‘Residues of parts unchewable’: stages two and three of a multivariate taphonomic analysis of the Dunefield Midden bovid bones

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This paper presents the second and third stages of a multivariate taphonomic analysis of the bovid bone assemblage from Dunefield Midden (DFM), a Later Stone Age site on South Africa’s west coast. The second stage investigates bovid skeletal element abundance and longbone fragmentation patterns at the site. The third stage integrates these data with bone modification data (Stewart 2010) to explore overall taphonomic variability between three different bovid size subgroups – small, small-medium and large. The results suggest that humans were the prime agents of assemblage formation, though carnivores are also implicated as contributors to density mediated attrition. The predominant taphonomic signatures of all bovid size classes are consistent with within-bone nutrient acquisition by the site’s occupants. However, major differences are apparent between the subgroups in element representation, longbone portion abundance and fragmentation patterning. These differences are shown to reflect variation in processing/food-preparation behaviours related to carcass size. It is suggested that whereas intensive fragmentation of large bovid bones resulted from efforts to render bone grease, the small bovid bone assemblage was structured by marrow extraction. Further, small bovid elements with high marrow utility may have been preferentially targeted and treated in more standardised fashion. The small-medium bovids, most of which are domesticates (sheep), exhibit intermediate patterning between the other two, but this may be a sampling issue related to their relative scarcity at DFM.

Keywords: Dunefield Midden; skeletal element abundance; bone fragmentation; bovids; refitting; multivariate; Later Stone Age

Cet article présente les deuxième et troisième phases d’une analyse taphonomique multivariée engagée sur l’assemblage osseux des bovidés du site Later Stone Age de Dunefield Midden (DFM), situé sur la côte ouest de l’Afrique du Sud. La phase II se concentre sur l’abondance des éléments squelettiques bovidés et sur les types de fracturation des os longs. La phase III confronte ces données à celles précédemment acquises sur la modification des os (Stewart 2010) et a pour objectif d’explorer la question de la variabilité taphonomique des différentes classes de bovidés – petits, moyens et grands. Ces résultats suggèrent que les hommes ont été les principaux agents à l’origine de la formation de l’assemblage osseux des bovidés de DFM, avec une contribution mineure des carnivores. La signature taphonomique dominante est compatible avec un comportement d’acquisition des nutriments intra-osseux par les occupants de DFM. Néanmoins, des différences importantes sont observées entre les différentes classes de bovidés, selon la représentation des éléments squelettiques considérés, l’abondance des fragments d’os longs ou encore les types de fracturation. Ces différences sont
interprettées comme la conséquence de variation dans le traitement ou la préparation de la nourriture en fonction de la taille des carcasses. Si la fragmentation intensive des os de larges bovidés est la conséquence d’une exploitation de la graisse des os, la fragmentation des os de petits bovidés aurait pour sa part été structurée autour de l’extraction de la moelle. Par ailleurs, les éléments de petits bovidés présentant une forte valeur nutritive en moelle auraient été préférentiellement sélectionnés et exploités selon un mode plus standardisé. Les moyens bovidés, pour la plupart domestiqués (mouton), présentent des caractères intermédiaires dont l’interprétation demeure néanmoins délicate du fait de leur faible représentation sur le site (problème d’échantillonnage).

‘...when a goat was slaughtered, its skeleton was treated in a traditional manner and those parts the Hottentots considered inedible were tossed to the dogs. When the dogs in their turn had finished, a residue of parts unchewable by Hottentot or dog was left to bleach on the desert surface’ Brain (1981, 12).

Introduction

In a recent contribution to this journal (Stewart 2010) I presented some results of a faunal analysis of the refitted bovid bone assemblage from Dunefield Midden (henceforth DFM), a series of partially overprinted Later Stone Age coastal campsites in South Africa’s Western Cape Province. That paper was the first stage of an in-sitie multivariate taphonomic faunal analysis of the kind advocated by Bar-Oz and Munro (2004). This paper continues the investigation by offering the second and third stages in which other aspects of the assemblage are explored and all results integrated. Using a multivariate approach faunal assemblages are split into subgroups based on given attributes that may respond differently to the same taphonomic stimuli (e.g. taxon, size class, age group, bone density, bone tissue type etc.). Multiple zooarchaeological analyses are then applied in a hierarchical fashion to these assemblages and subgroups, with each stage informing subsequent stages, and results are compared between them (Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Munro and Bar-Oz 2005; Yravedra and Domínguez-Rodrigo 2009). Bar-Oz and Munro (2004, 202) have shown that, ‘Dividing a bone assemblage into subgroups allows fine-grained comparisons that can peel away the taphonomic layers and reveal meaningful patterns in zooarchaeological data.’ The subgroups under examination here are three bovid size classes from DFM – small, small-medium and large.

In the first stage of this analysis (Stewart 2010) I summarised primary quantitative data on the DFM bovids in relation to other taxa at the site and discussed types, frequencies and orientations of bone modifications. It was shown that: (1) bovids were the most important terrestrial dietary resource at DFM (perhaps notwithstanding plant foods, which did not preserve); (2) burning and rodent gnawing did not significantly alter the assemblage, and damage from trampling and carnivore ravaging are also relatively rare; (3) weathering and root etching on bone surfaces are prevalent, the former more seriously affecting large bovid bones and the latter small; (4) cut marks from carcass dismemberment are more frequent on large bovids than small, likely reflecting size-related differences in butchery effort; (5) most tissue severing damage on bones of all size classes occurs in the form of cut marks on longbone diaphyses; (6) longitudinal cut marks are commonly associated with surface and subsurface percussion damage and thus suggest localised cleaning prior to marrow cracking; and (7) the clustered distribution of longitudinal cut marks on high utility longbones, taken alongside percussion damage configurations, may indicate
that these were treated in a more standardised fashion than other elements, as observed in the Kalahari (Yellen 1991a).

Having used the modification data to identify the relevant human and nonhuman induced taphonomic variables and preliminarily assess their relative contributions to the formation of the DFM bovid assemblage, in this paper I explore bovid skeletal element abundance and longbone fragmentation (stage two). I then integrate the results of this with the bone modification data and compare subgroups with the goal of developing a taphonomic history of the DFM bovid assemblage (stage three). A key advantage to analyses of this assemblage is that the longbones were mechanically refitted for a study investigating intra-site spatial patterning in bone food refuse (Stewart 2008). As discussed previously (Stewart 2010), refitting can produce very accurate quantitative and qualitative assessments of ungulate assemblage compositions (Marean and Frey 1997; Marean and Kim 1998; Bartram and Marean 1999; Marean et al. 2001). This is important for faunal assemblages that have suffered one or more type of density-mediated attrition and/or are highly fragmented, such as those typical of African Stone Age sites (Klein 1989) including DFM. Extensive bone refitting is often impractical, particularly when used solely as a method of estimating element abundances (cf. Lyman 2008, 228). At DFM refitting was worthwhile because the site is horizontally extensive with sharp spatial resolution in bone (and other) refuse patterning.

