Reanalysis and Reinterpretation of the Kalkbank Faunal Accumulation, Limpopo Province, South Africa

Jarod M. Hutson*
School of Geography, Archaeology and Environmental Studies
University of the Witwatersrand, Johannesburg, South Africa
Department of Anthropology, University of Nevada-Reno
Reno, NV 89557, USA

Chester R. Cain
Department of Anthropology, Washington University, St. Louis, MO 63131, USA
Department of Anthropology, Rice University, Houston, TX 77251, USA

Journal of Taphonomy 6 (3-4) (2008), 399-428.
Manuscript received 20 October 2007, revised manuscript accepted 14 January 2008.

Previous accounts of the late Pleistocene Kalkbank faunal accumulation cited humans as the primary agent of accumulation. Here we present the first in-depth taphonomic analysis of the fauna. Revised interpretation based on surface modification and bone breakage patterns reflect an overwhelming carnivore presence at the site. The only indications of human involvement with the fauna were a few stone tools and three possible hammerstone percussion marks. Porcupine involvement with the assemblage was considerable, but appears to be secondary to carnivore predation. The site likely represents a serial predation site where carnivores regularly ambushed prey near the margins of an ancient pan. Published accounts of fossil predation hot spots are rare, and much of the available data on these sites originate from modern landscape studies. Evidence from the Kalkbank accumulation suggests that patterns seen at fossil predation hot spots may not conform to patterns observed in modern accumulations.

Keywords: KALKBANK, TAPHONOMY, CARNIVORES, PREDATION HOT SPOT

Introduction

The Kalkbank site featured prominently in Revil Mason’s (1962) Prehistory of the Transvaal, which has been a key publication for understanding the Stone Age of the southern African interior for decades. Although potentially useful to understanding hunter-gatherer cultures of southern Africa at the end of the Holocene, the site has been
interrogated little over the past four decades (Mitchell, 2002). The site was originally excavated in 1954 and 1966 and represents a rare open-air locality at which a large accumulation of animal bones was preserved alongside stone tools of suspected Middle Stone Age (MSA) origin. Mason (1962, 1967) made specific reference to Kalkbank when characterizing the later Middle Stone Age as being culturally less-modern and distinct from subsequent Later Stone Age cultures. Open-air sites with substantial faunal assemblages remain uncommon in southern Africa, and thus this site would be uniquely valuable in understanding the resource procurement strategies of MSA hunter-gatherers and to document the transition to the Later Stone Age. The generic association of animal remains and stone tools at archaeological sites could make Kalkbank critical to the understanding of southern African prehistory, but this association has been shown to be spurious in many places (see Binford, 1981).

An assessment of the published faunal analyses for Kalkbank showed an incomplete examination of the taphonomic indications of human involvement in the assemblage versus non-human agents (Hutson, 2006). This reanalysis of the Kalkbank fauna aimed to accomplish a number of objectives, including an in-depth study of bone breakage patterns and surface modification in order to discern the primary agent of accumulation. The authors specifically aim to give a definitive assessment of the primary faunal accumulator at Kalkbank and to understand the various taphonomic processes that produced this potentially critical late Pleistocene faunal assemblage.

Since excavation, four researchers analyzed the Kalkbank faunal material, leading to multiple interpretations of the principal bone accumulator (Mason et al., 1958; Cooke, 1962; Mason, 1962, 1967, 1988a; Welbourne, 1971; Brown, 1988), which largely centered on humans as the primary agent. This investigation, relying heavily on taphonomic data from bone surface modification and bone breakage patterns, identifies carnivores as the primary agent of accumulation. Evidence for human involvement with the fauna is scarce—only a small scatter of stone tools and three possible hammerstone percussion marks on the bones. Kalkbank’s environmental setting is reminiscent of a serial predation site, or predation hot spot, of which few fossil examples have been reported. However, Kalkbank does not adhere to all of the characteristics associated with modern predation hot spots, although research at such modern attritional death sites is ongoing (see Tappen et al., 2007).

**Site Description**

The Kalkbank site is located 64 kilometers northwest of Polokwane (formerly Pietersburg) in Limpopo Province, South Africa, in a region of grass and bush-covered plains underlain by granite and gneiss geology. Topographically, the Kalkbank deposit sits at an elevation of 1,100 meters above sea level. Excavations in 1954 and 1966 under the direction of Revil Mason encompassed some 190 m² and uncovered a total of 6,394 faunal remains and 130 stone tools near the margins of a relict water accumulation (Mason et al., 1958; Mason, 1988a; Brown, 1988). According to Mason et al. (1958:100), all of the bone specimens from the 1954 excavation were kept; the same is likely true for the 1966 excavation. The faunal remains are currently housed at the University of the Witwatersrand, Johannesburg, South Africa.
Paleoenvironment

The dominant geological feature at Kalkbank is a 1.2-meter-thick bed of surface calcrete. This thick hardpan is known to cover several acres, and similar examples generally indicate the location of an ancient pan. Netterberg (1974) identified two to three distinct calcrete hardpans separated by layers of silty sand or sandy clay directly overlying a 20-30 centimeter thick fossil horizon. The profile beneath the fossil horizon consists of 2.1 meters of combined colluvial and alluvial deposits related to pan formation (Mason, 1988a). Numerous southern African archaeological and palaeontological sites bear remnants of calcrete formations and relict water accumulations, such as Doornlaagte (Mason, 1967, 1988b; Butzer, 1974), Elandsfontein (Butzer, 1973), and Swartklip (Hendey & Hendey, 1968; Klein, 1975), but none provide a useful analog for Kalkbank in terms of environmental setting. Previously identified taxa, compared to current and historical fauna of the area, indicate a climate during site formation similar to that of the present day (Table 1). The immediate environment likely consisted predominantly of grassland with some open woodland nearby. Most of the large ungulate species are grazers, and a few considered both browsers and grazers. Only the black rhinoceros is strictly a browser. Grasses, reeds, and sedges were undoubtedly present in and around the pan as many of the bones exhibit pre-fossilization root etching (Hutson, 2006: 37-39).

Unfortunately, the Kalkbank calcretes lack pollen crucial for a more detailed paleoenvironmental reconstruction (Mason, 1967). However, all three distinct calcrete hardpans contain fossil gastropod shells typical of the porous diatomaceous hardpans in the present day Kalahari. Most modern pans occur in areas with less than 500 millimeters of rainfall per year, or 1000 millimeters of free surface evaporation (Goudie & Thomas, 1985). The average yearly rainfall in Polokwane, 64 km southeast of the Kalkbank site, spanning 1961 to 1990 was 478 mm. The average daily high temperature recorded during the same period was 25°C. Both of these modern conditions approach sufficient levels to allow for pan formation. Stable isotope measurements of the upper hardpan indicate considerable evaporation during calcrete formation and an aggrading profile associated with pan formation, thus, a drier climate is inferred only subsequent to bone and stone artifact deposition (Netterberg, 1974). These studies suggest that the faunal assemblage accumulated near a small pan in an environment similar to that of the present day, with calcrete formation beginning under more arid conditions after the site was buried.

Dating

Like most ancient open-air sites, Kalkbank has been difficult to date securely. Netterberg (1974) attained a minimum C\textsuperscript{14} date of 17,000 years BP on the lowest calcrete hardpan associated with the bone and stone artifact accumulation. This must be taken as a generous minimum estimate due to the nature of calcrete formation. Calcrete undergoes continuous dissolution and recalcification during seasonal periods of rain and drought, eventually forming hardpans from younger nodule and powder calcrete. In such an open system, it becomes increasingly difficult to date during later stages of development. The lower hardpan at Kalkbank appears to be in a late stage of development, but may also incorporate earlier stages, thus yielding only a minimum age.

