ZOOARCHAEOLOGICAL TESTS FOR MODERN HUMAN BEHAVIOR AT BLOMBOS CAVE AND PINNACLE POINT CAVE 13B, SOUTHWESTERN CAPE, SOUTH AFRICA

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

ARIZONA STATE UNIVERSITY

August 2008

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has been approved

June 2008

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ABSTRACT

Data were collected and analyzed from the fossil animal bones at two archaeological sites in the southwestern Cape, South Africa: Blombos Cave and Pinnacle Point Cave 13B (PP13B). Both sites date to a time known as the Middle Stone Age (MSA), from ca. 280 – 30 thousand years ago (ka). This was a critical period in human evolution, and recent discoveries from Blombos have shown that creativity and symbolic behavior were present in *Homo sapiens* by at least 70 ka. However, the relationship between these factors and diet remains unknown. Work on this problem has been seriously hindered by a lack of empirical data: in all of Southern Africa only one other faunal collection from this time period has been comprehensively analyzed and published (Die Kelders Cave 1 [DK1]).

The study presented here replicates many of the methods employed at DK1, effectively tripling the empirical record for faunal collections that are complete, have been fully analyzed using taphonomic methods, and are comparable to one another. For the first time, behavioral comparisons of MSA faunal exploitation can be made between sites with abundant evidence for symbolic behavior (Blombos) and with less such evidence (PP13B and DK1).

This dissertation examines in detail the taphonomic histories at PP13B and Blombos, including fragmentation, the relative contributions of human and non-human bone accumulators, and density-mediated destruction. With these factors understood and controlled for, evaluations of MSA hunting ability, transport decisions, and carcass processing strategies are made from these sites and at DK1 using both standard zooarchaeological measures and new methods for reconstructing these behaviors from

fossil collections. These analyses reveal that MSA hominins were adept hunters with a prey focus on large ungulates but who also opportunistically exploited smaller ungulates, tortoises, and small mammals. There is a great deal of variability in how ungulates of all body sizes were processed and transported, but at all sites there is an intensive use of all animal resources, including bone grease, and an emphasis on the filleting of meat from shafts.

This dissertation is dedicated to my mother, Jo Ann Asher Thompson, who first inspired me to become a doctor but always encouraged me to be whatever I wanted.

ACKNOWLEDGEMENTS

Data collection for this project was funded with the aid of National Science Foundation (NSF) Dissertation Improvement Grant number 0620317, a Fulbright Fellowship to South Africa, an NSF Graduate Research Fellowship, funds from NSF grant number 0524087, and a grant from the School of Human Evolution and Social Change (SHESC) at Arizona State University. SHESC also provided the means for writing up with a Dean's Dissertation Writing Fellowship for the academic year 2007 – 2008. Further support was provided by the National Science Foundation (USA) (grants # BCS-9912465, BCS-0130713, and BCS-0524087 to Marean), funding from the Huxleys, the Hyde Family Trust, the Institute for Human Origins, and Arizona State University.

Curtis Marean generously provided access to the PP13B fossil assemblage, to his GIS files and database from DK1, to the microscope used in this study, and to valuable contacts in South Africa who facilitated the work. Throughout the study he has been a source of support, advice, and motivation. Geoff Clark and Kaye Reed rounded out my committee, providing valuable advice and comments on funding proposals through the entire process. Chris Henshilwood provided access to the Blombos Cave fossil assemblage and an affiliation with the African Heritage Research Institute during data collection.

Iziko: South African Museums of Cape Town (SAM) provided basic infrastructure without which this study could never have been done. The institution allowed me access to the archaeological and comparative skeletal collections, office space, internet access, and a key card that enabled all those late nights at the museum. Graham Avery, Royden Yates, and Sarah Wurz all went above and beyond simple

allocation of space, and I truly felt a part of the research community at the SAM while I was there.

The ideas presented in this dissertation about the 'special use' of certain MSA sites were inspired by conversations with Curtis Marean, and the evaluation of MSA hunters as members of the large-bodied carnivore guild was a concept suggested by Kim Hill. Candice Jagers was my gem of a lab assistant for a full 8 months and Ben Elliott spent untold hours in 2005 labeling fossil fauna from Blombos Cave, unpaid and with barely a grumble. Basil van Bergen assisted with bugs in the Access database and Bonesorter program codes, and Simon van Noort gave generously of both his time and his equipment in assisting with the microscopic photographs.

This project would never have been seen through to completion without the constant support and encouragement of friends and family. My brother, Tyler Thompson, employed his superior graphics skills to help simplify Figure 34. My parents, Bruce and Jo Ann Thompson have also gone a step further: there are dozens of bags in the South African Museum storeroom that have their handwriting curated alongside the fossils they contain. My husband, Glen Stevenson, additionally failed to escape a few Sunday afternoons of organization and curation – though his more significant contributions were his smile when he picked me up every day after work and his adamant stance that a dark and empty museum was no place for his girlfriend and later his wife to be after 8 pm.

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CHAPTER ONE: INTRODUCTION AND BACKGROUND

Overview of the modern human origins debate

One of the 'origins' questions that has dominated recent paleoanthropological work is that of the timing and nature of the emergence of the modern anatomical form, genotype, and behavioral repertoire of the single surviving representative of the genus *Homo*: modern *Homo sapiens* (e.g. Klein, 2000; McBrearty and Brooks, 2000; Marean and Thompson, 2003; Henshilwood and Marean, 2003; Grün, 2006; Fagundes *et al.*, 2007). One emergent theme of recent research is the key role that the African Middle Stone Age (MSA), from ca. 280 – 30 thousand years ago (ka), has played in both aspects.

This dissertation addresses several questions relating to the modern human origins debate by employing primary zooarchaeological data collected from two recently excavated sites in the southwestern Cape, South Africa: Blombos Cave and Pinnacle Point Cave 13B (PP13B). The study also draws on published and unpublished data from a third site, Die Kelders Cave 1 (DK1), to allow, for the first time, *taphonomically informed* comparisons between zooarchaeological assemblages from this region. These data are used to examine the faunal evidence in this area for traditional measures of modern human behavior, and they also provide an ideal dataset for characterization of variability in faunal exploitation behavior during a time period that was critical to the biological and behavioral evolution of modern humans.

Biological issues in the modern human origins debate

In modern human origins research the relationship between biological and behavioral modernity have been major points of inquiry, as traditional markers of behavioral modernity in the archaeological record do not always coincide with clear

evidence of anatomical modernity (e.g. Stringer, 1992; Frayer *et al.*, 1993; Clark and Willermet, 1997; Clark, 1999, 2002; Klein, 2000a; Templeton, 2003, Willoughby, 2007). Although this dissertation focuses on the behavioral aspects, it is important to understand the general issues and lines of evidence used in the anatomical debates so that the archaeological assemblages in question can be described in light of which hominin populations were the likely agents behind their deposition. It is further critical to review the biological evidence because the transition to behavioral modernity was part of an interrelated set of processes that likely involved several biological replacements. Unlike later replacements in the rest of the Old World, the first of these would have taken place on the African continent itself and would have involved extremely closely-related hominins, if not different populations of the same hominin. It may therefore be useful to examine the biological evidence from other regions such as Europe with the understanding that the mechanisms of replacement were likely to be similar but much more subtle to detect within the paleoanthropological record of Africa itself.

The main competing models for the origins of biological modernity were first comprehensively summarized by Aiello (1993). The *African replacement model* saw a relatively recent African origin for anatomically modern humans (between ca. 250 – 100 ka) who then spread across the rest of the world, outcompeting and displacing resident hominin populations with little or no interbreeding (e.g. Stringer and McKie, 1996). The *African hybridization and replacement model* was a less extreme version of this, and allowed for a small but overall insignificant amount of hybridization between anatomically modern human (AMH) populations with a recent African origin and non-

modern populations resident in the regions into which AMH dispersed (e.g. Braüer, 1989, 1992).

The *assimilation model* also accepted a relatively recent African origin for all modern humans but proposed that in some parts of Eurasia local evolution in existing populations was an important factor in the emergence of modern peoples from these regions (Smith *et al.*, 1989; Smith 1992). Finally, the *multiregional evolution model* argued for a more ancient and gradual origin for AMH that was derived from within local populations across the Old World that were prevented from extreme divergence by gene flow (e.g. Wolpoff *et al.*, 1988; Wolpoff and Caspari, 1997).

Since this original summary by Aiello (1993) the multiregional evolution model has been largely discarded and questions are now being addressed about more specific details of modern human evolution in Africa, such as how short-term events may have affected population densities (Ambrose, 2003; Gathorne-Hardy and Harcourt-Smith, 2003), what levels of detail about modern human population histories can be obtained through genetic research (Beaumont, 2004; Fagundes *et al.*, 2007; Relethford, 2008), or if freshly-studied specimens can provide information about the distributions of fossil populations (Grine *et al.*, 2007). However, at the core of the anatomical side of the modern human origins debate the same basic questions remain. These include the timing and more precise location of the first modern human populations, when and how they dispersed from Africa, and what effects this had on existing hominin populations in these new regions (Goebel, 2007).

The original biological debates represented a spectrum of views between two poles rather than incommensurable paradigms, and yet several decades of argument have yet to definitively settle the issues (Smith and Harrold, 1997; Relethford, 2008). Advocates of both extremes have proposed methodological and interpretive explanations for why the modern human origins debate continues in spite of the enormous amount of ink that has been spilled over the topic. Relethford (1999) and Wolpoff *et al.* (2000) argued that obfuscation arises from a basic misunderstanding of the premise of multiregional evolution. In contrast, Stringer and Braüer (1994) asserted that a major obstacle in resolving this debate is the selective use and misreading of available data in favor of the multiregional model. Frayer *et al.* (1994) countered that both ends of the spectrum are discussed haphazardly and with inconsistent definitions, and that approaches to testing these models have strayed from true hypothesis testing by seeking to support rather than falsify one model or the other. Unfortunately, all these authors are correct in their basic agreement that much of the data are of a nature that facilitates ambiguous interpretations and makes hypothesis testing difficult in many cases. However, an impressive array of biological data have been marshaled to determine which of these models best fits the evidence, and the sum of this research has produced a definite pattern of results.

The first critical point is the timing of the appearance of the first AMH fossils across the Old World (Aiello, 1993; Goebel, 2007). In support of a version of the African replacement hypothesis, the earliest anatomically modern fossils have all been discovered in Africa and the nearby Levant (e.g. Rightmire, 1989; Brooks *et al.*, 1993; Thackeray, 1993; Miller *et al.*, 1999; White *et al.*, 2003; Grine *et al.*, 2007), although in

general Pleistocene AMH were more robust than their Holocene counterparts, and may have had a level of sexual dimorphism that is not apparent in present-day populations (Rightmire and Deacon, 1991). Specifically, the oldest known cranial remains date to as early as 195 +/- 5 ka with the Omo Kibish specimens from Ethiopia (McDougall et al., 2005), and a comprehensive overview of hominin postcranial morphology shows that the modern human postcranial suite appeared in Africa between 600 and 125 ka (Pearson, 2000).

The second major line of evidence from the fossil record is the degree of distinct regional continuity outside of Africa between skeletally modern and non-modern populations (Aiello 1993). Despite the Australasian record having provided much of the original impetus for the development of the multiregional evolution model (e.g. Thorne and Wolpoff, 1981), the fragmentary and poorly-dated Middle Pleistocene fossil record from this region makes it difficult to obtain a complete picture of modern human evolution across the Old World (Brown, 1993). Relethford (1999) notes that predictions of anatomical traits as based on biological distance neither confirm nor deny any of the proposed models. If there was a larger long-term population in Africa than elsewhere, temporally more recent fossils across the Old World would be predicted to most closely resemble African populations under either model, and in fact they do – with the number of continuous traits in fossil and modern Asian and Australasian populations very small and expressed to varying degrees worldwide (Lahr, 1994). Although Lahr (1994) used this evidence to argue in support of an African replacement, Relethford (1999) countered that this is also expected under the multiregional model as genetic drift and natural

selection would have maintained these traits only in small and discontinuous quantities in the face of extensive gene flow.

The relatively large and well-dated European fossil record provides a more comprehensive body of evidence. In this region, Neandertals and their ancestors were contemporaneous with populations of AMH in Africa. Some proponents of multiregional evolution argue that several traits show continuity between Neandertals and AMH (e.g. Smith, 1992; Frayer, 1997), although some traits may simply be reflecting an ancient shared ancestry rather than more recent local gene flow. Other authors have identified derived anatomical criteria that are diagnostic of Neandertals even in very young individuals, indicating that these attributes are present from birth and not the result of environmental stresses (e.g. Rak *et al.*, 1994). A variety of studies indicate that Neandertal physiology also differed in several critical ways from modern humans, ranging from body proportions and morphology that are the likely result of long-term adaptations to cold environments (e.g. Holliday, 1997; Pearson, 2000), to inner ear morphology and its resultant influence on locomotion (Spoor *et al.*, 2003). Following this, Marean (2005, 2007) has posited a bio-behavioral adaptive suite in Neandertals that is dramatically different from that of AMH.

Though the precise taxonomic status of Neandertals relative to AMH has been hotly debated, the summary conclusions from the fossil evidence is that Neandertals represented a closely related but diagnostically distinct population that went extinct relatively soon after the arrival of AMH in Europe. Wolpoff *et al.* (2000:132) point out that no human population would be expected to persist unchanged indefinitely, and even

if Neandertals went extinct without a major contribution to modern populations in Europe, it would still not invalidate the possibility of multiregional evolution elsewhere. Though technically correct, this view accomplishes the same violations of Popperian science that Frayer *et al.* (1994) criticize advocates of the African replacement theory of doing: it renders multiregional evolution an unfalsifiable theory rather than a testable hypothesis because preservational biases preclude the discovery of representative samples from every possible fossil population that has existed. If one is to simply consider the sum of the fossil evidence for the two major models of modern human origins, the bulk of it currently stands in overwhelming support of a recent African origin with limited to no hybridization with other contemporaneous hominin populations.

Most of the genetic evidence brought to bear in the modern human origins debate is based on interpretations of DNA from modern populations. In general, these data have been used to support a version of the African replacement model (Cann *et al.*, 1987; Stoneking, 1993; Jorde *et al.*, 1998, 2000; Fagundes *et al.*, 2007). However, owing to a great deal of potential equifinality in the interpretation of genetic data and the different evolutionary histories of various loci, a much-enlarged dataset has since resulted in a highly complex picture of recent human evolution and yet more debate (Relethford, 1998, 2001, 2008). For example, *Homo sapiens* taken as a whole is characterized by a very high degree of between-group genetic similarity. This is strong evidence for a relatively recent origin from a single small population (Manderscheid and Rogers, 1996), but it could also be explicable by a relatively high – yet feasible – rate of migration with admixture into existing populations (Relethford, 1995). Similarly, although the greater

genetic divergence of modern sub-Saharan Africans relative to other populations could indicate that the most ancient split was between African and non-African populations, varying rates of gene flow would have the same result (Relethford, 1998:11).

The highest levels of within-group genetic variation are also found in sub-Saharan Africa. This has been argued to indicate that African populations are the most ancient in the world, as they would have had the longest time to accumulate mutations (Cann *et al.*, 1987). However, a larger effective population size over an extended period of time would also result in relatively high within-group diversity. Given that all models of modern human origins are in agreement that the early stages of human evolution took place in Africa, a larger African population is consistent with the tenets of either the African replacement or the multiregional models (Relethford, 1998; Relethford and Jorde, 1999).

Because the African replacement hypothesis requires a relatively late African origin, the timing of the genetic coalescence of all modern human populations is critical. Estimates have ranged from 137 ka (Stoneking *et al.*, 1992) to as early as 806 ka (Wills, 1995), although most studies fall close to the estimate of ca. 200 ka originally proposed by Cann *et al.* (1987) and a recent assessment based on a limited number of genes finds 141 ka to be most parsimonious (Fagundes *et al.*, 2007). Other authors emphasize the difficulty in estimating coalescence time from the available data and propose that instead these studies only tell us that population size has been small since coalescence (Rogers and Jorde, 1995). Templeton (2002) argues, based on the sum analysis of several possible haplotype trees, that the most likely scenario is one in which Africa was a

critical source for multiple expansions of modern human populations, but that these expansions were characterized by a substantial amount of interbreeding rather than replacement.

Multiple lines of evidence, mainly from the mitochondrial genome, indicate that the effective long-term size of populations ancestral to AMH was very small – around 10,000 individuals (Rogers, 1997; Fagundes *et al.*, 2007). It does not seem viable that this tiny effective population could be spread across the two or more regions in the Old World required under the multiregional model, although Templeton (1997) demonstrates that it is not impossible and Harris and Hey (1999) observe that this pattern is not as consistently evinced in nuclear genes. Sometime after ca. 100 ka, and likely closer to ca. 50 ka, human populations then underwent a rapid expansion (Rogers, 1997; Fagundes *et al.*, 2007). This evidence is what one might expect under the African replacement model, and coalescence estimates that track this increase could very well be dating a major expansion out of Africa and into the rest of the Old World. Relethford (1998) discusses several demographic scenarios that might simulate such an expansion, and concludes that more evidence is needed to determine which is most parsimonious. Similarly, Harris and Hey (1999) describe several possible scenarios that would accommodate the discord between the mitochondrial and nuclear evidence.

In further support of the genetic studies on modern populations, ancient DNA offers a direct look at the degree of difference between non-modern fossil populations and AMH. Neandertals again provide a case in support of a version of the African replacement hypothesis. Mitochondrial DNA extracted from a relatively late-surviving

Neandertal offers an independent line of evidence that these hominins were genetically distinct from modern humans and extensive interbreeding was unlikely (Krings *et al.*, 1997). Subsequent studies on multiple Neandertal and AMH fossils continue to support this finding (Serre *et al.*, 2004), though a recent sample from a ca. 100,000-year-old Neandertal specimen hints at a greater range of within-species genetic diversity than previously supposed (Orlando *et al.*, 2006). Preliminary examination of the small amount of nuclear DNA that has been recovered from a fossil Neandertal also supports the interpretation that these hominins were distinctly different from modern humans (Dalton, 2006). Overall, as was the case with the fossil record, the weight of the genetic evidence rests with an African replacement (Satta and Takahata, 2002). Almost all the data would strongly support a model of African replacement, while support for multiregional evolution is more often found in elaborate demonstrations of equifinality in the data.

As a final note on the 'middle ground' models, the degree to which hybridization between AMH and resident hominin populations may have taken place has also been addressed with both fossil and genetic evidence. Duarte *et al.* (1999) argued that a subadult skeleton recovered in Portugal shows both AMH and Neandertal characteristics, although this interpretation has been challenged (Tattersall and Schwartz, 1999). More recently, Evans *et al.* (2006) proposed that a gene which plays a role in brain size has undergone positive selection in modern humans, and was one that was contributed by an archaic lineage. Hawks and Cochran (2006) also note that introgression from archaic genes is implicated in several other cases, and that this could suggest a more extensive

degree of interbreeding than was previously accepted under a strict Out of Africa Replacement model. More evidence of direct physical contact between AMH and archaic populations is found in the genetic history of the human parasite, *Pediculus humanus* (Reed *et al.*, 2004). This species underwent an ancient genetic divergence over a million years ago, presumably in response to a population split between their hominin hosts. Their occurrence in modern human populations indicates that they were later re-acquired through direct contact with those archaic host lineages as modern humans passed through Asia.

The issue of hybridization is an interesting one from a behavioral perspective as well, as it speaks to the nature of interactions between hominin populations when they encountered one another. Fossil and genetic evidence points to an overwhelming replacement of archaic populations by modern humans, but the mechanisms by which this replacement came about are still poorly understood. Almost certainly, these mechanisms involved a degree of technological and behavioral innovation that provided a critical advantage to modern humans as they spread into novel environments and encountered resident populations that had been living there successfully for much longer (Marean, 2005). Understanding these mechanisms requires a systematic examination of the behavioral evidence for the origins of modern humans, and archaeological assemblages provide the empirical basis for much of this side of the debate.

Behavioral issues in the modern human origins debate

The sum of the biological evidence has resulted in a broad consensus, with some dispute, that at least from the Last Interglacial onward (from ca. 123 ka) African

archaeological assemblages were likely deposited by anatomically modern humans. Exactly where in Africa these populations evolved, and the degree of anatomical modernity in these populations prior to 123 ka, are both large and important questions that have yet to be resolved. However, even if it is accepted that early modern humans were the most likely creators of a given assemblage, there is yet more debate about the *behavioral* modernity of these hominins. As human paleontologists and geneticists have done with the biological side of the debate, several competing models have been proposed by archaeologists to address questions of the timing, tempo, and nature of the emergence of behavioral modernity. Henshilwood and Marean (2003) have summarized these into a series of models that posit different times and rates of the advent of behavioral modernity. Two of these stand out prominently and will be referred to extensively here.

The long-standing Later Upper Pleistocene (LUP) model posits a long period of stasis during most of the MSA followed by very rapid change in behavior at some point between 50 – 40 ka, which facilitated the spread of modern humans out of Africa and into Eurasia (Mellars, 1989; Mellars and Stringer, 1989; Gamble, 1994; Mithen, 1999). This 'cultural revolution' is explained by a sudden mutation or change in human cognition, perhaps mediated by the advent of fully articulate symbolic language (Klein, 2000a, 2003; Enard *et al.*, 2002). Interestingly, this revolution predates the MSA-LSA transition at almost all sites, although dates that push the limits of the radiocarbon technique now potentially place this transition as far back as between ca. 56.5 and ca. 41.6 ka at Border Cave in South Africa (Bird *et al.*, 2003).

Under the LUP model, prior to ca. 50 ka the material expression of human behavior was relatively simple and homogenous. Lithic artifacts showed little variation across time and space and the manufacture of artifacts on other materials such as bone was virtually unknown. Importantly, under this model the human behavioral suite at and after the MSA-LSA transition would have been largely independent of that which preceded the transition, and therefore any variability in MSA behavior during the long period leading up to this critical change is considered to be largely irrelevant.

The Gradualist model, while not as explicitly stated as the LUP model, regards the advent of modernity as an accretionary process deeply rooted in the Middle – Upper Pleistocene (Chase and Dibble, 1990; Foley and Lahr, 1997; McBrearty and Brooks, 2000). Modern human behaviors are considered to have appeared at disparate times over the course of the last 350 ka rather than in a suddenly-appearing suite. Some behaviors, such as symbolic use of pigment, may have made their first appearance early but in a very simple manner and then slowly become more complex over the course of time (McBrearty and Brooks, 2000). In contrast to the sudden-change model, this process-based model implicitly acknowledges that the MSA was not a behaviorally static period of time, and identifying variability in MSA behavior across time and space becomes essential for diagnosing changes in the adaptive strategies that ultimately led to the modern behavioral suite.

Testing these models has been problematic for both empirical and epistemological reasons. When compared to the record of western Eurasia, site survey data and the number of well-excavated and published MSA sites are few and patchy. Precise and

accurate dates from this period are also extremely rare because most of the MSA falls beyond the limits of radiocarbon dating, most sites have not be systematically subjected to more recently developed or less frequently applied alternative dating methods (e.g. Uranium-series, Thermoluminescence [TL], Optically-stimulated Luminescence [OSL], and Electron Spin Resonance [ESR]), and the homogeneity of the lithic assemblages relative to later industries makes it difficult to date sites typologically. Furthermore, the actual criteria and reasoning behind what constitutes modern behavior, and what material correlates to expect, remain vaguely defined.

Some researchers have compiled trait lists, including many that rely on faunal data, which they consider to be diagnostic of modern behavior (Mellars, 1989; Gamble, 1994). Henshilwood and Marean (2003) have critiqued this approach, noting that many of the allegedly diagnostic traits were assigned exclusively using the Eurasian record, and they would not be expected to occur in the very different environments found in Africa. Traits that focus on the use of particular resources, such as fish or fowl, as indicators of modern behavior can be more parsimoniously explained in terms of optimal foraging theory, intensification, and demographics. Moreover, some of the traits are defined by the nature of the archaeological record itself; if certain artifact classes do not occur until the Upper Paleolithic or Later Stone Age, they are used to mark the advent of 'modernity'. This is problematic not only for the circular reasoning involved, but also because the two datasets are taphonomically incomparable.

Recent work has shown that even if one does apply the trait list, many of the artifact classes used to define the Later Stone Age (LSA), the Upper Paleolithic (UP), and

modern behavior also occur in the MSA. Bone tools have been known previously to occur at the Peers Cave and Klasies River sites in South Africa, but were isolated finds with uncertain proveniences (Backwell *et al.*, 2008). Now at Katanda, Zaire (Yellen *et al.*, 1995; Yellen 1998), Sibudu, South Africa (Backwell *et al.*, 2008), and Blombos Cave, South Africa (Henshilwood and Sealy, 1997; d'Errico *et al.*, 2001, 2007; Henshilwood *et al.*, 2001a, Henshilwood *et al.*, 2002), formal bone tools have been dated to ca. 90 ka, ca. 61 ka, and between 70 - 85 ka, respectively. In the same MSA levels at Blombos, evidence of complex symbolic behavior was unearthed in the form of abundant worked ochre, ochre incised with cross-hatching, and shell beads (d'Errico *et al.*, 2005; Henshilwood *et al.*, 2004). While ochre has long been recognized to occur at MSA sites, particularly those postdating about 100 ka, recent work has shown that it was selected for its red color, rich saturation, and non-utilitarian qualities as a pigment (Watts, 1999; Hovers *et al.*, 2003).

As work at MSA sites has progressed over the last several years, these suggestions of symbolic behavior are becoming more and more frequently reported: Shell beads from MSA contexts have now also been recovered in both Northern Africa and the Levant (Vanhaeren *et al.*, 2006). In South Africa, ochre incised with cross-hatching and other deep gouges has been identified from Klein Kliphuis (Mackay and Welz, 2008), while incisions on bone at Sibudu (Cain, 2004) and ostrich eggshell at Diepkloof (Poggenpoel *et al.*, 2005) show that marking extended onto several different substrates.

Some researchers (Klein, 2000; d'Errico, 2003) have suggested that the new evidence may be unique, and that it does not represent a ubiquitous pattern of behavior

during the MSA. It remains to be tested if these are indeed isolated occurrences or if modern behavior arose as a generalized 'package' that included other facets of MSA life such as subsistence. However, it does seem to be the case that the more the MSA is investigated the less aberrant such discoveries appear to be. Recently reported finds from Pinnacle Point Cave 13B (PP13B) include ground ochre, bladelets crafted on quartzite and silcrete, and evidence of a previously undocumented marine resource adaptation (Marean *et al.*, 2007). Although much attention has been paid to the benefits of blade technology and its precocious appearance in Africa has been acknowledged (Bar-Yosef and Kuhn, 1999; McBrearty and Brooks, 2000), bladelet technology was previously been thought to be a hallmark of Later Stone Age and Upper Paleolithic stone tool technology.

Clark (1988) first suggested that regional diversity began during the early Middle Stone Age, and used evidence from the East African lithic record to support this. However, south of the Zambezi the MSA has traditionally been considered to be typologically and technologically very homogenous, with most sites dominated by Volman's (1984) monolithic category of 'MSA II' (Thackeray, 1993). Newer studies have determined that there are distinct technological differences that underlie these basic lithic categories (Wurz, 2002), but relative to later industries the MSA still represents a long stretch of time in which changes in lithic technology were generally quite subtle. Two notable exceptions in South Africa are the Still Bay, characterized by finely worked bifaces, and the Howieson's Poort (HP), characterized by backed pieces (Thackeray, 1993).

Quantities of Still Bay points have now been recovered from the upper layers of Blombos, which have been well-dated using luminescence techniques to ca. 73 ka (Jacobs *et al.*, 2006, Tribolo *et al.*, 2006). The industry has also been recovered at Sibudu, an inland site overlooking the Tongati River in the province of KwaZulu-Natal, and the dates for this industry are in general agreement with those from Blombos (Wadley, 2007). Recent dates for the HP at a variety of sites have shown that this industry was slightly younger than the Still Bay, likely dating to between 62 – 52 ka (Wadley and Jacobs, 2004; 2006; Tribolo, 2003). These recent advances in dating technology and their application to both previously-excavated and recently-excavated assemblages have better secured the place of these tool types in the MSA lithic record: they now appear less to be eccentricities and more as adaptive responses to environmental or social pressures (e.g. Deacon, 1989; Ambrose and Lorenz, 1990; McCall, 2007).

This better understanding of variability in MSA behavior is important for investigations of the specifics of when, how, and where in Africa the transition to modern behavior took place. The most parsimonious scenario is one in which a very small initial population in an as-yet unidentified region of the continent achieved an advantage over neighboring groups that allowed it to expand at their expense – either through replacement or assimilation. This scenario is supported by the genetic evidence, which has long advocated a bottleneck in human evolutionary history of ca.10,000 effective individuals, and which recent studies have also calculated to be ca.12,800 (Fagundes *et al.*, 2007).

The transition from near-modern to modern behavior was a process of change. Each change introduced a suite of potential strategies for dealing with the world, some of which were more successful than others. The advantages gained with certain strategies would have provided one or several mechanisms by which AMH were later able to replace not only Neandertals but other archaic hominins outside of Africa. Importantly, these advantages were likely the same as those that allowed a small population of AMH within Africa to replace its immediate relatives on that continent. Therefore, three important things about these advantages must be identified before an understanding of the larger process of the transition to behavioral modernity can be achieved: 1) when these changes occurred; 2) where they occurred; and 3) what they were.

Some of these details must emerge empirically, and patchy preservation of archaeological materials is likely to always be a problem. However, key research areas can also be targeted through an understanding of the conditions under which populations experience rapid change and where and when these conditions existed. Likely centers for where the founding population or set of populations may have emerged can then be identified, and within these areas the ways in which MSA populations dealt with their environment behaviorally can be described.

Archaeologists working on the origins of modern human behavior face two formidable tasks. First, they must arrive at a consensus for what constitutes such behavior, and then develop testable hypotheses of the archaeological traces one would expect to find associated with them (Henshilwood and Marean, 2003:627; Wadley, 2003). Second, they must build a robust database of well-excavated and studied sites in

key areas that is suitable for understanding the variability and patterning through time found within MSA artifact and faunal assemblages.

This dissertation adheres to the view that the southern African coastline was one of these key areas, for reasons described in detail in Chapter Three. Unlike some other areas with such potential, the Southern African coast also offers three distinct advantages for such an investigation. First, it has a long record of archaeological and paleoenvironmental investigation that continues at pace today. This has resulted in a wealth of foundational research that is not available in most other areas of the African continent. Second, recent work at PP13B has pushed back the dates of the earliest coastal MSA deposits into early MIS 6 (Marean *et al.*, 2007), making it possible to examine changes in MSA behavior more deeply in time than was previously the case. Finally, although good faunal preservation is not the norm at most sites, it is available in sufficient quantities to prevent interpretations of MSA behavior from being strictly confined to lithic assemblages. This is important because advantages in subsistence behavior might be expected to be tied tightly to relative reproductive success over the course of human evolution and population expansion, and zooarchaeological data potentially offer a way to examine this aspect of the emergence of modern human behavior.

Zooarchaeology in the modern human origins debate

Modern human dietary requirements are most effectively met by a diverse diet that includes animal-derived protein and lipids (Milton, 1999; Hockett and Haws, 2003). Furthermore, modern hunter-gatherers in all environments place a special importance on

hunted meat (e.g. Kelly, 1995), to such an extent that hunting of large terrestrial mammals has been proposed as a form of competitive display in human social and mating systems both today and over the course of their evolution (Hawkes and Bird, 2002). Although earlier hominins could have been hunters without being fully modern, they could not have been fully modern if they acquired most of their large animal resources without hunting. The emergence of the modern human behavioral repertoire is therefore one that includes effective hunting as a critical mode of large mammal resource acquisition.

Alternatively, a subsistence base that emphasizes marine resources has been proposed as a potentially advantageous adaptation that may have given early modern humans the required edge over their non-modern relatives both in Africa and later in the rest of the Old World (Broadhurst *et al.*, 2002), and archaeological evidence for such an adaptation has been reported from as early as ca. 164 ka (Marean *et al.*, 2007). Issues such as these place zooarchaeological assemblages in an ideal position to inform about how changes in environment, ecological niche, and diet may have been potentially interrelated factors in the emergence of modern human behavior.

Despite the rising evidence of variability in MSA behavior and its material residues, especially in Southern Africa, discussions of MSA faunal exploitation are often conducted in highly generalized temporal and spatial terms, with 'the MSA' being compared as a whole to another entity, such as 'the LSA' (e.g. Klein, 1975, 1976, 1978a, 1987, 2000). This is likely exacerbated by the generally small available sample of sites for which lithic assemblages are accompanied by good fossil preservation. Until more

recently, this has perpetuated the impression that human faunal exploitation behavior across the enormous spans of time and space encompassed by the MSA was rather static and homogeneous. The small sample of studied zooarchaeological assemblages has also resulted in previous contributions to the modern human origins debate being confined to basically one major issue: hunting ability.

Many zooarchaeological studies that have previously addressed the origins of modern behavior have focused on whether or not Late Upper Pleistocene hominins engaged in hunting and/or scavenging as a primary meat acquisition strategy (e.g. Klein, 1976, 1986, 1989a, 1995, 1998; Binford, 1984; Stiner, 1991a, 1991b, 1993, 1994; Marean and Frey, 1997; Marean and Kim, 1998; Marean, 1998; Bartram and Marean, 1999; Klein *et al.*, 1999; Marean and Assefa, 1999). In Southern Africa, the Klasies River cave complex (Singer and Wymer, 1982; Deacon and Geleijnse, 1990), dated from approximately 120 – 50 ka (Tribolo, 2003), has played a particularly salient role in this work. The few hominin remains recovered from Klasies are anatomically modern and have been dated to 118 – 94 ka (Grün *et al.*, 1990; Brooks *et al.*, 1993; McBrearty and Brooks, 2000). Workers that posit a mode of acquisition (such as obligate scavenging) that is inconsistent with those of modern hunter-gatherers have therefore decoupled anatomical from behavioral modernity.

Klein (1976, 1989a, 1995, 1998) examined the skeletal element and taxonomic abundances at Klasies and argued that MSA hominins were hunters of all but the most dangerous prey. Using the same dataset, Binford (1984) argued that the Klasies humans were instead primarily scavengers. Binford also used macroscopically visible carnivore

damage to make this assertion. However, by examining the same bone surfaces *microscopically* for evidence of human and carnivore damage, Milo (1998) argued that even large and dangerous animals were occasionally taken, and suggested that the data from Klasies are instead most consistent with a fully modern hunting ability.

Unfortunately, all interpretations from the Klasies faunal assemblage suffer from a persistent problem: selective post-excavation removal of certain components, such as shaft fragments, has rendered the assemblage incomplete and biased toward more easily-identified fragments (Bartram and Marean, 1999). Such bias has been proposed to be a serious impediment to accurate assessment of skeletal element abundance and surface modification (e.g. Marean and Frey, 1997; Marean and Kim, 1998; Pickering *et al.*, 2003; Marean *et al.*, 2004), although other researchers contend that this is not necessarily the case (e.g. Klein *et al.*, 1999; Stiner, 2002). This debate is discussed in full detail in Chapter Two.

Another important issue that has hindered previous interpretations of MSA faunal data is one of analytical method. As was seen in the Klasies scenario, even the same biased dataset yielded very different behavioral interpretations when different methods were used (such as microscopic versus macroscopic examination of bone surfaces). A standardized application of taphonomic method at both the data collection and interpretive levels is therefore absolutely critical for accurate assessment and reliable comparison of faunal datasets. A full discussion of which specific methods and interpretive frameworks are currently considered most appropriate is also provided in Chapter Two.

The wildly different interpretations based on the same dataset from Klasies, along with the potentially confounding effects of incomplete recovery and disparate analytical methodologies have clearly shown that three criteria must be met in future work. First, more sites and more lines of evidence must be examined before a confident assessment of MSA faunal exploitation behavior can be made. Second, data are needed from sites for which a completely recovered assemblage is available, and at which this entire assemblage has been subjected to a full taphonomic analysis. Third, these taphonomic methods must be consistent, comparable, and backed by a coherent body of theory.

Klein (e.g. 1975, 1976, 1978a, 1987, 2000) has partially addressed the first criterion through comparisons between MSA and LSA faunal assemblages, arguing extensively that although MSA hominins were hunters they lacked the ability to acquire key faunal resources that LSA people were able to exploit. In particular, he has interpreted MSA populations as not having the ability to fish or fowl effectively, nor map onto seasonal resources, nor hunt dangerous animals. Despite these efforts, the MSA sample used in these comparisons remains effectively focused on Klasies and does not include any comprehensive taphonomic analysis. Also, in most of this work Klein has relied on comparisons to Holocene LSA sites for his interpretations of non-modern behavior in the MSA. Watts (1999) suggests that if Pleistocene LSA assemblages had been used in the comparisons, they would barely differ from the MSA. Henshilwood and Marean (2003) argue further that there may be more parsimonious reasons that faunal remains from Holocene LSA sites differ from those of the MSA. For example, the apparent lack of fishing and fowling in the MSA may be related to low population densities and a lack of

need to expand the diet breadth into these resources, rather than to a lack of ability to manufacture the requisite technology.

Recent work has also been done that meets the first and second criteria. At Sibudu, the entire faunal assemblage was recovered through careful screening procedures. As well as basic fragmentation and taxonomic data, Cain (2006) conducted a microscopic examination of nearly 13,000 fragments dating from approximately 60 – 47 ka (Wadley and Jacobs, 2004; 2006). Cain (2006) found several patterns that do not support the general interpretations about MSA hunting ability set forth by either Klein (1976, 1989a, 1995, 1998) or Binford (1984). The Sibudu assemblage shows little evidence of non-human accumulators such as carnivores, and relatively abundant evidence of an intensive processing strategy by hominins. Furthermore, Cain (2006) argues that large and/or dangerous animals are represented in sufficient abundance to suggest that MSA hunters were not limited to smaller or more docile prey. Unfortunately, analysis of the Sibudu assemblage does not meet the third criterion: the data were not presented and analyzed in a way that is either quantitative or directly comparable to other taphonomic studies.

To date, the only analysis in Southern Africa that meets all three criteria is that conducted at Die Kelders Cave 1 (DK1), a coastal site in the Western Cape (Marean *et al.*, 2000b). A variety of techniques have loosely identified the deposits as dating to between 60 – 70 ka (Feathers and Bush, 2000; Schwarcz and Rink, 2000), or basically within the age range encompassed by both Klasies and Sibudu. At DK1 all fragments, including those traditionally considered less identifiable such as long bone shafts, were subjected to refitting. Complete estimates of skeletal element abundance were also

derived, and all bone surfaces were subjected to microscopic analysis. Results from the reported Layers 10 and 11 at DK1 fail to support the findings of either Klein (1976, 1989a, 1995, 1998) or Binford (1984) with regards to large mammal exploitation, and instead suggest that the MSA hominins who occupied this site had a fully developed hunting ability (Marean and Assefa, 1999; Marean *et al.*, 2000b).

The interpretations from Sibudu and DK1 lead to a very different picture than that from Klasies of MSA meat acquisition, processing, and landscape use. Although these analyses are suggestive, the results from two widely separated sites do not provide solid evidence that this pattern was typical during the MSA – nor does it provide a way to examine how such a pattern may have changed through time. Furthermore, there are methodological differences between the taphonomic analysis at Sibudu and that conducted at DK1 that make the two sites less easily compared to one another.

The only way to address these problems is through the detailed study of new collections excavated using modern techniques that involved complete recovery, retention, and proveniencing of the fauna. One of the primary results of the present study has therefore been to triple the number of sites in South Africa for which taphonomically informed analyses of large unbiased MSA assemblages have been conducted and reported in full. With these data, two important zooarchaeological debates are directly addressed: 1) the theoretical debate regarding MSA hunting ability; and 2) The methodological debates surrounding the effects that excavator selection can have on interpretation of fossil bone assemblages. A summary of the development and application of the procedures used to accomplish this is provided in Chapter Two.

CHAPTER TWO: DATA COLLECTION AND ANALYTICAL METHODS

Review of zooarchaeological method and theory

Zooarchaeology is a relatively young discipline in the sense that it is a specialized component of archaeological research with its own set of methodological and theoretical tools. In the English literature the development of these tools has taken place only over the last forty years, and much of it has been in the context of African faunal assemblages. This history of investigation has had an impact both on zooarchaeology as a whole and on ongoing debates specific to these African assemblages. Also as a consequence, certain methodological issues have influenced interpretations of MSA faunal exploitation behavior and in many cases continue to do so. It is therefore worthwhile in the context of the present study to present a brief summary of the development of zooarchaeology as a discipline (particularly with regards to African assemblages), provide a general background to zooarchaeological method, and describe the key issues and debates that are pertinent to the present study.

In the earlier part of the 20th century, the treatment of faunal remains from archaeological sites was customarily limited to taxonomic identifications by a biologist or other non-archaeologist (Reitz and Wing, 1999). When faunal analyses began to be conducted by archaeologists themselves many of these studies maintained this emphasis on taxonomic identifications but expanded into more detailed descriptions of the ages, sexes, and abundances of both the species that were present and the relative representation of their various skeletal components (e.g. White, 1952, 1953; Grayson, 1984; Klein, 1976; Klein and Cruz-Uribe, 1984). This approach began to relate

patterning in faunal assemblages to human behavior in ways that were not previously possible.

Despite this heightened degree of examination there remained a general acceptance that the composition of the larger mammal component of a faunal assemblage, when found in association with archaeological materials, was solely reflective of human or early hominin behavior (e.g. Dart, 1960; Perkins and Daly, 1968; Klein, 1978a). By the 1970's, some workers had begun to examine this assumption more critically (e.g. Bonnischen, 1973; Brain, 1967a, 1980; 1981; Binford, 1981). From this there arose a growing awareness that not all faunal remains from archaeological sites can be taken at face value to be the direct result of hominin behavior. To better understand what other taphonomic processes may have been operative over time, and how this would affect the final form of a faunal collection, some zooarchaeologists began to observe modern-day agents who modify bones in a more systematic manner, both in experimental and naturalistic settings (e.g. Behrensmeyer, 1978; Behrensmeyer and Hill, 1980; Behrensmeyer *et al.*, 1986; Brain, 1980, 1981; Gifford-Gonzalez, 1989; Blumenschine, 1986; 1988).

One essential question that was addressed was how to determine which agents were primarily responsible for accumulating a faunal assemblage. Brain (1980) observed that porcupines collect bones from the landscape, and that domestic dogs modify bones that have been initially collected by human groups (Brain, 1967b, 1969). In a landmark study he (1981) debunked the long-standing assumption that hominins were the main accumulator of the faunal remains recovered from the early hominin sites in South

Africa. He argued that patterns of breakage and surface damage on both the faunal remains and the hominins with which they were associated were indicative of having been collected by carnivores, and he supported this argument with some early examples of actualistic data.

The problem of determining the bone collector becomes much more complex when several bone modifiers have been at work on the same assemblage. Humans, carnivores, rodents, and raptorial birds are some of the most commonly-identified culprits, but fortunately each agent leaves traces on the bone surfaces that are diagnostic of their involvement (papers in Bonnichsen and Sorg, 1989; Lyman, 1994; Blumenschine *et al.*, 1996). Hominins leave marks with stone tools and hammerstone percussors (Binford, 1981; Blumenschine and Selvaggio, 1988), carnivores leave tooth marks and evidence of ingestion in the form of gastric etching (caused by swallowing and subsequent regurgitation or defecation of bone fragments, and resulting in a characteristic etching and smoothing of surface), rodents impress small parallel grooves from gnawing into the surfaces, and raptors leave distinctive patterns of gastric etching across skeletal elements (e.g. Andrews, 1990; Lyman, 1994).

At DK1 in South Africa examination of these types of modification and mapping of their incidence relative to cave features such as solution cavities where raptors still roost today led to an understanding that the predominant accumulator differed according to prey body size within the large mammal assemblage (Marean *et al.*, 2000b). The abundant small-bodied bovids (size 1) at DK1 were found to be the size class on which raptor modification most often appeared, while the less abundant high-caloric-return

larger fauna (size 2 - 4) were likely targeted by humans. If one had taken the species abundance at face value, the conclusion from the DK1 data would have been that MSA hunters were preferentially taking very small bovids such as grysbok and steenbok (*Raphicerus* spp.) while only sampling animals of other body sizes at random from the landscape. The detailed taphonomic and spatial analyses provided a completely different pattern that would otherwise have been invisible, in which humans were targeting eland (*Taurotragus oryx*) – a high-return size 4 bovid.

When more than one bone modifier is implicated in the formation of an assemblage and these cannot be separated out using prey body size or other criteria, it is critical to determine at what stage in the taphonomic history of that collection the modifications took place. This became particularly apparent in East African assemblages with much debate over whether or not early hominins were hunters or scavengers. Bunn (1981, 1986, 1991), Bunn and Kroll (1986), and Domínguez-Rodrigo (1997, 2002a) argued that early hominins were relatively accomplished hunters who left behind evidence of this in the form of cut marks. Workers such as Binford (1988a), Blumenschine (1991), and Selvaggio (1998) have countered that the fossils were only associated with stone tools because hominins had been scavenging from carnivore kills, and that the cut marks were simply the result of this scavenging.

Although cut marks on fossil bones provide important direct evidence of hominin faunal resource extraction, they do not by themselves speak to a purely hominin or even an initial hominin accumulator. Researchers such as Shipman and Rose (1983) examined the evidence using scanning electron microscopy, and argued that carnivores likely had

secondary access to carcasses hunted by hominins because tooth marks were sometimes found to be superimposed over cut marks. However, such a result could also be obtained under Selvaggio's (1998) 'three-stage' model in which hominins were the initial scavengers and bone-crunching carnivores had third and final access to the remains.

Binford (1981, 1988) has argued that the locations of these marks are critical factors to take into account, and that cut marks on midshafts were likely to have been the result of heavy processing to remove scraps of flesh from desiccated carcasses. Domínguez-Rodrigo (1997, 1999) used naturalistic observations of where meat can normally be scavenged from carcasses to argue that cut marks should not be preferentially found on midshafts if early hominins were pure scavengers. Bunn later (2001) suggested that the locations of these marks on midshaft fragments also supported a hominin-first scenario, as they would have been mistakes caused by stone tools inadvertently nicking heavily-fleshed bones. However, Bunn's (1986, 2001) assertion that early hominin butchers would have been taking care not to hit bone while butchering was recently found to be unsupported because such contact does not appear to significantly dull stone tool edges (Braun *et al.*, 2008). It has also been suggested that early hominin carnivorous behavior may have resided somewhere between the two extremes of hunting and scavenging, through active displacement of carnivores from kills that still retain a substantial amount of meat (Brantingham, 1998; Bunn, 2001).

Despite these disparate views on early hominin meat acquisition strategies, most of the contributors to this debate have developed their arguments by working with the same fossil assemblage: the FLK *Zinjanthropus* site in Olduvai Gorge, Tanzania (Bunn,

1981, 1991; Bunn and Kroll, 1986; Binford, 1988; Blumenschine, 1991; Domínguez-Rodrigo, 1997; Selvaggio, 1998). Such varying interpretations from the same dataset suggest that there may be some underlying methodological reasons that these workers have been unable to come to agreement. Some of these methodological issues may simply be a matter of presentation, such as when Monahan (1999) indicated that Domínguez-Rodrigo (1997) did not present his data in a way that was meaningfully comparable to the work of other researchers. This would indeed cause difficulty in understanding why there is so much difference in their interpretations, though Domínguez-Rodrigo (1999) has countered Monahan's (1999) proposition systematically and asserts that other methodological and interpretive problems are likely the culprit.

Most problematic is the suggestion that the data themselves have not been collected in a reliable manner. Domínguez-Rodrigo and Barba, (2006) returned to the *Zinjanthropus* assemblage and critiqued the methods by which Blumenschine (1991) identified tooth marks on the fossils. They suggested that many of the marks described by Blumenschine (1991) were actually caused by chemical etching that mimicked carnivore tooth marks and vastly inflated their relative representation in the assemblage. Blumenschine *et al.* (2007) assert that this is unlikely, but Thompson (2005) has also reported surface damage that can obscure existing tooth marks or possibly even mimic them. Hence, only high-confidence percussion, cut, and tooth marks that meet the criteria outlined in Blumenschine *et al.* (1996) are reported in the present study.

Amidst the initial debate surrounding the interpretation of cut and tooth marks on the *Zinjanthropus* assemblage, Blumenschine and Selvaggio (1988) introduced

hammerstone percussion marks as a form of surface modification that offered an alternative to cut marks for evaluating hominin involvement in zooarchaeological assemblages. A series of actualistic studies followed, in which the timing of access to carcasses by hominin and carnivore agents was known and the resultant marks they left on the surfaces could be directly examined in light of this information (Blumenschine, 1988, 1995; Marean *et al.*, 1992; Blumenschine and Marean, 1993; Capaldo, 1997; Selvaggio, 1994). From this, it was shown that for certain subsets of an assemblage the relative proportions of percussion and tooth marks are a reliable indicator of the *timing* of carcass access for these two agents. When the research objective is more focused on determining if hominins or carnivores were the primary *accumulator* of a given component of a faunal assemblage, as was the case at DK1 (Marean *et al.*, 2000b), comparison of these experimental data to surface modification observed on the fossil material can also provide a reliable answer to this question (e.g. Marean and Kim, 1998; Marean *et al.*, 2000b).

Since the initial debates about early hominin hunting versus scavenging, relative proportions of cut marks have also been used to estimate the degree of hominin involvement in the accumulation of an assemblage – similarly to how percussion and tooth mark proportions may be used (e.g. Domínguez-Rodrigo, 1997, 2002b). There has been some debate concerning the appropriateness of using cut mark frequencies for this purpose – particularly because the types, locations, and amount of cut-marking is contingent on so many different unknowable variables (Lupo, 1994; Domínguez-Rodrigo, 2002b; Lupo and O'Connell, 2002). These variables are generally related to the

state of the carcass when it is accessed (fresh or desiccated) and the goals of the butcher (disarticulation, filleting, periosteum removal, etc.). Again, as with critiques of previous uses of cut mark data the arguments have specifically concerned the manner and appropriateness of data presentation and interpretation, rather than the basic methods by which the data were collected (Domínguez-Rodrigo, 2002b; Lupo and O'Connell, 2002). Owing to this basic controversy, cut mark data as employed in this study will be restricted to interpretations of the strategies behind hominin carcass processing rather than the timing of these events.

Comparisons of surface modification on a zooarchaeological assemblage to proportions obtained in experimental or naturalistic settings are strengthened by taking several additional factors into account. First, proportions of tooth-marked specimens will differ according to the feeding ecology of the carnivore responsible for creating the tooth marks: flesh-eating specialists such as felids will be expected to leave fewer tooth marks than spotted hyenas (*Crocuta crocuta*) and canids, which can more easily access within-bone nutrients such as bone marrow or bone grease (Domínguez-Rodrigo and Barba, 2007). This is also true within the same taxon, where Faith (2007) has found that the incidence of carnivore tooth-marking changes with variables such as fragment size, prey body size, element, and element portion.

Second, a description of bone surface preservation and fragmentation is necessary because extensive post-depositional destruction of bone surfaces can depress surface modification frequencies (Thompson, 2005). Adhering matrix can have the same effect. Third, the relative proportions of percussion, cut, and tooth marks that are indicative of

human and carnivore interaction with an assemblage can be depressed by extensive post-depositional fragmentation. This is because extensive post-depositional fragmentation can lower the overall proportions of all mark types by increasing the number of fragments while the original number of marks remains the same (Abe *et al.*, 2002).

Even after these additional sources of variation and potential preservational bias have been accounted for, comparisons of the relative proportions of tooth and percussion marks in experimental assemblages to those in zooarchaeological assemblages is a procedure that works most effectively when it is restricted to use of the midshaft portions of long bones. This is for three reasons. First, the midshaft is a very likely area that percussion and tooth marks are to be found (as a result of the different hominin and carnivore marrow extraction strategies). Second, in any scenario in which carnivores have access to long bones, either broken or complete, they have been shown under both experimental and naturalistic situations to selectively remove epiphyseal portions and near-epiphyseal portions that retain some spongy bone by ingesting them to extract the bone grease (Marean, 1991; Marean and Spencer, 1991; Marean *et al.*, 1992; Blumenschine and Marean, 1993). Once midshafts have been emptied of their marrow there is no further reason for a carnivore to remove it or otherwise modify it, and these portions are therefore preserved in the archaeological record in proportions that much more closely approximate their original representation.

Finally, midshafts are the best indicator of the timing of carcass access or primary agent of accumulation because carnivores treat these bone portions differently if they are encountered as part of a whole bone (as in a fresh carcass) or if they are encountered as

fragments (as in a carcass that has already had the marrow removed by hammerstone percussion). Carnivores leave tooth marks on midshaft fragments as part of the process of marrow extraction, but in cases where the marrow has already been removed by hominins (secondary carnivore access) they typically ignore these bone portions (Marean, 1991; Marean and Spencer, 1991). Similarly, a hominin scavenger that encountered a long bone that has been emptied of marrow by carnivores will not employ hammerstone percussion on the midshafts.

The net result of this behavior is very low proportions of tooth marks relative to percussion marks on midshafts have been accumulated by hominins and later scavenged by carnivores, with the converse being true for assemblages that have had a mainly carnivore accumulation or been subject to hominin scavenging of carnivore kills (Blumenschine, 1988; 1995). Finally, because midshafts are not attractive to carnivores if the marrow is first removed, these portions also suffer the smallest amount of spatial relocation by scavenging carnivores and are therefore likely to be the most reliable indicator of the original location where the bone was discarded by hominins (Marean and Bertino, 1994). This is particularly true for very tiny long bone flakes that have been detached by hammerstone percussion, with the additional benefit that their small size makes them even less likely to be moved by other agents and they provide quite reliable indications of the original locus of marrow extraction activities (Marean and Bertino, 1994).

Because of the importance of midshafts in making these assessments, this robust and experimentally-supported framework for understanding the relative degrees of

hominin and carnivore involvement in an assemblage is only applicable for assemblages such as those used in this study, where all long bone portions are both available and have been examined microscopically following standard identification procedures outlined by Blumenschine *et al.* (1996). Unfortunately, as was seen in the discussion of zooarchaeological debates in modern human origins research, this has not typically been the case for MSA assemblages. In the classic example of the Klasies River assemblage, midshafts were among the bone fragments not considered identifiable and were therefore discarded (Marean and Kim, 1998; Bartram and Marean, 1999). Furthermore, even for assemblages in which midshaft fragments were collected as carefully as the rest of the assemblage, many researchers have chosen to leave them out of their analyses because they can be more challenging to identify to element and very rarely can be identified to species (Klein and Cruz-Uribe, 1984).

This traditional practice of examining and presenting only the most identifiable or complete elements in an assemblage can lead to two major problems. First, surface modification analyses cannot be as reliably quantified and compared to experimental data, and they become limited by the absence of these most diagnostic components for understanding hominin and carnivore interaction with an assemblage. Second, because midshafts are the portions not normally swallowed or fragmented beyond recognition by carnivores, they often provide the best measures of long bone abundances at a site. When instead only highly diagnostic long bone ends are used to count long bone representation (as recommended by Klein and Cruz-Uribe [1984]), they are very likely to under-

estimate the original abundances of these elements (Bunn, 1986; Marean 1991; Marean and Spencer, 1991; Marean *et al.*, 2001; Cleghorn and Marean, 2004).

A lack of understanding of the basic principles of carnivore attrition led early workers to construct elaborate explanations for what seemed to be a ubiquitous pattern of very high representation of calorie-impoverished head and foot elements relative to the calorie-rich meat-bearing elements (e.g. Perkins and Daly, 1968; Stiner, 1994). Binford (1978) quantified this pattern by plotting a standardized measure of long bone representation against a standardized measure of the caloric values of various skeletal elements. The former measure, which Binford (1978) originally termed the General Utility Index (GUI) for individual bones and the Modified General Utility Index (MGUI) for bones representative of different carcass segments, was later simplified by Metcalfe and Jones (1988) into an easily-employable quantification of element utility.

When plotted against the relative representation of skeletal elements in an archaeological assemblage, this provided the means by which element transport could be examined quantitatively in light of some possible expectations of optimal foraging theory (Stephens and Krebs, 1987; refer to Winterhalder and Smith [2000] for a basic summary of its application to hominin foragers). In its simplest permutation, optimal foraging theory would predict that if a whole carcass was available and decisions needed to be made about which segments to transport, then skeletal element transport should increase along with increasing food utility. This is because the marginal value theorem predicts that there will be a curve of diminishing returns, and that organisms seek to maximize their return through a combination of selection of the highest-return resources at the

lowest cost. For a forager returning to a central place, transport is one such cost (Stephens and Krebs, 1987). However, for a truly rigorous application of optimal foraging theory the net return rate that includes handling costs is required, and these data are not commonly available.

Based on simple gross return rates, Binford (1984, 1988b) found that at Klasies River and a variety of other sites that also exhibited the 'head and foot' pattern the predictions of optimal foraging theory were not upheld: bone representation actually *decreased* with food utility. This led to Binford's (1984) proposal that MSA hominins were primarily scavengers who only had access to the marginal, low-utility scraps of a carcass. However, given what was later learned through experimental research it became clear that these 'reverse utility curves' were the direct result of taphonomic and analytical biases rather than hominin behavior (Marean *et al.*, 1992; Marean and Frey, 1997; Marean and Kim, 1998). Because shaft fragments were not used in estimates of skeletal element abundance, the high-utility long bones were assigned unrealistically low representations that served to completely reverse the direction of the relationship between bone abundance and bone utility (Marean and Frey, 1997; Marean *et al.*, 2004).

Although carnivores are a well-documented agent responsible for the selective deletion of spongy elements and cancellous epiphyseal ends from faunal assemblages, they represent only one of several potential processes by which the same pattern of relatively high midshaft representation can come about. In general, it is not just midshafts that are better-represented at zooarchaeological sites. Teeth are often well-preserved, as are element portions such as the tympanic in the skull. Certain bone

portions such as the vertebral zygopophyses and the acetabulum of the pelvis also often preserve well relative to their less dense counterparts on the same bone (although midshafts and teeth are usually by far better-represented than even these somewhat denser portions of spongy elements). This pattern was first quantified by Lyman (1984) through determination of relative bone mineral densities using photon densitometry. Later, Lam *et al.* (1998; 1999; 2003) identified these values more precisely through the application of computed tomography (CT), and found a very robust relationship between bone portion density and survivorship in archaeological assemblages. Importantly, individual long bones were found to have a large range of variation in their density values, including some of the highest (on the midshaft) and some of the lowest (on the epiphyseal ends of certain elements).

The total suite of processes that differentially preserve denser bone fragments is encompassed under the umbrella term 'density-mediated attrition' or 'density-mediated destruction' (Lyman, 1994). Because entire elements that were originally present can become effectively invisible in assemblages that have been subjected to a heavy degree of such destruction, this can build large amounts of systematic bias into patterns of skeletal element abundance. It is therefore critical that the extent of such destruction be carefully documented in an assemblage before behavioral interpretations regarding relative skeletal element abundances may be undertaken – and these necessary steps are taken here during analysis of each faunal subset.

At the same time that actualistic studies were gaining acknowledgement as a critical component of zooarchaeological (and particularly taphonomic) research, other

workers began engaging in ethnoarchaeological research in order to observe how modern human groups process and discard bones. In much the same way that middle range theory was being used to link actualistic studies to the zooarchaeological record, this ethnoarchaeological work forged critical observational links between human behavior and what would eventually become the archaeological signature of that behavior (Binford, 1978; Bunn 1988; Gifford-Gonzalez, 1989; O'Connell *et al.*, 1998; Bartram *et al.*, 1991; Bartram, 1993; Lupo 1995; Lupo and O'Connell, 2002; Nilssen, 2000). A primary outcome of this research has been the production of data that are useful for understanding the ways in which modern humans process and transport faunal resources.

Carcass processing occurs in several stages, each of which represents a series of decisions by the butcher. Such processing can take place either before or after transport, depending on a variety of factors such as hunting technique, group size, prey body size, or distance from the kill site to the transport site (Binford, 1978; Lupo, 1994; O'Connell *et al.*, 1998, Monahan, 1998). Therefore, the processes of butchery, transport, and consumption are in reality all inter-related aspects that can occur anywhere along a continuum leading from initial prey acquisition to eventual discard.

In a zooarchaeological assemblage many of these aspects can be reconstructed, but the timing of some relative to one another may remain unclear. For example, cut marks in diagnostic locations on an element can speak to a specific activity, such as tongue removal or filleting of meat from long bones, but it may remain uncertain if this activity took place before or after the element was transported (Binford, 1984; Nilssen, 2000). In some cases the timing cannot be known absolutely but ethnoarchaeological

research has shown consistent and logical patterning in the ways in which modern humans approach carcass processing that can be applied to the zooarchaeological record. As an example, evisceration is generally the first step in a processing sequence and disarticulation often takes place prior to filleting (Nilssen, 2000).

Finally, there are some cases where the sequence of events can be known with high confidence. For example, the meat overlying a bone must be removed prior to marrow extraction, and a long bone shaft will not be transported for a nutritive purpose after the marrow is gone. Because the timing of each action is not always certain, it is useful for analytical purposes to examine each aspect individually and later assemble these data into the most logical overall sequence of strategies. Three general categories into which the entire continuum of actions may be usefully separated are transport, outside-bone nutrient processing, and within-bone nutrient processing. These are therefore presented separately in this study.

Ethnoarchaeological research has provided some valuable observations about patterning that would be expected in skeletal element and taxonomic abundance given different prey body sizes and carcass portions (e.g. Bunn, 1988; O'Connell et al., 1988, 1990; Monahan, 1998). However, because of the problems of density-mediated attrition that have been described above, reconstructing carcass transport decisions from archaeological assemblages and determining how much of the patterning is attributable to human behavior and how much to other taphonomic processes has been a topic of much debate (Bartram and Marean, 1999; Klein *et al.*, 1999; Rogers, 2000; Cleghorn and

Marean, 2004; Marean *et al.*, 2004; Pickering *et al.*, 2003; Stiner, 2002; Faith and Behrensmeyer, 2006; Faith and Gordon, 2007).

This problem of equifinality in skeletal element representation was identified relatively early in zooarchaeological work (e.g. White, 1956), but it has taken a long history of actualistic and ethnoarchaeological research to arrive at a more complete understanding of the processes involved, the patterning that results, and appropriate ways of dealing with the issue. Marean and Cleghorn (2003) approach the problem by grouping skeletal elements into low- and high-survival sets. Elements comprised entirely of low-density spongy bone fall into the low-survival group and elements with a higher-density portion in addition to spongy portions (such as mandibles and long bones) fall into the high-survival group. Marean and Cleghorn (2003) have further addressed the issue of processing effort, because *net* food utility might be expected to reduce the values of elements that require more effort to process. However, the strongest pattern of increasing abundance with increasing net meat return was found only at ethnoarchaeological sites where bones had not been subject to density-mediated destruction. Where agents such as carnivores had access to the sites, the status of an element as falling into the 'high-survival' or the 'low-survival' set predicted its abundance at the site quite well. Marean and Cleghorn (2003) conclude by suggesting that by restricting comparisons of relative skeletal element abundances to within these groups, much of the potential interference from density-mediated destruction can be removed, and this procedure is followed in the present study.

Outside-bone nutrient processing refers here to evisceration, skinning, disarticulation, the removal of flesh, and the extraction of specialized animal components such as the tongue. As discussed above, much attention has been given to the interpretation of the locations of cut marks throughout the skeleton as a proxy measure of outside-bone nutrient extraction. This patterning has been quantified by Abe *et al.* (2002), who employed an image-analysis GIS program to allocate marks to different zones on long bones, correct for preserved surface area of these elements, and then compare these data to ethnoarchaeological observations of two butchery strategies used by modern butchers (Nilssen, 2000). These butchery strategies are filleting only (in the case of the modern butchers for the production of dried meat), and disarticulation combined with filleting. This approach has been applied to a subset of the zooarchaeological assemblage from DK1 (Abe *et al.*, 2002), and the present study will expand on this both within DK1 and at the two other study sites in Chaptes Four, Five, and Six.

Within-bone nutrient processing refers primarily to the extraction of marrow and bone grease, though it can also refer to brain removal. However, little specific work has been done on the distribution of percussion marks and the implications this might have for within-bone nutrient removal. In carbohydrate-poor environments an essential source of energy is found in bone marrow and bone grease (Speth and Spielman, 1983). Carnivores process long bones by breaking the shafts with their teeth in order to access the calorie-rich marrow, and then proceed to crush and swallow long bone ends so that the greasy cancellous bone can be further processed in the gut (Marean, 1991). Modern

humans extract this same grease using the technological means of bone boiling (Thompson and Lee-Gorishti, 2007). These two taphonomic pathways create much potential for understanding the processes to which fossils have been subjected during within-bone nutrient extraction by both agents. This is because fragmentation of spongy portions can aid in grease extraction (Church and Lyman, 2003), and this is a behavior that is expected to leave evidence in the form of percussion marks.

The distribution of percussion marks across long bones should also provide a means for assessing the importance of bone grease extraction versus marrow extraction, because percussion marks for grease will be left on epiphyseal portions while percussion marks attributable to marrow extraction should be focused on the shaft. However, as with the problem that is encountered when disarticulation versus defleshing cut marks are compared, percussion marks on epiphyseal portions are expected to be relatively scarce simply because the bone portions bearing those marks are also poorly represented. Thus, two distinct behaviors for two distinct purposes are not taphonomically comparable in assemblages that have undergone heavy density-mediated destruction.

A modified procedure from that proposed by Abe *et al.* (2002) for correcting for cut mark proportions can also be applied to percussion mark proportions. Counts of percussion marks were made on long bone zones and these counts were adjusted by available bone surface area using the skeletal element abundance maps generated in an image-analysis GIS program (Marean *et al.*, 2001; Abe *et al.*, 2002). This gives an adjusted figure of the incidence of percussion-marking across long bone portions and a

new quantitative way of examining within-bone nutrient extraction at zooarchaeological sites.

In summary, the development of zooarchaeology as a specialized body of method and theory has also resulted in an important emphasis on understanding taphonomic processes. This has been accomplished both through actualistic research and through ethnoarchaeological observations. Over the course of several debates some dangerous pitfalls in methodology and interpretation have become apparent, and some robust ways of dealing with these potential problems have been developed. The present study seeks to build upon this history by presenting data from two new MSA zooarchaeological collections along with analyses of existing data from a third that has already been published. The methods for accomplishing this have been drawn from the rich body of zooarchaeological and taphonomic literature that is currently available, and at times some new methods in data collection, analysis, presentation, and interpretation are also piloted. Standard measures are discussed in the following section of this chapter, and new methods or modifications to old methods that have not been covered in sufficient detail in the preceding section are described in the sections under which the data are presented.

Data collection methods

Primary zooarchaeological data from Pinnacle Point Cave 13B (PP13B) and Blombos Cave were collected at Iziko: South African Museums of Cape Town. Data from PP13B were collected from the 2000, 2003, 2004, 2005, and 2006 excavation season assemblages. This material has all been piece-plotted to the greatest possible degree, with no size cut-off point. This has resulted in the majority of fragments being

tied to point coordinates in three dimensions but there is also a variety of specimens with basic provenience limited to square, subsquare, and stratigraphic unit only that have been recovered from the 10 mm and 3 mm screens. All mammalian specimens identifiable to element, including small mammals such as hyraxes (Procaviidae) and hares (*Lepus* spp.), were included in the PP13B study, as were all tortoise fragments. Fish and birds were not studied, but these represent a very low proportion of the overall assemblage (n = 19 and n = 57, respectively).

Data from Blombos were collected from the assemblages recovered during the 2000, 2002, and 2004 excavation seasons. The material from the 2000 season made up the bulk of the sample because bone was regularly piece-plotted beginning in 2002. This necessarily slowed excavations and resulted in smaller samples than those recovered from field seasons in which piece-plotting of fauna was not regularly practiced. Fauna was also recovered from Blombos Cave during the 1992, 1997, 1998, 1999, 2005, 2006, and 2007 seasons, with the first three at least as large as that recovered in 2000. Unfortunately, time constraints of the study did not allow for a complete examination of all of this material. The sample therefore includes all postcranial fragments from three excavation seasons only that are larger in their maximum dimension than 2 mm and identifiable to skeletal element from size 1 – 5 mammals (following Brain [1981]).

For both sites, all fauna identifiable to element was cleaned of sediment and adhering matrix with fresh water, although not all matrix could be removed with water. Fragments were then given individual specimen numbers and each numbered specimen was entered as an individual record into a Microsoft Access database designed for this

purpose. These specimens include less identifiable long bone fragments which are not assignable to a specific element but that could be identified at least to this very general level. The remainder was identified to the greatest degree possible to body size and skeletal element, with percentages of preserved diagnostic bone landmarks recorded in increments of 10% (e.g. deltoid tuberosity of the humerus, linea aspera of the femur, medial condyle of the tibia, etc.).