DFM: a synopsis

Here I offer only a very brief synopsis of DFM; a fuller overview of the setting and content of the site was provided in the previous paper (Stewart 2010; see also Parkington et al. 1992, 2009; Tonner 2005; Stewart 2008).

DFM is located in a dune system about 0.5 km from the shore of Elands Bay in South Africa’s Western Cape Province (Figure 1). Situated at the base of a Holocene dune cordon, the site has limited stratigraphy and much of the northern portion appears to have been deposited during a single occupational episode dating to cal. AD 1300-1400 (mean = cal. AD 1353 ± 35) (Parkington et al. 1992; Tonner 2002, 2005). Taking advantage of the site’s excellent scope for discerning highly resolved spatial patterning, the excavators employed large horizontal exposures (859 m²) and piece plotting of artefacts. Features are abundant (n = 114) and include hearths, roasting pits, ashy dumps, ash patches, stone-packed hearths, crusted features and small carnivore burials (Parkington et al. 2009). The site is structured into a domestic zone with abundant hearths adjacent to a main dump (Figure 2) with an intervening area of relatively low artefact density.

Artefacts include quartz dominated lithics, manuports, ceramics, ostrich eggshell beads and fragments, bone tools, white mussel (Donax serra) shell scrapers, tortoise carapace bowls, ochre fragments and a single marine shell pendant (Parkington et al. 1992; Orton 2002; Stewart 2005a, b, 2008; Stewart et al. in press). The fauna is numerically dominated by shellfish, with over 2500 kg recovered (Tonner 2002, 2005). Other fauna are also abundant and Richard Klein (pers. comm.) has identified over 10,000 skeletal elements. Besides shellfish, the most numerous taxa are seal, tortoise, small bovid, bird, eland, dassie, fish and other microfauna (Parkington et al. 1992; Woodborne et al. 1995; Tonner 2005; Stynder 2009). Organic materials (including bone) are generally well preserved although botanical remains have been
substantially removed, presumably by wind deflation (cf. Rick 2002). Excavations at DFM ceased in 2001, but post-excavation analyses and publication are ongoing.

Methods
The bovid bone analysis builds on work by Richard Klein (pers. comm.), who identified all the diagnostic DFM macrofauna. A major effort was subsequently
Figure 2. Dunefield Midden: The main dump(s) in relation to the arc of hearths in the domestic zone and the base of the Holocene dune cordon. Note: Total shell weight classes after Tonner 2005, 1394.
made to integrate undiagnostic bone fragments within each bovid bone size class using careful observation and refitting (for methods see Stewart 2010). In this way, the diagnostic (particularly longbone) component of each bovid size class was drastically expanded.

Skeletal element abundance was estimated for all bovid bones by calculating element minimum number of individuals (MNI) (Klein and Cruz-Uribe 1984; Klein 1989). This measurement is preferred here over the minimum number of animal units (MAU) because side and relative age were recorded and these data were taken into account to produce more accurate minimal estimates. Since the focus of the refitting programme was on longbones, I derived element MNIs for longbones differently from non-longbones. As the latter were not mechanically refitted, I used the methodology set out in Klein and Cruz-Uribe (1984) in which minimum numbers of elements (MNE) are calculated by tallying fragments as fractions of complete specimens, with the most abundant side (left or right) then being taken as the MNI. For longbones, the refitting and shaft identification effort allowed me to use conjoins and overlapping landmark features (the manual overlap approach – see Marean et al. 2001) as additional aids to side and age. This technique produces more accurate element MNIs since middle shaft portions are typically included in the estimates (Marean and Spencer 1991; Lam et al. 1998, 1999; Marean and Kim 1998).

A coded system, modifying that used by Gifford and Crader (1977) and Marean and Spencer (1991), was devised to enter the longbone portion represented by a given specimen in the database. Following these researchers, I partitioned longbones into five portions numbered 1 (proximal end) to 5 (distal end) (Stewart 2010, 248). Specimens were assigned either a one or two number code based on the bone portion represented. For example, an isolated proximal end was classified as 1, whereas a proximal end with a shaft splinter the length of which reaches into the middle shaft (portion 3) is classified as 13. A shaft fragment that extends from the middle shaft (portion 3) to the distal shaft (portion 4) is recorded as 34, and so on. This system accommodates fifteen longbone portion combinations, ranging from isolated epiphyseal or diaphyseal fragments to entire bones (Figure 3). It is more flexible and realistic than those that classify longbone fragments as one of the five numbers depending on the longbone portion into which the majority of the fragment falls.

Villa and Mahieu’s (1991) classificatory system for recording breakage patterns on longbones was employed to distinguish green from dry bone breaks. This is based on observations of five attributes of longbone fragments: fracture angle, fracture outline, fracture edge, shaft circumference and shaft fragmentation. Fracture edge, considered an unhelpful attribute by Villa and Mahieu, was not used here. Shaft circumference is a variable used to measure shaft fragmentation and thus is not addressed separately from the latter. Longbone fragments with twisted (helicoidal) longitudinal profiles were also noted, as this is considered a hallmark of green breaks (Potts 1988). Fracture angle, fracture outline and twisted profiles were assessed visually. Shaft circumference and shaft length were measured metrically (as percentages of complete bone) against comparative samples from the Iziko South African Museum mammal osteological collections.
Skeletal element abundance

Here, I summarise skeletal part frequencies before correlating these data against bone completeness and food and marrow utility indices. Estimating skeletal element abundance is central to reconstructing the taphonomic histories of zooarchaeological assemblages. However, a number of controlled actualistic studies demonstrate that density-mediated destruction can impose serious biases on such investigations. Carnivore ravaging coupled with in situ attrition are particularly problematic. The implications of this research should be taken seriously when examining the fauna at DFM, where Cruz-Uribe and Klein (1994) and Stynder (2008) demonstrate that ravaging by canids (dogs or jackals) was extreme on the highly greasy seal bone component. The results of the first stage of this analysis showed that, although less severe, diagnostic carnivore tooth and chew marks also occur on bones of all three bovid size classes under consideration (Stewart 2010, 253). Stage one also showed that evidence of weathering is present on nearly 20% of all bovid longbones, highlighting the possibility that skeletal part frequencies at DFM may also be affected by in situ attrition (Stewart 2010, 253).