The stone tool assemblage formed the basis of the original age for Kalkbank.
Kalkbank taphonomy

Table 1. Previous and current species lists. Counts for Cooke (1962), Welbourne (1971), and Brown (1988) represent MNI; those for Hutson and Cain (2008) represent MNI/NISP. (?) denotes uncertainty regarding presence or absence and (-) denotes absence.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bovid Size 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aepyceros melampus, Impala</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4/15</td>
</tr>
<tr>
<td>Antidorcas marsupialis, Springbok</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>5/25</td>
</tr>
<tr>
<td>Antidorcas bondi, Bond's springbok</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>6/13</td>
</tr>
<tr>
<td>Redunca fulvorfula, Mountain reedbuck</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1/1</td>
</tr>
<tr>
<td><strong>Bovid Size 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcelaphus buselaphus, Red hartebeest</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4/11</td>
</tr>
<tr>
<td>Connochaetes taurinus, Blue wildebeest</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>10/78</td>
</tr>
<tr>
<td>Damaliscus sp., Blesbok/Tsessebe</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>9/36</td>
</tr>
<tr>
<td>Kobus ellipsiprymnus, Waterbuck</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bovid Size 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Megalotragus priscus, Giant hartebeest</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>6/35</td>
</tr>
<tr>
<td>Taurotragus oryx, Eland</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2/2</td>
</tr>
<tr>
<td><strong>Other Ungulate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diceros bicornis, Black Rhinoceros</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1/8</td>
</tr>
<tr>
<td>Equus capensis, Giant Cape zebra</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5/98</td>
</tr>
<tr>
<td>Equus burchelli, Burchell's zebra</td>
<td>6</td>
<td>4</td>
<td>9</td>
<td>12/283</td>
</tr>
<tr>
<td>Giraffa camelopardalis, Giraffe</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hippopotamus amphibius, Hippopotamus</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1/1</td>
</tr>
<tr>
<td>Homoioeceras sp., Giant longhorn buffalo</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1/3</td>
</tr>
<tr>
<td>Loxodonta africana, Elephant</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1/2</td>
</tr>
<tr>
<td>Phacochoerus aethiopicus, Warthog</td>
<td>8</td>
<td>11</td>
<td>21</td>
<td>30/652</td>
</tr>
<tr>
<td><strong>Carnivore</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crocuta crocuta, Spotted hyaena</td>
<td>?</td>
<td>1</td>
<td>1</td>
<td>4/10</td>
</tr>
<tr>
<td>Ichneumia albicauda, White-tailed mongoose</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1/1</td>
</tr>
<tr>
<td>Lycaon pictus, Wild dog</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1/2</td>
</tr>
<tr>
<td>Panthera leo, Lion</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1/2</td>
</tr>
<tr>
<td>Panthera pardus, Leopard</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1/2</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. Georychus capensis yatesi, Mole</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1/1</td>
</tr>
<tr>
<td>Hystrix australis, Porcupine</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1/1</td>
</tr>
<tr>
<td>Struthio camelus, Ostrich</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1/1</td>
</tr>
</tbody>
</table>
According to Mason (1962, 1988a), the small assemblage included flakes, cores, and heavy pounding artifacts largely made from quartz, quartzite, and diabase. None are diagnostic to a specific period, but the grindstones appear similar to those found in the upper MSA levels at Cave of Hearths which may link Kalkbank to the Later Pietersburg culture. Although no longer a favored term, Pietersburg referred to a developed phase of the MSA dating to between 30,000 and 15,000 BP (Mason, 1962). This date range coincides with a minimum date of 17,000 BP for the calcere. However, as grindstones appear throughout the MSA and LSA (McBrearty & Brooks, 2000), the dating based on stone tools remains less than conclusive.

Past accounts of the Kalkbank faunal assemblage yielded species typical of the Florisian Land Mammal Age (Hendy, 1974), indicating an age range from the Pleistocene/Holocene boundary extending as far back as 500,000 BP (Brink, 1987, 1988; Grün et al., 1996; Lacruz et al., 2002). The presence of the extinct Bond’s Springbok (Antidorcas bondi), giant hartebeest (Megalotragus priscus), giant long-horned buffalo (Homoioceras sp.) and giant cape zebra (Equus capensis) at Kalkbank and similar MSA sites may indicate an age nearer to the Pleistocene/Holocene boundary, an age suggested by both the stone tool assemblage and chronometric dating of the calcere.

Previous Faunal Research

Over the years, four researchers have analyzed portions of the Kalkbank assemblage. Cooke (1962) studied much of the faunal material from the 1954 excavation, along with Ewer (1958, 1962), who studied only the suids. Together they identified 38 mammalian individuals represented by 15 species on the basis of 1,040 cranial and 847 post-cranial remains (see Table 1). Early interpretations based on evidence from the 1954 excavation focused on linking a number of “bone tools” identified at Kalkbank to the “osteodontokeratic assemblage” described by Dart (1957) at Makapansgat, just 80 kilometers to the southeast. According to Mason et al. (1958), both sites display comparable treatment of mammalian long bones as bone tools and weapons. These similarities led Mason (1962: 101) to conclude:

“The Kalkbank evidence shows that stone age people could depend almost entirely on bone tools at some sites, and moreover, that a skilled stone tool-maker of the Homo sapiens grade could make bone tools little different than those associated with the australopithecines, perhaps half a million years older”.

Although the authors presented convincing evidence for similarities between the two assemblages (see Mason et al., 1958: Figures 1-11), research has shown that implements at other sites argued to represent an osteodontokeratic culture result from natural bone fracture (see Myers et al., 1980; Shipman, 1981; Haynes, 1983a, 1991a).

Welbourne (1971) studied 268 cranial specimens from the 1966 excavation (see Table 1). However, little came of his analysis as Kalkbank was not his primary focus, and humans were still perceived to have accumulated the entire faunal assemblage. Most recently, Brown (1988) undertook a more complete analysis of the fauna from the 1954 and 1966 excavations, identifying 20 species and 71 individual animals from 1,527 skeletal parts (see Table 1). Unfortunately, she was not granted access to the entire assemblage (A. Brown, personal communication 2003). Nonetheless, Brown’s (1988) partial
Kalkbank taphonomy

analysis identified several patterns. For example, she (Brown, 1988:208-209) attributed the noticeable lack of phalanges to the “schlepp effect,” in which the phalanges may have been attached to animal skins used to transport meaty limb portions back to a campsite (see Perkins & Daly, 1968). Her brief taphonomic description of the assemblage mentioned several butchered and burned specimens. From those, the Kalkbank assemblage was thought to represent the remains of a kill or butchery site (Brown, 1988:209). Mason’s (1988a:201) assessment did not rule out hunting by carnivores or animals dying in the vicinity of a water supply as factors in accumulation, but every previous analysis had attributed humans as a significant accumulator at the site. This perception probably resulted from the low priority given to taphonomic studies in these projects since such techniques were rarely used in faunal analyses of non-palaeoanthropological sites at the time (Lyman, 1994; Gifford-Gonzalez, 1999).

Laboratory Methods

Faunal Identification

It was unclear which specimens were studied in the previous analyses. Therefore, the entire assemblage was reanalyzed, including remains not previously available for study. Each specimen was individually recorded by part, portion, segment, and side following Gifford and Crader (1977). Both number of identified specimens (NISP) and minimum number of individuals (MNI) were used to calculate species abundance (see Klein & Cruz-Uribe, 1984), with NISP serving only as an indicator of identified specimens determined to achieve MNI per skeletal element and taxon. Matching of elements in regard to side and age was employed whenever possible as to not artificially inflate MNI values.

