

# ANNE C. FETROW, PH.D.

## Curriculum Vitae

NSF EAR Postdoctoral Fellow  
Earth & Environmental Sciences Department  
University of Michigan, Ann Arbor, MI

afetrow@umich.edu  
651-233-0027 | she/her/hers  
Google Scholar: <https://rb.gy/iqp6et>

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## INTERESTS & EXPERTISE

Stable isotope and environmental geochemistry; paleoclimatology; paleoenvironments; terrestrial sedimentology.

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## APPOINTMENTS

NSF Postdoctoral Fellow	June 2023 – May 2025
Earth & Environmental Sciences Department, University of Michigan, Ann Arbor, MI	
Visiting Assistant Professor	August 2022 – May 2023
Earth and Climate Sciences Department, Bates College, Lewiston, ME	
PhD Candidate, Research Fellow, and Course Instructor	August 2016 – July 2022
Department of Geological Sciences, University of Colorado Boulder, Boulder, CO	

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## EDUCATION

PhD, Geological Sciences, University of Colorado Boulder	2016 – 2022
Thesis: <i>Paleoclimate and paleoelevation changes of the Western US during the Cretaceous</i>	
Advisor: Dr. Kathryn Snell	
BS, Geology, University of Puget Sound	2011 – 2015
<i>Cum Laude</i> ; Coolidge Otis Chapman Honors Scholar. Minor: Environmental Policy & Decision Making	
Thesis: <i>Temperature changes and Great Plains ecosystem evolution during the Pliocene to the Pleistocene in Meade Basin, KS using clumped isotope thermometry</i>	
Advisor: Dr. Kena Fox-Dobbs	

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## FELLOWSHIPS & SCHOLARSHIPS

Marcy and Bruce Benson Graduate Fellowship, Geological Sciences, University of Colorado Boulder	2021 – 2022
Graduate Research Fellowship, National Science Foundation (NSF GRFP)	2018 – 2021
Edwards Graduate Fellowship, Geological Sciences, University of Colorado Boulder	2017
Peter K. Wallerich Scholarship, Geology, University of Puget Sound	2014
Coy & Nadine Mobley Scholarship, Geology, University of Puget Sound	2014
Blaine Wiseman Scholarship, Geology, University of Puget Sound	2013

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## RESEARCH

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### PUBLICATIONS

- Fetrow, A. C.**, Snell, K. E., Di Fiori, R. V., Long, S. P., & Bonde, J. W. (2022). How hot is too hot? Disentangling mid-Cretaceous hothouse paleoclimate from diagenesis. *Paleoceanography and Paleoclimatology*, 37. doi.org/10.1029/2022PA004517
- Ingalls, M., **Fetrow, A. C.**, Snell, K. E., Frantz, C., Trower, L. (2021). Lake level controls the recurrence of giant stromatolite facies. *Sedimentology*. doi.org/10.1111/sed.12967
- Di Fiori, R., Long, S. P., **Fetrow, A. C.**, Snell, K. E., and Bonde, J. W., and Vervoort, J. D. (2021) The role of shortening in the Sevier hinterland within the U.S. Cordilleran retroarc thrust system: Insights from the Cretaceous Newark Canyon Formation in central Nevada. *Tectonics*, v. 40, p. 1-31. doi.org/10.1029/2020TC006331
- Bernasconi, S.M., Daëron, M., Bergmann, K.D., Bonifacie, M., Meckler, A.N., Affek, H.P., Anderson, N., Bajnai, D., Barkan, E., Beverly, E., Blamart, D., Burgener, L., Calmels, D., Chaduteau, C., Clog, M., Davidheiser-Kroll, B., Davies1, A., Dux, F., Eiler, J., Elliott, B., **Fetrow, A.C.**, et al. (2021). InterCarb: A community effort to improve interlaboratory standardization of the carbonate clumped isotope thermometer using carbonate standards. *Geochemistry, Geophysics, Geosystems*, v. 22, p. 1-25. doi.org/10.1029/2020GC009588

**Fetrow, A. C.**, Di Fiori, R., Snell, K. E., Long, S. P., and Bonde, J. W. (2020) Early Sevier Orogenic Deformation Exerted Principal Control on Changes in Depositional Environment Recorded by the Cretaceous Newark Canyon Formation. *Journal of Sedimentary Research*, v. 90, p. 1–22. doi.org/10.2110/jsr.2020.52