Table 1 presents the NISPs, MNEs, element MNIs and element%MNIs for all skeletal elements by bovid size class. The representation of skeletal parts is fairly

Figure 3. Longbone portions coding scheme used for the DFM bovids.
<table>
<thead>
<tr>
<th>Skeletal element</th>
<th>Small Bovid</th>
<th>Small-medium Bovid</th>
<th>Large Bovid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NISP</td>
<td>MNE</td>
<td>MNI</td>
</tr>
<tr>
<td>Cranium</td>
<td>109</td>
<td>82</td>
<td>17</td>
</tr>
<tr>
<td>Mandible</td>
<td>96</td>
<td>58</td>
<td>21</td>
</tr>
<tr>
<td>Atlas</td>
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<td>8</td>
</tr>
<tr>
<td>Axis</td>
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<td>5</td>
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<tr>
<td>Thoracic</td>
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<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Lumbar</td>
<td>25</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Pelvis/sacrum</td>
<td>49</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Ribs</td>
<td>196</td>
<td>126</td>
<td>5</td>
</tr>
<tr>
<td>Scapula</td>
<td>28</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Humerus</td>
<td>56</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Radius/ulna</td>
<td>69/18</td>
<td>22/15</td>
<td>12</td>
</tr>
<tr>
<td>Carpals</td>
<td>10</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Metacarpal</td>
<td>48</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Femur</td>
<td>73</td>
<td>27</td>
<td>16</td>
</tr>
<tr>
<td>Tibia</td>
<td>161</td>
<td>34</td>
<td>17</td>
</tr>
<tr>
<td>Tarsals</td>
<td>17</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>Metatarsal</td>
<td>103</td>
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<td>17</td>
</tr>
<tr>
<td>Astragalus</td>
<td>11</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Calcaneus</td>
<td>11</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>1st phalanx</td>
<td>48</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>2nd phalanx</td>
<td>22</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>3rd phalanx</td>
<td>12</td>
<td>11</td>
<td>2</td>
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</tbody>
</table>
complete for all three size classes with the exception of certain small and small-medium bovid vertebral elements, which are under-represented. Mandibles are the most abundant element in each size class, which is unsurprising since teeth have the highest density of all anatomical elements and mandibular bone is also very dense (Lam et al. 1999). For the same reason, the cranium is also relatively abundant across size classes. Nevertheless, a $G$-test of NISP values yielded significant differences in skeletal part representation between the three bovid size classes ($G = 16.293, p = 0.01$). The small bovids have relatively high numbers of scapulae and pelves compared to the other two, particularly large bovids. Small and small-medium bovid ribs (both around 25%) are proportionately higher than those of large bovids (around 15%). But the biggest differences concern the longbones. Small bovid tibiae and femora are slightly more abundant than small bovid humeri and substantially more than radioulnae and metacarpals. Complementing this pattern of higher hindlimb values are the larger number of small bovid astragali, calcanea and tarsals than carpals. The lower forelimbs of small bovids are thus poorly represented. Large bovid longbones, by contrast, form almost exactly the opposite pattern: humeri and radioulnae far outnumber tibiae and femora. The small-medium bovid longbones are more evenly varied between fore- and hind- as well as upper and lower limbs.

The under-representation of vertebral elements and predominance of crania suggests that density-mediated attrition may have acted upon the bovid assemblages. To test this, DFM bovid longbone portion frequencies are compared against Lam et al.’s (1998, 563) mineral density values for the longbones of domestic goat (Capra hircus). This analysis is restricted to longbones because DFM non-longbone elements were not recorded in a way that allows the correlation of element portion frequencies to Lam et al.’s (1998, 1999) precise CT scan sites. Significant and positive correlations exist between longbone portion mineral density and DFM longbone portion representation for every size class, and thus density-mediated attrition affected each (Table 2). The relationship is especially strong with large bovids ($r_s = 0.71, p < 0.001$), which is consistent with the relatively high incidences of subaerial weathering surface damage recorded on the bones of this size class, as presented in the first stage of this analysis (Stewart 2010, 253). Density-mediated attrition must have been substantially less severe on the smaller bovid size classes since, although significant, the correlations in each case are weak (small bovids: $r_s = 0.47, p = 0.01$; small-medium bovids: $r_s = 0.43; p = 0.05$).

<table>
<thead>
<tr>
<th></th>
<th>Small bovid</th>
<th>Small-medium bovid</th>
<th>Large bovid</th>
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</thead>
<tbody>
<tr>
<td>Spearman’s $r$ longbone portion survivorship vs. density</td>
<td>$r_s = 0.47, p = 0.01$</td>
<td>$r_s = 0.43; p = 0.05$</td>
<td>$r_s = 0.71, p &lt; 0.001$</td>
</tr>
<tr>
<td>Spearman’s $r$ bone survivorship vs. food utility (FUI)</td>
<td>$r_s = 0.32, p = 0.14$</td>
<td>$r_s = -0.36, p = 0.87$</td>
<td>$r_s = -0.18, p = 0.40$</td>
</tr>
<tr>
<td>Spearman’s $r$ bone survivorship vs. unsaturated marrow utility (UMI)</td>
<td>$r_s = 0.91; p &lt; 0.01$</td>
<td>$r_s = 0.63; p = 0.05$</td>
<td>$r_s = 0.73; p = 0.02$</td>
</tr>
</tbody>
</table>
Having established that density-mediated attrition was a factor in assemblage formation, we may ask what processes were responsible for this? Did (most?) attrition occur pre- or post-depositionally? To evaluate this, Marean's (1991) Completeness Index was applied to small bovid compact bones (astragalus, cuneiforms, fibula, lunate, magnum, navicular-cuboids, pisiform, scaphiod, sesamoids, unciform). Marean (1991) has shown that the compact bones of smaller bovid size classes – i.e. Brain's (1981) Bovid Sizes I and II – are well-suited to evaluating post-depositional destruction because these elements are not typically fragmented by carnivores (when eaten, they are swallowed whole) and only rarely by humans (in cases of extreme resource stress, cf. Binford 1978, 164–165). The Completeness Index for DFM small bovid compact bones is 95.3%. Taken alongside the generally excellent, ‘fresh’ condition of the vast majority of the DFM bone assemblage, this suggests preliminarily that in situ attrition at DFM, whether by mechanical or chemical processes, did not bias the representation of bovid skeletal parts. This supposition is tested more robustly below in the analysis of longbone morphological attributes.