The smaller overall available sample from PP13B allowed this study to be more complete. It included cranial fragments, less identifiable specimens such as non-identifiable pieces of enamel, crania, and horn core, as well as all small mammal and tortoise fragments. Pieces of spongy bone, bits of cortical bone with no evidence of having a medullary cavity or having otherwise come from a long bone, and fragments of cortical bone with no facets, diagnostic shape, or muscle markings that could indicate their approximate location in the skeleton, were not included in either study. An additional 6,265 piece-plotted specimens from PP13B, the majority of which were large mammals, fell into these non-identifiable categories and were not studied despite having been piece-plotted. The same was true for a small number of piece-plotted specimens from the 2002 and 2004 excavation seasons at Blombos.

Taxonomic affinities were recorded to the family level or above. For the purposes of this project all large mammal data will be presented in terms of body size and general taxonomic category of the family level or above. Age at death was roughly divided into ‘adult’ or ‘subadult’ (using fused versus unfused epiphyses, bone texture exhibiting an open or woven structure and enlarged nutrient foramina as seen in very young mammals,

unerupted teeth, etc. [Reitz and Wing, 1999). If a distinguishing characteristic was available for either adult or subadult, this was recorded. All other specimens were recorded as 'not observed'. Burning stages were recorded on a scale of 0 – 6, with 0 representing no burning, 3 representing full carbonization, and 6 representing full calcination. The criteria used were heavily based on discoloration, which is easily observed and recorded. It is used here as a rough indication only because although discoloration can be used quite effectively to determine charring and calcination in fresh assemblages it may be a less reliable indicator of burning in fossil assemblages that have undergone other color changes and diagenetic processes (Shipman *et al.*, 1984; Lyman, 1994).

Each fragment was placed under a 10 – 40 x binocular light microscope with a fiber-optic halogen light shining obliquely across the bone surface. This is a method that successfully diagnoses cut, tooth and percussion marks 97-100% of the time with minimal training (Blumenschine *et al.*, 1996), and for which I have been administered blind tests to ascertain my own level of accuracy. The percentage of the surface that was covered by matrix or rodent gnawing was recorded in increments of 10%. Gastric etching was recorded as presence/absence, weathering stages followed Behrensmeyer (1978), and post-depositional/geochemical alterations of the bone surface followed Thompson (2005). The angle and outline of break edges were recoded for long bones following Villa and Mahieu (1991), and excavation versus sediment or ancient breaks were recorded as being 'extremely different', 'slightly different', or 'not different' from the adjacent bone surface.

Data presentation and analytical methods

Several different standard measures of zooarchaeological data were employed throughout the study. The specific benefits and complications of each measure are described in detail by Grayson (1984). The most basic presentation is through a simple listing of the Number of Identified Specimens (NISP). This can be a list of any subset of data, and simply indicates that no further quantitative transformations have been performed. In this study, basic species abundance and skeletal element abundance data are presented by NISP so that the entire composition of the assemblage can be seen. In some cases, the NISP is also used where sample sizes for a particular subset of data are relatively small because they are characterized by a very specific set of criteria. For example, fragmentation data are presented as the simple NISP of fragments that exhibit a particular set of qualities (e.g. all long bone fragments with an obliquely-broken end and evidence of burning may comprise the NISP of one subset and be compared to all long bone fragments with an obliquely-broken end and no evidence of burning as a second subset). Surface modification data are also presented in this way (e.g. all long bone midshaft fragments that display a tooth mark and have less than 70% coverage by matrix *and* no evidence of heavily-exfoliated surfaces may comprise the NISP of one subset, and so forth).

In theory, a skeletal element can be broken into an infinite number of smaller fragments. Therefore, a more derived way of presenting skeletal element abundances is by using the Minimum Number of Elements (MNE). The MNE provides a way to establish the minimum number of a given element in an assemblage, and to therefore

examine skeletal element abundances from the perspective of how many whole bones were once present. It is then easy to know the Minimum Number of Individuals (MNI) represented at a site because this will be the highest MNE (each animal can only have one right femur, for example, so if the highest MNE is on the right femur this is also the MNI).

Another derivative of the MNE is the Minimum Animal Units (MAU). The MAU is the total number of a particular element that is represented at a site divided by the number of times it occurs in the body. This measure does not take element side into account and was therefore considered by Binford (1978, 1981) to be a way of understanding skeletal element abundances that is more representative of how the people who processed and transported carcass segments would have actually viewed them. Depending upon the method of determining MNE estimates they may or may not be presented in terms of whole elements. In contrast, the MAU is always presented as fractions of whole elements. Also, because simple counts can be difficult to compare to one another, a final transformation can be made using MAU data. The %MAU sets the element that occurs most often in an assemblage to 100% and then scales the representation (by MAU) of all other elements as percentages of this maximum abundance. For example, if the MAU values for an assemblage are ten for femur, three for scapula, and one for cervical vertebra, the %MAU of each of these elements would be 100%, 30%, and 10%, respectively.

Grayson and Frey (2004) have used case studies from a variety of zooarchaeological assemblages to argue that from a statistical perspective there are

highly predictable relationships between the NISP, MNE, MNI, and MAU and that none is necessarily more reliable than the other. The principle advantage of NISP counts is that they do not suffer the adverse effects of aggregation measures such as the non-fractional MNE or MNI (Grayson, 1984). Related to this is the fact that NISP counts can be easily added, subtracted, and otherwise manipulated by a reader without access to the primary data, whereas MNE estimates cannot. This is because MNE values are often based on visual examination of where bone fragments overlap or on counts of the fractions of particular bone portions that are preserved (Marean *et al.*, 2001). Each subset of data is therefore likely to provide a different MNE. For example, if Layer 1 has an MNE of three for the left tibia based on the medial malleolus and Layer 2 has an MNE of four for the left tibia based on the anterior crest, the combined MNE for left tibiae in the two layers could be any number between four and seven (owing to the fact that all three of the medial malleolus fragments could belong to the same tibiae that posses the anterior crest fragments). A reader would never know which was the case, and would be forced to use the same analytical units or groupings as those presented by the author.

For this reason, the skeletal element abundance data presented in each chapter are given by both NISP and MNE. For the MNE data several options are also provided, beginning with a very basic value with minimal aggregation (Appendix D). The first MNE estimate is based on the overlap of all fragments by individual body size. The second assumed that body sizes had been assigned correctly to all fragments, and that therefore the same elements from two different body size classes were necessarily from different individuals. For this second estimate the MNE for all body sizes was simply

counted – and this almost always resulted in a higher MNE estimate than did estimates based solely on overlap. This is an example of the problem with splitting and lumping MNE data as described by Grayson (1984). Taking this theme to its maximum, one could take a final step and assume that individuals of different body sizes from different analytical units or layers could also not possibly be from the same individual, and this does indeed boost overall MNE estimates even higher (these numbers are not provided but can be summed by the reader if needed). The MNI is provided given all three of these scenarios, and the element from which it was derived is also listed.

The principle advantage of using MNE estimates and their derivatives is that they are much less sensitive to extensive or differential fragmentation of an assemblage (Grayson, 1984). This makes NISP counts between sites or even between layers or taxa at the same site basically incomparable unless the effects of peri- and post-depositional breakage can be reliably accounted for first. Grayson and Frey (2004) recommend that the needs of each particular analysis be weighed up in light of these advantages and disadvantages and the basic measure that is more appropriate for the dataset be the one that is employed. Because one of the principle goals of this dissertation is to bring together both published data and new data from different sites, MNE estimates and their derivatives are the preferred measure for behavioral interpretations in this study but NISP data are also made available.

Unfortunately, although the MNE is a standard measure in zooarchaeology and forms the basis of even more derived measures of skeletal element abundance, the actual methodology by which the MNE is initially estimated can differ vastly between

researchers (Marean *et al.*, 2001). This can render assemblages incomparable in a more insidious way than does simply selecting one measure over another. If researchers are not first specific about how they arrived at their MNE estimates, it becomes a matter of trust that the resultant values are both reliable and comparable. These are large assumptions to be made when all subsequent data presentation and behavioral interpretations in an analysis are based on values generated within such a methodological 'black box'.

Marean *et al.* (2001) have proposed an image-analysis approach to deriving MNE estimates, and this was employed consistently throughout the present study. Each specimen identifiable to both side and element was entered as a vector into a GIS image-analysis application written for the program ArcView GIS 3.3. This application shows the size and shape of a fragment relative to the complete element and provides tools for analyzing them relative to one another (Marean *et al.*, 2001). The fragments used in the study were cut from a template of each element and side designed for this purpose, and then linked by specimen number to the external database created in Access. This overall data entry procedure resulted in a database entry for each specimen, with a linked digital drawing of the shape and areal extent of those fragments that could be identified to side and element.

The radius, metacarpal, and metatarsal are all long bones that are easy to identify to element from a small fragment, owing to the distinctive ulnar scar on the posterior portion of the radius and the line of fusion along the midlines of the metapodials. However, the otherwise extremely uniform shafts make it difficult to side and precisely

place these elements on the GIS templates. This problem was overcome by arbitrarily assigning every other fragment for which side could not be determine to either right or left. This procedure makes the assumption that there would be no systematic preservational or transport bias for or against one side of the body or the other. Pelves, ribs, and scapulae presented a similar difficultly, and fragments with a sufficient proportion preserved to be able to identify location on the template were therefore also assigned arbitrarily to either left or right. All specimens for which this was done have been noted in the Access database.

The MNE was estimated using the same image-analysis GIS application used for drawing the specimens (Marean *et al.*, 2001). This application is a virtual method of determining the number of overlapping fragments in a given skeletal element. Vector files created as a part of the data collection process were selected based on a set of criteria, e.g. 'all ungulate size 1 left tibiae' or 'all ungulate size 3 right femora'. These vectors were then converted to raster files, which have a numerical value underlying each pixel or group of pixels. Pixels falling within the area of a drawn fragment each had a value of one, and pixels outside the area were assigned a value of 0. When all raster images were overlain upon one another and added up, a simple map calculation gave the highest number of overlapping fragments. This number is also the MNE.

Sometimes the highest number occurred on a single pixel, which is more likely to be a slight miscalculation during drawing of the specimen and not a real overlap. All MNE images produced by the program were first examined to eliminate over-inflation of MNE values before the final MNE count for each set of criteria was determined.

Metapodials and tibiae presented a special difficulty in being highly identifiable even from small shaft fragments, but the uniformity of the shape down the length of the shaft made it difficult to position them even with an arbitrarily-assigned left or right designation. These elements will therefore be more highly represented by the Number of Identified Specimens (NISP) but not as well-represented in the MNE estimates.

Metapodials were further problematic owing to the similarity between metacarpals and metatarsals, with the result that even the easily-positioned distal portions are underrepresented in the MNE images. Marean (pers. comm.) arbitrarily assigns such problematic specimens to either 'metacarpal' or 'metatarsal' while drawing the fragments into the GIS. Because this was not done at PP13B or at Blombos, MNE estimates of these fragments using data from DK1 provided by Marean and colleagues are made comparable by being based only on fragments that could be confidently assigned to one or the other element. All single-element measures (MNE, MNI, MAU, %MAU) used in this study were derived using the GIS method. Furthermore, following the recommendations of Marean and Cleghorn (2003), representation of elements within the high-survival set are only compared to one another, while those within the low-survival set are compared to one another separately.

Cut mark data are presented within both a qualitative and quantitative manner that compares the locations of cut marks to patterns established by ethnoarchaeological observations of modern-day butchers (Nilssen, 2000). Both approaches employ the use of a visual data-entry method in which the numbers and orientations of cut marks have been drawn onto virtual templates of the fragments upon which they occur. This image-

analysis technique was developed for the program ArcView 3.3 by Abe *et al.* (2002) as a way to examine patterning in cut mark data in a more intuitively visual way that is also quantitative and flexible enough to accommodate large datasets.

After cut marks were drawn onto the fragments they were merged into a single file that shows the locations of all marks on fragments that could be identified to element and side. These files were then queried to show only the subset of data needed for a given analysis (e.g. body size, analytical unit, etc.). Long bones were further divided into five portions: proximal epiphysis, proximal shaft, midshaft, distal shaft, and distal epiphysis. The numbers of marks could then be counted for each portion and adjusted by surface area using skeletal element abundances generated using the method described above (Marean *et al.*, 2001).

This overall procedure corrects for the effects of extensive fragmentation and density-mediated destruction. For example, Nilssen (2000) identified two strategies in modern butchers that left distinctly different patterns of cut marks across long bone portions. The first was where filleting was the primary objective and the other began with disarticulation and then moved on to filleting. Unfortunately, a disarticulation strategy results in higher relative proportions of cut marks on long bone ends, and owing to density-mediated destruction these portions are not preserved in the same relative frequencies as their accompanying shafts. By adjusting for preserved bone surface area, Abe *et al.* (2002) were able to quantitatively define where relative proportions of cut marks would have occurred in a 'fresh' assemblage that had not undergone any taphonomic alterations.

The present study also undertakes several corrective measures to accommodate for the effects that post-depositional fragmentation (i.e.: fragmentation when the bone was in a non-nutritive state) and the state of bone surface preservation can have on surface modification analyses. Long bones that are broken while fresh tend to retain oblique fracture angles and curved or v-shaped fracture outlines, while bones broken while in a 'dry' state tend to have right fracture angles and transverse fracture outlines (Villa and Mahieu, 1991). Post-depositional fragmentation is then quantitatively evaluated by examining long bone fracture patterns and comparing them to modern experimental assemblages in which all bones were broken while fresh (e.g. Marean *et al.*, 2000b).

Fragments with poorly preserved surfaces (as defined by Thompson [2005]) or extensive matrix coverage (> 70%) are simply eliminated from the analysis. This can be problematic, given that each fragment has a different size and so the percentage of each surface that is heavily exfoliated or covered by matrix represents a very different absolute amount of exposed surface. For example, smaller fragments with 10% of their surfaces covered by matrix can have exactly the same amount of exposed surface as larger fragments with 90% of their surfaces covered. A potential way to overcome this problem would be to draw the preserved area onto each fragment in the GIS system as other surface modifications such as percussion and cut marks are entered (Abe *et al.*, 2002). Then, the amount of visible surface could be corrected for in terms of both the area represented by the fragment and the area of well-preserved surface – thus eliminating the dual problems of fragment size differences and differential preservation almost completely. Unfortunately, both the entry and analysis would be a time-consuming

process, and when time is an issue and sample sizes are adequate heavily affected fragments can simply be eliminated from analysis using conservative criteria as was done here.

CHAPTER THREE: RESEARCH GOALS OF THE PRESENT STUDY

General research agenda

Recent excavations in the Western Cape, South Africa have bolstered the available sample of systematically excavated, analyzed, and well-dated sites with well-preserved faunal remains. The present study gives primary taxonomic and taphonomic data from two of these: Pinnacle Point Cave 13B and Blombos Cave. It also provides new analyses of skeletal element data collected by Marean *et al.* (2000b) from DK1. Having access to these three datasets makes it feasible to do several things. First, long-held assumptions about MSA faunal exploitation behavior can now be tested with an increased sample size. Second, the consistency of behavioral patterns revealed at DK1 and inferred from Sibudu can be checked. Third, because of the scarcity of sites with preserved fauna that have been systematically excavated, analyzed, well-dated, and completely published, very little is known about variability in MSA artifact production – and even less about faunal exploitation. Comparable data collection methods on complete assemblages makes this study the first in the South African record to allow taphonomically-informed interpretations of MSA faunal exploitation behavior to be directly compared between sites and variability in use of faunal resources to be systematically explored.

Today the sites employed in this study are situated on the South African coast of the Western Cape Province, although changes in global sea level over time would have periodically placed them at varying distances to the sea (Figure 1). The sites have been dated maximally to ca. 449 ka at PP13B based on a cutoff date for the maximum age of the underlying non-anthropogenic units, and minimally to ca. 60 ka at DK1 (Table 1). However, the anthropogenic sediments at PP13B likely were accumulated much later

than the maximal age suggests, and this is supported by a direct maximum age estimate near the base of the sequence of 178 ka (Marean *et al.*, in prep). The sediments at Blombos have been dated minimally to ca. 70 ka, with overlap in MSA occupation between the two sites at ca. 143 – 92 ka (Jacobs *et al.*, 2003a, b; Jacobs *et al.*, 2006, Tribolo *et al.*, 2006). This time period covers both the arid and potentially cooler MIS 6 and the relatively warm MIS 5 – including the height of the Last Interglacial (MIS 5e) between about 130 – 119 ka. DK1 extends this record into MIS 4, with deposits dating to approximately 70 – 60 ka (Feathers and Bush, 2000; Schwarcz and Rink, 2000). The continuous and in some cases overlapping range of time represented by the three sites, along with their proximity to one another within a 300-km stretch along the South African coast, makes them extremely well situated for behavioral comparisons as well as understanding how changes in environment and local ecology may have affected MSA faunal exploitation strategies. Such a relatively constrained area and time range is also ideal for capturing any subtle variability in faunal acquisition and processing strategies that the limited empirical record has previously rendered undetectable.

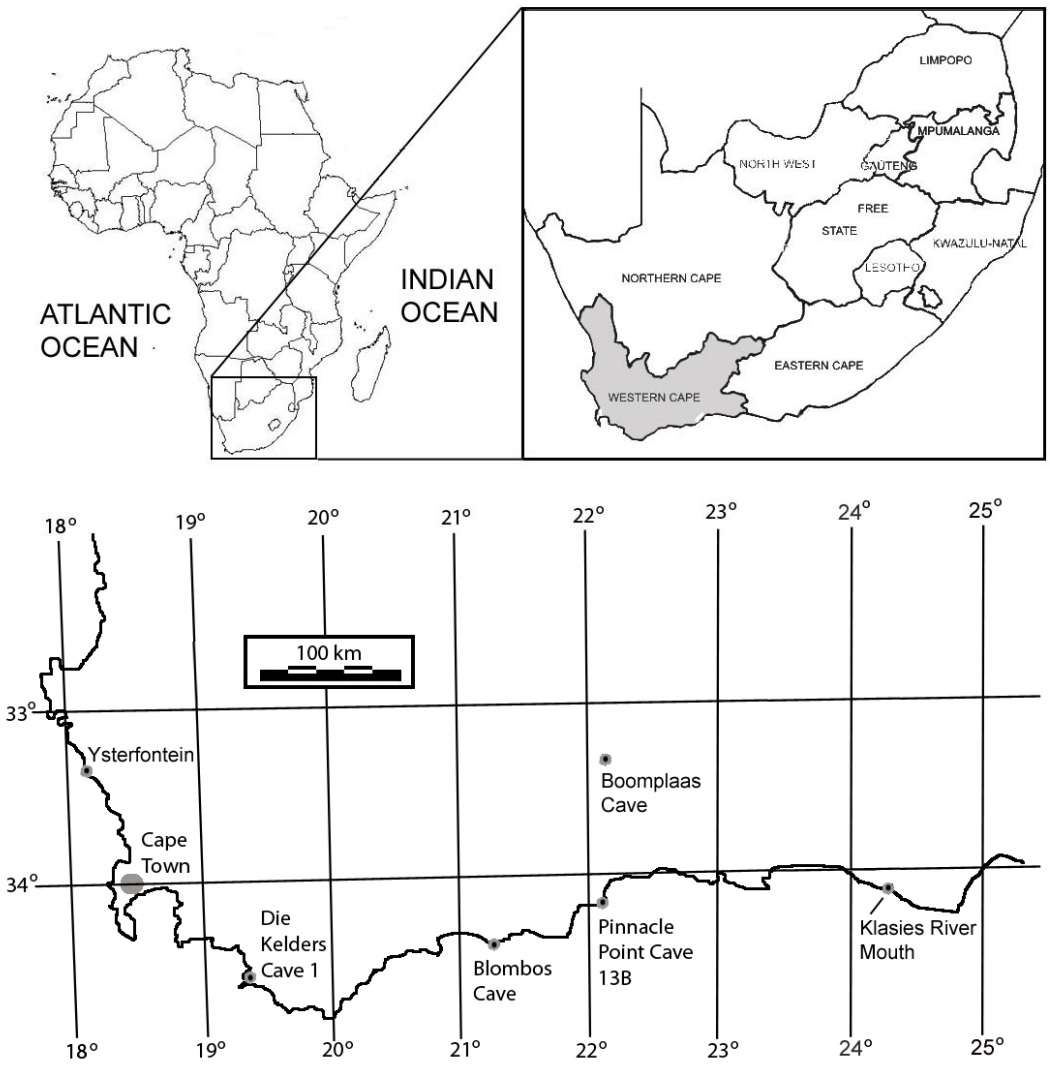


Fig. 1 South Africa (top right) relative to the rest of the continent, with the Western Cape Province highlighted. Detail map (below) of coastline and locations of sites discussed in the text.

Table 1

Age ranges of sediments at the three main sites described and discussed in the text.

MIS	Warm/Cold	Min Age (ka)	Max Age (ka)	PP13B	Blombos	DK1
3	Cool	35.1	43.8	Surface sediments	-	-
3	Cool	38.7	38.9	Re-opening of cave	-	-
3 - 4 (5b?)	Cool - Cold	45.4	95.3	-	-	Layers 9 - 14
3 - 4	Cool - Cold	62.8	71.8	-	Capping dune on MSA deposits	-
3 - 4	Cool - Cold	69.6	75.8	-	BBC M1	-
5a	Warm	73.7	90.4	-	BBC M2	-
5b	Cool	91.6	91.6	Initial sealing of cave	No gaps in sequence	-
5b	Cool	91.1	96	LB Sand 1 (Western)	No gaps in sequence	-
5b - 5d	Cool - warm - cool	91.1	127	Upper DBS Units (Western) + LC-MSA Upper	No gaps in sequence	-
5b - 5d	Cool - warm - cool	91.1	115.8	Shelly BS/Upper RS (Eastern)	No gaps in sequence	-
5c	Warm	94.4	103.4 (149)	No gaps in sequence	BBC M3	-
5d	Cool	111.3	120.7	Lower RS (Eastern)	-	-
5 - 6	Very warm - Cold	99.2	178.1 (449)	Lower DBS Units (Western)	-	-
6	Cold	128.8	141.6	LC-MSA Middle	-	-
6	Cold	137.7	148.7	No gaps in sequence	Basal dune under MSA deposits	-
6	Cold	154.3	176.8	LC-MSA Lower	-	-

Notes: Ages for PP13B and Blombos are near-basal, the maximum age of the underlying non-anthropogenic units is given in brackets. Ages from DK1 are centered on ca. 70 - 60 ka, and likely do not continue into MIS 5 (Feathers and Bush, 2000).

Much of the variability that may be detected in MSA faunal assemblages could potentially be accounted for by differences in site context. Here, site context refers to the *physical*, *environmental*, and *behavioral* characteristics of the sites themselves and the artifactual assemblages recovered from them. The sites used in this sample cover a range of such attributes, each of which will be described generally here and in more detail at the beginnings of Chapters Four, Five, and Six as part of the background to each site.

Physically, Blombos is a small, isolated crevice inset into a cliff high above sea level (ca. 35 m). PP13B and DK1 are large caves set 15 and between 3 - 10 m above modern sea level respectively, and in close proximity to other large openings on the landscape. These basic attribute differences are likely to have remained similar relative to one another over time, although some key changes such as rockfalls may have changed the site configurations somewhat over the courses of their human occupations. Although not strictly a part of the physical configuration of the sites, sea level would have had an influence on the relative accessibility of the sites. At the height of the Last Interglacial, with a global sea level that rose rapidly to between approximately 4-6 m higher than today (Rohling *et al.*, 2008), PP13B would have become nearly inaccessible even if its physical properties did not otherwise change substantially (Chappell and Shackleton, 1986). In comparison, rising sea levels during the warm period MIS 5e would not have had much effect on Blombos, which would have remained relatively difficult to access for a different reason: its position on a steep cliff. Accessibility was not likely a major problem at DK1 at the time it was occupied, owing to its relatively low position and the age of the deposits as post-dating MIS 5e.

In contrast to most physical characteristics of the site, environmental parameters such as precipitation, temperature, and local biotic communities would have constantly shifted over time, even on a decade scale. Current local data from paleoenvironmental proxies such as speleothems, microfaunal assemblages, magnetic data, isotopes from shellfish, etc. are either not available or not of sufficient resolution to be tied with much detail to the faunal data presented here. However, broad descriptions of changes in proximity to the ocean, temperature, and the overall ecology of the terrestrial and marine ecosystems of the Western Cape are available and these provide a general basis for outlining key paleoenvironmental descriptions of the study sites (e.g. van Andel, 1989; Meadows and Baxter, 1999; Rau *et al.*, 2002; Cowling and Procheş, 2005).

MIS 6 is generally accepted to have been a period of extreme climatic deterioration in both the northern and southern hemispheres, followed by an extremely rapid climatic amelioration (Jouzel *et al.*, 1993; Blunier *et al.*, 1998; Augustin *et al.*, 2004; Rohling *et al.*, 2008). During MIS 6 Africa experienced a bout of severe aridity, and this resulted in drastic reconfiguration of vegetation over the whole of Africa during the Middle Pleistocene (Schefuß *et al.*, 2003). Using the better-documented paleoclimatic reconstruction of the Last Glacial Maximum (ca. 17 ka) as a proxy for the conditions of MIS 6, a general vegetation map shows that the most productive ecosystems would have contracted into smaller pockets or refugia while neighboring areas declined (Marean and Assefa, 2005:95).

This indicates that during climatic extremes floral and faunal communities (including the populations that gave rise to modern humans) were likely concentrated into

smaller but relatively more productive areas and isolated from one another. Fragmentation and isolation of populations can lead to drift in both genetic and cultural traits, such that as the climate improved and populations once again came into contact during MIS 5 they would have been characterized by substantial biological and behavioral differences that had formed over the course of their separation from one another. If some of these differences were highly advantageous over others, then the stage would have been set for one modern or near-modern group to outcompete the others and expand into new territories at their expense – particularly if further climatic pressure was then applied. Such pressure during MIS 5 is apparent in the terrestrial record of tropical Africa, including regions into which populations emerging from refugia would have expanded, and which shows discrete periods of extreme aridity between 135 and 90 ka (Scholz *et al.*, 2007; Cohen *et al.*, 2007)

Following this climate-driven model of bio-behavioral change and replacement, it is important to identify likely areas where populations would have been concentrated and likely isolated during MIS 6 and then follow their progression into MIS 5 and beyond. There is evidence that the southern and eastern African subregions experienced quite different overall climate histories and therefore potential responses among hominin populations to changing conditions (Maslin and Christensen, 2007). However, the selection of potential centers of evolutionary change can be narrowed down somewhat.

The modern distribution of biodiversity 'hotspots' for floral or faunal communities are good indicators of where potential refugia would have existed during climatic extremes in the past because refuge localities would have maintained much of their

diversity while species in adjacent areas of high disturbance went extinct or became locally extirpated (Connell, 1978). An important aspect of this study is that it involves three sites that fall within one such hotspot: the Fynbos Biome within the Cape Floral Region of the southwest coast of South Africa (Richardson *et al.*, 2001; Linder and Hardy, 2004).

The plant diversity observed in the biome includes a high incidence of geophytes, or species that store much of their energy in carbohydrate-rich underground storage organs, which fall along a diversity gradient running from highest in the west to less so in the east (Cowling and Procheş, 2005). One suggestion for why this diversity increases toward the west is that this area may have had a longer-term climatic stability that included predictable rainfall relative to other parts of the biome (Cowling *et al.*, 2005; Cowling and Procheş, 2005). During the Late Quaternary precipitation over Southern Africa, and specifically the Cape, may have been out of phase with that from the interior of the continent (Meadows and Baxter, 1999). If this was also the case during MIS 6, then this reinforces the inference that the southwestern Cape of South Africa may have been a place of special refuge during a time when the rest of the continent was experiencing serious aridity (Marean *et al*., 2008).

The archaeological sites sampled here punctuate the coast along this gradient, and thus changes from east to west may have affected the resources that were locally available to MSA hominins. Most importantly, however, is their overall location within an ecological refugium during the climatic stresses of MIS 6. In this area, modern or near-modern *Homo sapiens* would have been part of a larger community of species

packed into a relatively small area and isolated from sister populations that had been contiguous prior to the onset of climatic deterioration. The presence of MSA hominins as part of this community is supported empirically by the archaeological record at PP13B, the site farthest to the east, which records an MIS 6 occupation that then continues into MIS 5 (Marean *et al.*, 2007).

Another important point, albeit on a more local scale, is that ecotones where two or more ecosystems meet tend to also be areas of high productivity and biodiversity (Hansen and di Castri, 1992; Lachavanne and Juge, 1997). Ecotones are therefore highly attractive localities for 'edge species' that can exploit a variety of resources (Naiman *et al.*, 1988). Today, all three study sides reside on the ecotone between the terrestrial and marine ecosystems. Again, changing sea levels would have varied the distance of each site to the shoreline – particularly during the height of MIS 6 when global sea levels were likely at least 130 m lower than today and the sea had receded up to 100 km distant from the modern South African shoreline (Rohling *et al.*, 1998). However, throughout some of MIS 6, the majority of MIS 5, and part of MIS 4 the sea would have been within 10 km of all three, thus affording an opportunity to exploit a variety of resources within a relatively small foraging radius (Chappell, 1983; Chappell and Shackleton, 1986; van Andel, 1989; Marean *et al.*, 2007).

Some indication of localized and time-specific paleoenvironments is provided by examination of the taxonomic abundances of the fauna recovered from the sites. Mixed faunal communities that include grazers, browsers, arid-adapted, and occasionally more water-dependent species have been recovered from all three sites, although in different

proportions (Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b; K. Reed and A. Rector, pers. comm., 2007). Care must be taken to acknowledge that different potential accumulators and different prey transport strategies make it unlikely that the assemblages will represent random samples of the surrounding faunal communities, but it does provide further evidence that in addition to their proximity to the marine-terrestrial ecotone MSA hominins positioned themselves so that they could access resources in a variety of solely terrestrial habitats.

Returning to the issue of contextual differences between the sites, the material culture context refers to the behavioral traces that have been recovered from each site. There are substantial differences between the lithic assemblages from PP13B, Blombos, and DK1, as well as differences between major stratigraphic layers within PP13B and Blombos (Thackeray, 2000; Henshilwood *et al.*, 2001b; Marean *et al.*, 2007). Such differences may be partially explicable by the model proposed above, where competing MSA populations were continually fragmenting, changing, merging, and at times going locally extinct over the course of several major climatic oscillations. However, the abundance of artifacts at Blombos that are less commonly recovered in MSA contexts (e.g. worked bone, ochre, and shell) indicates that this site in particular was used differently than most other MSA cave sites in South Africa, and that early symbolic behavior was a component of this use.

Modern hunter-gatherers from around the world reserve particular symbolic behaviors for private places with restricted access. At large and accessible sites like DK1 and PP13B that also have excellent preservation, the quantities of ochre are much smaller

and bone tools, personal ornaments, and engravings are unknown. This shows that there was differentiation in behavior across the MSA landscape in the study area, and that some places may have been used primarily for 'special' activities. Although Blombos indeed gives this initial first impression, it is important to understand other aspects of the behavioral contexts in which these more unusual materials were deposited. This can be done by comparing the evidence for faunal exploitation between Blombos and other sites such as PP13B and DK1 that do not have unusually high amounts of evidence for symbolic behavior.

The dataset also offers an unprecedented opportunity to examine the evidence for both traditional and alternative means of employing zooarchaeological data in the modern human origins debate. The ages of the archaeological deposits at all three sites provide a continuous record of MSA subsistence within a geographically and ecologically restricted area that spans several major climatic oscillations and ends about ten thousand years prior to the 'revolution' proposed by the LUP model for the origins of modern human behavior. It further includes MIS 6, the critical time period suggested here for when significant bio-behavioral advantages may have been gained and later employed in earnest as the climate improved in fluctuating degrees and groups were both able to expand and come into competition. Faunal exploitation strategies are therefore examined over the duration of this extended time period and in Chapter Nine are presented in light of the expectations of the gradualist and the LUP models.

The collections studied here are also presented with a body of ecological theory regarding other medium- to large-bodied predators. As early hominins started to bring a

substantial meat component into their diet they also began infiltrating existing carnivore guilds. Invasion of the predatory guild would have brought hominins into some degree of competition with other predators, both through competitive resource exclusion and direct interaction. Despite lacking the natural killing equipment with which other medium- to large-bodied predators are born, modern humans have emerged as the dominant predator in a variety of ecosystems, and while using a range of technologies.

Their ascendance into this position is likely attributable to a combination of cooperation and innovation, both of which have been implicated in the transition to fully modern behavior. If MSA hominins were fully efficient hunters that filled the top predatory niche, then MSA prey body size profiles should not look any different from faunal accumulations expected from sympatric carnivores of similar body size, sociality, and feeding niche. This allows predictions to be made about what prey body sizes and skeletal elements would be expected at MSA assemblages if their predation patterns were similar to the other carnivores with which they shared the landscape, and for potential deviations that may have been part of the process of the emergence of modern human behavior to be illuminated. It further allows for a more community-based approach to examining how contraction of hominin populations during periods of climatic stress may have affected other major predators on the landscape.

Specific goals and hypotheses

Several specific hypotheses about patterning in the faunal data were set forth prior to the study, and these are examined in the following chapters. These hypotheses are

encompassed within four more general research questions for which additional aspects can also now be addressed empirically with data collected over the course of this project.

The first question is what the pattern of hunting behavior is across this sample of sites and time periods. This question relates to the broader issues of modern human origins research because of the historical focus on the relationship between hunting ability and behavioral modernity (Klein, 1975, 1987, 1989b, 2000; Milo, 1998; Binford, 1984; Marean *et al.*, 2000b). The competing arguments surrounding MSA hunting ability are examined by testing the following three hypotheses: 1) hunting was the main mode of meat acquisition; 2) prey selection was focused on high return animals; and 3) MSA assemblages will have prey body size profiles that are most similar to those taken by the dominant mammalian predators in an ecosystem.

The practical effects that excavator selection can have on interpretations of human behavior, as argued by Bartram and Marean (1999), have never been corroborated with taphonomic data from a second unbiased South African MSA assemblage. Therefore, this study also provides data necessary for resolving this important methodological issue. Finally, the significance of hunted faunal resources in the MSA diet is reviewed in light of nutritional, ecological, and ethnographic considerations and its relevance the modern human origins debate is addressed.

The second question is what specific carcass processing strategies were employed at the study sites. These decision-making processes are examined in detail to identify patterns in the methods used by MSA inhabitants of these sites for defleshing, demarrowing, and discarding skeletal elements. Although transport, outside-bone

nutrient processing, and within-bone nutrient processing are all interrelated aspects they are examined separately and then overall carcass processing strategies are reconstructed in a final interpretation.

Because much of this patterning has emerged empirically over the course of the study only one specific hypothesis was examined: that meat-drying would be identified as a potential form of storage. Meat drying is a behavior that requires planning and foresight, both of which have been implicated as hallmarks of modern human behavior. Although it is important to establish its origin, the first appearance of food storage has not been well-documented, and using the combined methods of Abe *et al.* (2002) and Nilssen (2000) the datasets available here offer an opportunity to support or falsify this possibility.

The third question is what the extent and characterization is of variability between MSA faunal assemblages? The physical, environmental, and behavioral aspects of site context described in the previous section would be expected to influence the local availability of fauna and subsistence decisions related to the exploitation of these resources. A logical starting point for exploring the effects that context had on faunal exploitation is with the physical characteristics of each site, which would have resulted in differences in faunal acquisition and transport effort.

Comparisons of the relative abundances of animals of different body size classes at Blombos, PP13B, and DK1 are used to infer differences and similarities in MSA hunting decisions. Ungulate prey were obviously not acquired within the caves themselves, but primary prey acquisition or kill localities were certainly within the transport radius of the

sites examined here. Inferences about what the body size representations indicate must be made with an understanding that simple prey choice is not the sole explanation for body size abundances. Rather, these data represent two separate decisions in the spectrum of prey acquisition and carcass processing: the decision to pursue a prey item of a particular body size and the decision to transport all or part of this prey item back to a secondary site.

The steep terrain around Blombos is expected to raise the energetic cost of transport of ungulates with a larger body size, which suggests that differences between the two sites may be most parsimoniously explained by effort minimization models (Winterhalder and Smith, 2000). The first hypothesis to be tested is therefore that ungulates with a smaller body size should be more abundant at Blombos than at PP13B or at DK1. This is for two reasons. First, sea level data suggest that the surrounding environment at the time of the deposits would have been near-coastal fynbos and the terrain would have been more suitable for browsers such as grysbok/steenbok (*Raphicerus* spp.), common duiker (*Sylvicapra grimmia*), and even klipspringer (*Oreotragus oreotragus*). Therefore, transport of larger ungulates would have necessitated carrying carcasses acquired from farther away. Second, all else being equal the energetic cost of carrying a small carcass up a steep slope is expected to be less than the cost of carrying a large carcass, and this should result in higher overall representation of small ungulates at Blombos.

The second hypothesis is that Blombos should have evidence of individual animals with body sizes of three or higher being more extensively processed off-site than they were at PP13B or DK1. This should be true even given the relative inaccessibility of

PP13B during MIS 5e, as this substage when sea levels were higher cannot be precisely separated out from the other MIS 5 deposits without severe reduction of the size of the faunal sample. The MIS 5 deposits at this site therefore represent a time period during which overall the site was relatively quite accessible.

Following upon the same concept that energetic constraints will influence faunal representation at a transport site, skeletal element abundance at Blombos is expected to show relative impoverishment of elements from large mammals that can be quickly field-processed and discarded. Conversely, small species can be more easily transported whole and do not require intensive off-site processing in order to facilitate transport (Metcalfe and Barlow, 1992; Monahan, 1998; Marean and Cleghorn, 2003). Because selective transport entails more disarticulation, larger mammals at Blombos should also have greater relative frequencies of disarticulation cut marks on elements from larger species (Nilssen, 2000; Abe *et al.*, 2002).

The results of the study are examined in light of these three major research questions and their specific hypotheses in Chapter Nine. Ultimately the goal is to understand MSA faunal exploitation behavior and integrate this understanding into a sensible and testable model of the emergence of modern human behavior. First, however, a more proximate goal must be achieved. This goal is the production of a detailed taphonomic analysis of the faunal assemblage from each site. The next three chapters will provide a comprehensive analysis that will serve as the foundation for higher-level interpretations. Because much of this has already been done for DK1, and some of it has

been published (Marean *et al.*, 2000b), this site will be treated minimally in comparison to the assemblages from PP13B and Blombos Cave.

CHAPTER FOUR: THE PINNACLE POINT 13B FAUNAL ASSEMBLAGE

Site description

Pinnacle Point Cave 13B (PP13B) is one of several sites test-excavated in 2000 and has subsequently been the target of extensive investigation from 2003 onwards (Nilssen and Marean, 2000; Marean *et al.*, 2004, Marean *et al.*, 2007). PP13B resides about 13 meters at the mouth above modern sea level as part of a complex of other caves named the Site 13 Complex, most of which retain MSA deposit (Figure 2). PP13B is in turn one of several cave sites that perforate the coastline about 20 kilometers southwest of the town of Mossel Bay, a small community nearly 400 km east of Cape Town. The caves themselves are formed in fault breccias in shear zones that have been eroded out to form cavities within quartzite cliffs of Table Mountain Sandstone (Marean *et al.*, 2004, 2007). An ancient series of calcareous dunes has cemented at the top of the cliffs to form a calcrete, and water percolating through from the top becomes charged with calcium carbonate that counteracts the otherwise acidic chemical environment within the underlying quartzite. It is to this calcareous capping that the excellent faunal preservation within PP13B is owed.

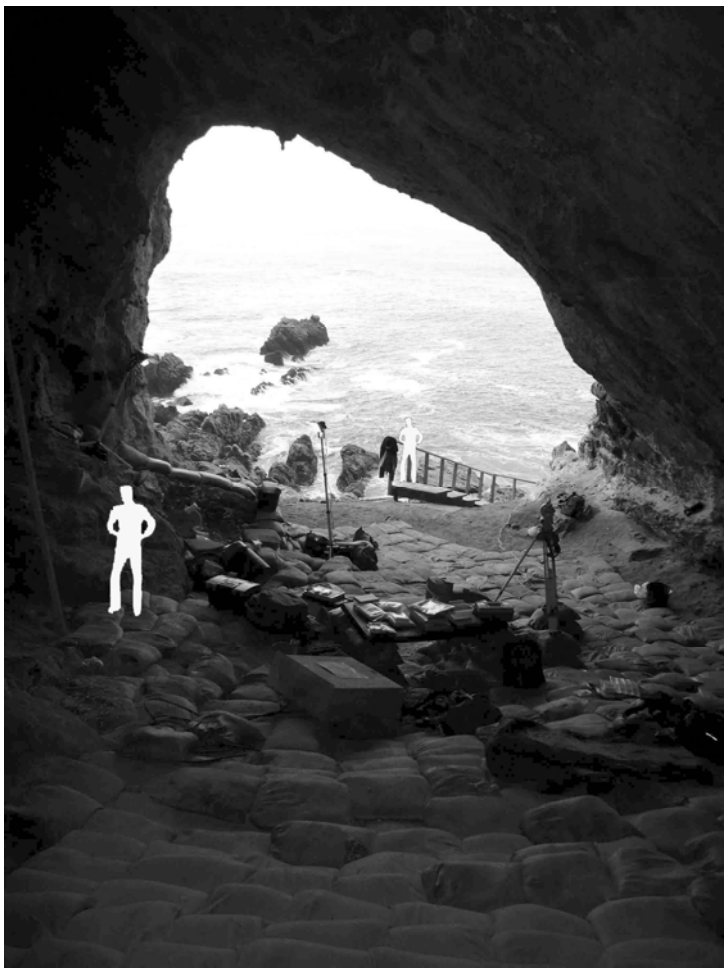


Fig. 2 View looking out at modern ocean from rear of PP13B.

The full stratigraphic sequence at PP13B documents initial formation of the cave and the build-up of non-anthropogenic deposit, followed by periods of occupation. These occupation periods alternated with at least one major environmentally-driven closure of the cave mouth by migrating dune systems. The western (rear) area of the cave documents the oldest portion of this sequence. Here, a boulder beach lies at the base and may date to MIS 11, although another high sea stand may be responsible for the initial hollowing out of the cave. The boulder beach is covered by a thin rind of silty loam with

some open spaces between the rocks. This is subsequently overlain by a series of laminated silts and sands that lack archaeological material but do contain occasional well-rounded bone fragments (Marean *et al.*, in prep.).

The archaeological deposits likely begin between 178.1 ka and 161.9 ka, although a small amount of anthropogenic deposit below the location of this near-basal age estimate can only be maximally dated to the same age as the non-anthropogenic layers at the base of the sequence (449 ka; Marean *et al.*, in prep). Archaeological deposits in the western area are comprised of some silty but mainly sandy sediments with varying degrees of anthropogenic input. In the eastern (front) area sediments are have a much higher roofspall component and evidence of extensive hearth formation. The majority of sediments at PP13B are unconsolidated, except for sections along the sides of the cave where lightly consolidated MSA (LC-MSA) deposits capped by a flowstone have been cemented to the walls. External dune formation eventually invaded and blocked the mouth of the cave from occupation by hominin bone collectors between ca. 92 – 46 ka, at which point the cave re-opened (Marean *et al.*, 2007). The majority of dates from PP13B indicate that there was not much re-occupation represented at the site after the cave re-opened, although the possibility of an ephemeral late MSA occupation cannot be entirely ruled out.

The deposits at PP13B can be roughly divided into those dated to between ca. 130 – 92, or MIS 5, and those dated to between ca. 178 – 131, or MIS 6. At the height of MIS 6 the shoreline would have been at least 100 km distant from the site, but global sea levels were by no means static over the entire course of MIS 6 (van Andel, 1989). Large

fluctuations in global sea level include periods of rebound in which the ocean would have crept to within 10 km of PP13B (Dansgaard *et al.*, 1993; Lambeck and Chappell, 2001) or even as close as 4.5 km (Marean *et al.*, 2007 supplementary video). It is therefore perhaps not only the severity of the climatic deterioration during MIS 6 that would have placed strain on MSA populations, but also the amplitude of the differences that occurred over the course of this period. At PP13B the faunal assemblages are too small and the ages too general for the data to be meaningfully divided into each of these fluctuations. Owing to this, the data are presented under the general model of a relatively arid and potentially cooler MIS 6 period and an overall warmer and possibly wetter period during MIS 5.

The artifactual assemblage is dominated by unretouched flakes and flake-blades on quartzite, although very early examples of bladelet technology are also present on both quartzite and silcrete in the LC-MSA (Marean *et al.*, 2007). Ocher is present but not abundant, and was clearly being transported to the site and the pigment extracted by rubbing or grinding (Marean *et al.*, 2007). A single fragmentary bone tool was recovered from a section cleaning of the western area in 2003. It is a simple shaft fragment from a large mammal that has been smoothed and polished along one side. A series of shallow notches along one side have also been polished into smooth hollows (Figure 3).

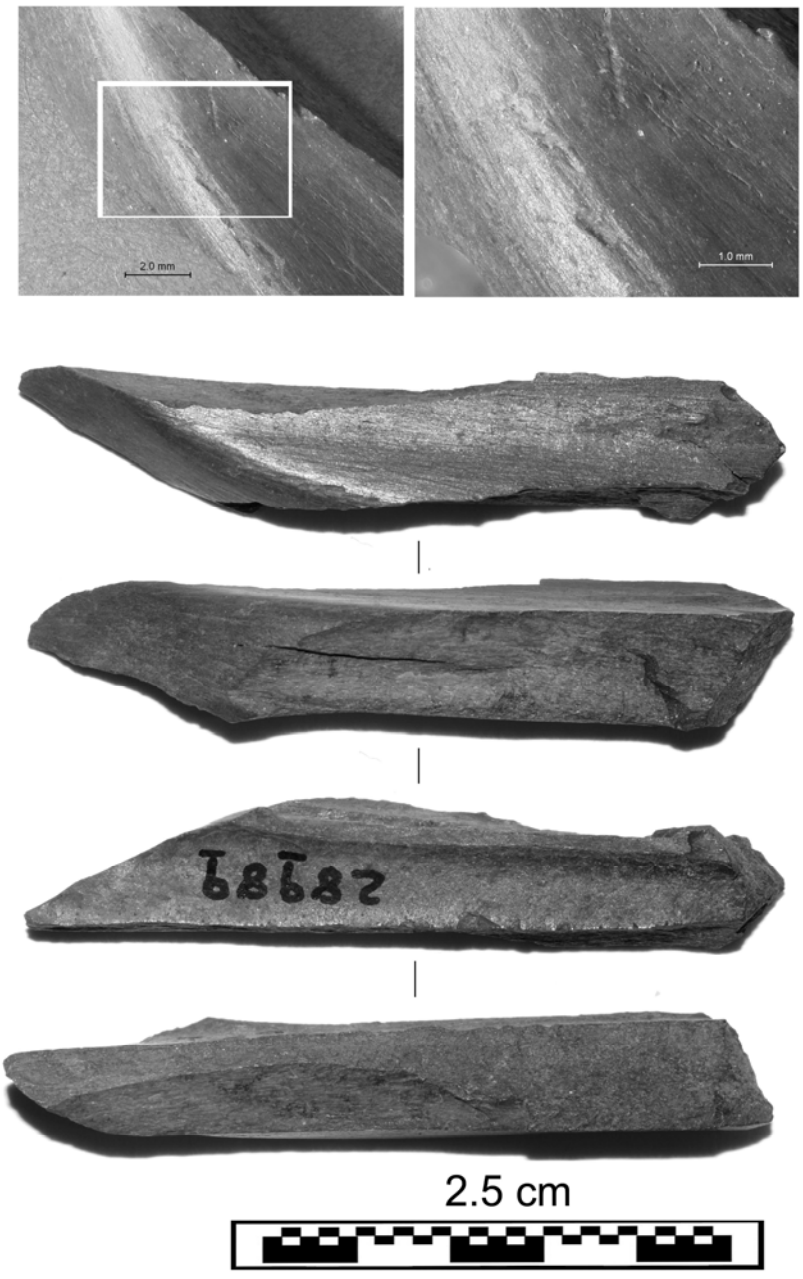


Fig. 3 Various aspects of the single bone tool recovered from PP13B. Close-up at top with boxed area magnified to the right. Scalebars in close-ups are 2.0 and 1.0 mm, respectively.

The area at the back of the cave has been interpreted as a midden (Marean *et al.*, 2004), but the presence of many large mammal bones and several broken and intact hammerstones suggests that some marrow processing may have also taken place in this part of the cave (pers. obs.). The front appears to have been the focus of domestic activities such as hearth maintenance, artifact production, and processing of large mammals. Only 145 specimens in the total fossil assemblage are derived from the non-archaeological deposits that underlie the initial occupation at ca. 178 ka, and these are not included here.

For many analyses that can be performed using NISP data (which provides a larger sample size), seven analytical units are defined at PP13B. These include both intra-site spatial information (i.e.: eastern versus western excavations, which represent the front and back of the cave, respectively) and chronological information. These analytical units are larger groupings of the stratigraphic aggregates as defined by Marean *et al.* (in prep), but do not include disturbed or filled areas, recent surface sediments, or non-anthropogenic basal layers. The ages of these analytical units relative to those used at the other two sites in this study are given in Table 1. These seven analytical units have been shorthanded with the aliases 1 – 7 in the following way: Light Brown Sand 1 = 1, Upper Dark Brown Sand Units/LC-MSA Upper = 2 (combined because of a very small sample of 16 bones from LC-MSA Upper that falls within the same age range as the Dark Brown Sand Units), Shelly Brown Sand/Upper Roof Spall = 3, Lower Roof Spall = 4, Lower Dark Brown Sand Units = 5, LC-MSA Middle = 6, LC-MSA Lower = 7. These shorthand numbers *do not* have any necessary stratigraphic or chronological ordering.

Other analyses that require transformed single-element data such as MNE, MNI, or MAU are generally conducted on aggregates of these analytical units, such as MIS 5 or MIS 6, or fossils from the front or back of the cave.

Taxonomic representation

Taxonomic representation at PP13B is heavily weighted in favor of large mammals of size classes 1 – 5 (n = 15,917 out of 16,283 for all proveniences), following Brain's (1981) categorization of size class and body weight. Only 2% of the total assemblage by NISP is comprised of small mammals, 21% are tortoises, and a full 77% are identifiable large mammals. The relatively small sample of small mammals and tortoises at PP13B has made it possible to include analysis of these categories within the time constraints of the present study, and to date this will constitute the only thorough taphonomic analysis of these faunal components for any MSA site in South Africa. Small fauna are presented separately in the section following the large mammals. Appendix A gives a summary by NISP of the size class 1 – 5 mammals from PP13B. Note that these data and those that follow are henceforth restricted to only the analytical units described above (n = 12,883).

PP13B has a very low representation of marine versus terrestrial mammal bone (1% of fragments identifiable as one or the other in the sample). Marine mammals lack long bones with a medullary cavity surrounded by a dense cortical shaft. Relative to terrestrial mammals, this may reduce the degree of differential density throughout the skeleton, and especially in the long bones. Though this remains to be tested using the same density measures as those employed for terrestrial mammal bones (e.g. Lam, 1998,

2003), it does suggest that there may be fewer outstandingly dense element portions in the skeleton – excepting the dentitions. Relative proportions of dental fragments may therefore provide a way to compare these two groups in the absence of marine mammal density data because teeth in both are some of the densest elements in the skeleton. Of the 136 tooth fragments identifiable beyond the generic 'Mammal' category, only 1 is a seal. Assuming that there was no reason that marine mammal crania would be transported less frequently than terrestrial mammal crania, this serves as supporting evidence that the very low proportion of marine mammals is not an artifact of either methodology or a high degree of differential destruction.

Reported proportions of marine mammals relative to large terrestrial mammals are also low at other coastal MSA sites, but not as low as at PP13B: 5% at DK1 by NISP and 8% at Ysterfontein 1 by NISP - though the latter sample is very small (Klein and Cruz-Uribe 2000; Halkett *et al.*, 2003). Proportions also appear to be much higher at KRM1 but these data are based on summed MNI estimates and may not be accurate: 15% at KRM Cave 1, 37% at KRM Cave 1A, and 38% at KRM Cave 1B (Klein, 1976).

The relatively low degree of marine mammal representation at PP13B may be a proxy indicator for climate. Warmer periods would have seen the ocean much closer to the cave than during cooler periods. By extension, marine resources of all types would have been more accessible during warmer periods and might be expected to be more abundant in the deposits. At PP13B there is very little variation between layers in marine mammal representation (proportions range between 0.9% and 0.4%). There is slightly higher marine mammal representation in MIS 5 (0.7%) than MIS 6 (0.5%), and this is the

expected pattern. However, Fisher's Exact Test (Appendix J:[a]) does not show this to be a significant difference ($p = 0.3463$). Even though they occur in low proportions, the presence of marine mammals indicates that such resources were available during both MIS 5 and MIS 6. During MIS 6 this was most likely during the earlier part of the stage when the sea would have moved to within 5 km of the site and been visible from the mouth of the cave (Marean *et al.*, 2007, supplementary video). However, looking at the marine mammal representation in light of hominin behavior, it is equally clear that although MSA populations may have had access to marine resources at various intervals throughout the course of the site's occupation, acquiring and transporting marine mammals to PP13B did not comprise a substantial portion of the overall subsistence strategy.

Primate representation at PP13B is negligible at about 0.1% of specimens identifiable to the order level or below. Large terrestrial carnivore representation is also very low (1.5% of the total assemblage), with most specimens being small tooth fragments not identified beyond this level. The three specimens attributed to the family Hyenidae are two halves of a complete fibula and a single scapho-lunar from a hyenid. This is an excellent initial indicator that the site was not extensively used by denning carnivores, as carnivore den sites often have high proportions of carnivore remains, many of which are juveniles (e.g. Stiner, 1991b). However, it does not rule out the possibility that carnivores used the site transiently either as a temporary lair or as scavengers after human occupation.

Ungulate taxa comprise 97.5% of the identifiable assemblage at PP13B. These are distributed nearly evenly between size classes 1 – 3, with a small contribution of larger size 4 and 5 specimens (Figure 4). A substantial proportion of ungulate specimens could not be identified to an exact body size category or to the family level or below, although of those that could 99% were bovids. In this, the uniformity of the assemblages is advantageous because it suggests that the majority of less identifiable specimens are also likely to be from size 1 – 3 bovids. Based on this, less identifiable specimens such as long bone flakes or shaft fragments will henceforth be referred to as 'ungulate' specimens.

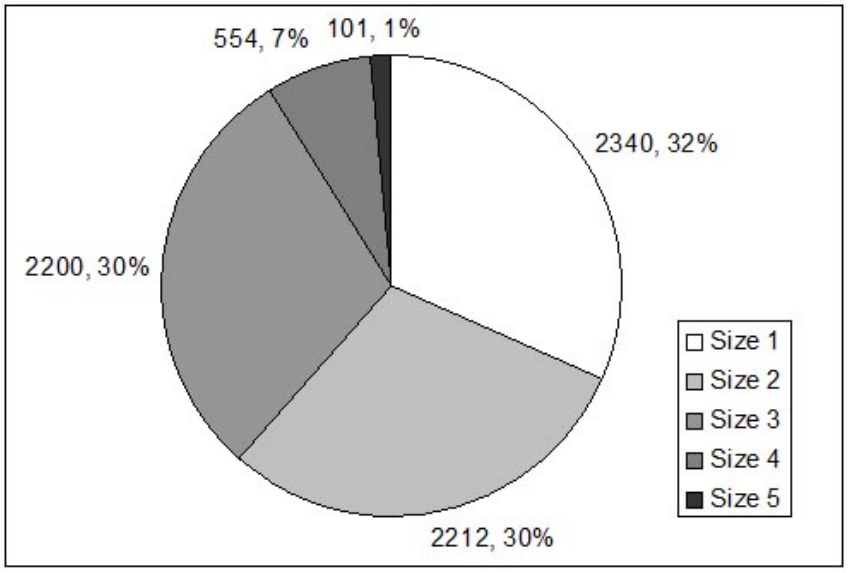


Fig. 4 Summary of overall body size representation at PP13B.

A Chi-squared test was used to examine how the distributions of body sizes between each analytical compared to one another (Table 2). If body size distributions are statistically indistinguishablebetween two analytical unites, then there is likely no

independence between analytical unit and the number of fragments that fall within each body size class. Significant differences below the $\alpha = 0.05$ level indicate a high likelihood of independence between analytical unit and body size distribution, although it does not identify within which body size classes the main differences occur. Most results in Table 2 are highly significant, suggesting that the compositions of body sizes between analytical units were generally quite different from one another.

Table 2

Results of chi-squared tests comparing the body size distributions between analytical units.

D.F.	Analytical Unit 1	Analytical Unit 2	Test Statistic	p-value
5	LB Sand 1 (1)	Upper DBS/LC-MSA Upper (2)	1.216	0.9433
5	LB Sand 1 (1)	SBS/Upper RS (3)	30.398	<0.0001
5	LB Sand 1 (1)	Lower RS (4)	54.87	<0.0001
5	LB Sand 1 (1)	Lower DB Sand (5)	11.399	0.0440
5	LB Sand 1 (1)	LC-MSA Middle (6)	13.171	0.0218
5	LB Sand 1 (1)	LC-MSA Lower (7)	17.972	0.0030
5	Upper DBS/LC-MSA Upper (2)	SBS/Upper RS (3)	59.842	<0.0001
5	Upper DBS/LC-MSA Upper (2)	Lower RS (4)	101.35	<0.0001
5	Upper DBS/LC-MSA Upper (2)	Lower DB Sand (5)	14.571	0.0124
5	Upper DBS/LC-MSA Upper (2)	LC-MSA Middle (6)	17.533	0.0036
5	Upper DBS/LC-MSA Upper (2)	LC-MSA Lower (7)	32.664	<0.0001
5	SBS/Upper RS (3)	Lower RS (4)	63.837	<0.0001
5	SBS/Upper RS (3)	Lower DB Sand (5)	55.571	<0.0001
5	SBS/Upper RS (3)	LC-MSA Middle (6)	6.8691	0.2306
5	SBS/Upper RS (3)	LC-MSA Lower (7)	16.304	0.0060
5	Lower RS (4)	Lower DB Sand (5)	116.52	<0.0001
5	Lower RS (4)	LC-MSA Middle (6)	5.5581	0.3516
5	Lower RS (4)	LC-MSA Lower (7)	78.792	<0.0001
5	Lower DB Sand (5)	LC-MSA Middle (6)	30.41	<0.0001
5	Lower DB Sand (5)	LC-MSA Lower (7)	24.59	0.0002
5	LC-MSA Middle (6)	LC-MSA Lower (7)	12.366	0.0001

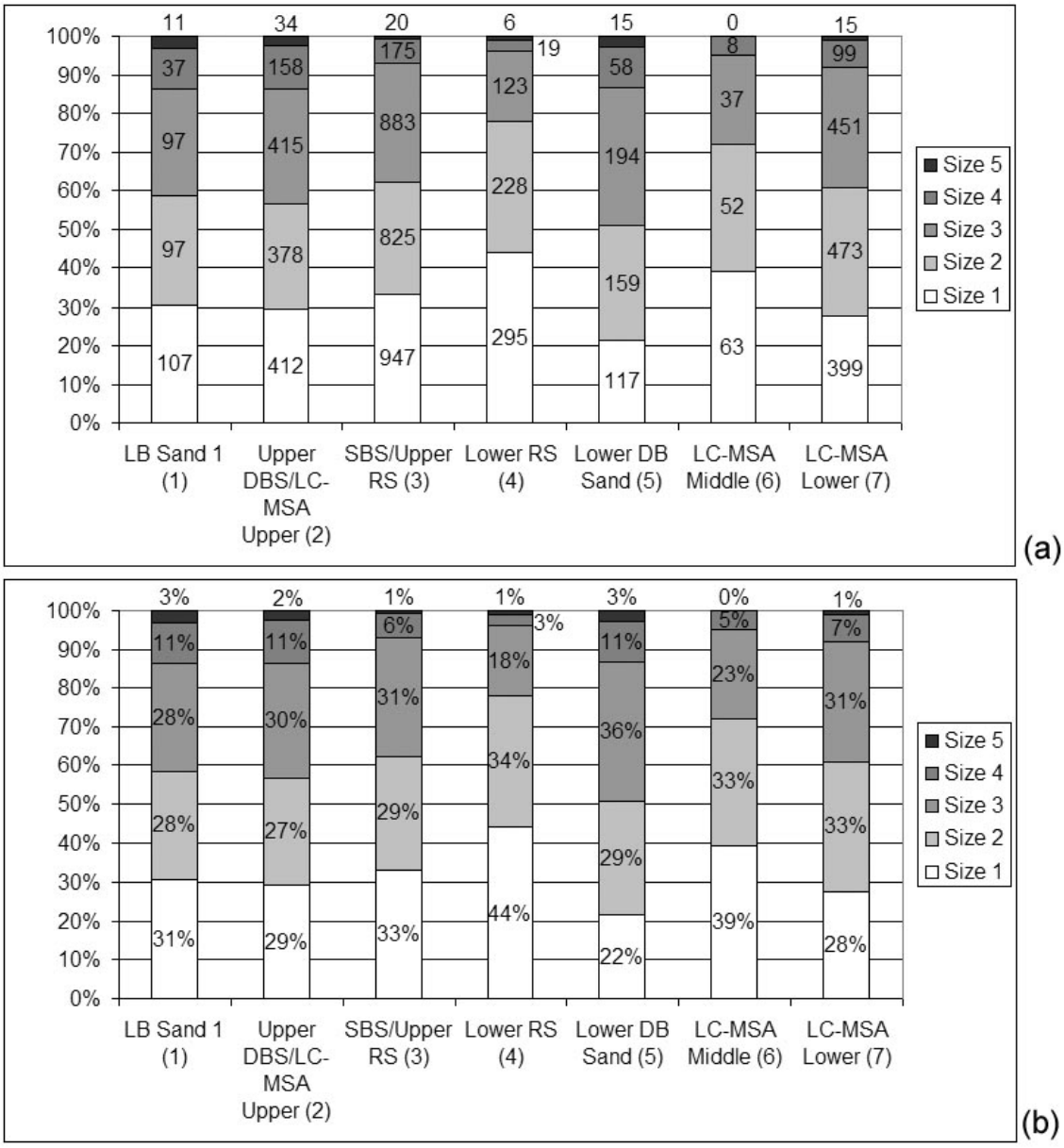


Fig. 5 Larger mammal body size representation in each of the seven major analytical units at PP13B by NISP (a) and percentage within each AU (b). Full names of the analytical units are provided with their shorthand number assignments in brackets beside them.

This is similar to published accounts of DK1, where Layer 10 was found to be dominated by size 3 and 4 bovids, while Layer 11 was dominated by size 1 bovids.

Visually, the most obvious differences between analytical units at PP13B are between the Lower Dark Brown Sand Units (5) at the rear of the cave and the Lower Roof Spall Units (4) at the mouth (Figure 5). The biggest difference appears to lie between the representation of size 1 mammals, and is interesting for two reasons. First, the major difference at DK1 between layers also fell onto the representation of size 1 ungulates. Second, at PP13B there are both temporal and spatial differences between these two analytical units that might account for this disparity.

Aggregating the data into spatial (i.e.: front versus back) and chronological (i.e.: MIS 5 versus MIS 6) groupings, the initial patterning observed when all analytical units were separate becomes more clear (Figure 6). When sample size differences between the two areas are corrected for by dividing the front and back into its constituent size classes, small fauna (sizes 1 and 2) are found to be more abundant at the entrance of the cave and large fauna (sizes 3, 4 and 5) more abundant at the rear. This difference is highly significant (Chi-squared value = 116.84; D.F. = 5; p-value = < 0.0001), and does not appear to be influenced by wildly high or low proportions in any single square (Figure 7). The spatial difference could be either because the relative contributions of human, carnivore, and raptor accumulators differed between the front and the back or because there was one major accumulator that differentially distributed larger mammal bones toward the rear.

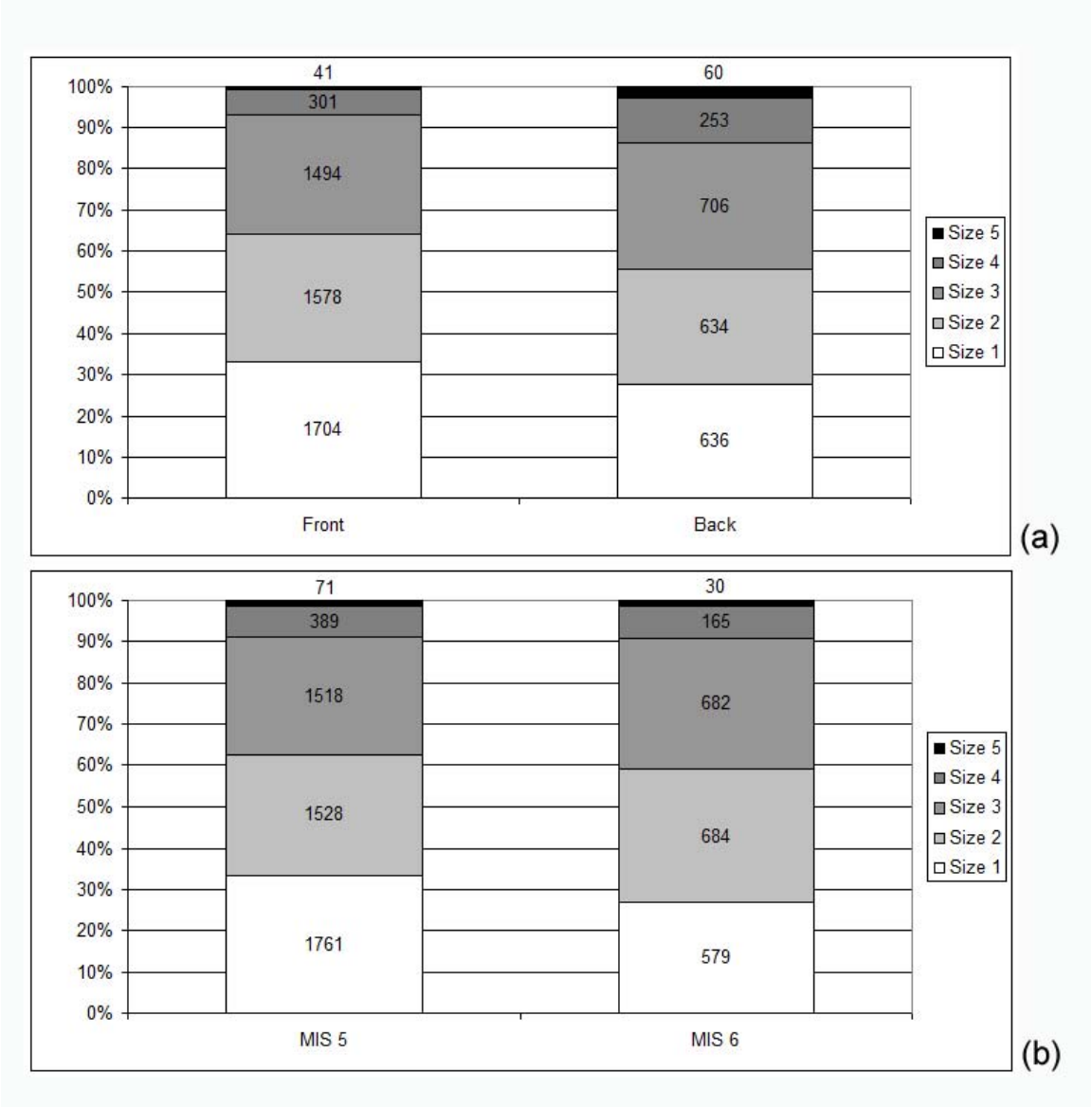


Fig. 6 Body size representation in the deposits from the front of PP13B compared to those from the back (a) and body size representation within MIS 5 compared to MIS 6 (b).

Body sizes are also significantly different in their distributions between MIS 5 and 6 (Chi-squared value = 29.045; D.F. = 5, p-value < 0.0001). Specifically, size 1 ungulates are more common during MIS 5, and very large ungulates (size 5) are more

abundant in MIS 6 – although samples for this size class are quite small overall. An obvious question is if this merely reflects the spatial pattern, where smaller fauna are more common at the front and where a larger sample of MIS 5 fauna is also available.

