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*NUMBER 2*

*Series Editors Kathy Schick and Nicholas Toth*

# BREATHING LIFE INTO FOSSILS:

## Taphonomic Studies in Honor of C.K. (Bob) Brain

*Editors*

**Travis Rayne Pickering**
University of Wisconsin, Madison

**Kathy Schick**
Indiana University

**Nicholas Toth**
Indiana University

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*COVER CAPTIONS AND CREDITS.*

*Front cover, clockwise from top left.*

*Top left:*
*Artist's reconstruction of the depositional context of Swartkrans Cave, South Africa, with a leopard consuming a hominid carcass in a tree outside the cave: bones would subsequently wash into the cave and be incorporated in the breccia deposits. © 1985 Jay H. Matternes.*

*Top right: The Swartkrans cave deposits in South Africa, where excavations have yielded many hominids and other animal fossils. ©1985 David L. Brill.*

*Bottom right: Reconstruction of a hominid being carried by a leopard. © 1985 Jay H. Matternes.*

*Bottom left: Photograph of a leopard mandible and the skull cap of a hominid from Swartkrans, with the leopard's canines juxtaposed with puncture marks likely produced by a leopard carrying its hominid prey. © 1985 David L. Brill.*

*Center: Photo of Bob Brain holding a cast of a spotted hyena skull signed by all of the taphonomy conference participants. © 2004 Kathy Schick, Stone Age Institute.*

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# CHAPTER 5

# TAPHONOMIC ANALYSIS OF AN EXCAVATED STRIPED HYENA DEN FROM THE EASTERN DESERT OF JORDAN

KATHY SCHICK, NICHOLAS TOTH, THOMAS GEHLING AND TRAVIS RAYNE PICKERING

## ABSTRACT

A recent striped hyena den was excavated in the eastern desert of Jordan to examine taphonomic patterning in the bone assemblage. A total of 4,847 specimens of bones and teeth was recovered from a 16 $m^2$ excavation, with the majority of these (94.7%) buried to a depth of up to 20 cm. While large and even complete bones dominated the surface assemblage, the buried assemblage also contained very large numbers of smaller bones and bone fragments. Taxonomically, the assemblage is composed predominantly of camel, dog, sheep/goat, and gazelle, but also contains donkey, human, horse, fox, stork, hare, hedgehog, other bird, oryx, hyena, honey badger, and snake remains. A minimum number of 54 individuals was represented at the site (26% of which are carnivores), with 510 specimens identifiable to both element and taxonomic group. It is likely that many of the smaller animals could have been introduced to the den as more complete carcasses, while larger animals were likely transported as body parts such as limbs and skulls. The assemblage and its modification (toothmarks and breakage patterns) are consistent with hyena accumulation and consumption, with very little evidence of human or rodent modification. Also examined were the effects of differential bone weathering on toothmark frequencies and fracture patterning. Of special interest is the high degree of fragmentation of limb bones, similar to the patterns seen at many Plio-Pleistocene archaeological sites. This analysis adds to the comparative database of hyena bone accumulations and their taphonomic patterning to aid in interpreting prehistoric faunal assemblages.

## INTRODUCTION

Bob Brain's contributions to taphonomy, human origins studies, and natural history have inspired a generation of researchers, including ourselves. His seminal book, *The Hunters or the Hunted* (1981) was the catalyst that made two of us (K.S. and N.T.) go to Jordan and excavate a recent striped hyena den in the eastern desert. We modeled our methodology after Brain's analysis of the taphonomic patterns at Sterkfontein, Swartkrans and Kromdraai, as well as his studies of modern bone accumulations at locales such as brown hyena dens and Hottentot camps.

Over the past few decades, a sizeable database has been compiled by researchers investigating patterns of bone accumulation and modification by modern and recent hyenas, as well as considering the possible role of hyenas in collecting and modifying bone assemblages in the prehistoric past (e.g., Binford, 1981; Brain, 1981; Bunn, 1982, 1983; Cruz-Uribe, 1991; Henschel et al., 1979; Hill, 1989; Horwitz and Smith, 1988; Hughes, 1954; Kerbis-Peterhans and Horwitz, 1992; Klein, 1975; Kuhn, 2005; Lacruz and Maude, 2005; Leakey et al., 1999; Maguire et al., 1980; Mills and Mills, 1977; Owens and Owens, 1979; Pickering, 2002; Scott and Klein, 1981; Skinner et al., 1980; Skinner et al., 1986; Skinner et al., 1998; Stiner, 1991; Sutcliffe, 1970). Bone collecting activities have now been well documented among all three living species. Although there are some notable differences among hyena species, particularly between, on the one hand, the striped hyena (*Hyaena hyaena*) and the brown hyena (*Parahyaena brunea*), and, on the other hand, the spotted hyena (*Crocuta crocuta*), as to their bone transporting activities and the nature of the bone

accumulations they produce, all three species have now been well documented as veritable bone collectors, particularly in situations involving provisioning of young.

Hyenas are of particular interest to the archaeologist since they are one of a select group of species, including humans and porcupines, which sometimes collect large quantities of bones at specific locations over time. The striped hyena (Figures 1 and 2), is especially interesting in view of its possible role in the formation of the Plio-Pleistocene bone assemblages at Makapansgat in South Africa (Brain, 1981). A fossil subspecies of this form *H. hyaena makapani* is known from the Makapansgat site (Toerian, 1952) and has been implicated as a likely source of the faunal accumulations there (Maquire et al., 1980).

This study provides detailed information about a large bone accumulation at a striped hyena den in Jordan that was excavated in order to retrieve detailed taphonomic and comparative information for use in paleoanthropological studies. Surface collection, excavation, and screening of sediment from a substantial portion of the den provided a large bone sample subsequently subjected to detailed taxonomic and taphonomic analysis.

The faunal sample retrieved from this hyena den is especially valuable for paleoanthropological purposes in that a substantial portion of the den was excavated and sieved. Thus, the excavated materials include a good proportion of bone fragments often not retrieved in high numbers in surface collections. In addition, differential weathering (and thus potential for fossilization and modification traces) was observable in the surface versus the buried bone sample, and the buried bone in particular provides a sample well-suited for study of bone fragmentation and surface modification.

*Figure 1. A nineteenth century representation of a striped hyena. ("Striped Hyena," aquatint by W. Daniell, from Wood, 1807).*

*Figure 2. A modern striped hyena during a zoo bone-feeding experiment.*

## The Umari Den

### History

The Umari hyena den was discovered in 1984 by a paleoanthropolocial reconnaissance team searching for fossiliferous sediments. The den is located in the eastern desert of Jordan near the Saudi Arabian border, approximately 45 km southeast of the town of Azraq and six km east of the village of Umari (Figure 3). The team (and their affiliations at the time) included archaeologist Mujahed Meheissen (Yarmouk University), paleoanthropologists Donald Johanson (Institute of Human Origins) and Tim White (University of California at Berkeley), and geologist Robert Drake (University of California at Berkeley). The following year, two of the authors (N.T. and K.S.) undertook excavations of the den site and obtained an extensive excavated sample of faunal material from the den accumulation. Subsequent analysis has provided information regarding the faunal remains represented at the site.

The den was no longer active by the time of its discovery. Of environmental importance in the area is a permanent spring located at Azraq 45 km to the northwest. Historically, recent wild fauna of the region include oryx, gazelle, ass, ostrich, lion, leopard, cheetah, hyena, wolf, jackal, and fox. Although hyenas have reportedly been quite widespread over the Arabian peninsula (except in the interior deserts) in the past, and apparently plentiful as recently as the 1960s, they, along with other wild animals such as oryx and gazelle, appear to have become rare or absent in the

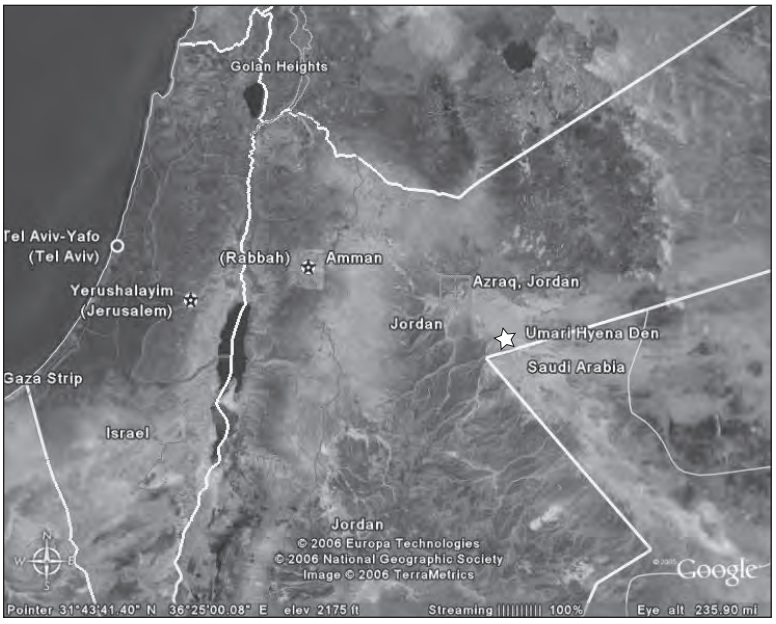


*Figure 3. Map showing the location of the Umari striped hyena den in the eastern desert of Jordan, near the Saudi border.*

eastern desert in recent times (although the oryx has been reintroduced in the region during the past two decades).

## Location

The area in which the Umari den is located is today a sparsely vegetated desert, characterized by flat, flint-paved surfaces and badlands topography where erosion has exposed Miocene marine sediments, creating a network of small escarpments and gullies. The faunal remains were recovered from the surface and buried within up to 20 cm of soft sediment derived from limestone weathering. Due to the unconsolidated nature of the sediment, the lack of identifiable strata, and the visible bioturbation from small animal burrows, this assemblage was considered as one horizon.

The den is situated on a small ridge overlooking a wadi cutting through Miocene limestones (Figures 4–11). A rock layer at the base of the ridge is composed of a less consolidated limestone which has been undercut in many areas along the outcrop, leaving overhangs of the harder, more consolidated limestone. Several narrow, shallow tunnels, too small for most human adults to crawl through, have also been cut or dissolved into the softer limestone layer at the base of the outcrop. Some of these interconnect and some cut all the way through the outcrop to exit on the opposite side of the ridge, steeply overlooking a small wadi. This system of tunnels and overhangs, as well as the gently sloping terrace in front of the den, provides shade, a degree of safety, and an excellent view of the desert plains to the south. The bones had accumulated primarily on the terrace directly in front of the tunnel openings, with very few present within the small tunnels themselves.

The sediment in which the bones were found constitutes erosional residues from the limestones forming the den's rock overhangs and tunnels. This sediment, essentially limestone "flour," was not hard and would be unlikely to produce natural striations on bones that might be interpreted as toothmarks or cutmarks.

## Excavation and Recovery

Bones were subaerially exposed over a total area of approximately 80 $m^2$ but were concentrated especially on the terrace in front of the rock outcrop and, secondarily, on the slope leading down to the nearby wadi. A 16 $m^2$ area was gridded in 2 m × 2 m squares within the region of densest accumulation directly in front of the rock outcrop. Approximately 10% of the den accumulation was excavated in terms of total extent of surface bone, but as the excavation selectively sampled the denser areas of the deposit, it retrieved an estimated 30% of the total surface deposit (in terms of counts of surface bone and bone fragments). As bone burial appeared to be concentrated within the excavation in close proximity to the outcrop face and near the major tunnel entrances, and this area was fully excavated, the excavated sample is estimated to represent minimally 30%, and likely nearly 50% or more, of the buried bone.

*Figure 4. The location of the Umari hyena den from a distance. The arrow shows the location of the den within residual sedimentary outcrops in the Jordanian desert.*

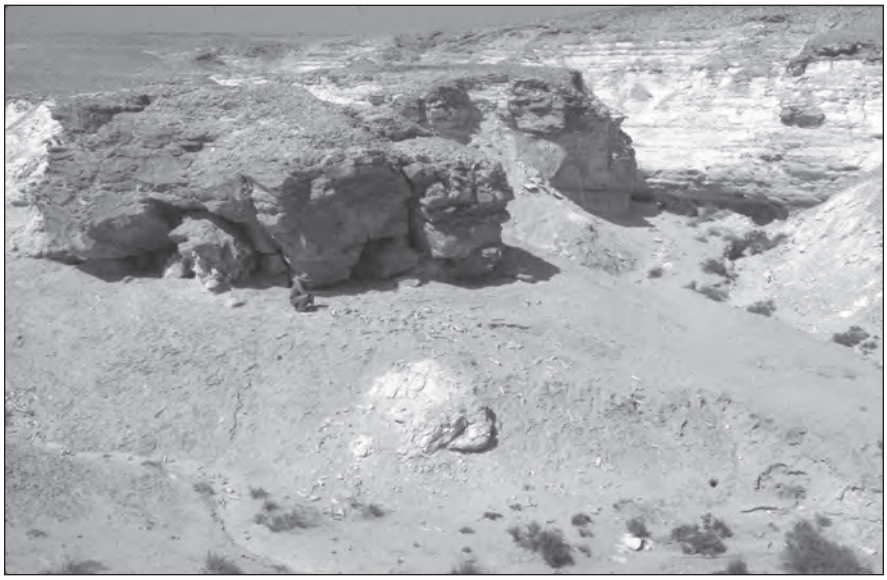

*Figure 5. The limestone outcrop at the den location. Bones were concentrated on the apron in front of the outcrop (in the foreground), with highest densities near the openings of the tunnels.*

*Figure 6. The limestone outcrop with bones scattered across the apron and some extending down the slope toward the adjacent wadi.*

*Figure 7. Surface scatter of bones in front of the limestone outcrop.*

Within each 2 m × 2 m grid unit, the surface bone was plotted and picked up. The underlying sediment was then excavated to the maximum extent of bone burial (up to 20 cm below the surface), the buried bone retrieved, and the sedimentary matrix passed through a 5 mm mesh screen, retrieving small bone and tooth fragments, scat, and other organic materials. (Curiously, scattered over a wide area of the den outside of the excavation were a number of complete and even mummified dog skulls; these were collected but are not part of the formal analysis here of the assemblage from the excavated area.)

The highest density of bones and hyena droppings was not directly under the rock overhangs or in the tunnels, but rather on the broad, flat terrace in front of the limestone outcrop and above the nearby wadi (Figure 11). The density of faunal remains visible on the surface varied along the terrace, with highest densities somewhat closer to the outcrop and to the main tunnel entrances, but as there was no other obvious spatial patterning of surface materials, the excavated sample is here considered as representative of the overall composition of the den assemblage.

## The Bone Sample

A sample of 4,847 bones, bone fragments, and isolated teeth/tooth fragments was recovered from the 16 $m^2$ excavated area. Of these, only 189 specimens were exposed on the surface (3.9 % of the sample), while the remaining 4,658 specimens (96.1%) were buried within the sediment. The surface and buried faunal materials from the 16 $m^2$ excavated area were examined for the purpose of taxonomic and element identification, as well as to identify patterns of modification, including tooth marks, breakage, and weathering stages. The

*Figure 8. View from top of the outcrop showing distribution of exposed bones.*

analysis presented here includes all of the faunal materials from the excavated area, both the small surface sample and the large proportion of buried remains.

This analysis was designed to compare and contrast the Umari hyena den with the taphonomic patterns presented by C.K. Brain in *The Hunters or the Hunted* volume published in 1981. For this reason, levels of element identifiability were comparable to those Brain employed in that classic study.

## Weathering and element fragmentation

It should be noted that the surface and excavated samples from the excavated area show some very important differences. The surface materials overall are more extensive weathered than the buried sample, and consist of relatively larger, even many complete, bones. The excavated sample is overall more highly fragmented and less readily assigned to taxonomic group. While over half (50.3%) of the surface bones are identified to taxon, only a small portion (8.9%) of the buried sample is identifiable. It is probably that larger bones have a greater tendency to "ride high" as animals moving back and forth would be prone to kick them up and help them escape burial, while smaller and more fragmentary bones and teeth would tend to be incorporated into the sediment more readily.

