanan landmasses such as India, South America, and Madagascar. We report a partial skeleton of sauropod dinosaur from Maastrichtian levels in central Jordan that is quite small by sauropod standards. The femur measures only 57 cm long, and its circumference implies a body mass of approximately 1,800 kg. Despite its small body size, sutural closure and long bone histology indicate the individual had already reached skeletal maturity and represents an adult of a small species. Skeletal features such as the presence of camellate pneumaticity and a femur with a medially deflected proximal third indicate affinities with Titanosauriformes, the group that includes brachiosaurids and titanosaurs, and the absence of hyposphene-hypantrum intervertebral articulations suggests it was a member of Titanosauria, a widespread Cretaceous lineage that included many of the largest and the smallest sauropods. Additional features, such as camellate pneumaticity extending into the sacrum and pelvis and canted femoral condyles may help indicate lower-level affinities within Titanosauria. The Jordan sauropod specimen was preserved a shallow marine to coastal environment, as indicated by the presence of *Teredo*-bored ("shipworm") wood and infrutescences of a *Nypa*-like mangrove palm. A similar marginal environment is preserved in coeval neighboring horizons in central Egypt, which also record *Teredo*-bored wood, *Nypa*, and a small sauropod specimen. In addition to these Afro-Arabian sites on the southern margin of the Neotethys Ocean, several European sites on its northern margin also preserve small titanosaur taxa (*Magyarosaurus*, *Garrigatitan*, *Lirainosaurus*). These peri-Neotethyan dwarf sauropods appear to have evolved small body size independently, perhaps in response to living in restricted habitats with limited resources.

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## MORE SITES, MORE FOSSILS—AN IMPROVED BASIS FOR UNDERSTANDING FLORAL CHANGE DURING THE PALEOCENE-EOCENE THERMAL MAXIMUM IN THE BIGHORN BASIN

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The first record of floral change during the Paleocene-Eocene Thermal Maximum (PETM) came from the Bighorn Basin (BHB) in 2005 and consisted of only three megafossil plant sites—two from the body of the carbon isotope excursion (CIE) and one from the CIE recovery. Here we update patterns of megafloral change across the PETM using >2,000 fossils from a total of twelve sites in the CIE body and six in the CIE recovery. Nine CIE body sites are in the southeastern BHB, one is in the south central BHB, and two are in the northwestern BHB. All six CIE recovery sites are from the southeastern BHB. The collection documents 45 leaf taxa in the CIE body and 37 in the CIE recovery, with a total of 70 in the PETM. There are 10 fruit taxa in the PETM. No specimens from the CIE body belong to the families Platanaceae, Betulaceae, Juglandaceae, Fagaceae, Cercidiphyllaceae, GInkgoaceae and Cupressaceae, which are all common in the late Paleocene and post-PETM Eocene. The most ubiquitous leaf types in the CIE body are two legumes, a lauralean, *Populus cinnamomoides*, and "*Cedrela*" *schimperi* (Sapindales). Legume leaflets are abundant at all but three CIE body sites and comprise six species. This contrasts strongly with late Paleocene and early post-PETM Eocene floras in the BHB from which only a single legume leaflet type is known. Other macrofossils occurring in multiple sites from the CIE body include *Gyrocarpus* and *Illigera* (Hernandiaceae), and many distinctive leaf types of unknown family affinity. The earliest occurrence of *Salvinia preauriculata*, a floating aquatic fern that is an index fossil for the Eocene, is also within the CIE body. Floras from the CIE recovery phase, like those of the late Paleocene and post-PETM Eocene, include members of Platanaceae, Fagaceae and Juglandaceae. They also, however, share some taxa with the CIE-body flora (e.g., "*Artocarpus*" *lessigiana*) that do not occur in the Paleocene or post-PETM Eocene of the BHB.

The earliest macrofossil occurrence of the Eocene index fossil *Platycarya* (Juglandaceae) is in the CIE recovery. The added sites and specimens from a broader area of the BHB support the early observation of a highly distinct flora in the CIE body caused by a gap in the temporal ranges of many plants with extant relatives living in wet, warm-temperate to subtropical climates and the presence of many taxa not found in the latest Paleocene or early post-PETM Eocene that have extant relatives in the seasonally dry tropics. Floras from the CIE recovery phase are intermediate in composition between the CIE body and the post-PETM Eocene, which was not appreciated with the small initial dataset. The dramatic shift in floral composition during the PETM is consistent with strong warming and increased water stress. The transition from late Paleocene to PETM floras took place in as little as ~30 ky and the transition to early Eocene floras was completed within ~100 ky of the end of the PETM.

## A NEW APPROACH FOR COMPARING PALEOCLIMATE MODEL RESULTS AND FOSSIL PLANT DISTRIBUTIONS

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For >150 years paleobotanists have understood that fossil floras from high latitudes contained plant types that implied much warmer climates than presently exist in these regions. In the 1980s general circulation models (later Earth system models) based on physical and chemical processes began to produce paleoclimate estimates that could be compared with those inferred from fossil floras. Paleobotanists developed several methods for estimating paleoclimate values from plant fossils, all of which rely on correlations between present climate and leaf form or between present climate and plant distributions. All make the uniformitarian assumption that those correlations apply to the past. The method we propose here does not assume a modern correlation between plant distributions and climate, but only that climate has always been a leading predictor of plant distributions. We used historic tree species distribution maps for North America and gridded climate information for preindustrial time to develop a 'random forest' decision tree analysis in which bootstrapped subsamples of grid cells were used to predict the presence or absence of species in the remaining grid cells from bioclimatic variables representing temperature, rainfall, and seasonality. This formed a best-case scenario to test the ability of climate data to predict floral composition since all North American grid cells were sampled and both tree distributions and climate information are reliable. Following this, we restricted subsampling of the original historic data set to replicate the geographic properties (e.g., total area, sample density, mean distance from coastline) of our Paleogene pollen samples, thus quantifying the decrease in predictive ability that results from having a lower density of samples from only part of North America. Finally, we performed the same type of random forest analysis on a set of Paleogene palynofloral lists derived from samples across North America from the North Slope of Alaska to the Mississippi Embayment, using bioclimate variables from Community Earth System Model (CESM1) simulations as the predictors. A decrease in the predictive power of climate in the Paleogene analysis vs. the historic analysis would indicate that modeled paleoclimate is less consistent with the observed geographic distribution of palynotaxa than expected. Regions in which floral composition is difficult to predict from modeled paleoclimate should focus attention on specific problems with the proxy data, models, or both. Although this form of analysis does not produce quantitative estimates of climate from fossil data, it does test the consistency of modeled paleoclimate with observed geographic distributions of fossil plants. Thus, it takes advantage of the relatively large number and high density of fossil pollen samples, while at the same time avoiding the strong assumption that Paleogene plants had the same climatic preferences as their living relatives.

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## APPLICATION OF CONSERVATION PALEOBIOLOGY TO RESOURCE MANAGEMENT: EXAMPLES AND LESSONS LEARNED FROM THE GREATER EVERGLADES ECOSYSTEM RESTORATION

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Restoration of large geographic areas can take decades and cost billions of dollars. Resource managers are tasked with setting goals to monitor success as changes are implemented, and because of the time frames, these goals are moving targets that take future change into consideration. Conservation paleobiology (CPB) provides resource managers with an understanding of how species and ecosystems respond over longer-time frames and allows them to anticipate future responses to change. Conservation paleobiologists at the USGS have worked with Greater Everglades ecosystem resource managers for the last 30 years. The primary goal of Everglades restoration is to reestablish more natural hydrologic

patterns, so our initial CPB research focused on determining pre-alteration salinity and freshwater flow. Molluscan modern-analog data were compared to down-core assemblages to estimate paleosalinity. These estimates were then used in models based on present conditions to estimate the freshwater flow needed to produce the estimated paleo-salinities. Results of these analyses were used to establish salinity restoration targets for Florida Bay (Everglades National Park). Around 2010, resource managers became concerned about the impacts of sea level rise and climate change on restoration. To address questions about coastal resiliency, we used a variety of CPB tools (biotic remains, isotopes, sediments) to analyze sediment cores collected on islands in Florida Bay. Results indicated that wet/dry cycles, accompanied by increased storm frequency, can cause retreat of the coastline, even during times of low sea level rise. These results highlighted the need to incorporate additional uncertainty related to climate change in the predictive models for 2050 conditions. Most recently, resource managers were developing a suite of indicator species to monitor the progress of restoration efforts. CPB data assisted in this effort by mapping the location of mollusk species in sediment cores and comparing those locations to the modern distribution. We identified a suite of species indicative of the critical nearshore low salinity habitats that are a focal point of restoration. Convincing resource managers that data from geohistorical records can assist with decision-making is a challenge for CPB, but one that we have successfully overcome. First, by virtue of being part of a participating agency, we were able to engage with restoration planners and communicate the potential of CPB. However, it took continued dialogue, participation in meetings, and listening and responding to resource management needs to break through the implementation gap and have our data used as guidance. CPB research provides critical insights into conservation and restoration efforts on all scales and in all environments, so it is essential that we overcome the hurdles in working with resource managers because our data from the past provide the window to anticipating and planning for future change.