Di Fiori, R., Long, S. P., **Fetrow, A. C.**, Snell, K. E., Bonde, J. W., and Vervoort, J. D. (2020) Syncontractional deposition of the Cretaceous Newark Canyon Formation, Diamond Mountains, Nevada: Implications for strain partitioning within the US Cordillera. *Geosphere*, v. 16 (2), p. 546-566. doi.org/10.1130/GES02168.1

Fox, D. L., Martin, R. A., Roepke, E., **Fetrow, A. C.**, Fischer-Femal, B., Uno, K. T., Fox-Dobbs, K., Snell, K. E., Haveles, A., and Polissar, P. J. (2017) Biotic and Abiotic Forcing During the Transition of Modern Grassland Ecosystems: Evolutionary and Ecological Responses of Small Mammal Communities Over the Last 5 Million Years. *Earth-Life Transitions: Paleobiology in the Context of Earth System Evolution, Paleontological Society Paper*, v. 21, p. 197-218. doi.org/ 10.1017/S1089332600003016

\*\*\* Other research presentations (colloquiums, conference presentations, and abstract co-authorships) listed at end of CV

## ON-GOING PROJECTS

\*\*Significant authorship contribution to proposal, but unable to be listed as co-PI due to appointment status

*No significant surface uplift of the North American Sevier Hinterland by the mid-Cretaceous determined by carbonate clumped isotope paleoaltimetry* Nevada, USA. In collaboration with: Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. Manuscript in prep

*Quantifying evaporation in Mono Basin: Bridging the gap between hydrologic modeling and paleoclimate records using triple oxygen and clumped isotope geochemistry* (NSF EAR PF#: 2204433) Mono Basin, California, USA. In collaboration with PIs Levin, N. E., Passey, B. H., Gronewold, A. D. Also funded by \*\*Meet the Moment grant, University of Michigan (2022-2024) On-going, funded

*A dual clumped isotope approach to characterize disequilibrium in terrestrial carbonates.* Great Basin, USA and BC, Canada. In collaboration with lead-PI Ingalls, M., Penn. State University \*\*Proposal funded by NSF Geobiology & Low-Temperature Geochemistry (Award#: 2244707) On-going, funded

*Developing an isotopic framework for palustrine (i.e., wetland) carbonate formation to inform paleoclimate and environmental research* Las Tablas de Daimiel National Park, Spain. In collaboration with: Alonso-Zarza, A. M., Snell, K. E. On-going

## FUNDING & AWARDS

### Research Grants, funded

Friends of the Graduate School Fellowship, Graduate School, University of Colorado Boulder.	2020
Research Grant, Geological Sciences, University of Colorado Boulder	2020, 2018
McCormick Scholar Summer Research Grant, Geology, University of Puget Sound	2013

### Travel Grants, funded

AGU Student Volunteer, American Geophysical Union	2019
Conference Travel, Geological Sciences, University of Colorado Boulder	2019
Conference Travel, United Government of Graduate Students, University of Colorado Boulder	2018
Conference Travel, Graduate School, University of Colorado Boulder	2018
Conference Travel, Goldschmidt Conference	2017

### Honors, unfunded

Best Field Camp Student Award, 6-week Field Camp, Lehigh University	2015
Norman R. Anderson Award, Geology, University of Puget Sound	2015
Roderick MacArthur Honors Award, Honors Program, University of Puget Sound	2015
Seniors of Excellence Award, Student Affairs, University of Puget Sound	2015
Leadership Award, Student Affairs, University of Puget Sound	2015, 2014