The degree of weathering evident varies greatly among the bones and appears to be a function of the amount of time the bones were exposed to sunlight and the elements. In effect there were two weathering gradients: bones further from the rock outcrop tend to be more heavily weathered, and, as noted above, the surface sample is more heavily weathered than the buried

*Figure 9. Close-up of surface bones. Note the prominence of large limb bones and the advanced degree of weathering of many of the surface materials.*

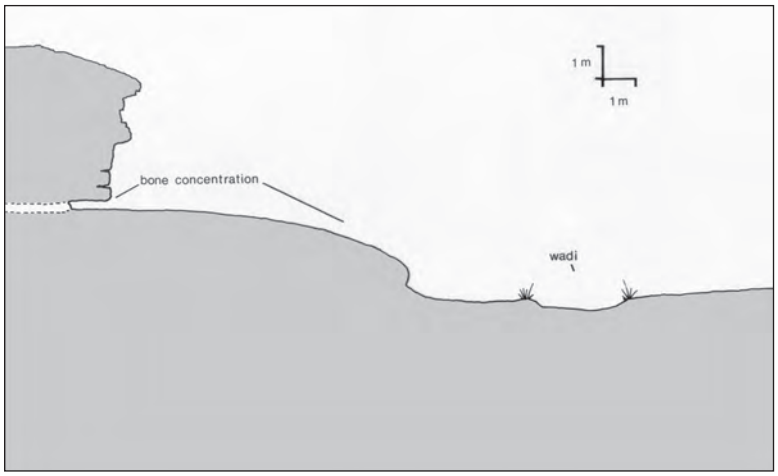


*Figure 10. Cross-section of the major topographic features at the hyena den. The major concentration of bones stretched from in front of the rock outcrop several meters toward the erosion slope above the wadi, with the bones closer to the wadi more highly weathered.*

sample. Bones under the rock overhang in the tunnels are best preserved, sometimes with dried tissue still attached.

The differential weathering of the surface and buried samples likely reflects the differences in rapidity of burial and relative exposure to the elements: the larger bones were more identifiable to taxon, less likely to be buried, and thus more prone to weathering; the smaller bones and bone fragments were less identifiable but more readily buried and hence less vulnerable to weathering processes. As a result, a final assemblage that might become fossilized over time in such circumstances would likely be the more heavily fragmented and less identifiable portion of the faunal assemblage originally present.

## Taxonomic composition

At least 16 different taxonomic groups are represented, with a minimum number of 54 individuals (Table 1 and Figure 12). Taxa present include both wild and domestic animals of the region from modern or recent

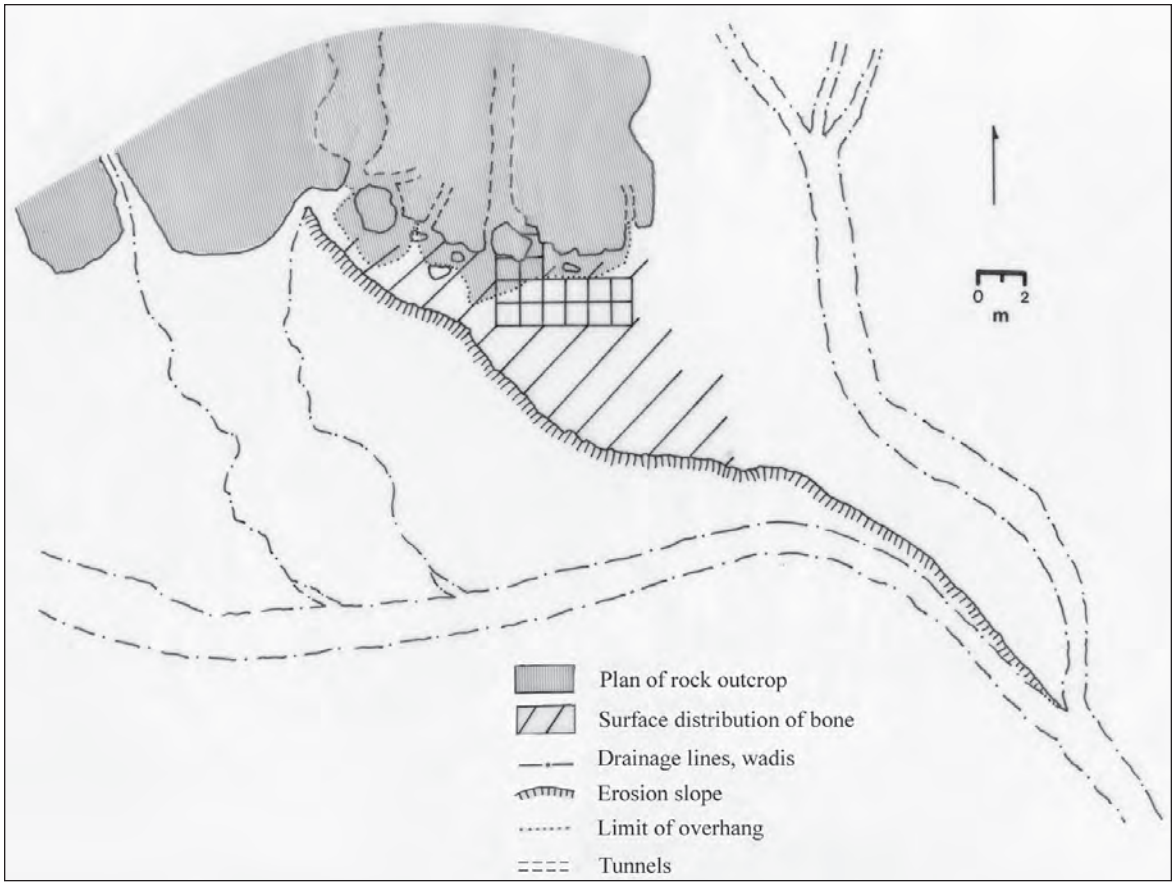


*Figure 11. Plan view of the hyena den showing the extent of surface distribution of bones and the 16-$m^2$ excavation grid (extending under the rock overhang in its northwest corner). Bone recovery was complete from within this 16 $m^2$ area, with the majority of the recovered bone (96.1%) buried and only 3.9% exposed on the surface.*

*Table 1. Taxa represented at the Umari striped hyena den, showing NISP (number of identifiable specimens), MNI (minimum number of individuals), and the NISP/MNI ratio for each taxonomic group*

| Taxon | NISP | | MNI | | NISP/MNI |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Camel *(Camelus dromedarius)* | 201 | 39.4 | 10 | 18.5 | 20.1 |
| Horse *(Equus caballus)* | 4 | 0.8 | 2 | 3.7 | 2.0 |
| Donkey *(Equus asinus)* | 20 | 3.9 | 3 | 5.6 | 6.7 |
| Oryx *(Oryx leucoryx)* | 1 | 0.2 | 1 | 1.9 | 1.0 |
| Gazelle *(Gazella dorcas)* | 52 | 10.2 | 6 | 11.1 | 8.7 |
| Human *(Homo sapiens)* | 13 | 2.5 | 3 | 5.6 | 4.0 |
| Hyena *(Hyaena hyaena)* | 1 | 0.2 | 1 | 1.9 | 1.0 |
| Goat/sheep *(Capra hircus/Ovis aries)* | 41 | 8.0 | 6 | 11.1 | 6.8 |
| Dog *(Canis familiaris)* | 151 | 29.6 | 10 | 18.5 | 15.1 |
| Honey Badger *(Mellivora capensis)* | 1 | 0.2 | 1 | 1.9 | 1.0 |
| Fox *(Vulpes sp.)* | 7 | 1.4 | 2 | 3.7 | 3.5 |
| Stork *(Ciconia* sp.*)* | 5 | 1.0 | 2 | 3.7 | 2.5 |
| Hare (Lagomorpha) | 8 | 1.6 | 2 | 3.7 | 4.0 |
| Hedgehog (Erinaceidae) | 2 | 0.4 | 2 | 3.7 | 1.0 |
| Bird indet. (Aves indet.) | 2 | 0.4 | 2 | 3.7 | 1.0 |
| Snake (Reptilia indet.) | 1 | 0.2 | 1 | 1.9 | 1.0 |
| **TOTAL** | 510 | 100 | 54 | 100 | |

times. They likely include remains scavenged by hyenas from death sites, as well as smaller animals that may have been preyed upon by the hyenas, and subsequently transported by hyenas to the den location. The most abundant taxa are camel, dog, goat/sheep, and gazelle. Other taxa include donkey, human, horse, fox, stork, hare, hedgehog, other birds, hyena, honey badger, and snake.

It is likely that animals of Group Size 1 (less than 50 pounds) could have been transported to the den as complete carcasses, while the larger animals were likely transported in as body parts (limb portions, crania and mandibles). (Two fossil Miocene shark teeth were recovered in the excavation, clearly eroded out of the limestone bedrock are not contemporaneous with the rest of the faunal sample, and are not considered in this study.)

The MNI (minimum number of individuals) of each taxonomic group in the excavated den assemblage, by descending body size (for animal size groups, see Brain, 1981; Bunn, 1982), are:

1. Animal Size Group 4 (750-2000 lbs)
   a) Camel (MNI=10)
   b) Horse (MNI=2)
2. Animal Size Group 3 (250-750 lbs)
   a) Donkey (MNI=3)
   b) Oryx (MNI=1)
3. Animal Size Group 2 (50-250 lbs)
   a) Human (MNI=3)
   b) Gazelle (MNI=6)
   c) Hyena (MNI=1)
   d) Goat/sheep (MNI=6)
4. Animal Size Group 1 (less than 50 lbs)
   a) Dog (MNI=10)
   b) Honey badger (MNI=1)
   c) Fox (MNI=2)
   d) Stork (MNI=2)
   e) Hare (MNI=2)
   f) Hedgehog (MNI=2)
   g) Other bird (MNI=2)
   h) Snake (MNI=1)

Camels and dogs have by far the best MNI representation (at least 10 individuals each), while camels are best represented in terms of number of identifiable specimens (NISP=201). Moderately high numbers of bovids (six goats/sheep and six gazelle) and equids (two horses and three donkeys) are also present in the sample. Carnivores overall are relatively well represented, with a minimum of four individuals present in addition to the dogs, including two foxes, a hyena, and a honey badger. The overall taxonomic composition of the Umari den is

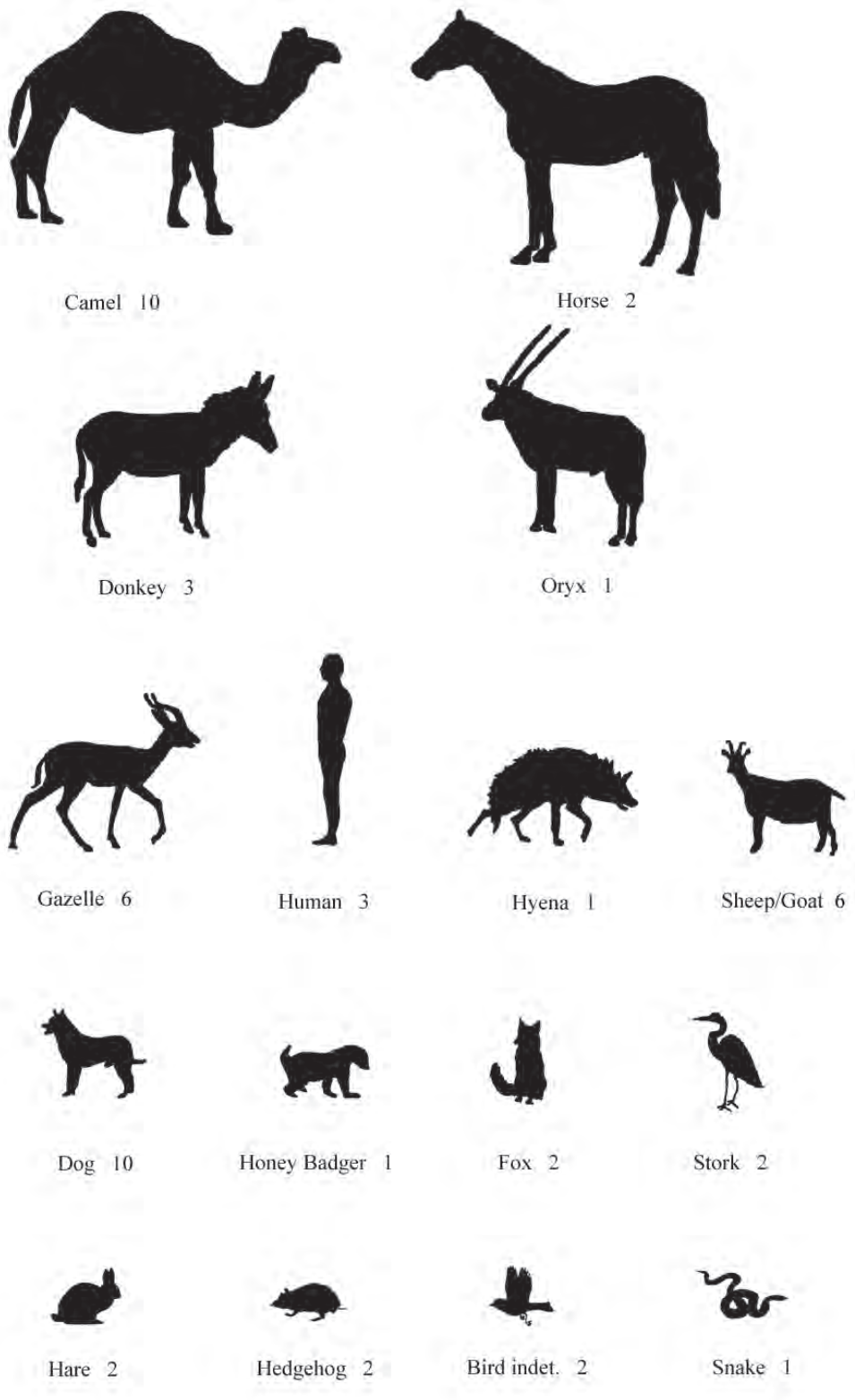


*Figure 12. The sixteen taxonomic groups represented in the Umari den excavation, showing MNI for each. The dominant taxa in terms of MNI and NISP are camel and dog.*

broadly similar to the striped hyena dens elsewhere in the region reported by Skinner et al. (1980), Kerbis-Peterhans and Horwitz (1992), and Kuhn (2005), although the proportion of wild animals included varies somewhat, probably according to differing ecological conditions and effects of human settlement and activities in each locale at the time of active den formation.

*Table 2. The Umari hyena den faunal assemblage broken down by general body part, showing the relative proportions of each body part that were identifiable to taxon and nonidentifiable to taxon*

| Body Part | Total (ID and non-ID to taxon) | | Non-ID to taxon | | ID to taxon | | | |
|---|---|---|---|---|---|---|---|---|
| | n | % assem-blage | n | % assem-blage | n | % body part | % ID | % assem-blage |
| **Skull parts (inc. isolated teeth and tooth fragments)[1]** | 1665 | 34.4 | 1454 | 30.0 | 211 | 12.7 | 41.4 | 4.4 |
| **Vertebrae** | 46 | 0.9 | 18 | 0.4 | 28 | 60.9 | 5.5 | 0.6 |
| **Ribs** | 152 | 3.1 | 140 | 2.9 | 12 | 7.9 | 2.4 | 0.2 |
| **Pelves/Scapulae** | 21 | 0.4 | 0 | 0.0 | 21 | 100.0 | 4.1 | 0.4 |
| **Complete Limbs[2]** | 26 | 0.5 | 0 | 0.0 | 26 | 100.0 | 5.1 | 0.5 |
| **Limb Ends[2]** | 83 | 1.7 | 0 | 0.0 | 83 | 100.0 | 16.2 | 1.7 |
| **Limb Shafts[2]** | 1404 | 29.0 | 1359 | 28.0 | 45 | 3.2 | 8.8 | 0.9 |
| **Manus/Pes** | 92 | 1.9 | 8 | 0.2 | 84 | 91.3 | 16.5 | 1.7 |
| **Subtotal** | 3489 | 72.0 | 2979 | 61.4 | 510 | | 100.0 | 10.5 |
| **Other Fragments** | 1358 | 28.0 | 1358 | 28.0 | 0 | | 0.0 | 0.0 |
| **Total** | 4847 | 100.0 | 4337 | 89.5 | 510 | | 100.0 | 10.5 |

*[1]Includes 1247 tooth fragments*
*[2]Limb counts include ungulate metapodials*

## General body part representation

The overall breakdown of the Umari den faunal assemblage by general body part is presented in Table 2. Of the 510 elements that were identified to taxon (10.5% of the entire assemblage), the greatest proportion of these consisted of cranial elements and teeth (41.5% of the identified specimens), with limb epiphyses and foot bones (manus and pes) also well represented among the taxonomically identifiable specimens. The specimens not taxonomically identifiable consisted largely of cranial and tooth fragments (30% of the assemblage), limb shaft fragments (28% of the assemblage), and other bone fragments (28% of the assemblage).