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## THE MIDDLE MIOCENE EAST AFRICAN RODENT FAUNAL TRANSITION: EVIDENCE FROM MABOKO ISLAND, KENYA

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Maboko Island fossil deposits (~14.7 Ma) have produced an extensive fauna and are perhaps best known for yielding a rich and diverse community of fossil primates. Among the non-primate taxa, there are also abundant rodents, which demonstrate affinity with both geologically older and younger faunas. The stratigraphic framework for Maboko includes 20 beds, with Bed 20 at the top of the sequence. Rodents are known primarily from Beds 3 and 5. Taxa from Bed 3 include *Bathyergoides* (mole rat), *Megapedetes pentadactylus* (large springhare), at least three thryonomyids (cane rats: *Paraphiomys pigotti*, *P. stromeri*, and a new taxon), the phiomyid, *Diamantomys*, and a muroid (group including rats, mice, hamsters etc.). Rodents are most abundant from Bed 5, which has yielded *Vulcanisciurus* (squirrel), a small pedetid (springhare; an extinct taxon), two taxa of cane rats (*Apodecter stromeri* and the new taxon), *Diamantomys*, *Mabokomys* (extinct nesomyine known only from Maboko) and murids. Rodents are poorly known from higher in the section, but there are pedetids and murids from Bed 12. The most noteworthy difference between the rodents from Bed 3 and younger units is the apparent absence of nesomyines and murids from Bed 3 and their presence and relative diversity in younger sediments. As a starting point, the Maboko fauna was compared with other Kenyan faunas from the early Miocene (e.g., Songhor, Rusinga, Kalodirr/Moruorot), and slightly older (Muruyur Beds sites, 15.5 Ma) and slightly younger middle Miocene sites (Fort Ternan, 14 Ma; Ngorora Formation sites, 12.55–12.33 Ma). Maboko rodents in common with early Miocene sites include *Bathyergoides, M. pentadactylus, Paraphiomys pigotti, P. stromeri, and A. stromeri.* Others known from early and middle Miocene faunas include *Vulcanisciurus*, *Diamantomys* and the small pedetid. There are no definitive records of nesomyines (other than the archaic afrocricetodontines [e.g., *Afrocricetodon*] or murids in Kenya (East Africa in general) until the middle Miocene: in Kenya, the earliest records (exclusive of afrocricetodontines) are from Maboko. Anomalurids (scaly-tailed flying squirrels) are absent from the Maboko fauna. In Kenya, they have been reported since the early Miocene but are rare to absent in middle Miocene faunas. Extant anomalurids are found in rain, montane and gallery forests and their absence in faunas such as Maboko suggests absence of suitable habitats. In summary, in East African rodent faunas, the transition from the early to middle Miocene is characterized, in part, by the loss of characteristic early Miocene taxa, decrease in the abundance and diversity of thryonomyids and the introduction and diversification of murids and derived nesomyines. Characterization of the Maboko rodent fauna is important in documenting this transition.

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## HISTORY OF INTERLOCKING THREATS USING JOINT BIOSTRATIGRAPHY OF MOLLUSKS AND OSTRACODES: SPECIES INVASION AND CULTURAL EUTROPHICATION IN THE WESTERN FINGER LAKES OF NEW YORK

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Direct monitoring in freshwater lakes often commences after invasive taxa become established and hypoxic areas proliferate. Using the mineralized discards of once-living organisms allow for the capture of truly pre-human ecosystems. In this study, we elucidate the history of species invasions and cultural eutrophication using a joint biostratigraphic study of mollusks and ostracodes. Conesus Lake is the westernmost Finger Lake of New York, is mesoeutrophic, and has undergone remediation beginning in the early twenty-first century. The presence of non-indigenous taxa in the Finger Lakes region extends at least back to the mid to late nineteenth century. In addition, Conesus continues to suffer from periodic summer hypoxia caused by input of anthropogenic nutrients. The goal of this study is to capture the history of species invasion and cultural eutrophication on the same time scale in order understand past environmental impact and aid in modern remediation. Two sediment cores were collected from the north and south basins of Conesus Lake. Comprising over 150 cm of sediment at both locations, calcareous subfossils (mollusks and ostracodes) were sampled at one-centimeter increments and identified to the lowest taxonomic rank possible. Companion sediment cores in both basins were dated using $^{210}$Pb and radiocarbon, resulting in over 3,000 years of archived sediments. Seven species of non-indigenous mollusks were identified from the south basin core sediments composing three pulses of introduction. Three introduced gastropods and one bivalve species became established in the late nineteenth century (pulse 1). A further bivalve species established itself in the mid-twentieth century (pulse 2), while two addition bivalves became established in the late twentieth century (pulse 3). *Dreissena polymorpha* ("zebra mussel") established itself in pulse 3 and today dominates molluskan death assemblages. Four species of ostracodes were identified as bioindicators of trophic status. Two *Candona* species, *ohioensis* and *elliptica*, peak in eutrophic conditions during the mid-20$^{th}$ century, coeval with pulse 2 of introduced mollusks. *Ca. candida* and *Cypridoposis vidua* reach peak relative abundances in the late nineteenth century prior to cultural eutrophication and coeval with pulse 1 of introduced mollusks. Their rise in the most-recent sediments indicates successful nutrient reduction and a return to a mesotrophic state. Invasion of mollusks precedes cultural eutrophication. Furthermore, pulse 2 of mollusk invasion coincides with the most severe cultural eutrophication. Finally, the last pulse of mollusk invasion (pulse 3) occurs prior to successful remediation efforts in Conesus Lake. Calcareous macro- and micro-fossils can thus reveal fine-scale timing of multiple environmental threats to lacustrine ecosystems, setting baselines goals for preset-day remediation and environmental monitoring.

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## ACCOUNTING FOR BURIAL POTENTIAL IN ESTIMATES OF FOSSIL MAMMAL DIVERSITY

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Taphonomic processes can act as a filter for biological information that enters the fossil record in many ways. One important filter acts against organisms that live (and die) outside the bounds of a depositional basin, that is, along the bedrock or other relatively steeply sloped margins, reducing their likelihood of ending up permanently buried in the fossil record. Terrestrial mammals are potentially subject to this taphonomic filter; given that their diversity is known to vary along elevational gradients, the potential for bias would be especially strong depending on the proportion of taxa that live exclusively at higher elevations. Here, I assess this kind of bias using occurrence data (n>10,000) for extant mammals from 5 regions in the US that each encompass a range of elevations and habitats where local mammal diversity is well represented by natural history collections (as available via GBIF.org). For each region, I examine if subsets of mammal assemblages that are only found in parts of the landscape likely to experience deposition are a reliable surrogate for the richness and structure of the entire assemblage. I then compare these results to determine if using these subsets routinely omit certain taxonomic or functional groups. This estimation of taphonomic bias from differential burial potential provides new insights into the reliability of paleo-diversity data of limited spatial scope for estimating diversity and faunal structure at a regional scale.

## QUANTIFYING THE REPRESENTATION OF THE SKELETON IN THE FOSSIL RECORD OF BIRDS AND BEYOND: IMPLICATIONS FOR USING INCOMPLETE FOSSILS IN PHYLOGENETIC ANALYSES

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In estimating the relationships of groups on the animal tree of life, phylogenetic analyses tend to rely on the most complete fossil specimens. However, most animal fossil records are made up of fragmentary remains and disarticulated parts, and

consequently, we are left with considerable uncertainty in the evolutionary relationships of most known fossil species. Maximizing the vast amount of evolutionary information available in incomplete fossils within natural history collections necessitates: 1) a quantitative characterization of the biases present in this record, and 2) knowing whether the phylogenetic data preserved in these incomplete samples are reliable and consistent. We surveyed 17,097 fossil bird specimens housed in six North American museum collections to characterize the representation of different anatomical regions in the fossil record of the most diverse group of tetrapods on earth: birds. We find that bones from the pectoral girdle and forelimb account for 58.5% of all skeletal element occurrences, the pelvic girdle and hindlimb account for 33.2% of sampled fossil bird skeletal element occurrences, and the rest of the skeleton (e.g., skull bones, vertebrae, ribs) account for 8.3% of occurrences. Several factors may be contributing to this pattern, including the preferential preservation of larger (e.g., humeri, tibiotarsi) as well as denser elements (e.g., tarsometatarsi). These results differ from the distribution of characters across the avian skeleton in a recent morphological phylogenetic dataset (655 characters; pectoral girdle & forelimb: 30.0%; pelvic girdle & hindlimb: 25.6%; skull: 32.2%). These patterns reveal that the avian fossil record is biased against the region of the skeleton that holds the greatest amount of phylogenetic information: the skull. This bias against the preservation of the skull is similar to previously reported patterns in the second most diverse group of tetrapods: squamates (lizards, snakes, and their relatives). However, the overrepresented regions of the skeleton within the fossil record of birds and squamates differ. While the bird fossil record consists mostly of limb bones, the squamate fossil record consists mostly of tooth-bearing bones in the skull, vertebrae, and ribs. These differences illustrate how anatomical differences among animal groups lead to distinctive biases in skeletal representation in their fossil records. Our results invite us to: 1) further quantify the degree to which the taphonomic durability of specific skeletal elements in vertebrates (e.g., tooth enamel, dense bone) influences preservation of fossils that are collected; 2) investigate the phylogenetic signal of characters that correspond to over- and under-represented skeletal elements in the bird fossil record; and 3) assess whether these patterns are universal in other animal groups outside of the chordate phylum, including scleractinian corals and echinoderms.