The description of skeletal part representation was based on minimum number of elements (MNE), largely following Binford (1978, 1981, 1984). Minimum number of elements for each skeletal part represented the sum of both left and right sides based on the most common portion of that particular element identified using distinct anatomical landmarks (see Bunn & Kroll, 1988; Bunn, 1991), such as foramina and muscle attachment loci. All effort was made to identify the cranial material to species, but most postcranial cranial specimens only allowed for identification to more general taxa (i.e. Bovid, Equid, Felid, etc.). Bovids were separated into general size classes according to Brain (1974). Here, bovid size class 2 (23-84 kg) includes impala, springbok, Bond’s springbok, and mountain reedbuck. Bovid size class 3 (84-296 kg) includes hartebeest, wildebeest, and blesbok/tsessebe. Bovid size class 4 (296-400 kg) includes the giant hartebeest and eland. The giant buffalo is often placed in bovid size class 5 (>900 kg) (Klein, 1976), but here it was included into the indeterminate large mammal category.

Surface Modification

The preservation of bone surfaces and bone surface modifications was an initial concern for this reanalysis of the Kalkbank fauna. During excavation, the faunal material became dry and brittle (Mason et al., 1958), which the excavators attempted to ameliorate by applying glyptal to consolidate the bone surfaces. Brown (1988) applied a second coat, leading to variable, but good surface
shaft fragments can indicate early access to carcasses by humans. 

Limb bones included in this analysis included bovid humerus, radius, metacarpal, femur, tibia, metatarsal, and indeterminate metapodial with adequate surface preservation. All qualifying limb bones displaying carnivore induced damage were identified as epiphysis, epiphysis+ shaft, shaft, or complete and tabulated by NISP. Epiphysis portions are defined as “epiphysis only” specimens with no shaft included, while epiphysis + shaft portions do include some length of shaft and at least some portion of epiphysis. Shaft portions are portions of the midshaft with no epiphysis. The limb bone portions defined here differ slightly than those used in the original experiment by Blumenschine (1988), but their interpretive value remains consistent.

Carnivore damage according to limb bone portion was recorded in order to assess the timing of potential hominid and carnivore influence on the assemblage. This analysis loosely follows experiments by Blumenschine (1988) which involved the simulation of archaeological sites and the subsequent disturbance of those sites by carnivores. Through an analysis of carnivore tooth marks on certain limb bone portions, results of the experiments generally follow that assemblages ravaged only by carnivores can be differentiated from hammerstone-generated assemblages ravaged by carnivores and assemblages broken only by hammerstone for marrow extraction (Blumenschine, 1988; Blumenschine & Marean, 1993). Carnivore ravaging on complete limb bones, which may suggest direct predation or early scavenging opportunities, yields an even distribution of tooth markings on epiphysial fragments and limb shaft portions. Ravaging of assemblages consisting of hammerstone-broken limb bones generally yields a lower number of tooth-marking on limb shaft fragments as opposed to epiphysial portions. Extremely low incidence of tooth marks on shaft fragments can indicate early access to carcasses by humans.

Bone Breakage

Brown (1988) found 51% of the bones at Kalkbank consisted of unidentifiable bone flakes, meaning the assemblage as a whole is comparatively intact in relation to many human-produced assemblages. Yet, with nearly 1.2 meters of calcrite overlying the thin fossil horizon, it was necessary to determine whether the degree of fragmentation reflects the action of biotic agents or post-depositional destruction through profile compaction. The means of determining post-depositional breakage included an examination of compact bone completeness, bone cylinders, and long bone fracture patterns.

Completeness

We used a “Completeness Index” developed by Marean (1991), who recorded ungulate compact bones (carpals, tarsals, and sesamoids) as a measure of post-depositional destruction.
Because these bones contain relatively little nutritional value, humans and carnivores rarely fragment them; thus, an assemblage with high completeness values would have experienced a low degree of post-depositional breakage. The Completeness Index is calculated by estimating the observed fraction of all ungulate compact bones present. To standardize estimates, complete compact bones for various size groups of ungulates were drawn on a 2 millimeter grid and the squares counted within the preserved section of each Kalkbank specimen. Summing the values, dividing by the total number of specimens attributed to that bone, and multiplying by 100 resulted in percentage values for each element (Marean, 1991:685).

Humans are known to damage some compact bones (Binford, 1978), usually calcanei (Marean, 1991); whereas carnivores, namely hyenas, often swallow and subsequently regurgitate them (Sutcliffe, 1970; Bearder, 1977). Therefore, calcanei and any other bones displaying human or carnivore-induced modifications were excluded. We compared the Kalkbank completeness values with those attained from two late Pleistocene archaeological sites referenced in Marean’s (1991:687) original study.

**Bone Cylinders**

Humans tend to break long bones at the mid-shafts to extract marrow, resulting in faunal assemblages more fragmented than those of carnivores (Richardson, 1980; Brain, 1981; Payne, 1981; Bunn, 1983). This is a rather simplified view of bone breakage, and high degrees of fragmentation can also result from factors such as weathering, leaching, trampling, and profile compaction (Potts, 1988; Cruz-Uribe, 1991). Few specimens exhibit weathering beyond Behrensmeyer's (1978) Stage 1 and criteria to identify the effects of leaching and trampling were not recorded. Only the effects of profile compaction at Kalkbank will be discussed here.

Numerous researchers have noticed that carnivores tend to attack limb bones from the epiphyses and gnaw down the shaft, consuming the epiphyses, but leaving complete limb shaft “cylinders” unconsumed (Sutcliffe, 1970; Skinner et al., 1980; Hill, 1983; Binford et al., 1988; Blumenschine, 1988; Horwitz & Smith, 1988; Potts et al., 1988; Cruz-Uribe, 1991; Marean & Spencer, 1991). Cruz-Uribe (1991) and Pickering (2002) consider an abundance of “bone cylinders” indicative of faunal assemblages accumulated by carnivores, primarily hyenas. Here, limb shafts were analyzed and only those bones were counted which preserved their entire original circumference with no attached epiphysis. Limb shafts, as defined here, included ungulate humerus, radius, metacarpal, femur, tibia, and metacarpal specimens.

**Fracture Patterns**

**Villa and Mahieu** (1991) have developed a set of criteria involving long bone fracture patterns to determine the timing of bone breakage. These criteria were applied to the Kalkbank assemblage in order to determine the timing of fracture for the bone cylinders. Three attributes, fracture angle, fracture outline, and fracture edge, were recorded for the Kalkbank assemblage, and the results were compared with those from Fontbrégoua, Sarrians, and Bezouce, three sites with known modifying agents from southern France analyzed by Villa and Mahieu (1991).

**Villa and Mahieu** (1991:34) define fracture angle as the angle formed by the fracture surface and the cortical bone surface. Obtuse
Villa and Mahieu (1991) were employed with some alterations to conform to the available sample from Kalkbank. Photographic illustrations are not provided here, but are shown clearly in figures provided by Villa and Mahieu (1991:Figures 5, 7, and 9). Only long bone shafts preserving at least three-quarters of the original circumference were used in order to increase the sample size over the more strict definition of bone cylinders mentioned earlier. The analysis also included those epiphysis-plus-shaft fragments where the shaft extended a sufficient distance from the epiphysis to minimize the effect of differential fracture characteristics of shafts and epiphyses. Epiphysis-only fragments, partial epiphyses, juvenile specimens, and modern breaks were therefore excluded. And lastly, shaft specimens displaying fractures on proximal, distal, and lateral margins were “averaged” to reflect the overall breakage pattern. Alcántara García et al. (2006) record all limb shaft fracture loci individually, but most of the Kalkbank specimens display consistent breakage patterns within a single element and the resulting sample of 145 specimens offers an appropriate comparison to the assemblages used by Villa and Mahieu (1991).