## Element representation

Table 3 and Figure 13 show the elements represented for the three major animal groups: camel, small bovid (sheep/goat and gazelle combined), and dog. For camel, the best represented elements are the tibia, mandible, metacarpal, and calcaneus. For the small bovids, the best represented elements are the mandible, maxilla, cranium/horn core, and tibia. For dog, the best represented elements are the mandible, maxilla, and cranium. Element representation (relative to MNI) is, of course, a function of both hyena transport and preferential destruction/survival of elements. The smaller animals are especially well-represented by head elements (mandible, maxilla, and identifiable cranial fragments), while the camel has good representation not only of some head elements (especially mandibles) but also of many of the larger and/or denser limb elements such as the tibia, metacarpal, calcaneus, metatarsal, astragalus and radius-ulna.

A camel death site was discovered a few kilometers from the hyena den (Figure 14) that had apparently been ravaged by carnivores, probably hyenas, with some parts of the body removed or destroyed. The remaining skeleton was dominated by axial elements (cranium, vertebrae, ribs, pelvis), but only one limb was present (presumably this limb had been underneath the carcass and harder for carnivores to access). Interestingly, the elements represented at this ravaged death site (with the exception of this one forelimb) generally had an inverse relation to the camel elements that were present at the hyena den (Figures 15 and 16). Figures 15 and 17 show the preferential element representation for the three major taxonomic groups at the den: camels, dogs, and small bovids.

## Cranial/postcranial ratios

Table 4 shows the cranial/postcranial ratios for each of the taxonomic groups found at the Urami hyena den. As can be seen, overall small animals have a much higher cranial/postcranial ratio (0.68) than do larger animals (0.19). Since it is more likely that smaller animals could have been transported by hyenas as complete carcasses to the den, while large animals were probably transported especially as disarticulated body parts, especially limbs and mandibles, the lower proportion of postcrania among small animals is probably partially due to greater destruction of identifiable limb ends and more extensive breakage of small animal limb shafts into unidentifiable fragments.

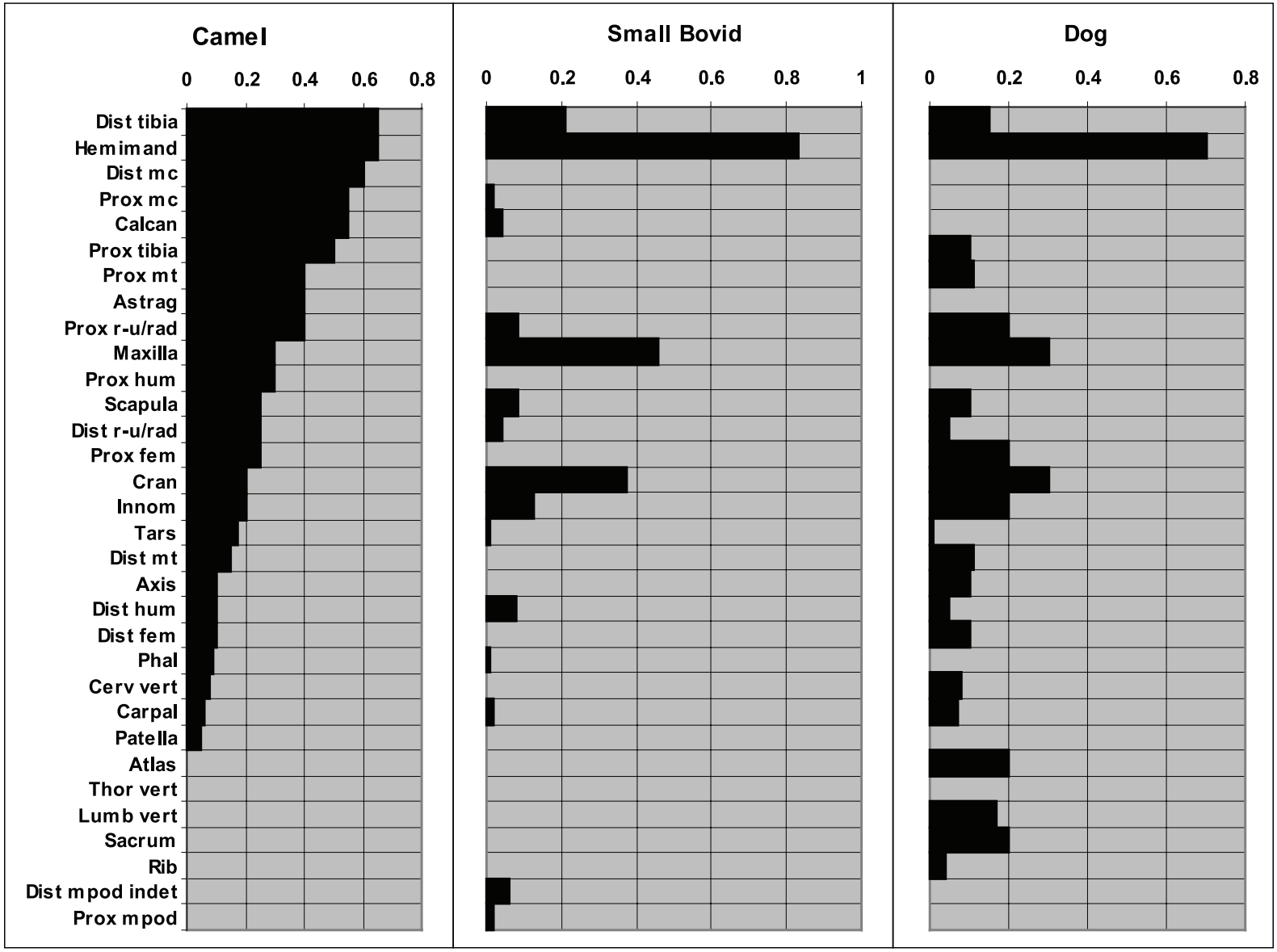


*Figure 13. Comparison of relative element frequencies of camel, bovid and dog. Camels exhibit high percentage of the hemimandibles as well as many limb elements (distal tibia, metacarpal, calcaneus, proximal tibia, proximal metatarsal, astragalus, and proximal radius-ulna), but low frequencies or absence of many other, especially axial, elements (including ribs, sacrum, lumbar and thoracic vertebrae, atlas, patella, carpals, caudal vertebrae, phalanges, distal femur, distal humerus, axis vertebrae, and distal metatarsals). Note that both the smaller-bodied bovids (goat, sheep and gazelle combined) and dogs are best represented by the hemimandible, maxilla and other cranial parts, but dogs also have relatively high frequencies of various other axial as well as appendicular elements, including the proximal femur, innominate, proximal tibia, atlas vertebra, sacrum, and lumbar vertebra.*

## Axial/appendicular ratios

The frequencies of axial and appendicular elements for the major taxa at the Umari den are presented in Table 5. Large animals tend to have a much lower axial/appendicular ratio (0.17) than small animals (1.37). Again, this is likely a result of hyenas having transported more complete carcasses of the smaller animals, so that proportionally more axial elements were likely introduced to the den site, and probably also having preferentially destroyed or heavily comminuted the smaller mammal appendicular elements relative to those of the larger mammals.

## Forelimb/hindlimb ratios

Table 6 shows the forelimb/hindlimb ratios for the major taxa. The overall ratios for the large and small animals tend to be similar, and in both cases identifiable hindlimbs outnumber the forelimbs. Whether these differences are due to differential transport or differential destruction of identifiable elements is not clear.

## Limb fragmentation

Figure 18 shows limb fragmentation for a range of prehistoric and modern bone accumulations, including a number of Plio-Pleistocene sites, hyena dens, a porcupine lair, and a recent hunter-gatherer camp. As can be seen, the Umari hyena den shows a very high degree of fragmentation, with the vast majority of the limbs represented by shafts and with complete limbs and epiphyses present in very small proportions relative to the shafts. Interestingly, the Umari den clusters with many of the Plio-Pleistocene sites in East Africa (Koobi Fora and Olduvai Gorge). The high proportion of limb shafts is likely a function of this hyena den assemblage having

*Table 3. Element representation among the three most abundant taxonomic categories at the Umari hyena den. (small bovids=sheep/goats and gazelle; MNEP=minimum number of elements present; ENE=expected number of elements based on MNI; %=percentage present for the expected number of elements for MNI for that taxonomic group)*

| ELEMENT | CAMEL (MNI=10) | | SMALL BOVIDS (MNI=12) | | DOG (MNI=10) | |
|---|---|---|---|---|---|---|
| | MNEP/ENE | % | MNEP/ENE | % | MNEP/ENE | % |
| Distal tibia | 13/20 | 65.0 | 5/24 | 20.8 | 3/20 | 15.0 |
| Hemi-mandible | 13/20 | 65.0 | 20/24 | 83.3 | 14/20 | 70.0 |
| Distal metacarpal | 12/20 | 60.0 | 1/24 | 4.2 | 0/100 | 0.0 |
| Proximal metacarpal | 11/20 | 55.0 | 1/24 | 4.2 | 0/100 | 0.0 |
| Calcaneus | 11/20 | 55.0 | 1/24 | 4.2 | 0/20 | 0.0 |
| Proximal tibia | 10/20 | 50.0 | 0/24 | 0.0 | 2/20 | 10.0 |
| Proximal metatarsal | 8/20 | 40.0 | 0/24 | 0.0 | 11/100 | 11.0 |
| Astragalus | 8/20 | 40.0 | 0/24 | 0.0 | 0/20 | 0.0 |
| Proximal rad-ulna/rad. | 8/20 | 40.0 | 2/24 | 8.3 | 4/20 | 20.0 |
| Maxilla | 3/10 | 30.0 | 11/24 | 45.8 | 3/10 | 30.0 |
| Proximal humerus | 6/20 | 30.0 | 0/24 | 0.0 | 0/20 | 0.0 |
| Scapula | 5/20 | 25.0 | 2/24 | 8.3 | 2/20 | 10.0 |
| Distal rad-ulna/rad. | 5/20 | 25.0 | 1/24 | 4.2 | 1/20 | 5.0 |
| Proximal femur | 5/20 | 25.0 | 0/24 | 0.0 | 4/20 | 20.0 |
| Cranium/horn core | 2/10 | 20.0 | 9/24 | 37.5 | 3/10 | 30.0 |
| Innominate | 4/20 | 20.0 | 3/24 | 12.5 | 4/20 | 20.0 |
| Tarsal | 14/80 | 17.5 | 1/132 | 0.7 | 1/120 | 0.8 |
| Distal metatarsal | 3/20 | 15.0 | 0/24 | 0.0 | 11/100 | 11.0 |
| Axis | 1/10 | 10.0 | 0/12 | 0.0 | 1/10 | 10.0 |
| Distal humerus | 2/20 | 10.0 | 2/24 | 8.3 | 1/20 | 5.0 |
| Distal femur | 2/20 | 10.0 | 0/24 | 0.0 | 2/20 | 10.0 |
| Phalanx | 11/120 | 9.2 | 2/288 | 0.7 | 0 | 0.0 |
| Cervical vertebra | 4/50 | 8.0 | 0/60 | 0.0 | 4/50 | 8.0 |
| Carpal | 7/120 | 5.8 | 2/132 | 1.5 | 1/140 | 0.7 |
| Patella | 1/20 | 5.0 | 0/24 | 0.0 | 0/20 | 0.0 |
| Atlas vertebra | 0 | 0.0 | 0 | 0.0 | 2/10 | 20.0 |
| Thoracic vertebra | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Lumbar vertebra | 0 | 0.0 | 0 | 0.0 | 12/70 | 17.0 |
| Sacrum | 0 | 0.0 | 0 | 0.0 | 2/10 | 20.0 |
| Rib | 0 | 0.0 | 1/312 | 0.3 | 10/260 | 3.8 |
| Dist. metapod. indet. | 0 | 0.0 | 3/48 | 6.3 | 1/200 | 0.5 |
| Prox. metapod. indet. | 0 | 0.0 | 1/48 | 2.1 | 0 | 0.0 |

*Figure 14. A camel death site several kilometers from the Umari den. Note the dominance of axial skeletal elements (which are relatively poorly represented at the Umari den) but the near absence of appendicular elements, with the exception of one forelimb (that likely was under the carcass at time of death and inaccessible to scavengers).*

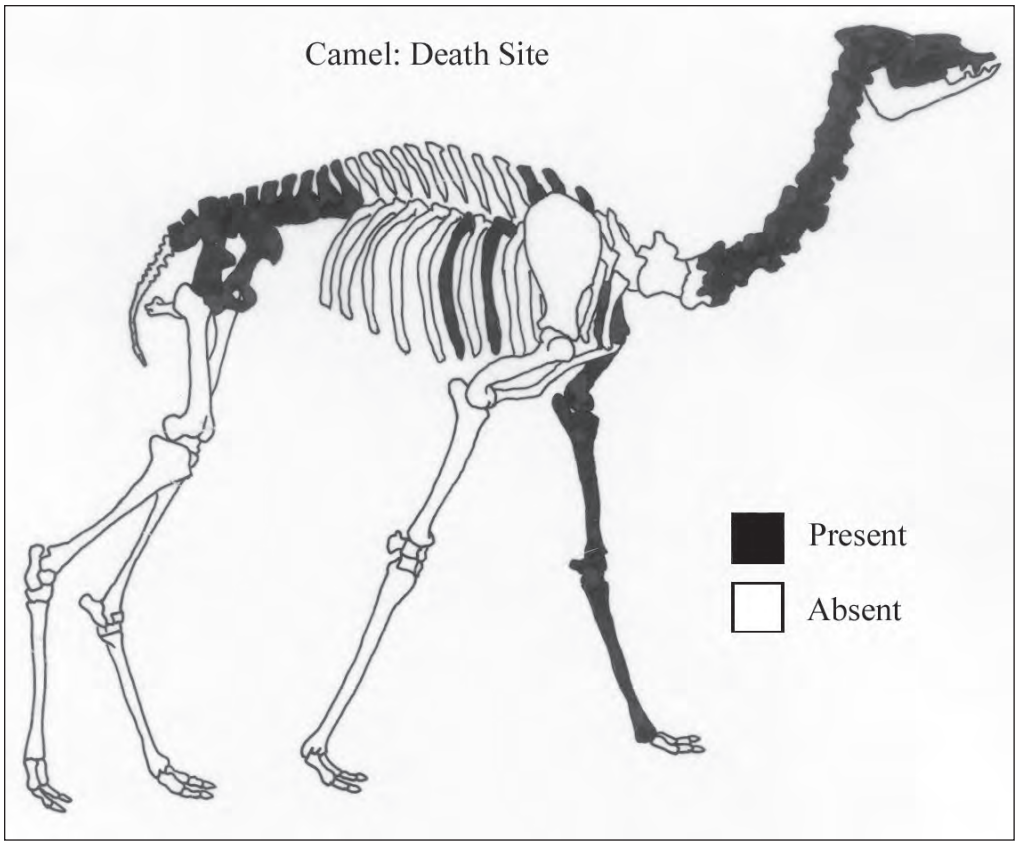


*Figure 15. Element representation at the camel death site. Bones present are represented in black. As mentioned in Figure 12, primarily axial elements are represented, with the exception of one forelimb.*