## TEACHING

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### COURSE INSTRUCTION

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<i>Environmental Geochemistry</i> (EACS 240), Primary Instructor, Bates College Lecture/lab focused on understanding the behavior of aqueous ions during interactions between the lithosphere, hydrosphere, and atmosphere and connecting these processes to local environmental examples/issues. Designated as “writing intensive course” that fulfills degree requirement for discipline-specific writing. Managed instructional team of a full-time course assistant and two student TAs. Enrollment: 20	Spring 2023
<i>Past Climates and Paleoclimate Proxies</i> (EACS 231), Sole Instructor, Bates College Lecture course focused on understanding the geochemical proxies and sedimentological evidence used to reconstruct paleoclimates. Enrollment: 18	Spring 2023
<i>Earth Surface Processes &amp; Environmental Change</i> (EACS 103), Primary Instructor, Bates College Introductory lecture/lab focused on developing skills in description of Earth's materials, and spatial and temporal analysis of sedimentological environments, and discussion of climate change-driven environmental change. Managed instructional team of full-time course assistant and two student TAs. Enrollment: 20	Fall 2022
<i>Stable Isotope Geochemistry</i> (EACS 341), Sole Instructor, Bates College Lecture course that examines the fundamental principles of stable isotope fractionation and the current state of major stable isotope proxy tools (e.g., H, O, C, N, S, and Ca). Enrollment: 6	Fall 2022
<i>Introduction to Geochemistry</i> (GEOL 3320), Primary Instructor, University of Colorado Boulder Lecture/recitation course exploring formation and chemical differentiation of Earth, modification of Earth surface by chemical weathering and mineral dissolution/precipitation, and how redox biogeochemistry shapes aquatic environments. Managed a teaching assistant (graduate student peer). Enrollment: 45	Spring 2020

### TEACHING ASSISTANT

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<i>Introduction to Geochemistry</i> (GEOL 3320), University of Colorado Boulder	Spring 2017
<i>Introduction to Physical Geology</i> (GEOL 1030), 2 sections, University of Colorado Boulder	Fall 2016
<i>Biogeochemical Approaches to Environmental Science</i> (GEO 324), University of Puget Sound	Fall 2014

### GUEST LECTURES AND INSTRUCTION

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Guest lecture, “ <i>Clumped Isotopes: Systematics and Applications</i> ” Stable Isotope Geochemistry (EACS341), Bates College	2023
Guest instructor, <i>Earth Camp</i> Assisted with instruction of four-day, field-based module focused on lake water quality for high school-aged students, University of Michigan Earth and Environmental Sciences department	2023
Guest lecture, “ <i>Applications of Clumped Isotopes in Paleoclimatology</i> ” Biogeochemical Approaches to Environmental Science (GEO 324), University of Puget Sound	2021, 2019
Guest lecture, “ <i>Clumped Isotopes: Systematics and Applications</i> ” Introduction to the Fossil Record (GEO 306), University of Puget Sound	2020
Guest lecture, “ <i>Stable Oxygen Isotopes and Paleoclimate</i> ” Exploring Earth (GEOL 1010) course, University of Colorado Boulder	2018
Guest field instructor Introduction to the Fossil Record (GEO 306), University of Puget Sound	2017, 2016

## MENTORING & SERVICE

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### STUDENT THESES MENTORSHIP

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Senior Undergraduate Thesis (2-semester), Earth and Climate Sciences, Bates College Maddy Broda. Advised student through project involving field skills (water isotope and quality sampling), data production and interpretation (in-house: major ions; external: $\delta^2\text{H}$ , $\delta^{18}\text{O}$ ), and scientific writing.	2022 – 2023
Honors Undergraduate Thesis mentor, Geological Sciences, University of Colorado Boulder Anna Todd. Advised student on field skills (section measurement, description, sediment sampling), data production and interpretation, and professional writing. Served as a non-voting member of honors senior thesis defense committee for undergraduate geology major.	2017 – 2019

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## OTHER MENTORING

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Indigenous Scholars Mentoring Program mentor Virtual mentorship program coordinated by the Center for Diverse Leadership in Science, University of California Los Angeles. Weekly professional and education mentoring sessions with student from Navajo Technical University, Crownpoint, NM.	January – May 2022
GEOL graduate peer mentor, University of Colorado Boulder Peer mentor to an incoming Geological Sciences graduate student.	2020 – 2022
Graduate School peer mentor, University of Colorado Boulder Peer mentor to an incoming STEM graduate student.	2019 – 2022
Research Experience in Solid Earth for Students writing mentor, University of Colorado Boulder Scientific writing mentor for RESESS undergraduate student from traditionally underrepresented backgrounds in the geosciences.	Summer 2019
Graduate Admission in The Earth Sciences (GATES) mentor Mentor to undergraduate students interested in pursuing graduate school.	2018 – 2019