**Results**

**Species Abundance**

Table 1 shows the species list based on this current analysis. A total of 112 individuals were identified from 27 species, with wild dog (*Lycaon pictus*) representing a new species overlooked in previous analyses. As few bovid postcranial elements were identified to species, all bovid skeletal elements are

angles indicate green bone breaks, and right angles suggest dry bone breaks (Johnson, 1985; Morlan, 1984). The study by Villa and Mahieu (1991) highlighted the relatively low incidence of right angle breaks at Fontbrégoua, a cave site in southern France with an assemblage of cannibalized long bones broken for marrow extraction (Villa & Mahieu, 1991). Fracture outlines were separated into three categories: 1) transverse-straight or perpendicular to the bone's long axis; 2) curved, spiral or v-shaped; and 3) intermediate— including straight, diagonal or stepped outlines (Villa & Mahieu, 1991:34, 36-38). The assemblage at Fontbrégoua display a majority of curved outlines, while Sarrians and Bezoce, both known to have been heavily affected by post-depositional destruction, display mostly transverse outlines (Villa & Mahieu, 1991). Thus, curved outlines suggest green bone breakage, and transverse outlines are found on dry bone. Fracture edge simply represents the texture of the fracture surface—smooth or jagged (Villa & Mahieu, 1991:38,40). Smooth fracture edges indicate green bone breakage, while jagged edges represent dry bone breaks (Johnson, 1985; Morlan, 1984). Based on the two previous criteria, the expected patterns would be for Sarrians and Bezoce to display a majority of jagged edges (dry breaks), and Fontbrégoua to show smooth edge breaks (fresh breaks). It is also possible that fracture edge may be a factor in the type of force (static or dynamic) used to break the bones (Villa & Mahieu, 1991:40). Hammerstone percussion affected the Fontbrégoua assemblage, whereas the Bezoce specimens were broken by a pick-axe. Both display a higher frequency of smooth fracture edges. Sarrians, on the other hand, was affected by sediment pressure, a static force, and displays a majority of jagged edges.

Such an analysis has a fair degree of subjectivity, and thus the methods of Villa and Mahieu (1991) were employed with some alterations to conform to the available sample from Kalkbank. Photographic illustrations are not provided here, but are shown clearly in figures provided by Villa and Mahieu (1991:Figures 5, 7, and 9).
Kalkbank taphonomy

represented by size classes following Brain (1974). All bovids sorted by size class are shown in Table 1.

Skeletal Part Representation

Table 2 includes all skeletal parts identified to ungulate species and larger taxonomic groups based on MNE. Non-ungulate species comprised a small portion of the fauna assemblage and only MNI and NISP are provided here (see Table 1). A complete inventory of all skeletal elements for non-ungulate species is provided elsewhere (see Hutson, 2006:Table 4.3).

The study of skeletal part representation at Kalkbank revealed a number of important observations. Brown (1988) reported a discrepancy between front and hind limb bones; 145 humerus and 106 radius fragments, but only 26 and 84 femur and tibia fragments, respectively. The pattern shown in her NISP values is reproduced with the new analysis and the use of MNE. Minimum Number of Elements values of 66 humeri and 55 radii far outnumber the MNE values of 15 and 38 for femur and tibia. Brown (1988) also notes the low numbers of phalanges. She counted 40 NISP, while this analysis records 41 NISP and 30 MNE for all ungulates. Phalanges should be well represented, as there are up to 24 per individual in the case of bovids, yet relatively few phalanges were recovered at Kalkbank. Brown (1988) attributed the lack of hind limb elements and phalanges to the “schlepp effect,” popularized by Perkins and Daly (1968), in which disarticulation and selective transport produces patterning in body part representation of larger animals. In this case, she hypothesized that phalanges often were removed from Kalkbank as part of the animal skin used to transport meaty limb portions back to a campsite.

While the pattern associated with the “schlepp effect” is evident, the cause may not be solely the result of human activity. Phalanges are nearly absent at many modern hyena dens, and fossil carnivore accumulations often exhibit low numbers of phalanges and other small compact bones. Bearder (1977) collected only nine out of 409 total bones at a spotted hyena den in the Timbavati, and Skinner et al. (1980) only recorded seven from a total of 267 bones from a striped hyena den in Israel. The ancient faunal assemblages recovered from Equus Cave (Klein et al., 1991) and Swartklip (Klein, 1975), both probable carnivore accumulations, exhibit low proportions of phalanges, carpals, and tarsals.

In addition to comparisons with modern and ancient hyena accumulations, replication work by Marean et al. (1992:119) shows that “the result of hyena ravaging is to mimic the schlepp effect.” Their experimental data show that when hyenas scavenged from a simulated hominid site comprised of broken and unbroken sheep (Ovis aries; bovid size 2) bones, all portions of the vertebrae and ribs were destroyed nearly 100% of the time, all portions of pelves and compact bones (tarsals) were destroyed between 50% and 75% of the time, the limb bone epiphyses were destroyed frequently, but the midshaft fragments were virtually never destroyed. A similar pattern was also seen when the limb bones were left unbroken and then ravaged by hyenas. Based on NISP and MNE values from the Kalkbank assemblage, ribs, vertebrae (excluding atlas and axis), pelvic elements, and compact bones constitute a small portion of the assemblage relative to limb bones (see Table 2).

The experiments performed by Marean et al. (1992) showed that hyenas
Table 2. Ungulate skeletal part representation by MNE/NISP.

<table>
<thead>
<tr>
<th></th>
<th>Bovid 2</th>
<th>Bovid 3</th>
<th>Bovid 4</th>
<th>Zebra</th>
<th>Giant Cape zebra</th>
<th>Wart-hog</th>
<th>Black rhino</th>
<th>Hippo</th>
<th>Elephant</th>
<th>Indet. Large Mammal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull:teeth</td>
<td>9/24</td>
<td>18/60</td>
<td>7/30</td>
<td>12/182</td>
<td>5/38</td>
<td>22/148</td>
<td>1/3</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
</tr>
<tr>
<td>Horn core</td>
<td>2/2</td>
<td>23/36</td>
<td>2/3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hemi-mandible:teeth</td>
<td>17/27</td>
<td>27/46</td>
<td>4/7</td>
<td>12/43</td>
<td>3/11</td>
<td>44/86</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1/4</td>
</tr>
<tr>
<td>Atlas</td>
<td>4/4</td>
<td>18/35</td>
<td>3/4</td>
<td>2/2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1/2</td>
</tr>
<tr>
<td>Axis</td>
<td>1/1</td>
<td>7/9</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cervical vertebrae</td>
<td>1/1</td>
<td>13/22</td>
<td>9/10</td>
<td>1/2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thoracic vertebrae</td>
<td>3/3</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lumbar vertebrae</td>
<td>2/5</td>
<td>1/1</td>
<td>2/3</td>
<td>-</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sacrum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Caudal vertebrae</td>
<td>-</td>
<td>-</td>
<td>9/10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rib</td>
<td>6/6</td>
<td>8/8</td>
<td>2/2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pelvis:half</td>
<td>6/13</td>
<td>6/21</td>
<td>7/13</td>
<td>5/7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1/1</td>
<td>1/2</td>
</tr>
<tr>
<td>Humerus</td>
<td>17/24</td>
<td>34/113</td>
<td>15/35</td>
<td>7/10</td>
<td>6/6</td>
<td>6/9</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>1/2</td>
</tr>
<tr>
<td>Radius</td>
<td>11/22</td>
<td>32/88</td>
<td>12/25</td>
<td>2/6</td>
<td>1/1</td>
<td>5/5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ulna</td>
<td>-</td>
<td>9/20</td>
<td>3/4</td>
<td>1/1</td>
<td>-</td>
<td>4/5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scapula</td>
<td>6/11</td>
<td>8/16</td>
<td>5/7</td>
<td>-</td>
<td>1/1</td>
<td>2/2</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Metacarpal</td>
<td>5/12</td>
<td>27/55</td>
<td>6/10</td>
<td>7/9</td>
<td>5/5</td>
<td>7/13</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Indet. metapodial</td>
<td>2/3</td>
<td>4/28</td>
<td>2/20</td>
<td>1/4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carpals</td>
<td>-</td>
<td>11/11</td>
<td>3/3</td>
<td>1/1</td>
<td>1/1</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Femur</td>
<td>4/8</td>
<td>9/23</td>
<td>2/4</td>
<td>-</td>
<td>1/1</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tibia</td>
<td>7/13</td>
<td>17/59</td>
<td>14/22</td>
<td>11/25</td>
<td>6/10</td>
<td>3/5</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Metatarsal</td>
<td>9/16</td>
<td>28/68</td>
<td>11/23</td>
<td>7/9</td>
<td>3/3</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acc. metapodials</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1/1</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Patella</td>
<td>1/1</td>
<td>1/1</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Astragalus</td>
<td>1/1</td>
<td>16/16</td>
<td>2/2</td>
<td>12/12</td>
<td>8/8</td>
<td>3/3</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Calcaneum</td>
<td>3/3</td>
<td>17/22</td>
<td>8/9</td>
<td>3/3</td>
<td>2/2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other tarsals</td>
<td>-</td>
<td>1/1</td>
<td>1/1</td>
<td>2/2</td>
<td>2/3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phalanges</td>
<td>5/6</td>
<td>9/11</td>
<td>5/5</td>
<td>4/6</td>
<td>3/6</td>
<td>4/7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lateral maleolus</td>
<td>-</td>
<td>3/3</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sesamoids</td>
<td>-</td>
<td>1/1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Kalkbank taphonomy