To explore whether the patterns of differential limb bone abundance described above result from variable transport decisions, the element%NISPs of each bovid size class are plotted against Metcalfe and Jones's (1988) Complete Bone Food Utility Index (FUI)³. Since there is much evidence to suggest that DFM was a residential campsite (Henshilwood 1990; Parkington et al. 1992, 2009; Reeler 1992; Stewart 2008), it is expected that: (1) primary butchering and differential transport at kill sites would have resulted in the high utility elements being brought back to DFM for consumption (e.g. Binford 1978; Bunn et al. 1988; O'Connell et al. 1988, 1990, 1992; Bartram et al. 1991; Bartram 1993; Kent 1993) and (2) differential transport should only have involved large bovids since wild small bovids are typically transported whole or nearly so to camps by recent African foragers (Silberbauer 1981; Yellen 1991a, b), and sheep are domesticates that were presumably slaughtered, consumed and discarded at residential locales (e.g. Gifford-Gonzalez 1989).

Fig. 4(a–c) shows the %NISP plotted against FUI for all bones of each bovid size class. Correlation tests (Spearman's rank) show that none of the relationships are statistically significant (small bovids: \( r_s = 0.32, p = 0.14 \); small-medium bovids: \( r_s = -0.36, p = 0.87 \); large bovids: \( r_s = -0.18, p = 0.40 \); Table 2), as is typical of food utility curves (Marean and Frey 1997). Nevertheless, the small bovids show a positive slope, the small-medium bovids a neutral slope and the large bovids a negative slope. Although axial bones can bias correlation results due to their susceptibility to density-mediated attrition, separating longbone utility analyses from those of non-longbones (as advocated by Marean and Frey 1997) does little to alter the patterning (Fig. 4d–f). However, this does allow us to examine longbone representation independently. As with the pattern when all bones are included, it seems that the lowest utility longbones – radius/ulna, humerus and metacarpal – of large bovids and the highest utility longbones – tibia, metatarsal and femur – of small bovids are the best represented at DFM. This pattern differs from what we would expect in the scenario offered above; the large bovid assemblage is dominated by elements (whether longbones or non-longbones) with low rather than high food utility, whereas small bovids exhibit the reverse pattern despite the expectation that their elements would be more evenly represented, as is the case with small-medium
Figure 4. Dunefield Midden: NISPs plotted against Metcalf and Jones’s (1988) Food Utility Index (FUI) for each bovid size class.
bovids. These discrepancies between small and large bovid bones are not expected from a ‘typical’ residential campsite if differential treatment for transport was a major factor of assemblage formation. Like in situ attrition, selective transportation of skeletal elements is thus unlikely to have heavily influenced the representation of DFM bovid skeletal elements.

Skeletal part representations are next correlated against marrow utility. Marrow utility often predicts element representation better than food utility, indices of which are heavily dominated by meat weight (Binford 1978; Jones and Metcalfe 1988). Caution is warranted when choosing an appropriate marrow index for application to archaeozoological datasets since the skeletal distribution of marrow in ungulate taxa differs both between and within species depending on a host of variables (Binford 1978; Jones and Metcalfe 1988; Blumenschine and Madrigal 1993; Morin 2007). Unfortunately, however, the single published study providing marrow utility data on a diverse range of African boids focussed only on longbones and gives incomplete data for African large bovid (buffalo) longbone marrow utility (Blumenschine and Madrigal 1993). Further, Morin (2007) has recently shown that marrow indices that incorporate unsaturated fatty acids correlate better to which skeletal parts are selected for marrow processing than those based on marrow quantity alone. Frequencies (NISPs) of marrow-bearing bones of all DFM bovid size classes were thus compared against Morin’s (2007) Unsaturated Marrow Index (UMI). The results, presented in Table 2 and Figure 5, indicate that positive and significant relationships exist in all cases between the representation of marrow-bearing bones and unsaturated marrow values. However, the correlation is considerably stronger for small boids ($r_s = 0.91$; $p < 0.01$) than for large ($r_s = 0.73$; $p = 0.02$) or small-medium ($r_s = 0.63$; $p = 0.05$) boids. Thus, consistent with a number of other African faunal assemblages (Blumenschine 1991; Marshall and Pilgrim 1991), it appears that

![Figure 5. Dunefield Midden: NISPs plotted against Morin’s (2007) Unsaturated Marrow Index (UMI) for each bovid size class.](image)
marrow value is a much better predictor of DFM bovid skeletal part representation than meat value, with small bovids exhibiting a particularly significant relationship.

**Longbone fragmentation**

The above analyses suggest that the frequency of bovid skeletal elements at DFM is dictated more by marrow utility than by *in situ* attrition or selective transport decisions of the site’s occupants. If the DFM bovid bones were thoroughly processed for marrow, it should come as no surprise that the assemblage is heavily fragmented. However, bones can also undergo extensive post-depositional fragmentation from trampling, sediment compaction and chemical diagenesis, and these can mimic human-induced damage. Similarly, carnivores can fracture and modify bone in ways similar to humans since both are attracted to the same nutritional products (meat, marrow and grease) (Marean and Kim 1998).

Fortunately, diagnostic criteria now exist to distinguish human-specific signatures, with hammerstone percussion notches and marks being two of the most reliable (Blumenschine and Selvaggio 1988; Domínguez-Rodrigo 2002; Domínguez-Rodrigo and Barba 2006). However, in most archaeological assemblages these occur in relatively low frequencies (≤ 20%) (Villa and Mahieu 1991; but see also Marean and Kim 1998), with only slightly higher incidences noted on experimental assemblages (Blumenschine 1995; Pickering and Egelund 2006; Galán *et al.* 2009). At DFM, hammerstone percussion damage likewise occurs on only 19.9% of marrow-yielding bovid longbone fragments (Stewart 2010), meaning the mechanisms that fragmented the remaining 80.1% of the assemblage are unknown. The array of taphonomic forces that have been demonstrated to break bone should caution against generalising from one-fifth of an assemblage to explain the formation processes responsible for the whole. Here, therefore, I investigate the causes of DFM bovid longbone fragmentation by analysing longbone fragment morphologies. Villa and Mahieu (1991) have demonstrated that the morphologies of longbone fragments can be used to determine whether a bone broke when fresh (green) or post-depositionally (dry). As outlined above, I use three of Villa and Mahieu’s (1991) five morphological attributes: fracture angle, fracture outline and shaft fragmentation. These are augmented with the presence or absence of twisted profiles (cf. Potts 1988). The results are presented in Table 3 and Figure 6 and 7.