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## PROFESSIONAL DEVELOPMENT

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### CERTIFICATES

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Certificate in College Teaching (CCT) Center for Teaching and Learning, University of Colorado Boulder 50+ hours of pedagogy workshops and trainings, classroom experience, and teaching evaluations by graduate student peers and Geological Sciences faculty.	Fall 2021
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### COMPUTATIONAL SKILLS

Expert – Microsoft Office, Adobe Suite  
Advanced – R (Routinely processes data, conducts statistical analyses, and generates publication-quality data visualizations)  
Intermediate/Beginner – Python, MatLab, and Jupyter Notebooks (Experience during graduate-level coursework)

### TRAININGS, WORKSHOPS, & SHORT COURSES

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Active Ally Training, Bates College Workshop focused on supporting LGTBIA+ students through proactive pedagogy strategies.	March 2023
Inclusive Community of Practice, University of Colorado Boulder Community member in campus-wide group designed to share best practices on topics related to diversity, inclusion, equity, and social justice in weekly workshops and discussions.	2020 – 2022
“Effective Bystander Intervention Training” Office of Institutional Equity and Compliance workshop, University of Colorado Boulder	2020
“Establishing and Sustaining an Undergraduate Research Program” Early career scientist workshop, American Geophysical Union, San Francisco, CA	2019
“Engaged Scientist Workshop” Office for Outreach and Engagement, University of Colorado Boulder	2019
Urbino Summer School in Paleoclimatology, Urbino, Italy. Focus: “Past Global Change Reconstruction & Modelling Techniques”	July 2018

### LEADERSHIP & COMMITTEE EXPERIENCE

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Unlearning Racism in Geoscience Education, Geological Sciences, University of Colorado Boulder URGE Pod organizer for group dedicated to share, discuss, and modify anti-racist policies and strategies.	2021– 2022
Geology Social Misconduct Awareness and Reaction Team (Geo-SMART). President and founding member, Geological Sciences, University of Colorado Boulder	2017 – 2021
Faculty Meetings Graduate Student Representative, Geological Sciences, University of Colorado Boulder	2019 – 2021
Department Action Team – “Assessing undergraduate curriculum learning outcomes” Committee member, Geological Sciences, University of Colorado Boulder.	2017 – 2019
Geological Sciences Colloquium Social Hour Founder and lead coordinator, Geological Sciences, University of Colorado Boulder	2017 – 2018
Colloquium Committee Committee member, Geological Sciences, University of Colorado Boulder	2016 – 2018
Society of Sigma Gamma Epsilon, University of Puget Sound. Chapter officer and founding member of university of Puget Sound’s chapter	2015

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## OUTREACH ACTIVITY

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Girls at the Museum Exploring Science (GAMES), University of Colorado Boulder Tour and activity facilitator, CU Boulder Earth Systems Stable Isotope Laboratory.	2020, 2019, 2017
CU Science Discovery Day Camp, University of Colorado Boulder Guest laboratory guide.	Summer 2019
“Are they melting? Reconstructing past climates to examine our changing world.” Workshop developer and leader for Expanding Your Horizons conference serving middle school-aged girls interested in STEM hosted at University of Colorado Boulder.	2018, 2017
“How to explore ecosystems: a wetland case study”, Horizons K-8 Elementary School, Boulder, CO Guest instructor and developed lesson plan for 4 <sup>th</sup> grade students.	2017

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## MEMBERSHIPS & HONOR SOCIETIES

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American Geophysical Union (AGU)	Since 2013
Geologic Society of America (GSA)	Since 2013
Society of Sigma Gamma Epsilon	Since 2015

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## OUTDOOR EXPERIENCE

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### LEADERSHIP AND EDUCATION

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YMCA Camp Seymour, Gig Harbor, WA Outdoor educator and naturalist for middle school-aged students	2015 – 2016
Puget Sound Outdoors (PSO), University of Puget Sound Program and Trip Coordinator	2013 – 2015
Outdoor Leadership Experience (OLE), University of Puget Sound Facilitator and Coordinator	2011 – 2015
Puget Sound Outdoors Program, University of Puget Sound Trip Leader, day and overnight trips	2012 – 2015
New Student Orientation, University of Puget Sound Trip Leader, multiple overnight trips	2012 – 2015