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## CHARACTER EVOLUTION MODELS MATTER IN PHYLOGENETIC PALEOBIOLOGY: IMPACTS ON TREE TOPOLOGIES, DIVERGENCE TIMES, AND MACROEVOLUTIONARY DYNAMICS

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Investigating patterns of morphological character evolution is a major component of macroevolution. Character evolution models are fundamental to documenting evolutionary trends, interpreting patterns of morphological disparity in the fossil record, and testing alternative hypotheses of trait evolution using time-calibrated phylogenetic trees. Despite decades of major advances and key insights from molecular systematics, organismal anatomical features remain a key source of biological data for both inferring phylogenies and studying patterns of trait evolution among fossil and extant species. However, in paleobiology, morphologic characters are typically the only source of information available for reconstructing phylogenies. Thus, paleobiologists are often faced with what seems like an inescapable dilemma: given a phylogenetic hypothesis and a model of character evolution, phylogenies make predictions regarding patterns of character change. But character evolution models are used to infer phylogenetic hypotheses—a seemingly catch-22 situation. However, probabilistic phylogenetic methods present a way out "where all the different kinds of truths fit together," i.e., simultaneous inference of topology, divergences, macroevolutionary parameters, etc. Nevertheless, even in this framework systematists must make decisions regarding how characters are coded, whether they are modeled as continuous or discrete, and how to address biological sources of rate variation, which can vary among characters, through time, among lineages, and may be influenced by changes in species ecology or developmental shifts. To determine the impact of how different models of morphological evolution influence phylogenetic inferences and downstream comparative analyses of fossil data, we used Bayesian stepping stone sampling to compete a series of increasingly complex models of character evolution to a dataset of Cambrian-Ordovician trilobites, the Olenidae, comprising 38 species, 62 discrete characters, and 12 continuous traits. Competed models vary in complexity, ranging from simple constant rate scenarios with only discretized traits, to complex models including discrete and continuous traits across multiple ecological partitions allowing for multiple sources of rate variation. We also compared topological distributions across competed models by visualizing their distances in multidimensional treespace. Results indicate the addition of continuous traits dramatically improves support for complex evolutionary scenarios. Remarkably, we find model complexity also has a major impact on which regions of treespace are explored, which suggests a critical need to carefully model morphologic evolution even when systematists only want to infer patterns of phylogenetic relationships alone.

## THE TAPHONOMY OF PARASITISM: TWO CASE STUDIES AND A VISION FOR CONSERVATION PALEOBIOLOGY

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Parasitism is the most common mode of life today; however, the fossil record of parasitism is generally poor, and often unsuitable for quantitatively rigorous analysis of ecological trends across broad spatial or temporal scales. As a result, the ecology of parasitism in deep time remains a relatively underdeveloped subject of study in comparison to the larger body of work exploring the importance of predation in the fossil record. Neontological studies have demonstrated the tremendous diversity and abundance of extant parasites and their integral part in shaping and stabilizing ecosystems, highlighting the need to better understand the processes hindering quantitative exploration of the fossil record of parasitism. One likely bias impacting the fossil record of parasitism is taphonomy. Understanding the taphonomy of parasitism in the fossil record is critical to isolating ecological signals from data biases, and will allow meaningful ecological study of parasites in deep time, such as the creation of baselines for parasite prevalence and range before human impacts, and modelling future changes to parasite ecology using data across past intervals of climatic change, such as the Paleocene-Eocene Thermal Maximum. Here, we present two case studies for understanding the preservation of parasitized crustaceans, relative to their healthy counterparts. First, we use X-ray computed tomography (CT) scanning and a computationally intensive physical simulation method, finite elements analysis (FEA), to analyze the impact of a parasite-induced fossil swelling (Ichnotaxon *Kanthyloma crusta*) on host preservation. FEA was used to assess differences in the peaks and distribution of stresses between healthy and swollen branchial chambers, using seven models of fossil and modern parasitized decapods across three species (*Munida valida*, *Panopeus nanus*, and *Macroakaena rosenkrantzi*). We find increased peak stress in parasitized branchial chambers, indicating that the presence of this pathology compromises the structure, which in turn likely hinders preservation during fossilization. Second, we use experimental tumbling to observe, compare, and contrast taphonomy characteristics between blue crabs (*Callinectes sapidus*) infested with a rhizocephalan parasite (*Loxothylacus texanus*), and healthy blue crabs from the Gulf of Mexico. Normalized taphonomy scores were used to evaluate and compare preservation between infested and healthy specimens semi-quantitatively. These studies are early but critical steps toward a better quantitative understanding of the fossil record of parasitism, and highlight the need disentangle bias from ecological signal, to allow for the informed use of parasite paleobiological data to inform current and future conservation.

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## MINING FOR BLANCAN GOLD: THE RICHMOND HILL LOCAL FAUNA OF THE BLACK HILLS, SOUTH DAKOTA

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A fossil assemblage from the northern Black Hills, designated the Richmond Hill Local Fauna, was obtained from fissure fills in a limestone quarry associated with a gold mine from 1995–1999. The assemblage, consisting of eleven individual sites, is identified as Plio-Pleistocene (Blancan/Irvingtonian). Seven localities appear to be Blancan based on the co-occurrence of *Blarina*, *Paenemarmota*, *Pliogeomys*, *Pliophenacomys*, and *Ondatra*, and four appear to be Irvingtonian based on the co-occurence of *Allophaiomys*/*Microtus*, *Cynomys*/*Urocitellus*, *Mictomys* cf. *kansasenses*, and *Prodipodomys*. Renewed attention to Richmond Hill material permitted the curation and study of this important late Cenozoic collection. The local fauna is unique for two reasons: 1) it encompasses a time interval from the late Neogene/early Quaternary virtually undocumented in the region, and 2) it preserves a high-altitude, montane assemblage, an environment rarely preserved in the fossil record. Approximately 4,000 specimens have been cataloged thus far, with thousands more awaiting curation. Preliminary work has identified at least 30 unique taxa ranging in size from Camelidae (*Gigantocamelus*) to Soricidae (*Sorex*). Canids, mustelids, and rodents are the most abundant mammalian groups. The diversity of taxa represents a confluence of environments. Taxa indicated forested habitat include chipmunk (*Neotamias*/*Tamias*), packrats (*Neotoma*), and a variety of passerine birds. Conversely, other taxa suggest an open environment, including ground squirrels (*Cynomys*/*Urocitellus*, *Ictidomys*, *Otospermophilus*), gophers (*Pliogeomys*, *Geomys*, *Thomomys*), and pronghorn (Antilocapridae). Other taxa imply a local water source, such as bog lemming (*Mictomys*), muskrat (*Ondatra*), and numerous amphibians. Based on this taxonomic disparity, the local environment is interpreted as a high-altitude, montane meadow associated with a marsh or pond adjacent to closed forest. The Richmond Hill site demonstrates the importance of fissure fill deposits to serve as paleoenvironmental archives and provides novel insights into the Northern Great Plains during the late Neogene to early Quaternary.