Table 3. Surface modification by NISP. Percentage values are provided below each category.

<table>
<thead>
<tr>
<th>NISP</th>
<th>Porcupine gnawed</th>
<th>Carnivore gnawed</th>
<th>Root etched</th>
<th>Butchery marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1184*</td>
<td>169</td>
<td>207</td>
<td>792</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>14.3%</td>
<td>17.5%</td>
<td>66.9%</td>
<td>0.3%</td>
</tr>
<tr>
<td>1478</td>
<td>93</td>
<td>74</td>
<td>797</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>6.3%</td>
<td>5.0%</td>
<td>53.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2662*</td>
<td>262</td>
<td>281</td>
<td>1589</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>9.8%</td>
<td>10.6%</td>
<td>59.7%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

actively destroy bone elements with the lowest densities, but focused on element survival subsequent to simulated hominid activity and may not be directly relevant to assemblages exclusively ravaged by hyenas. Experimental data provided by Richardson (1980) show that when hyenas do feed on whole carcasses, they produce low survival rates for ribs, vertebrae, pelves, and small compact bones—the same pattern seen at Kalkbank.

The skeletal element proportions displayed at Kalkbank provide little definitive information in terms of agent of accumulation. High proportions of cranial and limb elements and few ribs, vertebrae, pelves, and elements of the foot can be explained in several ways; “schlepp effect,” carnivore ravaging, or density mediated attrition, for instance. Such problems with equifinality in skeletal element profiles have been addressed by researchers (see Munro & Bar-Oz, 2004 and references within), but the problems are far from resolved. It has been recommended that bone surface modification and bone breakage patterns be used to provide more useful taphonomic information for determining agents of accumulation (Domínguez-Rodrigo, 1999).

Surface Modification

Table 3 shows the total numbers of observed surface modifications on post-cranial elements and 46 mandibular fragments. Brown (1988: 208) identified four specimens with butchery damage; a bovid size 3 distal tibia with chopping damage, an Equus cf. burchelli distal tibia with numerous cut marks, a bovid size 4 proximal radius with parallel cut marks, and a bovid size 3 proximal radius which has two parallel grooves on the shaft identified as batter marks. Upon review, all the marks identified by Brown appear different in color and texture to the surrounding bone surface and undoubtedly represent marks caused during excavation or preparation.

In this analysis, only three specimens exhibiting possible butchery damage have been identified. All represent hammerstone percussion marks on bovid limb bones. One occurs on a bovid size 3 proximal metatarsal (Figure 1), one on a bovid size 4 proximal metacarpal (Figure 2), and the other on a bovid size 3 distal metapodial (Figure 3). These modifications appear rather unlike carnivore tooth marks following the criteria.
upwards of 80% of bones show damage (Bearder, 1977; Maguire et al., 1980; Bunn, 1983; Skinner et al., 1986; Horwitz & Smith, 1988). In contrast, ancient hyena assemblages appeared to preserve low proportions of carnivore-gnawed specimens—as low as 0.4% of the specimens at Swartklip (Klein, 1975) and 1.2% at Equus Cave (Klein et al., 1991). These accumulations represent hyena den sites to which bones were brought from the surrounding landscape, while Kalkbank may represent the opposite—an open-air locality where prey were killed or scavenged and from which bones were subtracted—and accordingly, ought to include carnivore damaged bones in lesser quantities since some elements may never have been ravaged by carnivores.

There are a number of issues regarding variability in the amount of carnivore ravaging documented for presumed carnivore accumulated faunal assemblages; the foremost of which may be location, mentioned above. Other possible sources of variation may relate to carnivore density and diversity, degree of competition, and environmental stress.

Figure 1. Possible hammerstone percussion mark on a bovid size 3 proximal metatarsal fragment.

set out by several researchers (Blumenschine & Selvaggio, 1988, 1991; Capaldo & Blumenschine, 1994; Blumenschine et al., 1996). The three possible butchery marks and the stone tool assemblage certainly indicate a human presence at the Kalkbank pan, but only a peripheral association with the faunal assemblage in terms of accumulation.

The previous analysis recorded eleven carnivore gnawed specimens in the Kalkbank assemblage (Brown, 1988). In contrast, this analysis showed carnivore damage on 17.5% (207 of 1184) of the identifiable postcranial elements, including 46 mandibular fragments, and 5.0% (74 of 1478) of the unidentifiable postcranial elements—10.6% (281 of 2662) of the entire assemblage with adequate surface preservation (see Table 3). Tooth pits, punctures, scoring, furrows, and crenulated edge damage were identified during this analysis. Representative examples of the observed damage are provided in Figures 4-8.

The percentage of carnivore gnawed specimens at Kalkbank falls short of that reported at modern hyena collections, where
Figure 2. Possible hammerstone percussion mark on a bovid size 4 proximal metacarpal fragment.

Figure 3. Possible hammerstone percussion mark on an indeterminate bovid size 3 distal metapodial.

Figure 4. Carnivore tooth pit damage on a bovid size 3 humerus shaft fragment.
Recently documented long-term changes in the pattern of carnivore modification within Amboseli National Park in Kenya show that these factors are intricately related (Faith & Behrensmeyer, 2006). We are unsure of how these might affect the degree of carnivore ravaging in ancient assemblages accumulated over long periods of time. As the faunal assemblage at Kalkbank included few carnivore individuals, we do not have direct evidence that the carnivore population was particularly dense or diverse. Environmental stress could have affected the degree of carnivore ravaging as the area dried. Carnivore competition may have influenced the proportions of carnivore damaged specimens at Kalkbank. During the early wet periods, competition for meat at kill sites and possible scavenging sites were potentially low. Low competition for access to carcasses would thus yield an assemblage with slightly depressed numbers of carnivore damaged specimens. We suspect a possible increase in competition as the assemblage with the data available do not allow for that level of observation.