### FIELD SAFETY CERTIFICATIONS

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Wilderness First Responder (WFR) certification National Outdoor Leadership School, 80-hour course including CPR certification. Recertified: August 2023, August 2017. Original certification: May 2014.	Certificate Active
Conflict Resolution Training Office of Institutional Equity and Compliance, University of Colorado Boulder	November 2019
AIARE 1 Avalanche Training certification The American Institute for Avalanche Research and Education	March 2018

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## RESEARCH CONTINUED

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### INVITED COLLOQUIUM & SEMINAR TALKS

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Marine Chemistry and Geochemistry Colloquium series, Woods Hole Oceanographic Institute	June 2023
Earth Sciences Seminar series, University of Idaho and Washington State University (joint)	March 2023

### CONFERENCE PRESENTATIONS

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#### Talks

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(Invited) <b>Fetrow, A. C.</b> , Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. <i>Mid-Cretaceous Sevier Hinterland at Low Surface Elevation Based on Carbonate Clumped Isotopes</i> : Geological Society of America Abstracts with Programs, v. 50, no. 5, 9-12 Oct. doi.org/10.1130/abs/2022AM-380820	2022
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**Fetrow, A. C.,** Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. *Paleoaltimetry estimates suggest low surface elevations for the mid-Cretaceous Newark Canyon Formation within the Sevier hinterland.* Abstract EP026-03 presented at 2020 Fall Meeting, AGU, Virtual, 1-17 Dec. 2020

**Fetrow, A. C.,** Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. *Palustrine environments of the Early Cretaceous 'Nevadaplano' record warm and wet conditions.* Abstract PP51A-08 presented at 2018 Fall Meeting, AGU, Washington, D.C., 10-14 Dec. 2018

### Posters

**Fetrow, A. C.,** Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. *To Split or to Lump? The Importance of Facies Analysis for Interpreting Stable Isotope Paleoclimate Proxies from Lacustrine and Palustrine Carbonates.* Abstract PP15C-0937 presented at 2021 Fall Meeting, AGU, New Orleans, LA, 1-17 Dec. 2021

**Fetrow, A. C.,** Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. *Assessing how mid-latitude North America responded to a warmed Cretaceous climate using stable single and clumped isotope geochemistry.* Abstract PP13C-1468 presented at 2019 Fall Meeting, AGU, San Francisco, CA, 9-13 Dec. 2019

**Fetrow, A. C.,** Snell, K. E., and Alonso-Zarza, A. M. *Using modelling and modern calibration to determine the timing and driving forces of carbonate precipitation in palustrine environments.* Rocky Mountain Geobiology Symposium, Boulder, CO, USA. 2019

**Fetrow, A. C.,** Snell, K. E. *Determining the timing and driving forces of carbonate precipitation in palustrine environments to inform paleoclimate and paleoelevation estimates.* International Clumped Isotope Workshop, Long Beach, CA, USA. 2019

**Fetrow, A. C.,** Snell, K. E. *Reconstructing the depositional setting of the Early Cretaceous palustrine and lacustrine terrestrial sediments through a modern depositional framework.* Urbino Summer School in Paleoclimatology, Urbino, Italy. 2018

**Fetrow, A. C.,** Snell, K. E. *Reconstructing the palustrine and lacustrine depositional setting of the Cretaceous Newark Canyon Formation, Nevada.* Rocky Mountain Geobiology Symposium, Golden, CO, USA. 2018

**Fetrow, A. C.,** Snell, K. E., Di Fiori, R., Long, S. P., and Bonde, J. W. *A Paleoclimatic record from the "Nevadaplano" during the middle Cretaceous using stable and clumped isotope thermometry.* Goldschmidt, Paris, France. 2017

**Fetrow, A. C.,** Snell, K. E., Fox-Dobbs, K., Fox, D. L., Polissar, P. J., Uno, K. T., Martin, R. A., and Feinberg, J. *Temperature changes and Great Plains ecosystem evolution during the Pliocene to the Pleistocene in Meade Basin, KS using Clumped Isotope Thermometry.* Geological Society of America Abstracts with Programs. Vol. 46, No. 6, p.522. Vancouver, Canada. 2014