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## SPATIAL DIVERSITY AND TRAIT DISPARITY OF MODERN HETEROMYIDAE (RODENTIA) WITH IMPLICATIONS FOR THE RELATIONSHIP BETWEEN DYNAMIC LANDSCAPES AND EVOLUTIONARY HISTORY OVER DEEP TIME

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The Heteromyidae (pocket mice, kangaroo rats, and relatives) are a group of extant and extinct rodents abundant in North American fossil assemblages spanning the last 30 million years. Heteromyid species today are mostly desert-adapted and have a spatial peak in species richness in the desert ecosystems of the Basin and Range Province of western North America. However, the temporal peak of species richness in fossil Heteromyidae significantly precedes the formation of North American desert ecosystems in the Plio-Pleistocene, occurring instead during the Middle Miocene Climatic Optimum warming period and period of intensified mountain building regionally. The temporal disconnect between the geologic history of deserts and the fossil record of heteromyid species richness raises the question: what landscape or climate drivers might be influencing taxonomic and trait diversity in the Heteromyidae today and in the past? This study uses the EcoPhyloMapper R package to measure multi-faceted biodiversity metrics: taxonomic diversity (richness and turnover) and skull shape variation (disparity and turnover) in modern Heteromyidae across a 100 by 100 km spatial grid. We used a novel 2D morphometric landmarking scheme of the lateral view of the skull to quantify shape disparity. To relate diversity to regional environmental gradients, we used the BioClim database for temperature and precipitation indices and the EarthEnv database for topographic indices. Additionally, we used the EPA Ecoregions to divide the spatial grid into ecologically meaningful subregions for further comparisons. We found axes of biodiversity in the Heteromyidae are decoupled spatially, indicating there may be different eco-evolutionary processes shaping taxonomic and trait diversity patterns. Preliminary results indicate climate variables may correlate better with taxonomic richness and trait disparity while topographic variables may correlate better with taxonomic and trait turnover. Tectonically active ecoregions have higher taxonomic richness and turnover than tectonically passive ecoregions. Species richness and trait turnover are higher in warm deserts, which are geologically older, but species turnover is not significantly different between warm and cold deserts. Ecoregions with relatively high species turnover do not have high skull shape turnover, indicating skull shape is redundant across space, even though skull shape is variable across species. Our results illuminate the complex relationship between spatio-temporal environmental change and corresponding biodiversity patterns in the Heteromyidae and support the idea that both mountain building and desert formation in North America are potentially significant drivers of diversification and ecological adaptation in the Heteromyidae. Future investigations of evolutionary processes in extant and fossil heteromyids will illuminate how dynamic landscapes may have influenced taxonomic and trait diversification through time.

## HIGHLY DIVERSE INSECT MINES FOUND ON GYMNOSPERMS FROM MIDDLE JURASSIC YANLIAO BIOTA, CHINA

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The Yanliao Biota is a well-preserved plant assemblage that contains an insect fauna from the Middle Jurassic (165 Ma) Jiulongshan Formation, represented by the Daohugou locality of Northeastern China. Some associations between plants and insects have been previously documented from Yanliao, such as insect mimicry, pollination, and limited herbivory. Yet there is much to investigate, particularly endophytic feeding behaviors such as mining. Though confirmed mining was present as early as the Early Triassic, this distinctive functional feeding group was hosted overwhelmingly on gymnosperms until the Early Cretaceous, at which time mining insects diversified on angiosperms. We examined 2014 plant specimens from the Yanliao Biota, focusing on mines and their gymnosperm hosts, documenting detailed mine features based on the functional feeding group–damage type system, and compared Yanliao mines to those of the Mesozoic before and after the Middle Jurassic. The Yanliao material displays 27 mine occurrences on 14 specimens that resulted in eight, mostly new mine DTs present on six genera of bennettitalean, ginkgoalean, and pinalean hosts. Three conclusions result from this study. First, these mid-Mesozoic mines are morphologically conservative and track plant-host anatomical structure rather than plant phylogeny. Second, the insect culprits of these mines likely were members of three early lineages of polyphagan beetles, four early lineages of monotrysian moths, and an early lineage of tenthredinoid sawflies. Third, the nutrition hypothesis, indicating that endophytic groups such as miners had greater access to nutritious, inner tissues of the new plant lineages, best explains mine evolution during the mid Mesozoic. This diversity of Middle Jurassic mining from the Yanliao Biota, suggests continuity in the trajectory of mine evolution from the Late Triassic to Early Cretaceous and provides rare data linking the early evolution in miners and their plant hosts.

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## ON THE LATE EDIACARAN "KOTLINIAN CRISIS"

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The Terminal Ediacaran Stage (TES), or the last 12 million years (ca. 550–538) of the Ediacaran Period, is characterized by an apparent decline in the diversity of Ediacara-type macrofossils. This interval of depauperate diversity is known as the "Kotlinian Crisis," which is roughly equivalent to the Nama Assemblage of the Ediacara biota and bracketed by two proposed extinctions at the White Sea–Nama boundary and the Ediacaran–Cambrian boundary. While diversity decline during the TES was originally recognized based on the distribution of Ediacara-type macrofossils, recent analysis of globally distributed macroalgal fossils suggests the "Kotlinian Crisis" significantly impacted non-metazoan benthic marine organisms. Despite overall low diversity, contemporaneous trace fossils suggest the evolution of novel metazoan behaviors and body fossils the origination of biomineralizing animals, which heralded a major shift towards more 'Phanerozoic-type' animals of the Cambrian Period. This dichotomy in evolutionary dynamics between the Ediacara biota and Phanerozoic-type animals is puzzling. Here we hypothesize that this dichotomy may have been driven by episodes of expanded marine anoxia in the TES, which resulted in temporally dynamic and spatially heterogeneous redox conditions in the benthic realm. Such dynamic and heterogeneous redox conditions would have negatively impacted Ediacaran taxa unable to meet their oxygen demands while simultaneously promoting innovation in animals that evolved during these stressed times. Viewed in this light, the "Kotlinian Crisis" represents a complex interplay between biology and environment that precipitated different fates and opportunities for different organisms.

## THE ORIGIN AND EARLY EVOLUTION OF GINGLYMODIAN FISHES: FOSSIL EVIDENCE FROM THE MIDDLE TRIASSIC OF CHINA

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Living neopterygians fall into three major groups, Ginglymodi, Halecomorphi, and Teleostei. Recent molecular and morphological phylogenetic analyses generally place Ginglymodi and Halecomorphi as sister-groups, forming a monophyletic clade Holostei. Although living ginglymodians are represented by seven species (two genera) restricted to freshwater environments of North and Central America and Cuba, this clade has flourished throughout almost the entire Mesozoic with a higher morphological and taxonomic diversity than their living descendants; fossil ginglymodians were widely distributed from both freshwater and marine deposits in almost all continents except Australia and Antarctica, including Lepisosteiformes, Semionotiformes and Kyphosichthyiformes. In 2023, a new fossil ginglymodian, namely *Diandongichthys ocellatus*, was described based on 13 well-preserved specimens from the early Middle Triassic (Anisian) marine deposits exposed in Luoping, eastern Yunnan, China, which represents one of the oldest and smallest known ginglymodians with a maximum standard length of 41 mm. *Diandongichthys* displays several synapomorphies of ginglymodians, i.e., absence of a tooth patch on the parasphenoid (reversal in Semionotus and derived lepisosteiforms), presence of six or more infraorbitals between antorbital and dermosphenotic, presence of a lacrimal deeper than long (reversal in Ticinolepis), and presence of nine or fewer branchiostegal rays, but retains some primitive states with respect to other early ginglymodians (e.g., a short snout without anterior infraorbitals, a maxilla ending below the orbit, and a median gular). Results of a phylogenetic analysis based on a data matrix including 205 morphological characters and 46 taxa placed *Diandongichthys* at the base of the Ginglymodi. Additionally, recent studies reveal that the naked 'halecomorph' Guizhouamia and deep-bodied 'stem-neopterygian' Guizhoubrachysomus from the Middle Triassic (Ladinian) Xingyi Biota are likely basal members of ginglymodians. The three taxa cannot be referred to any named families or orders of ginglymodians but they provide important information for our understanding of the origin and early diversification of this clade.

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## COUPLING AND DECOUPLING OF TAXONOMIC AND ECOLOGICAL DIVERSITIES DURING THE LATE PALEOZOIC

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Changes in ecological communities during major geologic events have been studied for decades, but the overall impact of these events on the function and structure of marine ecosystems is still uncertain. Here we investigated the dynamics of marine ecological communities during the late Paleozoic in South China, selecting five periods from the late Visean to Induan. During this interval, two major biological

events occurred, including the Carboniferous-earliest Permian marine biodiversification event and the end-Permian mass extinction. Using data from the Paleobiology Database (PBDB) and the Geobiodiversity Database (GBDB), we generated a dataset of 38,193 fossil occurrences from 1,100 sections, and analyzed the genus-level taxonomic richness and ecological diversity (e.g., ecospace utilization and food web analyses). Ecological information was obtained from literatures, PBDB and/or modern analogues. Ecospace utilization was quantified on the basis of the number of life modes organized into three parameters: tiering, feeding mode and motility. Trophic roles were inferred based on direct evidence, functional morphology and modern analogues where highly plausible. Genera of the same phylum with identical consumers and resources were aggregated into trophic species, and seven key properties of "trophic species webs" were calculated. The results after rarefaction show that despite significant changes in biodiversity, ecological diversity has not changed much. There are also differences in the impacts on different ecological guilds, which have implications for the conservation of marine biota today.