Fracture angles with oblique aspects are considered by many authors characteristic of green bone breaks, while dry bone fractures tend toward right angles (e.g. Morlan 1994; Johnson 1985; Villa and Mahieu 1991). At DFM, the longbones of all bovid size classes are heavily dominated by fragments with oblique angles (Table 3). These account for over 60% in each case, and up to 86.7% in the small-medium bovid assemblage, while fragments with right angles and oblique and right angles (together on the same fragment) never exceed 21%. Right angles and oblique and right angles are highest in the large bovid assemblage (16.7% and 20.3%, respectively), but even here oblique angles predominate (63.4%). Green bone breakage is also strongly associated with curved and V-shaped fracture outlines. At DFM, the relative frequencies of fracture outlines are very similar to those of fracture angles (Table 3): a single attribute state – curved and V-shaped outlines – again characterises over 60% of the longbone fragments in each bovid assemblage. By contrast, transverse and intermediate outlines consistently fall below 20%. Like fracture angles, these rare
attribute states are most abundant among the large bovids, followed by small bovids and then small-medium bovids. The predominance of both oblique fracture angles and curved/V-shaped fracture outlines at DFM therefore heavily implies fresh breakage. Villa and Mahieu (1991) consider shaft fragmentation, which evaluates the relationship between shaft circumference and length, the best attribute for distinguishing green from dry bone breakage. Green breakage produces long and narrow bone splinters (longitudinal diaphyseal splitting), whereas ‘subfossil bone tends to break in short splinters’ (Villa and Mahieu 1991, 43). All bovid shaft fragments at DFM are dominated by splinters (circumference category 1) that are between one-fourth and one-half the length of the original bone (length category 2) (Figure 6). The smaller bovid size classes are very similarly patterned, but exhibit sharp contrasts to their larger counterparts. While sizeable proportions of the longbones of small (32%) and small-medium (31%) bovids are composed of long, narrow shaft fragments (shaft circumference category 1; shaft length categories 3 and 4), the vast majority (76%) of large bovid shafts are shorter splinters between one-fourth and one-half their original length (shaft circumference category 1; shaft length category 2). This suggests that although longbone breakage in all bovid size classes appears to have occurred when fresh (producing splinters over one-fourth their original length), the large bovids clearly underwent more intensive fragmentation. Consistent with higher incidences of surface weathering (Stewart 2010), some of this may have resulted from dry bone breakage.
Like longitudinal diaphyseal splitting, twisted (helicoidal) longbone fragment profiles correlate strongly with green bone breakage (Potts 1988; Villa and Mahieu 1991). In Villa and Mahieu’s (1991) analysis, twisted profiles are especially frequent on long shaft fragments (lengths exceeding three-fourths of the original bone; shaft length category 4). I therefore analysed twisted profile frequency against shaft length (Table 3). The results show that twisted profiles occur on the longest shaft fragments.
across all three bovid size classes. Again, this is consistent with fresh bone breakage (Villa and Mahieu’s 1991, 43). Moreover, their frequency increases consistently with shaft fragment length (Figure 7). This may suggest, first, that the longer a freshly broken shaft fragment is the greater the chance of it being helicoidal, and second, that a positive correlation between length and twisted profile frequency is highly diagnostic of green bone breakage.

Weighing up the evidence for green versus dry longbone breakage for the DFM bovids, the data presented above overwhelmingly support the former. Post-depositional processes can therefore largely be ruled out as a major agent of DFM bovid bone breakage. This leaves two primary causal agents: carnivores (either resident or otherwise) and humans. The relative contributions of each of these agents are thus taken up further in the third stage of this multivariate analysis, to which I now turn.

**Discussion: overall taphonomic variability**

In this final stage of the multivariate analysis, the results of the previous two stages (bone modifications, skeletal element abundance and longbone fragmentation) are summarised and integrated, several further analyses are also conducted to clarify questions that arise, and the DFM data are juxtaposed with those from actualistic and other zooarchaeological investigations to facilitate their interpretation. Special emphasis is placed on comparing the three bovid size classes and on offering explanations for differences and similarities that have been detected.

A key concern for this analysis has been to determine the extent to which natural versus cultural taphonomic agents were responsible for the formation of the DFM bovid bone assemblage. In the first analysis it was shown that, although human induced modifications far outnumber those produced by non-human agents, damage from surface weathering and root etching on the assemblage is considerable. This prompted two further analyses to evaluate the extent of in situ attrition: the Completeness Index for small bovid compact bones and the longbone morphological analysis. The results of both strongly suggest that the majority of the small, small-medium and large bovid bones at DFM broke when fresh. The Completeness Index is higher than that of assemblages that Marean (1991) determined had suffered very little post-depositional destruction. In terms of longbone fragment morphologies, oblique fracture angles and curved/V-shaped fracture outlines are over 60% in each size class, splinters fall under 60% (barely – 58.5%) in only the small-medium bovid assemblage and a number of (particularly long) fragments in all size classes have twisted profiles. The only deviation from this pattern are large bovid shaft lengths, most of which, unlike the smaller bovids, are less than half as long as the shaft before fracturing. This may indicate dry breakage (cf. Villa and Mahieu 1991), but the sheer weight of the other data in favour of fresh breaks implies that behavioural factors were responsible.