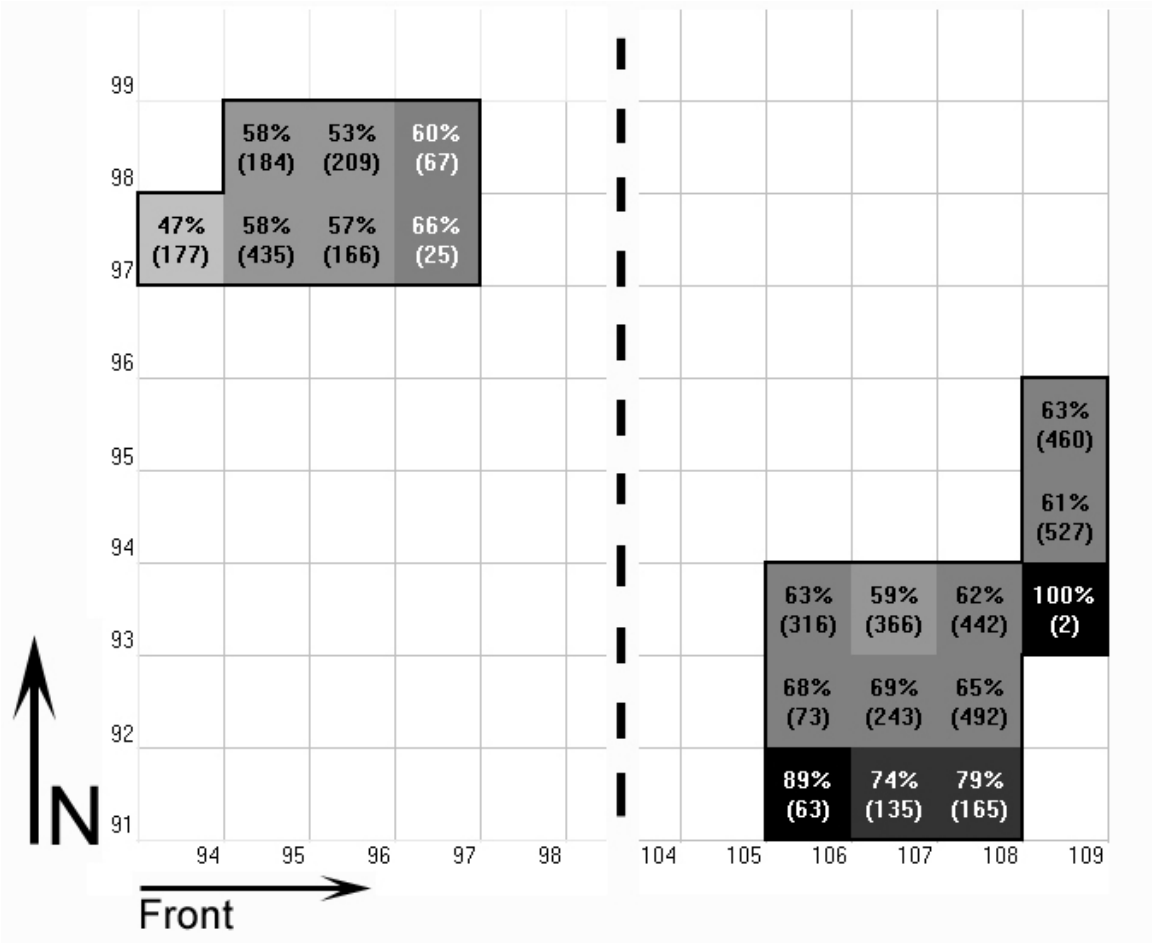


Fig. 7 Schematic map of the PP13B excavations with the percentage of fauna identifiable to body size from each square that is comprised of smaller (size 1 and 2) mammals.

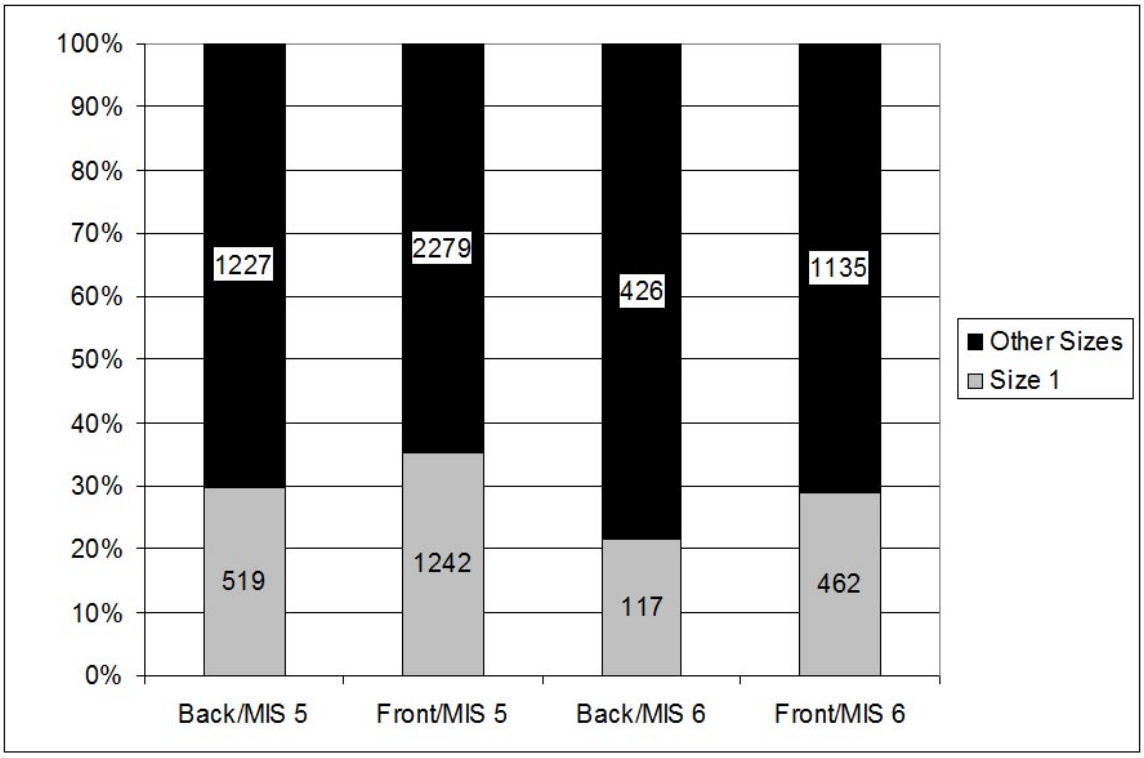


Fig. 8 Relative representation of size 1 fauna broken down further by both MIS and front or rear excavations.

The pattern visually appears to be one in which there are differences between MIS 5 and MIS 6, but only in the rear excavations (Figure 8). However, when size 1 ungulate proportions are compared to other body sizes within the more detailed categories of front/MIS 5, back/MIS 5, front/MIS 6, and back/MIS 6, some more subtle patterns emerge. Fisher's Exact Test for two-way tables of the NISP of size 1 versus all other body sizes (Appendix J:[b]) shows significant differences in the proportion of size 1 ungulates at the back and front in both MIS 5 ($p < 0.0001$) and MIS 6 ($p = 0.0008$). Significant differences are also apparent between MIS 5 and MIS 6 at both the back ($p = 0.0002$) and front ($p < 0.0001$). This indicates that size 1 fauna truly are more abundant

at the front of the cave throughout the entire history of the MSA occupation, and that there was an elevated input of size 1 fauna during MIS 5 into both areas.

The higher representation of size 1 fauna from MIS 5 may be a climatically-driven pattern. Local environments during warmer periods could have resulted in habitats (particularly fynbos) that favor small, pair-bonded antelope such as grysbok and steenbok (*Raphicerus* spp.) which use elusive hiding as their primary predator-defense system. During more arid MIS 6 times, local vegetation may have favored herding ungulates that prefer aggregation and speed for predator defense. The predator in question could have been either MSA hominins or carnivores, and in the case of the size 1 fauna may even have been raptors, as at DK1 (Marean *et al.*, 2000b). Alternatively, the pattern could be simply because the agent of accumulation was different during these periods (or had different relative contributions to the faunal assemblage). This last possibility is addressed in the section on surface modification.

Density-mediated destruction

At PP13B 76% of long bone fragments at PP13B are shaft fragments, with 13% near-epiphysis shaft fragments and a mere 11% represented by epiphyseal portions. This pattern of density-mediated destruction is clearly apparent in the available long bone portions used to estimate the minimum number of elements (MNE) for all ungulate body sizes.

Figure 9 illustrates composite MNE images of the major skeletal elements for all layers and body sizes at PP13B. These include data from the disturbed layers and the basal layers to promote sample size and illustrate the overall pattern at the site. All

images were derived using the GIS program described in the methods section (Marean *et al.*, 2001). Darker areas represent higher MNE estimates, with the best-represented area indicated by an arrow and dotted fill. Diagonal lines indicate areas where there is zero representation in the assemblage.

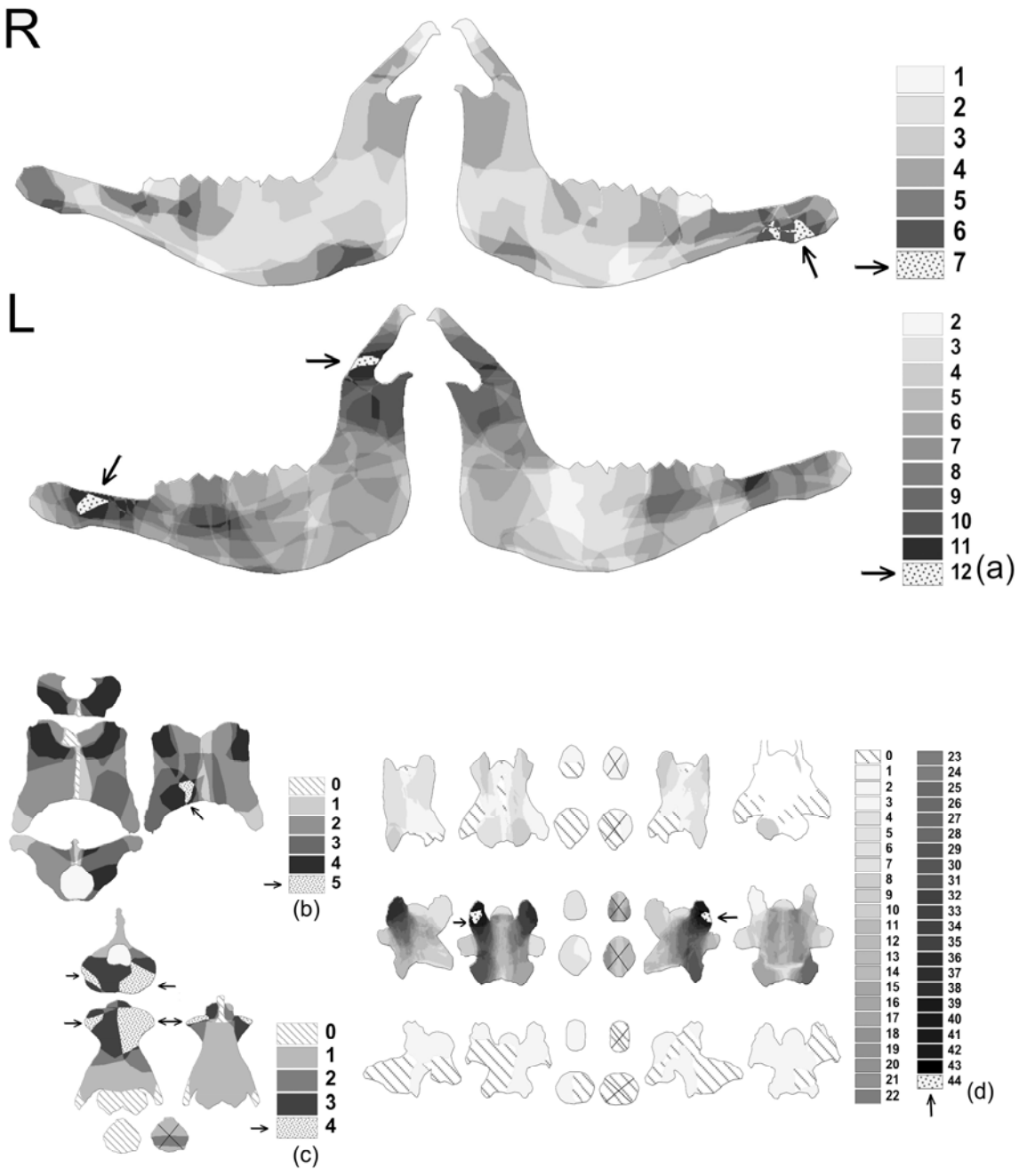


Fig. 9 Composite GIS images of mandibles (a), the axis (b), atlas (c), and cervical vertebrae (d) from all layers at PP13B. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

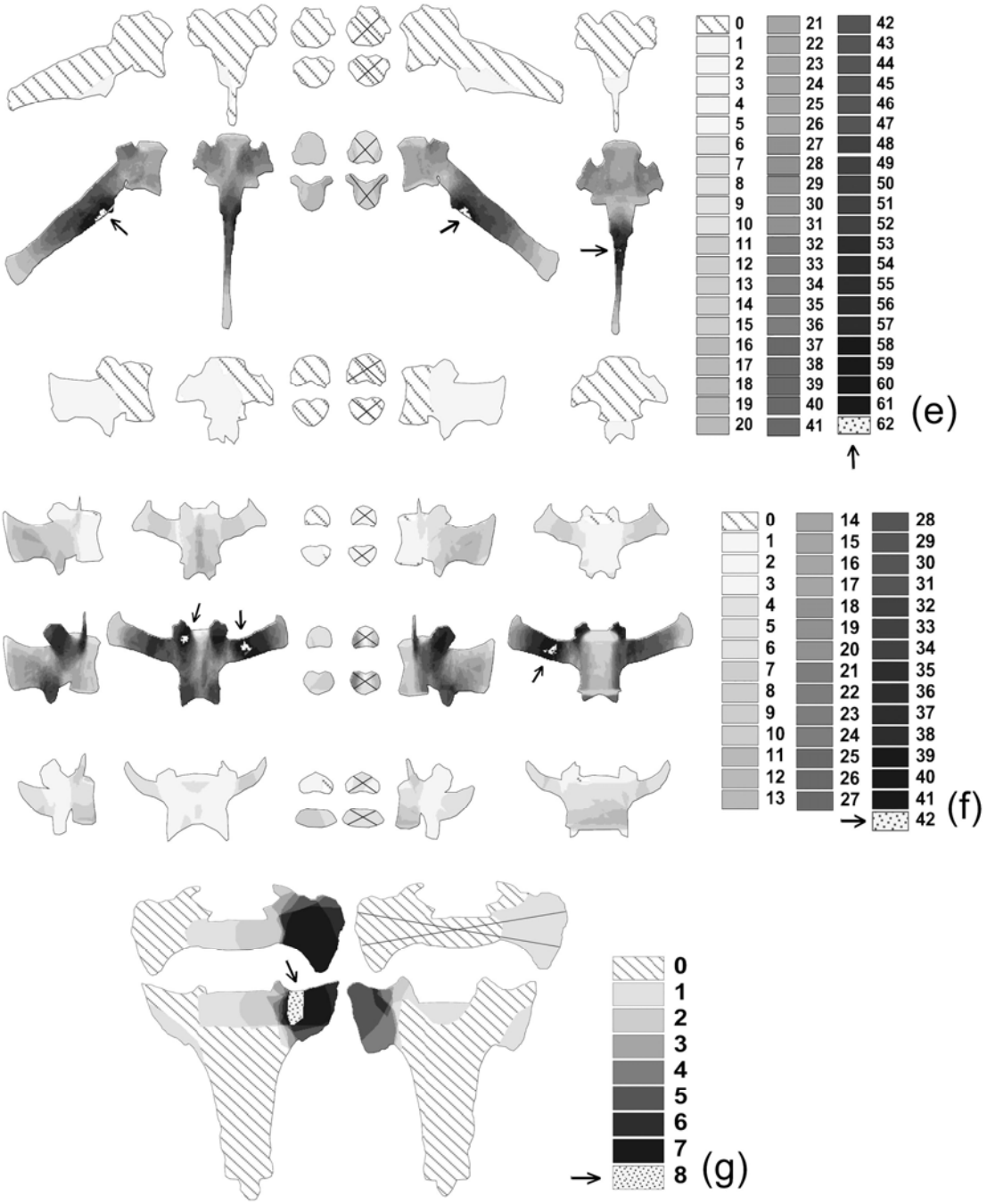


Fig. 9 (cont.) Composite GIS images of thoracic vertebrae (e), lumbar vertebrae (f), and the sacrum (g), from all layers at PP13B. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

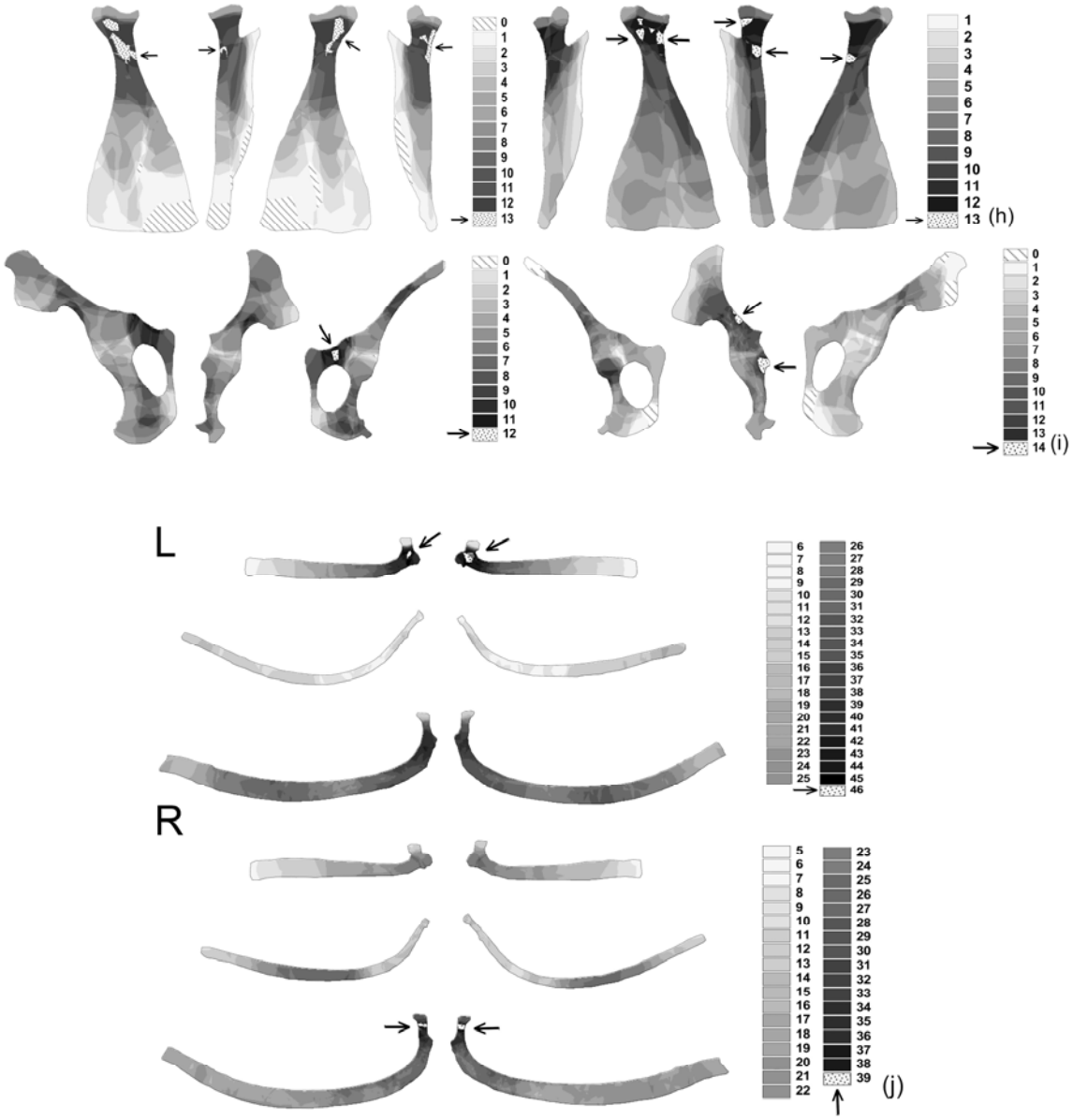


Fig. 9 (cont.) Composite GIS images of scapulae (h), pelves (i), and ribs (j), from all layers at PP13B. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

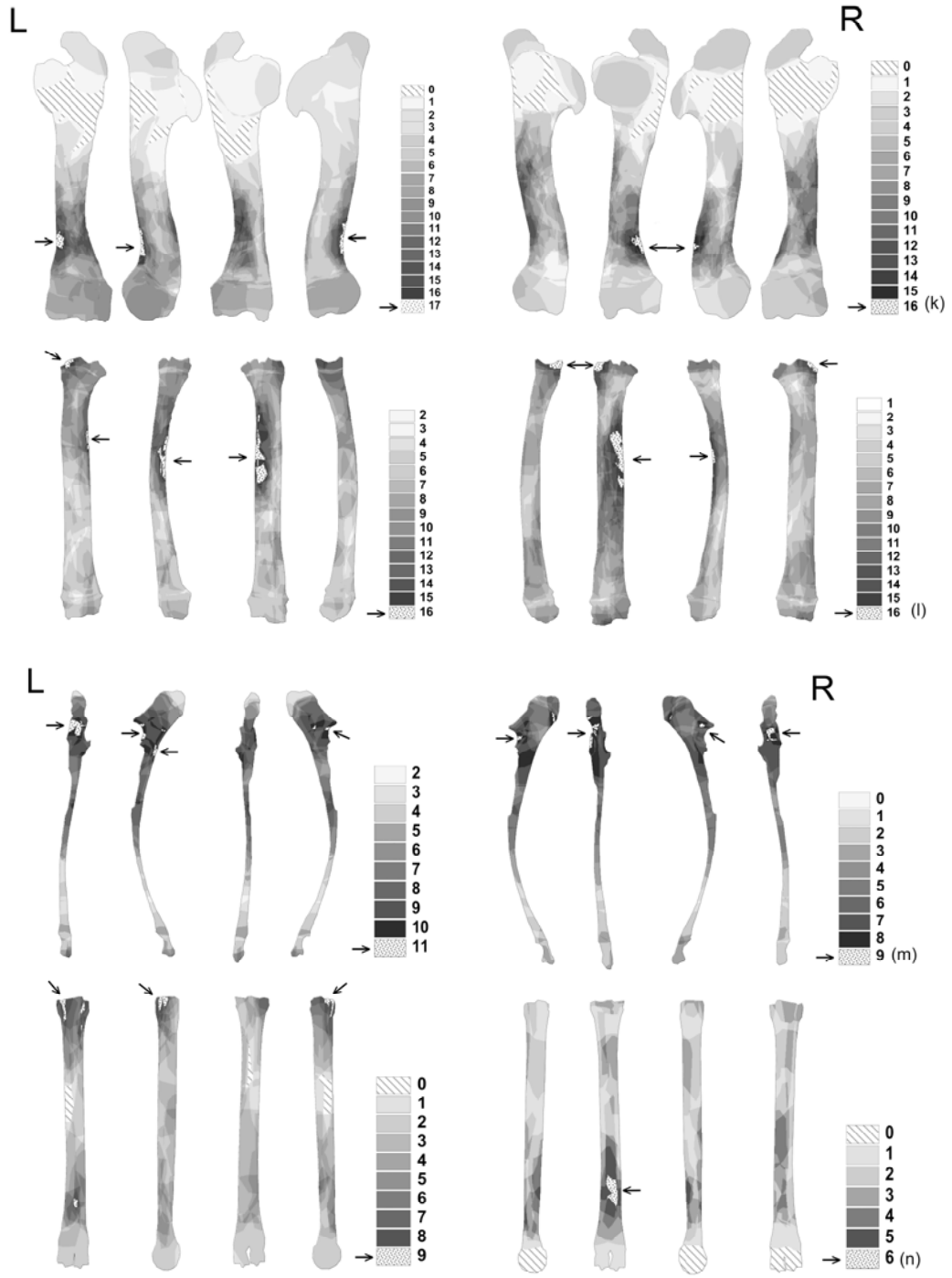


Fig. 9 (cont.) Composite GIS images of the humerus (k), radius (l), ulna (m), and metacarpal (n) from all layers at PP13B. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

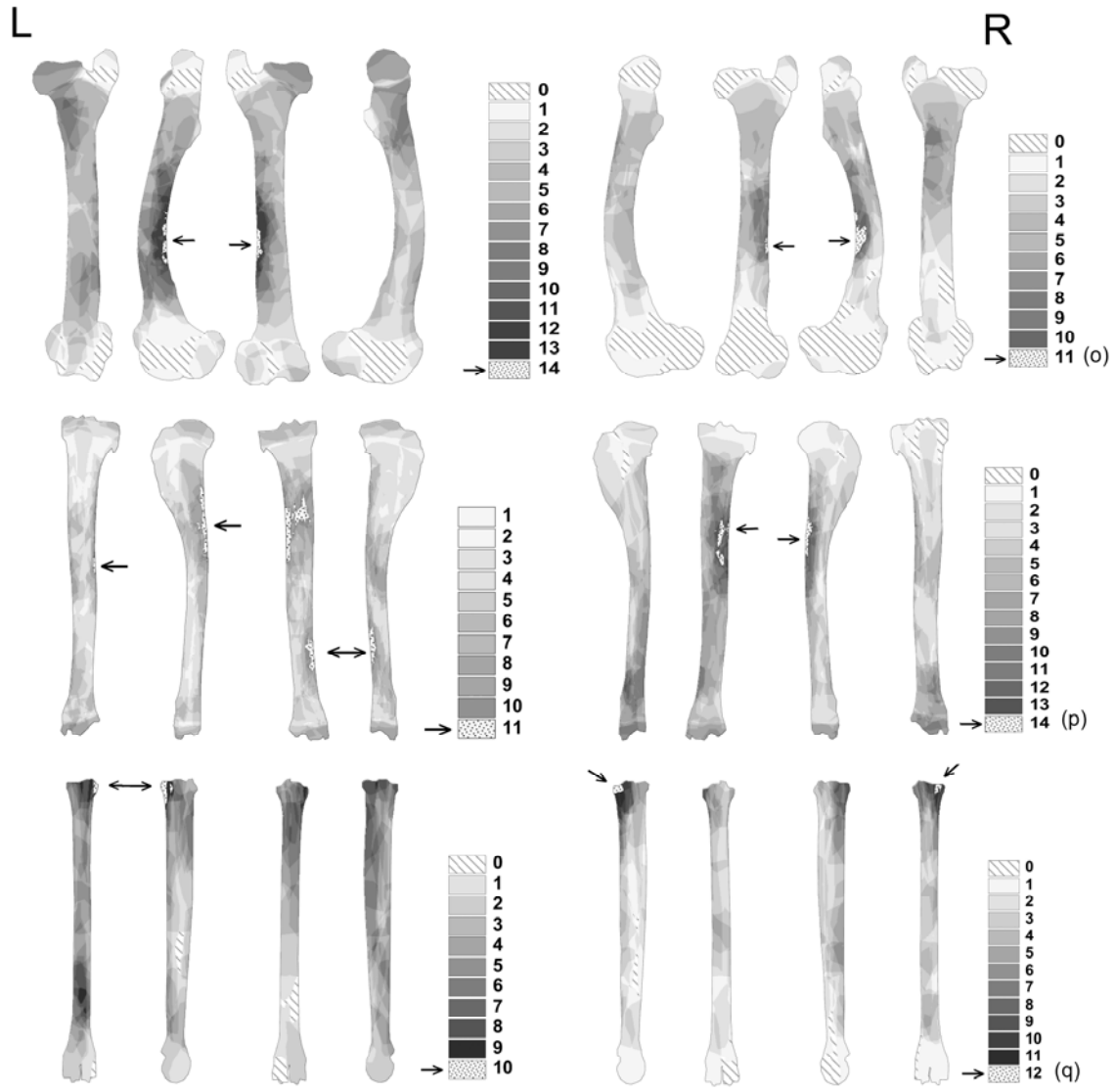


Fig. 9 (cont.) Composite GIS images of the femur (o), tibia (p), and metatarsal (q), from all layers at PP13B. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

It is readily apparent that at both sites the highest representation occurs on dense long bone shaft portions and denser portions of spongy elements such as the vertebral

zygopophyses and acetabulum of the pelvis. Lower representation is consistently found on the epiphyseal ends of long bones. Proximal radii and metapodials are semi-exceptions amongst long bones in also providing relatively high MNE estimates, and this is certainly because of a combination of being highly identifiable and having high density relative to epiphyseal portions of other elements (Lam *et al.*, 1998, 2003).

This visual assessment is verified quantitatively when MNE values are derived using different portions of the same element. Long bones were divided into the five zones used by Abe *et al.* (2002): proximal epiphysis, proximal shaft, midshaft, distal shaft, and distal epiphysis. The MNE for each bone portion was then derived, and denser portions such as long bone shafts and proximal metapodials were found to consistently provide the highest MNE counts (Table 3).

Table 3

MNE estimates from each long bone portion at PP13B.

Element	Side	Prox. End	Prox. Shaft	Midshaft	Dist. Shaft	Dist. End
Humerus	Right	5	13	15	16	8
	Left	5	7	17	17	13
Radius	Right	16	16	16	13	14
	Left	16	16	16	11	10
Metacarpal	Right	3	4	5	6	1
	Left	9	9	5	9	4
Femur	Right	5	10	11	11	4
	Left	10	11	14	14	6
Tibia	Right	8	14	14	13	12
	Left	7	11	11	11	11
Metatarsal	Right	12	11	7	5	1
	Left	10	10	8	9	3

This patterning is also very robust from a statistical standpoint. Fragment representation across the five long bone zones can be represented in terms of area as described by Abe *et al.* (2002). The amount of the total area that falls within each zone is calculated and multiplied by its MNE value. For example, if the distal shaft zone is represented by some areas with an MNE of 1, some with an MNE of 2, and some with an MNE of 3, these areas are tabulated and multiplied by 1, 2, and 3, respectively. These are then added to obtain the total area count (in pixels) within that zone. The proportion of the total area that falls within the five zones is then expressed as a percentage. These percentages are given in Table 4 for all the major long bones in the skeleton at PP13B.

Table 4

Relative proportions of long bone portion representation at PP13B (all percentages add to 100% for a complete bone).

	Proximal Epiphysis			Proximal Shaft			Midshaft		
	Left	Right	Total	Left	Right	Total	Left	Right	Total
Humerus	13.4%	16.3%	14.7%	6.3%	14.3%	9.9%	19.7%	24.0%	21.6%
Radius	15.7%	14.1%	14.9%	26.2%	21.0%	23.6%	25.7%	25.9%	25.8%
Metacarpal	8.7%	5.3%	7.4%	33.5%	27.4%	31.2%	19.4%	28.0%	22.7%
Femur	19.5%	11.6%	15.6%	26.0%	35.3%	30.6%	16.3%	31.8%	23.9%
Tibia	15.5%	7.5%	11.5%	27.0%	25.2%	26.1%	25.4%	28.0%	26.7%
Metatarsal	14.9%	19.3%	16.8%	34.9%	33.3%	34.2%	24.5%	27.8%	26.0%

	Distal Shaft			Distal Epiphysis		
	Left	Right	Total	Left	Right	Total
Humerus	29.9%	29.8%	29.9%	30.7%	15.5%	23.9%
Radius	21.9%	27.1%	24.5%	10.5%	11.8%	11.2%
Metacarpal	32.2%	38.1%	34.5%	6.2%	1.2%	4.3%
Femur	20.1%	15.9%	18.0%	18.1%	5.5%	11.9%
Tibia	19.7%	24.4%	22.0%	12.4%	14.9%	13.6%
Metatarsal	22.1%	17.3%	20.1%	3.6%	2.3%	3.0%

Once quantified, these proportions can be input into a regression analysis with density as the x-axis (density values from the CT of a sheep skeleton in Lam *et al.* [1998]). The regression shows increasing density plotting positively with increasing %Area for long bone portion representation. Spearman's Rho is then used to quantify the degree of correlation between bone portion density and representation, as this nonparametric test is less susceptible to small sample sizes and influence by outlying points. Spearman's Rho confirms a highly significant positive correlation between the two variables ($R_s = 0.6047$; $p = 0.0004$). This quantitatively documents a high degree of differential destruction at the site, in accordance with what one would expect if this destruction was mediated by bone density (Figure 10).

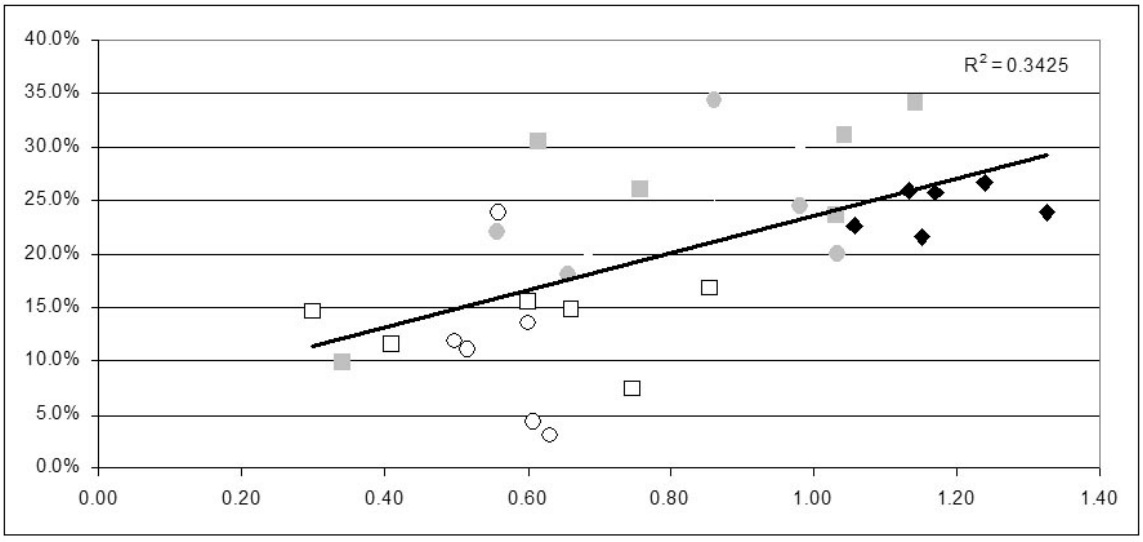
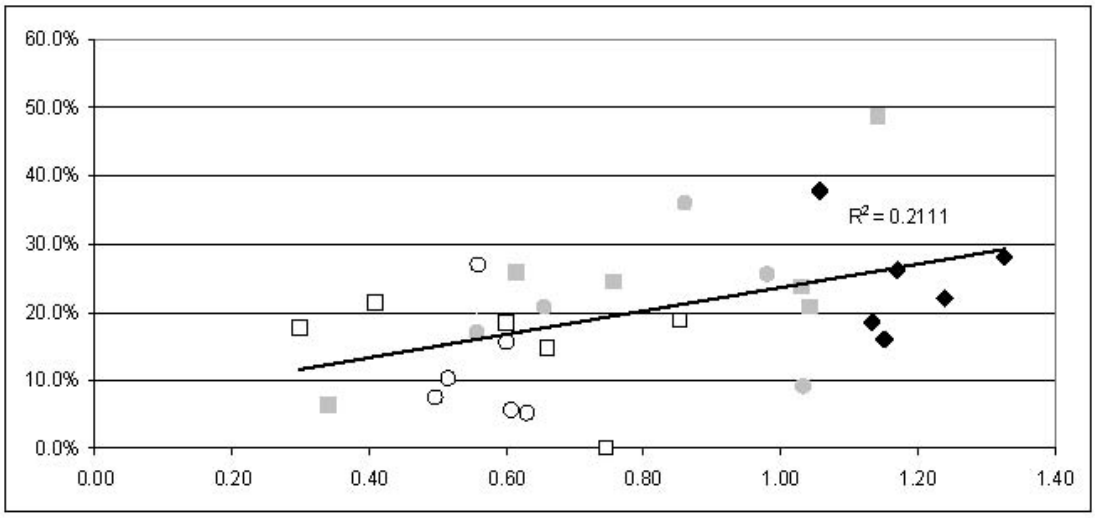
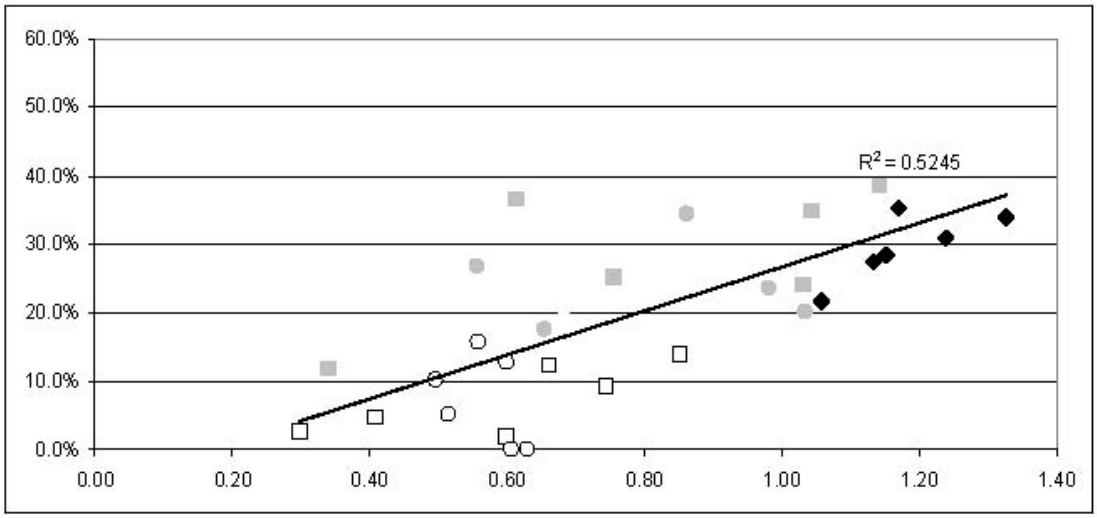


Fig. 10 Scatterplot of long bone portion representation at PP13B (y-axis) versus bone density x-axis) as measured by CT (Lam *et al.*, 1998). Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

It is important for future spatial and chronological comparisons of behavior to establish if this clear pattern of density-mediated destruction is equally apparent between excavation areas, between MIS 5 and MIS 6, and between body sizes (here, small fauna includes size 1 and 2 and large fauna includes size 3, 4, and 5). A simple linear regression is overlain on the scatterplot to illustrate the relationship between the two variables in each subset of data (Figures 11 and 12). The flatter the line, the less tightly increasing bone density plots with the increasing long bone portion representation.

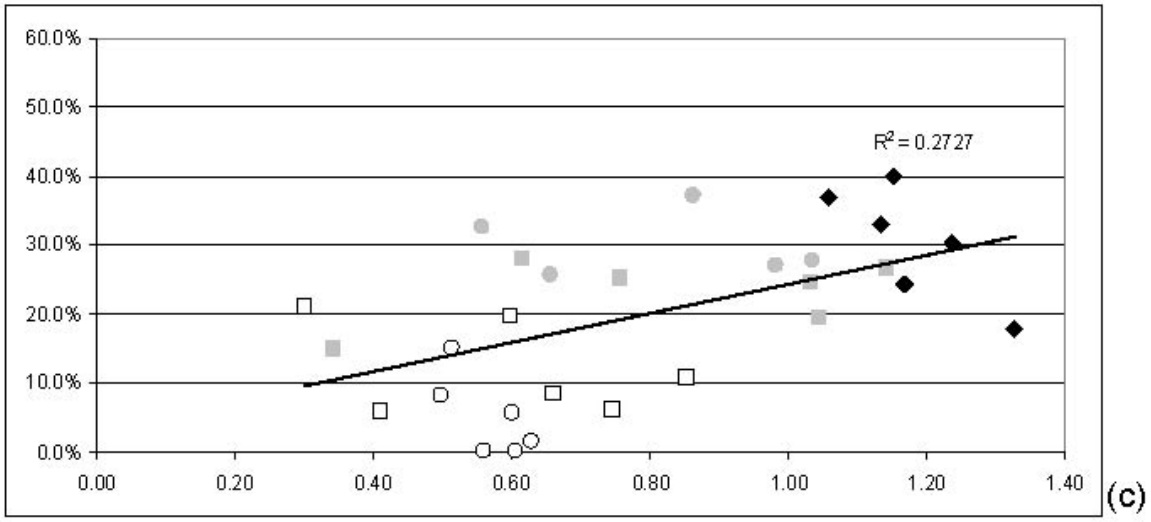


(a)



(b)

Fig. 11 Long bone portion representation at PP13B versus bone density for small (a) and large (b) fauna in MIS 5. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.



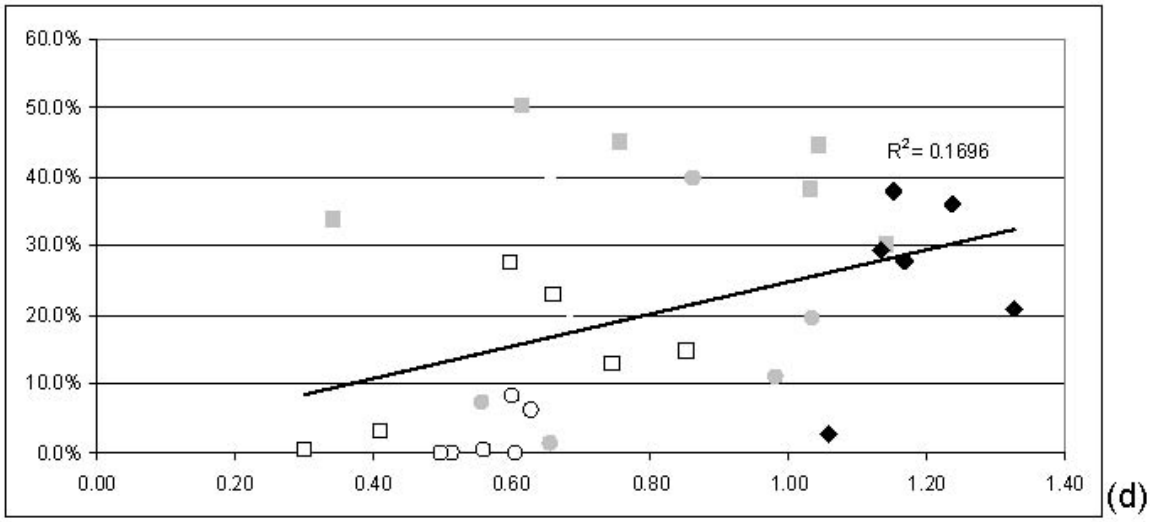


Fig. 11 (cont.) Long bone portion representation at PP13B versus bone density for small (c) and large (d) fauna in MIS 6. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

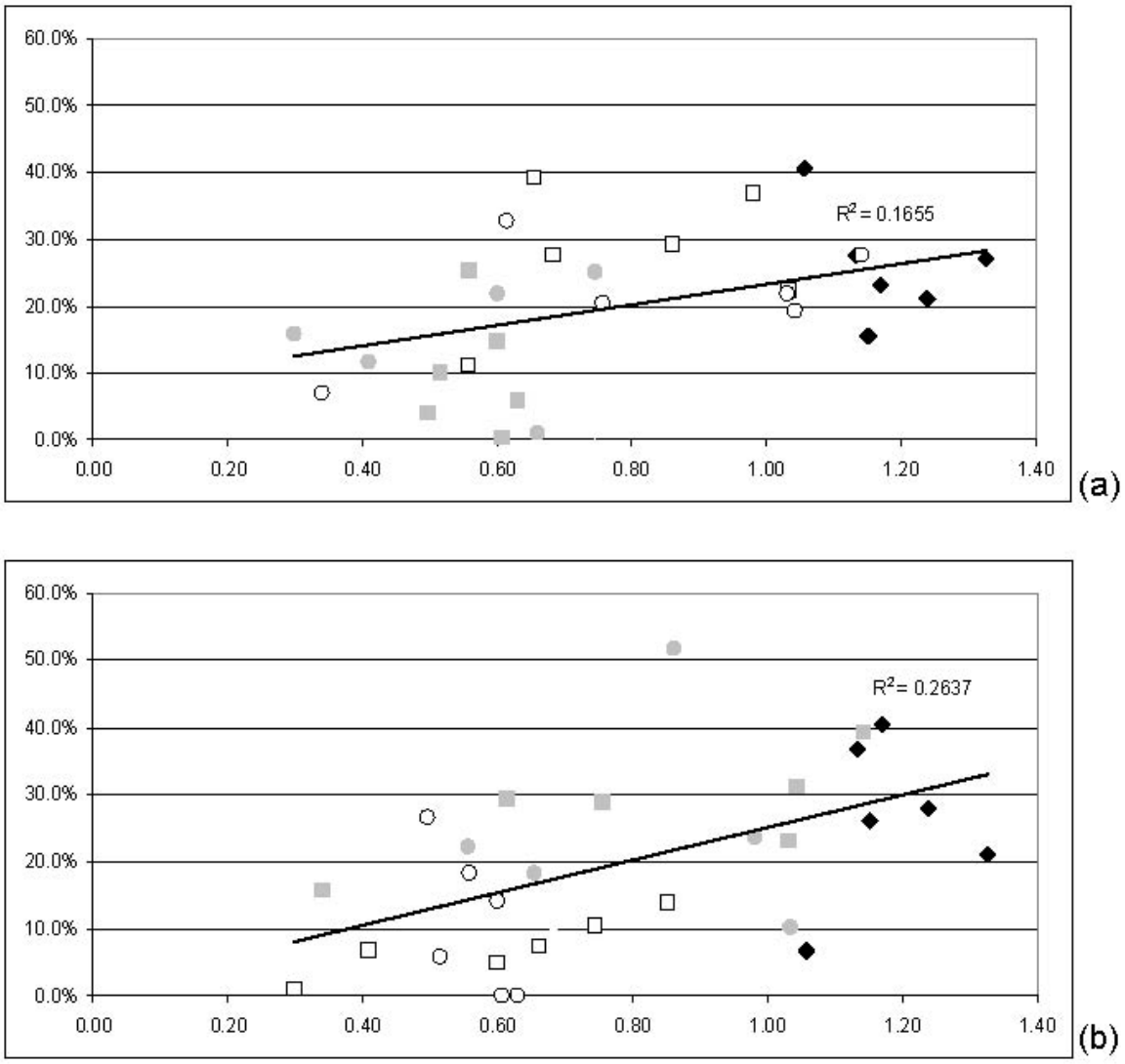
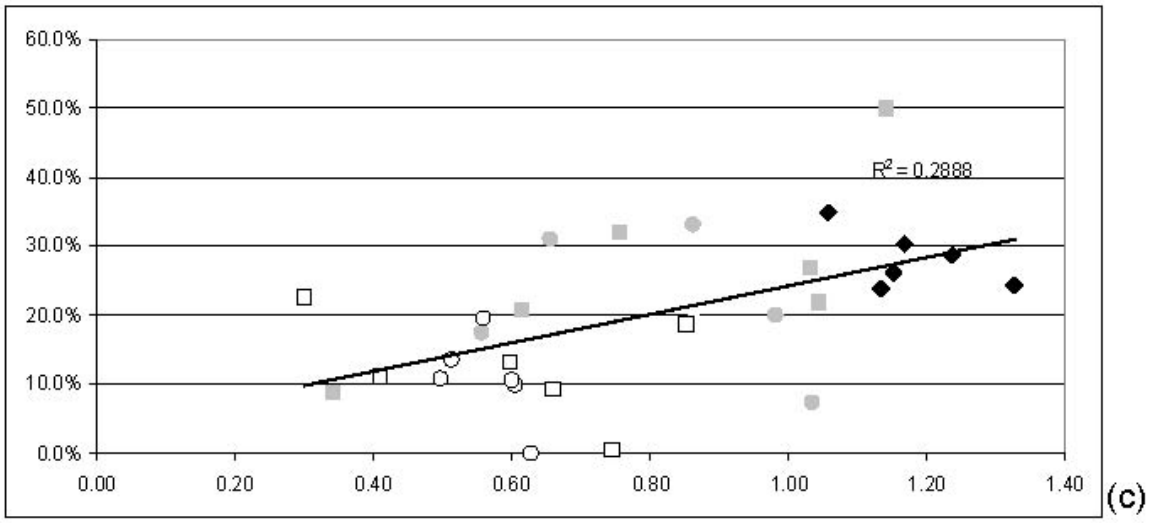


Fig. 12 Long bone portion representation at PP13B versus bone density for small (a) and large (b) fauna in the front of the cave. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.



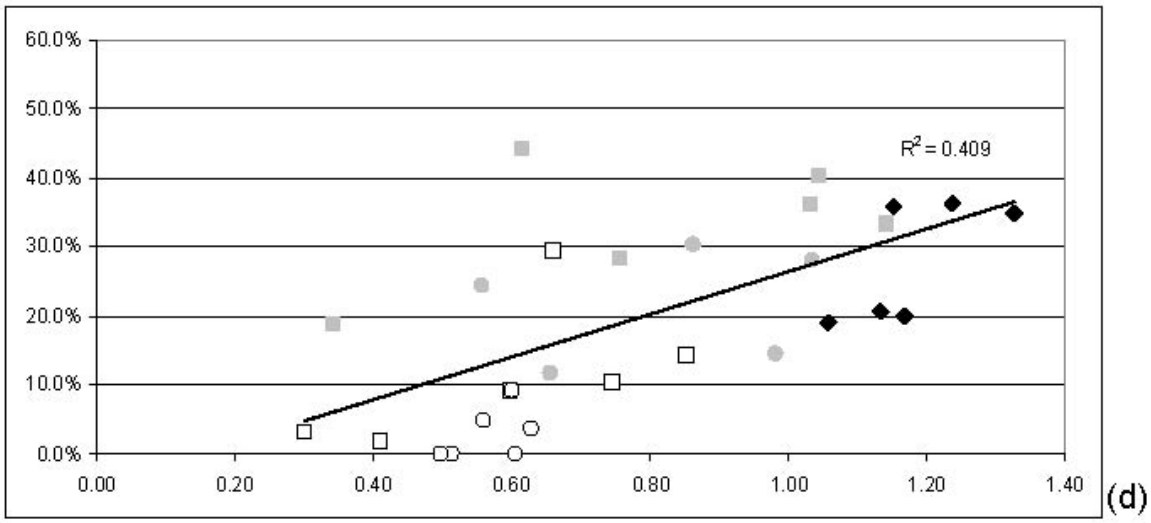


Fig. 12 (cont.) Long bone portion representation at PP13B versus bone density for small (c) and large (d) fauna in the back of the cave. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

Spearman's Rho finds a positive correlation between density and bone portion representation in all data subsets, and these correlations are all highly significant (Table 5). Density predicts bone portion representation most strongly in large ungulates from MIS 5 and least strongly in small ungulates from MIS 5. Within MIS 6, density predicts

representation between the two body size groupings to basically the same degree. This suggests that large ungulates in MIS 5 suffered slightly increased levels of density-mediated destruction relative to small ungulates.

Table 5

Spearman's Rho and p-values for the significance of the correlation between long bone portion representation and bone density.

Ungulate Size	Dataset	Spearman's Rho	p-value
Small	MIS 5	0.4443	0.0139
Large	MIS 5	0.7116	< 0.001
Small	MIS 6	0.5373	0.0022
Large	MIS 6	0.4915	0.0058
Small	Back	0.5306	0.0050
Large	Back	0.6818	< 0.001
Small	Front	0.4283	0.1822
Large	Front	0.5324	0.0020

There are basically no differences in the degree of this destruction between fauna from the front and the back of the cave. However, it is worth noting that within each subset of data small ungulate bone portion representation is always more even and less biased toward dense portions. This may be because fragments of a given element for small animals are likely to retain more diagnostic features and thus be more easily identified than the same-sized fragments for larger animals. It may also offer some preliminary evidence that during this time period carnivore ravaging of small ungulates did not exceed that of large ungulates, even though small ungulate bones may be more easily destroyed and portions swallowed. Differential degrees of fragmentation between

body size classes are further explored in the next section, and further evidence for modification by both carnivores and hominins is discussed in the surface modification section.

Surface preservation, fragmentation, and burning

At PP13B bone surfaces overall are preserved quite well, with less than 0.1% of the assemblage showing dendritic etching, pocking, or sheen that can erase or even mimic diagnostic marks (Thompson, 2005; Domínguez-Rodrigo and Barba, 2006). Smoothed surfaces that can indicate micro-abrasion by water- or wind-borne particles were only present in 1.4% of the assemblage, and most of these were recovered from the laminated facies below the archaeological horizons and not considered here. This indicates that abiotic factors such as water were not operative to such a degree that they resulted in polish or smoothing of faunal material at PP13B (Shipman, 1981; Behrensmeyer; 1988).

The few fragments that exhibit polish likely have derived it from a variety of taphonomic factors. Some may have been from human abrasion of the bone against another material (such as that on the bone tool) while others certainly are related to having been gastrically etched (Figure 13). The only relatively common type of surface destruction was exfoliation, which was severe (as defined by Thompson [2005]) in 5.5% of the assemblage. Crystal formation was apparent on much of the assemblage, although the minerals involved were not specifically identified. These crystals often formed a matrix over the fossils, with 21% of all fragments exhibiting matrix sufficient to cover half or more of the surface. Crystal growth was likely aided by the present-day proximity

of the site to the ocean, and growth from within bone surfaces could account for some of the observed exfoliation. Although understanding the instigation and progression of these processes is an interesting topic for future exploration, the present analysis requires only that fragments with extensive coverage by matrix or destruction by exfoliation be accounted for and not included in subsequent surface modification analyses.

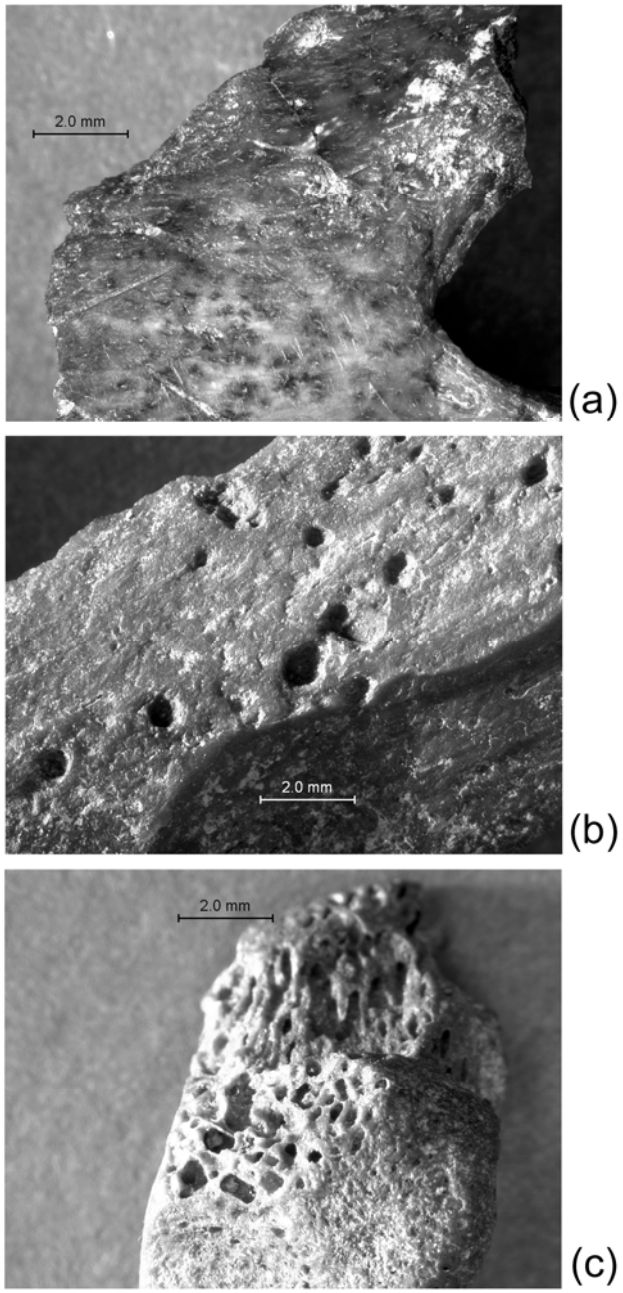


Fig. 13 Examples of sheen on a horn core fragment (a), a long bone fragment (b), and a gastrically etched carpal (c).

Proportions of gastric etching and rodent gnawing were negligible throughout the PP13B assemblage (1.3% for all body sizes and < 0.1% for all body sizes, respectively). This etching occurs more commonly on smaller fauna (2.4% for size 1, 1.9% for size 2, 1.1% for size 3, and 0.5% for size 4). These differences are small but statistically significant below the $\alpha = 0.05$ level using Fisher's Exact Test between small (size 1 and 2) and large (size 3 and 4) sizes – but not within these categories (Appendix J:[c]). This indicates that a very small proportion of the fauna at PP13B was likely contributed by raptors or carnivores, and that this contribution was more common for the two smaller body size classes.

This result is reminiscent to some degree of the faunal assemblage from DK1. Here, size 1 bovids from Layers 10 and 11 displayed a disproportionately high degree of gastric etching relative to all other size classes (Marean *et al.*, 2000b). The authors interpreted this as an indication of a substantial raptor contribution to the size 1 faunal assemblage, and they supported the inference with a spatial analysis that showed gastrically-etched size 1 bovid fragments concentrated under solution cavities that would have made good roosting sites. The modern-day physical configuration of PP13B also provides roosting sites along the north wall (on the left facing out of the cave), although the cave has experienced enough exfoliation of the walls that more sites may or may not have been available in the past (Marean pers. comm., 2008). However, when the percentages of gastrically-etched size 1 bone within each square are mapped they do not show a concentration in the area that today contains the most potential places for raptor roosting.

Instead of any north-south concentration, slightly higher proportions of gastrically-etched size 1 bone occur at the rear of the cave. There is a singular exception with square N91E108, in which all gastrically-etched fragments occur within analytical unit 5, the Lower Roof Spall. The spatial and chronological restriction of this anomalously high proportion could very well indicate a single incident of defecation or regurgitation. The pattern observed on the size 1 fauna is no different from that observed when all gastrically-etched bone is plotted throughout the cave (Figure 14).

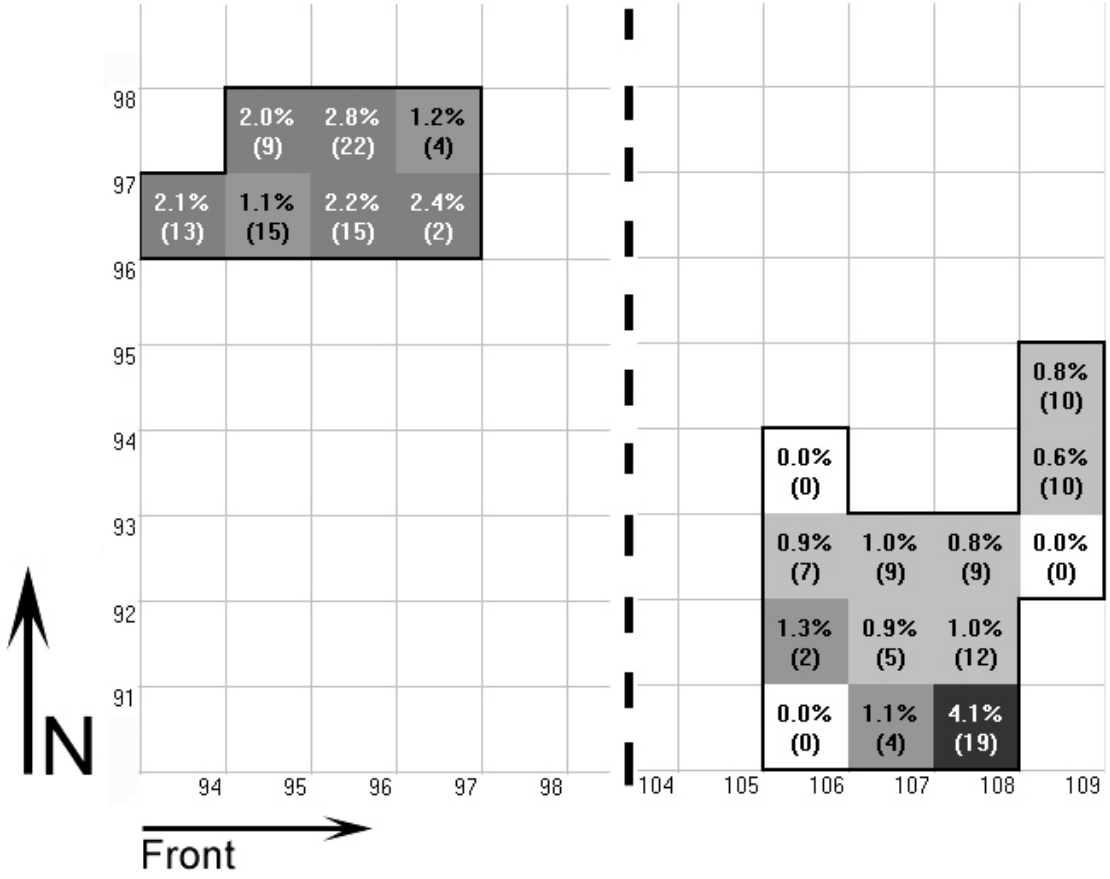


Fig. 14 Percentages of gastrically-etched bone in each square at PP13B.

As another line of evidence, if raptors were responsible for the small amount of gastric etching, then this would fit well with the observation that the majority of microfauna has also been recovered from the rear (western) excavations (Matthews pers. comm. 2007). However, if raptors were responsible then there should also be a similar pattern of distribution of small fauna such as hares and hyraxes. When the relative proportions of small and large mammals recovered at the front and the back areas are compared there is no significant difference between the two areas (Fisher's Exact Test p = 0.1165; Appendix J:[d]). Because the small mammal sample is so small it may be useful to consider the ratio of small fauna: large fauna as a whole, and include tortoises in the small fauna category. This also results in an insignificant association between basic size class and area of the cave (p = 0.0646).

The possibility of raptor accumulation of small ungulates is further weakened by the fact that gastric etching on fauna too large to be prey for raptors is also concentrated at the rear of the cave. When these results are combined with the body size data from the previous section they indicate strongly that there was no substantial raptor accumulation of small ungulates, as was indicated at DK1. This may be slightly confounded by the long period of time represented at PP13B, and indeed gastrically-etched bone is slightly more common in MIS 6 (1.7%) than MIS 5 (1.0%). However, the total sample of gastrically-etched bone is too small to be useful if the data are broken up both chronologically and spatially. When considered in sum, most of the evidence points to carnivores as the agents responsible for the small input of gastrically-etched bone at the

site, with raptors having an inconsequential, if any, contribution. The intensity of this carnivore input is evaluated in the section on surface modification.

The PP13B assemblage presented here has 5,874 long bone fragments, resulting in a potential 11,748 long bone ends that can be used for fracture analysis. Of these, 8,402 remained after elimination of unbroken ends, indeterminate ends, ends from fragments that could not be assigned to a body size, or fractures that suffered excavation damage and thus are uninformative about ancient breakage patterns (Appendix B).

Marean *et al.* (2000b) examined the fragmentation at DK1 and determined that there was no directional trend in the proportions of 'green' and 'dry' breaks by body size. On this basis they grouped their data into only two categories: Size 1/2 and size 3/4. At PP13B there is up to a 36.8% difference in fragmentation between body size classes. However, there is also no directional change and only small samples of sizes 4 and 5 animals are available for some analytical units – which could lead to wildly biased fracture proportions. These factors justify dividing the PP13B fragmentation data into two lumped body size groupings for analytical purposes. Size 5 fragments only comprise 1.1% of the available long bone ends, and so the groupings size 1/2 and size 3/4 are used here as was done at DK1 (Figure 15).

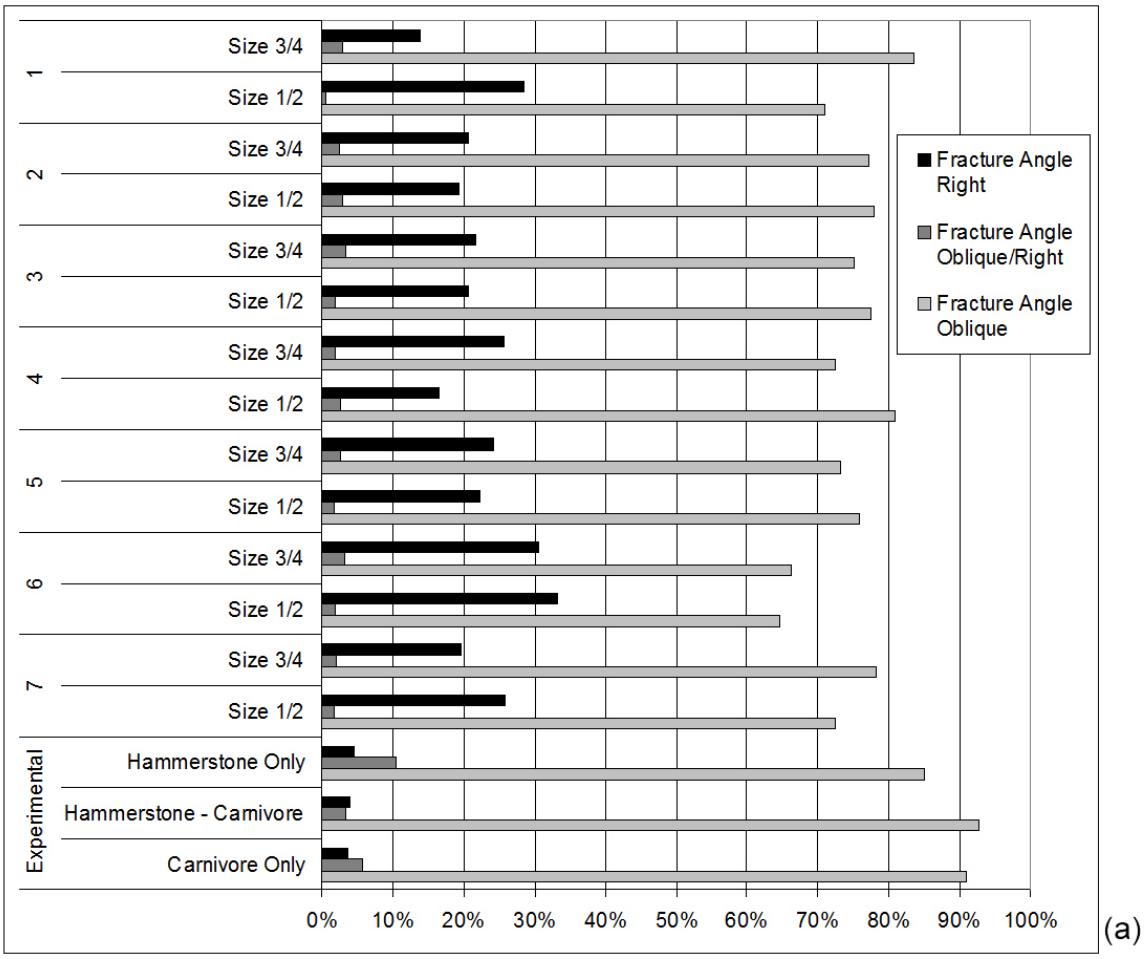


Fig. 15 Relative proportions of long bone fragments from PP13B that exhibit different fracture angles (a) in comparison to actualistic assemblages in which all bones were broken while fresh.

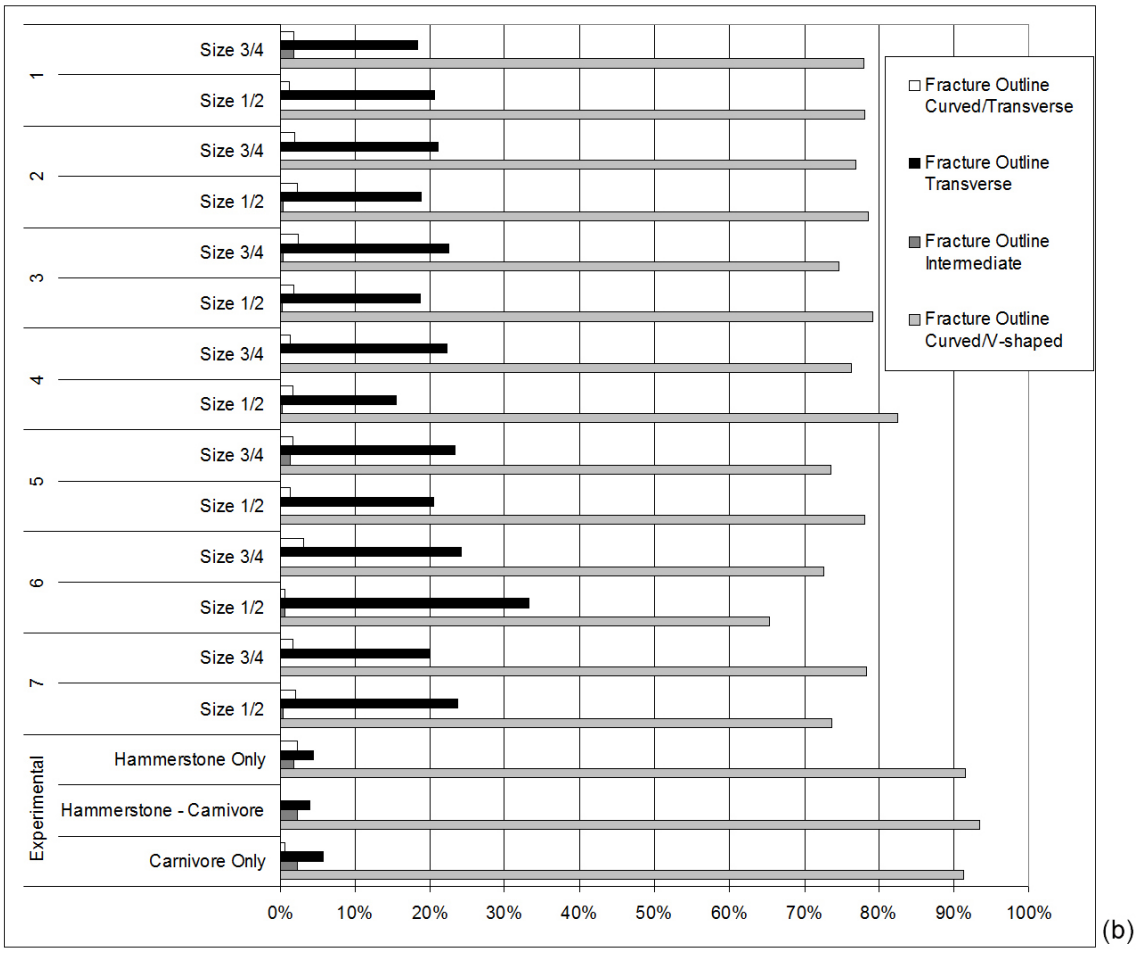


Fig. 15 (cont.) Relative proportions of long bone fragments from PP13B that exhibit different fracture outlines (b) in comparison to actualistic assemblages in which all bones were broken while fresh.