## EXPLORING STRATEGIES FOR FACILITATING INTERNATIONAL COLLABORATIONS TO ENHANCE PALEONTOLOGICAL RESEARCH

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It is increasingly clear that paleontology—like all scientific disciplines—is becoming more collaborative as scientists gain more confidence to reach out internationally –across geographical and cultural barriers—to increase the possibilities of discovery. According to Web of Science Core Collection database, the percentage of scientific publications with authors affiliated in at least two countries increased from 4.7% in 1980 to 25.7% in 2021, while in the field of paleontology, the proportion of such articles reached 50% in 2021. In spite of this rapid growth in international collaboration and co-authorship, in many cases acceptance of a research report for publication marks the end of a collaborative project. Moreover, it is not uncommon for researchers to encounter challenges in finding collaborators and/or maintaining collaborations due to political tensions, economic and sociocultural barriers. In addition, intellectual colonialism, has been cited recently as a factor that, in the past, has resulted in devaluation of contributions made by experts from lower-income countries that, in extreme cases has compromized opportunities for the continuance of international collaborative networks. There is no singular solution that can address or "solve" all these issues. However, there are several examples of strategies that have been successful in facilitating sustainable international collaborations in a paleontological context. Two of the newest of these are the Deep-time Earth and Life Transnational Alliance (DELTA) and the Deep-time Digital Earth (DDE). DELTA (http://nju-delta.com/), established in 2021, is an institution-powered paleontological alliance, currently spanning four leading universities in China and the UK. In addition to realizing research goals, DELTA prioritizes enhanced training of paleontology students by providing resources for members to engage in training/research collaborations across institutions. Since China lifted its COVID restrictions in 2023, three students visited/are visiting DELTA institutions with DELTAs co-sponsorship. Such personnel exchanges are expected to become more frequent in the immediate future. The DDE program (https://www.ddeworld.org/) is the first big-science project initiated by IUGS. Consisting of 23 founding members, including national geological surveys and professional societies, DDE aims to harmonize global deep-time data to facilitate data-driven earth-science discovery. Currently, DDE has secured its financial sustainability to advance and support scientific research through fundings mainly from China, but efforts are being made to expand its financial supports in Europe and North America. Comparing and contrasting these two initiatives with previous long-term paleontological collaborations sheds light not only on commonalities, but points up new opportunities that can be incorporated into the designs of future collaborative paleontological research-training networks.

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## MESOZOIC AND CENOZOIC ACTINOPTERYGIAN FISHES FROM JAPAN

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In 1919, D.S. Jordan described the first Japanese fish fossil *Iquius nipponicus* from Iki Island. The holotype was deposited in the California Academy of Science. Since then, approximately 70 species of actinopterygians have been described from Mesozoic and Cenozoic deposits in Japan. These fossils have provided insights into the relationships between the Japanese archipelago and the continent as well as the origins, transition, and evolution of fishes in East Asia and the Northwest Pacific Ocean. The Wakino fish assemblage from the Early Cretaceous lacustrine beds in Kyushu is considered to be closely related to the *Mesoclupea-Paraclupea* assemblage in Zhejiang, China, whereas *Sinamia kukurihime* from the Early Cretaceous Tetori Group in central Japan is considered to be closest to *S. liaoningensis* from Liaoning, China among the genus *Sinamia*. With regard to marine fishes, a peculiar ichthyodectiform and crossognathiform

were described from Upper Cretaceous marine deposits. In Cenozoic fishes, freshwater fish fossils including *I. nipponicus* from the Miocene deposits in Iki Island are an important group of fishes for investigating the relationship between the Miocene Japanese Islands and the continent as well as the evolution of freshwater fishes in East Asia. About Miocene marine fishes, seven species described from Tottori are important for considering the origin of the shallow-water fish fauna of the western Pacific. Pleistocene freshwater fish fossils from Kusu basin in Kyushu differ slightly from the extant species and are probably direct ancestors of the extant species distributed in the western part of Japan. Two species, *Clupea tanegashimaensis* and *Percichthys chibei* from the Pleistocene Tanegashima Island, are the fish fossils that a Japanese researcher described for the first time in 1929. Many marine fish fossils were excavated at the type locality in the 1980's and more than 20 species have been recognized. These fossils are important in considering the origin of the marine fish fauna in the East Sea and around Japan.

## PALEONTOLOGY AT BOWLING GREEN STATE UNIVERSITY: COLLECTING, RESEARCHING, AND TEACHING ABOUT THE ANCIENT LIFE OF THE GREAT LAKES REGION

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The paleontology program at Bowling Green State University in northwest Ohio has thrived for 67 years. This presentation highlights our invertebrate paleontology collections, our unique undergraduate Paleobiology specialization, and our regional outreach activities. Paleontology at BGSU was established with the arrival of invertebrate paleontologist Richard D. Hoare in 1957. Dick was joined by vertebrate paleontologist John A. Howe in 1965 and micropaleontologist Don C. Steinker in 1967. Glacial geologist Jane L. Forsyth, hired in 1965 as the first woman geology professor at BGSU, also contributed to paleontological collections. I arrived at BGSU in 1999, replacing both Dick Hoare and John Howe, who continued to be active for years after their retirements. All these faculty did extensive fossil collecting to build up BGSU's research and teaching collections. The Paleozoic marine invertebrate research collection includes over 130,000 individual fossil specimens. Brachiopods of various ages and Pennsylvanian gastropods are especially well-represented, numbering in the tens of thousands of specimens. We also hold a strong collection of marine invertebrates of the Middle Devonian Dundee and Silica Formations, including over 450 specimens of *Eldredgeops rana*, and exceptionally well-documented collections of Late Carboniferous fossils, especially mollusks, from eastern Ohio. The undergraduate Paleobiology program was established at BGSU in the 1960s as a specialization within the Geology B.S. degree. The curriculum includes all the core Geology courses plus multiple introductory and upper-level courses in invertebrate and vertebrate paleontology. Paleobiology students also complete an independent research project in a paleontological area of interest and take five Biology courses, including evolution and ecology, preparing them for graduate programs in both earth and life sciences. About half of all BGSU Geology majors choose the Paleobiology specialization, with about 30 Paleobiology students from across the country currently enrolled. With these students' help, we conduct multiple educational outreach activities each year that showcase Ohio's Paleozoic and Ice Age history with specimens from our extensive teaching collections. To safeguard BGSU's fossil collections, Paleobiology students are cataloging and digitizing our research specimens so we can share our collections on the web (both for virtual research and to encourage visitors to the collection). We also work with BGSU's marketing team to feature faculty and student research in various media outlets. Capitalizing on BGSU's slogan—A Public University for the Public Good—we emphasize the importance of our fossil collections for the state of Ohio and Great Lakes region whenever possible. Through careful stewardship, we hope BGSU's fossil collections will continue to grow and be used for research, education, and public outreach for decades to come.

## RE-EVALUATION OF THE *MAMMUTHUS COLUMBI* ASSEMBLAGE AT WACO MAMMOTH NATIONAL MONUMENT (WACO, TEXAS, U.S.A.)

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Using exposed *Mammuthus columbi* long bones and teeth from Waco Mammoth National Monument (WMNM), the total count, age, and sex of the individuals was reexamined to better understand herd dynamics in late Pleistocene Texas. The original interpretation for WMNM included 23–26 adult females, two juveniles, and one male in the first *M. columbi* nursery herd. Optically stimulated luminescence (OSL) dating identified two distinct layers, both with semi-articulated remains. A survey of in situ and excavated specimens was used to better define the number of individuals in each layer. Twenty-two complete, 96 partial, and 73 fragmented long bones were identified. Each element was assigned to an individual mammoth using original field maps, photographs, and age at death based on tooth wear and long bone fusion. Elements were separated into three groups based on ontogenetic and dental stages: juvenile (0–19 AYE), prime adult (20–59 AYE), and older adult (= 60 AEY). Juveniles were identified based on the presence of molars dp2–dp4 and/or complete lack of fusion on the long bones. Prime adults were identified using a combination of molars 1–3 and/or partial long bone fusion. Older adults were identified based on the presence of a well-worn molar 3 and/or complete long bone fusion. Minimum number of individuals

based on paired tusks in the lower layer, OSL dated to 66.8±5 ka, includes five juveniles, eight prime adults, and zero older adults. Examinations of collections identified two more prime aged individuals based on the presence of isolated teeth and skeletal elements. These mammoths include A–F, H–O, S, T, and U plus at least two newly identified adult individuals. Measurements and analyses of the lower level indicate the assemblage includes nine juveniles (45.0 %), ten prime adults (50.0 %), and one older adult (5.0 %), ranging from one year to 30+ AEY. The upper level, OSL dated to 51.3 ± 3.7 ka, also includes one juvenile and likely two adults. Additionally, there are at least four individuals with unknown stratigraphic ages, mammoths W, Y/Z, and the two new juveniles. In the lower level, there is a nearly even number of juveniles and adults, which is consistent with modern elephant herds with a steady population. Asian elephants typically form family unit herds with an equal number of adult females and juveniles. While male Asian elephants typically leave the herd around six to seven years old, they will temporarily rejoin herds when females are in estrus. The composition of the assemblage at WMNM may suggest a herd composition similar to their modern analog. Determining biotic or environmental causes of death and burial are beyond the scope of this project, but the high percentage of prime aged individuals preserved at WMNM is intriguing and requires additional investigation. This large assemblage of adults and juveniles provides a rare opportunity to better understand *M. columbi* herds and the paleoecology of central Texas.