The combined data show that post-depositional processes such as sediment compaction and chemical diagenesis very minimally affected DFM bovid bone fragmentation and thus assemblage formation. Nonetheless, there is much evidence to suggest that other forms of density-mediated attrition were active on the DFM bovid assemblage. We have seen that major differences exist within and between the size classes in the representation of both skeletal elements and element portions. Much of this patterning is density-related, with some of the least-represented bones or bone
portions the most likely to have been affected by carnivores or humans. For example, the abundance of small bovid axial bones relative to those of their larger counterparts is unsurprising considering that the large, brittle surface areas of large bovid scapulae and pelves are highly susceptible to trampling, while the glenoid, acetabulum and vertebrae contain sufficient greasy, cancellous tissue to warrant attention by carnivores. The same elements of small bovids may have been less attractive because they are smaller and less spongy. Like scapulae and innominates, the highly spongy and friable large bovid ribs would have presented tempting targets for carnivores, and can also be easily trampled into small particles. That few small bovid vertebrae are present is also to be expected given that these elements are small enough to be swallowed whole by dogs or jackals (Yellen 1991b; Kent 1993) or, indeed, people (Brain 1981, 18). The positive and significant correlation between longbone portion representation and density for each size class suggests that longbone end deletion was also extensive, particularly for large bovids. As expected, the most seriously impacted element portions are proximal humeri, proximal and distal femora and, although sample sizes are problematic, proximal tibias. The small and small-medium bovids show this pattern particularly clearly when frequencies of shaft fragments are plotted against epiphyses (cf. Binford 1981; Todd and Rapson 1988): tibia, femur and humerus shafts are all more abundant than articular ends (Figure 8). Large bovids show an even more extreme pattern of end deletion as only tibiae and metatarsals have higher proportions of epiphyses than shafts.

Density-mediated attrition induced by humans and carnivores is thus likely. Although surface evidence for trampling is slight (2.2% of the entire assemblage), these modifications can easily be confused with cut marks (Behrensmeyer et al. 1986). Their abundance frequency is almost certainly an underestimate. Similarly, only 4% of the total bovid assemblage was shown to exhibit surface and sub-surface modifications diagnostic of carnivore ravaging (Stewart 2010). Carnivore damage is, however, extreme on the seal bone assemblage (Cruz-Uribe and Klein 1994; Stynder 2008) and carnivores are notorious devourers of ungulate cancellous bone, including greasy longbone ends (Binford 1981; Bartram et al. 1991; Marean and Spencer 1991; Kent 1993; Lupo 1995; Egelund 2008). Indeed, actualistic studies by Marean and Spencer (1991), 657) demonstrate that ‘Since carnivore ravaging creates an error in MNE calculation as high as 80%, even slight amounts of ravaging can be significant.’ Like trampling, therefore, carnivores probably had a larger impact than their modification frequencies let on (see too Blumenshine 1988; Hudson 1990). Still, the severity of density-mediated destruction of large bovid axial and longbones raises the question of whether other taphonomic forces were at work. This is discussed further below.

The lack of significant relationships between bovid skeletal part representation and food utility suggests that differential treatment of carcasses for transport did not significantly influence assemblage formation. Grouping elements (MNE) of each size class according to anatomical regions (cf. Stiner 1991, 1994, 2002) reaffirms this. In Figure 9 we see that all anatomical region profiles conform, with varying degrees of closeness, to the pattern of element proportions that occur in the bovid skeleton; that is, to that expected were carcasses typically brought to DFM without substantial preliminary butchering. That small bovids have the closest fit to the expected pattern is consistent with ethnographic accounts of foragers introducing animals in this size range into campsites intact (Silberbauer 1981; Yellen 1991a). But at DFM efforts
were also clearly made to transport most elements of antelopes as large as eland. Although many variables condition the extent to which large carcasses are prepared for transport (Bartram et al. 1991), this at the very least indicates that distances of

Figure 8. Dunefield Midden: frequencies of longbone shaft fragments versus epiphyses for each bovid size class.

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Figure 9. Dunefield Midden: frequencies of small, small-medium and large bovid anatomical regions relative to their expected proportion in a whole animal carcass.
large bovid kill sites from DFM were probably not large. Indeed, these data, together with observations that eland were common in this area historically (Skead 1980), may lend support to Parkington et al.’s (1992, 70) original supposition that the reason for occupying the site may have been ‘the reasonable expectation of killing an eland at a seasonal water pan in the nearby high, active dunefield.’

The bovid longbones, echoing the general picture of skeletal part representation, also correlate poorly with food utility. This is not entirely surprising given that even when carcasses are preliminarily butchered at kill sites, foragers frequently transport all longbones back to camp for marrow processing (except metapodials, which are often cracked and consumed on the spot) (e.g. Kent 1993). However, the under-representation of large bovid high utility longbones and of small bovid low utility longbones runs counter not only to: (1) the pattern expected were foragers returning to DFM with whole small animals and only high utility parts of larger ones; but also to (2) that expected were they field butchering both size classes and returning with all longbones save for metapodials. If not transport, therefore, what can explain this patterning in small versus large bovid longbone frequencies?

One possibility is that, for each size class, different longbones experienced different pre-depositional trajectories of within-bone nutrient extraction by DFM’s inhabitants, resulting in variable degrees of fragmentation (cf. Rapson and Todd 1992). Both of the longbone fragmentation analyses presented in stage two showed consistent differences in breakage patterns between small and small-medium bovids, on the one hand, and large bovids on the other. Large bovid longbones are composed almost entirely of short, narrow fragments, while the smaller size classes have a more even distribution of circumferences and lengths. Since post-depositional breakage can be largely ruled out, an alternative explanation is needed. Numerous researchers working with African Stone Age faunal assemblages observe that large animals are almost always much more fragmented than smaller ones (e.g. Klein 1989; Marean 1991). Although this is frequently related to natural fracture mechanics as a function of size, humans can also generate or contribute to these patterns. At the Pastoral Neolithic site of Ngamuriak in Kenya, for example, the occupants processed cattle longbones much more intensively than those of caprines probably because the bones of larger animals contain more bone grease (Marshall and Pilgrim 1991). This resulted in the greater fragmentation of cattle bones, especially parts with high grease utility, making them at the same time more susceptible to diagenesis and difficult to identify.

More intensive processing of large bovid bones to render grease would also explain why longbone fragments of this size class are consistently short at DFM. Indeed, fragment sizes may be related directly the type of boiling technology used to render bone grease. The presence at DFM of a substantial pottery assemblage that includes reconstructed whole vessels (Stewart 2005a, b, 2008), but only three roasting pits (Parkington et al. 2009), makes it likely that boiling was regularly employed for cooking large mammals. Ethnographic observations of Kalahari campsites show that boiling can profoundly affect the average size of large animal bone fragments because carcasses must be substantially reduced to fit into cooking vessels (e.g. Yellen 1991a, b; Kent 1993; see also Oliver 1993 for similar observations with the Hadza). Indeed, Yellen (1991b, 302–303) notes that the lengths of kudu longbone fragments boiled by the Ju’hoansi are ‘directly related to pot size.’ The possibility that the consistently short lengths of DFM large bovid bone fragments resulted from boiling in ceramic
vessels was tested by checking whether large bovid metapodial fragments are longer on average than other longbones. Since metapodials have by far the lowest grease content of any longbone (Brink 1997; but see Morin 2007) and do not yield meat, they presumably would have been reduced for boiling less often. Of 19 large bovid longbone fragments that span three or more portions, 12 (63%) are metapodial fragments. This might suggest that metapodial fragments were less frequently reduced to ‘pot-sized’ fragments, providing support for the idea that large bovids were typically boiled in pots.