The amount of post-depositional fragmentation for all analytical units at PP13B exceeds the 95% confidence limits reported for three modern known-agent experimental assemblages (Marean *et al.*, 2000b:210-211). This degree of post-depositional breakage is moderate: not as substantial as that reported from some other archaeological sites (e.g. Villa and Mahieu, 1991; Thompson, 2005) and similar to the values reported from Layers 10 and 11 at DK1 (Marean *et al.* 2000b). However, because there has been some

fragmentation, proportions of surface modification such as cut, percussion, and tooth marks are likely to have been depressed from their original values (Abe *et al.*, 2002).

The only analytical unit from PP13B that stands out as having particularly high degrees of post-depositional breakage is the LC-MSA Middle (6). This semi-consolidated layer was difficult to excavate in parts, but all excavation breaks were eliminated from the dataset prior to analysis. An alternative explanation must lie behind the slightly elevated breakage proportions. The LC-MSA Middle from PP13B lies less than a meter below the surface even at its deepest part, so although sediment compaction may not have played a substantial role in the post-depositional breakage it is possible that trampling may have.

At DK1 Marean *et al.* (2000b) suggested that both subaerial weathering and burning can weaken the bone and lead to greater susceptibility to breakage by other means. At PP13B only 0.1% of all bones were weathered beyond Behrensmeyer's (1978) stage 1 (99.1% were in stage 0, and 0.8% were in stage 1). The proportion of bones showing any weathering at all is slightly higher at the back (1.4% rather than 0.6%), and none occur in the LC-MSA Middle at the front. This is unexpected if this weathering took place within the confines of the cave. Though it is difficult to say more with this small sample of weathered fragments, the data do indicate that at least occasionally bones were transported from outside the cave after being exposed to subaerial weathering, and that this weathering was almost always only sufficient to move the bone into stage 1.

Marean *et al.* (2000b) subtracted burned fragments from the DK1 long bone fragmentation analysis and found that this increased the proportion of fragments showing 'green bone' breaks. At PP13B only 12% of all fragments fall into burning stages 1 – 6. These proportions differ between analytical units, and indeed the LC-MSA Middle (6) has the highest proportion overall of burned bone compared to the other analytical units, at 18.4%. However, the next highest proportion of burned fragments occurs in the Shelly Brown Sand/Upper Roofspall (3) at 17.4%, and this analytical unit does not show the same degree of post-depositional fragmentation as the LC-MSA Middle (6).

Grouping the analytical units into front/back and MIS 5/MIS 6 aggregates makes comparisons more clear. A comparison of post-depositional fragmentation between MIS 5 and MIS 6 shows no difference between the proportions of right-angled breaks (22.7% and 21.9%, respectively) or transverse outlines (22.0% and 22.1%, respectively). However, more frequent or intense occupation of the front of the cave by both humans and other animals may have resulted in greater post-depositional fragmentation. To test this, proportions of 'green' and 'dry' breaks were compared between the front and the rear excavations. Proportions of dry breaks are lower in the rear but only marginally: 21.3% of fracture angles are right and 21.9% of outlines are transverse in the rear while 22.4% of angles are right and 22.4% of outlines are transverse in the front. This may be explicable by more fragments from the front of the cave being burned (7.5% in the front and 4.7% in the back). Also, because the LC-MSA Middle and Shelly Brown Sand/Upper Roofspall lie to the front, this may be help explain the slightly elevated proportions of 'dry' breaks in these analytical units.

When burned fragments are eliminated from the long bone fragmentation data, proportions of 'dry' breaks in the back decrease by less than 1%: 21.0% of the breaks now display right fracture angles and 20.9% have transverse fracture outlines. In the front proportions lower by 1.0 – 2.5%: 21.3% of fracture angles become right while 19.9% have transverse outlines. This indicates that although a very small amount of additional post-depositional breakage may have occurred in the front, possibly attributable to burning, it was not substantially greater than that at the rear. Furthermore, the small effect t of burning on the fragmentation patterns does not warrant that any adjustments be made.

Overall fragmentation, on the other hand, does appear to be different between the two areas. The area of each fragment was approximated using the maximum width x maximum length in mm. The data were then broken up into six fragment size classes: 0 – 99 mm^2, 100 – 199 mm^2, 200 – 299 mm^2, 300 – 399 mm^2, 400 – 499 mm^2, and > 500 mm^2. Proveniences were divided into simple front vs. back of the cave, and the percentage of fragments falling into each fragment size class was calculated for both areas. The western (rear) area of the cave consistently has lower proportions of small fragments and higher proportions of large fragments than the eastern (front) of the cave. Fragment size representation is approximately the same between the two areas at between 300 – 399 mm^2 in size (Figure 16).

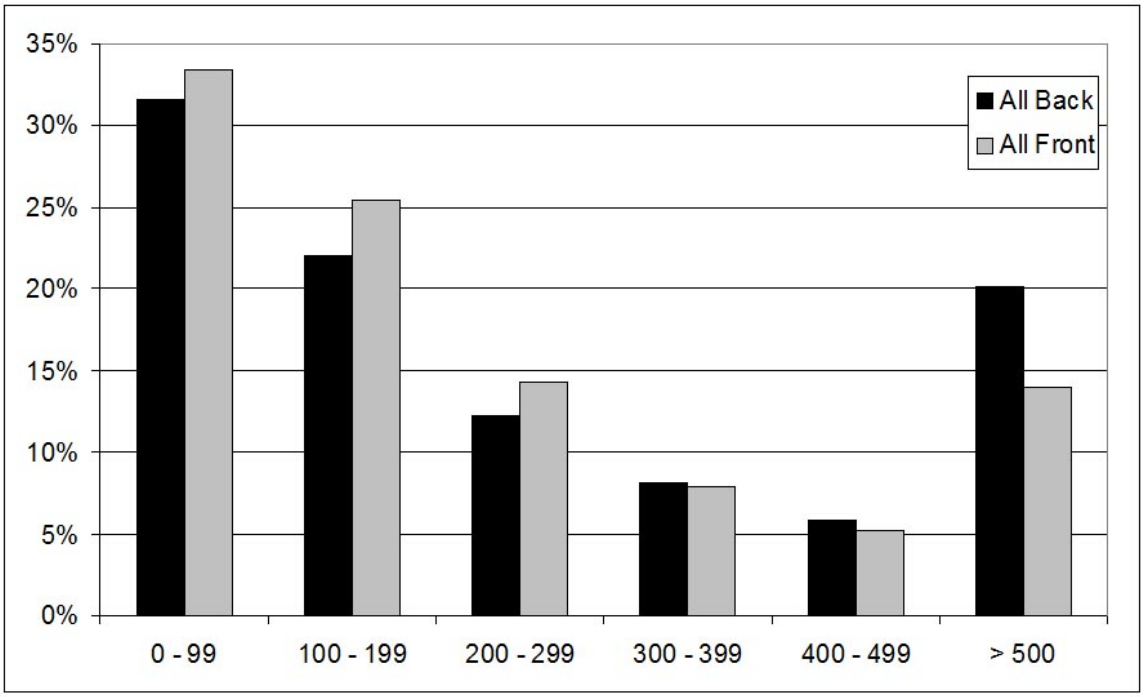


Fig. 16 Distribution of different fragment size classes in the front and back of PP13B.

The long bone fracture data show that there was not substantially more post-depositional breakage in the front, and the body size data indicated that size 1 fauna is more common in this area. These two lines of evidence combined show that smaller fauna, and the smaller fragments they produce, were more commonly deposited at the front of the cave. These data may lend some support to Marean *et al.*'s (2004) inference that material at the back was dumped there as a midden, while the front was used for domestic activities. This is because larger fragments from larger animals would have been the more likely candidates for such 'house-cleaning' while smaller fragments went unnoticed as they became pressed into the sediment at the front. This possibility is

further examined in Chapter Nine when the spatial differentiation of butchery and discard tasks is examined.

Surface modification

As discussed in Chapter Two, cut, percussion, and tooth marks are some of the most commonly used indicators of hominin and carnivore modification of bone surfaces. Examples of these marks identified at PP13B are shown in Figure 17. There were 4,562 long bone midshaft fragments that could be potentially compared to modern actualistic data (summarized in Marean *et al.*, 2000b:215). However, once fragments with heavily-exfoliated surfaces or with > 70% of their surfaces concealed by matrix were eliminated from analysis for the reasons described in Chapter Two, this resulted in a reduced sample of 3,160 midshafts (Table 6). Unfortunately, sample sizes were too small after all the appropriate corrections to enable productive comparisons between body sizes within all seven analytical units. For this reason, data are presented here in aggregate by body size, body size with basic chronology (MIS 5 versus MIS 6), and body size with basic spatial information (front versus back.

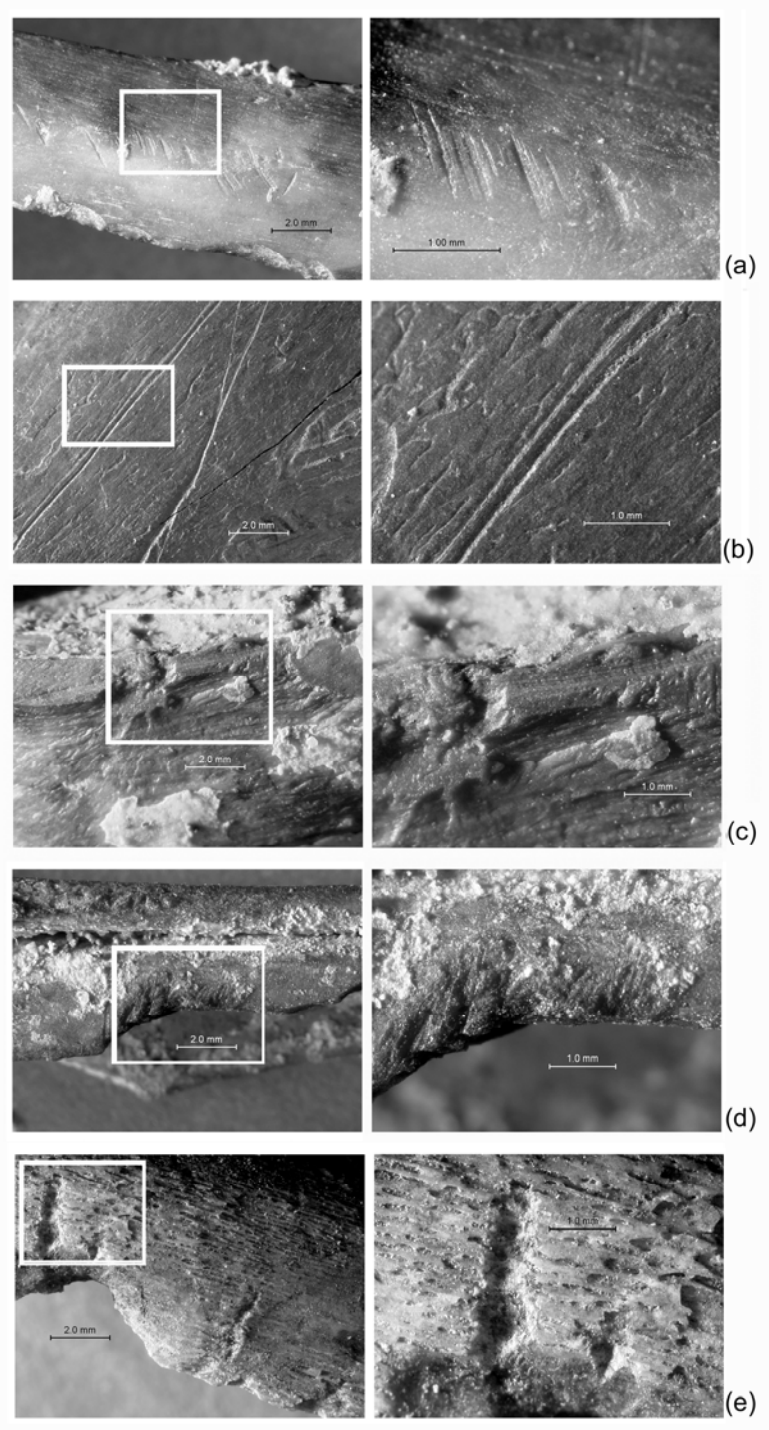


Fig. 17 Examples of cut marks (a & b), percussion marks (c & d), and tooth marks (e) at P13B. Note the notches left behind by both the percussion and the tooth activity. The area to the right is an enlargement of the area shown in the white box.

Table 6

Numbers of midshaft fragments bearing a percussion or a tooth mark at PP13B.

	Size Indet.		Size 1		Size 2	
Analytical Unit	PM	TM	PM	TM	PM	TM
LB Sand 1 (1)	8	1	3	5	11	2
Upper DBS Units/LC-MSA Upper (2)	46	9	15	8	45	18
Shelly Brown Sand/Upper Roof Spall (3)	54	3	91	19	137	28
Lower Roof Spall (4)	10	6	17	6	35	13
Lower Dark Brown Sand Units (5)	21	11	5	3	20	6
LC-MSA Middle (6)	7	1	5	3	5	0
LC-MSA Lower (7)	64	8	51	17	111	22
Total Fragments with Mark	210	39	187	61	364	89
Total Fragments	751		584		799	

	Size 3		Size 4		Size 5	
Analytical Unit	PM	TM	PM	TM	PM	TM
LB Sand 1 (1)	12	1	4	2	0	0
Upper DBS Units/LC-MSA Upper (2)	71	29	24	6	3	0
Shelly Brown Sand/Upper Roof Spall (3)	179	20	31	7	6	0
Lower Roof Spall (4)	18	3	4	1	2	0
Lower Dark Brown Sand Units (5)	29	13	9	2	0	1
LC-MSA Middle (6)	10	0	1	0	0	0
LC-MSA Lower (7)	90	17	21	6	7	0
Total Fragments with Mark	409	83	94	24	18	1
Total Fragments	825		174		27	

Taking the assemblage as a whole, when all analytical units from PP13B are combined they most closely fit a human-first scenario for all body sizes (Figure 18). Proportions of percussion-marked midshafts all either fall within or (more commonly) above the 95% confidence intervals for both Blumenschine and Marean's 'hominin only' and 'hominin-then-carnivore' scenarios as presented in Marean *et al.* (2000b). The co-

presence of tooth-marked midshafts indicates that carnivores were also involved in the taphonomic history of the assemblage. 95% confidence intervals for Capaldo's (1997) and Marean *et al.*'s (1992) reported proportions of tooth marks do not overlap, but both ranges are encompassed by Blumenschine's (1995) reported proportions. At PP13B, proportions of tooth-marked midshafts are overall between 3.7% and 13.8%, all of which fall within the reported ranges of actualistic 'hominin-then-carnivore' simulations.

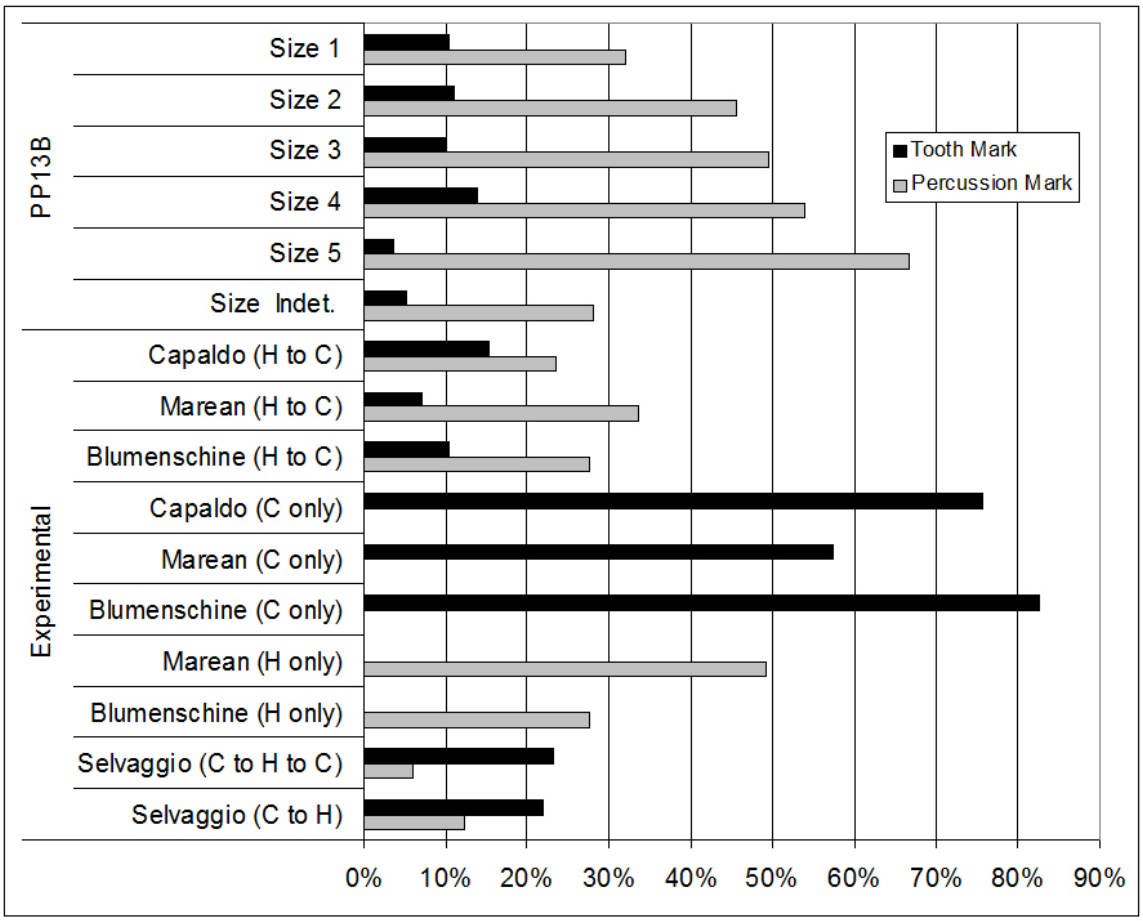


Fig. 18 Relative proportions of percussion and tooth marks on long bone midshafts at PP13B compared to different actualistic carcass-access scenarios.

There is a visually striking pattern at PP13B in which the proportions of percussion-marked midshafts steadily increase with body size, even as the proportions of tooth-marked midshafts remain approximately the same. This pattern holds true even when the very small sample of size 5 midshafts is discounted. Fisher's Exact Test (Appendix J:[e]) shows that this difference is highly significant between size 1 and all other sizes ($p < 0.0001$ for all comparisons) and quite significant between size 2 and 4 ($p = 0.0446$) and 2 and 5 ($p = 0.0478$) but not significant below the $\alpha = 0.05$ level between any other size classes. Examining this pattern in more statistical detail would require additional sampling of the assemblage in a manner designed specifically to test the hypothesis that there are increasing proportions of marks with increasing body size. However, for the purposes of this study, this observation offers strong initial evidence that size 1 ungulates were either less commonly accumulated by hominins or that they were less heavily modified by them. This is also supported by the slightly higher incidence of gastric etching on size 1 fauna.

To further explore the patterning in the surface modification at PP13B, comparisons were made between the front and the back of the cave, and separately between analytical units representing MIS 5 and MIS 6 occupations (Figure 19). For all of these different comparisons the same pattern of increasing proportions of percussion-marked midshafts is apparent, although there is now more variation in the accompanying proportions of tooth-marked midshafts. Having established that size 1 ungulates less commonly bear a percussion mark than other size classes, and that the incidence of gastric etching is overall slightly higher on this size class, this seems the most likely

subset of the data that has an elevated degree of carnivore input. It is therefore useful to compare the proportions of percussion-marked size 1 midshafts over space (i.e.: front versus back) and time (i.e.: MIS 5 versus MIS 6) to determine if this was consistently the case.

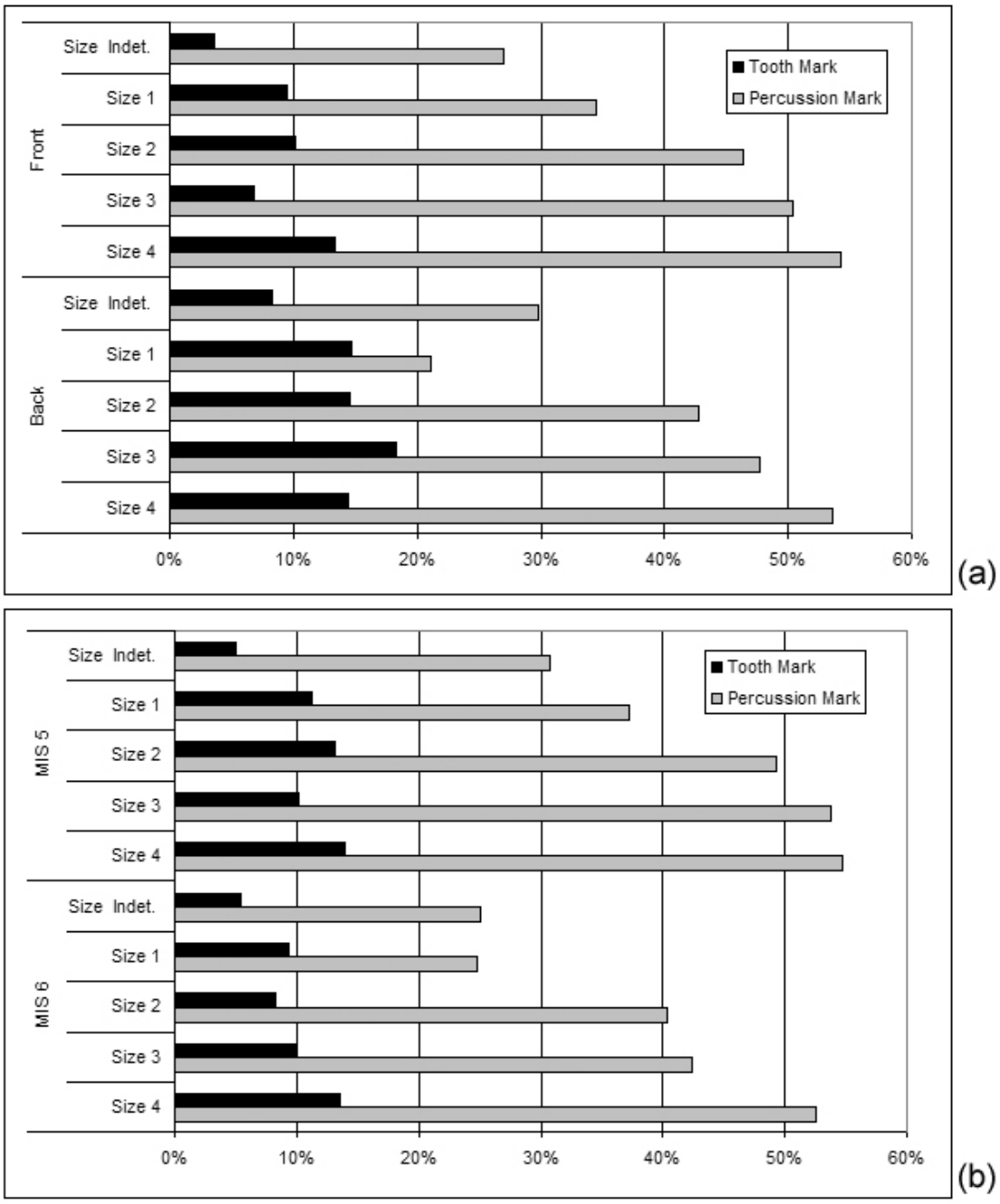


Fig. 19 Relative proportions of percussion and tooth marks on long bone midshafts at PP13B in the front versus back of the cave (a) and in MIS 5 versus MIS 6 (b).

Fisher's Exact Test (Appendix J:[f]) reveals significant differences in the proportions of percussion-marked size 1 midshafts between the front and back of the cave

($p = 0.0063$). The proportion is much lower in the back, suggesting that hominin accumulation or modification of size 1 fauna was more substantial near the entrance of the cave. A corresponding test for differences between the proportions of tooth-marked size 1 midshafts in these areas is not significant ($p = 0.1186$). This provides an important accessory piece of information, as it demonstrates that although human modification was more intense at the front, carnivore modification was approximately equal in both areas – the difference lies in the degree of human input only. A reasonable conclusion is therefore that this difference is attributable to an elevated contribution of size 1 ungulates by carnivores at the rear of the cave relative to the front.

There are also a much higher proportions of percussion-marked size 1 midshafts in analytical units representing MIS 5 than 6. As with the spatial difference, this chronological difference in percussion-marking is highly significant using Fisher's Exact Test ($p = 0.0016$) while the accompanying difference in tooth-marking is not ($p = 0.4956$). The body size data indicated a slight increase in the representation of size 1 ungulates during MIS 5, and the surface modification data show that a higher proportion of these ungulates were modified by MSA hominins. This suggests a behavioral difference between MIS 5 and 6 with regards to the procurement and processing of the smallest ungulates at PP13B.

If all carnivore ravaging occurred only after hominin discard, experimental studies have shown that we would expect a proportion close to 5% of midshafts with both a percussion and tooth mark on the same fragment (Capaldo, 1997, 1998; Marean *et al.*, 2000b; Egeland *et al.*, 2004). However, at PP13B only 1.7% of all midshafts exhibit both

mark types. This low degree of co-occurrence on the same fragment is most pronounced for size 1 ungulates, as would be expected if there was an elevated carnivore contribution in this size class (0.7% compared to 2.4%, 2.3%, and 2.7% for size 2, 3, and 4, respectively). This implies that some of the larger mammal fragments were contributed by carnivores independent of human activity, but that the overwhelming majority of tooth-marking can be accounted for by hominin accumulation and subsequent carnivore modification.

Unfortunately, the sample of midshafts bearing both mark types becomes too small for useful comparisons when the data are broken down into the two spatial and chronological units of analysis ($n < 4$ in each). Despite this, the incidence of the co-occurrence of a tooth mark and a percussion mark on the same midshaft fragment does suggest that independent carnivore accumulation is likely to have been most prevalent for smaller ungulates, which is in line with the other lines of evidence presented above.

Skeletal element representation

Over half (62%) of the total postcranial fragments at PP13B are long bones (Appendix C). First and second phalanges are included in this proportion with long bones, as these are also marrow-bearing bones with a shaft and two spongy ends. This ratio is typical in zooarchaeological assemblages that have not suffered from excavation or analytical bias (Marean and Kim, 1998).

MNE data are provided in Appendix D and MNI estimates are available for comparison between all body sizes and proveniences in Table 7, along with the element from which they are derived. One striking aspect of the MNI counts is the overall very

low number. At PP13B the highest MNI possible is 34 for all ungulate body sizes combined, and even then assuming that all layers have no mixing and have been immaculately excavated. Although this low number is quite typical for MSA faunal assemblages reported from other MSA sites, it has both taphonomic and behavioral implications that are often not discussed in detail (e.g. Klein, 1976, 1978b; Klein and Cruz-Uribe, 2000).

Table 7

MNI estimates and the element from which the highest MNI was derived at PP13B.

	Size 1		Size 2		Size 3		Size 4	
LB Sand 1 (1)	2	R Pelvis	2	Sacrum	2	Various	2	L Radius
Upper DBS/LC-MSA Upper (2)	5	R Mandible	4	R Ulna	5	R Scapula	3	R Tibia
SB Sand/Upper RS(3)	4	Various	4	Various	4	Various	4	L Metatarsal
Lower RS (4)	4	R Pelvis	2	Various	1	Various	1	Various
Lower DB Sand (5)	2	Various	3	L Femur	3	L Humerus	2	R Metatarsal
LC-MSA Middle (6)	1	Various	1	Various	1	Various	0	N/A
LC-MSA Lower (7)	2	Various	3	Various	2	Various	1	Various
PP13B All (Overlap)	8	R Pelvis	9	R Radius	12	R Tibia	3	Various
PP13B All (Count)	12	R Pelvis	14	R Humerus	11	L Humerus	6	R Tibia

	Size 5		All Sizes (Overlap)		All Sizes (Count)	
LB Sand 1 (1)	1	L Metacarpal	3	Various	4	R Pelvis
Upper DB Sand/LC-MSA Upper (2)	1	Various	6	Various	10	R Scapula
SB Sand/Upper RS(3)	1	Various	9	L Radius	12	L Radius
Lower RS (4)	1	Lumbar Vert	4	Various	5	Various
Lower DB Sand (5)	1	Various	4	L Humerus	6	L Humerus
LC-MSA Middle (6)	0	N/A	1	Various	2	L Ulna
LC-MSA Lower (7)	0	N/A	4	L Tibia	6	L Tibia
PP13B All (Overlap)	1	Various	16	L Humerus	20	Various
PP13B All (Count)	1	Various	24	Various	34	L Tibia

MNI counts are, as emphasized in the name, minimum estimates of the number of individual animals that are represented. However, even if owing to a small sample of excavated deposit this number is representative of only a tiny fraction of the individuals that have been transported all or in part to the site, it is still incredibly small when one considers the amount of time that is represented by the deposits and the caloric requirements of a group of hominins. Three possible implications follow from this: 1) that a massive amount of undocumented destruction of the fossils has taken place; 2) that site occupation was highly sporadic and indeed quite rare over the course of the accumulation of the deposits; or 3) that occupation was more consistent but transport of faunal resources to the site was not.

The following analyses make the assumption that if MSA hominins were in residence at PP13B, they would have exploited both plant and animal resources in the area, and they would have left traces of the latter in the form of fossil bones. It is important to keep in mind that because caves are good localities for fossils to both accumulate and be preserved, large amounts of deposit that might initially seem to represent an intensive or persistent occupation are likely in reality the remains of a great number of such events that involved transport of only small quantities or alternatively only a small number of individual transport events that involved large quantities.

The first possibility can be examined to some extent with refitting studies, although there will always be limitations caused by preservation, sample size, and time constraints. The second possibility can be partially assessed by examining hominin transport decisions apparent in the currently available dataset. This is because a whole-

animal transport strategy would more quickly result in the same number of fragments obtained over several periods of occupation in which a partial-animal transport strategy was operative. This pattern can be explored in more detail using patterns of skeletal element representation as represented by the MAU (Appendix E; Figure 20).

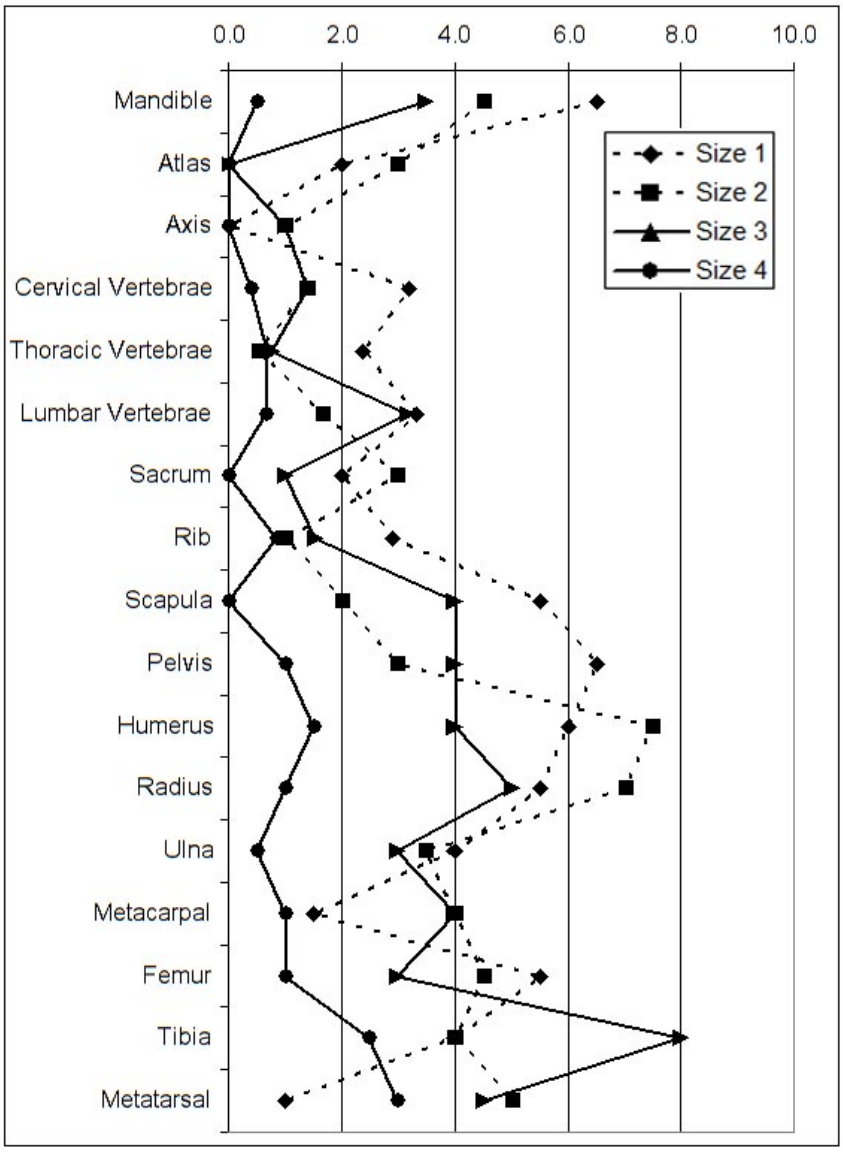


Fig. 20 MAU for all body sizes and analytical units at PP13B.

The overall MAU at PP13B shows some basic differences in the patterning of skeletal element abundances between body sizes. Size 1 - 3 ungulates show distinct peaks in representation, notably in the mandible and proximal limb elements (such as the humerus, radius, femur, and tibia). Of these, size 1 also shows a slight displacement in favor of girdle elements such as the pelvis and scapula. Size 4 ungulates show a very nearly even pattern of overall representation, which might initially suggest a whole-animal transport strategy for this body size class. However, the sample for size 4 ungulates is very small at PP13B and this pattern may be misleading and easily influenced by only a small number of individual transport events. After this overview, it is useful to break the data down further chronologically, as well as to simplify the presentation by showing small (size 1 and 2) and large (size 3, 4 and 5) ungulates as two groups (Figure 21).

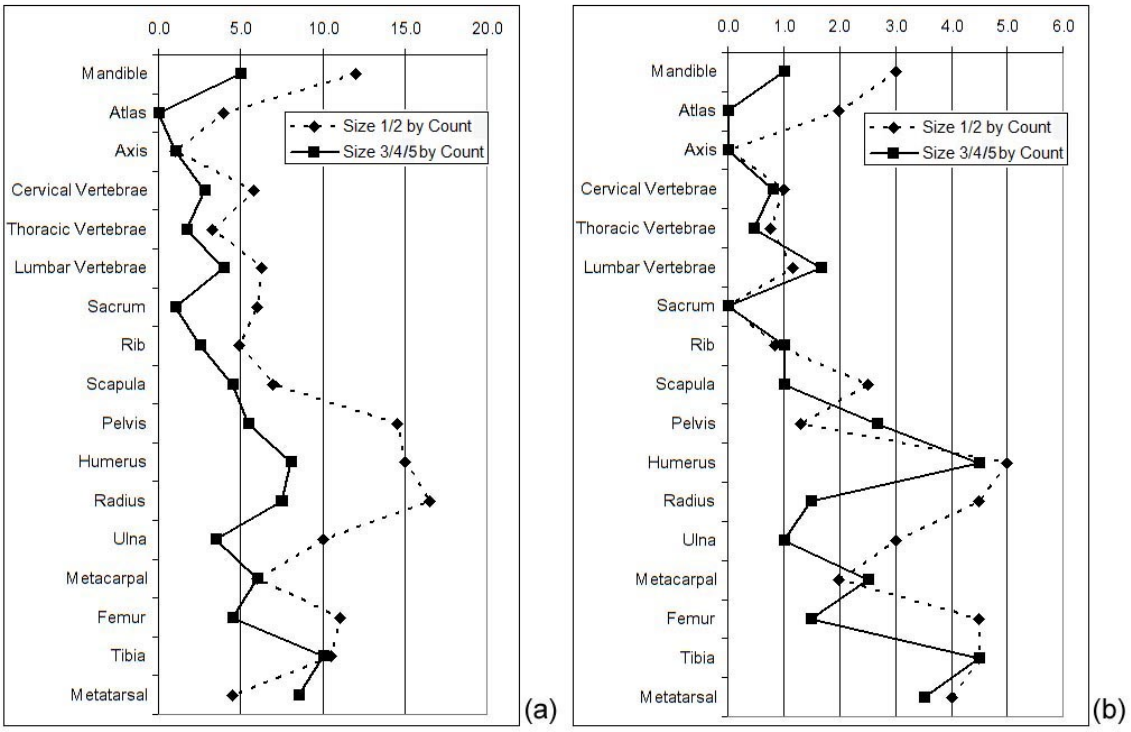


Fig. 21 MAU data from MIS 5 (a) and MIS 6 (b) showing patterns of skeletal element representation for small (size 1 and 2) and large (size 3, 4 and 5) ungulates.

Two things are apparent in Figure 21. First, the skeletal element representations of small and large ungulates tend to track one another closely. This suggests that transport strategies were similar for both large and small ungulates. The presence of head portions (as represented by the mandible) indicates that during both time periods this strategy included transport of complete or nearly-complete animals that had not had their heads processed off-site. However, differential transport does seem to be more apparent during MIS 6, as suggested by its jagged pattern of skeletal element representation.

It is interesting to note that the degree of whole-animal transport may have differed between time periods. Monahan (1998) synthesized a series of debates between

Bunn *et al.* (1988) and O'Connell *et al.* (1988, 1990) about carcass transport from two different groups of researchers who studied the Hadza in East Africa. Marean and Cleghorn (2003:28) summarized his findings as follows: "1) Size 1 and 2 animals are frequently transported completely or nearly completely; 2) Except for ribs, post-cranial axial elements are the most commonly transported elements; 3) Ribs and long bones are frequently discarded at the encounter site, and 4) Hadza try to maximize food transport and minimize transport weight by processing at the site those bones that are easily defleshed". The authors add that this pattern of selective transport for size 4 and 5 animals is slightly different, with the femur and humerus being more commonly transported because of a relative increase in food utility with larger body size for these elements.

At PP13B size 1 fauna is more common in MIS 5, and has a stronger hominin signature. Using the Hadza as an analogue it is expected that this size class should show less evidence of differential transport, but it does not logically follow that transport strategies as a whole should have shifted to also include larger fauna as seems to be apparent in the MAU patterning. One potential explanation for this is that hunting group size increased during MIS 5, and that this facilitated transport of whole animals that previously had to be partially processed off-site.

If this was the case, then it might be expected that during MIS 6 there should be a stronger relationship between the incidence of transport of a given skeletal element and its standardized food utility (SFUI; Metcalfe and Jones, 1988). Plots of %MAU versus SFUI provide a useful way to examine skeletal element transport decisions at PP13B.

However, before this analysis proceeds it is important to take into account the fact that the MNE estimates underlying the MAU values are based on data generated using a GIS image-analysis approach that has not previously been employed for such analyses (Marean *et al.*, 2001). Published accounts from DK1 provide a way to assess the potential differences in patterning that might result from this basic methodological issue. Figure 22 shows the plots of the %MAU versus SFUI for combined Layers 10 and 11 at DK1, exactly as presented in Marean *et al.*'s Figure 10 (2000b:222). The only difference is the underlying method of MNE estimation.

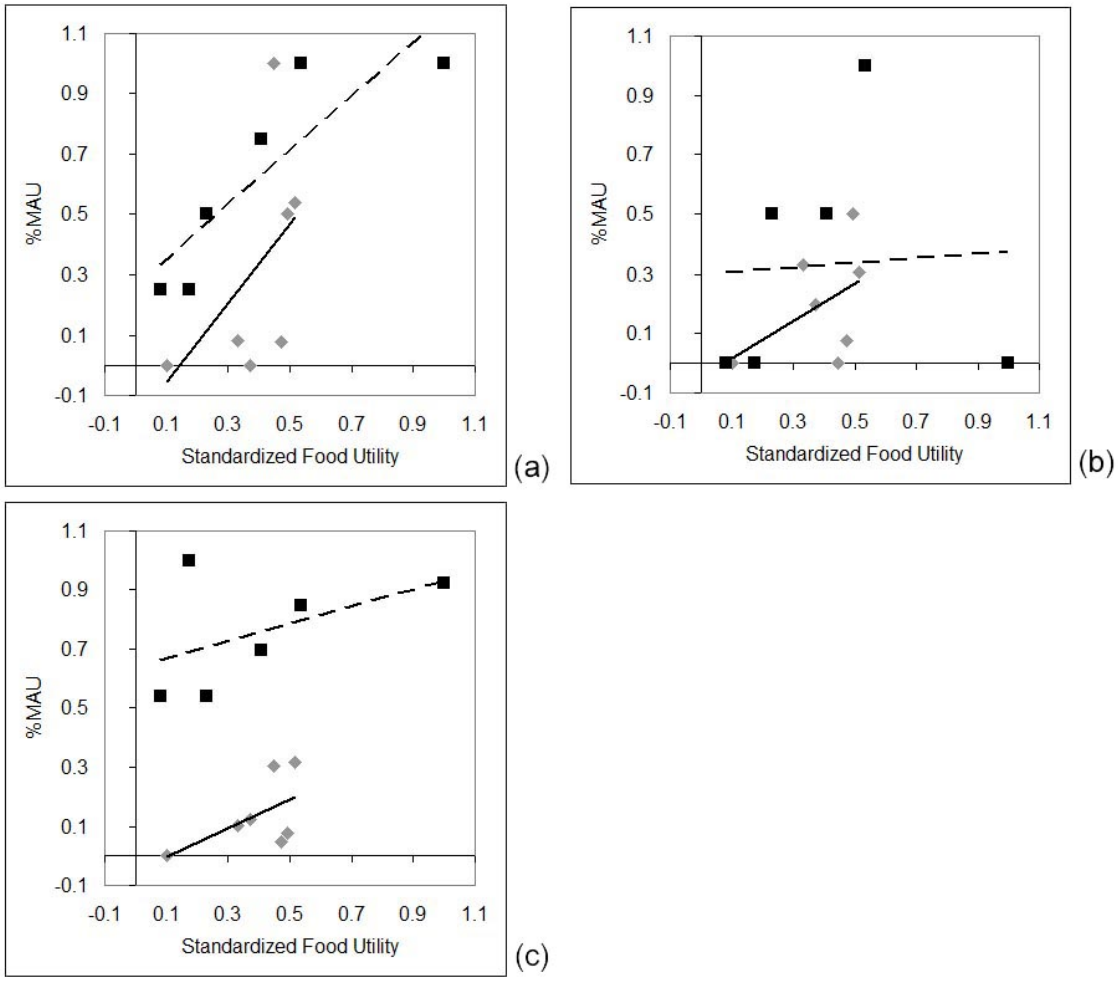


Fig. 22 %MAU versus SFUI at DK1 Layers 10 and 11.

The resultant charts (Figure 23) have two important differences from the published versions in Marean *et al.* (2000b). First, there is always a positive correlation between %MAU and SFUI for low-survival elements, while in Marean *et al.* (2000b) the correlation is negative or near-zero for this set of elements. Second, the relationship within the high-survival set for size 2 ungulates is much less tightly defined than in Marean *et al.* (2000b). However, in all cases the high-survival set still inhabits the upper

(more abundant) part of the graph, as would be expected given the degree of density-mediated destruction documented earlier.

These differences and similarities suggest that that the GIS method of estimating the MNE produces comparable results to the fraction-summation method underlying the data in Marean *et al.* (2000b:222). Furthermore, the GIS method potentially has a serious advantage in that it increases representation of the low-survival set enough to allow this set to be used in its own separate analysis of skeletal element transport – although it still cannot be reliably compared to the high-survival set.

However, some potential problems still exist. The criteria used in selecting which fragments went into the GIS were quite conservative, and for long bones included only ungulates from a particular body size and layer. In contrast, vertebrae and ribs are much less-easily identified to this level and all mammal fragments that fit the other criteria were used. This slightly reduced sample for long bones has made the %MAU more sensitive in the high-survival set to relatively minor differences in representation between elements. The pooling of layers, body sizes, and analytical units into larger datasets may overcome this problem and provide a useful way to make large-scale behavioral comparisons. Also, the estimation approach used by Marean *et al.* (2000b) produced MNE values for elements such as the phalanges, carpals, tarsals, and skull whereas the current form of the GIS system does not provide for this. Therefore, where each individual element falls on the graph will have a greater influence on the overall patterning (positive, negative, or otherwise) than it would in the plots used by Marean *et al.* (2000b).

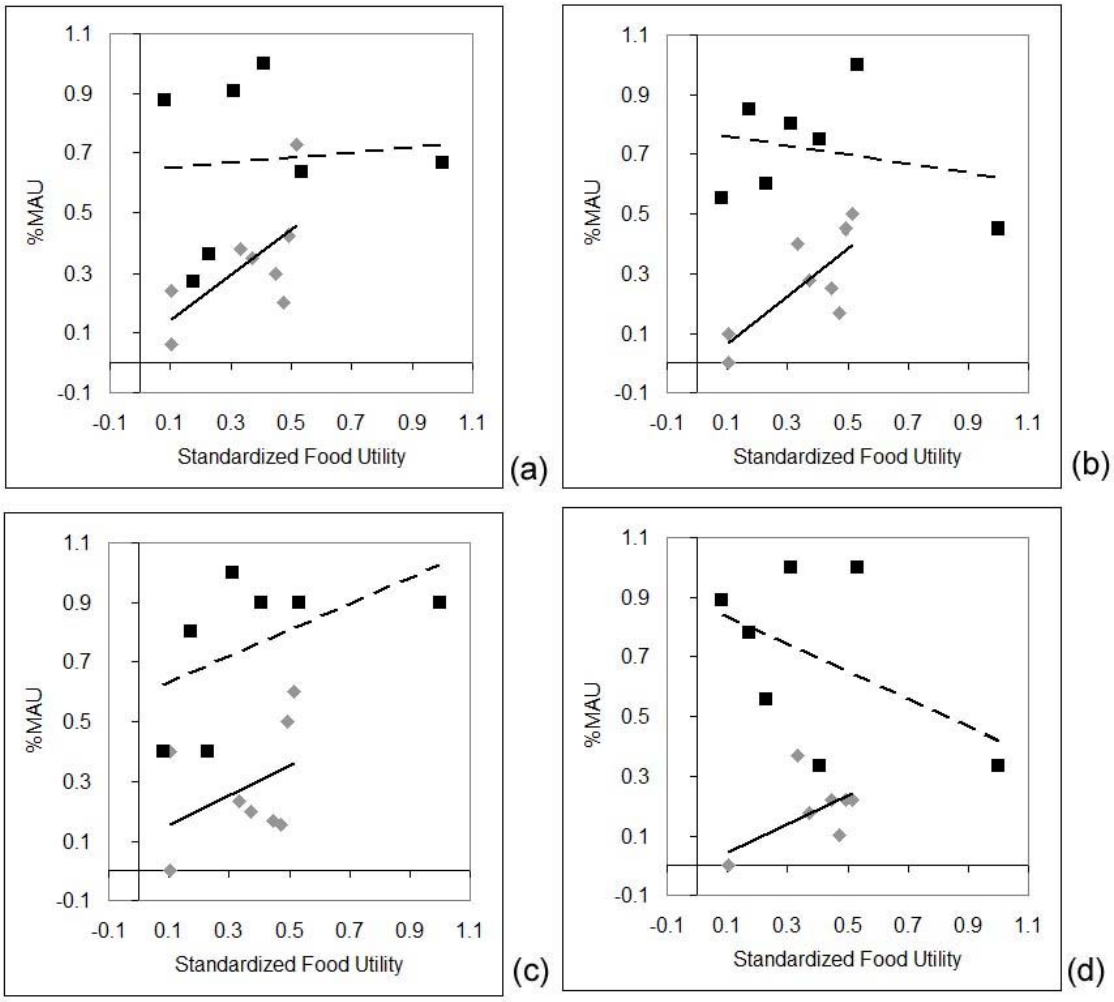


Fig. 23 %MAU versus SFUI in for small (size 1 and 2) and large (size 3, 4, and 5) ungulates in MIS 5 (a and b, respectively) and MIS 6 (c and d, respectively).

As with the DK1 data from Layers 10 and 11, the high-survival set at PP13B resides in the upper portion of the graph while the low-survival set occupies the bottom. Despite their low abundances, positive correlations between %MAU and SFUI are apparent in the low-survival sets for all body sizes in both MIS 5 and MIS 6, while there are differences in the high-survival set between large and small ungulates. Thus, in contrast to the initial patterning suggested by the MAU data there seems to be no

discernable difference in transport strategies between MIS 5 and MIS 6. Furthermore, the tendency for large ungulates in the high-survival set to show selective transport in accordance with *reverse* utility is not what would be expected given the Hadza model.

In previous studies where a negative correlation with utility was observed, it was taken as an indication that hominins were scavengers who only had access to lower-utility elements (e.g. Binford, 1984, 1988b). In the PP13B data, the consistently positive correlation in the low-survival set argues against this. Instead, both sets appear to have been transported in accordance with their relative food utility for small ungulates, while for larger body sizes the limb bones (which comprise the majority of the high-survival set) were subject to a different set of transport 'rules' than axial elements (most of which fall within the low-survival set). Axial elements appear to have been transported in accordance with their utility, and indeed they comprise the highest-utility elements in the skeleton (Metcalfe and Jones, 1988). In contrast, long bones appear to have been processed off-site in accordance with their utility and the remainder transported.

One issue with the plots of %MAU versus SFUI is that the regression lines for the high-survival sets are based on quite a wide scatter of datapoints. It is therefore useful to examine the strength as well as the direction of the correlations qualitatively assessed from Figure 23. In general, very few significant correlations are seen in the high-survival datasets, while low-survival elements show a much more robust relationship between skeletal element abundance and food utility (Table 8). This was also the finding of Marean *et al.* (2000b) at DK1, where none of the patterning in the high-survival sets was statistically significant below the $\alpha = 0.05$ level, and the only significant correlation

found was in the low-survival set (although their result was a negative one). This suggests that there may be pattern at MSA sites where the high-survival set simply does not show enough variability in food utility within itself to pick up on hominin transport patterns – a concern that was first broached by Marean and Cleghorn (2003).

Faith and Gordon (2007) have argued that the potential problem of restricting analyses to the reduced sample of high-survival elements is not insurmountable. They found that within the high-survival set a variety of transport strategies can be reliably discerned using a combination of the Shannon Evenness Index and Spearman's Rho for correlation. This further provided a quantitative way to assess how closely plots of the %MAU versus SFUI in an archaeological assemblage resembled one of the three transport strategies originally described by Binford (1978). Unfortunately, the restrictions of using only the high-survival set results not only in a reduced number of potential datapoints on the graph but also a much-reduced sample size overall. Faith and Gordon (2007) showed that the incidence of statistical error is most dramatically increased when a sample of fewer than 50 skeletal elements is input into the analysis. At PP13B the MAU in the high-survival set from MIS 5 is just slightly above this threshold, at 85.5 elements from small fauna and 53 elements from large fauna (Appendix E). The high-survival sample from MIS 6 falls below this threshold for both small (n = 30.5) and large (n = 20) fauna. The preceeding analyses are therefore not subjected to further statistical evaluation with the current sample size.

Table 8

Spearman's Rho and p-values for the strength of the correlation between %MAU and Standardized Food Utility at PP13B.

	Group	Body Size	Spearman's Rho	p-value
MIS 5	Low-Survival	1	0.7831	0.0215
	High-Survival	1	-0.0714	0.8791
	Low-Survival	2	0.2364	0.5730
	High-Survival	2	0.5189	0.2328
	Low-Survival	3	0.6386	0.0884
	High-Survival	3	0.0364	0.9383
	Low-Survival	4	0.2454	0.5580
	High-Survival	4	0.2182	0.6383
	Low-Survival	1/2	0.6484	0.0821
	High-Survival	1/2	0.1622	0.7283
	Low-Survival	3/4/5	0.4865	0.2683
	High-Survival	3/4/5	-0.0182	0.9691
MIS 6	Low-Survival	1	0.2470	0.5554
	High-Survival	1	0.9449	0.0013
	Low-Survival	2	0.8121	0.0143
	High-Survival	2	0.0909	0.8463
	Low-Survival	3	0.6545	0.0782
	High-Survival	3	-0.1684	0.7181
	Low-Survival	4	-0.1510	0.9045
	High-Survival	4	-0.1836	0.6936
	Low-Survival	1/2	0.6252	0.0938
	High-Survival	1/2	0.6736	0.0971
	Low-Survival	3/4/5	0.1497	0.7487
	High-Survival	3/4/5	-0.2546	0.5817

Although few strong or significant correlations were observed, this is not entirely unexpected. After separation of the skeletal elements into the high- and low-survival sets only small samples remained for input into the analysis. Even using Spearman's Rho, which is less susceptible to such influences, random variables affecting representation of a single element can still have a heavy influence on the overall regression. It is therefore

useful to look more closely at the representation of individual skeletal elements relative to the general pattern – particularly in light of the contrasting views on what is expected for metapodial representation.

For each set of MAU data the mean and standard deviation was determined. This was done separately for the high- and low-survival groups. A z-score was then calculated for each skeletal element so that its individual representation, in terms of standard deviations from the mean, could be examined relative to other elements in the set (Figure 24). Points falling above the dashed line are represented more often than the mean and points falling below the dashed line are represented less often than the mean.

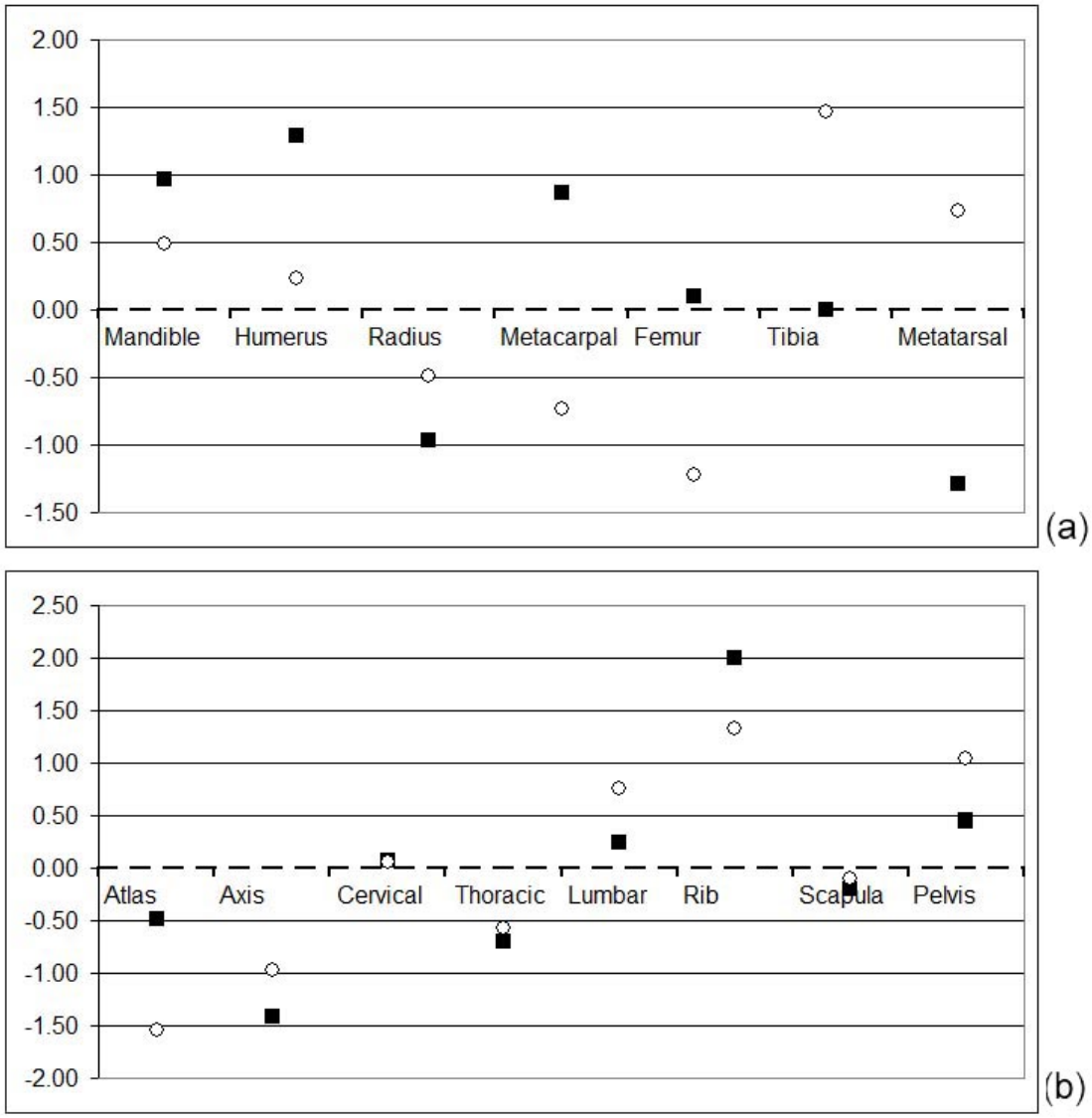
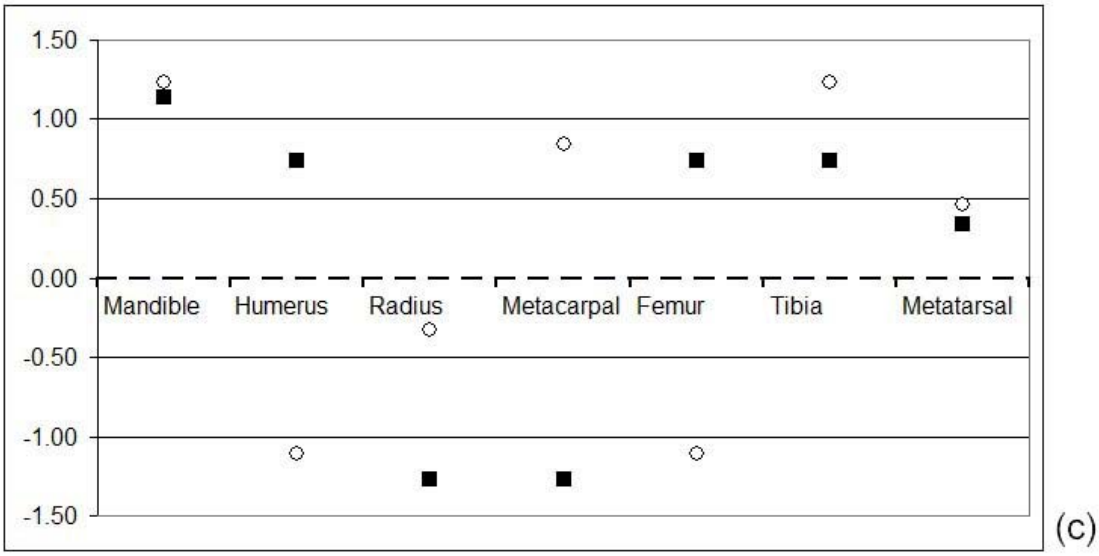


Fig. 24 Z-scores for the MAU of small (size 1 and 2, black boxes) and large (size 3, 4, and 5, open circles) ungulates during MIS 5 at PP13B. High-survival elements (a) are plotted separately from low-survival elements (b).



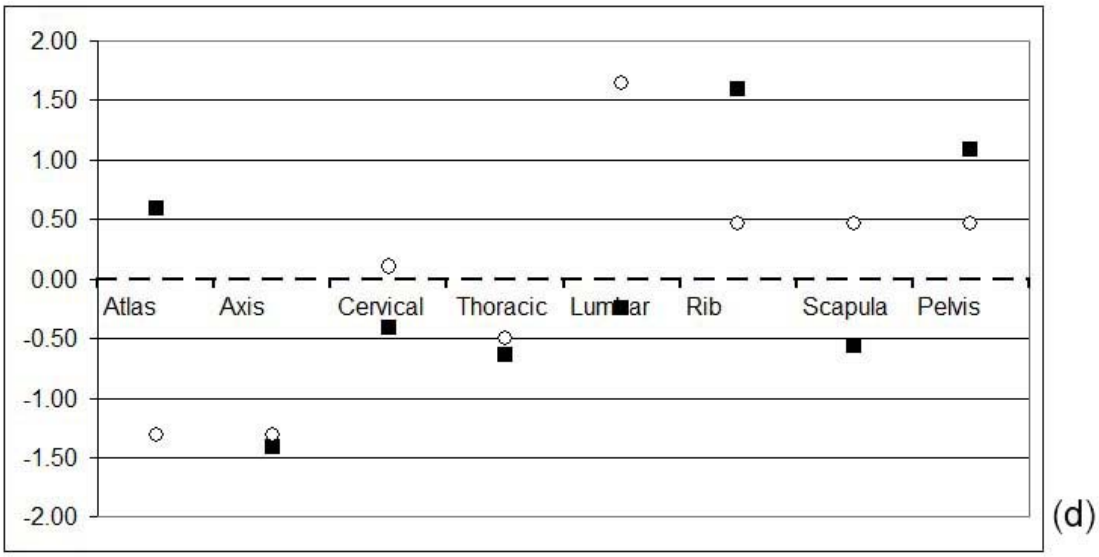


Fig. 24 (cont.) Z-scores for the MAU of small (size 1 and 2, black boxes) and large (size 3, 4, and 5, open circles) ungulates during MIS 6 at PP13B. High-survival elements (c) are plotted separately from low-survival elements (d).

Within the high-survival set, there is no obvious pattern in overall metapodial representation in either MIS 5 or MIS 6. Instead, what appears to be driving the negative correlations observed in large ungulates during both time periods is a relative lack of

representation for the femur, which is the highest-ranked long bone by SFUI. The tibia, which is the highest-ranked UMI long bone, has an average or well above average representation for both body size categories and both time periods.

In general, the z-scores are not particularly revealing of any preference for proximal versus distal limb elements, fore- versus hind-limb elements, or even axial versus girdle elements. However, there are two interesting cases that should be discussed. The consistently well-represented ribs are unexpected in light of the Hadza model, which predicts that they should be more commonly left behind at kill sites (Monahan, 1998; Marean and Cleghorn, 2003). Also, as suspected, a single element (the femur) is likely influencing the robusticity of the statistical relationship in the high-survival set – particularly for large ungulates in MIS 5.

Even disregarding the influence of the femur, the general pattern still appears to be one in which long bones were not transported with strict accordance to their food utility or even with regard to marrow quality. This could indicate one of two things. First, it may be that decisions regarding individual kill and transport events are so disparate that when accumulated over time the residues of these events become too murky to decipher. This has been observed even over a single season for modern Hadza assemblages, where large camps show very little patterning in skeletal element representation with regards to what was originally transported and small hunting stands where snack bones are discarded tend to preserve these behaviors much more clearly (Lupo, 2001). Since archaeological sites such as PP13B represent in many ways an

extreme version of such time-averaging, this effect has certainly been the case to some extent.

The abundance of long bones at the site, as a result of their high resistivity to density-mediated destruction, does not mean that they were originally well-represented at all. In fact, the transport and discard of a single limb element once per year would be more than sufficient to result in the accumulations we see at the site today. There is little evidence in the high-survival set to indicate that selective transport was extensive or that whole-animal transport was the norm. Given the domination of long bone fragments at the site, this suggests that the pattern of accumulation of the fossils at PP13B was the sum result of both strategies. Even a span of a few years, which can represent substantial variability in hunting success, would be undetectable in the MSA record and this appears to have been the result at PP13B.

However, a consistent indication of active carcass portion choice in the low-survival set suggests that the discussion should go farther before conceding to the limitations of the archaeological record. Among the Hadza, long bones were among the first to be discarded at the encounter site when a choice had to be made between which elements to transport (Marean and Cleghorn, 2003). If MSA hominins were frequently faced with these decisions, then we would not necessarily expect the occasionally-transported long bones to show a positive correlation with food utility. Thus a second possibility for the pattern seen at PP13B is that when making transport decisions MSA hominins at PP13B did not consider the relative utilities of limb units.

The lack of a positive correlation between representation and food utility in the high-survival group could easily be explained by a pattern of consumption and discard of different long bones at different encounter sites over time and subsequent transport of the higher-utility axial portions that require more extensive processing. This would be particularly true if spongy elements were further processed for grease, as Marean and Cleghorn (2003) have pointed out that even the removal of small pieces of flesh from the interstices of vertebrae and ribs requires extra effort.

Finally, it is unknown to what extent the underlying social and behavioral factors that structured MSA food transport decisions are mirrored in the behavior of the Hadza, which comprise the major available dataset for ethnoarchaeological reference. The Hadza transport data are based on a scenario in which kills are brought back to a central place, and where there are varying group sizes available to transport these kills. If the foraging group sizes for MSA hominins differed dramatically from those in the Hadza, then this model is not as useful for understanding skeletal element transport as it might initially appear. Furthermore, there may be a disjoin between the way in which archaeologists commonly perceive of caves as central places and domestic sites and the way in which they were actually used during the MSA. If PP13B was not a place to which MSA groups commonly returned immediately after a successful hunt, the Hadza model would not be an appropriate analogue for the expected patterning in larger ungulates.

There are a lot of variables that go even into modern human transport decisions that are effectively unknowable in the archaeological record (Marean and Cleghorn,

2003). For example, there is currently no way to reconstruct the size of the group available to transport elements, the duration of time spent at the butchery site, or the distance between the kill and the transport site. Indeed, the only truly certain factor is that the caves considered here were the transport sites and never the kill sites (though the kill sites may have been very nearby). The various stages of processing could theoretically have taken place at any point in between the two localities.

Having said this, the abundance of percussion marks and bone flakes, which is discussed in more detail later, do provide a measure of certainty that long bones were transported to PP13B with the marrow intact and that some processing occurred on-site. Taken altogether, the situation at PP13B fits a scenario in which nutrients surrounding the more-easily processed long bones were partially processed, consumed, and discarded at the encounter site but in different ways for each individual carcass acquisition event. Axial elements that required further processing seem to have been transported in accordance with their food utility – with this being true for ungulates of all body sizes.

Outside-bone nutrient extraction

At PP13B the primary accumulator of most of the ungulates has been shown to be MSA hominins – particularly for the larger ungulates. When examining the incidence of cut-marking throughout the ungulate skeleton at PP13B, it is therefore assumed that the locations of the marks are the result of conscious decisions by the MSA butchers to process a *complete* carcass in a particular way. Nilssen (2000) observed the actions of modern butchers as they disarticulated and filleted various skeletal elements and then recorded the types and placements of the resultant cut marks. Although there was some

variation, he discovered that there were certain placements that could be reliably attributed to a particular action for all body size classes (Nilssen, 2000:159). The locations of these marks in the PP13B assemblage are shown in Figure 25.