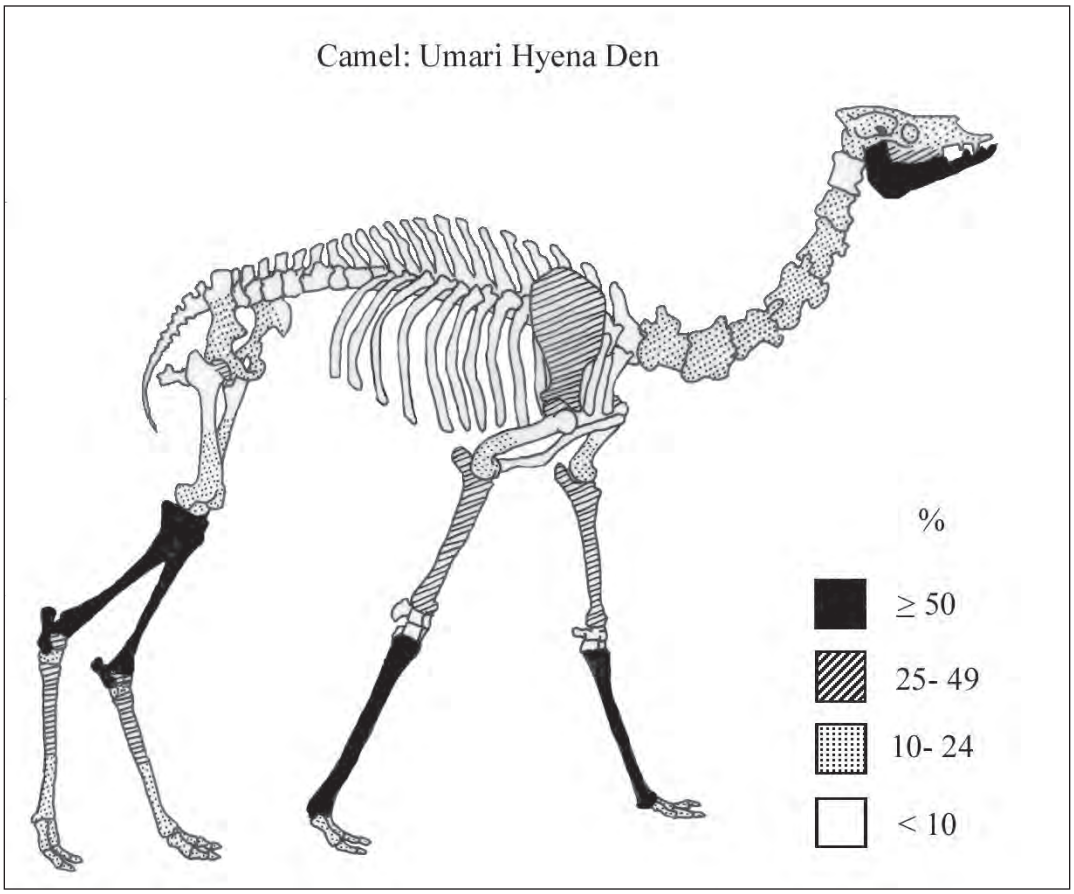


*Figure 16. Camel element representation at the Umari den relative to expectations from MNI. Note that mandibles, metacarpals, tibiae, and calcanei are especially well represented.*

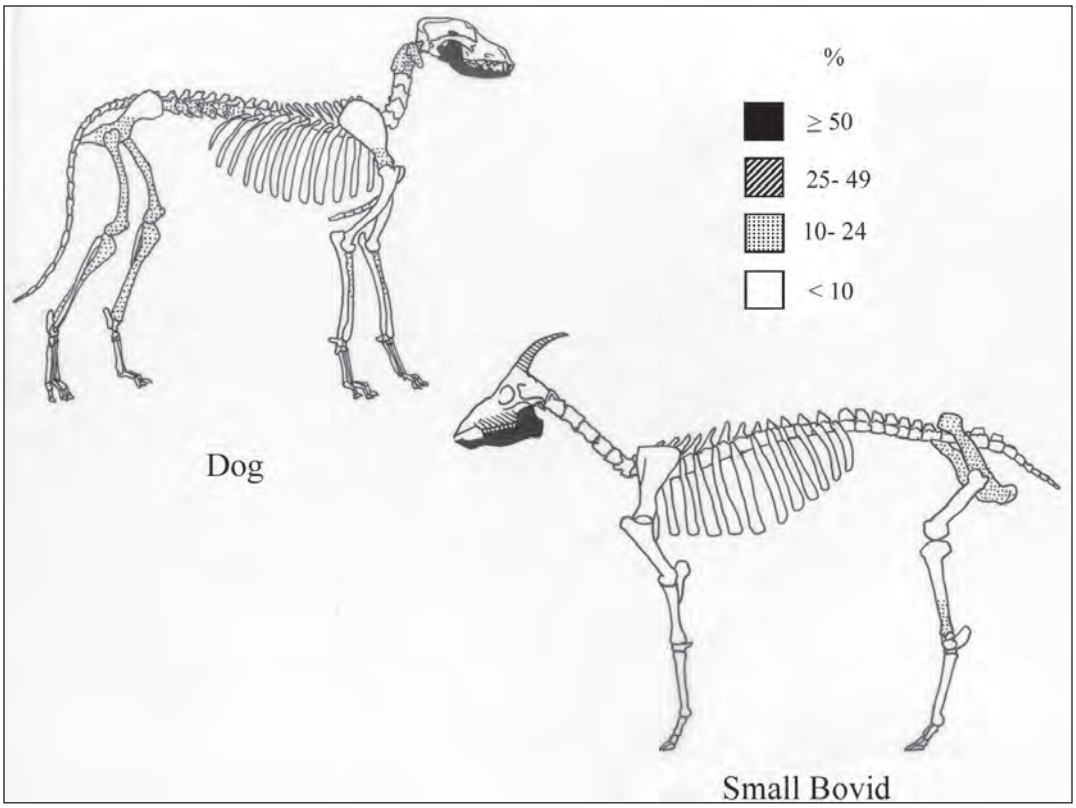


*Figure 17. Element representation of dogs and of small bovids (sheep, goat and gazelle) at the Umari den. Note the high frequencies of mandibles as well as bovid maxillae and horn cores.*

been excavated and sieved and thus having retrieved an extensive sample of broken limb bones from the 20 cm depth of buried accumulation.

Limb shaft fragments not identifiable to taxa or element were measured to see maximum thickness between the cortical surface and the marrow cavity wall (Figure 19). Measurements of identifiable limb shaft fragments showed that the majority of large mammal limbs tended to have a shaft thickness greater than 5 mm, while the majority of smaller mammal limbs had shaft thicknesses less than 5 mm, although there was some overlap between the two populations. The fact that over 70% of the non-identified shaft fragments were less than 5 mm strongly suggests that the majority of these fragments are from mammals smaller in body size than the hyenas. Conversely, the limbs of larger mammal were less likely to be comminuted into small unidentifiable fragments through hyena gnawing and remained as identifiable shaft fragments or sometimes even complete bones.

*Table 4. Ratio of cranial (excluding isolated teeth) to post-cranial elements for each taxonomic group from the Umari den. Note that overall the smaller animals (fox, gazelle, rabbit, goat/sheep, hedgehog, dog, and hyena) have much higher ratio of cranial to postcranial elements than do the larger animals (camel, horse, donkey, oryx, and human).*

| Animal | Cranial n | Postcranial n | Cranial/ Postcranial Ratio |
|---|---|---|---|
| **Fox** | 5 | 2 | 2.50 |
| **Gazelle** | 27 | 15 | 1.80 |
| **Rabbit** | 4 | 3 | 1.33 |
| **Goat/sheep** | 15 | 14 | 1.07 |
| **Human** | 2 | 2 | 1.00 |
| **Hedgehog** | 1 | 1 | 1.00 |
| **Dog** | 25 | 73 | 0.34 |
| **Camel** | 32 | 162 | 0.20 |
| **Horse** | 0 | 2 | 0.00 |
| **Donkey** | 0 | 15 | 0.00 |
| **Oryx** | 0 | 1 | 0.00 |
| **Honey badger** | 0 | 1 | 0.00 |
| **Stork** | 0 | 5 | 0.00 |
| **Snake** | 0 | 1 | 0.00 |
| **Hyena** | 1 | 0 | -- |
| **Large animals** | 34 | 182 | 0.19 |
| **Small animals** | 78 | 115 | 0.68 |

*Table 5. Axial/appendicular counts and ratios for the mammalian taxonomic groups at the Umari hyena den. Note that smaller animals tend to have a higher axial/appendicular ratio than larger animals.*

| Animal | Axial n | App. n | Ax/App. Ratio |
|---|---|---|---|
| **Fox** | 6 | 1 | 6.00 |
| **Gazelle** | 20 | 13 | 1.54 |
| **Dog** | 48 | 38 | 1.26 |
| **Goat/sheep** | 14 | 12 | 1.17 |
| **Human** | 2 | 2 | 1.00 |
| **Camel** | 24 | 131 | 0.18 |
| **Honey badger** | 0 | 1 | 0.00 |
| **Oryx** | 0 | 1 | 0.00 |
| **Donkey** | 0 | 13 | 0.00 |
| **Horse** | 0 | 2 | 0.00 |
| **Hyena** | 1 | 0 | -- |
| **Larger animals** | 26 | 149 | 0.17 |
| **Smaller animals** | 89 | 65 | 1.37 |

## Carnivore representation

The percentage of carnivores represented at the site based on MNI is 26%, and the percentage of carnivores represented based on NISP is 31%. The carnivore/ungulate ratio is 0.50. As has been suggested by other researchers, including Brain (1981), Cruz-Uribe (1991), and Pickering (2002), high frequencies of carnivores are characteristic of many hyena bone accumulations, but not all (Kuhn, 2005).

## Bone modification

### *Carnivore damage*

A total of 71% of the identifiable limbs specimens showed clear signs of carnivore damage: tooth scores, pits, punctures, and notching. This modification is consistent with damage from hyenas feeding behavior. Examples of carnivore tooth marks are shown in Figures 20–25. In addition, there are several bone flakes (Figure 26) as well as flake scars on limb shaft fragments (Figure 27) which are consistent with carnivore fracture.

We examined the effects of progressive bone weathering on the identifiability and abundance of toothmarks on cortical bone surfaces. Using a random sample of

*Table 6. Forelimb to hindlimb ratios for the mammalian taxonomic groups at the Umari hyena den. Small and large mammals have similar forelimb to hindlimb ratios.*

| Animal | Forelimb n | Hindlimb n | FL/HL ratio |
|---|---|---|---|
| **Rabbit** | 2 | 1 | 2.00 |
| **Gazelle** | 4 | 4 | 1.00 |
| **Goat/sheep** | 4 | 5 | 0.80 |
| **Camel** | 45 | 64 | 0.70 |
| **Donkey** | 3 | 5 | 0.60 |
| **Dog** | 6 | 13 | 0.46 |
| **Human** | 0 | 1 | 0.00 |
| **Horse** | 0 | 2 | 0.00 |
| **Hyena** | 0 | 0 | -- |
| **Hedgehog** | 0 | 1 | 0.00 |
| **Oryx** | 1 | 0 | -- |
| **Honey badger** | 1 | 0 | -- |
| **Fox** | 1 | 0 | -- |
| **Large animals** | 49 | 72 | 0.68 |
| **Small animals** | 18 | 24 | 0.75 |

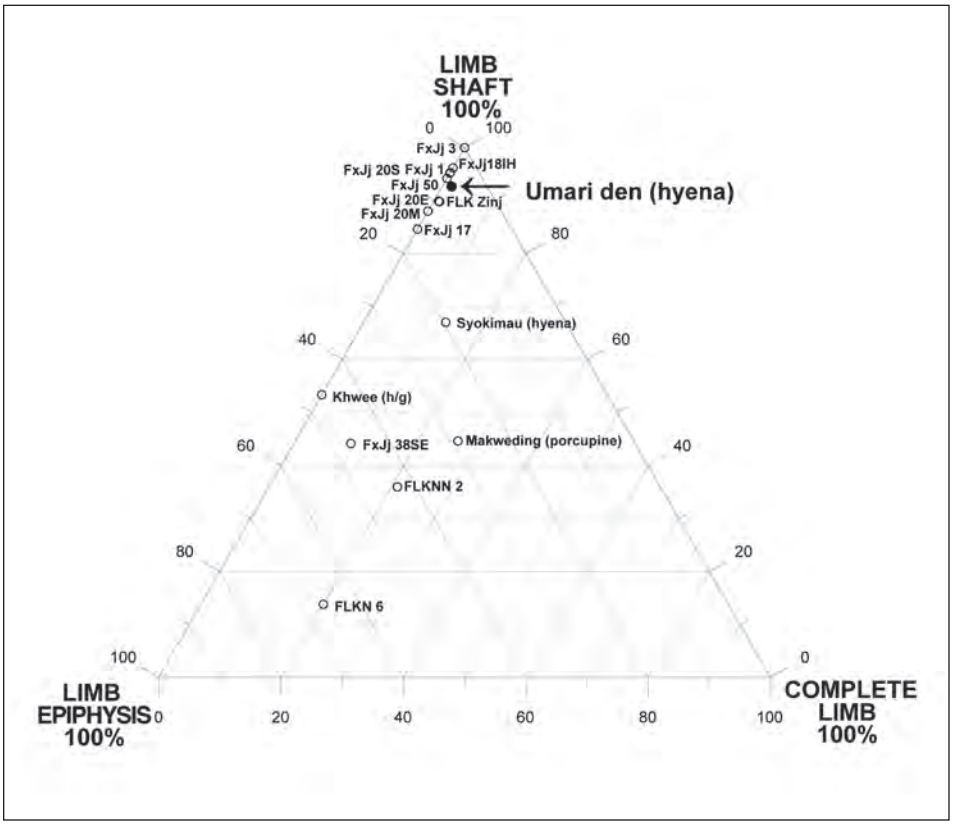


*Figure 18. Ternary graph of limb representation (complete limb v. limb shaft v. limb epiphysis) at the Umari den in comparison to ten Plio-Pleistocene archaeological sites at Koobi Fora and Olduvai Gorge, another hyena den (Syokimau), a porcupine den (Madweding), and a hunter-gatherer camp site (Khwee). Note that this excavated hyena den assemblage shows a very high limb shaft representation similar to many faunal assemblages at Plio-Pleistocene archaeological sites. (after Bunn, 1982).*

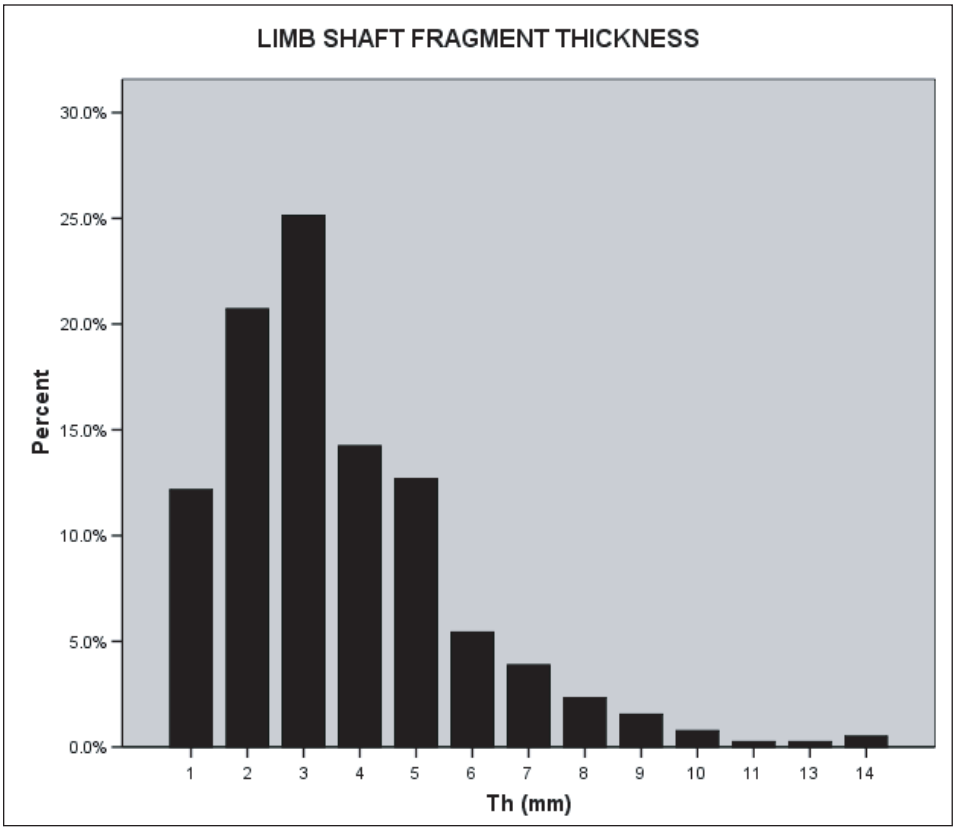


*Figure 19. Thickness of limb shaft fragments from a random sample of all size classes (n=388). Note that the great majority of the fragments are quite thin (mode of 3 mm) and would appear to represent primarily fragmented limbs of smaller animals. Only a small proportion of shaft fragments show a thickness of 6 mm or more. These thicker shaft fragments primarily represent bones of larger animals, whose shafts tended to be less heavily comminuted into nonidentifiable elements.*