Of course, the dominance of short large bovid longbone splinters does not in itself implicate boiling for bone grease extraction over boiling simply as a cooking method. But the former is also consistent with the broader taphonomic profile of this size class at DFM. First, rendering large bovid bones for grease is consistent with the higher incidences of large bovid bone surface weathering and dry breakage since the susceptibility of bone to post-depositional comminution increases with fragmentation and boiling (Klein 1989; Gifford-Gonzalez 1993; Roberts et al. 2002). Furthermore, the intensified effort at nutrient extraction implied by grease rendering (Binford 1978; Lupo and Schmitt 1997; Saint-Germain 1997; Munro and Bar-Oz 2005) fits well with the presence at DFM of smashed large bovid elements with low marrow utility, including mandibles, compact bones and phalanges (Nilssen 1989). That large bovids experienced the most extensive deletion of longbone ends is also what we would expect were humans targeting skeletal zones richest in cancellous bone in order to maximise grease extraction (cf. Binford 1978; Oliver 1993; Brink 1997; Church and Lyman 2003; Munro and Bar-Oz 2005). Finally, the intensive processing of bone portions after they had been cracked for marrow may also account for why the large bovids correlate least strongly with marrow utility. Taken together with the longbone fragmentation patterns presented above, all of this suggests the large bovids experienced intensive processing, most likely for rendering bone grease. To test this hypothesis, large bovid longbone survivorship was compared against mean percentage grease content of longbone portions (medial, midshaft and distal; Brink 1997) of Plains bison (*Bison bison*). The two variables correlate negatively and significantly (\( r_s = 0.83, p < 0.001 \)), which supports the hypothesis that DFM’s inhabitants were making efforts to extract grease from large bovid bones.

The patterns of small bovid longbone abundance suggest that carcasses of this size class underwent dissimilar processing activities from their larger counterparts. As with the large bovids, the acquisition of within-bone nutrients, rather than meat, appears to have been the principal taphonomic force that structured the assemblage. But whereas the overall taphonomic profile of the large bovid assemblage appears to reflect processing for bone grease, that of the small bovids signals processing for bone marrow. We saw in stage two that small bovid marrow-bearing bones correlate positively and very significantly to unsaturated marrow utility (Morin 2007), exhibiting a much stronger relationship than that for large (or small-medium) bovids. Marshall and Pilgrim (1991, 161) also found a stronger correlation between marrow utility and skeletal part representation for smaller (caprines) than larger bovids (cattle), noting that ‘[Caprine] bones may have been selected for processing of within-bone nutrients, but not broken up as much as cattle bones, perhaps because the focus was on marrow.’
At DFM, the most abundant small bovid longbones are those that comprise the hindlimb – the tibia, femur and metatarsal. These are the most marrow-rich bones in the steenbok/grysbok skeleton. This implies either that: (1) these hindlimb longbones were being preferentially transported to the site; or (2) both hindlimbs and forelimbs were transported to the site but hindlimbs were preferentially (more frequently or intensively) cracked for marrow. In the former case, we should expect major differences in longbone frequencies between hindlimbs and forelimbs, while in the latter we should expect differences not in longbone frequency but rather fragmentation, with the more marrow-rich hindlimbs exhibiting greater fragmentation rates. The first scenario is unlikely because although small bovid hindlimb longbones outnumber forelimbs (see stage two), this difference is insubstantial (MNE all hindlimb longbones = 91; MNE all forelimb longbones = 70). Moreover, ethnographic research shows that even when small bovid carcasses are preliminarily butchered for transport, metapodials are typically detached, cracked for marrow and discarded at the kill site (Silberbauer 1981; Kent 1993); the high frequencies of small bovid metatarsals at DFM militates against preliminary butchery. To test the validity of the second scenario, the fragmentation index (NISP: MNE ratio) of small bovid longbones is correlated against unsaturated marrow utility (UMI) (cf. Bar-Oz and Munro 2004; Munro and Bar-Oz 2005). A positive and significant relationship ($r_s = 0.89, p < 0.05$) was found between these variables, which shows that higher marrow utility elements are indeed more fragmented. This may suggest that, compared to forelimbs, small bovid hindlimb longbones were cracked for marrow either more frequently or intensively.

The possibility that small bovid hindlimbs were preferentially processed for marrow is intriguing since tibiae and femora – the richest marrowbones in the skeleton and two of the most abundant at DFM – also posses the vast majority (> 95%) of longitudinal cut marks. In the first stage of this analysis, I suggested that these bone modifications were probably produced during preparatory cleaning of periosteum to facilitate marrow cracking (cf. Binford 1981) because they are frequently associated with a range of hammerstone damage (Stewart 2010). We also saw that the distribution of hammerstone damage itself is more consistent on tibiae and femora than other longbones. With reference to observations of how the Ju/'hoansi process small bovid longbones for marrow (Yellen 1991a), I made the case that these distinctive patterns may indicate that the site’s inhabitants were processing higher marrow utility longbones in more standardised fashion than others. Together with the possibility that hindlimbs were also preferentially cracked for marrow, this suggests that bones with high marrow yields were treated differently, although why – or precisely what behaviour(s) this implies – is unclear. Exploring this further requires other methods, such as investigating the spatial patterns in bovid bone food-waste, which is outside the scope of this paper.

The latter statement also holds true for obtaining a better sense of the taphonomic processes that shaped the small-medium bovid assemblage. The patterning exhibited by this size class in bone modifications, skeletal element abundance and longbone fragmentation oscillates from intermediate between that of the small and large bovids to more in line with the former. We have seen, for example, that they show a more even representation of skeletal parts than the other two size classes (with an attendant neutral food utility slope), but correspond closely to the small bovids in patterns of longbone fragmentation. This is perhaps not surprising
since we are dealing with a mixture of specimens from wild (*Sylvicapra grimmia*) and
domesticated (*Ovis aries*) taxa; individuals of each of which would presumably have
been treated differently. As with the other two size classes, the fact that they correlate
significantly (albeit weakly) with marrow utility also shows that processing for
within-bone nutrients exerted the greatest influence on assemblage composition.
However, it has been difficult to differentiate genuine taphonomic patterns from
spurious by-products of the small sample size of this bovid size-class (Stewart 2010,
249), and the latter also precludes isolating diagnostic *Ovis* specimens in order to
analyse domesticates separately. Again, a more detailed understanding of the
behavioural inputs that structured the small-medium bovid bone assemblage must
be gleaned from its spatial configurations and patterns of refits (Stewart 2008); for
this, the small assemblage size is an advantage rather than a drawback.