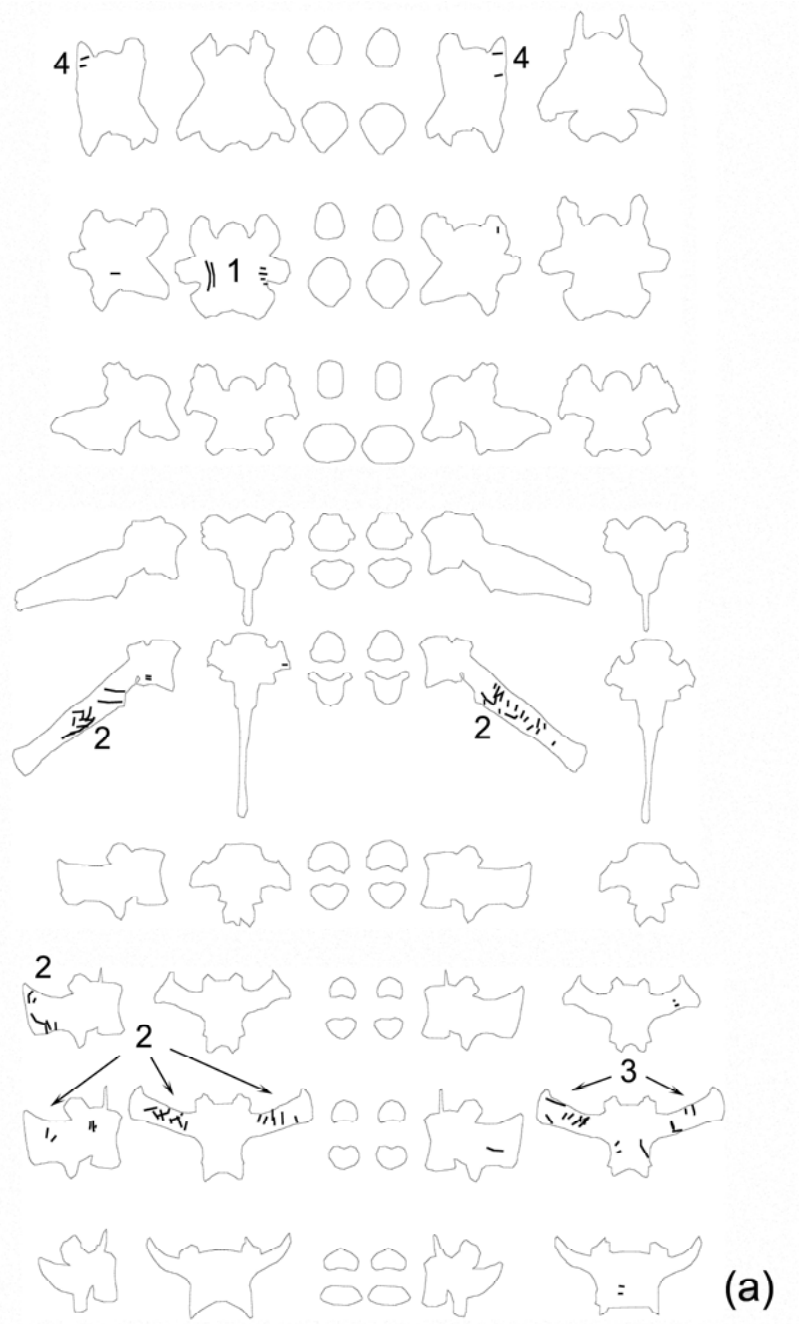


Fig. 25 Locations of cut marks and behavioral correlates on vertebrae from PP13B.

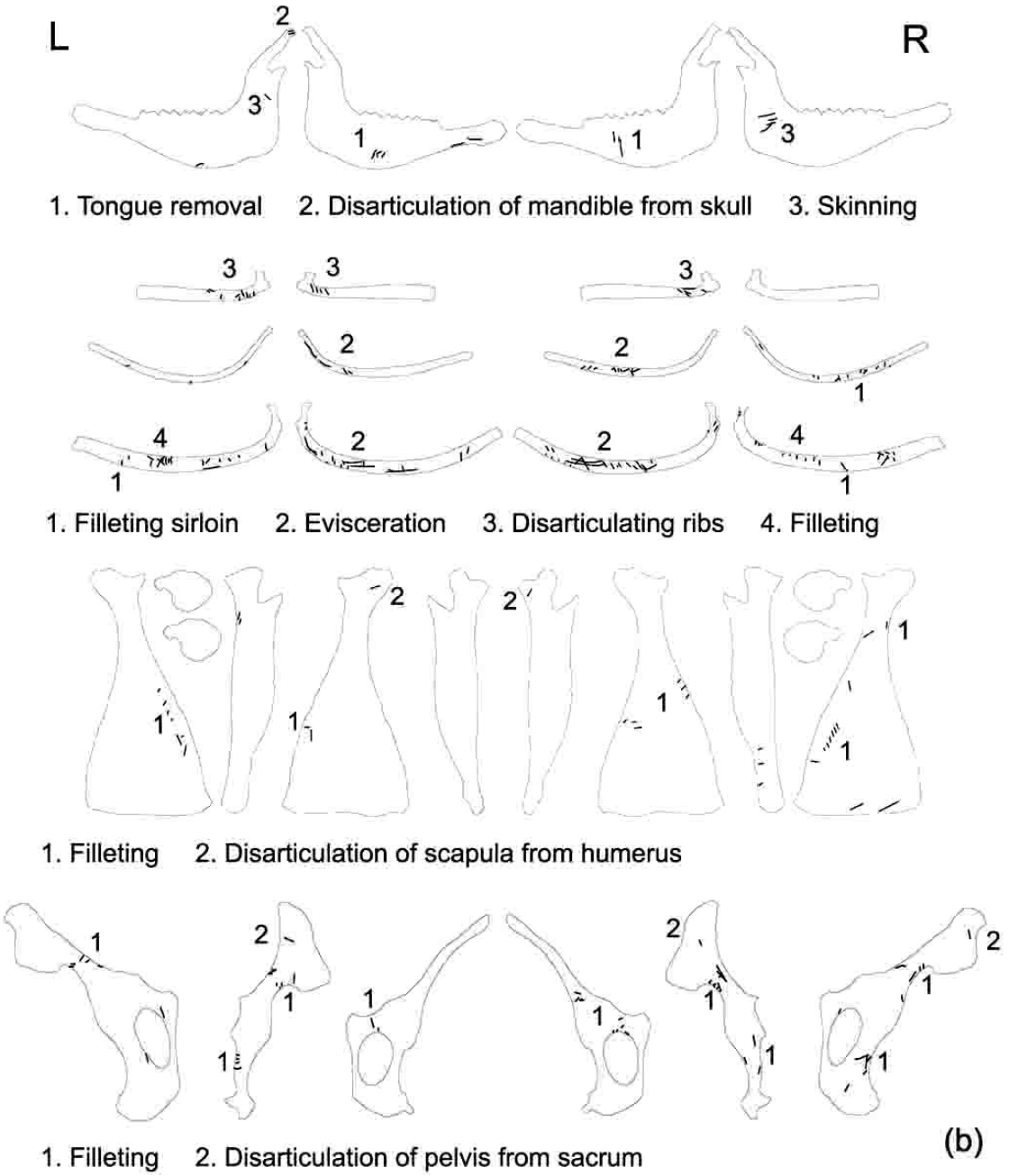


Fig. 25 (cont.) Locations of cut marks and behavioral correlates on non-long bones from PP13B.

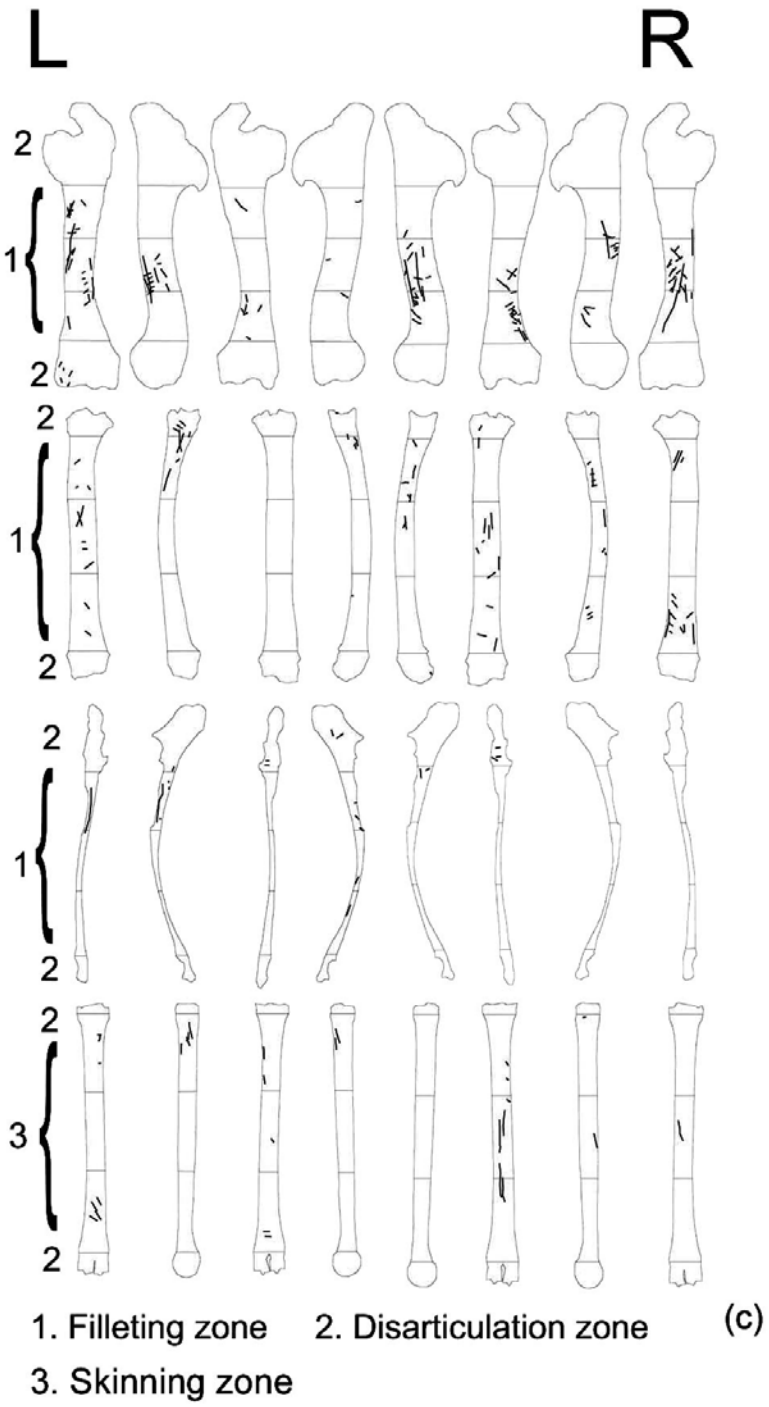


Fig. 25 (cont.) Locations of cut marks and behavioral correlates on forelimbs from PP13B.

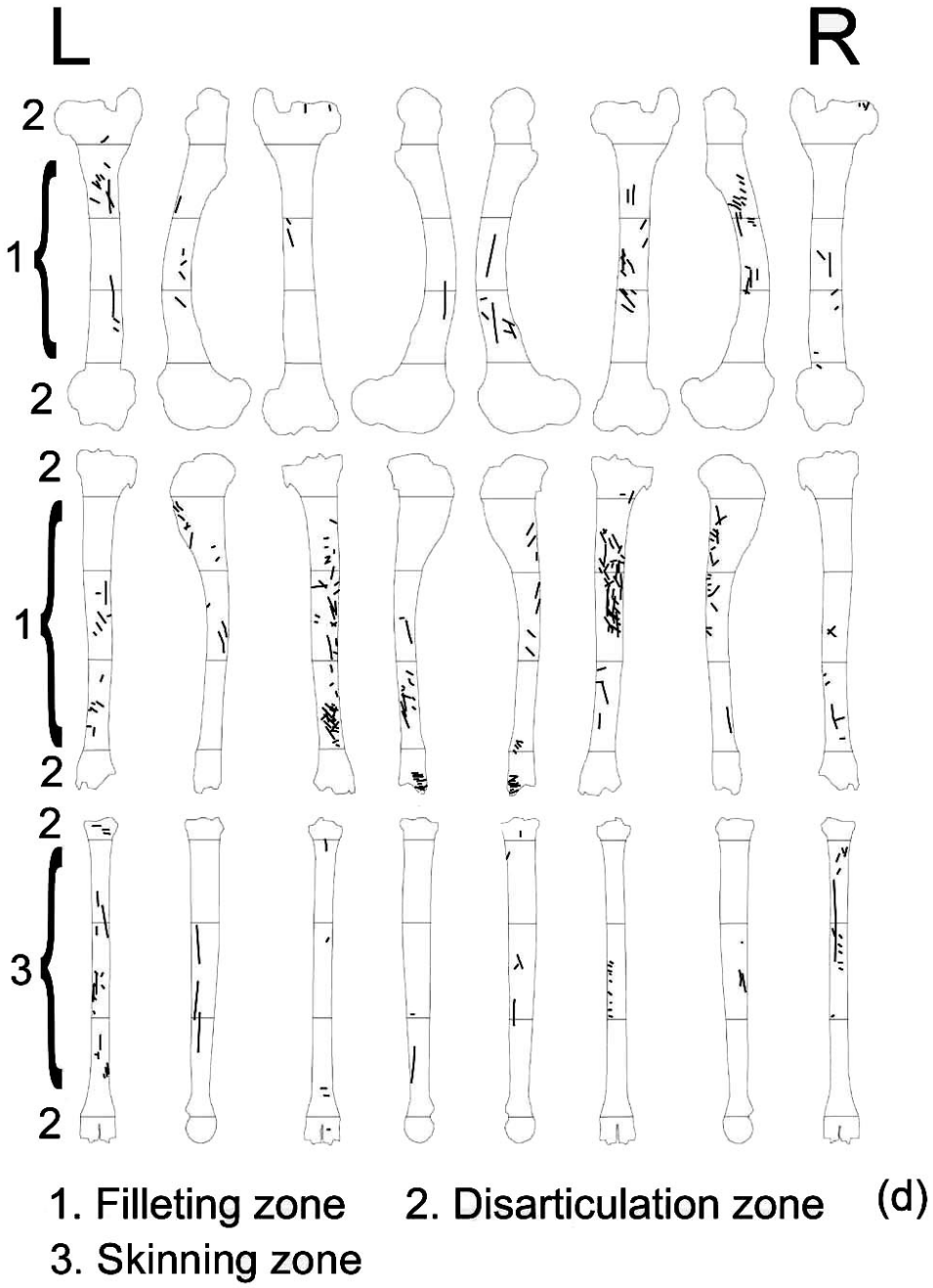


Fig. 25 (cont.) Locations of cut marks and behavioral correlates on hindlimbs from PP13B.

A variety of actions are implicated by the positions of the cut marks, including evisceration, skinning, disarticulation, and filleting of various cuts of meat. This is all in

support of the assumption made above, that MSA hominins had access to entire carcasses and were confronted with a series of decisions about how to divide them up for consumption. A general sequence observed in modern humans can be reasonably applied to these actions (e.g. Binford, 1978; Nilssen, 2000). First, the skin would have been initially opened along the ventral midline of the prey, resulting in the evisceration marks seen on the ribs. At some point that was likely early in the sequence the skin was removed, both at the head and at the metapodials. The major muscle groups of the back and limbs were removed, and the vertebrae were disarticulated – although infrequently. The mandible was also disarticulated from the skull at some point during the process, and the tongue removed.

Although most marks on long bones are predominately located along the shaft, there is evidence for disarticulation in the positions of cut marks at the epiphyseal ends of long bones and on the pelvis and scapula. However, the general sequence and the degree to which disarticulation is emphasized can only be qualitatively evaluated using the cut mark maps alone. Abe *et al.* (2002) have proposed a quantitative way to asses the patterning of cut marks across long bones from archaeological contexts and compare them to patterns seen in Nilssen's (2000) ethnoarchaeological study. The two strategies being evaluated by Abe *et al.* (2002) were one in which disarticulation preceded filleting, and one in which only the filleting of meat was the main goal of the butcher. In the study by Nilssen (2000) the former was primarily for the division of carcass segments for the production of different cuts of meat, while the latter was focused on filleting of meat for drying.

Abe *et al.* (2002) divided each major long bone into five portions: proximal end, proximal shaft, midshaft, distal shaft, and distal end. They showed that a disarticulation-to-filleting strategy should result in a greater relative proportion of cut marks on long bone epiphyses than would a filleting-only strategy, and that the overall distribution of marks across these zones can be diagnostic of the primary butchery strategy under which the marks were created. Because epiphyses (and the disarticulation marks they bear) are expected to be less well-represented at archaeological sites that have undergone density-mediated destruction, it is critical to first correct for this factor. Abe *et al.* (2002) divided the number of marks occurring on a given portion by the preserved surface area of that portion, and arrived at a corrected number of cuts per bone portion that would be expected to occur on a whole bone.

Adjusted proportions of where cut marks occur on the major long bones are provided in Appendix G. Because all percentages for each element add to a total of 100%, at least some area had to be represented in each zone in order for them to be calculated. Elements for which all zones were not present at least to some extent are therefore represented with a '-', whereas elements portions on which no cut marks occur, despite at least some representation of that portion, are indicated with a 0%. Raw numbers of marks per portion are provided in Appendix F. The adjusted values, scaled to 100% of the total marks on the bone, are shown in comparison to the two ethnoarchaeologically-documented strategies in Figure 26. The datasets have been divided into small and large ungulates, and between MIS 5 (on the left) and MIS 6 (on the right).

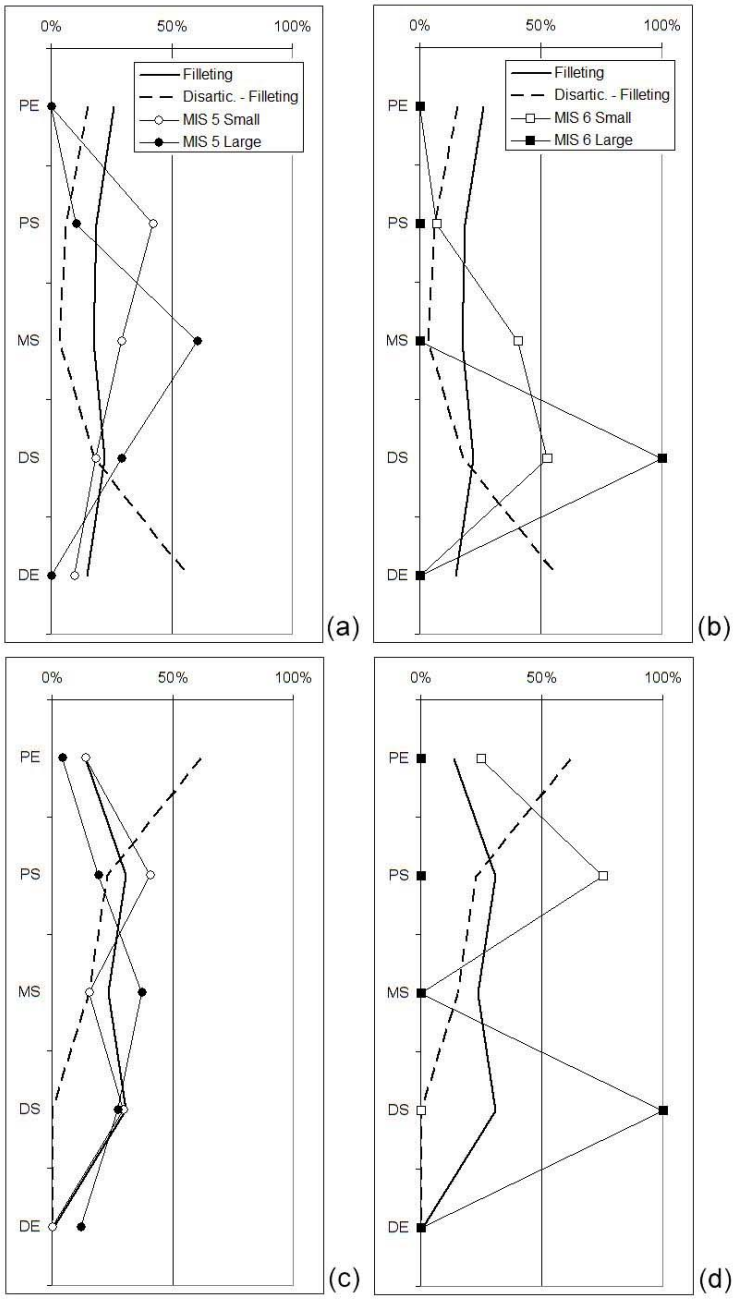


Fig. 26 The distribution of cut marks for small (size 1 and 2) and large (size 3, 4 and 5) ungulates across long bone zones for the humerus (a,b) and radius (c,d), during MIS 5 and MIS 6, respectively. PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

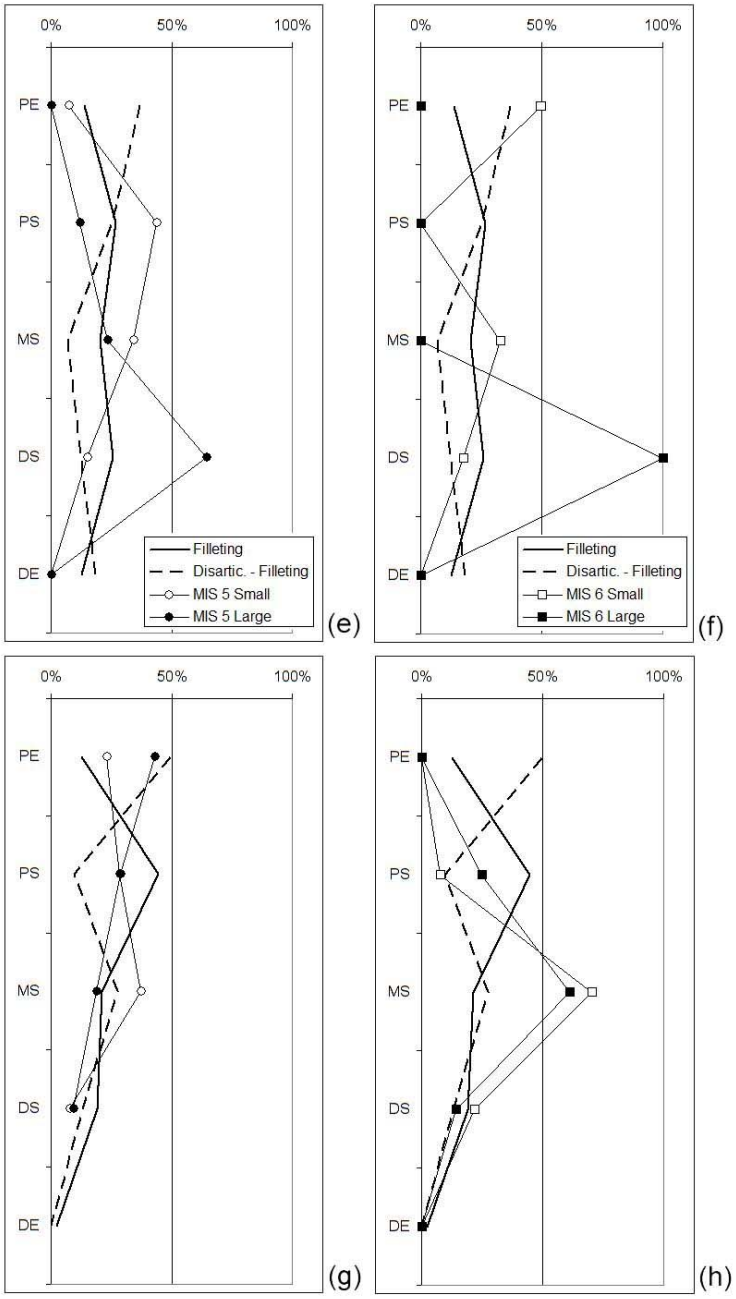


Fig. 26 (cont.) The distribution of cut marks for small (size 1 and 2) and large (size 3, 4 and 5) ungulates across long bone zones for the femur (a,b) and tibia (c,d), during MIS 5 and MIS 6, respectively. PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

Some interesting differences between the treatment of small and large ungulates seem apparent during both time periods. In general, small ungulates have a more even distribution of cut marks along the long bones or even a tendency for them to cluster closer to the proximal shaft, while large ungulates have a noticeably heavy distribution of these marks near the mid and distal shaft. However, in general, none of the distributions closely match either of the ethnoarchaeological patterns. A chi-squared test was used to assist with interpretation of the visual data by determining if there was a significant difference between the two variables of where on the long bone the cut marks occur and within what dataset they occur (ethnoarchaeological versus archaeological). The results are provided in Table 9.

Table 9

P-values from chi-squared tests determining if the difference is significant between the distribution of cut marks across each major long bone at PP13B and what would be expected for a filleting or a disarticulation and then filleting butchery strategy.

		Filleting			Disartic. - Fillet.		
		X^2	D. F.	p-value	X^2	D.F.	p-value
MIS 5 Small	Humerus	6.153	5	0.2916	18.004	5	0.0029
	Radius	0.387	5	0.9957	4.712	4	0.3181
	Femur	4.012	5	0.5477	12.950	5	0.0239
	Tibia	2.235	5	0.8157	9.638	5	0.0862
	All	37.535	20	0.0103	59.603	19	<0.0001
MIS 5 Large	Humerus	11.201	5	0.0475	22.273	5	0.0005
	Radius	2.597	5	0.7619	8.466	5	0.1324
	Femur	11.919	5	0.0359	31.359	5	<0.0001
	Tibia	2.689	5	0.7478	10.218	5	0.0693
	All	36.837	20	0.0132	75.982	20	<0.0001
MIS 6 Small	Humerus	16.827	5	0.0048	28.604	5	<0.0001
	Radius	3.790	5	0.5801	3.511	3	0.3193
	Femur	7.619	5	0.1785	8.665	5	0.1232
	Tibia	7.277	5	0.2009	9.003	4	0.0610
	All	48.746	20	0.0003	67.424	17	<0.0001
MIS 6 Large	Humerus	6.539	5	0.2572	7.713	5	0.1728
	Radius	N/A	N/A	N/A	N/A	N/A	N/A
	Femur	N/A	N/A	N/A	N/A	N/A	N/A
	Tibia	7.976	5	0.15756	16.915	4	0.0020
	All	89.677	20	<0.0001	87.751	17	<0.0001

Where no statistical differences can be found, the placements of cut marks on the fossils are taken to be indistinguishable from the signature left by the strategy to which the archaeological sample is being compared. For example, a statistically significant difference was found between the disarticulation-then-filleting (D-F) strategy and small ungulate humeri of MIS 5, whereas no significant difference was found between the filleting only (FO) strategy and the same archaeological dataset. This is interpreted to

mean that a D-F strategy was not employed for small ungulate humeri during MIS 5, but that an F-O strategy may have been.

The two strategies under comparison here were only defined by Abe *et al.* (2002) for size 3 and 4 ungulates. However, Nilssen (2000) notes that although variability exists in his dataset, the placements of many marks can still be reliably linked to a specific butchery behavior. Defleshing marks on the shafts of long bones and disarticulation marks on the epiphyses are among these diagnostic marks, although it is possible that their relative proportions may differ between small and large ungulates.

In almost all cases, a bone-by-bone comparison shows no significant difference from a F-O strategy and the locations of cut marks across the fossil dataset. This changes when all bones are pooled together, which suggests that although the complete long bone assemblage may not mirror Nilssen's (2000) ethnoarchaeological data, most bones when taken individually do not show a distinguishable difference. In contrast, several of the individual long bones did show statistically significant differences between the D-F strategy in addition to the complete assemblage showing such a difference. This strongly indicates that disarticulation marks clustered about the long bone epiphyses are extremely rare in all datasets at PP13B – despite adjustments having been made for preserved surface area.

The sum of this evidence indicates that a filleting strategy was the primary goal of MSA butchers for both small and large fauna. There is some indication that larger fauna were treated somewhat differently, but a filleting pattern still dominates all portions of the assemblage. The carcass transport data suggested that long bones were not

transported in accordance with their utility, and the paucity of disarticulation marks shows that transported long bones were not often subjected to intensive disarticulation procedures. Together, these data indicate that entire limb segments were likely transported to PP13B during both MIS 5 and MIS 6, and indeed these segments may have been attached to complete animals.

Within-bone nutrient extraction

Speth and Spielman (1983) have shown that in carbohydrate-poor environments fats are a critical source of energy for human groups. Bones contain two potential sources of fat: bone marrow and bone grease. The former is relatively easy to access with the aid of hammerstones, but bone grease extraction can be a time-consuming and intensive process. Given a strategy that reduces the overall cost of processing bone grease, this resource can become a valuable addition to a diet – particularly in groups that may be experiencing stress or heavy fluctuations in food resources. Carnivores process bone grease by ingesting spongy bone and extracting the nutrients in the gut (Marean and Spencer, 1991), while modern human groups boil these portions to access the grease.

Bone boiling increases the overall nutritional value that can be gleaned from a carcass in two ways: it taps a source of fat that would be otherwise inaccessible and it shortens the lengths of fatty acid chains, resulting in greater digestibility (Wandsnider, 1997). This strategy is a critical survival tool in highly seasonal environments, particularly in environments that are very cold or arid for large parts of the year (e.g. Bonnichsen, 1973; Vehik, 1977; Binford, 1978; Helm, 1993). The practice also extends into more temperate and even tropical and subtropical environments. In Africa two well-

studied hunter-gatherer groups in which the practice has been documented are the modern Hadza of Tanzania (Lupo, 1995) and the !Kung San of Botswana (Yellen, 1991).

Archaeological criteria used to infer bone boiling have ranged from the selective transport of grease-rich elements or portions of elements (Lupo and Schmitt, 1997), to the intensity of fragmentation and fracture patterns (Outram, 1999, 2001; Munro and Bar-Oz, 2005; Nagaoka, 2005), to the association of small fragments of cancellous bone with fire-cracked rock (Madsen *et al.*, 2006), and the recovery of low-ranked spongy fragments from in situ pits (Logan, 1998) or secondary dumps from such pits (Chomko and Gilbert, 1991). At many European Upper Paleolithic sites, large quantities of fire-cracked rock have also been used to infer that hot rock technology, and therefore possibly bone boiling, was in use (Marean and Assefa, 1999; Stiner 2003). However, there is little evidence prior to this for when such an intensive and important grease extraction strategy first became a part of the modern human behavioral repertoire.

Marean (2005) has argued that Neandertals did not have bone boiling technology, but that grease extraction in some form was essential for living in the harsh, seasonal, and low-productivity environments of glacial Europe. He used several lines of evidence to conclude that Neandertals used hammerstones to crush spongy bone and then swallowed the fragments to extract the grease from the bone internally. Two of the test implications for this behavior are: 1) Extensive fragmentation of spongy bone and correspondingly very low ratios of cancellous: medullary long bone portions; and 2) High proportions of percussion-marking on spongy bone, including long bone epiphyses. Marean (2005) asserts that both test implications are met at Neandertal sites relative to early modern

human sites from South Africa, as DK1 does not show the same degree of spongy bone impoverishment or heavy fragmentation as is found at Neandertal sites in the Zagros Mountains of Iran. However, this has not been quantified or examined in any detail.

It initially seems unlikely that bone boiling was employed during the MSA, given that there are no obvious receptacles for this and that fire-cracked rock is not reported from MSA sites in any abundance. However, fire-modified rock is present at many sites and receptacles may have been constructed of perishable materials. Rather than discount the possibility of boiling immediately, it is useful to explore the test implications proposed by Marean (2005) and determine if grease processing either by boiling or by swallowing may have been a part of the adaptive strategy of MSA hominins. This can be approached in several ways.

First, it is important to realize that it is not necessary to fragment cancellous bone prior to boiling in order to extract the grease (Thompson and Lee-Gorishti, 2007). Once the fats had been released from the bone the fragments would have been discarded on-site (rather than passed or regurgitated elsewhere), and in the same basic state of fragmentation as that in which they were boiled. However, in the absence of pots or other receptacles that can be placed directly in the fire it is extremely likely that spongy bone would have been fragmented first given that this reduces their boiling time by as much as one-half (Church and Lyman, 2003). Therefore, if either method was employed at the sites in this study, then the data should align with Marean's (2005) first test implication.

Again, zooarchaeologists are faced with a problem of equifinality. Carnivore scavenging of discarded human refuse is often cited as the culprit of spongy bone removal, and an experimental study of carnivore ravaging of boiled bone assemblages shows that up to 10 hours of continuous boiling of non-fragmented bones is still not enough to offset carnivore interest in freshly-boiled fragments (Thompson and Lee-Gorishti, 2007). Therefore, a relative impoverishment of spongy bone at a site may be attributable to either carnivore deletion of these portions or hominin fragmentation as suggested by Marean (2005).

However, Lupo (1995) found that at sites occupied by the Hadza, ravaging is reduced in assemblages to which carnivores did not have immediate access. This is true for both boiled and unboiled bones, indicating that the critical variable may not be how the fragments have been treated but rather how long they have been discarded in the open without carnivores having access to them. Although caves provide confined quarters from which human groups can keep carnivores from having the same scavenging opportunities, in these protected environments it would also be expected that bones would retain grease and therefore interest for carnivores long after these groups had left.

The second test implication would be expected if either swallowing or boiling was used to extract grease, as fragmentation by hominins for either purpose would result in hammerstone percussion marks on spongy portions.

The surface modification analysis indicated that a high degree of percussion activity was part of the overall butchery strategy at PP13B. Further evidence for a very intensive carcass processing strategy lies in the fact that it is not only long bone shafts that have

well-preserved percussion marks. Although 64% of percussion-marked fragments at PP13B are on long bone shafts, 27% are on near-epiphysis shafts of long bones, spongy bones such as pelves and ribs, and cranial bones (1% of the latter category are cranial). The remaining 9% of the marks occur directly on epiphyseal surfaces (Figure 27).

The plots of bone portion abundances versus density showed that spongy bone is definitely poorly represented. Extensive post-depositional fragmentation was not a major issue at any point in time at PP13B, so decreased identifiability owing to heavy post-depositional fragmentation cannot explain the pattern. This implies that these bone portions were either removed or heavily fragmented while they were in a nutritive state. The first test implication for extraction of bone grease as suggested by Marean (2005) is therefore fulfilled at PP13B but the cause of this lack of spongy bone cannot be reliably determined without additional evidence. Because percussion marks occur on spongy and epiphyseal portions in the assemblage, this is in accordance with the second test implication. It is now important to document the extent of this behavior and discuss its potential relevance to understanding grease processing strategies.

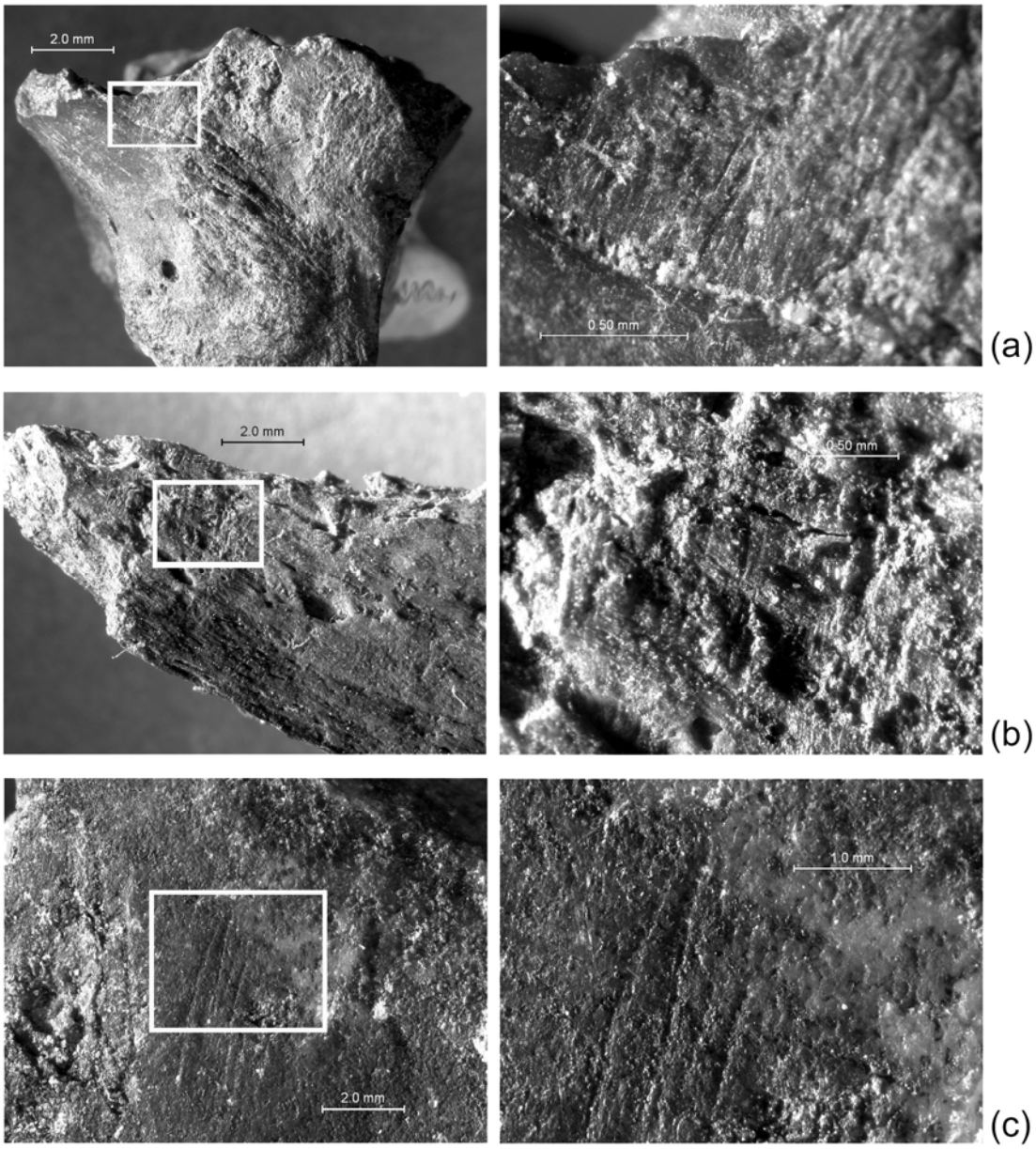


Fig. 27 Evidence for an intensive marrow-processing and grease processing strategy: percussion marks on a bovid second phalanx (a), a rib fragment (b), and a humeral epiphysis (c).

The standard use of percussion marks in zooarchaeology has been as an indicator of hammerstone percussion of long bones in order to access marrow (e.g. Blumenschine

and Selvaggio, 1988). However, hammerstone percussion can also be employed as a way to break larger carcass portions with most of the flesh removed into more manageable sizes (such as along the spine), to open up areas for easier access with sharp-edged stone tools (such as the ribcage), access the brain, and fragment spongy portions in preparation for further processing of cancellous bone grease (Church and Lyman, 2003).

Composite GIS images of the locations of all percussion marks in the entire sample from PP13B provide a map of percussion activity. These images include analytical units from disturbed areas and basal areas as a way to increase the sample size for illustrative purposes. (Figure 28).

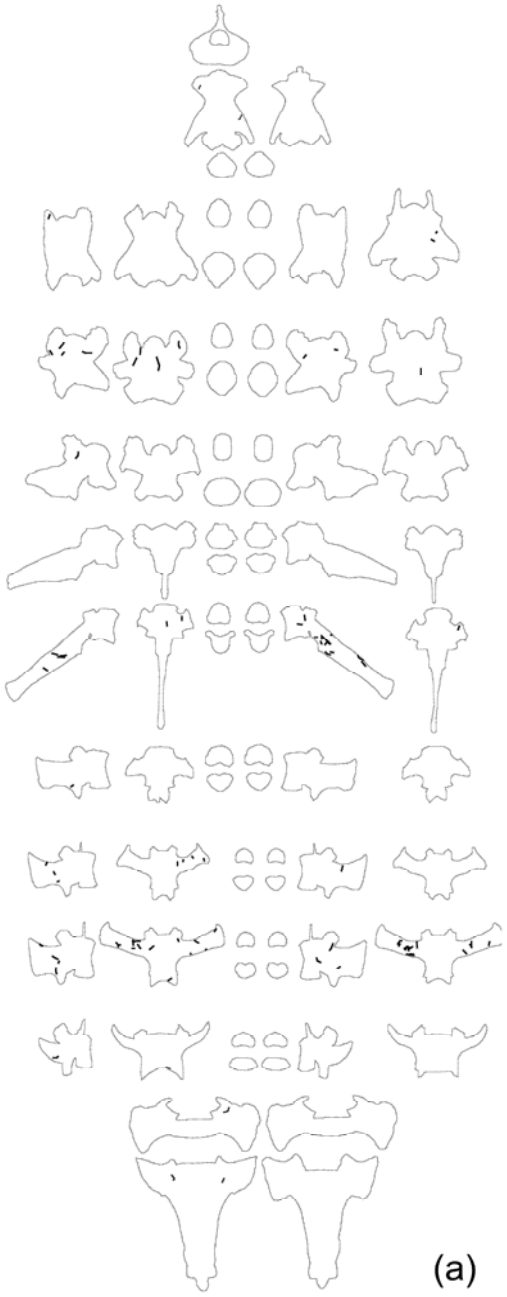


Fig. 28 The locations of percussion marks on vertebrae from PP13B.

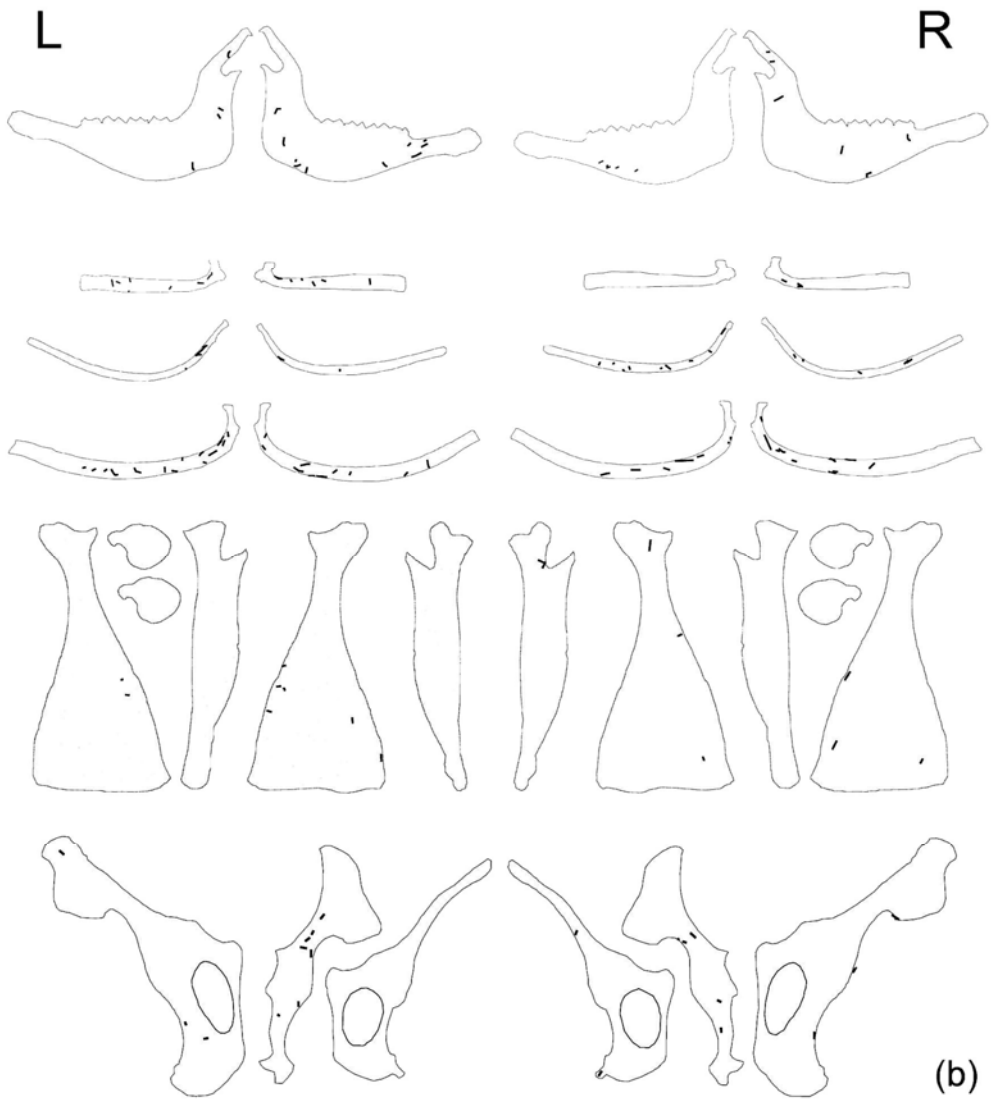


Fig. 28 (cont.) Locations of percussion marks on non-long bones from PP13B.

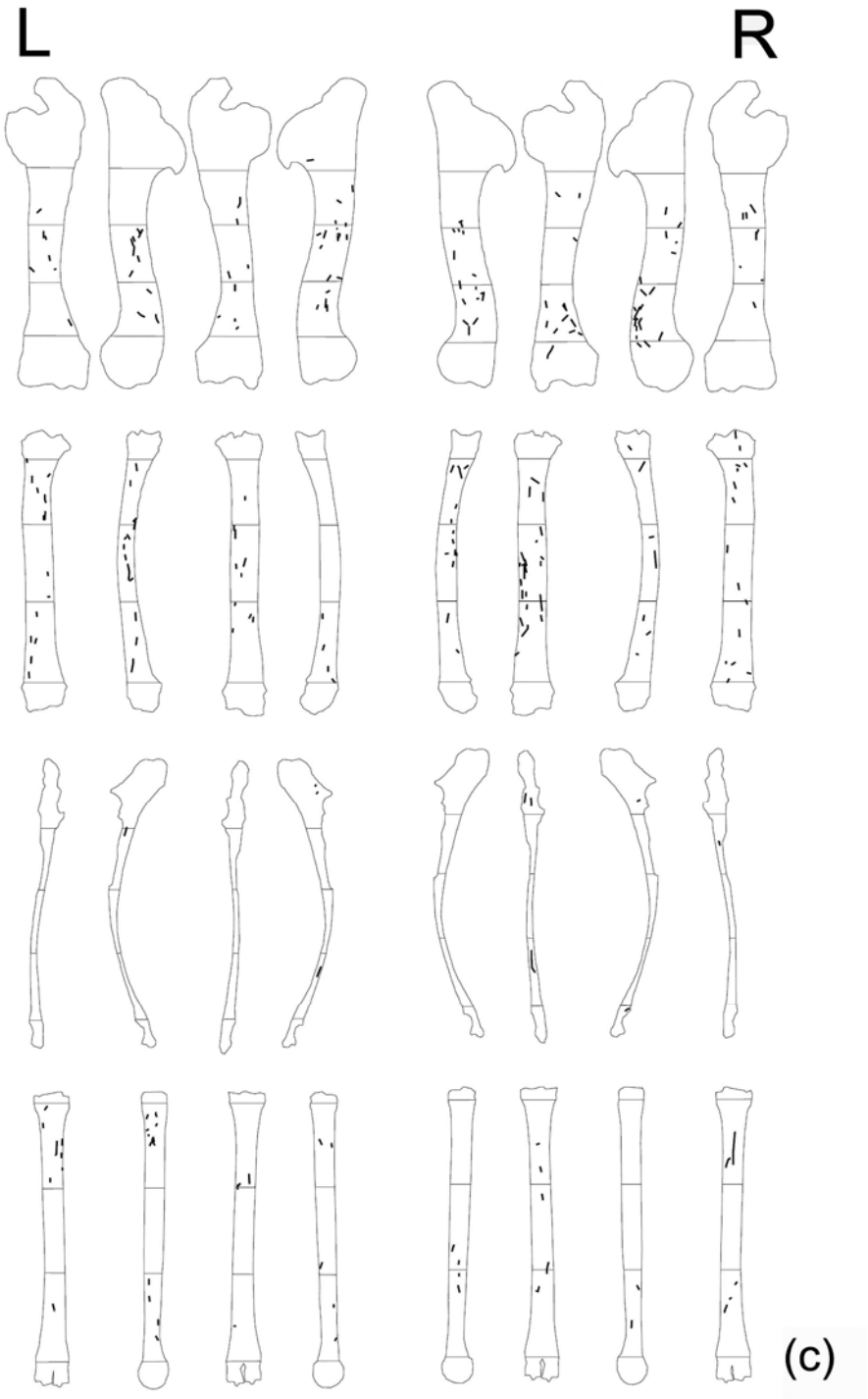


Fig. 28 (cont.) Locations of percussion marks on forelimbs from PP13B.

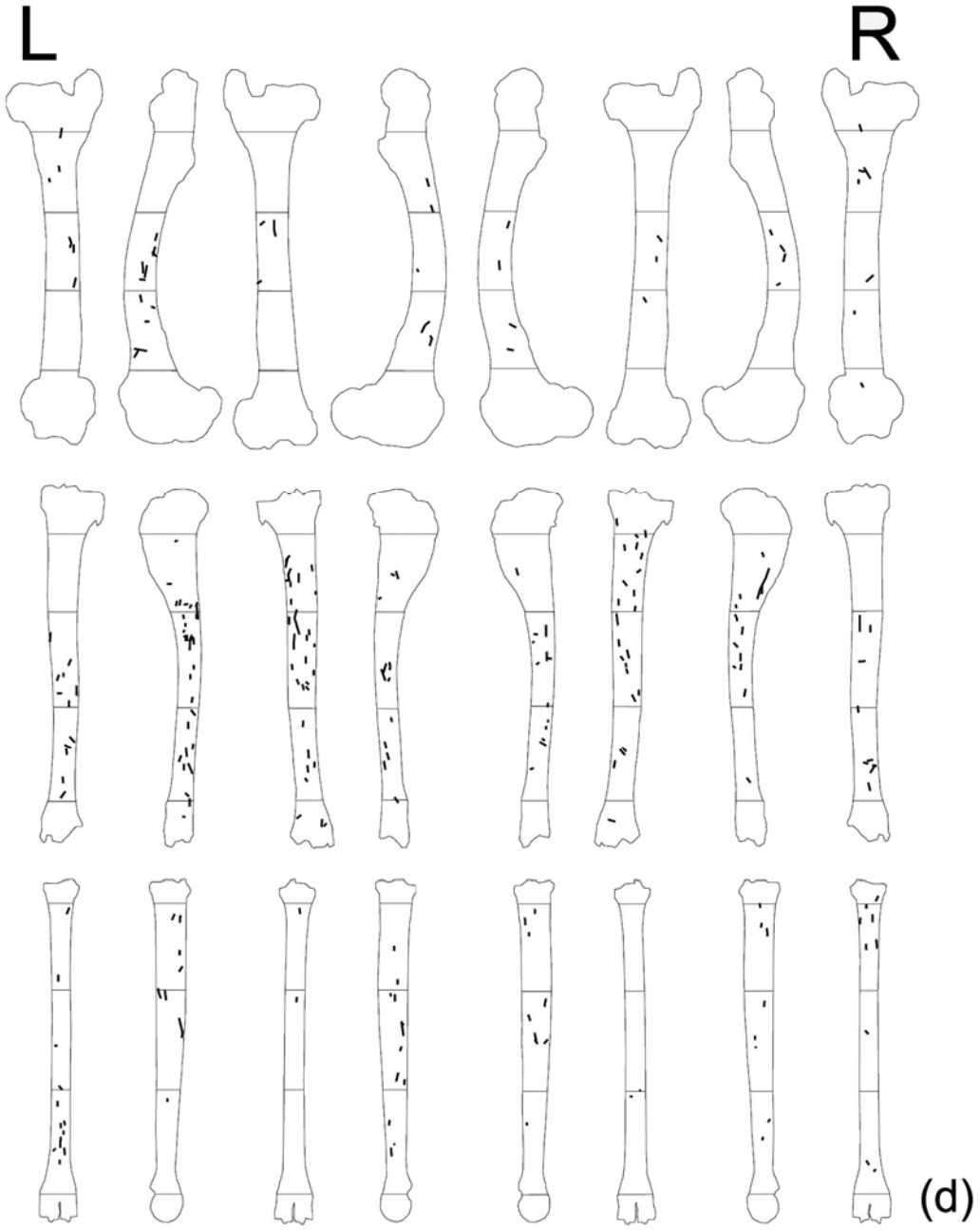


Fig. 28 (cont.) Locations of percussion marks on hindlimbs from PP13B.

Percussion marks on mandibles are most likely the result of marrow access, while marks on the vertebrae and ribs are probably related more to the breaking up of the carcass into manageable portions. This is supported by the mark locations being concentrated on the transverse processes of the lumbar vertebrae and the spinous processes of the thoracic vertebrae. This also indicates that the spinal column was most likely still bound together while percussion activities were taking place, or marks would also appear more commonly on the vertebral centrum.

Percussion marking of long bones is, as would be expected, concentrated on the shaft portions. However, the occasional mark does occur on near-shaft and epiphyseal portions. These marks may be mistakes from the slippery bone sliding along an anvil as it is percussed. Alternatively, it is possible that marks that appear on spongy portions, along with marks on the pelves and perhaps also on the vertebrae, represent purposeful actions on the part of MSA hominins to fragment these portions for further processing. Numbers of these marks by long bone portion for the entire PP13B assemblage are provided in Appendix H. Adjusted percussion mark proportions are given in Appendix I, and illustrated in Figure 29.

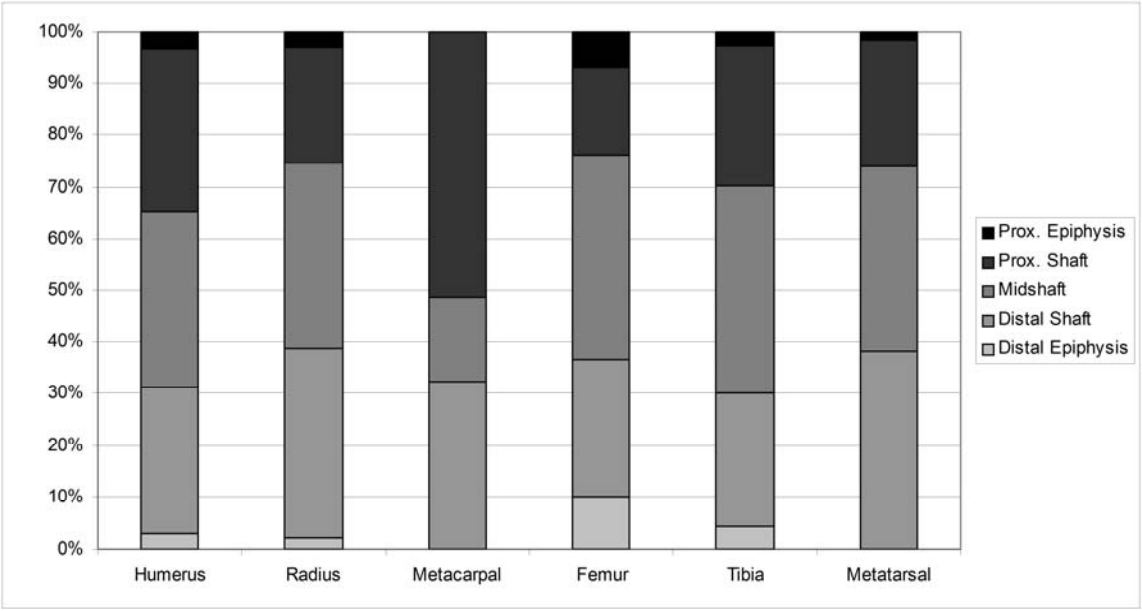


Fig. 29 The incidence of percussion-marking along long bone shafts at PP13B, adjusted by preserved surface area.

Adjusted proportions of percussion-marked bone portions have an average difference of only 4.3%. However, this difference ranges between 0.1% and 16.7%. In 46% of cases the adjusted proportion is higher and in 54% of cases the adjusted proportion is lower. This indicates that at PP13B adjusted proportions of percussion marks generally follow the same pattern as that which would have been revealed without the adjustment by surface area – perhaps because the large number of marks along the midshafts swamps some of the more subtle patterns. In both cases, percussion-marking is exceptionally high along the shafts of long bones and infrequent on epiphyseal portions.

The consistency in the two approaches to percussion mark distribution analysis provides good evidence that even at sites that have suffered extensive density-mediated destruction a large sample of unadjusted percussion mark counts by zone will likely

provide similar results to adjusted proportions. This is important, as it indicates that the large datasets should be comparable between sites with comparable degrees of destruction – even without time-consuming adjustments by surface area. However, smaller subsets of these data will still require these adjustments. Experimental data are required to provide a baseline indication of how these proportions compare to actual incidences of spongy bone fragmentation for boiling (or swallowing, which presumably requires even smaller fragments). In the absence of such actualistic studies, relative comparisons between analytical units at a site or between sites can still usefully be made.

Adjusted values for the incidence of percussion-marking across long bones at PP13B were examined for the major long bones for MIS 5 versus MIS 6 (Appendix I). The differences in proportions of percussion-marked midshafts revealed in the surface modification analysis indicate that percussion behavior differs between ungulate body sizes. This necessitates that these comparisons be further broken up into sub-categories of small (size 1 and 2) and large (size 3, 4, and 5) fauna.

It is also useful to compare the incidence of percussion-marking overall for the front and back of the cave, as several large hammerstones that were possibly used as percussors were discarded in the back (Marean *et al.*, 2004) and examining only midshafts may not reveal the true incidence of percussion activity if this activity also included the fragmentation of spongy bone. The relative proportions of this percussion-marking across long bones may then provide insight as to the spatial differentiation of these two types of percussion activity. For both sets of comparisons, proportions of adjusted percussion marks occurring on epiphyseal portions are used as a proxy for the

degree of grease extraction, either because of fragmentation to boil the portions or fragmentation to facilitate swallowing.

For all long bones with epiphyseal portions preserved, large fauna always have larger proportions of percussion-marked epiphyses than do small fauna. This is expected, as smaller fauna would not require the same extent of fragmentation for grease processing. This result further reinforces the impression that MSA percussion of on spongy bones was purposeful and goal-directed rather than random bashing. When an average for all long bones is calculated, epiphyseal portions are found to have been percussion-marked by a degree of magnitude of 61% more in MIS 5 than in MIS 6. This is somewhat unexpected given that grease extraction is most critical in harsh, seasonal environments and paleoclimatic data indicate that MIS 6 was one of the coldest experienced in African prehistory while MIS 5 included a period even warmer than the present day (Shackleton *et al.*, 2002).

However, when one considers the time compression of the samples examined here the pattern makes intuitive sense. Grease extraction could easily have been an innovation in resource intensification developed during MIS 6 that became more commonly employed only during MIS 5. This finding has serious implications for understanding the timing and nature of modern human behavior, but it can only be confirmed with data from other MSA sites.

Differences in the incidence of epiphyseal percussion between the front and the back of PP13B are much less than that found to occur between time periods, with only a degree of magnitude of 17% more on average at the front. The latter result is somewhat

counterintuitive because there is more percussion-marking of large ungulate epiphyses and large ungulate representation is greater at the back. It is tempting to attribute this difference to human behavior and imagine a scenario in which percussion activities actually took place at the front of the cave but the waste was disposed of at the back, leaving a slightly higher proportion of small marked fragments at the front. However, such a small difference could also be attributable to chance.

One way to test this is to compare the proportions of percussion-marked flakes between the front and back of the cave. Bone flakes are removed in the same manner as stone flakes when the shaft of a long bone is either hit with a hammerstone or squeezed between the teeth of a carnivore, and often leave behind negative scarring in the form of notches (Capaldo and Blumenschine, 1994). Percussion and tooth marks that reside on these flakes are the most reliable indicator of the agent behind their detachment, with the further benefit that these flakes are usually quite small compared to the other broken shaft fragments and are not as prone to being shuffled around (Marean and Bertino, 1994). Therefore, mapping the incidence of percussion flakes across the cave for undisturbed stratigraphic aggregates provides an independent way to monitor the spatial distribution of percussion activities. Some examples of the range of size and morphology of bone flakes at PP13B are illustrated in Figure 30.

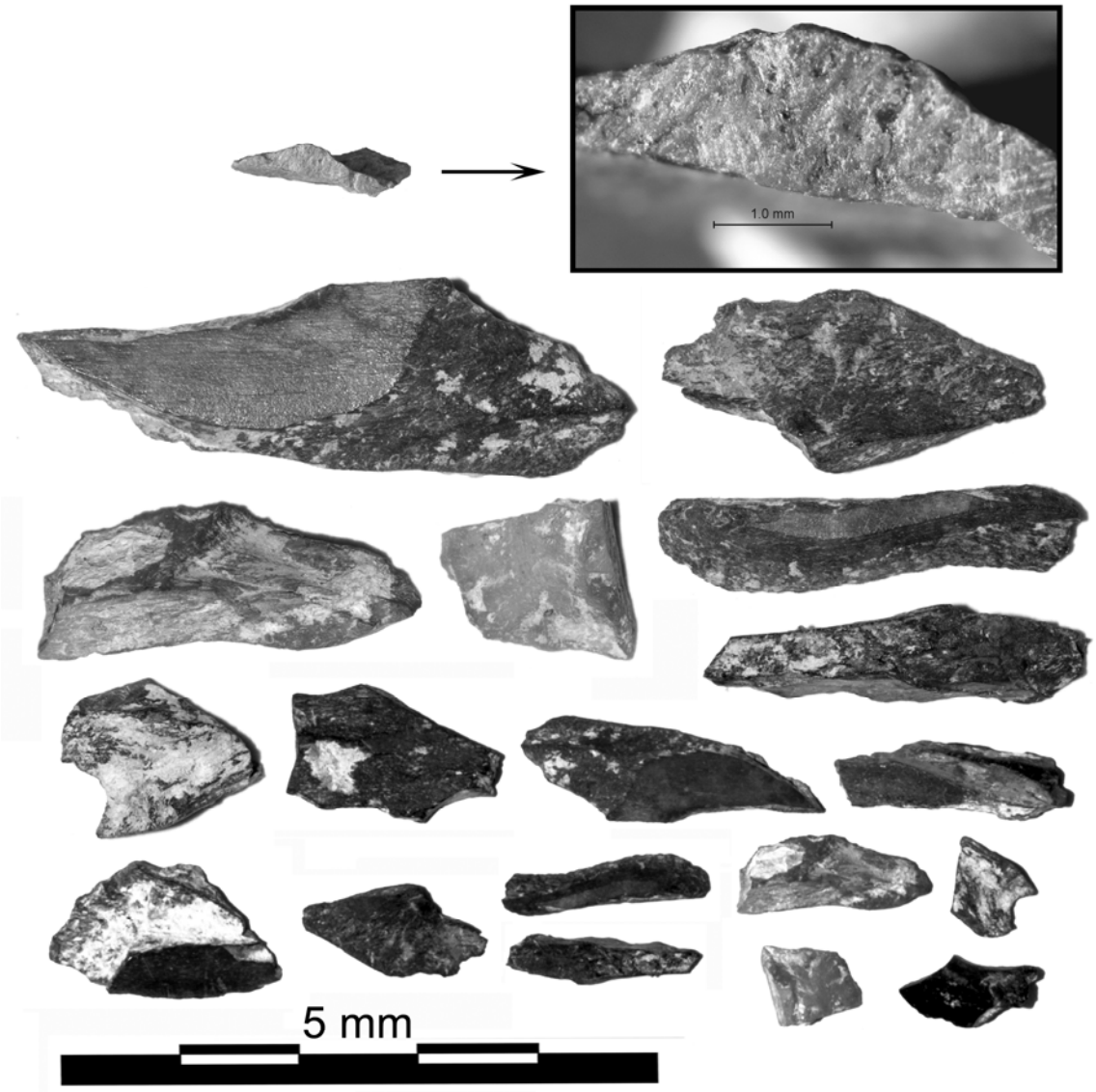


Fig. 30 Examples of the range of variability in size and morphology of long bone flakes at PP13B. The small flake at the top is enlarged to show a percussion mark preserved on the platform.

Overall, the proportion of long bone flakes to long bone fragments is the same between the two areas (21.0% in the front and 19.8% in the back). This indicates that the

proportion of flakes that bear a percussion mark will be a good measure of the relative incidence of percussion-marking in the two areas, as flakes are present in the same relative abundances in both. All body size categories will be considered together to boost sample size because size 1/2 and 3/4/5 fauna have similar proportions of flakes bearing a percussion mark (27.0% and 32.5%, respectively). Flakes with good surface preservation and exposure that bear percussion marks are proportionally more numerous in the front at 39.4% than they are in the back at 34.9%. However, this is a small difference and Fisher's Exact Test shows that it is not a significant one ($p = 0.3142$; Appendix J:[g]).

When the data are examined by horizontal provenience there is no single square that seems to be weighting the result in one direction or another (Figure 31). Thus, there is no reason to believe that percussion activities were mainly conducted at the mouth of the cave while the waste from these actions was discarded at the back. The co-occurrence of large hammerstones and large mammal bones at the rear may still represent spatially-conscious discard activities but the actual act of long bone percussion was one that was distributed throughout the cave.

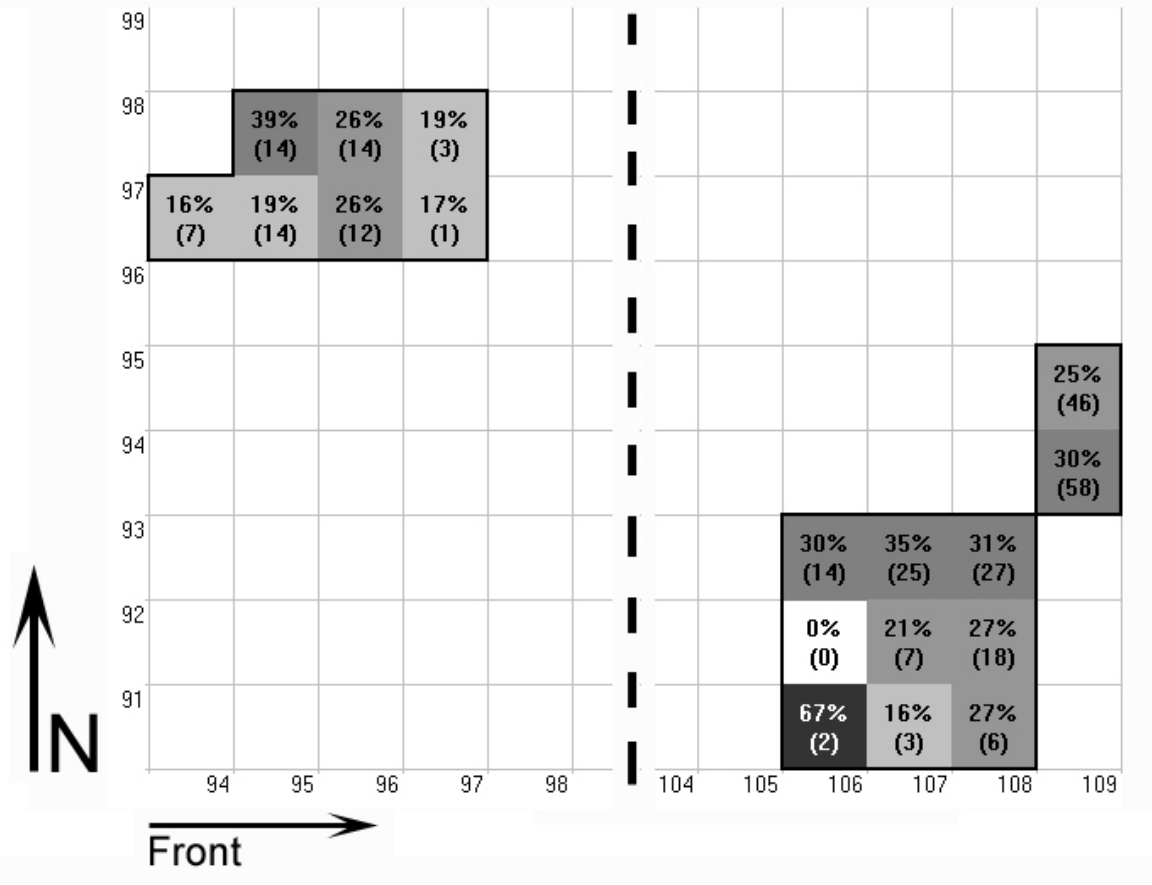


Fig. 31 Percentages of bone flakes from each square that bear a percussion mark.

There is a final possibility that a simple front versus back division is not adequate to capture the range of this spatial behavior over the large amounts of time represented at the site. During MIS 5 proportions are nearly identical (41.1% in the front and 39.4% at the back). However, during MIS 6 there is a much larger difference between the two areas (37.9% for the front and 22.2% for the back). The sample of flakes from only MIS 6 and the rear of the cave is quite small (n = 10 for all flakes with well-preserved surfaces), and Fisher's Exact Test does not show a significant difference between the proportions of percussion-marked flakes from the front and back for only MIS 6 (p =

0.1859). This suggests that there was also no difference over time in where in the cave *in situ* percussion most commonly occurred.

Zooarchaeology and taphonomy of small mammals

Of all identified mammalian specimens in the analytical units for PP13B presented here, only 2% (n = 366) are small mammals such as hares (*Lepus* spp.), hyraxes (Procaviidae), and small carnivores (body weight < 4.5 kg). Relative to other MSA faunal accumulations in the Western Cape, where small mammals can represent up to 85% of the overall mammalian assemblage, the small mammal collection from PP13B is very small. Even when the entire assemblage of large and small mammals, including the disturbed layers and the basal layers, is included, this difference is still dramatic (Klein, 1976, 1978b; Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b; Halkett *et al.*, 2003; Table 10).

Table 10

Small mammal representation by NISP at PP13B compared to published reports from other sites in the Western Cape. BBC = Blombos Cave, YF1 = Ysterfontein 1, DK1 = Die Kelders 1, KRM1 = Klasies River Mouth 1, KRM1A = Klasies River Mouth 1A, BPS = Boomplaas.