**Fetrow, A. C.,** Ivener, D., McKinley, E. M., Fox-Dobbs, K., and Foreman, B. *Swauk It Out: Carbon isotopic analysis of the Tertiary Swauk Formation, Central Cascades, WA.* Geological Society of America Abstracts with Programs. Vol. 45, No. 7, p.769. Denver, CO, USA. 2013

**Fetrow, A.,** C., Valentine, M. *Paleomagnetic and structural analysis of the basalts of the Summit Creek, Central Cascades, WA.* Abstract T11D-2495 presented at 2013 Fall Meeting, AGU, San Francisco, CA, USA, 9-13 Dec. 2013

### CONFERENCE ABSTRACT CO-AUTHORSHIP

Fox-Dobbs, K., Clementz, M., **Fetrow, A. C.,** Snell, K. E. *Clumped Isotope Temperatures from Beaver Teeth: Do Semi-Aquatic Mammals Record the Temperatures of Their Freshwater Environments?:* Geological Society of America Abstracts with Programs, v. 54, no. 5, 9-12 Oct. doi.org/10.1130/abs/2022AM-383015 2022

Di Fiori, R., Long, S. P., **Fetrow, A. C.,** Snell, K. E., Bonde, J. W., and Vervoort, J. D. *Shortening in the Sevier hinterland within the larger framework of the Cordilleran retroarc thrust system: insights from mapping and geochronology of the Cretaceous Newark Canyon Formation in central Nevada, U.S.A.* Abstract T52B-06 presented at 2021 Fall Meeting, AGU, New Orleans, 1-17 Dec. 2021

Di Fiori, R., Long, S. P., **Fetrow, A. C.,** Snell, K. E., Bonde, J. W., and Vervoort, J. D. *Shortening episodes in the Sevier hinterland within the larger context of the Cordilleran retroarc thrust system: Insights from the Cretaceous Newark Canyon Formation in central Nevada.* Abstract T039-0012 presented at 2020 Fall Meeting, AGU, Virtual, 1-17 Dec. 2020

Di Fiori, R., Long, S. P., **Fetrow, A. C.,** Snell, K. E., Bonde, J. W., and Vervoort, J. D. *Syncontractional deposition of the Cretaceous Newark Canyon Formation, Diamond Mountains, Nevada: Implications for strain partitioning within the US Cordillera.* Geological Society of America Abstracts with Programs. Vol. 51, No. 5. 10.1130/abs/2019AM-335173. 2019

- Snell, K. E., **Fetrow, A. C.**, Havranek, R., and Colwyn, D. *Advances in disentangling temperature, tectonics, and hydroclimate signals from stable isotope values of terrestrial carbonates*. Geological Society of America Abstracts with Programs. Vol. 51, No. 5. 10.1130/abs/2019AM-341152. 2019
- Snell, K.E., Uno, K. T., Lukens, W. E., **Fetrow, A. C.**, Fox, D. L., Layzell, A. L., Burgess, C. S., Fox-Dobbs, K., Haveles, A. W., Polissar, P. J., and Martin, R. A. *No change in clumped isotope temperatures during C4 grassland expansion in the Meade Basin, Kansas, during the Pliocene*. Geological Society of America Abstracts with Programs. Vol. 51, No. 5. 10.1130/abs/2019AM-339432. 2019
- Snell, K. E., Havranek, R., **Fetrow, A. C.**, and Colwyn, D. *Terrestrial carbonate perspective on  $\delta^{18}O$  of precipitation over the last ~100 million years in the western US from clumped isotope thermometry*. Water Isotopes Conference, Boulder, CO. Poster. 2019
- Snell, K. E., Eiler, J. M., Wernicke, D. J., Peppe, D. J., Fox, D. L., **Fetrow, A. C.**, Passey, B. H. *Disentangling Topographic and Climatic Change during the Late Cretaceous and Cenozoic in the Western US Cordillera*. Abstract T21C-4616 presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec. 2014
- Haveles, A. W., Fox-Dobbs, K., Talmadge, K. A., **Fetrow, A. C.**, Fox, D. L. *Characterizing isotopic variability of primary production and consumers in Great Plains ecosystems during protracted regional drought*. Abstract B32B-08 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec. 2012