## ECOLOGICAL AND EVOLUTIONARY DEVELOPMENT OF CENOZOIC MARINE LATITUDINAL DIVERSITY GRADIENTS

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Recent macroecological and paleobiological studies have been indicating the major role of temperature in shaping global marine biodiversioty patterns in the present day and also at least for the last hundreds of thousands of years. Species track their thermal niches, and optimal temperature for the most species is ~20 degree Celsius, resulting increasing diversity from the poles to lower latitudes. But present-day lowest latitudes have temperature >20 degree Celsius and thus are suboptimal for marine species. More specifically, the major global diversity pattern of the latitudinal diversity gradient is known to be being modified by ongoing warming from unimodal to bimodal pattern with a strong equatorial diversity dip, because of increasingly, overly high temperature there. While we may argue that temperature is the major driver of marine latitudinal diversity gradient on ecological timescales of the past hundreds of thousands of years, there are important open questions remained. Did temperature remain important for diversity on longer, evolutionary time scales, e.g., throughout the Cenozoic. Or had other mechanism (e.g., plate tectonics, biotic interaction) predominated in deeper time? Does temperature affect pelagic and coastal organisms similarly? How has temperature affected global-sum diversity? I will discuss more details in the presentation.

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## PALEONEUROBIOLOGY OF THE TETRAPOD OLFACTORY BULB INFERRED FROM EXTANT OLFACTORY RECEPTOR REPERTOIRES

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To date, the only window into inferring olfactory capabilities in fossils is using the olfactory bulb ratio, which is defined as the ratio between the largest diameter of the olfactory bulb and the cerebrum. There are direct interpretations of the functional implications of olfactory bulb ratio, such that the number of glomeruli cells within the olfactory bulb may directly reflect the number of distinct converging olfactory sensory neurons that express singular alleles of olfactory receptor genes. Thus, the larger the olfactory bulb relative to the brain may reflect a greater number of environmental odorants the brain can interpret, but the relationship has not been explicitly tested as a rule for tetrapods. Using the number of intact chemoreceptors (both olfactory and vomerolfactory genes) as a response, we used a Bayesian hierarchical model to predict olfactory bulb ratios in extant tetrapods. Of the > 300 tetrapod genomes available, we compiled complementary morphological and genetic data for ~200 specimens. Through the incorporation of all possible chemoreceptor genes, we discovered a very tight relationship between osteological proxies and the number of chemoreceptor genes. Thus, the predictive abilities of fossil morphology to understand the genomic basis of chemosensory diversity in extinct dinosaurs is possible. Using the olfactory bulb ratio of > 200 tetrapod fossils, we inferred the chemoreceptor repertoire size to help unveil shifts in expansions and contractions at the genomic level during tetrapod diversification. Important patterns discovered include independent reduction of olfactory bulb ratios and receptor repertoire sizes during the evolution of flight in both birds and pterosaurs, while non-avian dinosaurs maintained ancestral diversity and even independently expanded repertoire size. Our results exemplify one of the few instances of osteological correlates and genomics, which can help unveil evolutionary patterns of evolutionary diversification of neurosensory systems.

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## DEVELOPMENT OF AN INVERSE MODELING FRAMEWORK FOR DETERMINING THE DRIVERS OF MASS EXTINCTION EVENTS AND APPLICATION TO THE LATE ORDOVICIAN RECORD OF GRAPTOLITES

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Mass extinction events are typically associated with complex cascades of rapid and simultaneous global environmental perturbations, making it difficult to determine which specific changes were most important in driving extinctions. Extinction selectivity patterns can provide critical insight into the drivers of extinction, but most selectivity analyses consider only a single global change scenario and do not account for the potential effects of incomplete sampling. We present an inverse modeling framework for evaluating multiple hypothetical global change scenarios and determining the range of scenarios that are most consistent with paleogeographic occurrence and extinction/survival patterns observed in the fossil record. Our approach begins by simulating a broad range of potential global states with the cGENIE Earth system model, using constant paleogeography but varying boundary conditions such as atmospheric CO2 and O2. For each model we then use the paleogeographic distribution of observed pre-extinction fossil occurrences to generate probabilistic ecological niche models (ENMs) for all species. Randomly selecting a new model to represent the perturbed global state, we use these ENMs to predict where, if anywhere, each species would be expected to persist. Controlling for the geographic distribution of sampling, we evaluate model-data agreement by comparing these predictions to the observed record of extinction, survival, and range shifts. Considering hundreds of potential global change scenarios allows for broad exploration of the model-data agreement landscape. We apply this approach to the Late Ordovician Mass Extinction (LOME), an event that broadly coincides with glaciation but for which the drivers of extinction remain controversial. We focus on the well-studied fossil record of graptolites, planktonic heterotrophs that were widespread in the Late Ordovician oceans and experienced high extinction and macroevolutionary turnover that has previously been linked to climate change. Preliminary results considering only sea surface temperature as a niche parameter show that global cooling scenarios consistently show better model-data agreement than global warming scenarios. However even the best-fitting temperature-only models show modest model-data agreement, implying that additional environmental factors and niche parameters must be invoked to explain the magnitude and selectivity of graptolite extinctions during the LOME.

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## NONMINERALIZED "TABULUS" OF THE BASAL CAMBRIAN MEDUSOZOANS OLIVOOIDES

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The basal Cambrian Kuanchuanpu Formation in southern Shaanxi, China yields a diverse small shelly fossils (SSFs), including a variety of microscopic sedentary medusozoans, e.g., *Olivooides* known as a peridermal-bearing medusozoan generally with a pentaradial symmetry. However, little is known about the internal anatomy and growth of soft tissue within their post-hatching periderm. Here we describe the morphology of the transverse disc-shaped diaphragm (TDD), a thin organic tabulus-like structure identified inside the periderm of *Olivooides*, and discuss its probable position, composition, function, and secretory mode. As a primary feature, the TDD could be considered as a diagnostic characteristic to distinguish *Olivooides* from other genera within the family Olivooidae. The TDD most likely functioned to elevate the polyp, to improve the physical stability of the periderm, and to promote food acquisition. Additionally, the TDD differs markedly from the other fossil cnidarians with the similar structure, e.g., tabulate corals, conulariids, Sphenothallus, and Archotuba conoidalis, in the composition, morphology, and growth position, as well as the internal peridermal cusps of extant scyphistoma. Perhaps the TDD of Olivooides represents the earliest known internal plate-like structures in cnidarian tubes, however, the similar structures in anthozoans and medusozoan polyps probably evolved independently.

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## DETANGLING EQUATORIAL INDIAN OCEAN OXYGENATION, VENTILATION, AND DIAGENESIS WITH BULK AND FORAMINIFERA SHELL-BOUND D15N ACROSS THE LAST TWO GLACIAL TERMINATIONS

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The southwest summer monsoon winds blow over the equatorial Indian Ocean and result in the upwelling of cold, nutrient-rich waters. Productivity greatly increases and dissolved $O_2$ is consumed below the photic zone where respiration exceeds $O_2$ supply and produces an oxygen minimum zone (OMZ), with the core region located at the eastern and central Arabian Sea. There is a perennial OMZ in the eastern Arabian Sea that is developed between 150 and 1000 m water depth due to this seasonal influx in productivity and reduced ventilation of intermediate waters. We present the bulk sediment and foraminifera shell-bound nitrogen (FB-$d_{15}N$) record from the Inner Sea of the Maldives as part of IODP Expedition 359, Maldives Monsoon and Sea Level, across the last two glacial terminations (~180 kyr). The Maldives is at an ideal location to assess the relative strength because it is distal to the epicenter, allowing it to delineate strong and weak oxygen-deficient events. The bulk sediment d15N reveals depleted glacial $d_{15}N$ that enriches during the deglaciation before depleting again during the late Holocene as seen in other records across the global oceans. Likewise, bulk sediment d15N from the Maldives does not display the high frequency, precession-dominated cyclicity as observed in the epicenter of the Arabian Sea and suggests minimal consumption of dissolved O2 associated with monsoonal upwelling. Furthermore, we test the hypothesis lower LGM bulk $d^{15}N$ values are an artifact of diagenesis in global oceans while FB-$d^{15}N$ of the thermocline species, Neogloboquadrina dutertrei, is a better recorder of local, past water column denitrification. In addition, we present high-resolution $d^{13}C$ foraminifera record of five planktonic species: *G. ruber*, *T. sacculifer*, *N. dutertrei*, *P. obliquiloculata* and *G. menardii*. *G. ruber* and *T. sacculifer* are used to constrain sea surface conditions while *N. dutertrei*, *P. obliquiloculata*, and *G. menardii* are used to monitor variations in the thermocline nutrients or ventilation history. Combined with Cd/Ca measurements of the thermocline species, *P. obliquiloculata*, our data indicate minimal expansion of the Arabian Sea OMZ into the Maldives across glacial terminations and instead high latitude, Southern Ocean ventilation due to air-sea gas exchange as the primary influence of thermocline dynamics. Our study provides additional evidence for the need to understand OMZs across glacial-interglacial cycles in the equatorial regions to better constrain productivity and ventilation as global temperatures increase and dissolved oxygen content decreases with climate change. Lastly, peak glacial records, such as Marine Isotope Stage (MIS) 5e, from the Maldives will provide an analog for marine conversation since oxygen deficiency places immense stress on tropical coral reefs and benthic shoal ecosystems.