		MSA Site in Western Cape						
Taxon	Common Name	PP13B	BBC	YF1	DK1	KRM 1*	KRM 1A*	BPS*
Carnivora	Carnivores	4	35	0	352	21	6	1
Lepus spp.	Hares	13	72	1	16,128	1	0	5
Procaviidae	Hyraxes	25	767	0	2,753	51	33	0
Bathyergus suillus	Cape dune mole rat	0	890	172	150,167	7†	0	0
Erinaceus frontalis	Hedgehog	0	20	0	69	0	0	0
Hystrix africaeaustralis	Porcupine	0	2	4	25	22	4	0
Small Mammal	Small Mammal	324	-	-	-	-	-	-
Total ID Small Mammals		42	1786	177	169,494	102	43	6
Total ID Large Mammals		2427	2323	101	30,199	530	216	174

*These sites are only reported by MNI and likely are biased in the ways described in the text. †Only Cape mole rats (*Georychus capensis*) are reported from this site

Mammals of this size class have been a documented part of the hominin diet for over 1.7 million years (Fernández-Jalvo *et al.*, 1999), and small mammals are relatively abundant at other MSA sites in the Western Cape. Figure 32 shows the entire assemblage of identifiable small and large mammals from all analytical units at PP13B alongside comparable published data from other sites. Fragments illustrated here that are considered 'identifiable' follow the criteria set out by Klein and Cruz-Uribe (1984), as

this has been the standard way in which large and small mammal assemblages have been reported at other MSA sites in South Africa.

One outstanding problem with the comparisons here is the issue of how faunal data have been reported in the literature. Although NISP counts are available for Blombos (Henshilwood *et al.*, 2001b), YF1 (Halkett *et al.*, 2003), and DK1 (Klein and Cruz-Uribe, 2000), only MNI estimates are available for Klasies River Mouth (Klein, 1976) and Boomplaas (Klein, 1978b). Because the MNI counts are presented by layer, the summed numbers given here suffer from the problems of aggregation discussed in Chapter Two (Grayson, 1984). Furthermore, although the close relationship between NISP and single-element estimates such as the MNI has been documented for large mammals (Grayson and Frey, 2004), this has not been shown to necessarily be the case for small mammal estimates. Furthermore, because small mammals are often less fragmented than larger mammals it is possible that they were more readily identified to species and the relative proportions of the two categories are not comparable.

It is also unfortunate that no comprehensive taphonomic analysis using microscopic techniques has been done at any of these sites to determine the agent of accumulation of fauna such as hares, dune mole rats, small carnivores, and hyraxes. Despite these problems, some valuable patterns have emerged that provide a framework for the present study.

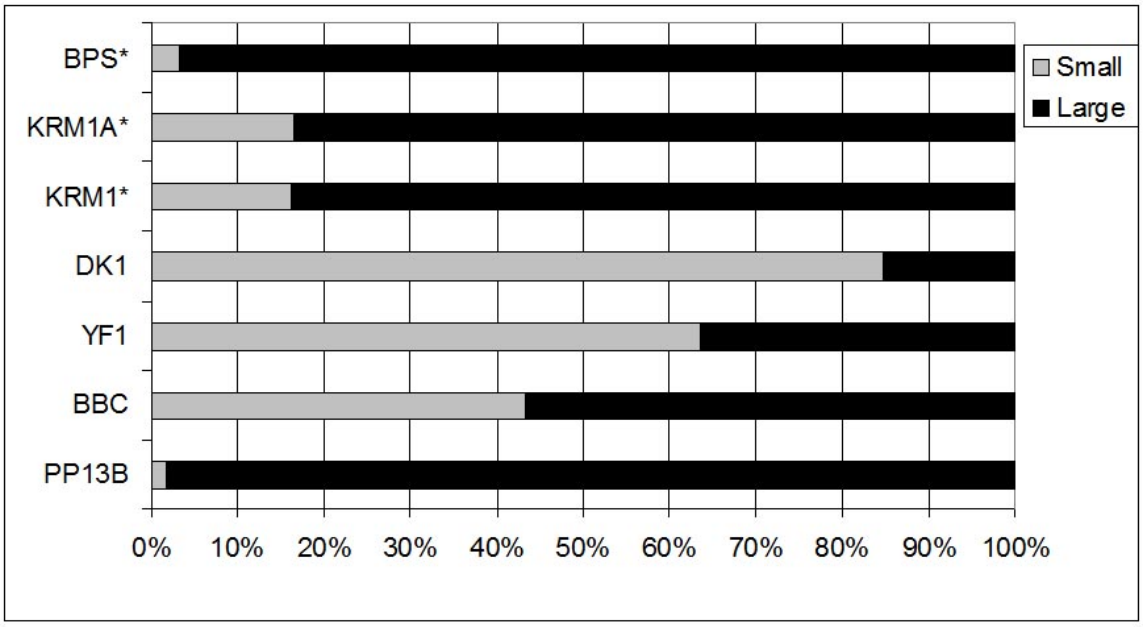


Fig. 32 Relative proportions of small and large mammals at PP13B and other MSA faunal assemblages reported in the Western Cape.

At PP13B there is a notable absence of Cape dune mole rats (*Bathyergus suillus*). This taxon is an extremely common component of other MSA faunal assemblages along the coast and their incidence at other sites is therefore worthy of a brief review here. These large rodents are sensitive ecological indicators of the surrounding landscape. Today they are restricted to the littoral zone in the Western Cape Province, and are found in areas with sand dunes or loose, sandy soil (Jarvis and Bennett, 1991, Skinner and Smithers, 1990). In modern times Cape dune mole rats, which average about 1 kg in weight, are exploited for food by humans in rural areas. This practice has also been documented archaeologically during the Later Stone Age (Henshilwood, 1997).

At DK1, where small mammals make up 85% of the fauna by NISP, Klein and Cruz-Uribe (2000) report macroscopically visible damage to Cape dune mole rat

postcrania in the form of etching and polish. They also report statistical analyses showing high frequencies of Cape dune mole rats in layers with little evidence of human occupation and low frequencies of this taxon in layers with abundant archaeological evidence. These authors conclude that Cape dune mole rats were introduced mainly by avian predators – most likely the Cape eagle owl, *Bubo capensis* (Avery *et al.*, 1997; Klein and Cruz-Uribe, 2000).

By comparing skeletal element abundances at DK1 to those at modern eagle roosts, Cruz-Uribe and Klein (1998) rule out the involvement of several South African eagle taxa as accumulators of Cape dune mole rats. However, for these authors the Cape eagle owl remains a suspect in the accumulation of hyraxes and hares. Bones from these species tend to vary inversely with the presence of Cape dune mole rats, and positively with layers containing abundant evidence of human occupation. The bulk of current evidence therefore points to a human accumulator of hares and hyraxes, but a microscopic taphonomic study is still required to confirm this (Avery *et al.*, 1997; Cruz-Uribe and Klein, 1999; Klein and Cruz-Uribe, 2000).

In contrast, at Blombos Cave Cape dune mole rat remains are spread relatively consistently throughout the stratigraphy, and this is taken as evidence for a potential human accumulator (Henshilwood *et al.*, 2001b). In anecdotal agreement with this, human modification was found on at least one randomly selected Cape dune mole rat specimen from Blombos. Such modification in the form of cut marks has also been observed microscopically on randomly selected elements from a variety of small mammal taxa. These include mongooses (Viverridae), porcupines (*Hystrix*

africaeaustralis), and hyraxes, but at this time no quantitative data are available to determine how extensive this human involvement was (Figure 33). As a footnote to the study from PP13B, these specimens stress the importance of future studies at Blombos and other MSA sites that focus on small mammal taphonomy. Without such studies, the complete range of MSA faunal exploitation will never be well-understood.

At Ysterfontein 1 (YF1) Cape dune mole rats are the most abundant mammalian species. Halkett *et al.* (2003) argue that the geologic context of the site, which is not one that would have provided suitable roosting areas for raptors, indicates that these large rodents were likely accumulated by people. However, all these sites still require direct examination of the surfaces of the fossils and the development of a supporting actualistic framework in which to situate data of this kind for the accumulator to be known with certainty. At PP13B the corresponding paucity of small carnivores may be an indicator that some of the major predators of Cape dune mole rats were also absent, and this is supported by the relatively abundant small carnivores that are recovered at sites that also have high numbers of Cape dune mole rats (such as Blombos and DK1; Table 10).

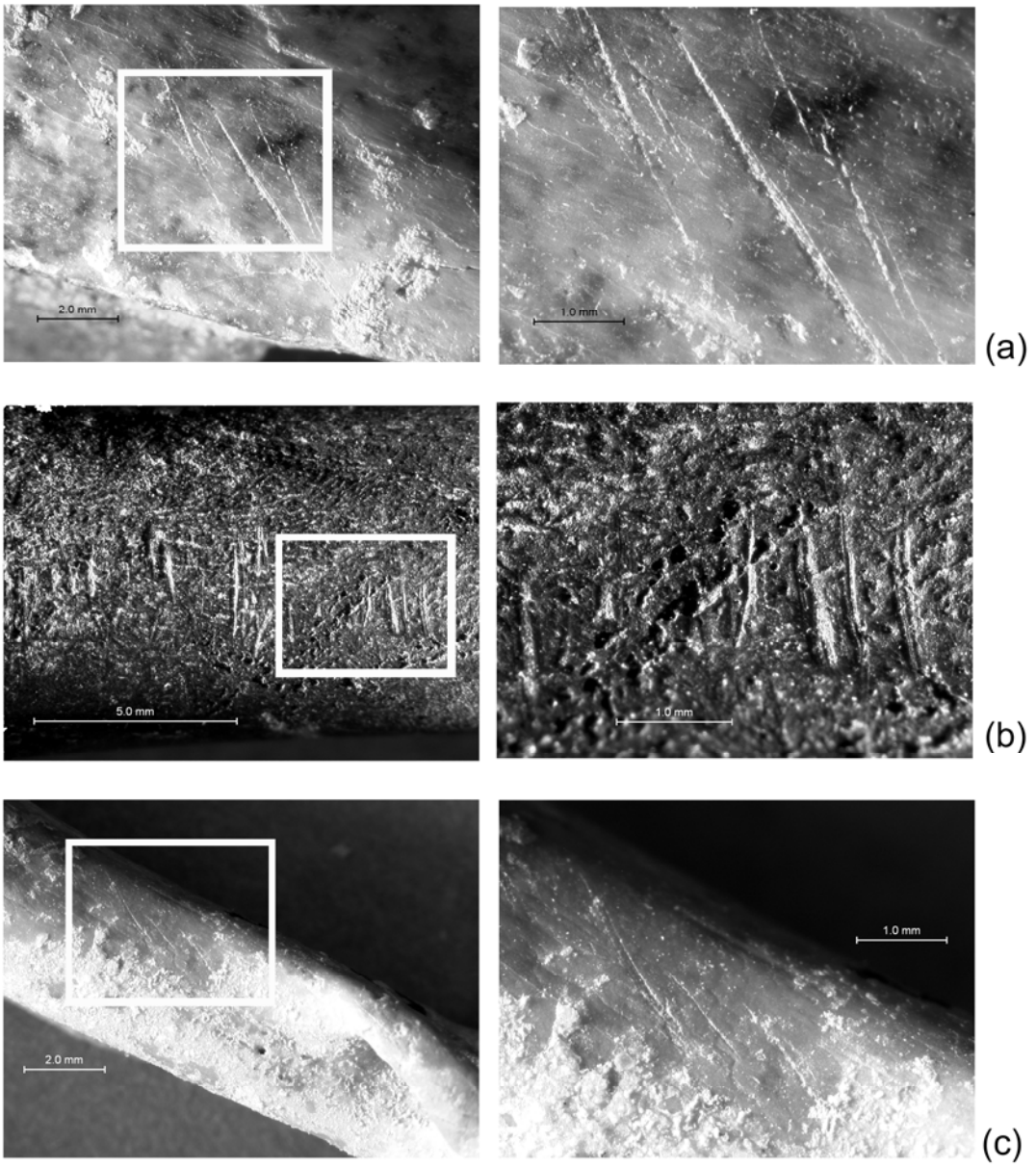


Fig. 33 Examples of cut marks on small fauna and carnivores from Blombos: small carnivore humerus (a), porcupine humerus (b), and mongoose humerus (c). The image to the right is an enlargement of the area in the white box on the left.

It is also possible that at PP13B there is an ecological explanation for the lack of Cape dune mole rats. The geologic evidence indicates that the cave was sealed between

ca 90 – 40 ka by extensive dune systems, and that the distance to the shore varied by over 100 km between the time the cave was first cut into the cliff and the modern day (Marean *et al.*, in prep). This would have made it unlikely that the preferred habitat of Cape dune mole rats was consistently available in the immediately accessible area facing the cave, although such habitat may have been present on the cliffs above the site. The poor sample of small mammals identifiable to the level of order or below makes it difficult to explore this possibility in depth, but this relative impoverishment is in itself extremely informative and points to a taphonomic situation at PP13B that is unique relative to other reported MSA sites in the Western Cape.

PP13B extends deeply into the cliff face, and in the present day extensive roosting areas for large raptors are not widely available except along the north wall. Of the 339 small mammal fossils from the site, only 22 (6.5%) show gastric etching. Gastrically etched fragments occur throughout the skeleton and half are pedal elements (n = 13). Gastric etching can be caused by either raptors or carnivores, with carnivore damage tending to be more severe (Andrews, 1990). Gastric etching can also be caused by human ingestion, and the degree of damage is similar to that of carnivores (Crandall and Stahl, 1995; Dewar and Jerardino, 2007). In support of at least a partial contribution by mammalian carnivores, 22 fragments (6.5%) have tooth marks.

However, human modification is also present to a low degree, with 11 (3.2%) cut-marked and 9 (2.7%) percussion-marked fragments. It is also possible that when dealing with potential prey of this small size class, humans may be responsible for tooth-marking and gastric etching as well as more obviously human-derived modifications such as cut

marks (Crandall and Stahl, 1995; Landt, 2007). Burning is present at a low level, appearing on 31 (9.1%) of small mammal fragments (compared to 12.4% for large mammals). This discoloration is distributed randomly throughout the skeleton and all burning stages are represented evenly, suggesting that most of this can be attributable to post-depositional incorporation of small mammal bones into sediments that were subsequently burned.

All of these samples are too small to be able to explore specific butchery patterns, but several certain facts about human behavior do emerge from these observations. First, the sheer under-representation of this size class shows that at PP13B small mammals were not normally transported, whereas they quite possibly were at sites such as Blombos and DK1. Second, small mammals may not have been frequently exploited, but human modification on a few specimens does indicate that the MSA inhabitants of PP13B were at least occasionally making use of this resource. This points to either a flexible and opportunistic foraging strategy in which small mammals figured quite insignificantly, or to a strategy in which small mammals were processed and consumed on the spot after they were captured and only rarely transported back to PP13B.

Zooarchaeology and taphonomy of tortoises

As with the small mammal representation, tortoise abundances are very low at PP13B relative to other MSA sites in the Cape. At sites such as DK1, YF1, and Blombos tortoises are so superabundant that they are not even counted in full, but are reported only with NISP counts of a single element such as the humerus or as MNI estimates based on humeri (Klein and Cruz-Uribe, 2000; Henshilwood et al., 2001b; Halkett *et al.*, 2003;

Klein *et al.*, 2004). Because very tiny fragments of tortoise bone can easily be identified as such, a straight NISP comparison to mammalian fauna would always tend to show inflation of tortoise representation. Both these unique problems presented by tortoise bone and the general lack of attention that has been given to reporting them in full make it difficult to know the relative representation of tortoises to other faunal categories at a site and to make comparisons between sites.

MNI estimates are likely the best option for such comparisons within a site, particularly relative to small mammals that, like tortoises, tend to have less fragmented elements (and therefore more identifiable) than larger animals. MNI counts for all species are often provided in the literature, but because these estimates may be based on different elements from different layers within a site it is not valid to simply add them up and then compare the same measure for tortoises (Grayson, 1984). Furthermore, tortoises are consistently reported by distal humerus MNE and this may not be the element that provides the highest MNI in all cases. As the published data stand it is impossible to compare the relative representation of mammals and tortoises either within or between sites.

These problems can be overcome given two critical sets of data: 1) The distal humerus MNE from one site (this is the same number as the NISP for the data subset 'complete distal tortoise humeri') ; and 2) The corresponding total tortoise NISP from the same site. The total tortoise NISP can then be compared to the total NISP for large mammals, small mammals, or any other NISP-based dataset. PP13B is the first site for

which both pieces of information are available, and from this information a percentage of the total NISP that is represented by complete distal humeri can be calculated.

This same percentage can be assumed to hold true for other sites, given two assumptions:1) That tortoises were transported whole to all the sites in question (this assumption is examined for PP13B later in this section); and 2) That different tortoise elements would have preserved in roughly the same proportions relative to one another at all sites. For the values at PP13B, the humerus makes up 3.8% of the total number of identified tortoise fragments that could be identified to element, including specific bones of the carapace or plastron. Having made these assumptions, this percentage can be assumed to be approximately the same for reported counts of complete distal humeri that are available in the literature and the total NISP for tortoises can be estimated baed on it.

However, an adjusted value is also needed to account for differences in reporting at the other three sites, where only the most complete and most identifiable elements have been counted as the standard methodology of these authors (Klein and Cruz-Uribe, 1984). The adjusted values for the PP13B mammals therefore represent the NISP when only epiphyseal fragments, dental material, and horn cores are counted. The adjusted values for tortoises are for carapace and plastron fragments that are at least 80% complete and could be identified to bone number (e.g. marginal 1-11, costal 1 – 9, hypoplastron, etc.), plus any portion of a limb or axial element. For the tortoise humeri counts the adjusted values include only complete distal humeri because the tortoise humeri data from the other three sites were drawn from charts in which distal ends were measured (Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b; Klein et al., 2004). For the adjusted

values, the humerus makes up 2.8% of the total NISP, and this figure is used to estimate the total NISP for tortoises at Blombos, YF1, and DK1.

Table 11 shows the estimated NISP of tortoises at several sites in the Western Cape, based on the index derived from the PP13B data and the reported NISP of identifiable small mammals, large mammals, and tortoise humeri from these other sites. The entire sample of fauna from PP13B, including the disturbed areas and basal layers, is employed here because a larger sample size is useful and knowing detailed provenience, age, or agent of accumulation is not critical for the purpose of this index. Note that in a later publication (Klein *et al.*, 2004) more tortoises are reported as a result of further excavations at YF 1 (total NISP = 77 rather than 34). The smaller figure was used here as it is accompanied by small and large mammal data for the site and the more recent figure is not (e.g. Halkett *et al.*, 2003).

When compared to the estimates based on reported numbers of tortoise humeri from other sites MSA sites in the Western Cape, the assemblage at PP13B is striking in its relative paucity of tortoises. Adding to this pattern, species abundances within the tortoises are also quite unusual at PP13B. Today the Western Cape lies within the geographic range of at least three species of tortoise: the leopard tortoise (*Geochelone pardalis*), the pancake tortoise (*Homopus areolatus*), and the angulate or bowsprit tortoise (*Chersina angulata*). The helmeted turtle (*Pelomedusa subrufa*) is also found here (Boycott and Bourquin, 1988). In most instances, if a faunal collection is sampling the immediate faunal community, species richness is expected to decrease with sample

size (Grayson, 1984, 1991). However, despite a smaller sample size at PP13B species richness of tortoises is much higher than that at other MSA sites in the Western Cape.

Table 11

Adjusted and unadjusted numbers of small mammals, large mammals, and tortoises at PP13B compared to reported and estimated numbers from other sites in the Western Cape. Adjusted data from PP13B have been used to estimate total tortoise NISP from the reported NISP of humeri at other sites.

	PP13B Unadjusted	PP13B Adjusted	Blombos Cave	Ysterfontein 1	Die Kelders 1
Small Mammals	42	25	1,786	177	169,494
Large Mammals	2,427	878	2,323	101	30,199
Tortoise humeri	34	15	620	34	4,213
Total ID tortoise (EST)	855	540	22,143	1,214	150,464
Total NISP (EST)	3,324	1,443	26,252	1,492	350,157

At PP13B 13% of all fragments (n = 356 of 2822 from the same analytical units used for the mammal study) could be identified to species. It is important to note that only tortoise species were definitely found in the assemblage, but that unless an assignment was certain fragments were recorded under the more general heading 'turtle/tortoise'. By NISP the pancake tortoise, *Homopus areolatus*, makes up 27% of the assemblage that could be identified to species. The angulate tortoise, *Chersina angulata*, comprises 73%, and five fragments in the assemblage are unidentified very large chelonians. MNE and MNI estimates were conducted for all identifiable elements,

including carapace and plastron fragments that could be assigned to their appropriate number within the skeleton (Figure 34).

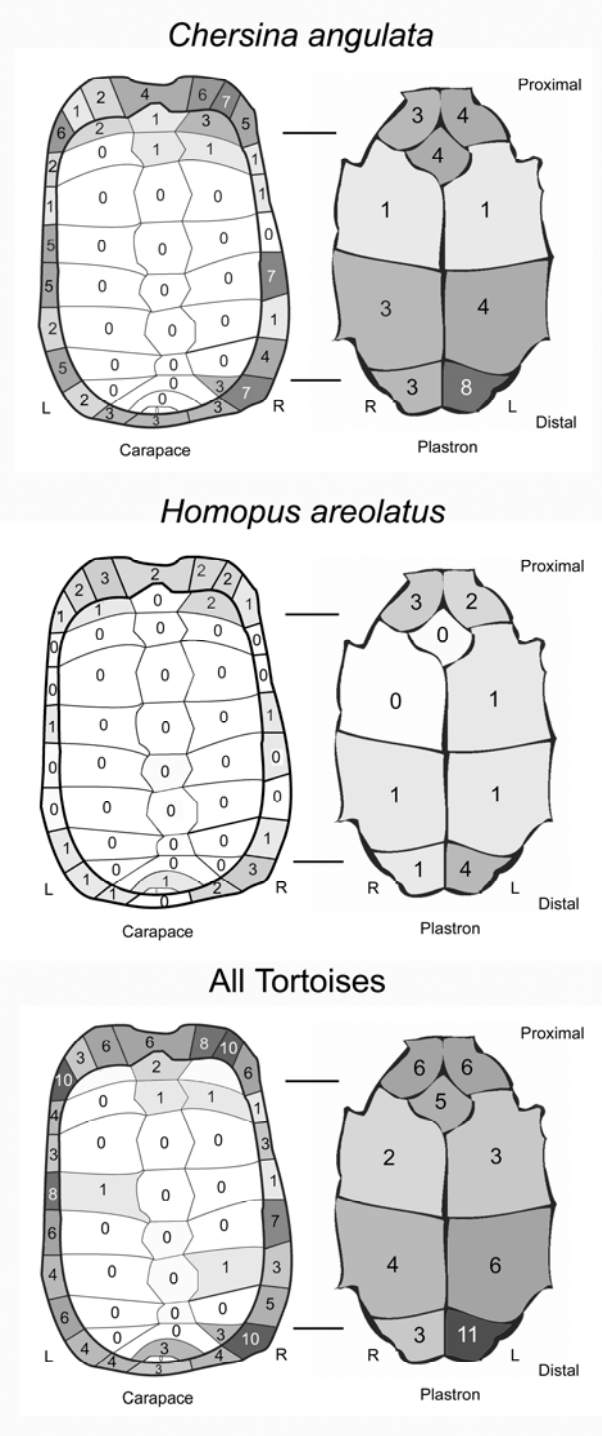


Fig. 34 Tortoise MNE based on various parts of the carapace and plastron. Note the very low representation of neurals and costals relative to marginals.

As with some mammal elements, the problem of element identifiability plays a role in producing MNE estimates. Costal and neural fragments appear underrepresented by MNE relative to the NISP counts owing to how difficult it is to determine side and number, whereas marginals are well-represented in the MNE estimates because each marginal has a distinctive shape and can be sided. For *H. areolatus*, *C. angulata*, and all tortoises combined the highest MNE estimates occur on both shell and limb elements. This suggests that a thorough taxonomic study should include representative elements from both portions rather than simply a single limb element as is normally done at MSA sites in South Africa. The total MNI for *C. angulata* is 8 (on xiphiplastra and femora), the total MNI for *H. areolatus* is 4, (on xiphiplastra and marginals), and the total MNI for all tortoises at PP13B is 12 individuals on femora (Table 12).

Table 12

Tortoise MNE on non-shell elements at PP13B.

	C. angulata		*H. areolatus*		All Tortoises	
Element	Right	Left	Right	Left	Right	Left
Scapula	3	7	0	3	7	11
Procoracoid	1	3	0	0	4	6
Humerus	4	4	2	3	7	8
Radius	1	4	0	0	1	5
Ulna	3	3	0	1	4	6
Ilium	6	6	1	1	10	10
Ischium	2	1	0	0	4	3
Pubis	6	4	0	0	8	4
Femur	2	8	1	1	5	12
Tibia	2	1	0	1	3	3
Fibula	1	0	0	0	2	0

Given the potential diversity of chelonians in the Western Cape, it is peculiar that only one species, *C. angulata*, is reported from DK1, Blombos, and YF1. The situation at PP13B seems to more closely mirror the modern ecological situation, with at least two species of tortoise represented and a third chelonian also present in very low frequencies. This raises the question of whether or not tortoises at other sites where they are superabundant were identified as thoroughly as possible. A study was conducted in which a very large sample of tortoise humeri from DK1 was re-examined, with the interesting result that at this site *C. angulata* was not the only positively identified species but did in fact make up the overwhelming majority of specimens (Lokken, 2007). This suggests that in terms of what we know so far about tortoise species abundances at MSA sites, PP13B truly is different.

Before any suggestions can be put forth about what these tortoise abundances mean in terms of hominin behavior, it is important to determine the most common agent of their accumulation. Sampson (2000) used skeletal element abundances from modern raptor roosting sites, inferred raptor accumulations, and Later Stone Age archaeological sites to identify unique patterns in element representation for each of these accumulators. He found that raptor roosts have a preponderance of cranial and axial elements, as well as relatively low frequencies of shoulder and pelvic girdle elements. Human accumulations have much higher representation of carapace and plastron fragments and very low representation of cranial and axial elements.

Based on his observations at modern kill and roost sites, Sampson (2000) gives frequency data for an inferred raptor roost and the inferred human-accumulated deposit

below it at the LSA site of Volstruisfontein. This is not an ideal situation as it does not provide tallies for element representation from modern assemblages where the accumulator has been positively identified, but it does provide some comparative data. When presented next to NISP counts of each element category it is clear that PP13B does not at all resemble a raptor assemblage (Figure 35). The low proportion of gastrically etched specimens (< 1%) is further evidence against nesting birds as the main accumulator.

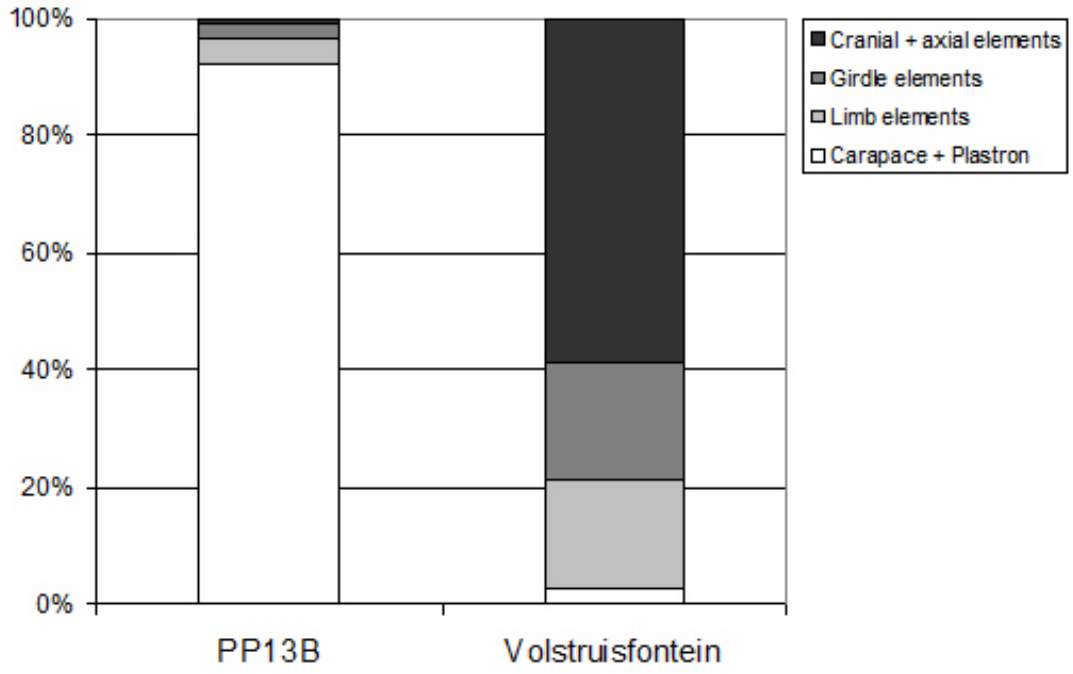


Fig. 35 Skeletal element abundances for tortoises at PP13B compared to the inferred raptor accumulation at Volstruisfontein (from Sampson, 2000).

The hard carapace and plastron of a tortoise gives their exploitation a very high handling cost that carnivores overcome by gnawing at the edges of the shell, and which

birds overcome by dropping tortoises from high places to break them open or by smashing smaller and thinner shells with their heavy beaks (Greig, 1979). For humans wielding both fire and hammerstones the handling cost is greatly reduced and tortoises become an easily exploited resource that can be collected by any member of a group. Their inclusion in the human diet at PP13B is therefore predicated on there being evidence that hammerstone percussion, burning, or both were used as methods for opening tortoises.

Sampson (2000) suggests that assemblages made by humans are heavily fragmented and exhibit 30 – 40% charring. He does not quantify a 'heavily fragmented' assemblage, but PP13B tortoise elements certainly fit this criterion. 77% of the assemblage was fragmented to such an extent that it could not be identified to element, and 13% of the assemblage was identifiable to element but still not complete. Only 7% of the assemblage was comprised of complete elements: 5% carapace/plastron elements and 2% limb/axial/girdle elements. However, PP13B falls somewhat short of Sampson's (2000) predictions for proportions of burned tortoise bone, with only about 19% (n = 533) of fragments affected.

With burning, the location on the shell as well as the frequency of charring is important, as a simple method for processing tortoises is to place the live animal upside down in the fire and allow it to cook in the shell (Sampson 1998). If the majority of burning was not related to tortoise processing and instead occurred postdepositionally while the fragments were scattered throughout the sediment, then burning should occur with equal frequency on both the inside and the outside of the shell. If tortoises were

normally processed in the same way suggested by Sampson (1998), then burning should occur preferentially on the exterior aspect of the shell. At PP13B both shell and limb fragments had similar proportions of burned and unburned fragments from the shell and from other elements (24% and 17% burned, respectively). With regards to the shell only, 51% (n = 263) of burned carapace and plastron fragments were burned on both the exterior and interior aspects. This indicates that much of the burning on tortoise fragments was likely the result of post-depositional fires that were not related to tortoise processing. However, four times as many fragments that were burned on either one aspect or the other had the burning concentrated on the exterior (n = 141 on the exterior versus n = 35 on the interior). This suggests that burning was at least infrequently employed as a part of tortoise processing, and that when it was used it may have been in the same manner as that observed in the modern day (Figure 36). Only actualistic studies of modern tortoise burning and fragmentation will confirm this pattern.

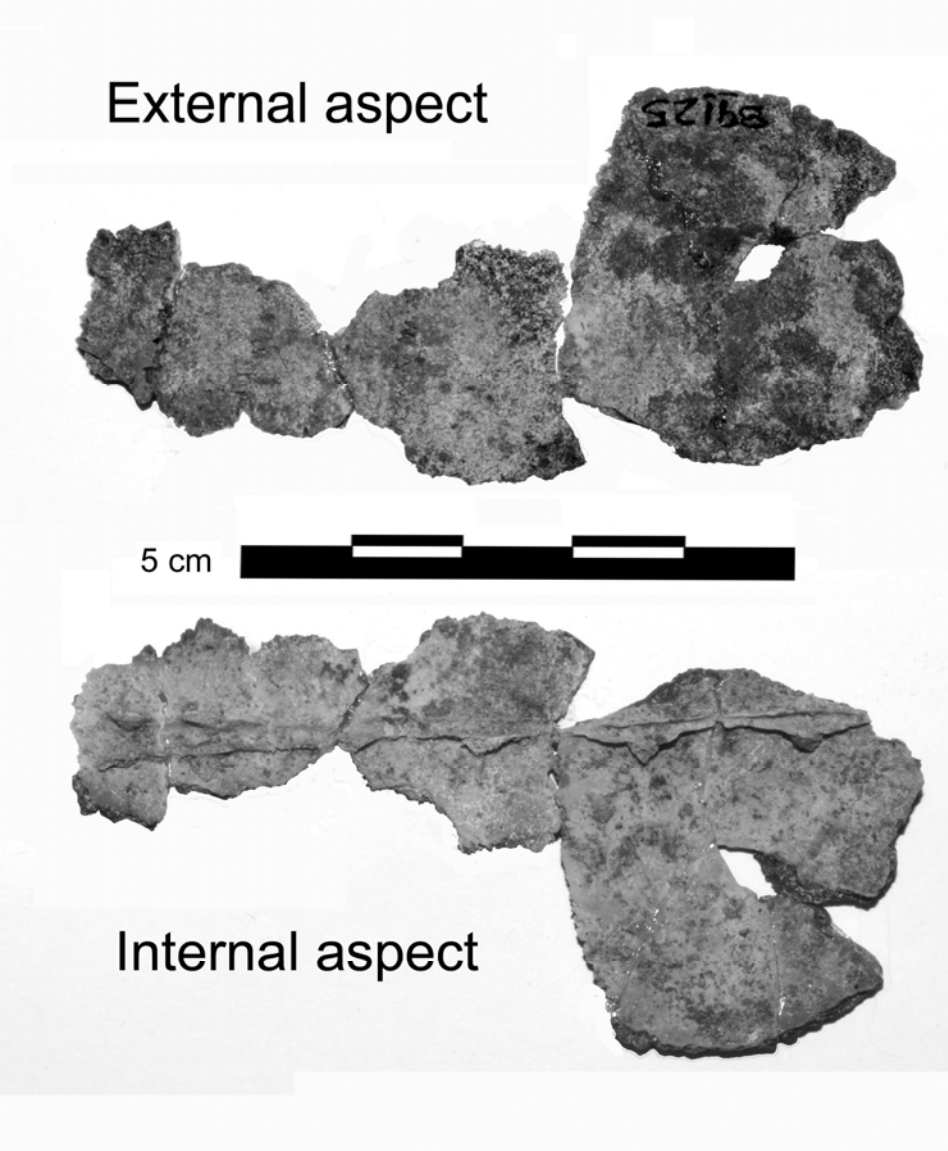


Fig. 36 Reconstructed series of tortoise neurals showing burning on the outside of the carapace only.

There are little data available for tortoise skeletal element representation in large carnivore accumulations, but in terms of skeletal element abundance they may be expected to resemble human accumulations because tortoises can be transported whole by both agents whereas raptors leave the majority of shell fragments at the kill site.

Sampson (2000) found that small carnivore accumulations are also similar to human accumulations but possibly with higher representation of forelimb and shoulder girdle elements. Surface modification is therefore the most telling way to separate human from terrestrial predator accumulations.

Unfortunately, there are no actualistic data on modern tortoise butchery and carnivore consumption that provides the proportions of cut, percussion, or tooth marks that would be expected if humans or carnivores were the predominant collector. There is the further problem that humans chewing on tortoise limbs may also leave tooth marks that are morphologically indistinct from those of carnivores (Landt, 2007). Despite these potential problems, a microscopic examination of the tortoises from PP13B does clearly indicate one salient fact: clear human modification occurs less frequently on tortoise elements than does probable carnivore modification.

Percussion marks (n = 19 fragments) were rare but present, and found predominately on the external aspect of carapace and plastron fragments. This indicates that hammerstone percussion of tortoises was a cost-saving method employed to open the shell (Figure 37). Cut marks were also rare (n = 27 fragments). Of these all occurred either on the interior aspect of shell (n = 20) or on limb or girdle elements (n = 7), indicating that stone tools were employed both for defleshing/disarticulating limbs and for removing adhering tissue from the interior of shells (Figure 38).

Tooth marks ranged from large (ca. 2 mm) to very tiny (< .25 mm), and were apparent on 2% (n = 57) specimens. Additional non-human modifications also occasionally made an appearance. Some elements retained smooth striae that may be

either the result of gnawing by rodents or gnawing by a tiny carnivore. Three more fragments displayed multiple sharp indentations that may be the result of multiple stabbings by raptor beaks (Figure 39).

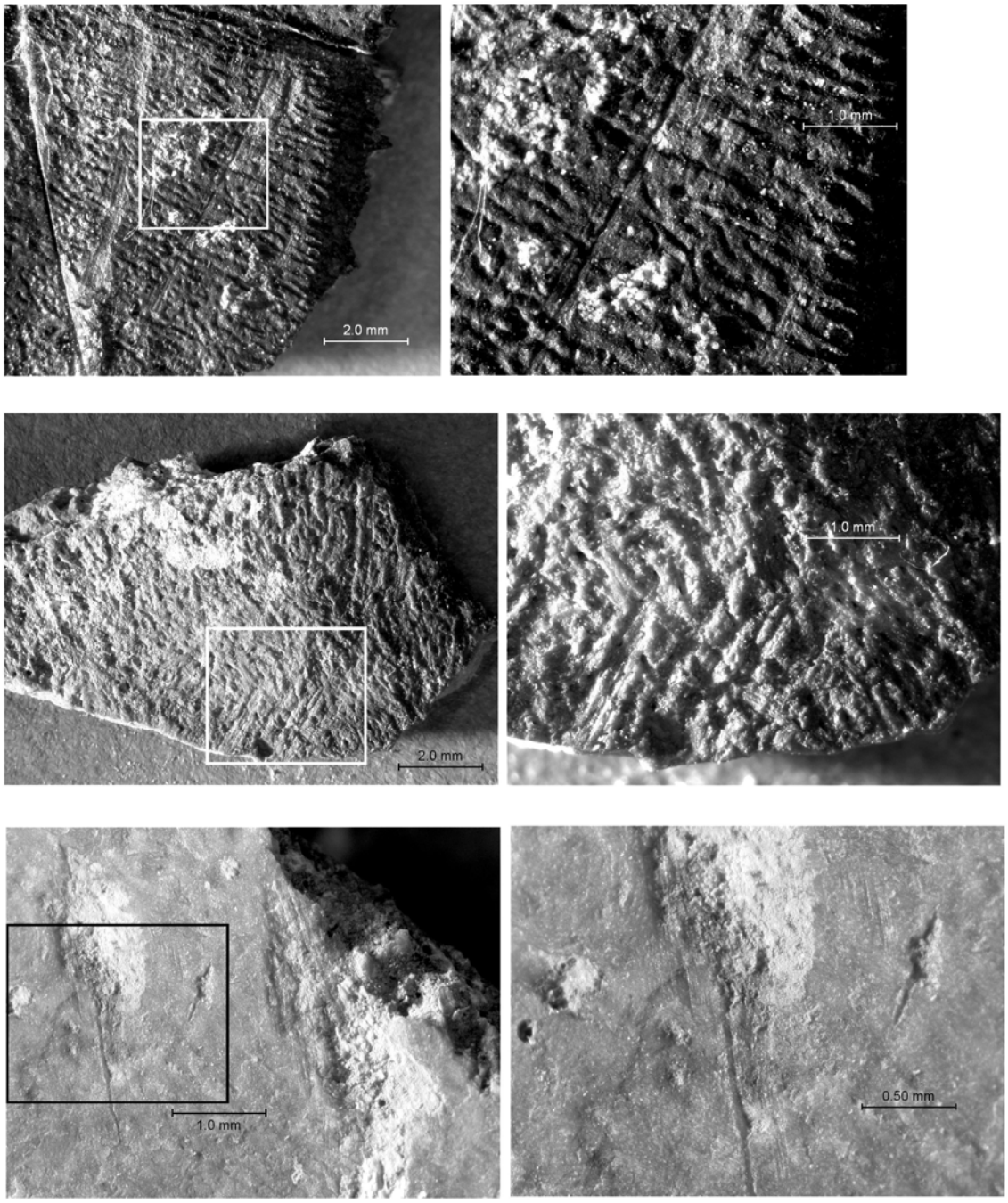


Fig. 37 Examples of percussion marks on tortoise carapace fragments. Images on the right are enlargements of the area in the box to the left.

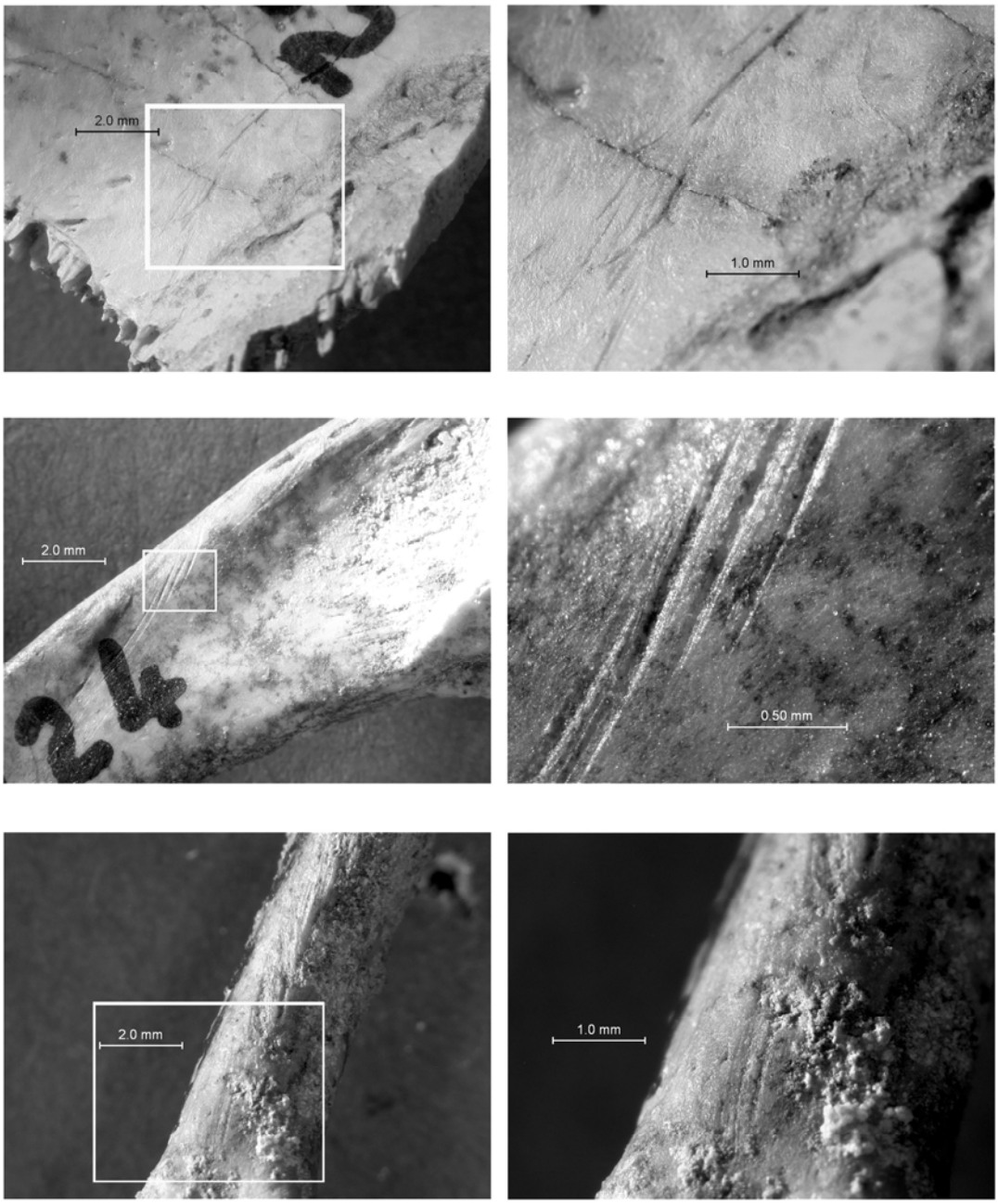


Fig. 38 Examples of cut marks on the interior of tortoise shell and on limb elements. Images on the right are enlargements of the area in the box to the left.

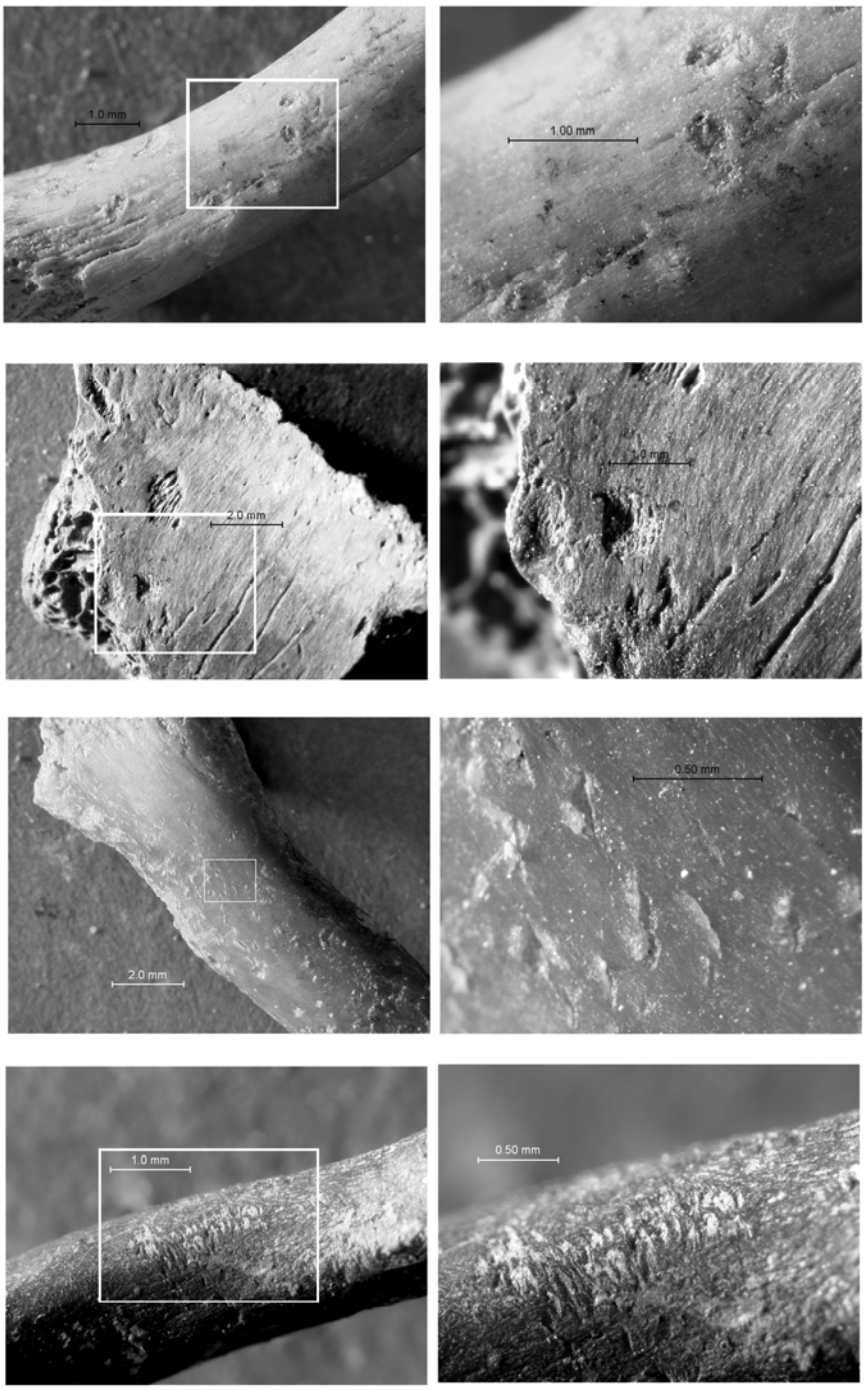


Fig. 39 Examples of tooth marks (top two images) and non-identified but likely non-human modification (bottom two).

At present, the majority of the evidence indicates that raptors may have made a very small and largely insignificant contribution to the PP13B accumulation, and that the majority of the tortoises were accumulated and modified both by humans and carnivores of several different sizes. Regardless of this, the overall poor representation of tortoises at PP13B and the relatively high representation of very small species such as *H. areolatus* indicate that over the course of the site's occupation tortoise exploitation did not comprise a major component of the MSA hominin diet. The high abundance and taxonomic homogeneity of tortoises at other MSA sites contrasts sharply with this conclusion from PP13B, and begs that a similar taphonomic study elsewhere be a priority in future work.

CHAPTER FIVE: THE BLOMBOS CAVE FAUNAL ASSEMBLAGE

Site description

Despite its relative proximity to other MSA sites, Blombos is quite different in its life history, physical configuration, and material culture context. It is a small, isolated cave situated in a steep wave-cut cliff 34.5 m above modern sea level, and thus did not suffer removal of sediments by rising sea levels during MIS 5e as have many other coastal caves in the region. It is set into the calcified sediments of the Wankoe Formation (Jacobs *et al.*, 2006), and the calcareous environment is at least partially responsible for the excellent state of the fossils that have been recovered (Henshilwood *et al.*, 2001b).

The entrance is long and low, about 10m across and 3 – 5m in height (Figure 40). MSA deposits at Blombos run back into the surrounding limestone just under seven meters, and have been well-dated with luminescence techniques (Jacobs *et al.*, 2003a, b; Jacobs *et al.*, 2006; Tribolo *et al.*, 2006). All MSA layers are separated from subsequent LSA layers by sterile dune sands that provide minimum age estimates for the underlying deposits. Multiple- and single-grain OSL techniques on this sand have resulted in dates between ca. 71 – 64 ka (Jacobs *et al.*, 2003a, b), and a second sterile sand at the base provides a maximum age of ca. 149 – 138 ka (Jacobs *et al.*, 2006).

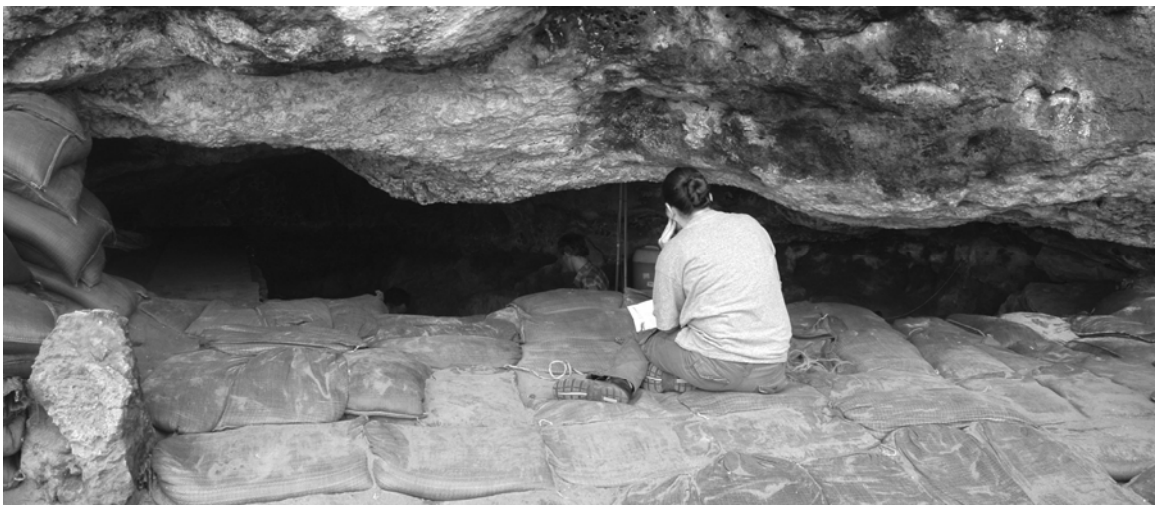


Fig. 40 View of the entrance to Blombos Cave. Note that the person whose head is visible inside is standing on deposits from the lowest major stratigraphic horizon.

Between 1992 and 2000 about 13 m^3 of MSA deposit was excavated from Blombos (Henshilwood *et al.*, 2001b), and excavations continue to the present. The deposits consist of three main MSA horizons with smaller stratigraphic units identified within each. These comprise the analytical units used in this study. Fish, shellfish, large numbers of tortoises, large and small mammals, and *in situ* features such as hearths have been recovered throughout the sequence. A preliminary analysis of the taxonomic abundances of the large mammals has been conducted, and these authors have concluded that most of the large mammals were accumulated by humans (Henshilwood *et al.*, 2001b). However, this assertion has not been examined in detail and the authors recommend that a thorough taphonomic study that employs microscopic techniques would definitively address the accumulative agent (Henshilwood *et al.*, 2001b:435).

At the base of the sequence, BBC M3 has abundant ochre and a rather generalized MSA lithic assemblage that emphasizes hard-hammer percussion (Henshilwood *et al.*,

2001b). BBC M3 has a date from near the base of between 104 and 93 ka, although the maximum age of this horizon is 149 ka based on the age of the underlying dune. This indicates that an MSA presence could potentially have begun as early as late MIS 6 during the height of a cold and arid phase. However, shellfish and marine mammals have been recovered from BBC M3 and this suggests that at the time of occupation the sea was within the ca. 9 km foraging radius beyond which ethnographically-observed humans do not tend to transport such resources (Bigalke, 1973; Erlandson, 2001). This further implies that occupation of Blombos began only after climatic conditions in the Western Cape began to improve, and that the underlying dune sand may have sealed Blombos from human occupation during the arid period of MIS 6 much in the same manner as did the capping dune sand about 70 thousand years later Jacobs *et al.* (2006).

Jacobs *et al.* (2006) suggest that the detachment of large blocks from the ceiling of the cave created a hiatus in occupation between BBC M3 and BBC M2 at around 85 ka, and certainly subsequent archaeological deposits have a very different artifactual character from BBC M3. The second horizon, BBC M2, retains a similar lithic assemblage and abundance of ochre, but formal and informal bone tools also now make an appearance (Henshilwood *et al.*, 2001b). These deposits have been dated to between 90 – 74 ka, a time period that saw fluctuations in global sea level of between -19 m and -44 m below that of the modern day (Chappell and Shackleton, 1986). Because the continental shelf off the coast of Blombos is quite shallow, this would have resulted in dramatic changes in the distance between the ocean and the site (van Andel, 1989).

The uppermost horizon, BBC M1, was likely the occupation shortest in duration and has been dated to between 76 – 70 ka. The overlapping dates with BBC M2 suggest that starting in the warm period MIS 5a occupation was relatively continuous through and into the start of the cold period MIS 4. At Blombos, this shift in climatic regime is roughly in approximation with some important changes in the artifactual assemblage. BBC M1 is characterized by Still Bay bifaces, numerous biface thinning flakes, some bone tools, and several ochre specimens. A piece of engraved bone, two pieces of abstractly engraved ochre, and nearly 40 shell beads were also recovered from this horizon (d'Errico *et al.*, 2001, 2005; 2007; Henshilwood *et al.*, 2002, 2004). At the end of BBC M1, during a relatively cold and arid period around 70 ka, the cave was sealed from further human occupation by a dune and remained closed until the Later Stone Age.

As at PP13B, dune migrations and their periodic incursions into the cave placed constraints on when the sites could have been occupied during the MSA. In a very broad sense these incursions appear to have been asynchronous between the two sites, with PP13B available for occupation during MIS 6 while Blombos was not and with Blombos continuing to be accessible into the start of MIS 4 up to 20 thousand years after PP13B was sealed. The two sites therefore offer to inform about separate but equally important issues in the modern human origins debate. PP13B provided an opportunity to examine shifts in hominin subsistence during and immediately after a time at which the southwestern coast of South Africa is postulated to have been a refugium for fragmented MSA populations. In comparison, Blombos is an excellent site for detailed examination of subsistence strategies that were established in populations following this time of severe

climatic stress. It also offers the chance to examine these strategies in tandem with the substantial changes in technology and the material expression of symbolism that have been documented at the site.

Taxonomic Representation

The taxonomic composition of the Blombos Cave fauna is similar to other published MSA sites in the Western Cape (e.g. Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b; Halkett *et al.*, 2003). Even without a quantitative study it is readily apparent that small mammals such as hyraxes, hares, and Cape dune mole rats are very abundant, and that tortoises comprise an estimated 80% of the assemblage by NISP. Very useful future projects would therefore be: 1) A return to the cranial portion of the 2000, 2002, and 2004 large mammals; 2) A study of the small fauna component at Blombos; and 3) A taphonomic study of the remaining excavation seasons.

Marine mammal representation at Blombos is relatively low, at 5% by NISP. This is lower than the 10% reported by Henshilwood *et al.* (2001b), but still higher than that at PP13B. The discrepancy between the two results from Blombos is likely because Henshilwood *et al.* (2001b) were reporting only specimens identifiable to element and did not include shaft fragments that are easily identified as being terrestrial mammal owing to the presence of a medullary cavity. Increased scrutiny of these less identifiable fragments (such as long bone shaft fragments) therefore likely results in a relative increase in terrestrial mammal representation.

Despite the relatively low overall proportions, differences in marine mammal representation are apparent between layers at Blombos: M1 has the highest proportion at

6%, M2 the lowest at 2%, and M3 a slightly higher proportion at 5%. These are all close figures, and it may be more useful to return to the larger set of published taxonomic data available in Henshilwood *et al.* (2001b). These mirror the results from the subsample reported here, and in accordance with the methodological factors discussed above they are higher: M1 has 12%, M2 has 5%, and M3 has 10%.

If environmental change and proximity to the coastline is the driving force behind marine mammal representation, then the similarity between proportions in M1 and M3 are not necessarily what would be expected given the range of dates reported for these layers. M1, dated to a time when the climate was shifting to one that was much cooler, should have the fewest marine resources relative to the other sites, and the most abundant marine resources should occur in the warmer ca. 100 ka layer M3. However, reported abundances of shellfish recovered from Blombos do follow this expected pattern: in terms of the kg shell/m^3 of recovered sediment, shellfish are least abundant in M1 and become progressively more so through M2 and M3 (Henshilwood *et al.*, 2001b). This likely indicates that as at PP13B the marine mammals comprise too small of a sample to be usefully employed as a paleoclimatic proxy for the site. It further suggests that even at the same time that extensive shellfish exploitation was occurring the exploitation of other marine resources such as seals was minimal and likely opportunistic in nature.

There were no primate specimens identified in the Blombos sample. Large terrestrial carnivore representation is also very low (1%) – even slightly lower than at PP13B (1.5%). There were no hyenid remains recovered from the sample reported here, and Henshilwood *et al.* (2001b) also report only a single specimen. Small canids and

felids such as the black-backed jackal (*Canis mesomelas*) and the African wild cat (*Felis libyca*) instead comprise the larger carnivore representation at the site – although these species are just barely larger than some of the mongooses and other small carnivores that make up the majority of the carnivores at Blombos but are too small to be included here (Henshilwood *et al.*, 2001b).

Ungulate taxa dominate the identifiable assemblage at Blombos (90% of identifiable specimens). Body size representation overall sees nearly 50% of the overall ungulate assemblage represented by body size 1 (Figure 41). Of these, 81% at Blombos were positively identified as bovids and it is very likely that other, more general categories such as 'artiodactyl' and 'ungulate' are also bovids. NISP data for all taxa are provided in Appendix A.

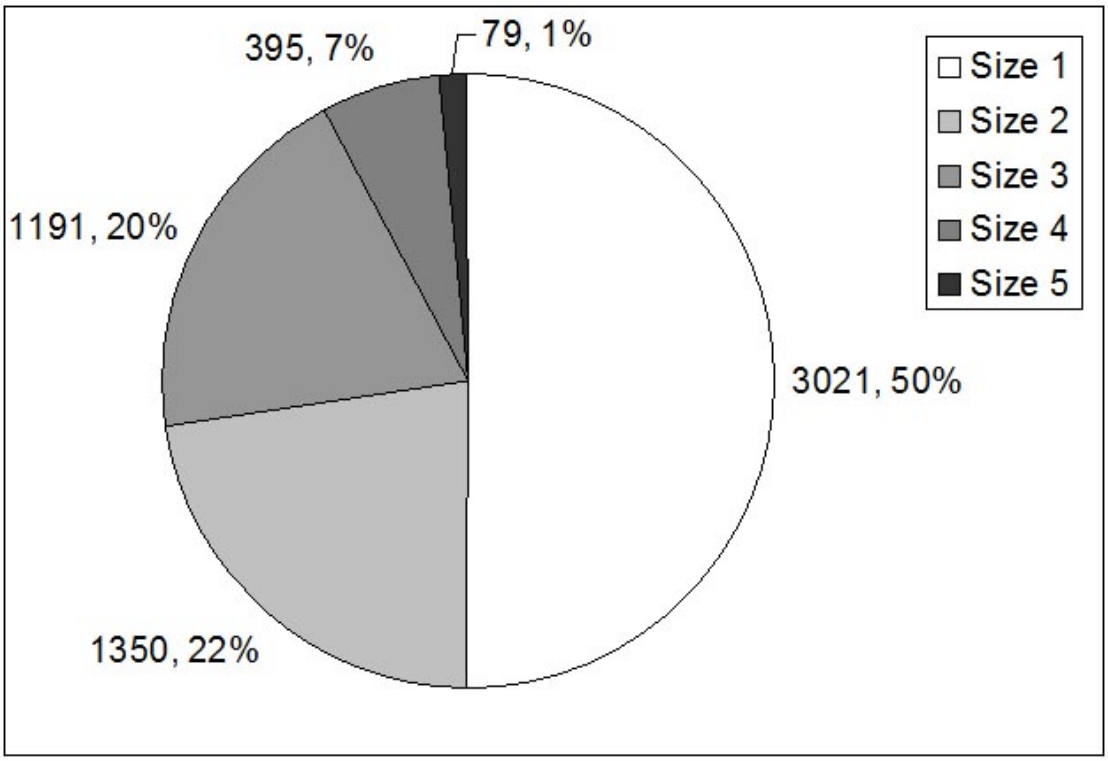


Fig. 41 Overall larger mammal body size representation at Blombos.

There are quite dramatic differences in body size representation between major stratigraphic units at Blombos. There is a nearly even distribution between size 1, 2, and 3 ungulates in M1, a superabundance of size 1 (65%) in M2, and nearly 60% of M3 also comprised of this smallest size class (Figure 42). The distribution of body sizes are shown to be independent from the layer from which they are derived when a Chi-squared test was used to examine each layer side-by-side to another layer (between M1 and M2 Chi-squared value = 405.35; D.F. = 5; p-value = < 0.0001; between M1 and M3 Chi-squared value = 123.76; D.F. = 5; p-value = < 0.0001, between M2 and M3 Chi-squared value = 33.909; D.F. = 5; p-value = < 0.0001).

This is reminiscent of the published report from Layer 11 of DK1, in which small ungulates are the most abundant size class (Marean *et al.*, 2000b). In the case of DK1 the small ungulates were found to have been predominately collected by raptors, while at PP13B we also saw an elevated non-human input for this size class – although from carnivores, and likely during MIS 6 only. Results from these other two sites cautions that small ungulate taphonomy at Blombos should be examined carefully, as differences in small ungulate representation may be attributable to the agent of accumulation rather than human prey choice. At the same time the question is raised of whether increased hominin use of small ungulates during MIS 5 might also be apparent at Blombos as it was at PP13B.

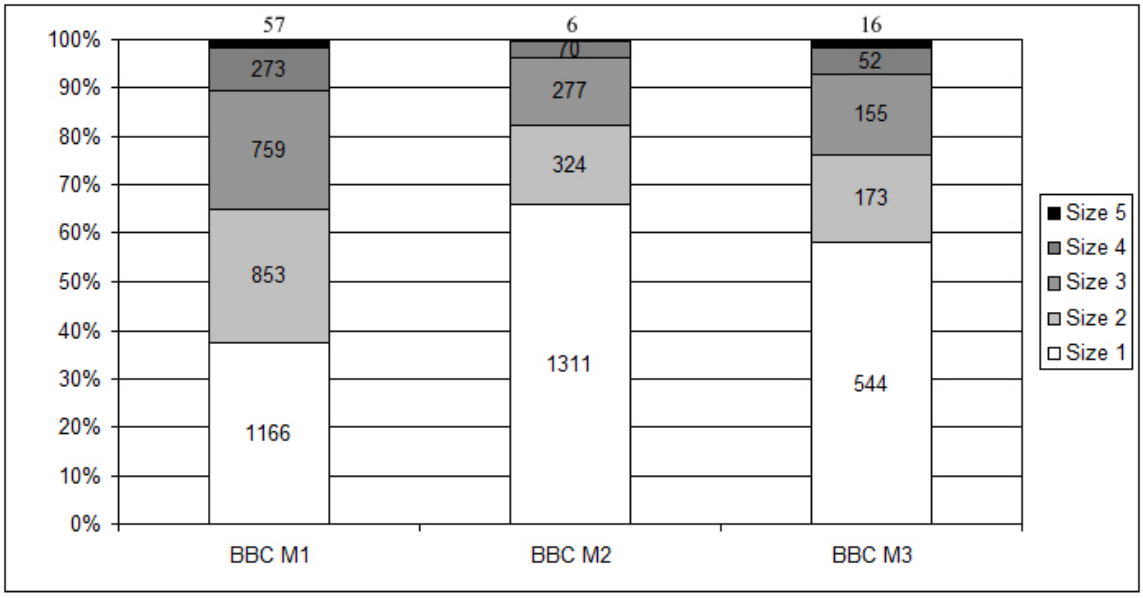


Fig. 42 Ungulate body size representation at the three major layers at Blombos.

Finally, the differences in patterning may be attributable to climatic change. Most of the size 1 ungulates are grysbok/steenbok, which are typical inhabitants of fynbos

environments in the modern day (Skinner and Smithers, 1990; Henshilwood *et al.*, 2001b). These data are therefore in line a scenario in which during M2 and M3, both periods that have been dated to rather warm climatic intervals, the vegetation immediately around Blombos was fynbos and the animal communities supported by it were typical small-bodied fynbos inhabitants. The situation seems to have changed during M1, during which climatic conditions, especially if accompanied by the aridity documented in MIS 4, could have resulted in more open vegetation and a subsequent reduction in the available habitat for small browsers. A small ungulate component remains present, but there is a large expansion in the relative representation of size 2 ungulates.

These taxonomic data suggest that during M1 environmental shifts were sufficient to chop the previously-uniform vegetational and animal communities surrounding Blombos into a variety of smaller patches that offered different foraging opportunities for MSA hominins. Alternatively, there may have been some key behavioral shifts in the strategies employed by the hominins themselves, such as an extension of the distance over which animal resources would be transported Dates for the three layers roughly correspond to a cold period only in M1, and this is where the lowest representation of size 1 fauna is found.

Despite these general patterns within the size 1 fauna, the overall tabulations from Henshilwood *et al.* (2001b) show the presence of both water-dependent animals (e.g. southern reedbuck, *Redunca arundinum* and Hippopotamus, *Hippopotamus amphibius*) and open-terrain, arid-adapted fauna (e.g. springbok, *Antidorcas* spp. and Cape zebra,

Equus capensis) distributed throughout the major layers in a way that shows no clear patterning with climate. However, large mammal species abundances as presented in Henshilwood *et al.* (2001b) are not likely not the best guides for past climate at Blombos. First, prey selection and transport will vary with the major predator responsible for the accumulation and faunal representation is not likely to be a random sample of the surrounding environment. Second, generalized differences in climate as inferred by the overall MIS record do not take into account local shifts in temperature and precipitation around the site. Therefore, very subtle changes on a local scale may have resulted in the introduction of one or two species within a layer that appear anomalous but that are simply the result of time compression and small sample sizes.

Density-mediated destruction

As is often typical at archaeological sites for the reasons described in Chapter Two, midshaft fragments are highly represented at Blombos relative to spongy epiphyses: 67% of long bone fragments are shafts, 20% are near-epiphysis shafts, and 13% are epiphyseal portions. Denser parts of spongy elements, such as vertebral zygopophyses, are the best-represented portions of these bones. The relative representation of all major element portions for all layers is illustrated in Figure 43. These MNE maps show the region of the bone from which the highest MNE was estimated. Darker areas indicate higher amounts of overlap, dotted areas with an arrow indicate where the highest numbers of overlaps occur, and diagonal lines represent areas of the bone not represented at all in the identifiable portion of the Blombos assemblage.