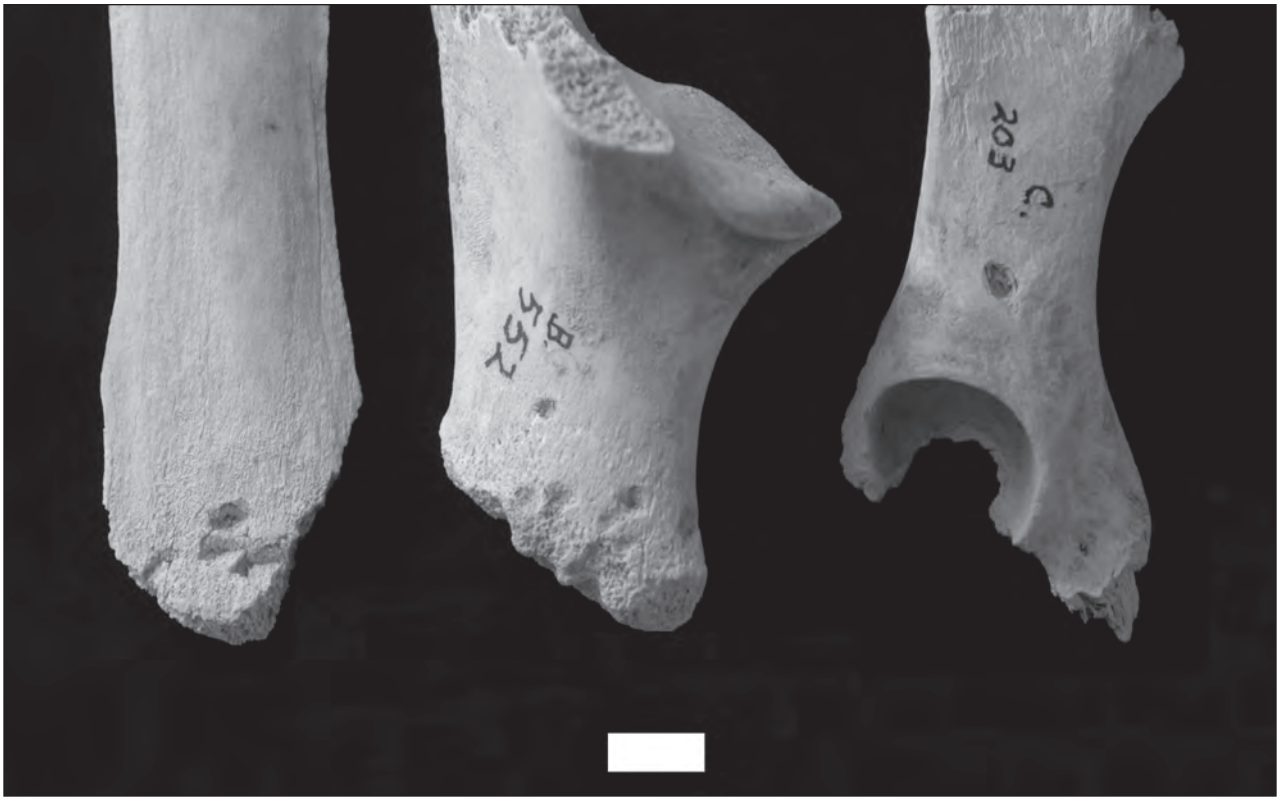


*Figure 20. Examples of carnivore-induced tooth pits and punctures. (White bar = 1 cm).*

non-identified shaft fragments, we estimated the cortical surface area of each specimen by multiplying shaft fragment length times mean fragment breadth. As can be seen in Table 7 and Figure 28, the number of identifiable toothmarks goes down markedly as bone surface weathering increases.

### *Fracture patterning*

A sample of limb shaft fragments was analyzed to identify whether fracture was green (i.e. broken when fresh and organic-rich), dry (broken when weathered), or a combination of both. As can be seen in Figure 29, bones with a weathering stage of 0–1 (Behrensmeyer, 1978) showed predominantly green fracture, while bones of weathering stage 3 showed predominantly dry fracture. This strongly suggests that much of the bone fracture at the hyena den was made during hyena feeding, but that a portion of the bones were subsequently broken (naturally or by trampling) as the bones dried out and weathered. For the broken limb ends of weathering stage 0–1 over half showed either spiral fracture or irregular spiral fracture.

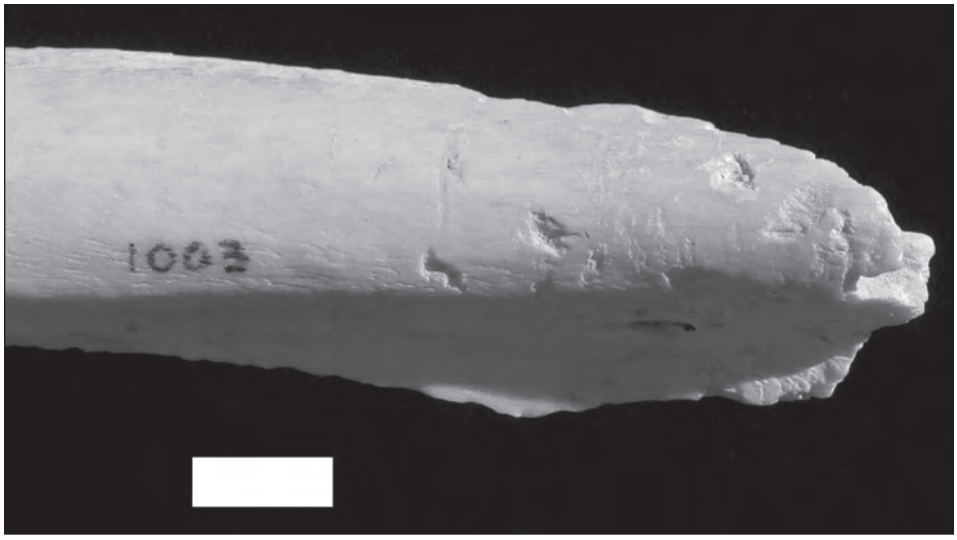


*Figure 21. Examples of toothmarks and pits on a limb shaft fragment. (White bar = 1 cm).*

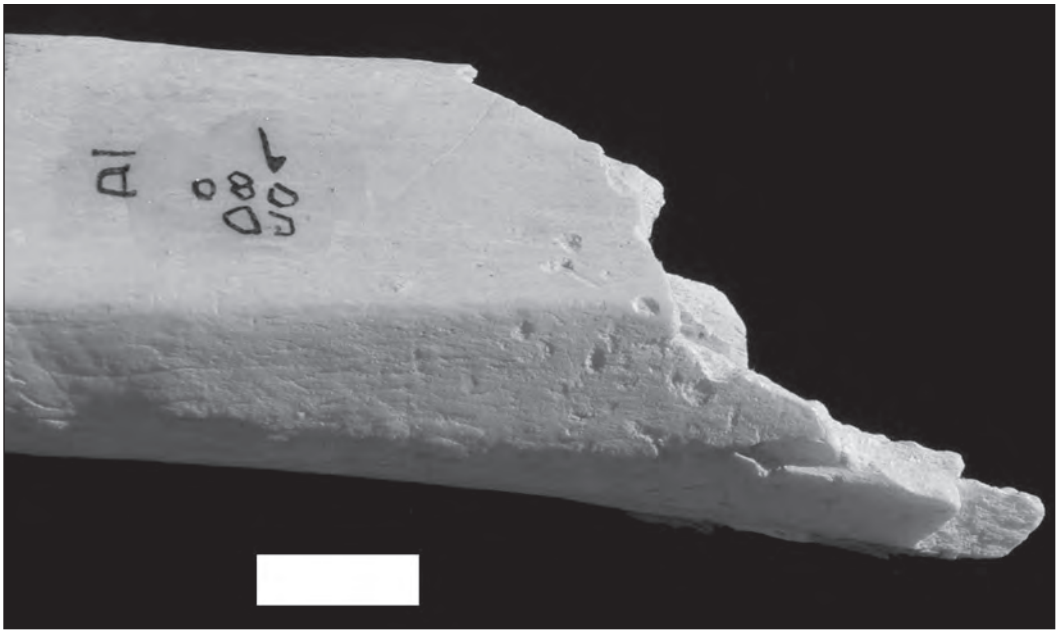

Figure 22. Examples of toothmarks and limb shaft fracture. (White bar = 1 cm).

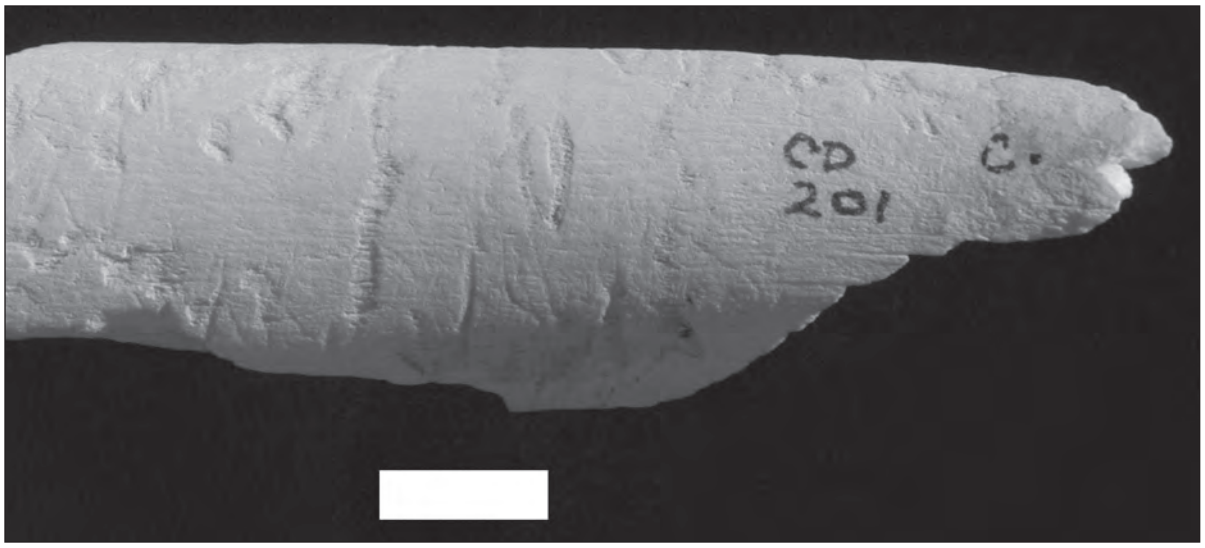

Figure 23. Example of a shaft fragment with tooth scores. (White bar = 1 cm).

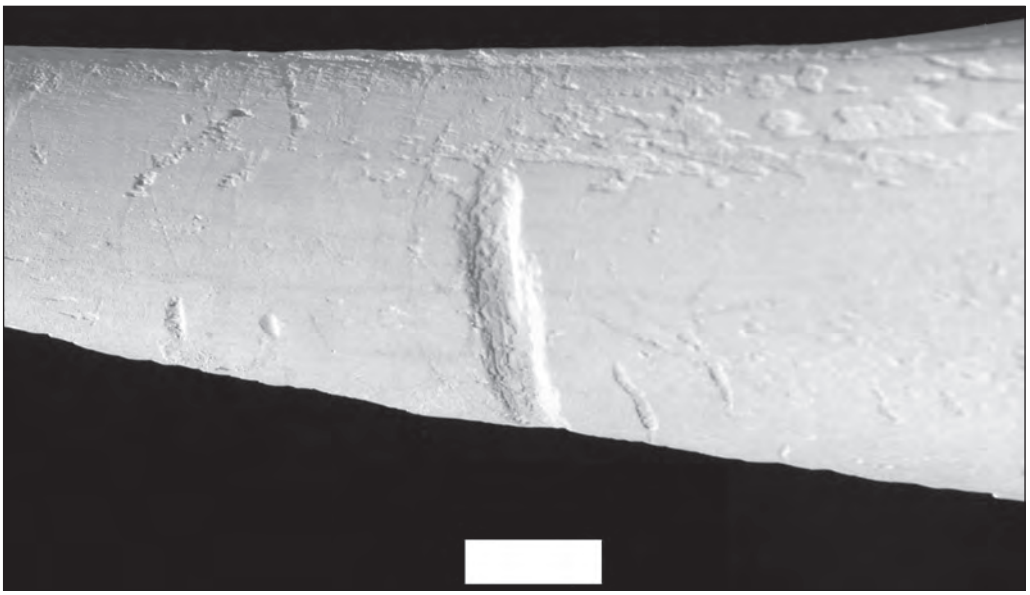

Figure 24. Example of toothmarks on a broken limb shaft. (White bar = 1 cm).

*Figure 25. Example of a large carnivore-induced tooth score. (White bar =1 cm).*

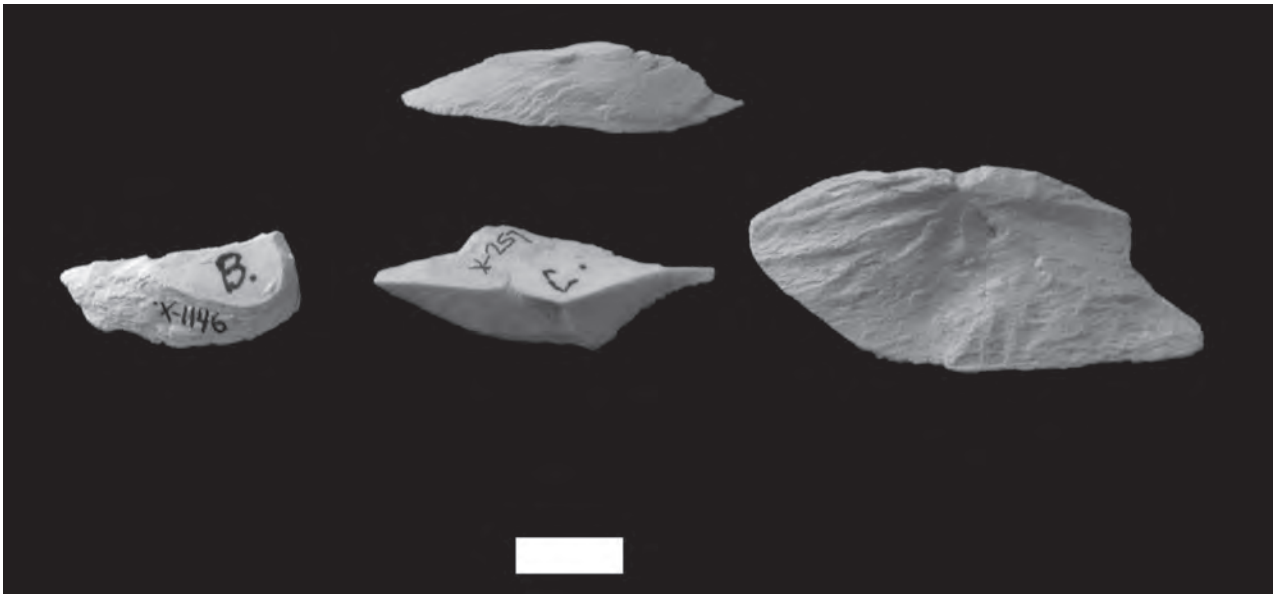


*Figure 26. Examples of bone flakes. (White bar = 1 cm).*

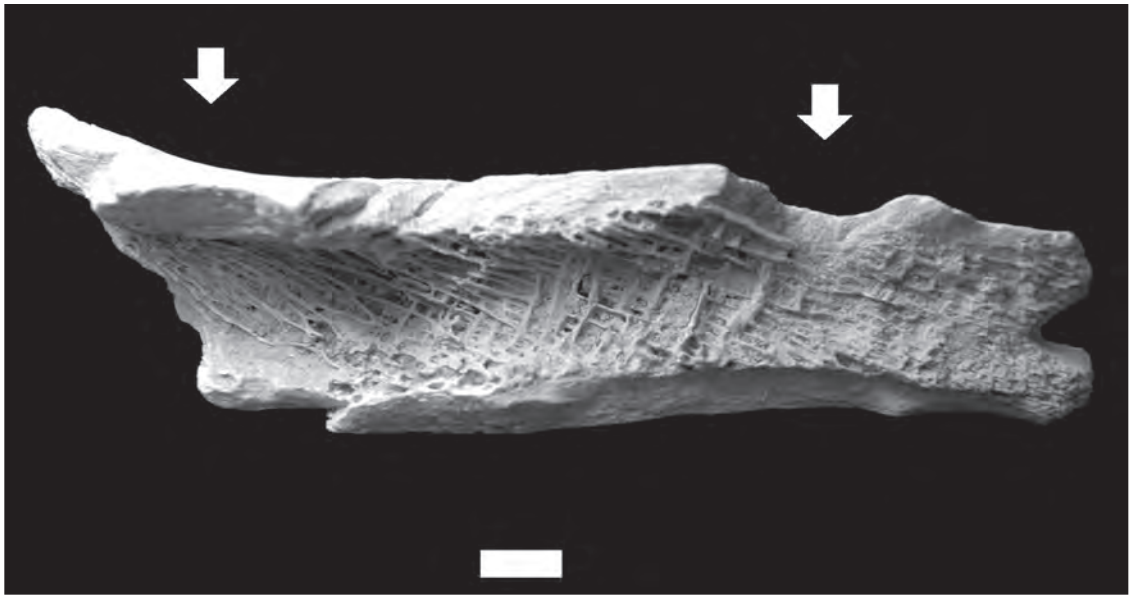

*Figure 27. Examples of negative flake scars or notches (arrows) on a shaft fragment. (White bar = 1 cm).*