**Conclusion**

A number of insights have emerged from this multivariate analysis into the diverse
and often interlinked formation processes that structured the DFM bovid bone
assemblage. Despite relatively substantial root etching and weathering, a range of
tests demonstrates that post-depositional destruction of bone was insignificant.
Carnivore ravaging and trampling are both implicated, but much more marked
discrepancies between the subgroups result from size-related differences in carcass
processing. The greater abundance of disarticulation cut marks on large bovid
longbone epiphyses probably reflects increased energy expenditure required to
butcher animals of this size. Large bovid longbones are also more fragmented, and
have more uniform fragment lengths, than their smaller counterparts. There are
strong indications that this resulted mainly from enhanced breakage of cancellous
bone-rich elements and element portions to render grease by boiling in ceramic
vessels.\(^4\) Marrow extraction, rather than bone grease rendering, appears to have been
the principal force that conditioned the small bovid assemblage. The clustering of
longitudinal marks and the consistent patterns of breakage on small bovid hindlimb
longbones is particularly striking since these elements are more abundant, marrow-
rich and heavily fragmented than forelimbs. Their high marrow yields may have
encouraged the preferential targeting and standardised processing of hindlimbs,
although the precise behaviour(s) this implies is not well understood.\(^5\)

The wild bovids acquired by DFM’s hunters would have been attracted to Elands
Bay’s ample fresh water supply, including the Verlorenvlei and perhaps also nearby
seasonal water pans in the coastal dune system. Both resources would have also been
important for watering domestic stock, whether herded on a low-intensity basis
(Sadr 1998, 2003; Stewart 2008) or stolen from more dedicated pastoralists in the
landscape (Nilssen 1989; Parkington *et al.* 1992). The patterns of large bovid element
representation, which show whole eland carcasses were brought to the site, may
suggest the nearby presence of these animals provided incentive to camp at the dunes.
But the bovids, though important, were only one component of a diverse terrestrial
and marine diet that the immediate area provided. Also hunted or collected were a
host of smaller mammals (Parkington and Fisher 2006; Stewart 2010), reptiles
(Stewart *et al.* in press), fish and birds (Parkington *et al.* 1992) A walk to the beach
and reefs half a kilometre west to or to Baboon Point two kilometres south also
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DFM seal assemblage (MNI = 83) which, together with the standardised nature of the lithics (Orton 2002) and seasonality data from seal mandibles (Woodbourne et al. 1995), might suggest that one or more of the DFM occupations was geared towards exploiting the seasonal wash-up of drowned seal pups (Stewart 2008). The presence at DFM of the whale barnacle, *Coromula diadema*, also shows that the inhabitants took advantage of at least one washed-up or stranded whale (Parkington 2006).

Indeed, DFM appears to have been optimally placed to take advantage of a wide range of subsistence resources within short distances. The site’s broad spectrum of food remains and shellfish composition, which closely parallels that of the local shoreline (Tonner 2005), suggests that the subsistence strategy practised by the DFM occupants was opportunistic. This appears to have been typical of foragers living in the western Cape during the first half of the second millennium AD, as recently argued by Jerardino et al. (2009). These authors point to a number of broadly contemporaneous sites with faunal inventories similar to DFM containing variable mixes of local terrestrial and marine taxa depending on distance from the coast. These sites include Borrow Pit Midden (Jerardino et al. 2009), Elands Bay Cave (Klein and Cruz-Uribre 1987; Parkington et al. 1988), Elands Bay Open (Horwitz 1979), Grootdrif G (Jerardino 2007), Hailstone Midden (Noli 1988), Pancho’s Kitchen Midden (Jerardino 1996, 1998) and Tortoise Cave (Robey 1987; Jerardino 1996). Alongside DFM, these sites and others contribute to an increasingly coherent reconstruction of late Holocene lifeways in the region.

What sets DFM apart are the opportunities it affords for investigating in-depth the formation processes of the assemblages upon which such reconstructions are based. This is because DFM’s assemblages were recovered with precision from the near entirety of a briefly occupied prehistoric campsite, bringing us closer to the people that generated them. In the case of the bovid bones, the systematic inclusion of shaft fragments into the analytical sample through refitting and the isolation of significant taphonomic agents by interrogating multiple variables permitted a detailed, accurate reconstruction of carcass processing behaviours. Future efforts will go towards investigating the spatial correlates of these behaviours, with the ultimate aim of comprehensively reconstructing on-site subsistence and hopefully social organisation at this exceptional LSA site.

Acknowledgements
I thank John Parkington and Judy Sealy of the University of Cape Town’s Department of Archaeology for making the DFM materials accessible and for such warm hospitality during my time there. Delores Jacobs dedicated immense time and effort helping me refit DFM bones and other materials, for which I am hugely grateful. Peter Mitchell, Genevieve Dewar and Jack Fisher provided guidance and advice. Peter Nilssen and Richard Klein generously made their data available. I thank Chris Stimpson for providing statistical advice and Guillaume Porraz for translating the abstract into French. I am also grateful to Oxford University Press, St Hugh’s College and the University of Oxford African Studies Centre for funding.

Notes
1. The recent results of a DNA analysis (Horsburgh 2008) showing that the canid bones from the site are jackals rather than dogs, though interesting, do not preclude the presence of dogs, but rather may simply mean none died during the occupation.
2. Small-medium bovids are excluded from this analysis because compact bones of this size class are extremely rare at DFM.

3. To ensure statistical reliability, NISPs rather than element MNIs were used when correlating skeletal element representations with food and marrow utility indices. This not only increases sample sizes, but also reduces the number of tied observations, which are detrimental to obtaining reliable rank correlation coefficients (Spearman’s rho).

4. This has significant implications for interpreting differences in bone fragmentation rates of large taxa in faunal assemblages dating to before and after the introduction of pottery to the subcontinent roughly 2000 years ago.

5. One possibility is that these elements were ‘gang processed’ for marrow (cf. Binford 1981, 158–163), which may have occurred if multiple small bovid individuals were hunted (snared?) at the same time or over a short period.

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