Of the remains with carnivore damage, there were 172 bovid bones (17 size class 2, 109 size class 3, 46 size class 4), 32 equid bones, two suid bones, and one rhinoceros specimen. The highest concentration of marks occurs on bovid limb bones. Table 4 shows the distribution of carnivore marks on bovid remains with adequate surface preservation according to limb portion and size class loosely following Blumenschine (1988; also see Blumenschine & Marean 1993). The evidence provided shows that carnivore marks on the Kalkbank bovid limb bone are generally well distributed on epiphyseal portions and limb shafts. Although these totals do not approach the high values identified by Blumenschine (1988:491) where upwards of 85% of the midshafts, 90% of the near-epiphyses, and 100% of the epiphyses show tooth marks for experimentally produced assemblages ravaged only by carnivores. Kalkbank yielded more modest results, with grand totals of just over 24% of the shaft fragments, 27% of the epiphysis+shafts, and 13% of the epiphyses displaying carnivore markings. Additionally, 31% of the complete

Table 4. Carnivore damage distribution by bovid limb bone portion. For each category, the first value represents total number of carnivore damaged specimens and the second value represents NISP for that limb bone portion and bovid size class. Percentage values are provided below each category.

<table>
<thead>
<tr>
<th></th>
<th>Bovid 2</th>
<th>Bovid 3</th>
<th>Bovid 4</th>
<th>Total Bovid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand total</td>
<td>14/93</td>
<td>88/401</td>
<td>42/133</td>
<td>144/627</td>
</tr>
<tr>
<td></td>
<td>15.0%</td>
<td>21.9%</td>
<td>31.5%</td>
<td>22.9%</td>
</tr>
<tr>
<td>Epiphysis</td>
<td>0/10</td>
<td>10/90</td>
<td>7/30</td>
<td>17/130</td>
</tr>
<tr>
<td></td>
<td>0.0%</td>
<td>11.1%</td>
<td>23.3%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Epiphysis+shaft</td>
<td>3/25</td>
<td>32/108</td>
<td>13/41</td>
<td>48/174</td>
</tr>
<tr>
<td></td>
<td>12.0%</td>
<td>29.6%</td>
<td>31.7%</td>
<td>27.5%</td>
</tr>
<tr>
<td>Shaft</td>
<td>11/58</td>
<td>43/195</td>
<td>20/54</td>
<td>74/307</td>
</tr>
<tr>
<td></td>
<td>18.9%</td>
<td>22.0%</td>
<td>37.0%</td>
<td>24.1%</td>
</tr>
<tr>
<td>Complete</td>
<td>—</td>
<td>3/8</td>
<td>2/8</td>
<td>5/16</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>37.5%</td>
<td>25.0%</td>
<td>31.2%</td>
</tr>
</tbody>
</table>

413
Figure 5. Carnivore tooth puncture damage on a bovid size 3 metacarpal distal+shaft.

Figure 6. Carnivore tooth scoring damage on a Bovid size 3 humerus shaft fragment.
not all of the individual remains at these sites were actively hunted by carnivores, but rather portions of the assemblages could be scavenged. However, in the case of the Kalkbank accumulation, it is clear that humans played a relatively insignificant role with the fauna, and carnivores almost certainly had early access to carcasses at the site.

Disagreement over the significance of porcupine involvement preceded our assessment of Kalkbank. Cooke (1962) identified nearly 25% (903 of 3619) of the assemblage excavated in 1954 as porcupine gnawed. In contrast, Brown (1988) identified only about 3% of bones gnawed when provided with a portion of the 1954 and 1954 specimens show damage. Aside from several low values in the bovid size 2 category, these totals roughly mirror the results reported by Monahan (1996) in his analysis of the HWK E 1-2 site from Bed II Olduvai Gorge. The results of that study identified roughly 19% of the midshafts, 36% of the near-epiphyseal fragments, 35% of the epiphyseal fragments, and 10% of the complete specimens as carnivore damaged (Monahan, 1996:108). Lower incidences of identifiable carnivore damage on the assemblages from Kalkbank and HWK E 1-2 likely reflect differences between the studies of a modern experimental assemblage as opposed to ancient faunal accumulations. It may be possible that
1966 faunal material (the sample size used is unclear, but 193 bore porcupine marks). This represents a substantial drop considering Brown potentially analyzed twice the number of specimens. In this current analysis, 14.3% (169 of 1184) of the identifiable post-crania (including 46 mandibular specimens) were gnawed. A further 6.3% (93 of 1478) of the unidentifiable specimens were modified by porcupines, bringing the total to 9.8% (262 of 2662) (see Table 3).

The percentage of porcupine gnawed bones at Kalkbank is relatively high for the typical open-air archaeological site, yet low for a porcupine lair. Of the known porcupine lair accumulations in southern Africa, most range from 60% to 100% of the specimens gnawed (Brain, 1981:117). Other sites display less damage, such as Winkelhoek lair in northern KwaZulu Natal where only 22% of the bones were gnawed (Maguire, 1976). The open-air setting of Kalkbank near an ancient pan does not seem a likely place for a porcupine accumulation, as porcupines bring bones from the surrounding landscape to a den. However, the Nossob porcupine lair was located in a solution cavity in the calcrete on the bank of the Nossob River in Botswana (notes by A. Hughes in Brain, 1980:109, 1981:112), a similar setting to Kalkbank. No specific evidence supports the existence of a solution cavity within the Kalkbank calcrete. Although a portion of the Kalkbank assemblage could have resulted from a porcupine lair locality, it is also possible that porcupines frequently visited the pan area where animal bones were readily available. Porcupines are known to visit such open-air sites in Hwange National Park, Zimbabwe, sometimes leaving isolated and atypical gnaw marks on specimens (G. Haynes, personal communication 2008). Numerous episodes of porcupine ravaging and various types of porcupine involvement may explain the moderate amount of porcupine gnawing seen at Kalkbank.

The acids and fungi associated with plant roots in contact with bone surfaces produce root etching in many environments (Behrensmeyer, 1978; Binford, 1981; Grayson, 1988). Such markings appear as dendritic patterns of shallow grooving (Behrensmeyer, 1978); distinctive, broad, sinuous, smooth-bottomed, u-shaped grooves (Andrews & Cook, 1985); spaghetti-like (Hesse & Wapnish, 1985); and linear-to-wavy depressions (Grayson, 1988). A total of 59.7% of the Kalkbank postcranial and mandibular specimens display root etching (see Table 3). Most of the Kalkbank specimens exhibit very shallow, discontinuous surface depressions (see Figures 7 and 8), while others show rather deep pitting (Figure 9), presumably from grasses, reeds, and sedges growing around the Kalkbank pan. The locations of root marks on limb shaft fragments provide information regarding the timing of bone fracture (Figure 10). Of the 563 identifiable limb shaft, and proximal and distal epiphysis-plus-limb shaft fragments with adequate preservation, 26% (148) show root etching on either their fracture surface or within the medulary cavity. Just over 50% (289) are root-etched on their outer surfaces only, and 22% (126) with none at all. Also, 29% (355) of the unidentifiable limb specimens are root-etched on the outer surface only, while 27% (334) show root etching on their fracture surface, medulary cavity, or both. Similar root markings were reported on the faunal material recovered at Mancos 5MTUMR-2346 (White, 1992). As root markings occurred on external and internal bone surface in equal numbers, White (1992) determined the bones to have been broken prior to burial. With relatively high percentages of bones that display root etching on the inner cavity and fracture surface, it
seems likely that the majority of the Kalkbank limb bones were broken prior to deposition—a topic that is further discussed below.