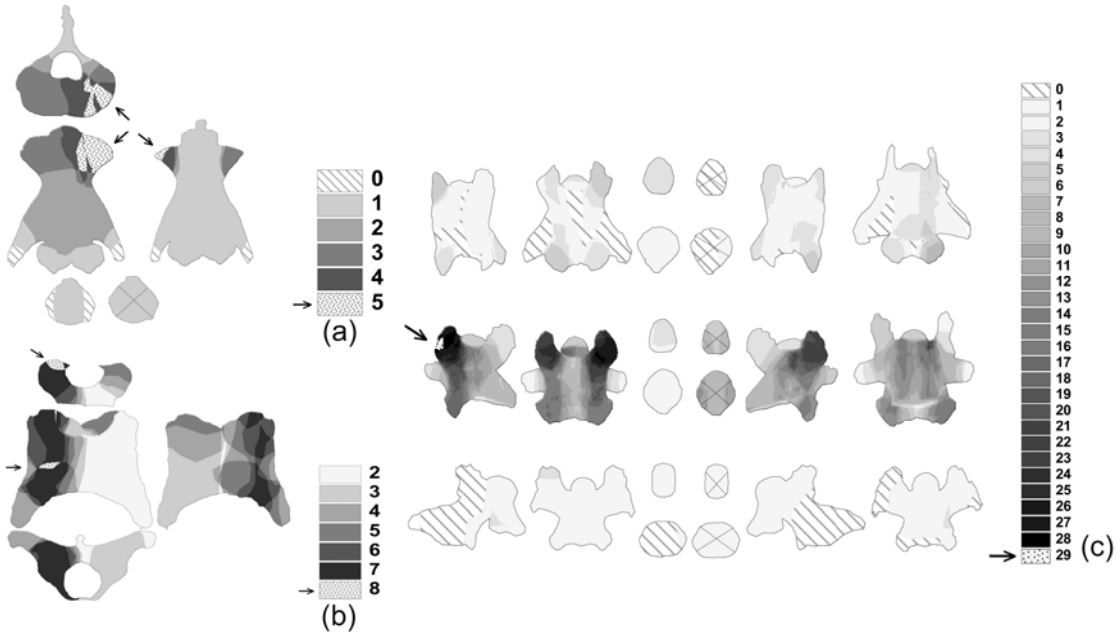


Fig. 43 Composite GIS images of the axis (a), atlas (b), and cervical vertebrae (c), from all layers at Blombos. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

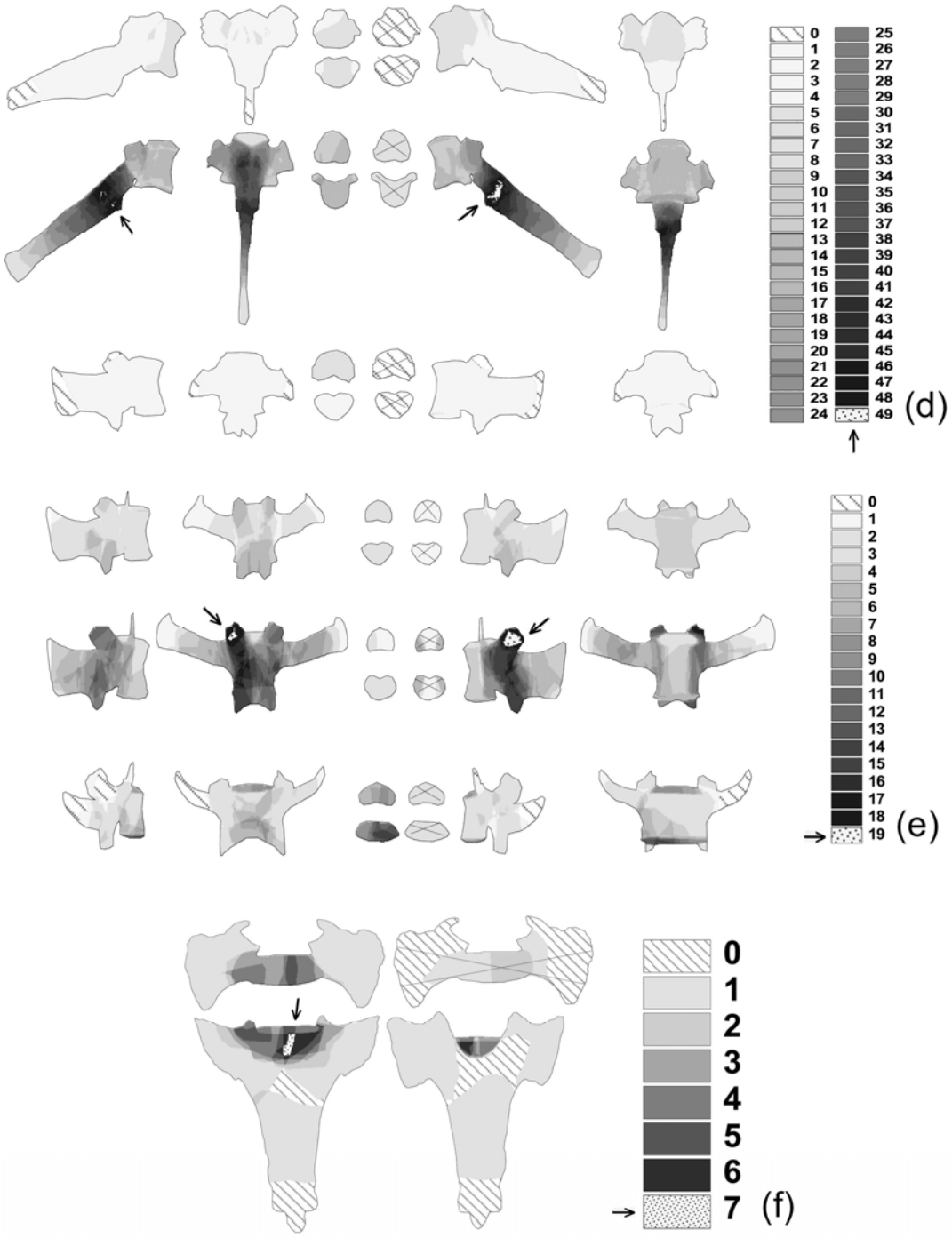


Fig. 43 (cont.) Composite GIS images of the thoracic vertebrae (d), lumbar vertebrae (e), and sacrum (f), from all layers at Blombos. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

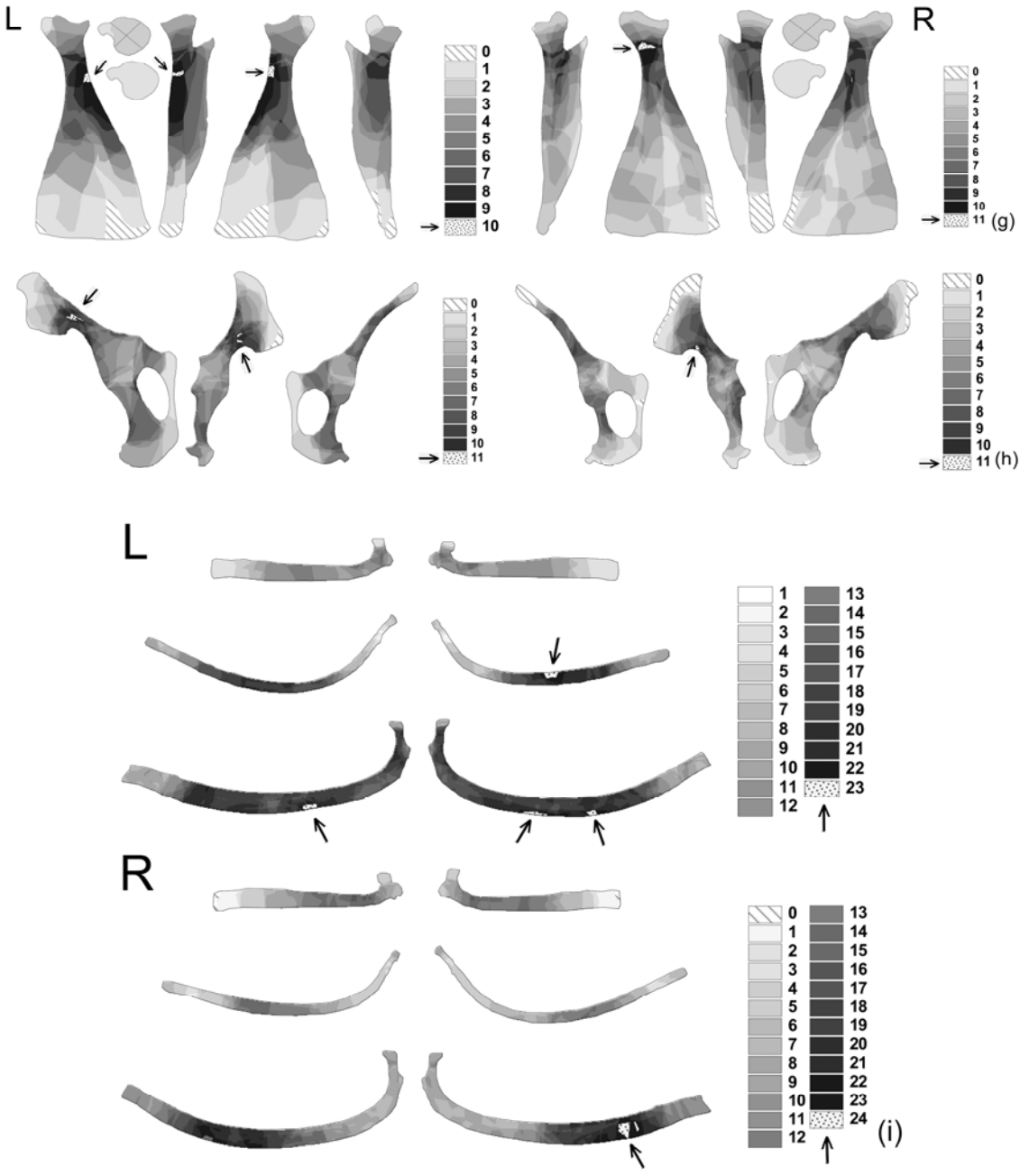


Fig. 43 (cont.) Composite GIS images of the scapulae (g), pelves (h), and ribs (i), from all layers at Blombos. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

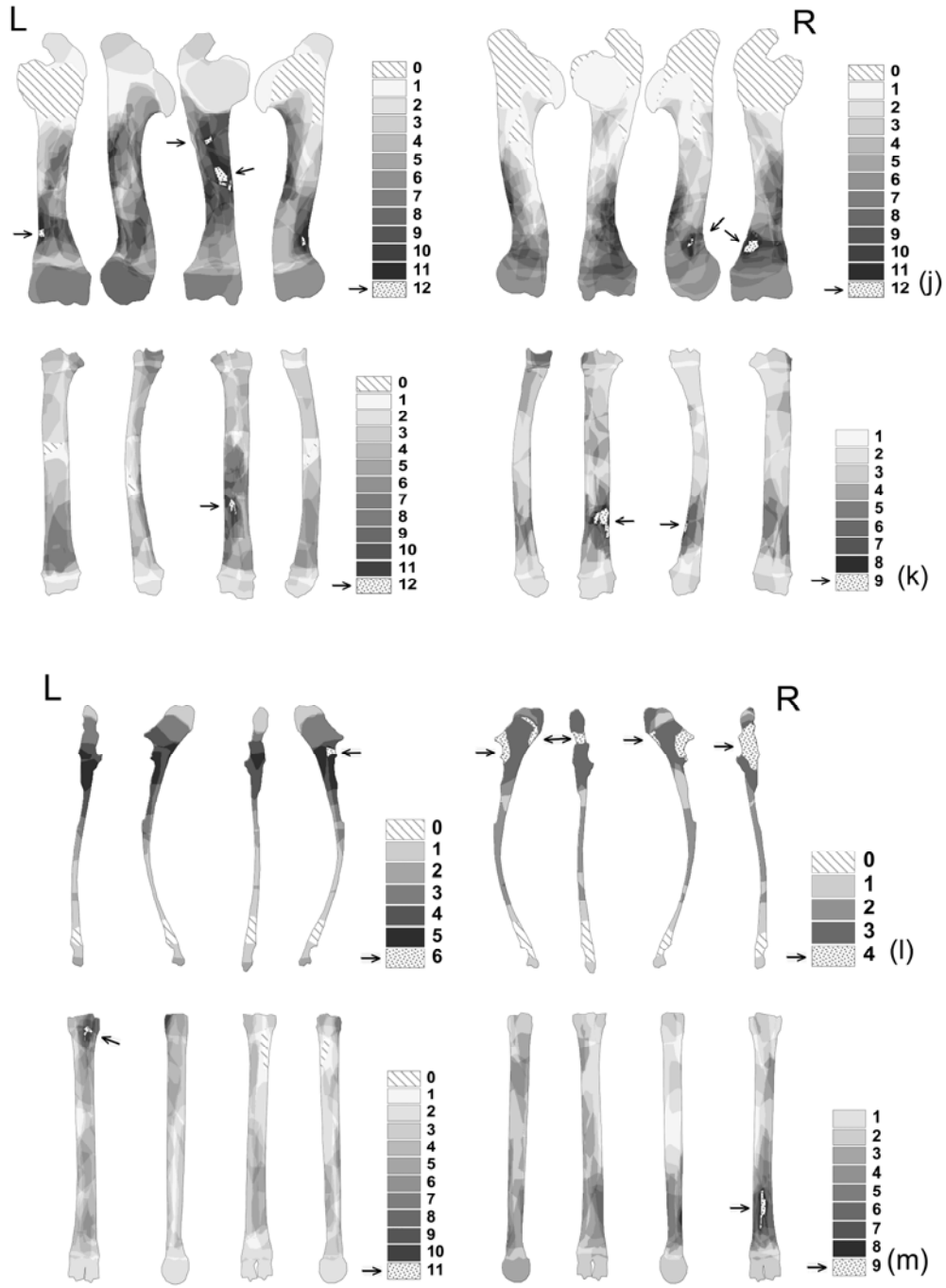


Fig. 43 (cont.) Composite GIS images of the humerus (j), radius (k), ulna (l), and metacarpals (m) from all layers at Blombos. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

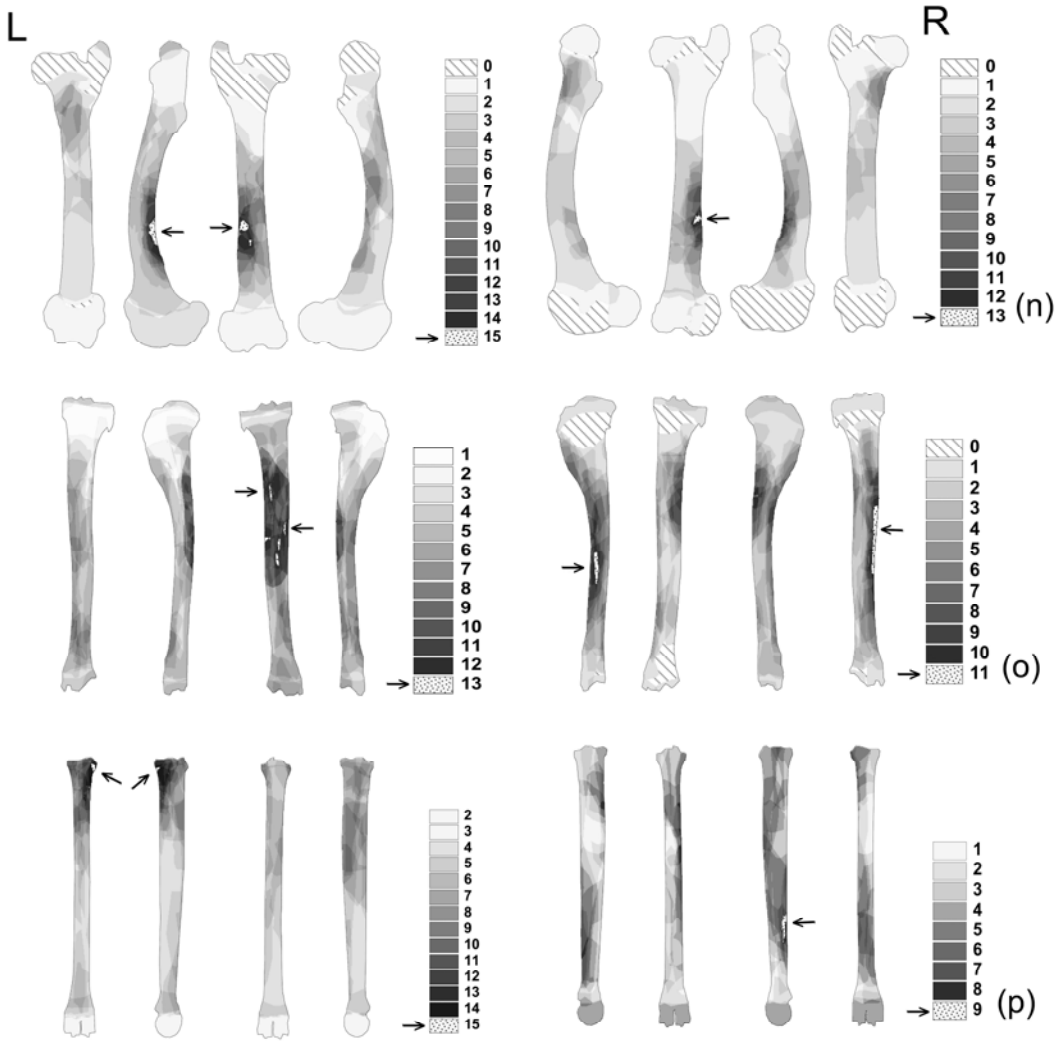


Fig.43 (cont.) Composite GIS images of the femur (n), tibia (o), and metatarsals (p) from all layers at Blombos. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

This visual assessment is verified quantitatively when MNE values are derived using different portions of the same element. Long bones were divided into the five zones used by Abe *et al.* (2002): proximal epiphysis, proximal shaft, midshaft, distal

shaft, and distal epiphysis. The MNE for each bone portion was then derived, and denser portions such as long bone shafts were found to consistently provide the highest MNE counts (Table 13).

Table 13

MNE estimates from each long bone portion at Blombos.

Element	Side	Prox. End	Prox. Shaft	Midshaft	Dist. Shaft	Dist. End
Humerus	Right	4	6	12	12	11
	Left	9	12	12	12	9
Radius	Right	6	5	6	9	3
	Left	8	6	11	12	7
Metacarpal	Right	3	5	6	9	3
	Left	10	11	7	6	3
Femur	Right	7	7	11	13	5
	Left	6	8	15	15	5
Tibia	Right	4	11	11	11	5
	Left	6	13	13	10	8
Metatarsal	Right	7	8	9	9	5
	Left	15	15	10	7	6

Long bone portion representation can also be presented as the %Area preserved for each element using the procedures outlined in Marean *et al.*, (2001) and given in Table 14. Again, it is clear that the highest proportions of preserved area occur on the denser parts of long bones. When these percentages are plotted against bone density as measured by CT of a sheep skeleton (Lam *et al.*, 1998), this relationship is verified and found to be statistically very robust (Figure 44).

Table 14
Relative proportions of long bone portion representation at Blombos (all percentages add to 100% for a complete bone).

	Proximal Epiphysis			Proximal Shaft			Midshaft		
	Left	Right	Total	Left	Right	Total	Left	Right	Total
Humerus	12.5%	4.2%	9.0%	19.0%	9.1%	14.8%	20.0%	17.8%	19.1%
Radius	11.0%	11.2%	11.1%	17.8%	18.3%	18.0%	22.4%	21.8%	22.1%
Metacarpal	7.0%	3.6%	5.5%	31.6%	21.3%	27.0%	26.0%	20.4%	23.5%
Femur	5.1%	9.6%	7.0%	18.7%	19.6%	19.1%	28.7%	27.8%	28.3%
Tibia	9.9%	5.8%	8.3%	25.1%	29.9%	26.9%	31.8%	35.7%	33.3%
Metatarsal	13.3%	8.5%	11.4%	34.4%	25.1%	30.7%	25.2%	29.1%	26.7%

	Distal Shaft			Distal Epiphysis		
	Left	Right	Total	Left	Right	Total
Humerus	22.3%	33.9%	27.2%	26.2%	35.0%	29.9%
Radius	41.9%	39.4%	40.8%	6.9%	9.2%	8.0%
Metacarpal	28.7%	45.4%	36.1%	6.8%	9.3%	7.9%
Femur	30.8%	31.6%	31.1%	16.7%	11.4%	14.4%
Tibia	22.0%	23.7%	22.7%	11.2%	4.9%	8.7%
Metatarsal	22.1%	27.0%	24.0%	5.0%	10.3%	7.0%

Spearman's Rho gives a highly significant correlation between bone portion representation and bone density at Blombos ($R_s = 0.4879$, $p = 0.0062$). This indicates that a substantial proportion of density-mediated destruction has occurred and long bone epiphyses are preserved in proportions that are much farther removed from their original representation than denser portions such as long bone shafts. Therefore, adjustments must be made during subsequent analyses of surface modification such as cut mark placement to account for this differential representation (Abe *et al.*, 2002).

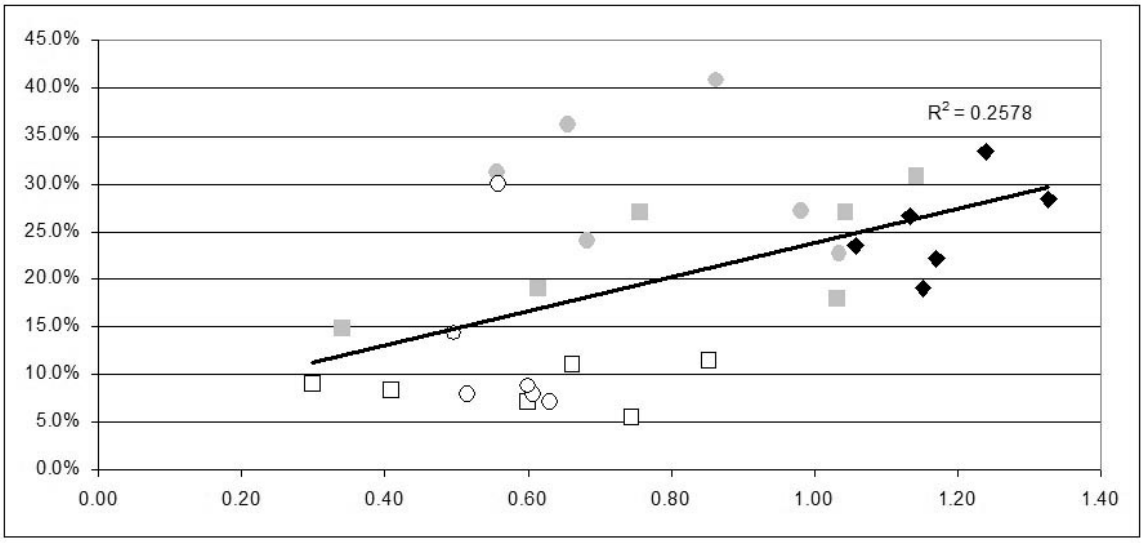


Fig. 44 Long bone portion representation at Blombos versus bone density. Density data from Lam *et al.* (1998). Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

Although Blombos displays a highly significant positive correlation between bone portion representation and density, the correlation itself is somewhat small. One possible explanation is that it might be linked to the body size abundances at the site. Blombos Cave has a relatively high representation of size 1 ungulates overall, and although smaller fauna might be expected to be more fragile, they might also be more likely to fragment into portions that represent a larger proportion of the original long bone. This would make them easier to identify and be entered into the GIS system that forms the basis of this analysis, and the latter possibility is examined in more detail in the following section. In order to determine how body size might affect the correlation, It is useful to examine this patterning by individual layer, and broken down into small (size 1 and 2) and large (size 3, 4, and 5) ungulates (Figure 45).

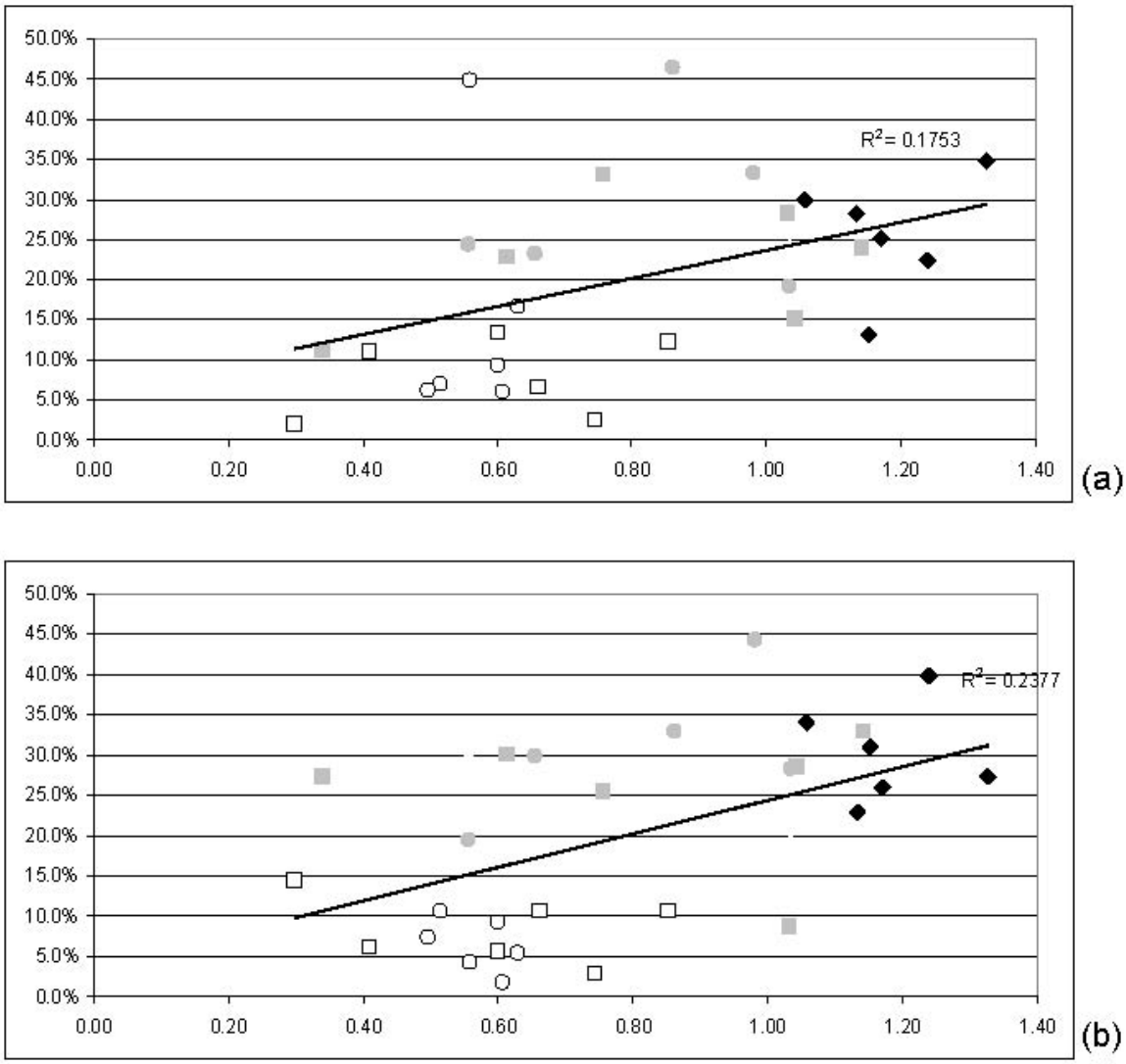


Fig. 45 Long bone portion representation at Blombos versus bone density for small (a) and large (b) fauna in M1. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

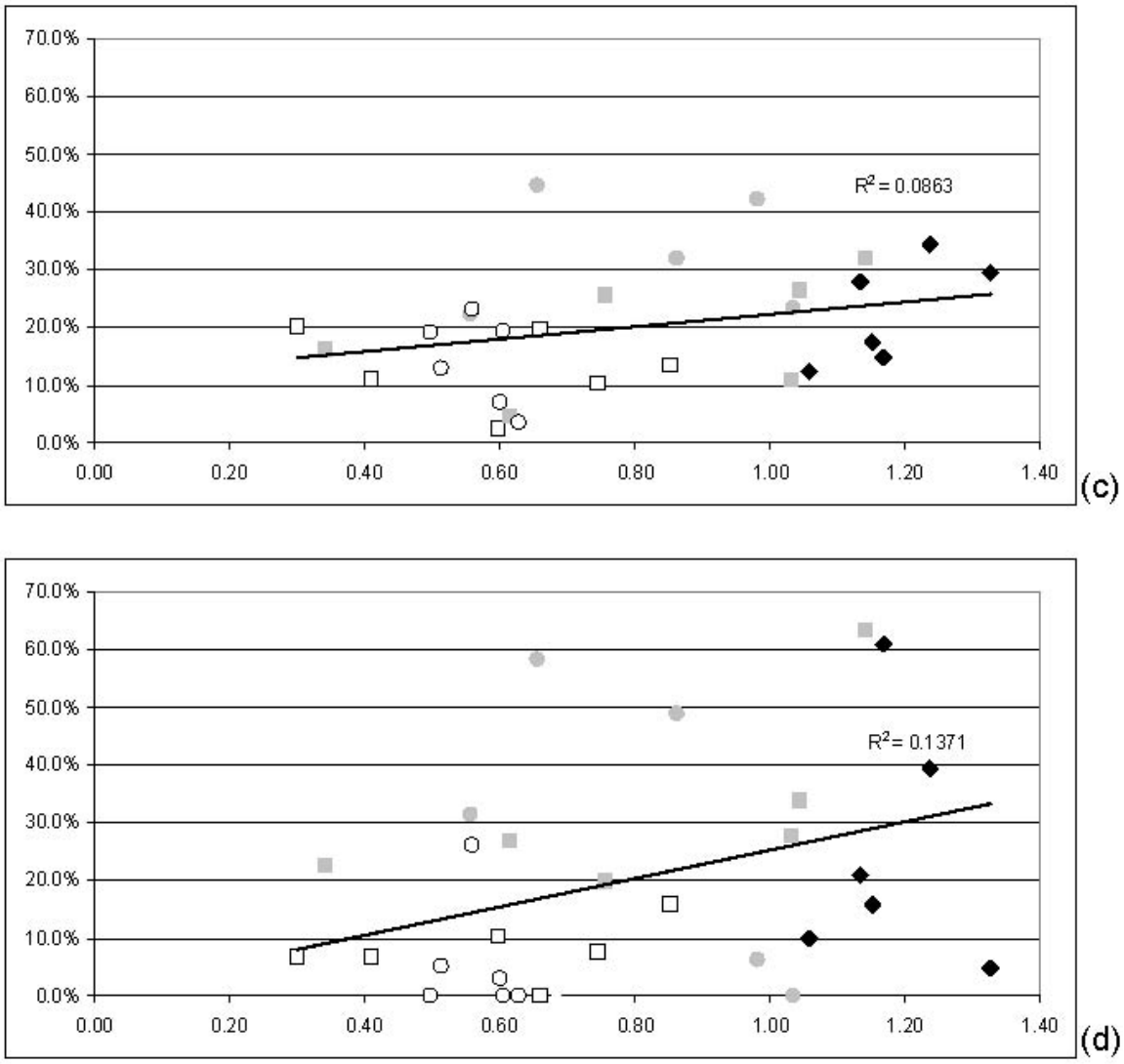


Fig. 45 (cont.) Long bone portion representation at Blombos versus bone density for small (c) and large (d) fauna in M2. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

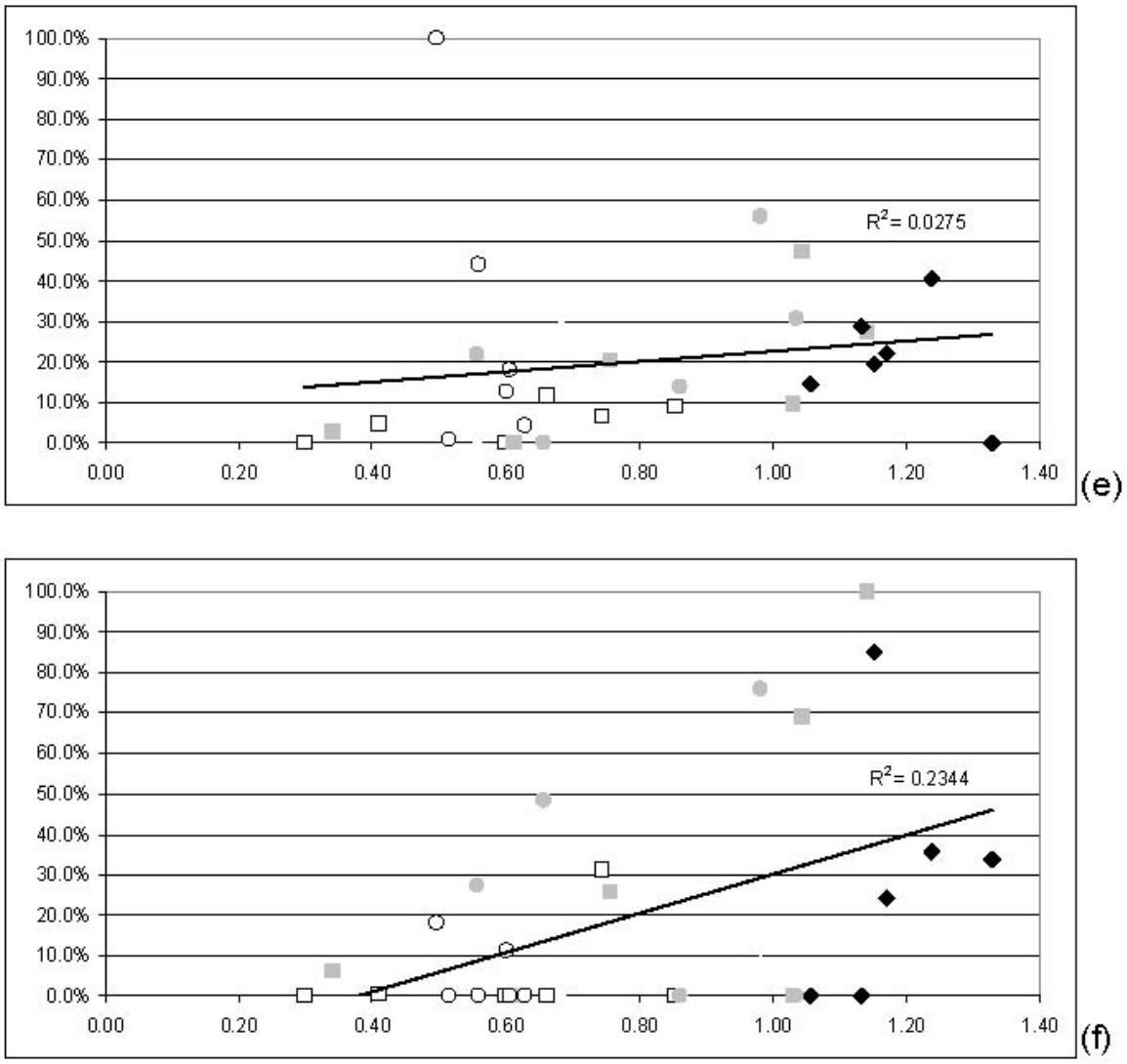


Fig. 45 (cont.) Long bone portion representation at Blombos versus bone density for small (e) and large (f) fauna in M3. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

Clear differences in the degree of density-mediated destruction can be seen both between layers and between body size categories. It is highest in M1 and similar between the two body size groupings. It is intermediate in M2 but also similar between the two body size groupings. In M3 small ungulates appear to have suffered less density-

mediated destruction than large ungulates. These observations are confirmed by Spearman's Rho, which shows a positive and significant correlation between increasing bone density and increasing bone portion representation in all cases (Table 15).

Table 15

Spearman's Rho and p-values for the significance of the correlation between long bone portion representation and bone density within different subsets of data at Blombos (density data from Lam *et al.*, 1998).

Ungulate Size	Dataset	Spearman's Rho	p-value
Small	M1	0.4999	0.0049
Large	M1	0.4732	0.0083
Small	M2	0.3348	0.0705
Large	M2	0.3699	0.0442
Small	M3	0.3880	0.0341
Large	M3	0.4625	0.0101

Differences between the layers indicate that butchery analyses must first be corrected by surface area in order to make behavioral inferences between layers and body sizes comparable. Differences between small and large ungulate bone portion representation in M3 indicate that this layer is particularly in need of these adjustments and that they must be done according to both layer and body size grouping. Finally, because ravaging carnivores are often sources of density-mediated destruction (Marean *et al.*, 1992), the density data may be giving an early indication of differences in either the independent input of carnivore-accumulated fauna or the degree of carnivore access to hominin-accumulated fauna via scavenging.

Surface preservation, fragmentation, and burning

Proportions of poorly preserved bone surfaces are very small at Blombos, although coverage by matrix is also a potential problem. Overall, less than 1% of the assemblage shows extensive dendritic etching, pocking, sheen, or smoothing. These types of post-depositional surface modification were spread evenly throughout the three major layers, suggesting that the factors that created these modifications were basically the same over time. In the case of dendritic etching root activity was almost certainly the culprit, as evidenced by the preservation of small clusters of tubular plant cells that occasionally still follow these etchings (Figure 46). These clusters may represent modern rootlet invasion or they may be the calcined ash remnant of a plant that etched the surface of the bone long ago and was subsequently burned, similar to the plant structures preserved in Karkanas *et al.* (2007:203). This issue can be resolved during future study by touching a small amount of dilute HCl to the remnants and examining them under a microscope for the effervescence that would be expected in the case that it was ash (Karkanas pers. comm., 2008).

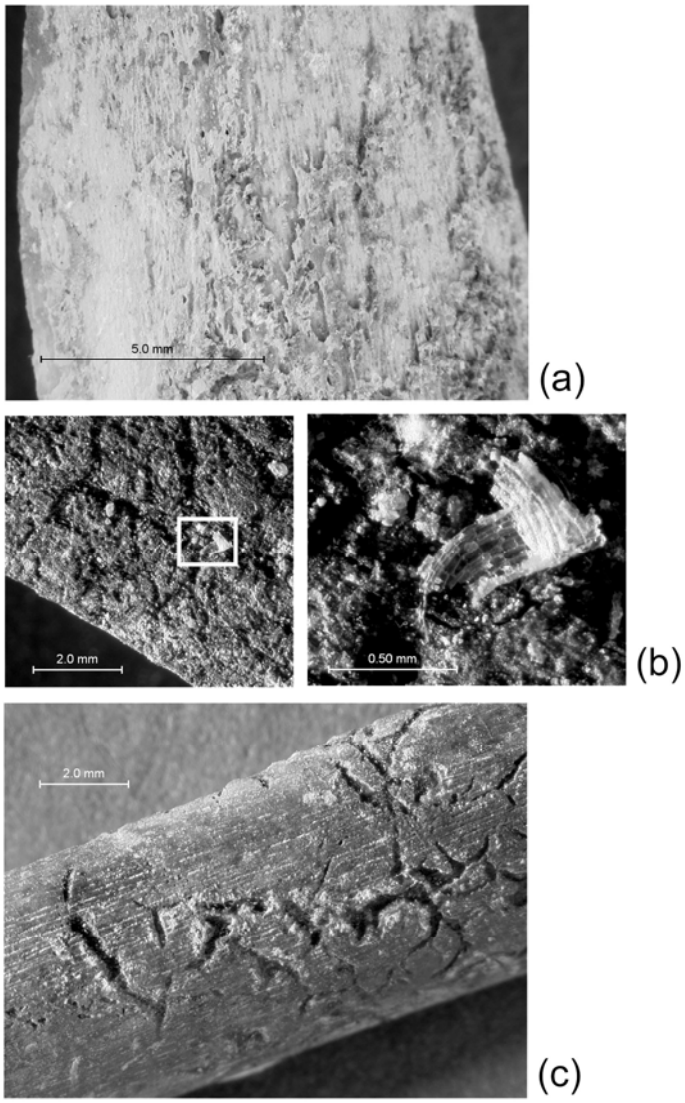


Fig. 46 Examples of surface exfoliation (a), dendritic eching (b & c), and etching with plant cells still preserved (enlarged portion of b).

Exfoliation at Blombos was by far the most common form of bone surface destruction, and occurred on 14.7% of specimens (Figure 46a). Unlike the other types of surface destruction, exfoliation was not evenly distributed throughout the layers, but instead is highest at the top in M1 (19.6% of bones affected), intermediate in M2

(11.4%), and lowest in M3 (6.0%). The agent behind such exfoliation is unknown, but it appears to proceed via the crystallization of minerals in miniscule fissures in the bone surfaces such that layers of bone peel away. It is possible that the abundant shellfish in M3 counteracted this process through the maintenance of high levels of $CaCO_3$ in the sediments, but this is a hypothesis that requires further testing. This pattern shows that M1 requires the greatest amount of adjustment in order to make it comparable to the other layers: it has suffered both the most density-mediated destruction and the most destruction of bone surfaces.

Gastric etching and rodent gnawing are low at Blombos at 3.9% and < 0.6% for all layers and body sizes, respectively. The proportions of gastric etching differ between layers: 2.2% in M1, 4.7% in M2, and 7.4% in M3. Furthermore, they differ a great deal between body sizes, with the highest proportions always occurring on size 1 specimens (Table 16). Proportions of gastric etching between body sizes 2, 3, and 4, are not statistically different below even the $\alpha = 0.10$ level using Fisher's Exact Test (Appendix J:[h]). However, proportions of gastrically etched size 1 fragments are significantly higher than all other body sizes ($p < 0.0001$). This indicates that more than the other body size classes, the size 1 fauna was partially accumulated by non-human agents the abundance of size 1 ungulates at Blombos cannot be attributed entirely to hominin prey choices.

The gastrically etched fragments are distributed evenly throughout the cave and well inside the dripline beyond appropriate roosting areas for raptors (Figure 47). This suggests that carnivores are a more likely agent. The distribution of this etching across

the skeletal elements of size 1 ungulates is in general agreement with this. Raptors typically are not able to digest elements much larger than the small bones of the distal limbs such as carpals, tarsals, and phalanges (Andrews, 1990), yet at Blombos between 46 – 61% of all gastrically etched elements are on axial elements or long bones.

Table 16

Numbers and proportions of gastrically-etched bone in each layer at Blombos.

Layer	Size 1	Size 2	Size 3	Size 4
M1	57	7	6	3
M2	85	6	5	1
M3	69	6	2	1
Total	211	19	13	5

Layer	Size 1	Size 2	Size 3	Size 4
M1	4.9%	0.8%	0.8%	1.1%
M2	6.5%	1.9%	1.8%	1.4%
M3	12.7%	3.5%	1.3%	1.9%
Total	7.0%	1.4%	1.1%	1.3%

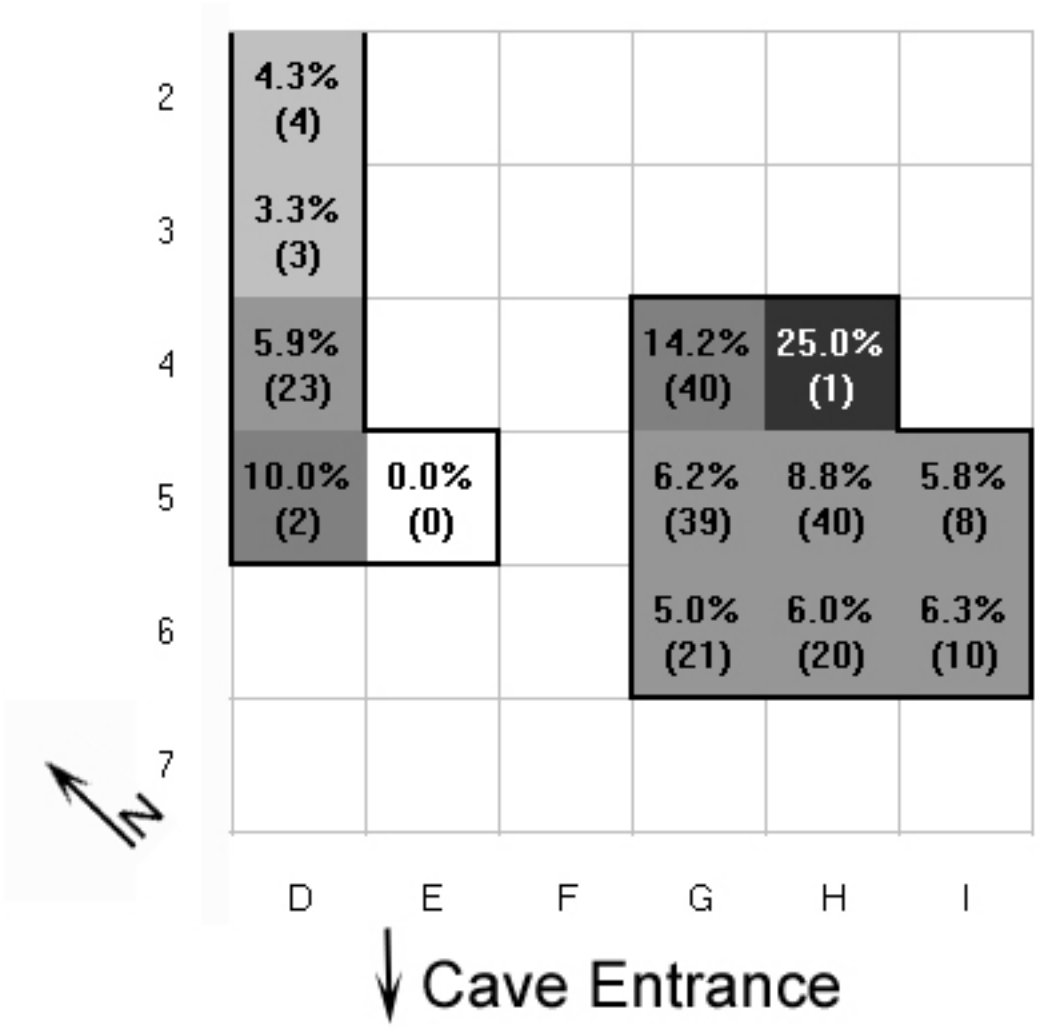


Fig. 47 Percentages of gastrically-etched bone by square at Blombos.

The distribution of this etching differs between major layers, with close similarity between M2 and M3 and a slightly higher proportion of small bones in M1 (Figure 37). There are also significant differences between layers in the overall incidence of gastric etching on size 1 ungulates ($p = 0.01$ between M1 and M2, $p = < 0.0001$ between M3 and the other two layers; Appendix J:[h]). These two lines of evidence suggest that the

carnivore contribution was likely highest in M3, lowest in M1, and intermediate in M2. Raptors were likely not major agents of accumulation throughout the occupation sequence, although they may have had a slight input of size 1 fauna during M1.

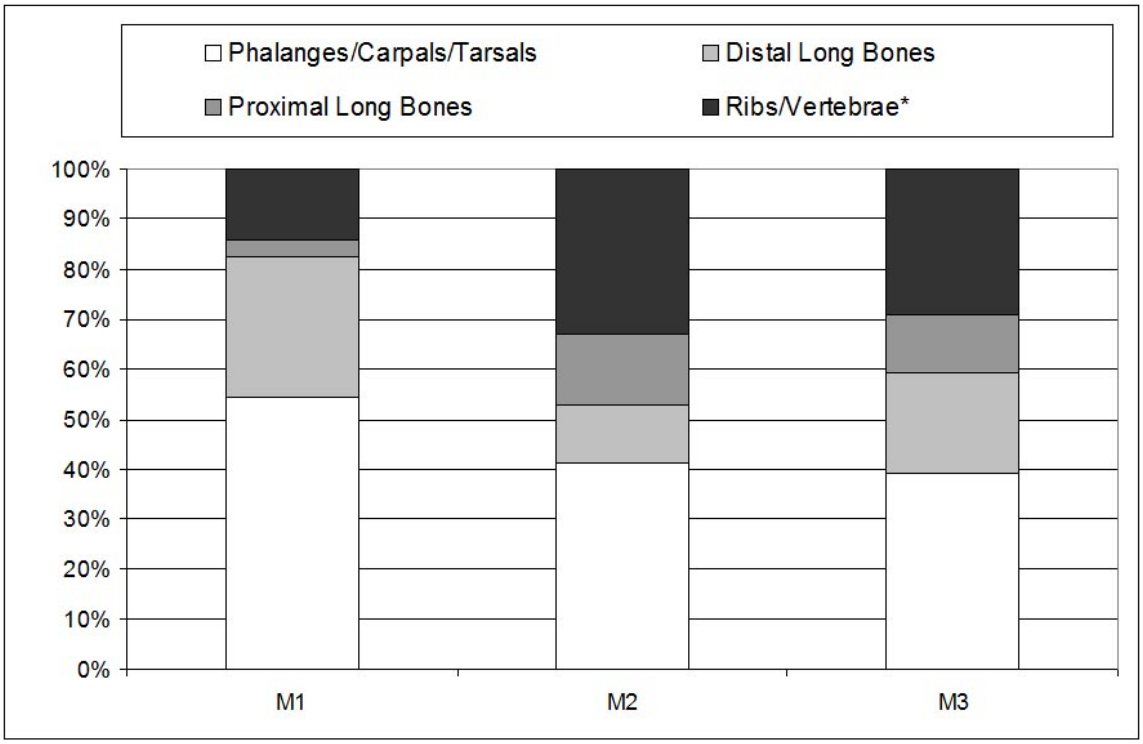


Fig. 48 Distribution of gastric etching across size 1 skeletal elements at Blombos. *The category Ribs/Vertebrae also includes a single scapula specimen in M2.

Moving forward to fragmentation patterns, the Blombos assemblage had 5,110 long bone fragments, resulting in a potential 10,220 potential long bone ends. After elimination of unbroken ends, indeterminate ends, ends from fragments that could not be assigned to a body size, fractures that suffered excavation damage, surfaces with heavy exfoliation, and surfaces with > 70% matrix coverage, only 5,533 remained for fragmentation analysis. A breakdown of these data is provided in Appendix B.

At Blombos there is no directional change in fragmentation between body size classes. When the size 5 data are removed, owing to a very small sample, the greatest observed difference between body sizes is 11.3% (on right-angled breaks from M1). This indicates that differences between body size classes are small as well as non-directional. Because the size 5 long bones comprise 0.4% of the total sample these are eliminated and the Blombos data are divided into two groupings of small (size 1 and 2) and large (size 3 and 4) fauna (Figure 49).

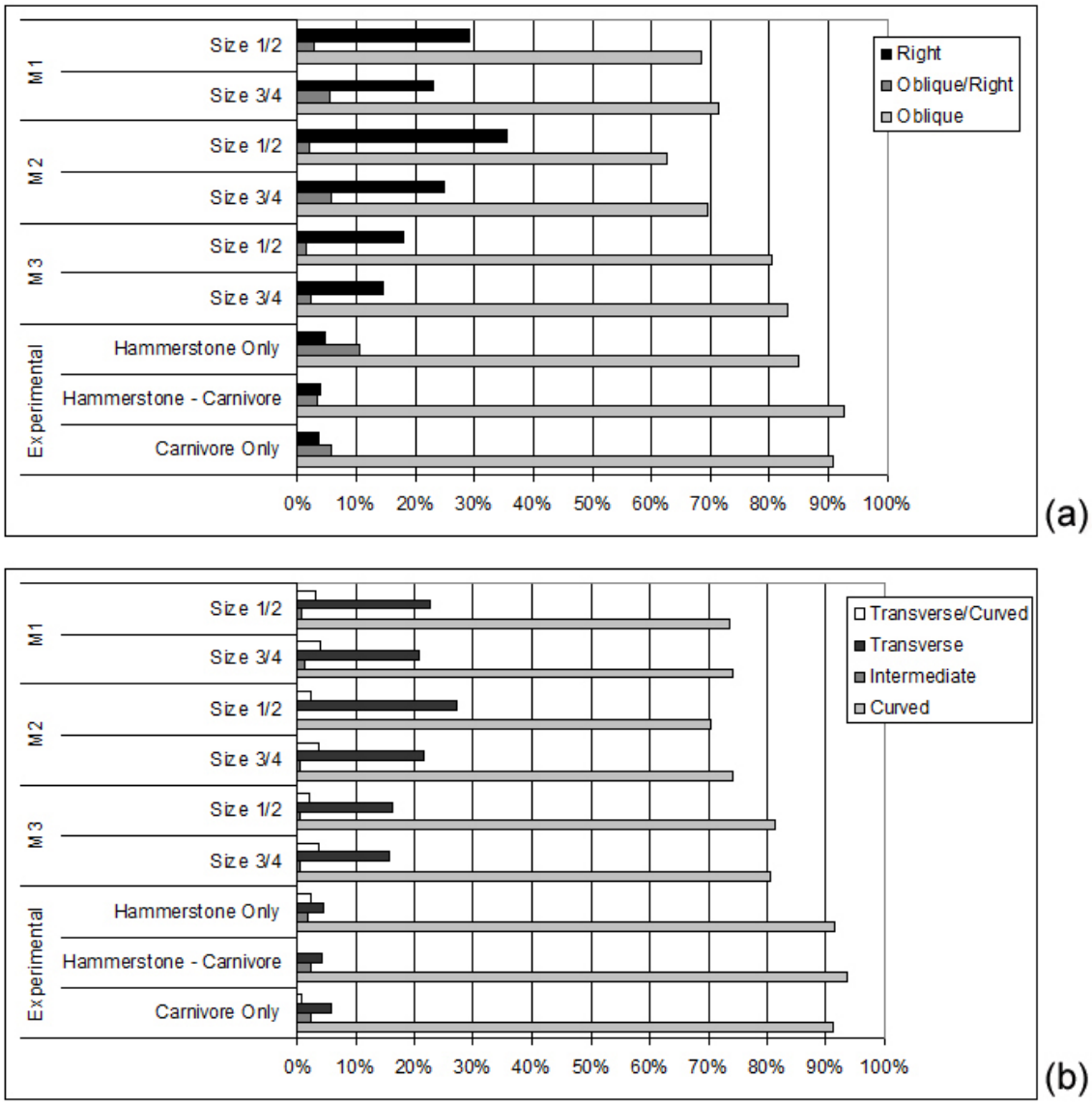


Fig. 49 Relative proportions of long bones at Blombos with different fracture angles (a) and outlines (b) compared to modern actualistic assemblages in which all bones were broken while fresh.

The amount of post-depositional fragmentation for layers M1 and M2 at Blombos exceeds the 95% confidence limits reported for three modern known-agent experimental assemblages (Marean *et al.*, 2000b:210-211). M3 from Blombos is positioned at the

lower end of the confidence limits, and suggests that very little breakage occurred after the bones were deposited in this layer. It is interesting that the lowest degree should occur in the basal level, given that sediment compaction is considered to be one of the primary causes of post-depositional breakage (Villa and Mahieu, 1991).

At Blombos 27% of the assemblage shows some evidence of coloration changes owing to having been burned. The lowest proportion of burned fragments occurs in M3 at the base of the sequence, the highest is in M2, and there is an intermediate proportion at the top in M1. As predicted, this is the same pattern as that found in the amount of post-depositional breakage. Eliminating burned fragments results in a decrease in the relative proportions of 'dry' breaks and a corresponding increase in the proportions of 'green' breaks for all layers. These increases also occur in the expected pattern: M3 has the lowest increase, M2 the highest, and M1 is intermediate. Overall, none of the proportions decrease by more than 3.5%. However, the decrease observed in M2 brings it into line with the same amount of post-depositional fragmentation as in M1.

Despite the small amount of burning in M3, elimination of these fragments nudges this layer even more securely into the lower end of the 95% confidence intervals for fracture angles and outlines established by the experimental data provided in Marean *et al.* (2000b). This indicates that although burning in M2 increased the friability of the bones and made them more susceptible to post-depositional fragmentation, the processes in M1 were not as heavily influenced by burning and the processes in M3 were negligible. Again, because the lowest level shows the smallest degree of such breakage, sediment compaction is unlikely to be the culprit. A reasonable conclusion is that M3

was accumulated more rapidly than the others, and thus was subject to less trampling and surface activity that could lead to post-depositional breakage. This can be tested using sediment volume estimates tied in to a careful dating program and records of the materials that were recovered from each of the major layers.

Although there is no pattern in the degree of post-depositional fragmentation between body sizes at Blombos, there is a difference in the degree to which animals of different body size classes were fragmented overall. Converting the vector files of each fragment drawn into the GIS into a raster image allowed the area of each fragment as a percentage of the whole bone to be calculated. This is a superior method to calculating area by using simple width x height because it takes into account the unique shape of each fragment. Furthermore, it much more accurately calculates the area of the fragment relative to the entire bone without having to use average bone surface estimates for whole bones of animals with different body sizes. The disadvantage is that this technique is extremely time-consuming.

The %Area of each fragment was calculated for the humerus, radius, femur, and tibia at Blombos. Average areas of all bones and layers combined show a definite decrease in the %Area according to body size: size 1 = 9.6%, size 2 = 6.0%, size 3 = 4.9%, and size 4 = 5.0%. N for these samples was 210, 91, 117, and 36, respectively. These averages imply that bones of larger animals were more heavily fragmented into smaller and therefore more numerous pieces relative to their overall surface area. If the bones were predominately modified by MSA hominins, then these differences in the degree of peri-depositional breakage at Blombos could indicate behavioral differences in

hominin marrow processing strategies according to body size. Furthermore, increased fragmentation of larger animals would have implications for body size representation using NISP: at Blombos, size 1 fragments make up nearly half of the NISP, and yet on average should have fewer fragments per whole bone. This would mean that larger animals are even less abundant than indicated by the NISP. However, the pattern observed in the averages could equally be the result of a lack of normality in the dataset and extreme influences by a few very large outlying fragments.

In order to compensate for this potential problem, the median %Area represented by a bone fragment, the quartiles, and outlying datapoints are given for Blombos (Figure 50a). These data clearly show a greater range of %Area with smaller body sizes, likely in part because samples are larger for smaller body sizes. Unlike the average %Area, the median %Area does not provide a clear pattern of increasing fragmentation with increasing body size – and this pattern is even less clear where the sample size is smaller, as in M3. When all layers are combined to compensate for the small sample in M3 the medians become nearly identical for all body sizes, with a maximum difference between body size classes of only 0.9% (Figure 50b).

These data indicate that overall fragmentation for whole long bones is similar for all body size classes. The moderate degree of post-depositional fragmentation indicates that the majority of breakage occurred while the bones were in a fresh state, and can therefore be attributed to marrow extraction activities. It therefore seems that at Blombos the strategy was one of maximum marrow extraction resulting in a minimum of breakage, regardless of if excessive breakage of small body size classes was more energetically

feasible. It further indicates that the much higher NISP of small ungulates at Blombos is not the result of excessive fragmentation of small, relatively fragile long bones in either a fresh or a dry state.

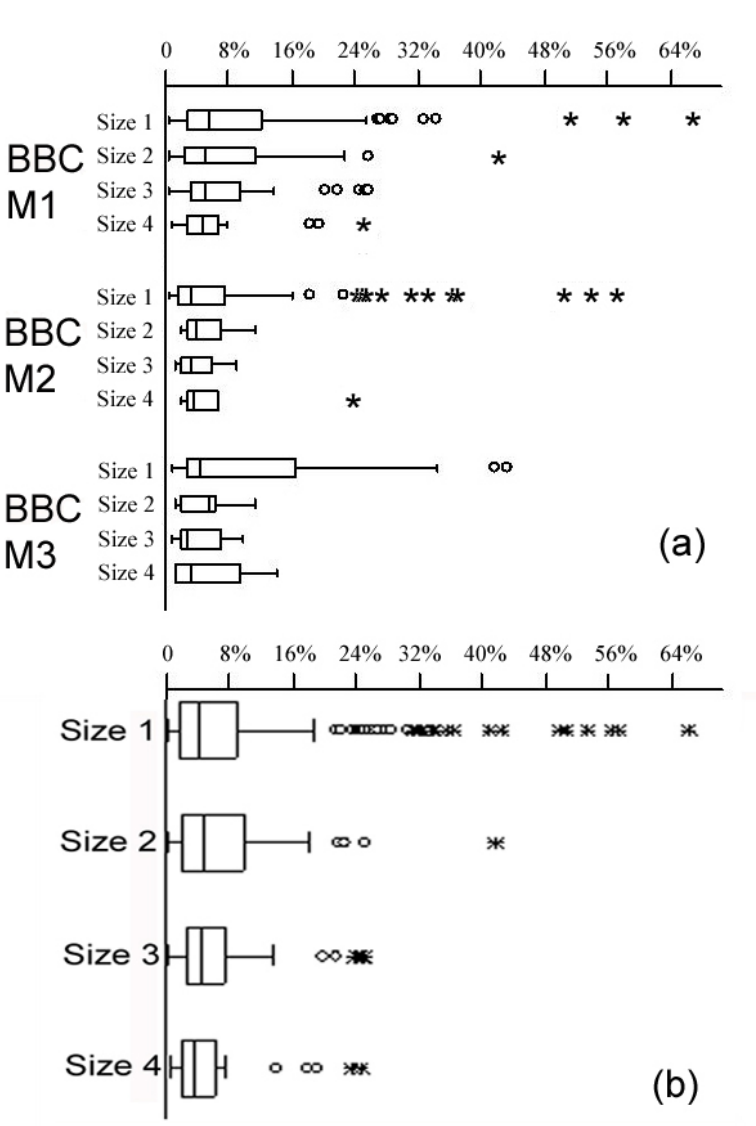


Fig. 50 Medians and quartiles of the proportions of surface area of a whole bone represented by different long bone fragments at Blombos. Data are combined from the humerus, radius, femur, and tibia. They are shown by layer in (a) and together in (b).

Surface modification

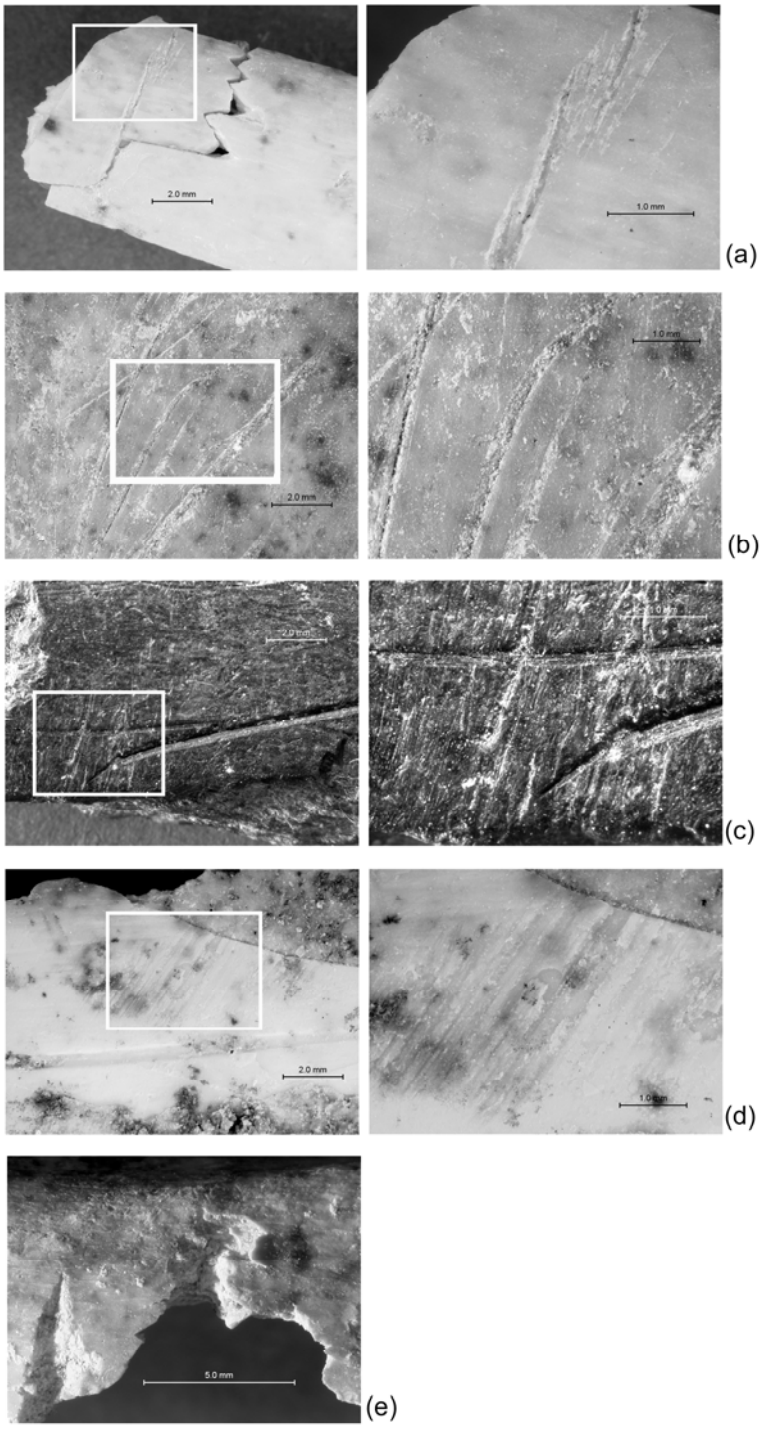


Fig. 51 Examples of cut marks (a & b), percussion marks (c & d), and tooth marks (e) on fauna from Blombos. The image to the right is an enlargement of the boxed area on the left.

Cut, percussion, and tooth marks were all confidently identified in the Blombos assemblage. Examples of these three types of surface modification are provided in Figure 51. At Blombos, proportions of percussion-marked midshafts for all body sizes combined all either fall within or above the 95% confidence intervals for both Blumenschine and Marean's 'hominin only' and 'hominin-then-carnivore' scenarios as presented in Marean *et al.* (2000b). Proportions of tooth-marked midshafts are between 8.1% and 17.2%, which places them all within the reported ranges of actualistic 'hominin-then-carnivore' simulations (Table 17).

Table 17

Numbers of midshaft fragments that bear a percussion or a tooth mark from Blombos.

	Size Indet.		Size 1		Size 2		Size 3		Size 4		Size 5	
Layer	PM	TM	PM	TM	PM	TM	PM	TM	PM	TM	PM	TM
M1	54	12	121	56	85	18	63	22	55	13	1	2
M2	40	13	187	60	34	21	48	16	14	2	0	0
M3	41	13	69	23	32	8	43	5	13	6	2	0
Total Marked	135	38	377	139	151	47	154	43	82	21	3	2
Total Frags	472		1079		335		317		122		13	

Overall, the signature at Blombos is overwhelmingly one of a human accumulator with a small carnivore input either by scavenging of human waste or by independent accumulation (Figure 52). With the exception of the very small sample of size 5 midshafts, a pattern of increasing proportions of percussion-marked midshafts with increasing body size is apparent at Blombos. When size 5 is not considered, Fisher's

Exact Test shows these differences in proportions to be statistically significant between all body sizes below the $\alpha = 0.01$ level, excepting the difference between body sizes 2 and 3 ($p = 0.3883$; Appendix J:[i]).

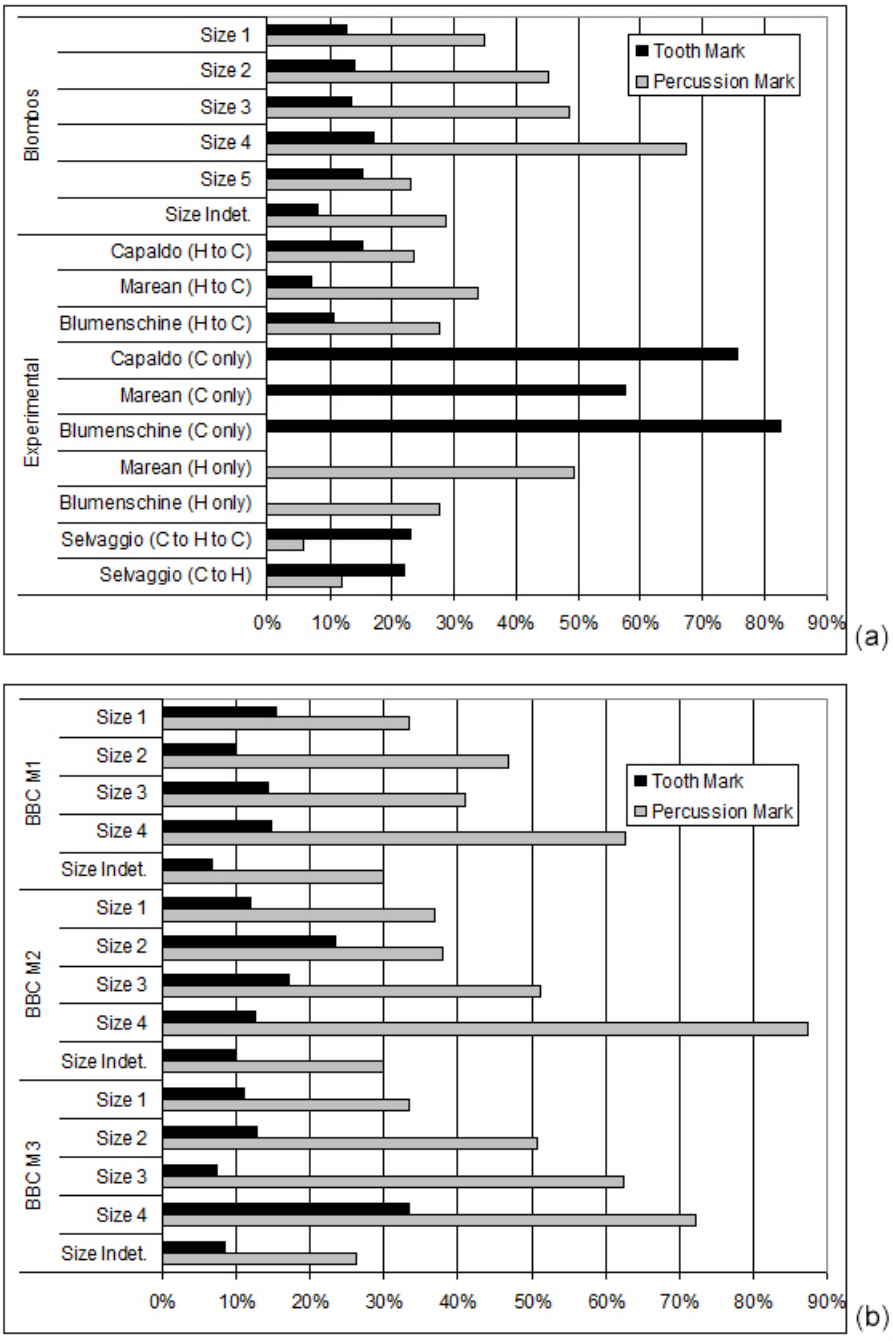


Fig. 52 Relative proportions of percussion- and tooth-marked midshaft fragments from Blombos compared to actualistic assemblages where the sequence of carcass access is known (a) and compared between layers at Blombos (b).