*Table 7. Incidence of toothmarks on samples of bones from each of three weathering stages. Note that bones in weathering stage 0-1 had higher values in terms of mean number of toothmarks, percentage of bones with toothmarks, and extensiveness of toothmark modification (number per unit of bone area) than did the more heavily weathered bone. Less weathered bones (state 0–1) exhibit more than 15 times the number of toothmarks per bone, more than 13 times the proportion of bones with toothmarks, and more than 14 times the number of toothmarks per unit area of cortical bone than do heavily weathered bone (stage 3).*

| | Sample of Non-ID Shaft Fragments Weathering Stages | | | |
|---|---|---|---|---|
| | **Stage 0–1** | **Stage 2** | **Stage 3** | **All Stages Total** |
| **Sample size (# shaft fragments)** | 132 | 120 | 136 | 388 |
| **Number of toothmarks** | 329 | 162 | 19 | 510 |
| **Number of shaft fragments with toothmarks** | 65 | 41 | 5 | 111 |
| **Mean number of toothmarks/shaft fragments** | 2.49 | 1.35 | 0.14 | 1.31 |
| **% of shaft fragments with toothmarks** | 49.24 | 34.17 | 3.68 | 28.61 |
| **Approx. surface area ($cm^2$) of cortical bone** | .1583 | .1222 | .1344 | .4149 |
| **No. toothmarks per 10 cm x 10 cm area (100 sq. cm) of cortical bone** | 20.78 | 13.26 | 1.41 | 12.29 |

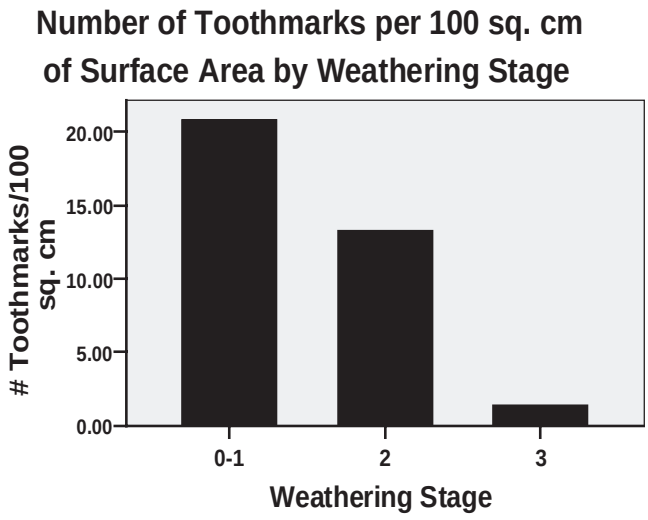


*Figure 28. Number of tooth-marks per 100 sq. cm. of bone surface, by weathering stage (Stage 0-1, Stage 2, and Stage 3) from a random sample of bone fragments. Note that the number of toothmarks evident decreases markedly with increased bone weathering.*

### *Other modification*

There were very few examples of human-induced cut-marks (n=3), burning (n=1), or rodent gnawing (n=2).This suggests that the hyenas were not scavenging human food refuse to any great degree, and that the overwhelming majority of the bones represent hyena collection and transport of animals and animal parts from locations of natural deaths, road kills, and hyena predation. Examples of these types of modification are shown in Figures 30, 31 and 32.

### *An atlas of element representation and modification*

Figures 33–50 show the elements, element portions, and bone and tooth fragments recovered from the hyena den. As noted above, the great majority (96.1%) of the 4,847 bone and tooth specimens were buried within 20 cm of the surface and were recovered through excavation and sieving of the soft sediment. These photographs show the degree of completeness of different skeletal parts and the fragmentation of cranial, dental, and limb shaft remains.

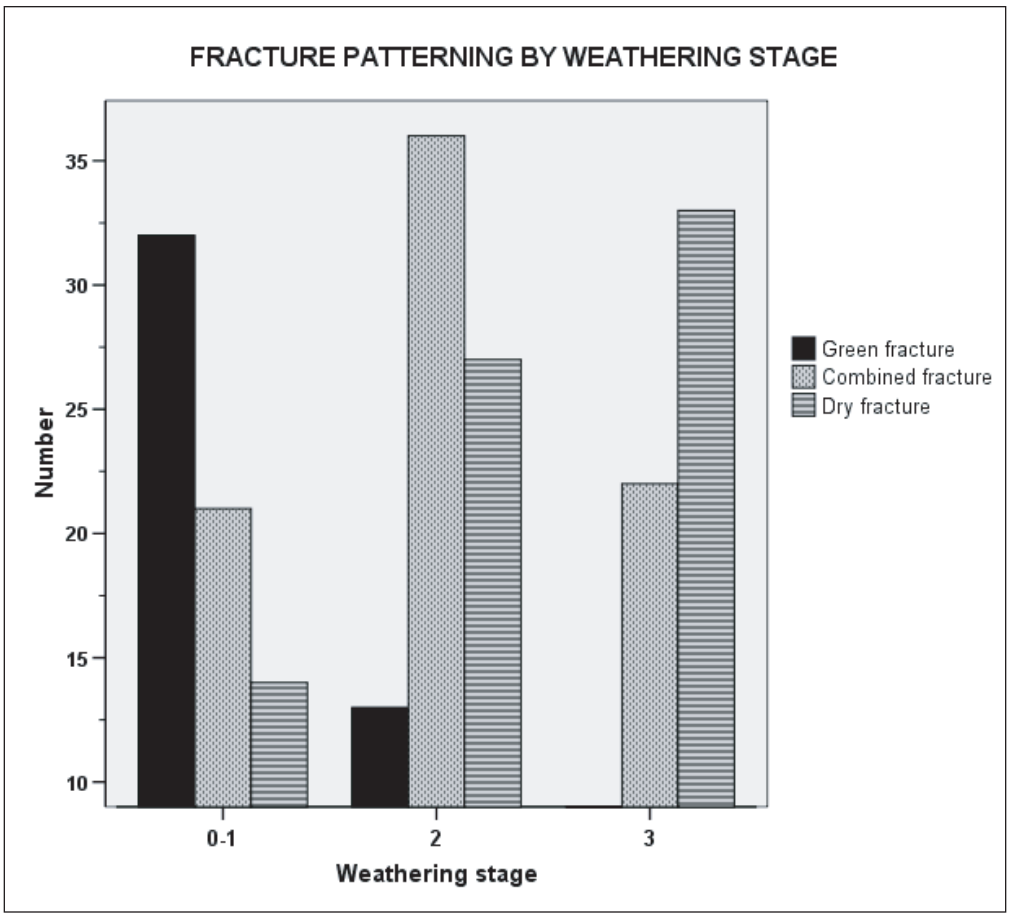


*Figure 29. Fracture patterning (green fracture, dry fracture, or a combination) observed on samples of shaft fragments at three different weathering stages. Note that fresher bone (Stage 0-1) is dominated by green fracture as well as green and dry combined, while bone in weathering stage 3 is dominated by dry fracture.*


*Figure 30. Rare example of cut-marks, probably from a metal knife, on a bone fragment. (White bar = 1 cm).*

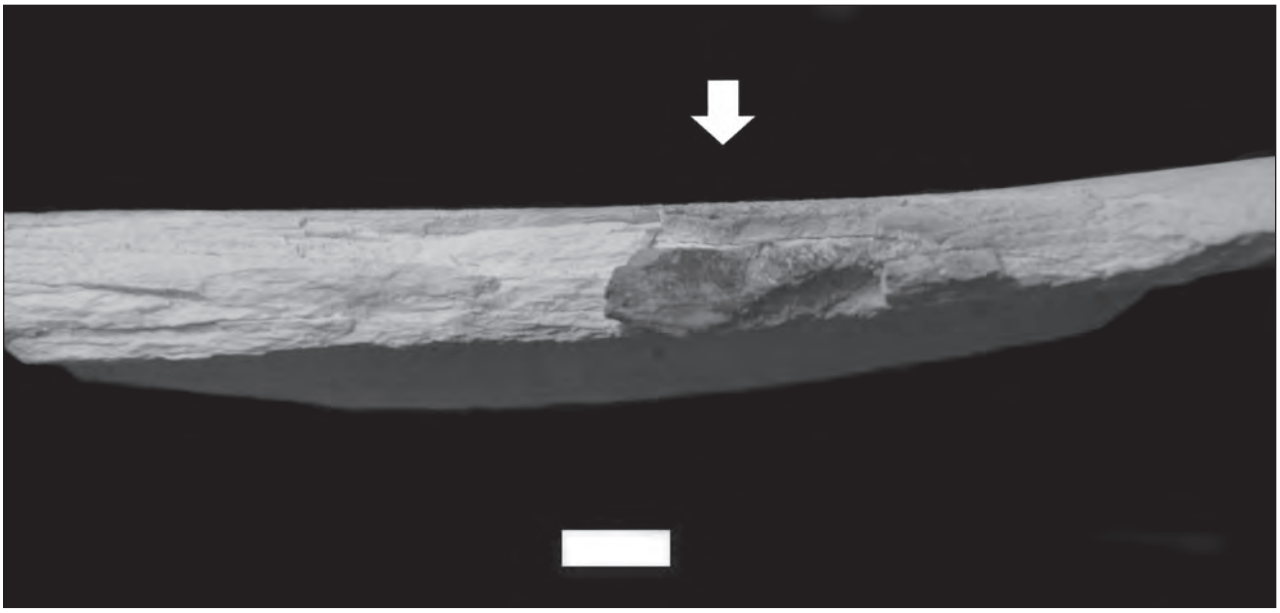

*Figure 31. Rare example of dark discoloration, probably from burning, on the surface of a bone fragment. (White bar = 1 cm).*

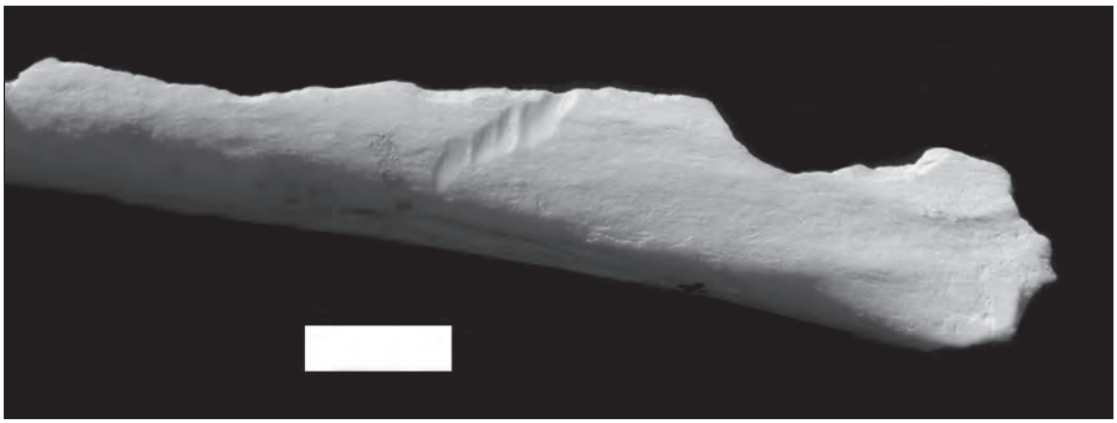

*Figure 32. Rare example of probable rodent toothmarks on a shaft fragment. (White bar = 1 cm).*

*Figure 33. Examples of carnivore crania and mandibles, including hyena mandible (lower right), from the excavated area. (Smaller squares on scale = 1 cm.)*

*Figure 34. More complete dog crania and a whole mandible collected from the surface outside of the excavation area. Note the two mummified skulls (second and fourth from left).*

*Figure 35. Examples of cranial fragments, horn cores, and mandibular pieces from smaller bovids (goat/sheep, gazelle).*

*Figure 36. Examples of cranial and mandibular pieces from larger mammals (camels, donkeys and horses).*

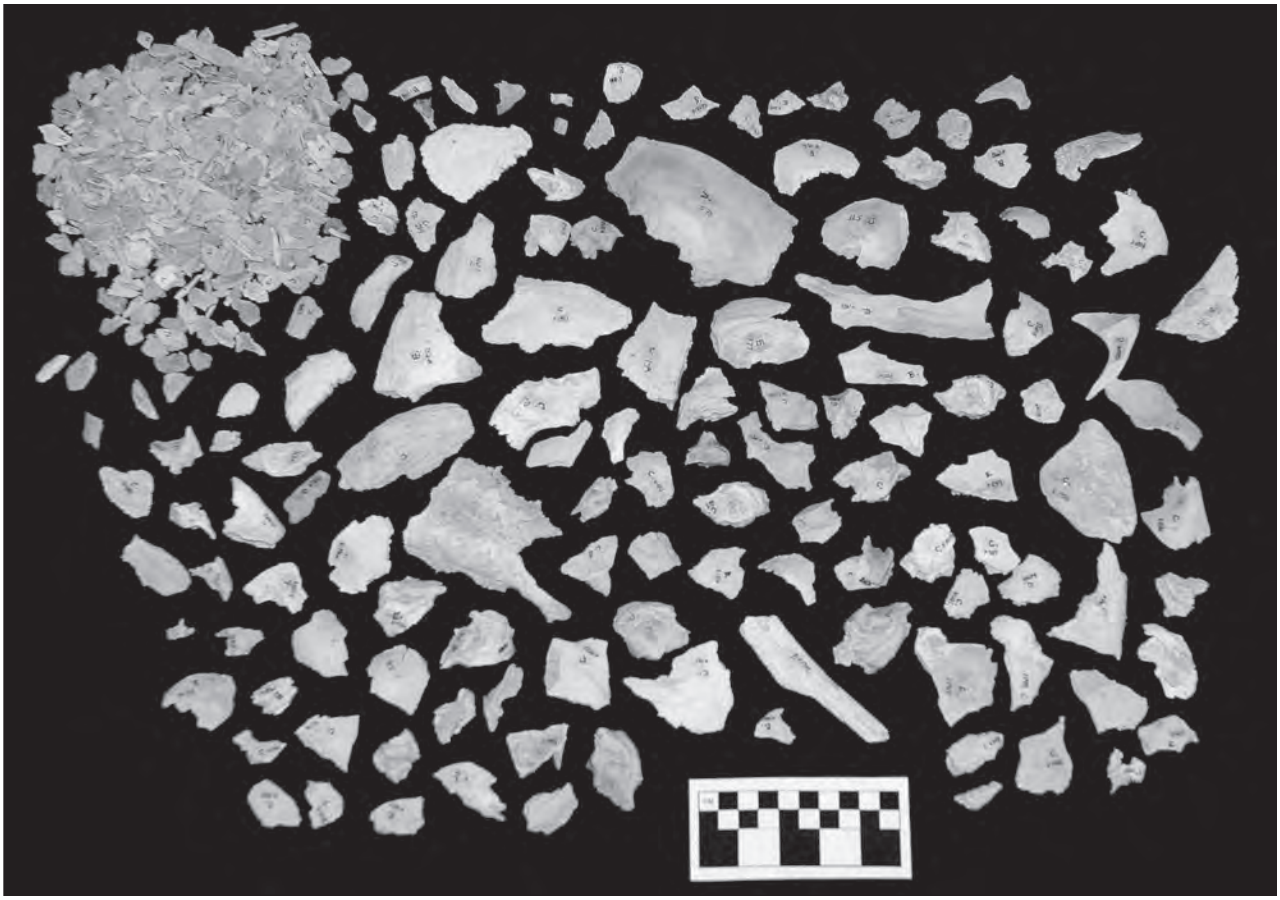

Figure 37. Examples of smaller cranial fragments (all taxa).