**Bone Breakage**

**Completeness**

Most Kalkbank elements had completeness values in excess of 80% (Figure 11). Although many compact bone categories contain a small number of specimens, the astragalus and navicular-cuboid (bovid naviculo-cuboid and equid navicular) categories offer sufficient sample sizes. The Completeness Index values for astragali and navicular-cuboid at Kalkbank were 78% (32 NISP) and 55% (19 NISP) respectively. At site GvJm22 the values for astragali are 87% and 58% for navicular-cuboid. In contrast, the values for astragali and navicular-cuboid at GvJm46 are 19% and 18% respectively (Figure 12). Marean (1991) concluded that from these proportions the faunal assemblage from GvJm22 experienced considerably less post-depositional destruction than GvJm46. This comparison suggests little post-depositional destruction at Kalkbank, and the observed fragmentation of limb elements and other bones is more likely the result of carnivore activity.

**Bone cylinders**

The Completeness Index suggests only minor post-depositional breakage and surface modification data imply a considerable carnivore involvement at Kalkbank. We used additional bone breakage analyses to further identify the carnivore contribution to the assemblage. An analysis of limb shaft fragments for the entire Kalkbank assemblage according to bovid size class revealed that a relatively high percentage of long bone fragments were represented by bone cylinders (Figure 13); 57.1% (32 bone cylinders/56 total limb shaft fragments) for bovid size 2, 17.0% (34/106) for bovid size 3, 12.1%
Kalkbank taphonomy

(7/58) for Bovid size 4, and a total bovid count of 23.2% (73/314). The trend of decreasing bone cylinders with increased bovid size likely reflects the higher difficulty of carnivores to consume the limb bone epiphyses of larger bovids.

Fracture Patterns

Just over 70% (102/145) of the bones sampled at Kalkbank display obtuse angles, while only 1% (1/145) display right angle breaks, and 29% (42/145) intermediate between the two (Figure 14). This pattern suggests that a majority of the bones at Kalkbank were broken in a green state prior to deposition. More than three-quarters (112/145) of the Kalkbank specimens have curved outlines, while transverse and intermediate outlines only represent 9% (13/145) and 14% (20/145) of the sample respectively (Figure 15). Again, a pattern of green bone breakage at Kalkbank seems evident. In terms of fracture edge (Figure 16), Kalkbank shows a pattern similar to Sarrians (69% with jagged edges), which may imply bone breakage from static forces since fracture angle and outline suggest most breakage occurred while the bones were green. Sediment pressure can be excluded as the static force at Kalkbank as the Completeness Index, fracture angle, and fracture outline suggest little post-depositional destruction. Carnivore jaws also create static forces on bones and likely account for a portion of jagged fracture edges on the long bones at Kalkbank, which is reinforced by the high incidence of carnivore gnaw marks.

This analysis of fracture patterns includes only bone cylinders and “near” bone cylinders, but would greatly benefit from a complete analysis of all the limb shaft fragments as recommended by Alcántara García et al. (2006) and successfully executed by Pickering et al. (2005) with the Swartkrans Member 3 fauna. At the least, fracture pattern data at Kalkbank suggest the bone cylinders were largely created during feeding by carnivores. Post-depositional breakage appears to be minimal.

Discussion

The evidence presented here suggests carnivores as the major accumulator of the faunal assemblage near the ancient Kalkbank pan. The criteria to distinguish accumulations produced by various carnivores, however, relate largely to hyena den sites or leopard accumulations (see Brain, 1981). Pickering (2002; also see Cruz-Uribe, 1991) suggests hyena accumulations include the following: 1.) a relative abundance of carnivores in the faunal assemblage—predominantly juvenile individuals from a denning locality; 2.) an abundance of ungulate limb bones with intact shafts and lacking epiphyses (bone cylinders); and 3.) an abundance of carnivore bone surface damage. Of the seven identified large carnivore individuals at Kalkbank, only a single hyena tooth came from a juvenile. This is not unexpected as features potentially related to a hyena den were absent from records of the site. No acid-etched bones were identified nor were any hyena coprolites recovered. The Kalkbank assemblage conforms to the remaining criteria, showing numerous bone cylinders and carnivore damage. Haynes (1983b) has published guidelines for differentiating carnivore taxa responsible for gnaw damage to limb bones, but such an analysis of the Kalkbank assemblage was not undertaken. Nonetheless, in the absence of large numbers of human modified bones, these two criteria may be sufficient to
Figure 10. Total root etching on limb shaft fragments. Within each category, the first value represents number of specimens by root etching location and the second value represents the total number of root etched limb shaft fragments, both by NISP.

![Root Etching on Limb Shaft Fragments](image)

Figure 11. Completeness Index for all ungulate compact bones. Navicular-cuboid category includes all bovid naviculo-cuboids and equid navicular. Values within each category represent NISP.

![Completeness Index](image)

Figure 12. Completeness Index comparison between Kalkbank and two sites in Kenya (Marean, 1991). Kalkbank Navicular-cuboid category includes bovid naviculo-cuboid and equid navicular. Values within each category represent NISP.

![Completeness Index Comparison](image)
Figure 13. Total bovid long bone cylinders by size class. The first value within each category represents number of bone cylinders and the second value represents the total number of limb shaft fragments. All values represent NISP.

Figure 14. Fracture angle of the Kalkbank long bones as compared to the three assemblages studied by Villa and Mahieu (1991). Values within each category represent NISP.

Figure 15. Fracture outline of the Kalkbank limb bones as compared to the three assemblages studied by Villa and Mahieu (1991). Values within each category represent NISP.
identify large carnivore accumulations including those from hyenas in open-air and den settings. A past focus on cave accumulations and ravaged human assemblages has led to the development of criteria that may not be appropriate for the type of carnivore dominated accumulation at Kalkbank. Instead, concentrating on the transformation of carnivore-dominated assemblages into the palaeontological record and identifying specific criteria for ancient pan accumulations will help in discussing assemblages like that at Kalkbank. The Kalkbank accumulation was likely the result of lion and hyena predation, similar to the modern accumulations documented by Haynes (1985, 1988) at Ngamo Pan in Hwange National Park, Zimbabwe and Etosha Pan in Etosha National Park, Namibia. Repeated carnivore kills near the ancient watering hole at Kalkbank created a large bone concentration in a restricted area; this type of site has been referred to as a “predation hot spot” or “serial predation site” (Behrensmeyer, 1983, 1987; Haynes, 1988, 1991b; Tappen, 1995; Tappend et al., 2007). Archaeological or palaeontological examples of these sites are rare, and much of the data from such sites have come from modern landscape studies, such as those at Amboseli Park, Kenya (Behrensmeyer, 1975, 1981, 1983, 1991; Behrensmeyer et al., 1979; Behrensmeyer & Dechant-Boaz, 1980; Cutler et al., 1999; Faith & Behrensmeyer 2006), Serengeti National Park, Tanzania (Blumenschine, 1989), Parc National des Virunga, Congo (Tappen, 1995, 2001), Etosha National Park, Namibia (Haynes, 1985), and Hwange National Park, Zimbabwe (Haynes, 1988, 1991b). Tappen et al. (2007) recently published a preliminary report of the serial predation site at Dmanisi in the Republic of Georgia, and included seven predicted characteristics of predation hot spots as opposed to carnivore den sites. The characteristics of predation hot spots include: 1.) a restrictive landscape feature which improves hunting success and acts to concentrate bones; 2.) more diffuse spatial distribution of bones as opposed to dense

Figure 16. Fracture edge of the Kalkbank long bones as compared to the three assemblages studied by Villa and Mahieu (1991). Values within each category represent NISP.
Kalkbank taphonomy

concentrations near the periphery of den sites; 3.) small-scale bone transport; 4.) less carnivore surface modification; 5.) fewer juvenile carnivore individuals; 6.) variable bone surface weathering; 7.) fewer carnivore coprolites; and 8.) more trampling by large ungulates. Kalkbank adheres to some of these criteria. However, some characteristics are only theoretical as too few examples have been described to test their relevance.