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## LANDSCAPE, CLIMATE AND ECOLOGY INTERACT TO SHAPE REGIONAL SPECIES ASSEMBLAGES

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Topographic complexity and associated environmental heterogeneity can generate and/or accommodate more species through a variety of mechanisms. By creating barriers to dispersal, topographic complexity can elevate diversification rates, promoting speciation without ecological divergence, but when diversification is promoted by environmental heterogeneity, speciation is likely to be accompanied by ecological divergence. Even if diversification rates are not elevated by topographic complexity, complex regions could accommodate more species, if only because more small-ranged species are more densely packed within a given area and more ecological variety might be expected in more heterogeneous environments. Considering that species cannot persistently overlap in geographic range unless they can coexist, classic assembly rules may extend to larger spatial scales. If topographic complexity directly elevates species-richness it may indirectly also elevate functional diversity, as expected by assembly rules, but it might also directly affect functional diversity, amplifying or diminishing the effect of richness. We examine the impact of topographic complexity on species-richness and of the effects of both of those on functional and phylogenetic diversity, on two morphological traits: size and jaw shape. We focus on three lineages of rodents, two in western North America (Heteromyidae, Marmotini) and one in southeast Asia (Callosciurinae). Marmotines and heteromyids occupy open habitats that progressively expanded and experienced glacial cycling that fragmented and reconnected relatively homogeneous forests at upper elevations, driving non-adaptive radiations (especially of chipmunks). In contrast, most callosciurines occupy tropical forests on both mountains and lowlands in areas that remained forested since the Miocene Climatic Optimum. We find that, in both North American lineages, diversification rates are unrelated to topographic complexity, but rate and complexity are inversely related in Callosciurinae. As anticipated, geographic ranges are smaller in species-rich regions, but

contrary to expectations, richness does not increase with topographic complexity except in the case of callosciurines. In general, as predicted by assembly rules, the range of both traits increases and nearest-neighbor distances (NNdist) decrease with species-richness, and variance is largely independent of species-richness. But topographic complexity has varied effects on these metrics both within and between continents. Whereas complexity slightly increases NNdist and variance of size and shape in Heteromyidae, it diminishes minNNdist of size and the variance of both size and shape in Marmotini, and is directly related to all metrics for size but inversely related to metrics for shape in callosciurines. These contrasting patterns highlight the complex interplay between evolutionary history and biogeography, and the ecological interactions that shape regional assembly.

## THE FIELD MUSEUM'S 2022 KONECNY FOSSIL INVERTEBRATE COLLECTION DIGITIZATION PROJECT

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Over the last 125 years, the Field Museum has accumulated a collection of over two million fossil invertebrate specimens divided into around 350,000 specimen lots, most of which have their data recorded in handwritten labels and catalog entries. From 1980 to 2011, approximately 35,000 specimen lot records, or less than 10% of the total collection, have been digitized in a Filemaker Pro database. In 2011, this database was converted into an EMu database, which started a series of smaller digitization projects designed to be completed by undergrad and high school interns working during the summer. A total of 37 high school and undergrad student interns have participated in 11 digitization projects over the last 12 summers. These projects have successfully converted over 50,000 paper-based specimen records to electronic records into our fossil invertebrate database with a total of 107,000 specimen and label images. The Women in Science project in 2022 focused on digitizing and curating the James and Sylvia Konecny fossil collection, a collection of around 2,000 marine invertebrate fossil lots from the Paleozoic of the Midwest and Southwest that was donated to the museum in October of 2019. About half of these lots were digitized during this project. Each lot was given a Field Museum catalog number and this number was hand-written onto each specimen in the lot. Each specimen lot had an original label from the Konecnys that included Konecnys' collection numbers, locality, taxonomic, chronostratigraphic, and lithostratigraphic information, as well as any additional collection notes from the Konecnys. The museum's catalog number and the information on these labels were entered into the EMu database. When necessary, the database was also updated with new locations, taxonomy and stratigraphy as needed. Alongside the digitization of these 1,080 specimen lots, the work on the Konecny collection also introduced the potential of 3D modeling as a means of providing a more detailed way to access the collection. The digitization projects of the past 40 years are part of an ongoing effort to both preserve fragile records and improve accessibility for researchers and visitors alike. Currently, the data from this collection can be accessed from the Global Biodiversity Information Facility (GBIF) and Field Museum websites.

Funding source: This work was supported by the Field Museum of Natural History and the Women's Board of the Field Museum's Women in Science program.

## CONSTRUCT A HIGH-RESOLUTION GEOLOGICAL TIMELINE THROUGH THE DEVONIAN TO TRIASSIC

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The different resolutions of geological records have long been a problem for scientists to understand the rates and orders of environmental and evolutionary events and compare them with current situations. The stratigraphic data are the only material to restore these events and realize global comparison. However, the current scheme to define stages with specific stratigraphic records neglect too much information and only kept a low resolution with several million years. Therefore, we integrated 1280 global sections through the Devonian to Triassic, with 4852 fossil species, 262 ash beds and 8443 chemical records, and applied multiple quantitative stratigraphic methods to construct a high-resolution geological timeline. The timeline was tested by several statistical methods and data from other sources. It had an original mean resolution of 22.69 thousand years and a concrete mean resolution of 44.09 thousand years. We displayed the functions of the timeline to estimate the ages of local events and other sections, and correlating geochemical records to build their composite time series. In addition to the construction of a high-resolution geological timeline through the Devonian to Triassic, this process applies to the whole geological history and multidisciplinary stratigraphic data as well. The high-resolution geological timeline would facilitate our understanding of the detailed Earth history.

## LATE ORDOVICIAN OSTRACODS OF VALCOUR ISLAND, NEW YORK STATE, U.S.A.

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Ordovician ostracods of the New York State had been recorded preliminarily with systematic paleontology under an unrevised classification scheme. New materials are collected from the Late Ordovician Crown Point Formation of Valcour Island, northeastern New York State, for thorough studies on systematic revision, diversity analysis, paleoecological and paleogeographical implications. Fifty-one species of 39 genera are identified with 6 species being reexamined and revised accordingly. Within the fauna, *Krausella variata*, *Cryptophyllus oboloides*, *Eohollina depressa* and *Eurychilina placida* are the most common species. Faunal comparison shows close relationships between Laurentia and Baltica, Avalonia and Ibero-Armorica during this time interval. Hill number is used for diversity analysis on each sample, and a general increase in diversity is recognized. Furthermore, exceptionally well-preserved palaeocopid *Eurychilina placida* with moult retention reveals a new survival strategy for ostracods during the period of unstable environment.

## A LATE TONIAN LAGERSTÄTTE: PICKLED VASE-SHAPED MICROFOSSILS FROM THE CHUAR GROUP, GRAND CANYON, U.S.A.

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Vase-shaped microfossils (VSMs), representing the earliest fossil record of arcellinid amoebae, are potential index fossils preserved in a wide array of rock samples of late Tonian age (ca. 789–729 Ma). Recently, a remarkable assemblage of organically-preserved VSMs featuring details of test microstructure as well as soft-part preservation has been discovered from the lower Walcott and upper Awatubi members of the Chuar Group. This stands in sharp contrast with the trillions of mineralized VSMs in carbonate nodules throughout the uppermost Walcott Member and other assemblages worldwide, typically as mineralized casts and molds. Interestingly, organically-preserved VSMs occur in strata displaying evidence indicative of hypersaline conditions, including halite casts, mudcracks formed under evaporative conditions, and high levels of gammacerane—a proxy for hypersalinity. Here we test the hypothesis that the hypersaline environment was responsible for the preservation of organic VSMs by inhibiting microbial decomposition. Energy dispersive X-ray spectroscopy (EDS) spot analyses reveal notable variations in silicon (Si) and phosphorus (P) contents on the test wall and bitumen within VSMs. The organic walls have unusually high Si and low P content compared to the jarosite walls, while the bitumen within organic VSMs exhibits significantly high Si content compared to that within the jarosite VSMs. Raman spectroscopic analysis shows that both the organic walls and the bitumen within VSMs have similar peak metamorphic temperatures T(RmcRO%) at approximately 200. PCA analysis indicates significant overlap in the chemospace distribution between organic walls and bitumen within VSMs, suggesting that the organic walls and bitumen have similar organic precursors and experienced low-grade metamorphism. Furthermore, the high Si content of organic walls and bitumen is consistent with these materials possessing a greater Si diffusion ability, while jarosite walls demonstrate greater P adsorption capacity. We conclude that the high Si saturation state in the pore water, promoted by hypersalinity, stabilized the organic walls and inhibited the growth of decomposing microorganisms.