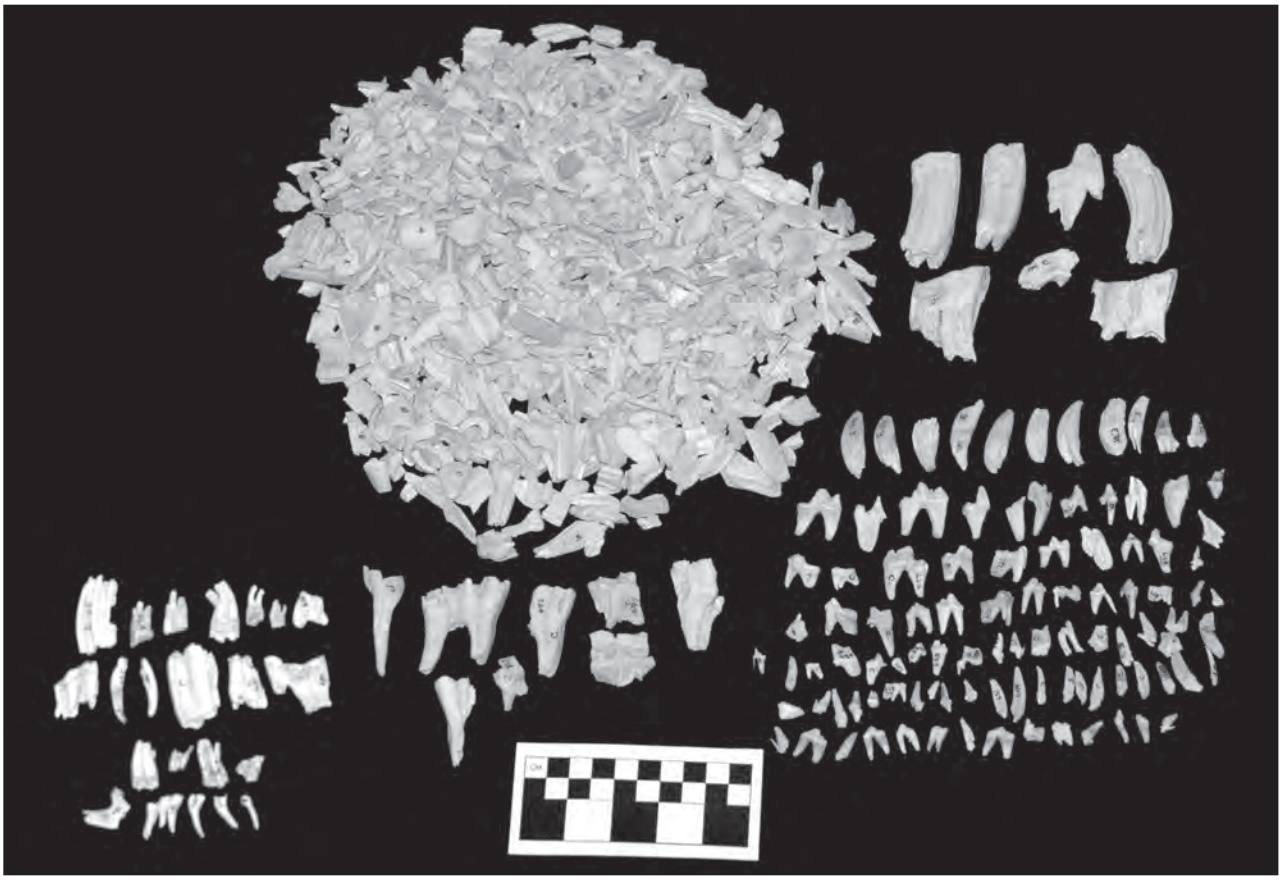

Figure 38. Examples of isolated teeth and tooth fragments (all taxa).

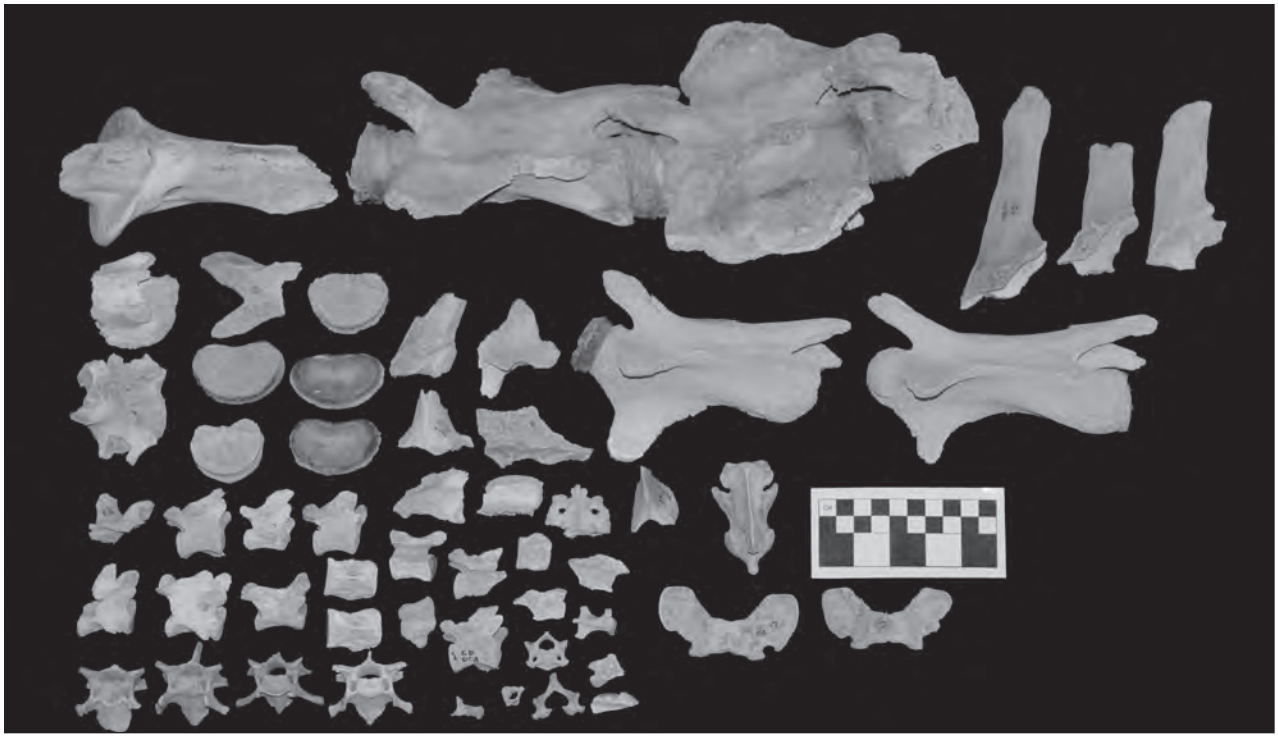

*Figure 39. Examples of vertebrae (all taxa). Note the articulated vertebrae top center.*

*Figure 40. Examples of ribs and rib fragments (all taxa).*

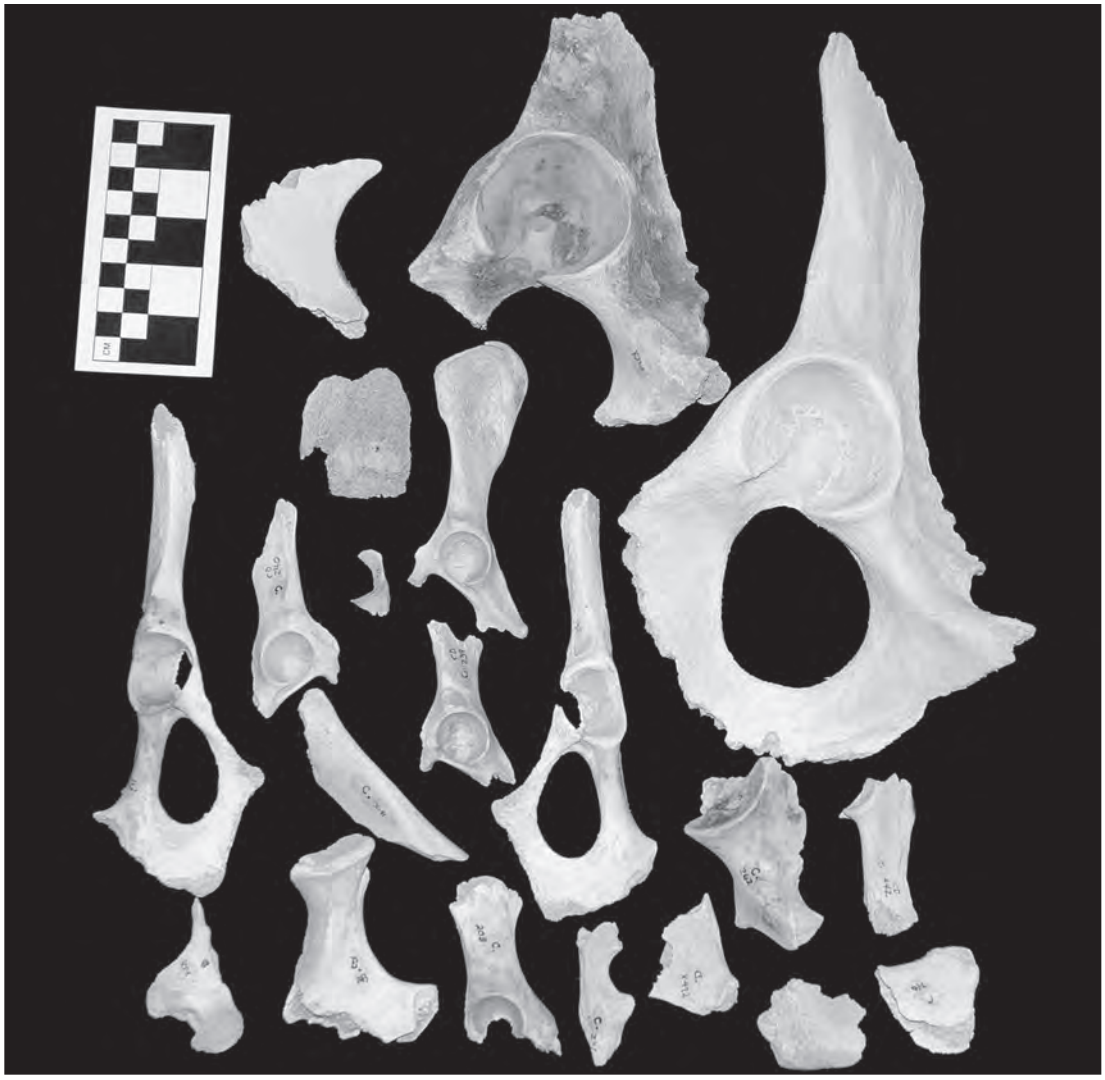

*Figure 41. Examples of innominates (all taxa).*

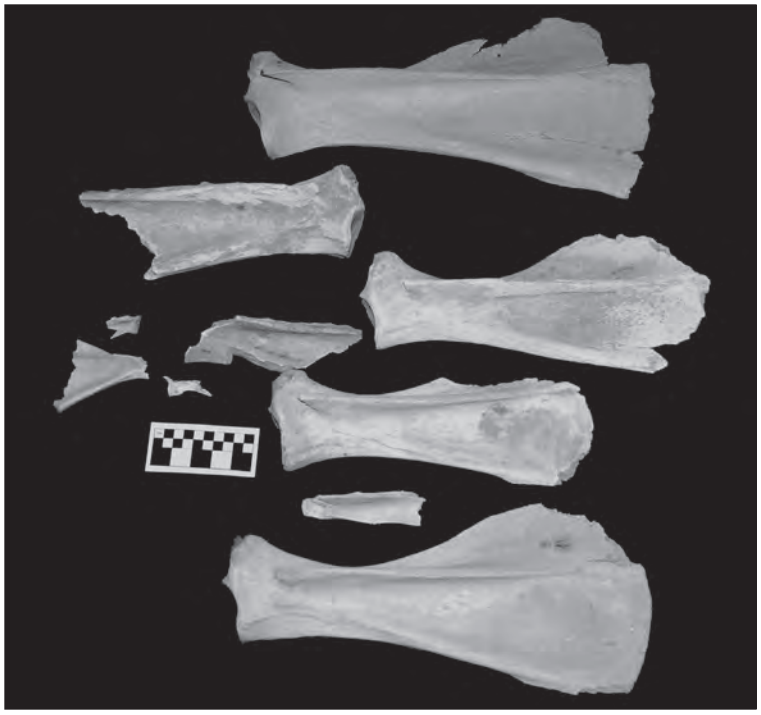

*Figure 42. Examples of scapulae (all taxa).*

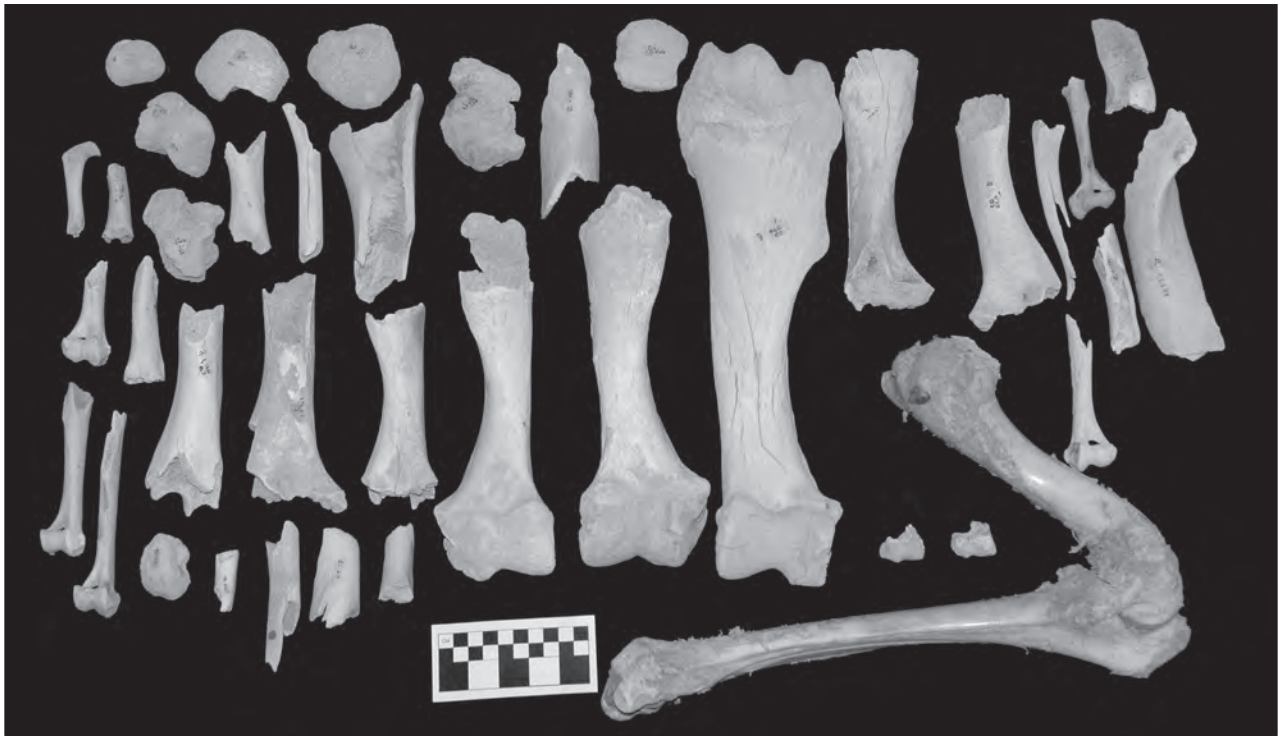

*Figure 43. Examples of humeri (all taxa); at lower right, still articulated with the radius-ulna.*

*Figure 44. Examples of radii and ulnae (all taxa); at upper right, still articulated with the humerus.*