The ancient pan at Kalkbank would have offered an excellent focal point on the landscape for ambush hunting by a variety of predators. The large complex of natural pan depressions at Ngamo Pan in Hwange National Park serves as a good model for the Kalkbank pan. During the rainy season, the area surrounding the pan is wet and covered in tall grasses, and during the dry, winter months, the pan attracts numerous large ungulate species which become easy prey for lions and hyenas (Haynes, 1988). At Ngamo Pan, Haynes (1988) reports the entire pan complex covers roughly one square kilometer, and he recovered over 700 bones along a 3.0 km x 30 m transect, but only surveyed roughly 11% of the entire area. The excavations at Kalkbank reveal a more dense accumulation than at Ngamo Pan, and Welbourne (1971) believes there to be an unknown amount of material which remains to be exposed at Kalkbank, as the calcrete covers several acres. Neither site shows distinctive spatial distribution similar to modern and fossil carnivore den sites.

Predation hot spots should experience little bone transport. In general, as loci of repeated carnivore kills, bones are expected to be transported away from the site rather than introduced from another location on the landscape. Hyenas often prefer to transport skeletal elements away from the kill site to an area providing more cover or to a den. This can be observed in modern cases, but skeletal element survival is subject to a variety of taphonomic processes and not exclusively carnivore transport. It has been suggested that relative to dens, hot spots should include more vertebrae and fewer skulls, which tend to be transported, depending on size of prey and carnivore competition (Behrensmeyer, 1983; Tappen, 1995). Kalkbank shows higher survival of cranial elements in the form of maxillary teeth and horn cores in most ungulate taxonomic classes except bovid size 4. As we discussed earlier, skeletal part representation suffers from equifinality with other processes and should be used with other criteria.

Predation hot spots should also show less carnivore surface modification than carnivore den sites. Kalkbank shows carnivore damage on 17.5% of the identifiable postcranial elements and 10.6% of the entire assemblage. Modern hyena dens usually record between 38 and 100% of specimens with tooth marks, while the modern attritional death assemblage from Parc National des Virunga shows at least 15% with carnivore markings (Tappen, 2007; also see Blumenschine et al., 1996); however this assemblage includes numerous bone patches distributed widely throughout the park and does not offer an appropriate comparison the the Kalkbank location, yet these percentages are consistent with the expected pattern of less carnivore modification than at den sites. Gnawing by juveniles would also be much higher at den sites, although no specific data are available for identifying gnawing by juvenile carnivores, this criteria can be directly tied to the number of juveniles in the assemblage. As mentioned previously, only
one juvenile carnivore individual was identified in the Kalkbank assemblage, and likewise, no juvenile carnivore tooth marks were observed.

Significant but variable weathering at open-air predation hot spots is potentially expected as opposed to little weathering at sheltered den sites. All stages of weathering are reported on the bones from Parc National des Virunga, but most specimens tended towards the early stages of weathering. No data on weathering from Ngamo Pan are available, but Haynes (1988) notes the observed skeletons were being quickly buried or uncovered by windblown sediments. He also notes the presence of tall grasses surrounding the pan. Root etching shows that tall grasses, reeds, or sedges occupied the landscape immediately adjacent to the Kalkbank site. The vegetation may have also provided adequate shade to prevent significant weathering, because very few Kalkbank specimens exhibit weathering beyond stage 1.

Den sites frequently include carnivore coprolites, while it is perceived that open-air accumulations rarely preserve them. A quantified lack of coprolites at open-air sites has never been established; yet, as no coprolites were recovered, this trend holds true with the Kalkbank assemblage.

No evidence of trampling by large ungulates was recorded in the Kalkbank assemblage. The effects of trampling are often shown in striations that mimic cut marks (Fiorillo, 1984; Haynes & Stanford, 1984; Andrews & Cook, 1985; Behrensmeyer et al., 1986). Trampling is difficult to detect in fossil accumulations. Tappen et al. (2007) suggest trampling may reduce the number of bone cylinders into shaft fragments. Kalkbank includes a moderate number of bone cylinders, but sites with a low occurrence of bone cylinders may have also suffered from factors other than trampling.

The aforementioned criteria relate well to modern predation hot spot accumulations, but complications arise when applying these to fossil accumulations. A wider range of fossil sites is needed to further describe the range of characteristics at predation hot spots. The outlook is promising. Recent taphonomic studies of Olduvai Bed I sites reveal that DK and several accumulations from the FLK North sequence may incorporate some elements of a predation hot spot (Egeland, 2007). The latest account of the fauna at Dmanisi also suggest a large scale involvement of carnivores indicative of a predation hot spot (Tappen et al., 2007). The possibility exists for other previously excavated sites subjected to a taphonomic reanalysis to include a larger carnivore involvement. Such reanalyses, like our work at Kalkbank, will refine the characteristics of predation hot spots and work to compliment the ongoing research on modern landscape assemblages.

Conclusion

The assemblage at Kalkbank appears to have been accumulated to a large extent by non-human agents. There is significant carnivore involvement in both the accumulation and modification of the Kalkbank assemblage. Carnivores undoubtedly exploited the site’s location near an ancient pan for ambush hunting, but may also have frequented the location in search of scavenging opportunities. Porcupine involvement is significant as well. It is possible that a porcupine lair was located near the pan; however, it is equally possible that the porcupine involvement was limited to post-accumulation gnawing and removal of
skeletal elements. The palimpsest of carnivore and porcupine activity created a faunal signature that diverged from the published modern studies of these agents separately. Humans, to a small extent, contributed to the assemblage using the pan as a hunting area. The opportunity to exploit animal carcasses abandoned by carnivores or limited hunting may have encouraged humans to frequent the pan as evidenced by the hammerstones and grinding stones recovered at the site. Natural death of animals visiting the pan may have significantly contributed to the faunal assemblage. These natural deaths would have produced carcasses that may have been ravaged by carnivores and porcupines. Overall, the assemblage is of little importance to understanding human behavior at the end of the Pleistocene because of admixture with components from non-human accumulators. The Kalkbank assemblage should be considered for the most part palaeontological.

Yet, the assemblage from Kalkbank is significant. Kalkbank is a rare example of a pan associated faunal assemblage from the late Pleistocene in which non-human and human taphonomic processes have been identified. As we have discussed, it can be seen as a likely predation hot spot assemblage. Additional analyses may be applied to further understand the taphonomic history of the assemblage and further research is needed to identify the specific appearance of ancient carnivore predation hot spot assemblages, which may differ from modern examples.

Acknowledgments

We thank Gary Haynes and Chris Monahan for their thoughtful reviews of an earlier draft of this paper. Robert Blumenschine also provided insightful comments on this work. We however bear the responsibility of any errors in this publication. This study was funded partially through a Post-graduate Merit Award granted to JMH by the University of the Witwatersrand. JMH would like to thank CRC and Dr. Kathy Kuman for their expert guidance and instruction in the preparation of this paper. CRC would like to thank Lyn Wadley, the ACACIA programme, the University Research Council of Wits University, and the National Research Foundation (South Africa) for their support of his post-doctoral fellowship at Wits. The authors would like to thank the Palaeontology Unit of the School of Geosciences at Wits for access to the Kalkbank assemblage and comparative material. We would also like to thank the faculty and students from the Archaeology Section of the School of Geography, Archaeology, & Environmental Studies at the University of the Witwatersrand for their advice and assistance. Lastly, we thank Charles Egeland for organizing this issue and for his support and patience in putting it together.

References


Kalkbank taphonomy