## LOSS AND REBOUND OF MORPHOLOGICAL AND FUNCTIONAL DISPARITY AFTER A NON-SELECTIVE MASS EXTINCTION AT THE K/PG BOUNDARY (FAMILY VENERIDAE, BIVALVIA)

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It is a classical observation in paleobiology that mass extinctions qualitatively alter the selective regimes governing background extinctions. Many key factors promoting survivorship during background extinctions no longer confer selective advantage, while some traits which do not themselves buffer against extinction may become important by hitchhiking on other favored traits. In particular, a tight bottleneck may create a macroevolutionary founder effect shaping the clade's post-extinction fates. Here, we test whether the K/Pg mass extinction was morphologically selective among genera in the most diverse bivalve family, Veneridae, using traditional and geometric morphometric tools, and investigate patterns of morphological and ecological rebound within the family during the Cenozoic. We found no selectivity in the K/Pg extinction in terms of body size, aspect ratio (length/height), and internal shell features, e.g., the geometric configurations of the tooth bank, muscle scars, and pallial line. The considerable heterogeneity in morphology and biogeography within the survivors (only 3 out of 22 genera; all infaunal siphonate) implies that no single trait alone decisively promotes persistence through the K/Pg boundary. The surviving genera

became extinct within the Paleogene (median ~9 Myr after the K/Pg boundary), suggesting a decoupling of factors governing persistence through the extinction and then during the subsequent rebound. Variations in the stratigraphic ranges of the survivors suggest that the validity of the "survival of the average" rule (e.g., Liow 2007) may depend on whether and when extinction events occur within the study interval, as well as the nature of the extinction. Nevertheless, the survivors initiated one of the most prolific radiations across the bivalve phylogeny, giving rise to the rich taxonomic and morphological diversity observed in extant members of the Veneridae. Most parts of the morphospace emptied during the extinction were reoccupied during the Cenozoic, as the family explored new areas of morphospace, e.g., via the deepening of the pallial sinus, and ecospace. Whereas extinct morphologies, such as elongate shells (high aspect ratios), originated multiple times and thus were not selected against during the rebound, they were only adopted by a small number of genera, offering a potential example of innovations that failed to promote diversification. Between the Maastrichtian and the Recent taxa, the overall range of body size doubled without a significant change in the shape of the overall distribution. Compared to the Maastrichtian venerids, the Recent taxa show a statistically significant but very slight increase in mean aspect ratio. During both intervals, the highest aspect ratios are concentrated around median body size, suggesting a potential conflict between extreme body size and high aspect ratio that may reflect a biomechanical tradeoff, ecological demand, and/or developmental constraint.

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## MODERN OSTEOLOGIES REQUIRE MODERN TECHNOLOGIES: MOSASAURS AS MODELS FOR THE CRITICAL IMPORTANCE OF SCAN DATA IN ANATOMICAL DESCRIPTIONS

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Detailed anatomical descriptions are critical to studies dependent on traditional comparative morphology, especially within paleontology, for which the gross morphology of an animal is often the only biological data available. Recent advances in 3D imaging technology have greatly expanded the toolset for paleontologists to understand and describe the anatomy of extinct clades. Computed tomography (CT) data has been critical to countless advances in paleobiology, including studies of vocalization, neuroanatomy, and skeletal pneumaticity in extinct animals. 3D scan data also improves figure clarity, enables wider accessibility of data, and facilitates construction and illustration of phylogenetic characters. Here, we review how two new mosasaur species exemplify the usefulness of scan data in anatomical description and phylogenetic systematics: *Sarabosaurus* and *Jormungandr*. Mosasaurs, a group of extinct marine lizards, have a notoriously tricky taxonomic history: their position within Squamata is contentious and in-group relationships labile. Both levels of systematic uncertainty limit a clear understanding of important macroevolutionary questions (e.g., secondary invasion of marine habitats). Contributing to this uncertainty is the relative stasis in the number of characters used to analyze mosasauroid systematics, which has not been substantially updated since its conception in 1997; e.g., characters for many bones–including those of the braincase–are completely absent. The description of *Sarabosaurus* includes extensive comparison of CT data of the braincases of it and other mosasaurs, which revealed a pattern of basicranial circulation completely unique to plioplatecarpine mosasaurs, highlighting a new source of potential phylogenetic characters. These characters, however, are inaccessible without CT scan data in many specimens, both due to their internal nature and the flattened state of many mosasaur fossils. Additionally, mosasaurs have historically been incompletely figured, which is challenging to comparative works and students wishing to learn their anatomy. Both CT and laser scan data improve the illustration of mosasaur fossils in the scientific literature. Unlike photographs, the renders of scan data can be presented in orthographic view, manipulated into exact positions, and lit to highlight key features: e.g., the entire holotype of *Jormungandr* was laser scanned and bones were figured and labeled in multiple views in its description. Every scan was uploaded to a digital repository, making the specimen accessible to researchers around the world regardless of their ability to physically travel. We acknowledge that many paleontologists, particularly students, face significant barriers to generating scan data: the necessary machines and software are extremely expensive and of limited accessibility. Therefore, we urge professional societies to establish grant opportunities to specifically support acquisition of scan data.

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## THE SIGNIFICANCE OF ENCRUSTING TAXA AND BORING ICHNOTAXA ON MARINE FOSSILS IN FORAMINIFERAL BIOSTROMES IN THE LATE EOCENE (PRIABONIAN) LOWER PAGAT MEMBER, TANJUNG FORMATION, IN THE ASEM ASEM BASIN, SOUTH KALIMANTAN, INDONESIA

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Marine sedimentary rocks of the Eocene Pagat Member, Tanjung Formation in the Asem Asem Basin, southern Kalimantan, provide an important geological archive for understanding the paleontological evolution of Indonesian Borneo in the interval leading up to the establishment of the Central Indo-Pacific marine biodiversity hotspot. Recent work highlighted the diversity of the invertebrate fauna, which includes abundant larger benthic foraminifera (LBF), crabs, bivalves, gastropods as well as a modest assemblage of echinoids, asterozoans, scleractinian corals and bryozoans. Fossil diversity and abundance are highest in foraminiferal packstone /rudstone lenses interpreted as low-relief biostromes that occurred in a succession dominated by calcareous shale. The biostromes developed in a depositional setting interpreted as mid-ramp or mid to distal continental shelf. The base of each biostrome is characterized by a low-diversity *Glossifungites* or (more rarely) *Trypanites* trace fossil assemblage, recording storm scour and shell concentration on an erosional surface that was subsequently colonized by firm / hard substrate-preferring organisms. Bivalves, gastropods and crabs are among the most abundant organisms in the study interval, however only rare specimens exhibit evidence of boring or encrustation. Five ichnotaxa were identified on bioclasts in the study interval. Entobia were observed penetrating the outer surface of several bivalve and gastropod shells. *Oichnus* were recorded on several bivalve shells, rare corals, and commonly, on LBF. *Gastrochaenolites*, *Rogerella*, and *Trypanites* were observed on micritic intraclasts that were most common in the basal laminasets of bioclastic rudstone lenses. Microscopic borings in gastropod and bivalve shell material identified in thin-section ranged in width from 10 to 25 µm. These consist of simple pit-like structures, clavate or vase-shaped structures, and more complex meandering excavations that penetrate deeply into thicker shells. Encrusting organisms also occur in the Pagat fauna. These include small, simple serpulids (both Serpulinae and Spirorbinae) and minute ostreids that both occur cemented to the external surface of small solitary corals (cf. *Caryophyllia* sp. and cf. *Cycloseris* sp.). Echinoid spines are commonly encrusted by cyclostomate bryozoans, cheilostomate bryozoans, and, rarely, coiled spirorbids. Larger patches of bryozoans and coralline algae occur on the bioclastic detritus that formed the Pagat biostrome surfaces. The Pagat boring and encrusting assemblage is unusual in that few bivalves and gastropods are affected. In contrast, encrusters are common on corals, LBF and echinoid spines and borings are common on LBF. Constraints that affected the development of this part of the Pagat fauna include occurrence in a setting commonly characterized by turbid water conditions and the isolated nature of the individual Pagat biostromes on a low-relief ramp / shelf dominated by calcareous mudrock.

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