*Figure 45. Examples of metacarpals (all taxa).*

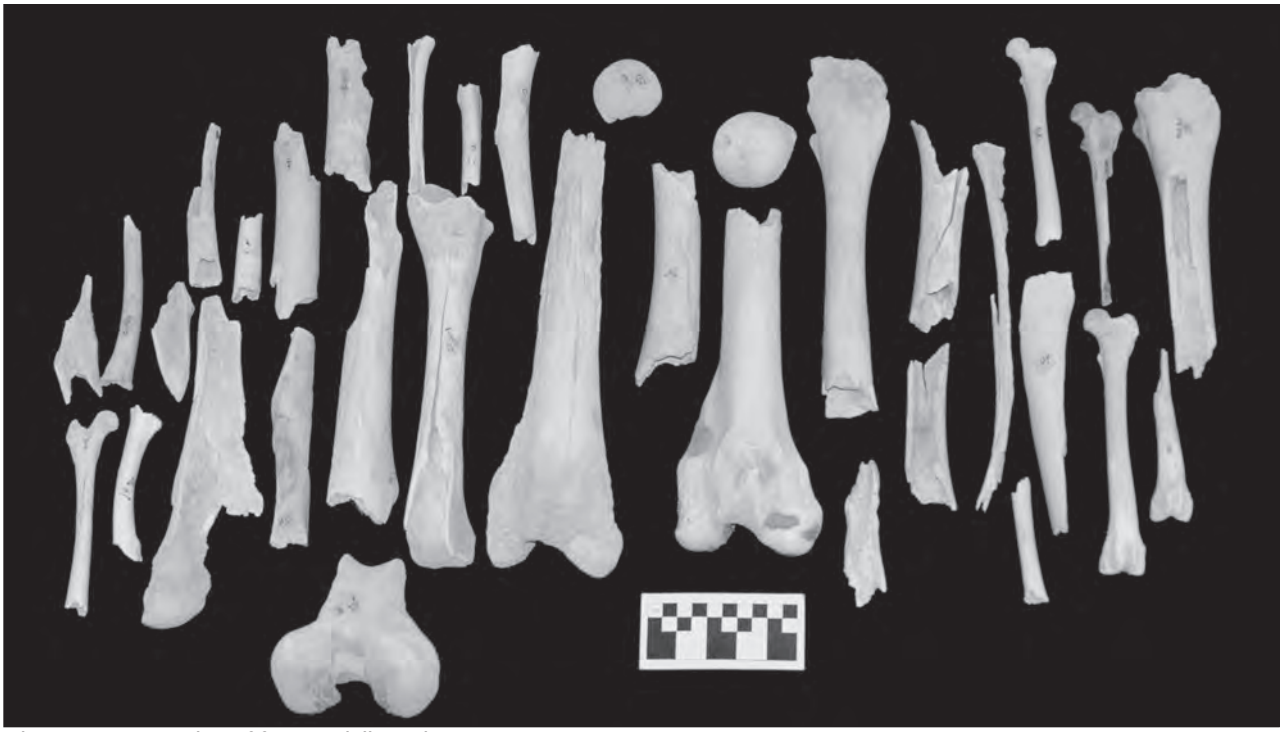

*Figure 46. Examples of femora (all taxa).*

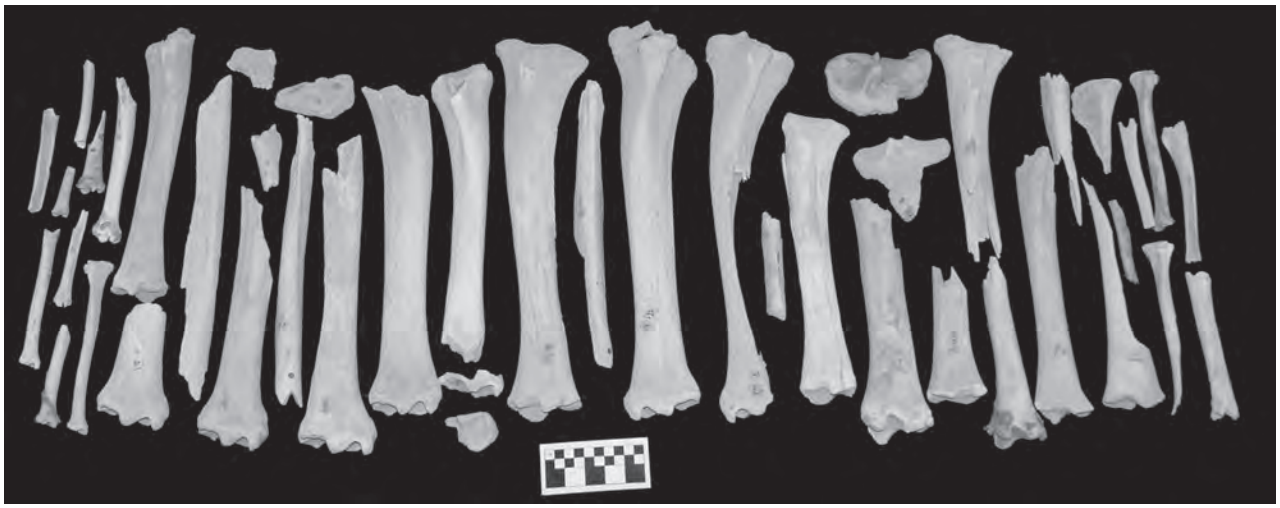

*Figure 47. Examples of tibiae (all taxa).*

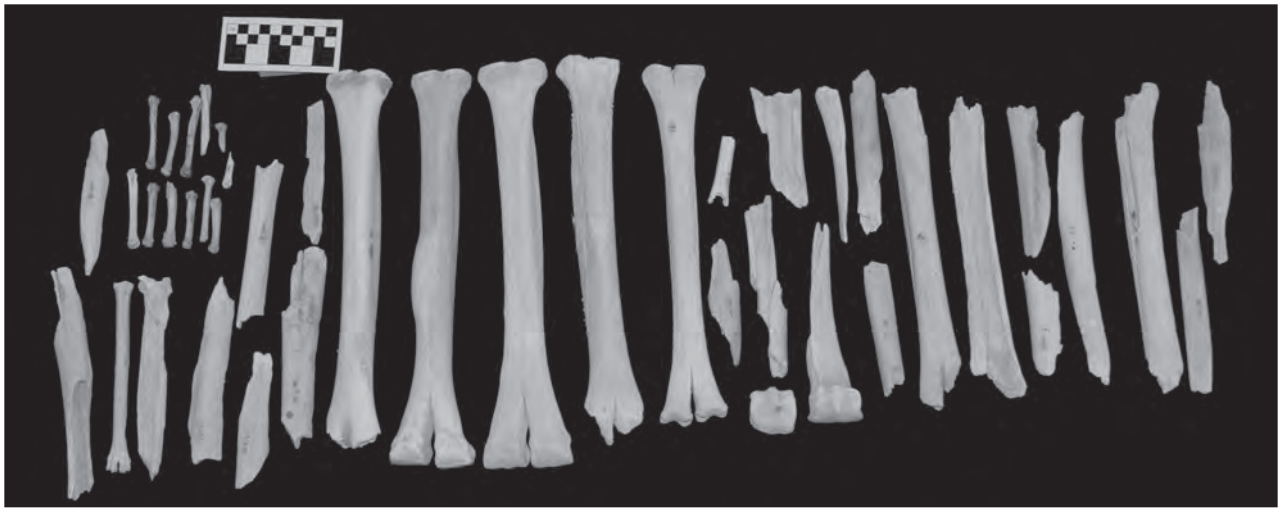

*Figure 48. Examples of metatarsals (all taxa).*

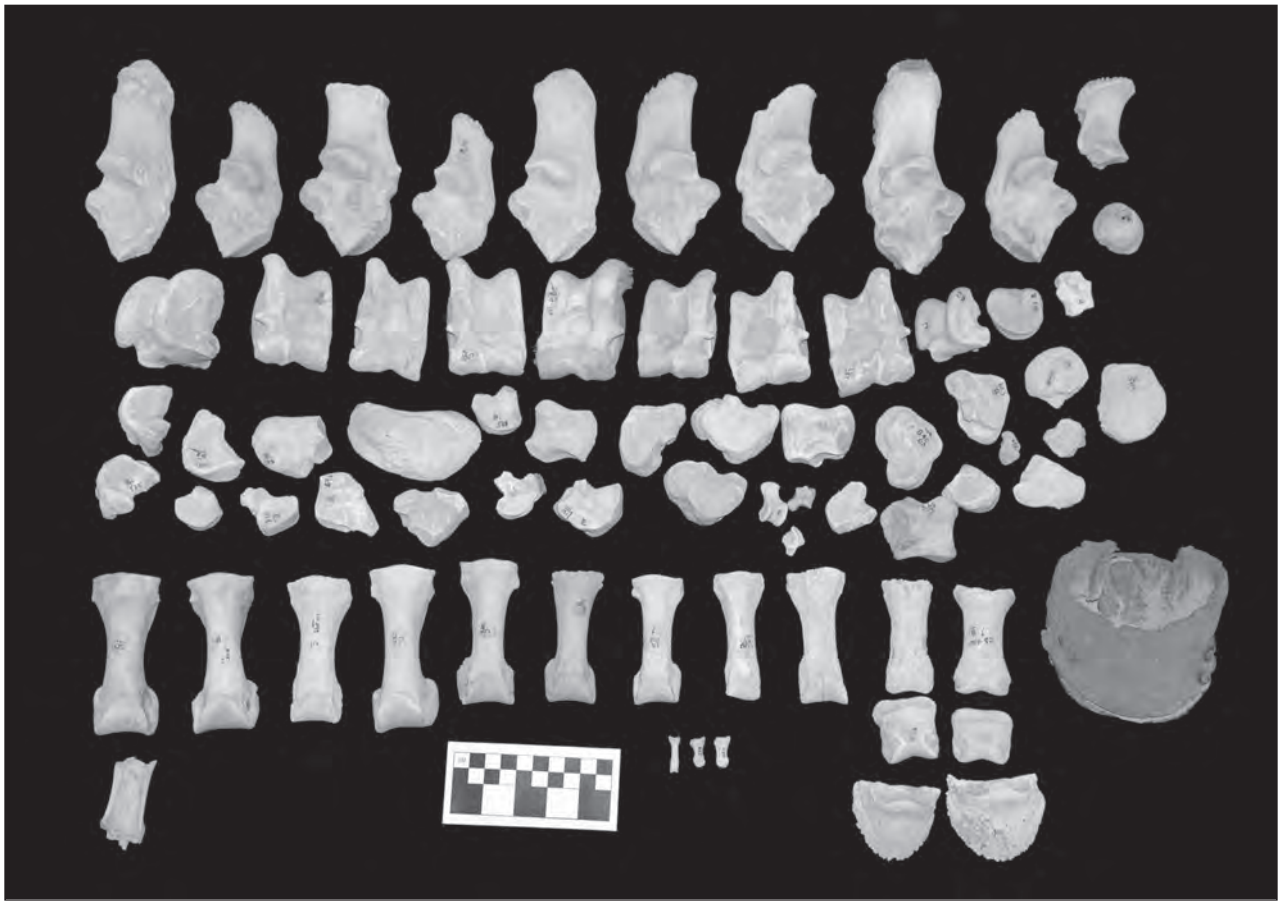

*Figure 49. Examples of podials and phalanges (all taxa). Note hoof with attached horseshoe at lower right, without bone present.*

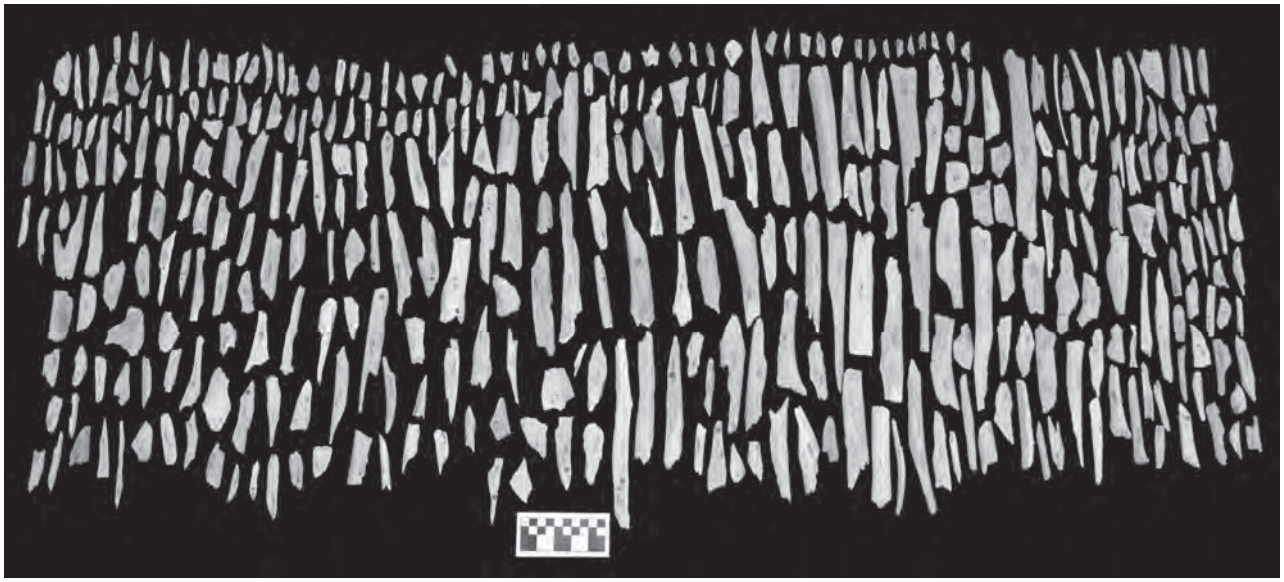

*Figure 50. Examples of limb shaft fragments (all taxa). The smallest fraction is only represented by a small sample in the top row.*

## Conclusion

This study is an analysis of the faunal assemblage of one of the few excavated hyena dens with an appreciable depth of deposit. Almost 5,000 bone specimens were recovered from an area of 16m$^2$. The major results of this study were:

- The primary taxonomic groups represented at the den are camel, dog, sheep/goat, and gazelle; other taxa include donkey, human, horse, fox, stork, hare, hedgehog, indeterminate birds, oryx, hyena, honey badger, and snake. The assemblage thus consists of a mix of domestic and wild forms, and both larger and smaller animals. It is likely that the larger animals were primarily acquired through scavenging, while the smaller animals could have been acquired through either hunting or scavenging.
- The proportion of carnivores in this assemblage is quite high (25.9% of the MNI and 31.4% of the NISP).
- A minimum number of 54 individuals representing at least 16 taxa are represented from the excavated area.
- The majority (96.1%) of the bone assemblage was buried, with only 3.9% exposed on the surface of the 16m$^2$ excavation area. The great majority of the buried faunal materials consist of fragmented bones and teeth, and the bones tend to be less weathered. The surface materials consist largely of larger, sometimes complete, bones, and tend to be much more heavily weathered than the buried portion of the assemblage. The buried sample would have had much greater likelihood of mineralization and fossilization over time.
- The average number of bone and tooth specimens (including both surface and sieved, buried materials) per m$^2$ is 303; the average number of specimens identifiable to both element and taxon was 32 per m$^2$.
- Smaller animals have a much higher cranial to postcranial ratio than large animals; this suggests that smaller animals may have been transported to the den as more complete carcasses than were the larger animals.
- Smaller mammals have a much larger axial to appendicular ratio than larger mammals; again, this appears to be due smaller animals being transported as more complete carcasses, while larger animals may have often had portions of the carcass, particularly limbs, transported to the den.
- The faunal assemblage shows a high degree of limb shaft fragmentation, comparable to that found at many Plio-Pleistocene archaeological sites. Bones of weathering stages 0–1 (primarily from the buried portion of the sample) predominantly exhibit green, often spiral, fracture.
- More weathered bones exhibit much higher frequencies of dry fracture and much lower frequencies of carnivore toothmarks than do relatively unweathered bones, suggesting that such surface modification had been obliterated by the weathering process.
- The vast majority of the modification observed on the bones of this assemblage consist of carnivore toothmarks and notches, strongly suggesting that hyenas were the principal agent of accumulation, consumption, and modification of these bones. Very few specimens (roughly one out of a thousand) show traces of human modification (cutmarks or burning) or rodent gnawing. Bone flakes are present but very rare in the assemblage.
- These patterns conform to the criteria emphasized by Pickering (2002) for differentiating faunal as-

semblages accumulated by hyenas as opposed to hominids.

This type of actualistic study, as emphasized by Brain (1981), provides the kinds of comparative evidence and patterning that can be used to evaluate prehistoric bone assemblages and assess the principal agents of bone accumulation and modification. This study adds to a growing corpus of hyena den studies and adds information as to the range of variation in hyena bone collecting and processing.

*Figure 51. Highway road sign in the eastern desert of Jordan.*

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