The pattern of increasing proportions of percussion-marked midshafts with increasing ungulate body size is generally also true when the data are divided by layer – with the exception of relatively high proportions of size 2 percussion-marked midshafts in M1. The incidence of percussion-marking increases with body size, even though at Blombos the relative degree of fragmentation was found to be similar between body size classes. Furthermore, most of the fragmentation was found to have been conducted while the bone was in a fresh state, and the surface modification analysis shows that hominin marrow extraction was the most likely agent behind it. If breaking a large long bone into the number of pieces needed for maximum marrow extraction is expected to take more force or more applications of force than breaking a small long bone of the same morphology, then this could provide a feasible explanation of why larger body sizes tend to have higher proportions of percussion marking.

Despite these differences in the incidence of percussion-marking, proportions of tooth-marked midshafts remain statistically indistinct between all body sizes using Fisher's Exact Test (no p-value less than 0.01; Appendix J:[i]). Together, these two variables indicate that although the majority of fauna at Blombos was accumulated by hominins, the intensity of marrow processing changed predictably according to differences in body size (greater intensity for larger body sizes) – even as the degree of carnivore ravaging remained more or less the same overall.

When fragments bearing both a percussion and a tooth mark are examined, an overall proportion of ca. 5% would be expected if all the tooth marks in the assemblage were attributable to carnivore scavenging of hominin food waste (Capaldo, 1997, 1998;

Marean *et al.*, 2000b; Egeland *et al.*, 2004). At Blombos 2.8% of midshafts meet these criteria, indicating that a relatively small proportion of the tooth-marked midshafts at Blombos can be attributed to independent carnivore accumulation. However, size 1 ungulates have the lowest proportion (2.5%), while size 2, 3, and 4 ungulates have proportions of 3.9%, 3.5%, and 9.0%, respectively. This provides another indication that the size 1 component at Blombos likely had slightly greater independent carnivore input than the other size classes.

When all body sizes are considered together, including fragments not identifiable to body size, comparisons between layers show slight differences. M1 is the highest at 1.2%, M2 is intermediate with 1.0% and M3 lowest at 0.6%. This may suggest that M3 had a greater carnivore input than the other layers, but when only fragments that could be confidently assigned to body size are included these proportions become extremely similar. M1 now has 3.4%, M2 has 3.2%, and M3 also has 3.4%. The sample of midshafts bearing both a tooth and a percussion mark is small, but it supports the gastric etching data and the relative proportions of percussion-marked midshafts, which both indicated that any increased independent carnivore input would have been predominately of ungulates in the size 1 body size class.

Skeletal element representation

Skeletal element abundances are given by NISP in Appendix C, by MNE in Appendix D, and by MNI in Table 18. The MNI for the sample from Blombos is extremely small with a maximum of only 25 individuals when all body sizes and layers are counted separately. This relatively low MNI is typical at other reported MSA sites

(e.g. Klein, 1976, 1978b; Klein and Cruz-Uribe, 2000), but Blombos is different from these in that it has a relatively small area of deposit from which fossils could potentially be recovered in the future (Henshilwood *et al.*, 2001b). The MNI for the sample studied here therefore represents a larger overall proportion of the potential maximum MNI that could be obtained with further excavation and analysis than do the MNI estimates from many other reported sites. This is potentially a good thing, because it might allow for more visibility of individual transport events (Lupo, 2001).

Table 18

MNI estimates and the element from which the highest MNI was derived at Blombos.

	Size 1		Size 2		Size 3		Size 4	
BBC M1	5	Various	5	R Metatarsal	5	L Tibia	3	Various
BBC M2	5	Various	2	Various	2	Various	2	L Metatarsal
BBC M3	4	Various	1	Various	2	R Tibia	1	Various
BBC All (Overlap)	10	L Metatarsal	5	R Tibia	9	L Femur	4	Various
BBC All Count)	11	L Pelvis	6	Various	9	L Femur	5	L Tibia

	Size 5		All Sizes (Overlap)		All Sizes (Count)	
BBC M1	1	Various	11	L Femur	14	Various
BBC M2	1	Axis	8	Various	9	Various
BBC M3	1	Various	5	Various	7	L Tibia
BBC All (Overlap)	1	Various	15	Various	19	L Metatarsal
BBC All Count)	1	Various	18	R Humerus	25	Various

An overall picture of transport strategies can be inferred by examining MAU data for patterning in skeletal element representation (Appendix E). Given the degree of density-mediated destruction documented at Blomobos, it is best to look for such patterning independently within the high-survival set and the low-survival set of elements as described in Marean and Cleghorn (2003). The overall MAU for size 1 – 4 ungulates at Blombos is illustrated in Figure 53, with low-survival elements at the top (atlas through pelvis) and high-survival elements at the bottom (humerus through metatarsal).

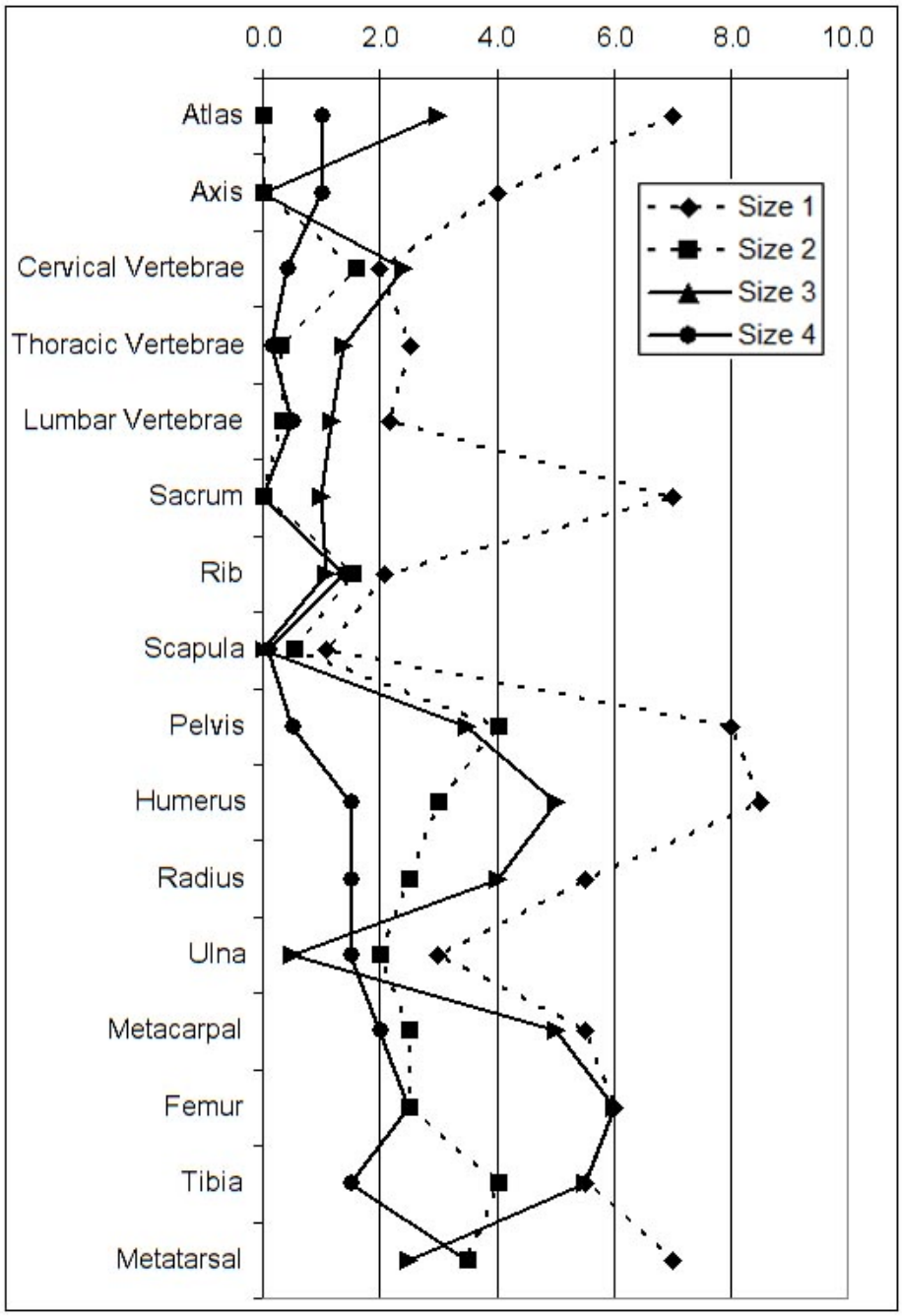


Fig. 53 MAU data from all layers at Blombos showing patterns of skeletal element representation for size 1 – 4 ungulates.

One pattern that is apparent in the low-survival set is the relative abundance of the axis and atlas for size 1 ungulates. These elements may be detached along with the head

and thus their relatively high representation could be indicative of a transport strategy that includes whole animals that have not had their heads removed (Nilssen, 2000). Further evidence for a whole-animal transport strategy is apparent in the relatively high incidence of lower girdle elements such as the pelvis and sacrum, which are not as readily detached from the axial skeleton as is the scapula (Nilssen, 2000). It makes sense that a whole-animal transport strategy for smaller ungulates is indicated in this overview, given Monahan's (1998) observations about carcass transport decisions and the general propensity for smaller ungulates to be transported whole relative to larger ones.

Within the high-survival set there is generally even representation of limb elements with the exception of the ulna. This is likely attributable to the method of estimating the MNE, as it was difficult to precisely place the ulnar shaft onto a GIS template. Size 4 ungulates are most evenly represented, but this could be owed to a very small sample size. Indeed, at Blombos the sample of all larger ungulates is quite small. When the data are broken up by layer this sample becomes even smaller for each analytical unit, and MAU data are likely to be heavily influenced by only one or two fragments. For this reason, size 1 and 2 ungulates have been plotted separately from larger size 3, 4 and 5 fauna when the three major horizons at Blombos are considered separately (Figure 54).

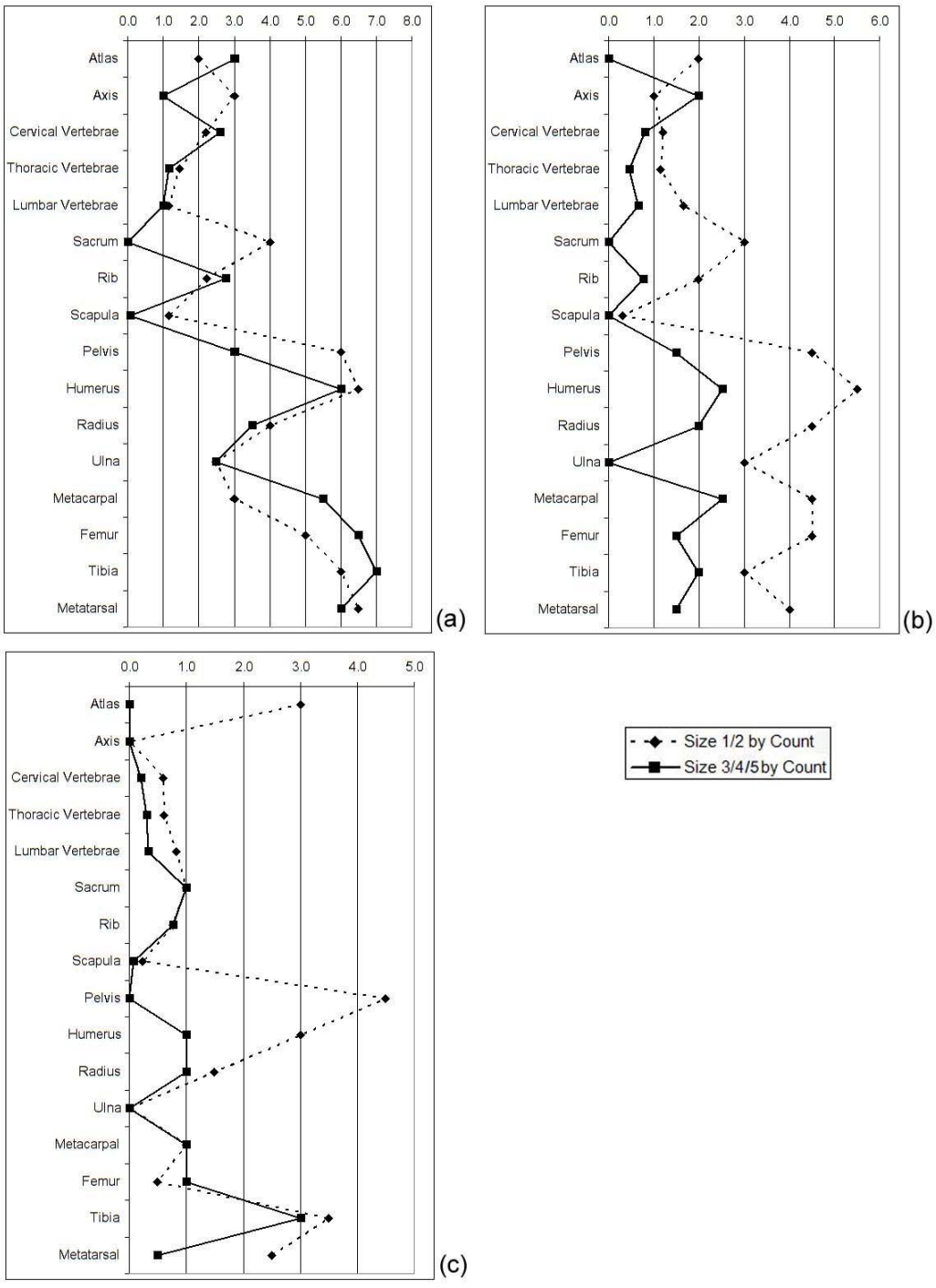


Fig. 54 MAU data from M1 (a), M2 (b), and M3 (c) showing skeletal element representation for small (size 1 and 2) and large (size 3, 4, and 5) ungulates.

In M1 the relative abundances of small and large ungulate skeletal elements track one another quite closely. In M2 this is also the case, but with subtle differences in the relative abundances of single elements in the hindlimb (the tibia and metatarsal). In M3 these differences are more obvious, with a much higher relative representation of neck and lower girdle elements. Given the discussion in Chapter Five, the Hadza model in which smaller ungulates are subject to a lesser degree of selective transport (Monahan, 1998) does not seem to have been in effect at any time over the course of the hominin occupation at Blombos.

Although the MAU data suggest that transport strategies for large and small ungulates were similar (except possibly in M3), it is not apparent if these strategies involved whole animals or animal portions. To determine if differential transport may have occurred and if it may have been based on relative food utility, the % MAU was plotted versus SFUI for both large and small ungulates in all three major horizons (Figure 55). Sample size and the number of individual transport events per unit of time represented in the deposits may both be factors that reduce clarity in the data at Blombos. Where datasets are largest they may also be the most reliable places to examine overall patterning in faunal exploitation. Yet, at the same time it is difficult to justify the aggregation of smaller datasets in which differences in human behavior are suspected. In the case of Blombos, it is doubtful that the sample from M3 is large enough to provide clear patterning, but the differences in artifactual assemblages between M1, M2, and M3 indicate that these analytical units should also be examined separately for other

indications of human behavior, such as diet. For these reasons data from M3 are presented but the interpretive focus here is on the larger samples from M1 and M2.

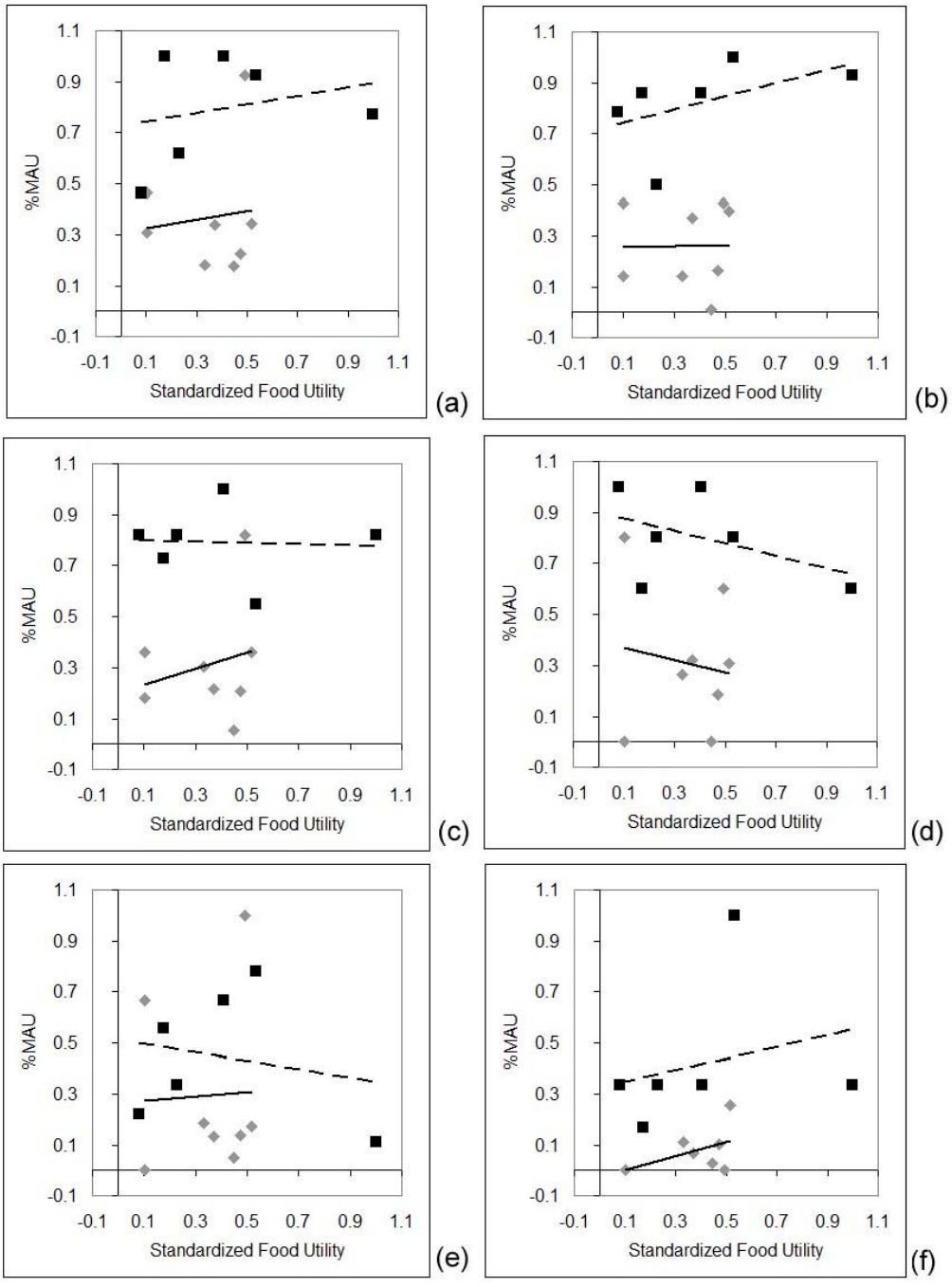


Fig. 55 %MAU versus SFUI at Blombos for small (size 1 and 2) ungulates in M1 (a), M2 (c), and M3 (e) and for large (size 3, 4, and 5) ungulates in M1 (b), M2 (d), and M3 (f). Dashed regression lines and black squares indicate the high-survival set and solid regression lines with grey triangles represent the low-survival set.

Within the high-survival set of M1, the plots of %MAU versus SFUI show a pattern that is in line with what one would expect from a situation where both large and small fauna were subject to a slight degree of selective transport in accordance with utility. M2 shows an even pattern for small ungulates and a slightly negative correlation for large ungulates, while M3 generally shows the reverse. There is a tendency for a positive correlation to exist within the low-survival set for all layers, which might suggest that higher-utility elements (which tend to fall within the low-survival set) were subject to greater selective transport.

Taken at face value, these patterns at Blomobs appear to represent three different strategies of skeletal element transport. However, it is important to note that these regression lines are based on a scatter of datapoints that are not tightly distributed and may not be reflective of hominin behavior at all. This is supported statistically when Spearman's Rho is applied and it can be seen that the resultant correlations are quite low and fail to be significant in almost all instances (Table 19).

Table 19

Spearman's Rho and p-values for the strength of the correlation between %MAU and Standardized Food Utility at Blombos.

	Group	Body Size	Spearman's Rho	p-value
M1	Low-Survival	1	-0.1210	0.7753
	High-Survival	1	0.4414	0.3809
	Low-Survival	2	0.7962	0.0181
	High-Survival	2	0.2942	0.5714
	Low-Survival	1/2	0.0000	1.0000
	High-Survival	1/2	0.2609	0.6175
	Low-Survival	3/4/5	0.3621	0.3780
	High-Survival	3/4/5	0.5768	0.2307
M2	Low-Survival	1	-0.1180	0.7807
	High-Survival	1	0.3586	0.4852
	Low-Survival	2	0.8228	0.0121
	High-Survival	2	-0.5976	0.2103
	Low-Survival	1/2	0.2532	0.5452
	High-Survival	1/2	-0.0305	0.9545
	Low-Survival	3/4/5	-0.0443	0.9170
	High-Survival	3/4/5	-0.3586	0.4852
M3	Low-Survival	1	0.2089	0.6196
	High-Survival	1	0.0000	1.0000
	Low-Survival	2	0.7251	0.0418
	High-Survival	2	0.1852	0.7254
	Low-Survival	1/2	0.2840	0.4954
	High-Survival	1/2	0.0857	0.8717
	Low-Survival	3/4/5	0.4639	0.2469
	High-Survival	3/4/5	0.5071	0.3046

The low strength of the correlations, along with their lack of significance, indicates a situation where hominin transport decisions in both sets generally do not follow any pattern of selectivity and any weak correlations observed are likely the result of chance. This is suggestive of a whole-animal transport strategy for both small and large ungulates or. There is also a possibility that the pattern is the result of selective

transport over time that was not focused on any one set of predictable parameters. For example, some elements may have been brought in because of their high food utility (Metcalfe and Jones, 1988), while others were transported because of a preference for particular types of marrow (Morin, 2007).

Burger *et al.* (2005) have noted that when modern humans make processing and transport decisions they take into account different forms of currency (e.g.. caloric content versus fat content), depending on the set of conditions present in the environment within which the decisions are made. Blumenschine (1987) has shown that carnivores make similar adjustments to their overall ranking of skeletal elements based on variables such as the age or nutritional state of the animal when it died. Finally, the small number of available datapoints may mean that an overall correlation is unlikely to reveal some of the more subtle details of the underlying patterning. To further explore this possibility, individual skeletal elements were examined to determine which may be more or less frequently represented than others.

This was accomplished by determining the mean and standard deviation in the MAU for the high-survival and low-survival sets of elements. A z-score was calculated for each bone so that its individual representation, in terms of standard deviations from the mean, could be examined (Figure 56). Points falling above the dashed line are represented more often than the mean and points falling below the dashed line are represented less often than the mean.

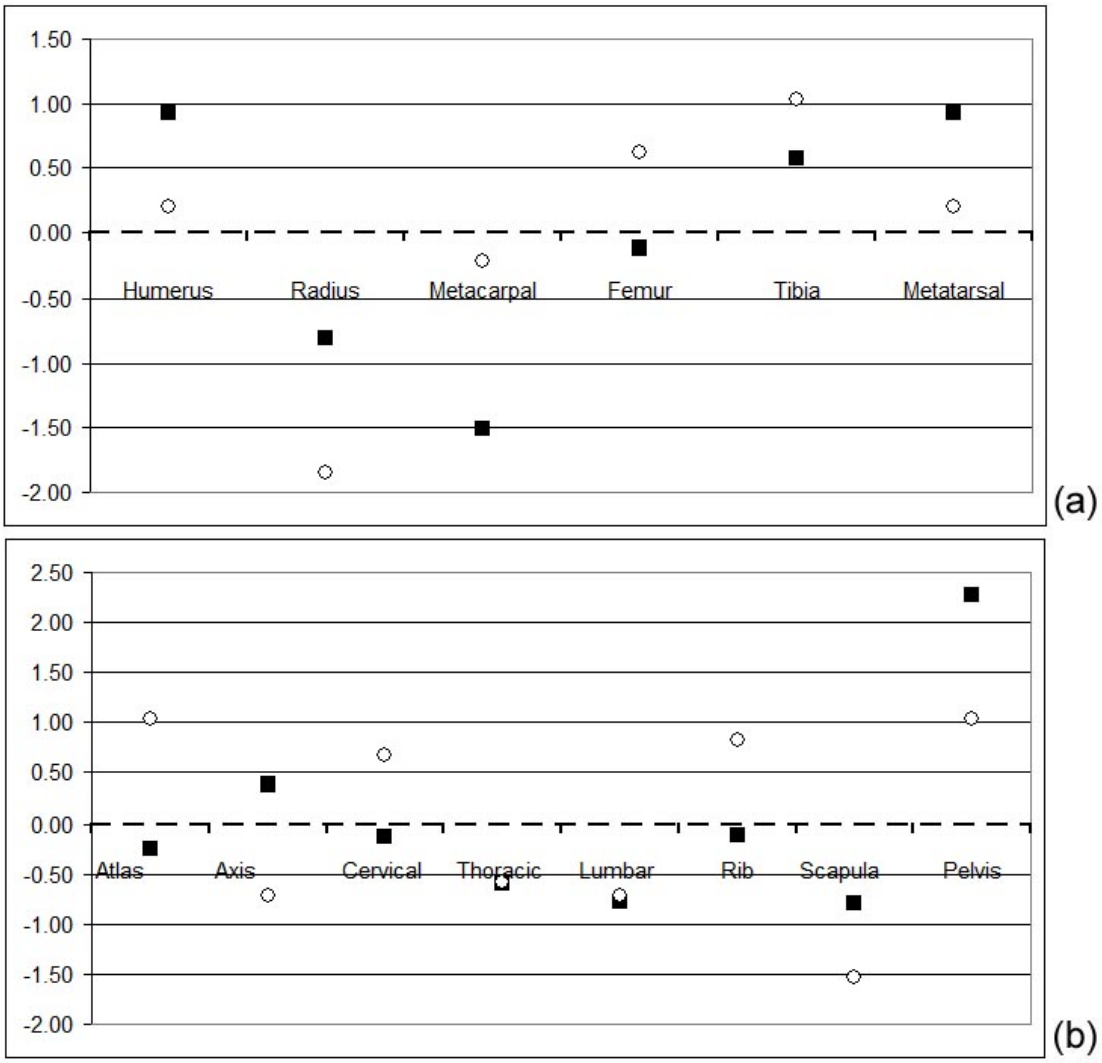


Fig. 56 Z-scores for the MAU of small (size 1 and 2, black boxes) and large (size 3, 4, and 5, open circles) ungulates in M1. High-survival elements (a) are plotted separately from low-survival elements (b).

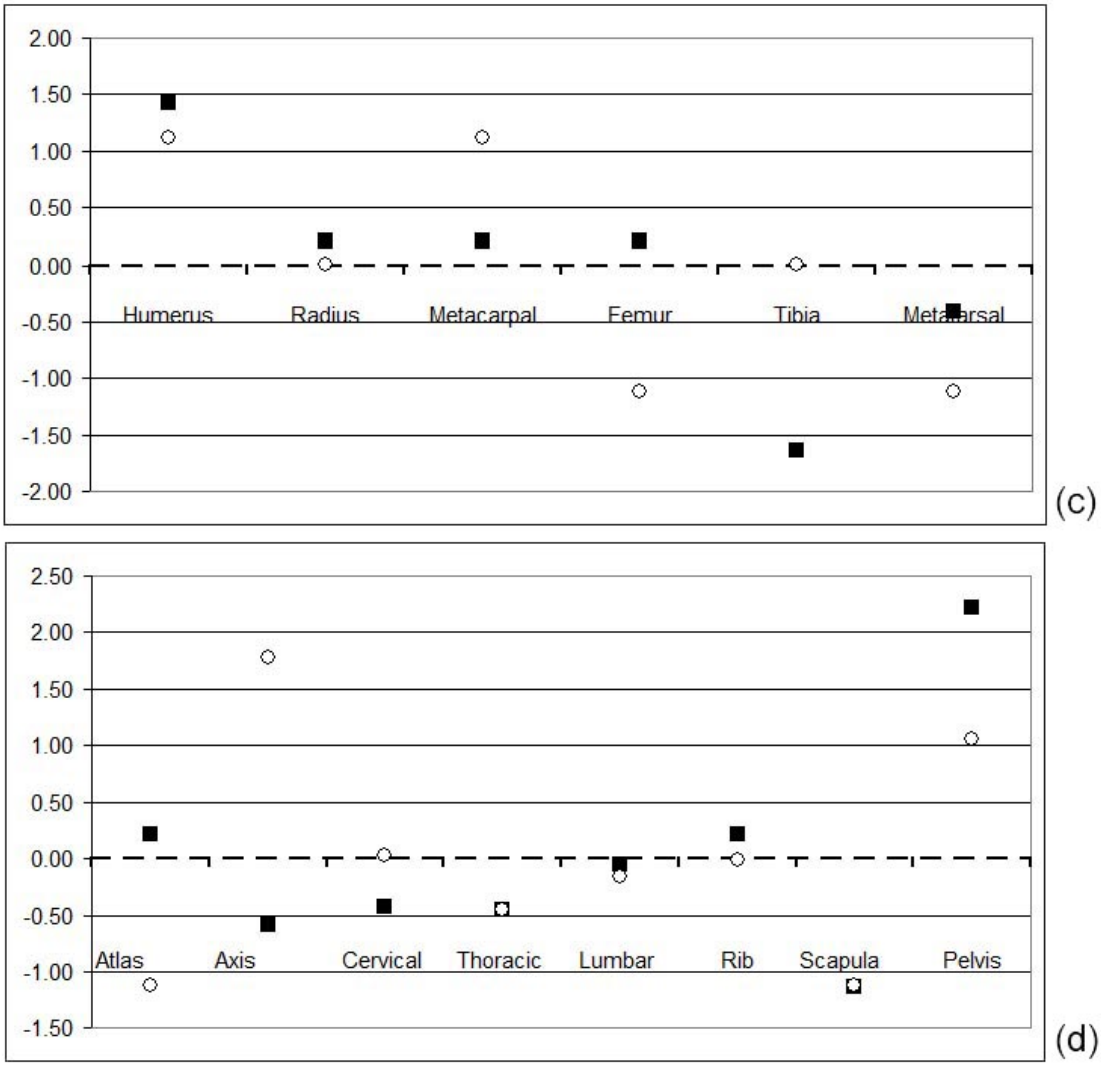


Fig. 56 (cont.) Z-scores for the MAU of small (size 1 and 2, black boxes) and large (size 3, 4, and 5, open circles) ungulates in M2. High-survival elements (c) are plotted separately from low-survival elements (d).

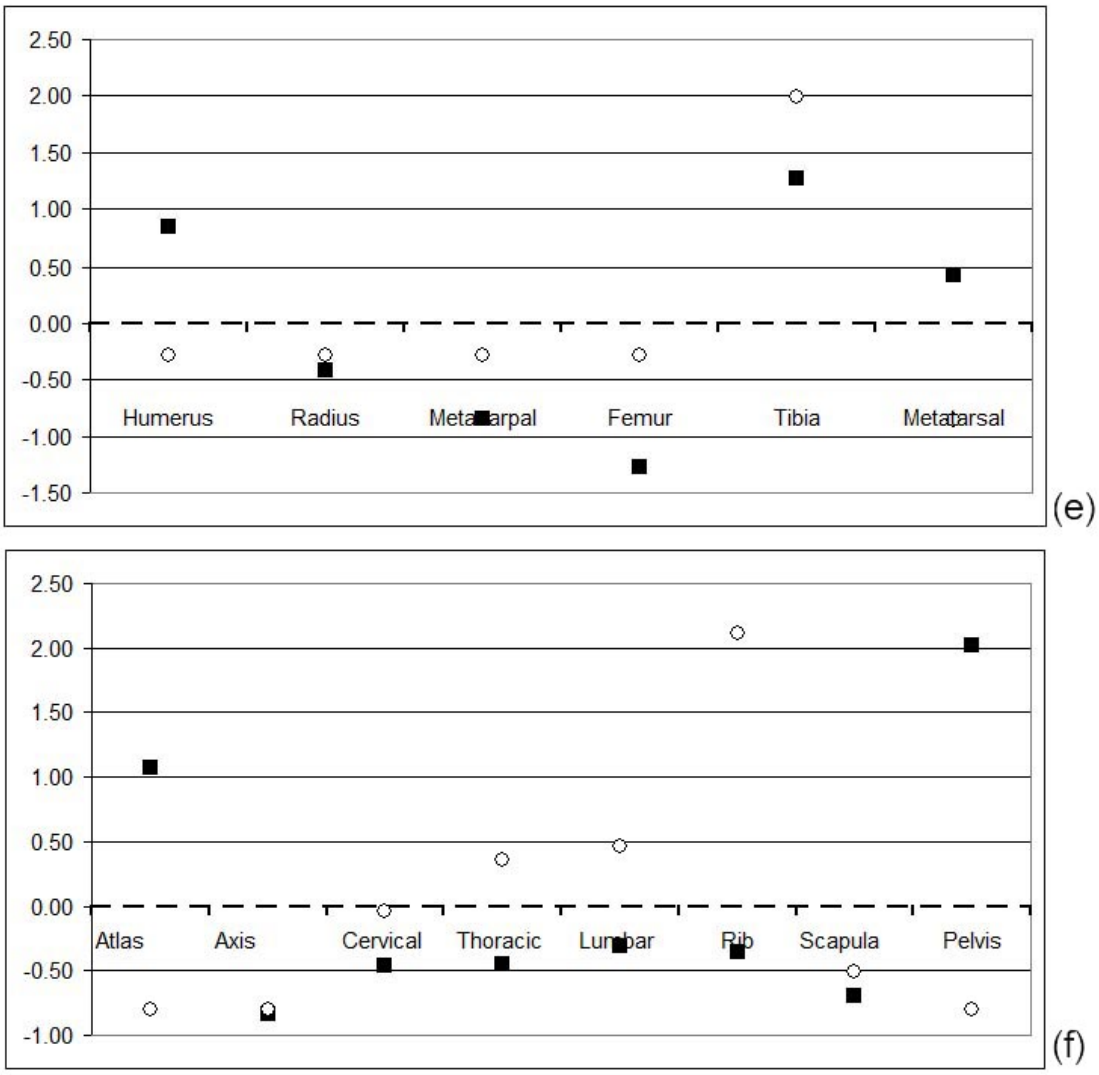


Fig. 56 (cont.) Z-scores for the MAU of small (size 1 and 2, black boxes) and large (size 3, 4, and 5, open circles) ungulates in M3. High-survival elements (e) are plotted separately from low-survival elements (f).

For large ungulates in M1, hind-limb elements are generally better-represented than other long bones for both small and large ungulates. Within the low-survival set most elements for both body sizes fall quite close to the mean with the exception of the pelvis, which is better-represented. This is interesting, as the pelvis is a part of the hind-

limb unit, but it may also be the result of a taphonomic pattern relative to the scapula. The less-robust scapula is subject to heavier fragmentation and even small glenoid fragments can be difficult to place accurately on a GIS template relative to the more topographically-varied analogous portion of the pelvis (the acetabulum).

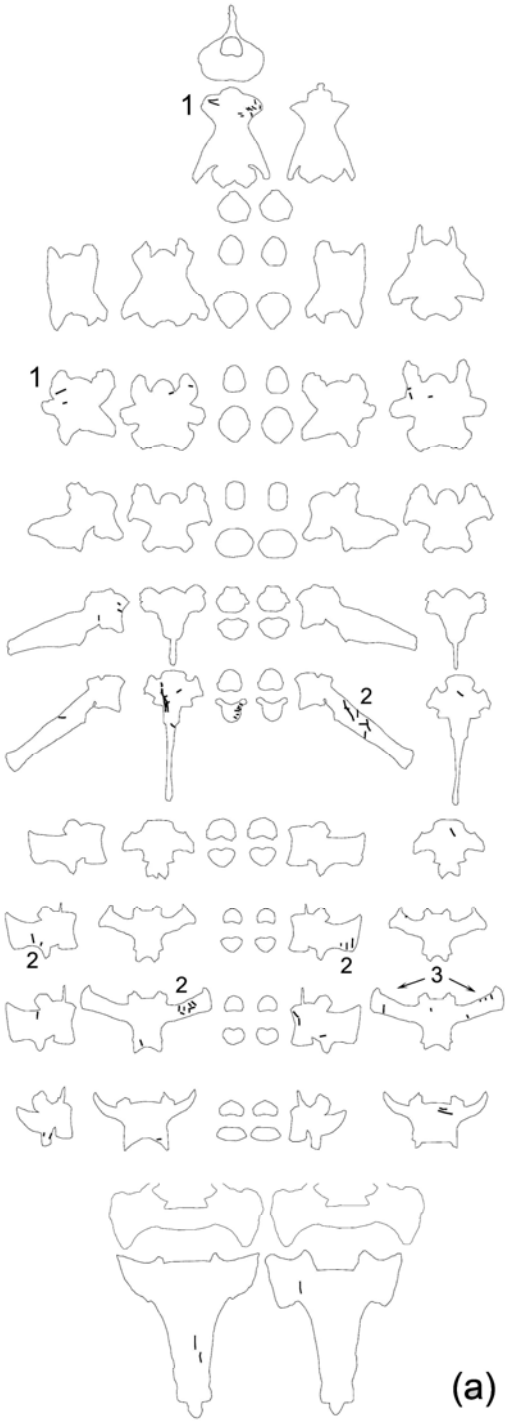
During M2 the patterning is less clear for small ungulates but there is now a tendency within both size categories for lesser hindlimb representation. Within the low-survival set the high representation of the pelvis relative to other elements likely drives much of the patterning, while the tibia takes on this role for the high-survival set in M3.

Even disregarding the pelvis for all datasets, the general pattern of similar small and large ungulate representation seems to be upheld throughout. The transport strategy underlying this pattern may be one of more intensive processing of fore-limbs off-site in M1 and hind-limbs off-site in M2. However, none of these patterns is clearly defined enough to confidently demonstrate consistent selection criteria in hominin transport decisions.

Extreme variability in the z-scores for different elements suggests that a whole-animal transport strategy was not the norm, as this would have resulted in a series of z-scores that more closely approximated the mean. Instead, the data suggest that carcass segments were transported to Blombos as a series of individual transport events, each of which was defined by its own set of contingent variables. This strongly suggests that group size was relatively small and that site use may have been somewhat sporadic. Certainly, it indicates that the Hadza model for transport back to a central place is not applicable as an analogue for the situation at Blombos.

Outside-bone nutrient extraction

At Blombos the primary accumulator of most of the ungulates has been shown to be MSA hominins. When examining the incidence of cut-marking throughout the skeleton at Blombos, it is therefore assumed that the locations of the marks are the result of conscious decisions by the MSA butchers to process a *complete* carcass in a particular way. Figure 57 shows the distribution of cut marks throughout the ungulate skeleton, with locations of those with unambiguous behavioral correlates as determined by Nilssen (2000) indicated in the key.



1. Disarticulation 2. Filleting sirloin
3. Filleting tenderloin

Fig. 57 Locations of cut marks on vertebrae from Blombos.

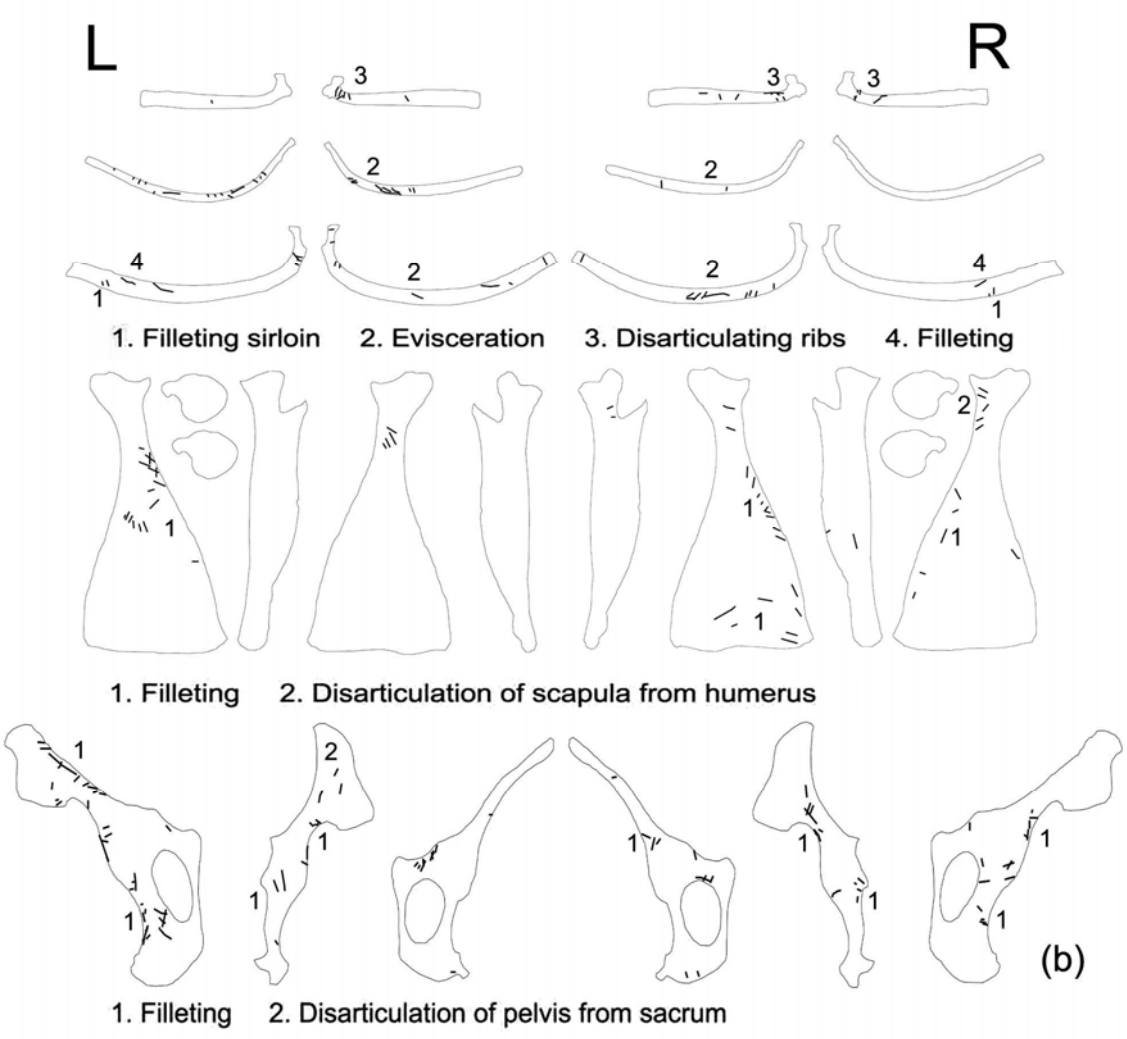


Fig. 57 (cont.) Locations of cut marks on non-long bones from Blombos.

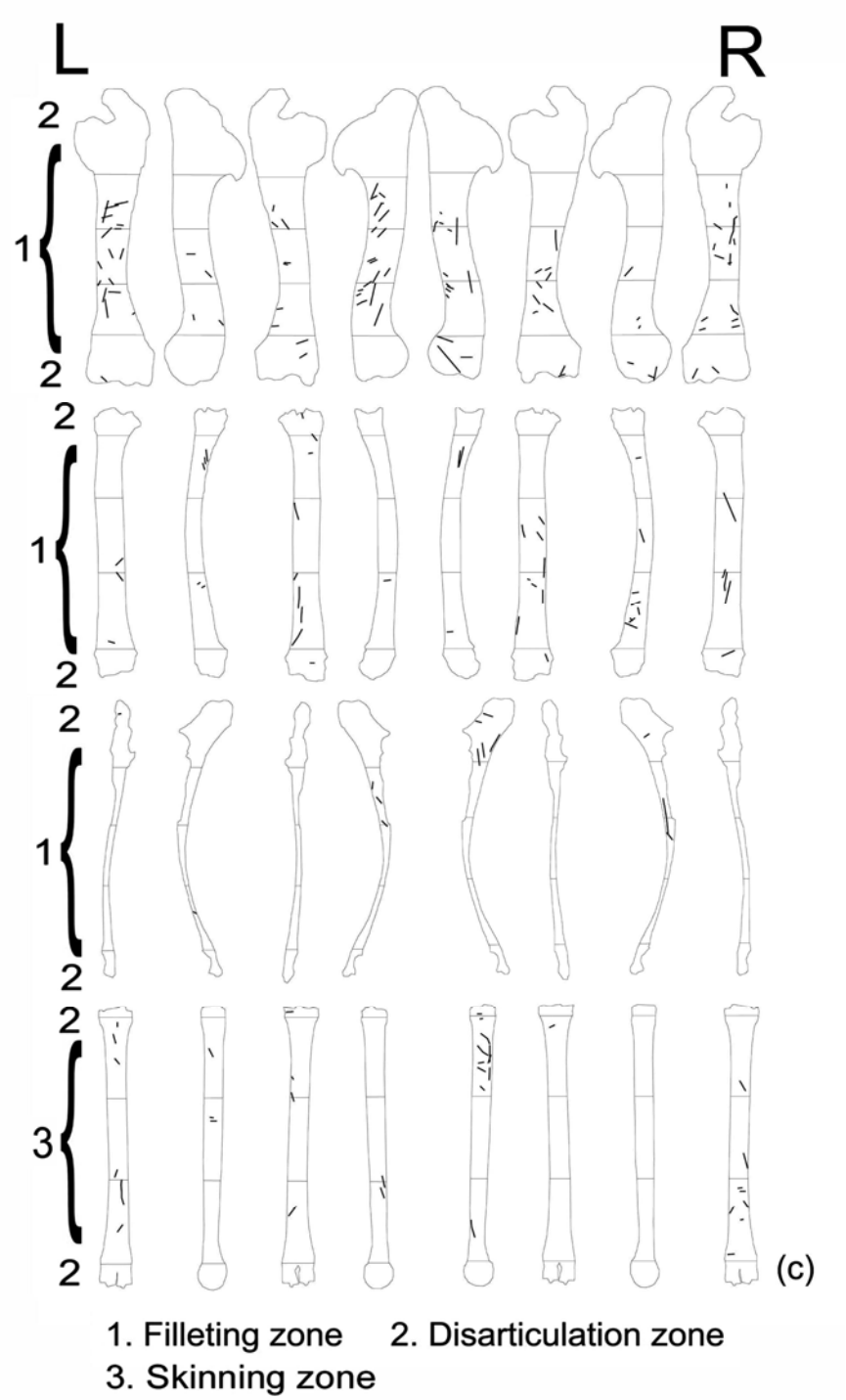


Fig. 57 (cont.) Locations of cut marks on forelimbs from Blombos.

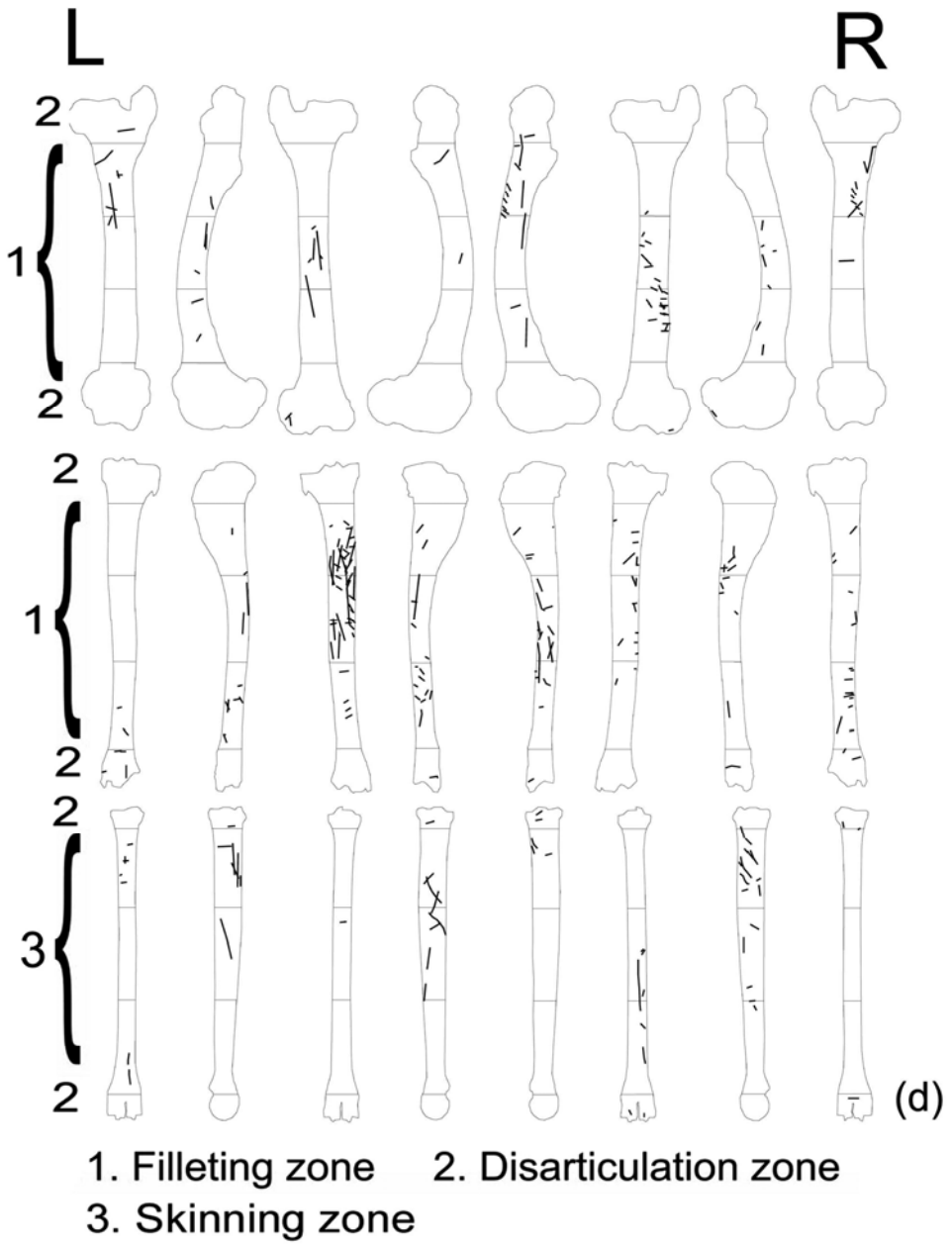


Fig. 57 (cont.) Locations of cut marks on hindlimbs from Blombos.

A variety of actions are implicated by the positions of the cut marks, including evisceration, skinning, disarticulation, and filleting of various cuts of meat. A general

sequence observed in modern humans can be reasonably applied to these actions (e.g. Binford, 1978; Nilssen, 2000). First, the skin would have been initially opened along the ventral midline of the prey, resulting in the evisceration marks seen on the ribs. At some point that was likely early in the sequence the skin was removed at the metapodials (cranial elements were not examined for the purposes of this study). The major muscle groups of the back and limbs were removed, and the vertebrae were sometimes disarticulated. The head was also removed at some point in the process, although because these are composite images and the sample of disarticulation marks on the axis and atlas are rare it is difficult to establish any patterning in this behavior.

Although most marks on long bones are predominately located along the shaft, there is evidence for disarticulation in the positions of cut marks at the epiphyseal ends of long bones and on the pelvis and scapula. However, the general sequence and the degree to which disarticulation is emphasized can only be qualitatively evaluated using the cut mark maps alone. Abe *et al.* (2002) have proposed a quantitative way to determine if the archaeological pattern best matches a butchery strategy that was primarily focused on dividing carcass segments for different cuts of meat or if it was instead focused almost entirely on filleting (possibly for the production of dried meat).

Abe *et al.* (2002) showed that a disarticulation-to-filleting strategy should result in a greater relative proportion of cut marks on long bone epiphyses than would a filleting-only strategy, and that the overall distribution of marks across these zones can be diagnostic of the primary butchery strategy under which the marks were created. Because Blombos has undergone a relatively high degree of density-mediated

destruction, epiphyses (and the disarticulation marks they bear) are expected to be less well-represented than shafts. A correction was made to accommodate this by dividing the number of cut marks by the preserved surface area to obtain an estimate of how many cut marks were likely represented on a whole bone (Abe *et al.*, 2002).

These adjusted values, scaled to 100% of the total marks on the bone, are shown in comparison to the two ethnoarchaeologically-documented strategies in Figure 58. The datasets have been divided into small and large ungulates, and between the major horizons at Blombos. Some sample sizes were extremely small, especially for M3. Thus, interpretations focus on data from M1 and M2. Adjusted proportions of where cut marks occur on the major long bones are provided in Appendix G. Because all percentages for each element add to a total of 100%, at least some area had to be represented in each zone in order for them to be calculated. Elements for which all zones were not present at least to some extent are therefore represented with a '-', whereas elements portions on which no cut marks occur, despite at least some representation of that portion, are indicated with a 0%. Raw numbers of marks per portion are provided in Appendix F.

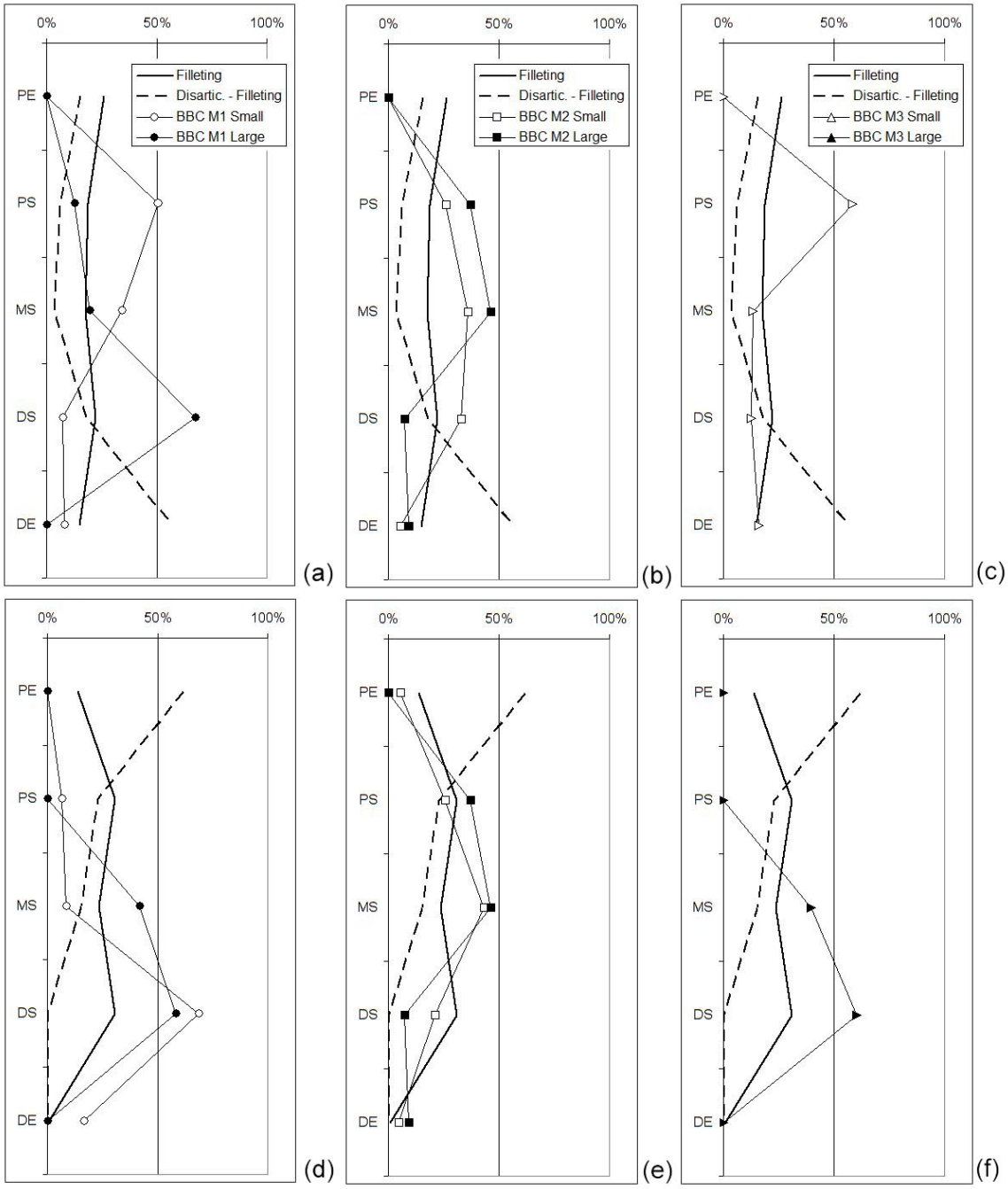


Fig. 58 The distribution of cut marks for small (size 1 and 2) and large (size 3, 4 and 5) ungulates across long bone zones for the humerus (a,b, c) and radius (d, e, f), during M1, M2, and M3, respectively. PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

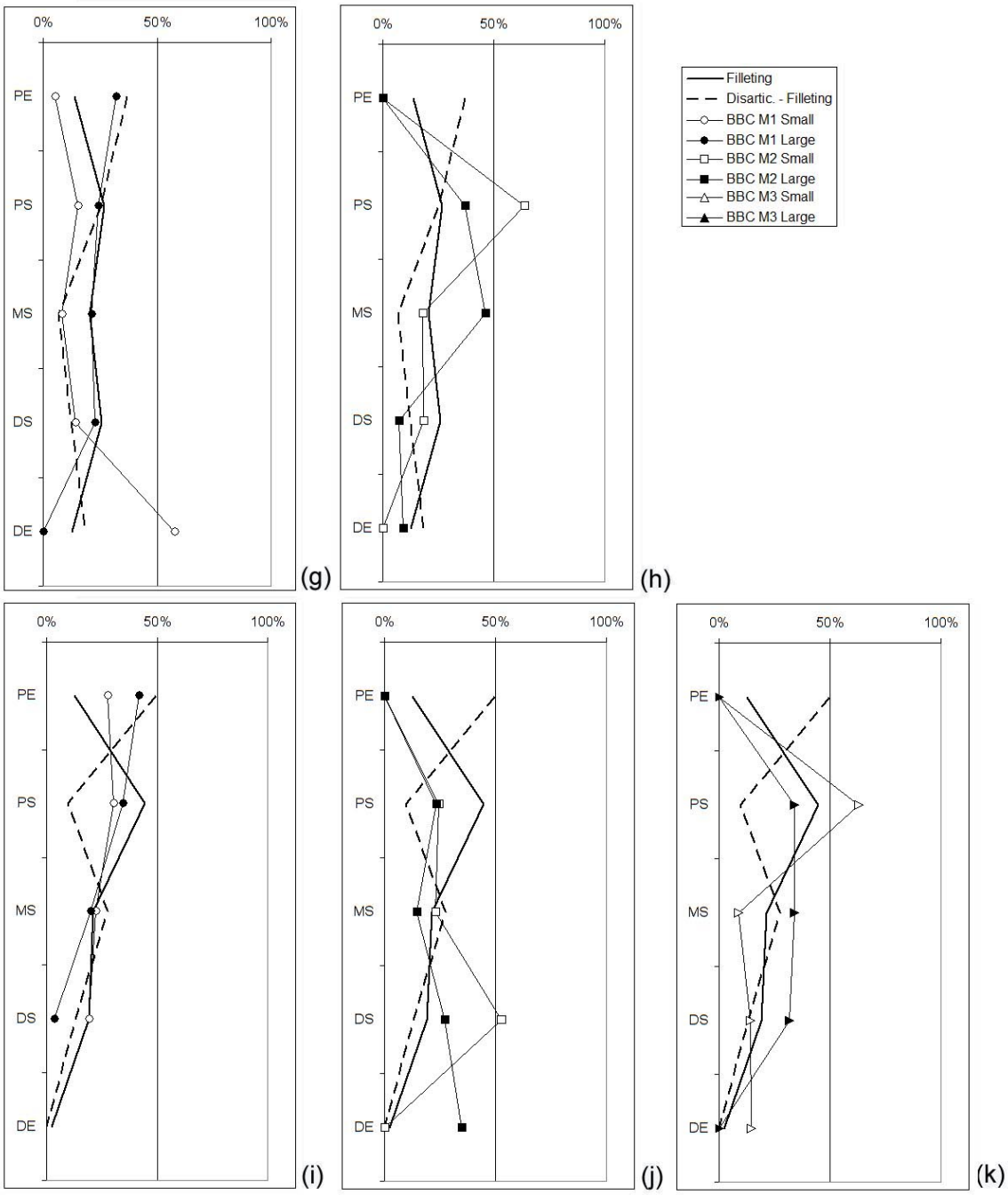


Fig. 58 (cont.) The distribution of cut marks for small (size 1 and 2) and large (size 3, 4 and 5) ungulates across long bone zones for the femur (g,h) and tibia (i, j, k), during M1, M2, and M3, respectively. PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

In general, the distribution of cut marks across large and small ungulate long bones is quite similar. This is in accordance with the skeletal element transport data, which suggested that there was little distinction between the treatment of prey in these two size categories. Within each of these datasets, there are differences both between layers and between the fore- and hindlimbs. Within M1 the forelimbs bear the majority of their marks in the near-epiphyseal zone while the hindlimbs have a much more even distribution of marks. Within M2 the forelimbs have a heavy emphasis on marking in the midshaft zone, while the hindlimbs are now weighted toward the near-epiphysis shafts. There are no immediately noticeable similarities to either ethnoarchaeological scenario, and indeed in many cases the archaeological data appear to follow a pattern that is nearly converse of what was observed by Nilssen (2000). A chi-squared test was used to assist with interpretation of the visual data by determining if there was a significant difference between where on the long bone the cut marks occur and within what dataset they occur (ethnoarchaeological versus archaeological). The results are provided in Table 20.

Table 20

P-values from chi-squared tests determining if the difference is significant between the distribution of cut marks across each major long bone at Blombos and what would be expected for a filleting or a disarticulation and then filleting butchery strategy.

		Filleting			Disartic. - Fillet.		
		X^2	D. F.	p-value	X^2	D.F.	p-value
BBC M1 Small	Humerus	10.039	5	0.0742	23.185	5	0.0003
	Radius	5.335	5	0.3764	10.571	5	0.0606
	Femur	12.465	5	0.0289	13.438	5	0.0196
	Tibia	3.364	5	0.6440	9.612	5	0.0872
	All	38.360	20	0.0080	60.390	20	< 0.0001
BBC M2 Small	Humerus	7.973	5	0.1577	21.204	5	0.0007
	Radius	1.636	5	0.8968	7.116	5	0.2122
	Femur	9.966	5	0.0762	19.399	5	0.0016
	Tibia	3.833	5	0.5737	9.716	4	0.0455
	All	29.569	20	0.0771	63.122	19	< 0.0001
BBC M3 Small	Humerus	6.956	5	0.2239	14.802	5	0.0112
	Radius	N/A	N/A	N/A	N/A	N/A	N/A
	Femur	N/A	N/A	N/A	N/A	N/A	N/A
	Tibia	3.845	5	0.5719	15.659	5	0.0079
	All	57.227	20	< 0.0001	77.526	18	< 0.0001
BBC M1 Large	Humerus	6.627	5	0.2499	11.581	5	0.0410
	Radius	3.455	5	0.6303	8.916	4	0.0163
	Femur	2.501	5	0.7764	4.175	5	0.5246
	Tibia	2.460	5	0.7825	10.032	5	0.0743
	All	39.402	20	0.0059	56.755	19	< 0.0001
BBC M2 Large	Humerus	11.270	5	0.0463	25.583	5	0.0001
	Radius	19.425	5	0.0016	17.364	4	0.0016
	Femur	10.378	5	0.0652	22.796	5	0.0004
	Tibia	9.205	5	0.1012	25.279	5	0.0001
	All	89.297	20	< 0.0001	115.320	19	< 0.0001
BBC M3 Large	Humerus	N/A	N/A	N/A	N/A	N/A	N/A
	Radius	7.446	5	0.1895	14.751	4	0.0052
	Femur	N/A	N/A	N/A	N/A	N/A	N/A
	Tibia	4.864	5	0.4327	13.657	4	0.0085
	All	80.377	20	< 0.0001	98.998	18	< 0.0001

Small ungulates in M1 and M3 show no similarity to the disarticulation-then-filleting (D-F) strategy defined by Abe *et al.* (2002). Only the locations of cut marks across the radius is indistinguishable from this strategy in M2. There is a similar pattern for large ungulates, with only the femur in M1 showing a pattern of cut marking that cannot be statistically distinguished from a D-F strategy. This indicates that for both small and large ungulates, disarticulation played a very minor role in the overall butchery strategy.

There are mixed results when the archaeological data from Blombos are compared to the ethnoarchaeological dataset for a filleting-only (F-O) strategy. Within the small ungulates some bones show no difference while others do. This changes when the entire sample of long bones is pooled, and the overall distribution of cut marks becomes statistically different from a F-O strategy for small ungulates in both M1 and M3. The same is generally true for large ungulates in all three layers, although the sample from M3 may to too small to be informative.

Throughout all layers at Blombos there appears to have been a combination of both filleting and disarticulation, although the emphasis was definitely on filleting. Even here, the data do not fit precisely with an F-O strategy as defined by Abe *et al.* (2002). One major difference between layers appears within the large ungulates in M1 and M2. In M1 none of the cut marks patterns across long bones could be distinguished from an F-O strategy, while all but one in M2 (the tibia) could. This difference is particularly interesting because sample sizes from these two analytical units are approximately equal.

Although the cut mark placements from M1 fit well with a filleting strategy, their relative numbers and positions in M2 seem to have no currently-defined analogue.

In sum, the visual maps of cut marks show a clear signal that various cutting activities took place throughout the skeleton. However, when the only the long bones are examined visually and then compared to ethnoarchaeologically-documented strategies, they do not show any consistent pattern either across body sizes or within layers. This supports the transport data, which suggested that decisions made regarding individual prey acquisition and processing events were so disparate and perhaps separated in time as to leave little consistent patterning in the zooarchaeological record. Despite this, one clear pattern that emerges from the cut mark data is that disarticulation was not a major part of any of the strategies that were employed at the site over time. This in turn feeds back into the transport model, indicating that whole-animal (or at least whole-limb) transport without extensive disarticulation characterized most butchery events recorded at Blombos.

Within-bone nutrient extraction

Outram (1999, 2001) has emphasized that understanding the degree to which an assemblage has been subjected to bone marrow and bone grease extraction will be informative about the nutritional needs and stress levels experienced by the groups making use of these resources. Outram (2001) has recommended a series of procedures to measure fragmentation that are designed to reveal grease processing in the zooarchaeological record and untangle it from other taphonomic processes that can leave similar signatures. One important point he presents is that substantial taphonomic

information can reside in very small fragments, as these can be assigned at least to the level of 'spongy' fragment' versus 'shaft fragment', and both types offer potential sources of fat for foraging hominins. However, one critical issue that fragmentation patterns alone do not address is the agency behind that fragmentation. To know this, bone surfaces must be examined for evidence of percussion or tooth marks.

The degree of marrow processing relative to grease processing can be assessed using simple NISP counts of spongy fragments relative to shaft fragments that bear percussion marks. However, this is not feasible with the current dataset because spongy fragments not identifiable to element were not examined as part of the data collection procedures. However, an approximation of this relationship can be determined by restricting the analysis to identifiable long bones, which contain both grease-retaining spongy epiphyses and marrow-containing shaft fragments. This procedure offers an advantage over that suggested by Outram (2001) in that it allows for correction by preserved surface area to offset the taphonomic bias against spongy elements potentially fragmented for grease that may have been deleted through various agents of density-mediated destruction.

Percussion marks are apparent on a variety of skeletal elements and element portions at Blombos: 62% on long bone shafts, 29% on near-epiphysis shafts of long bones, spongy bones such as pelves and ribs, and 9% on epiphyses. The incidence of percussion-marking throughout the ungulate skeleton is illustrated in Figure 59.

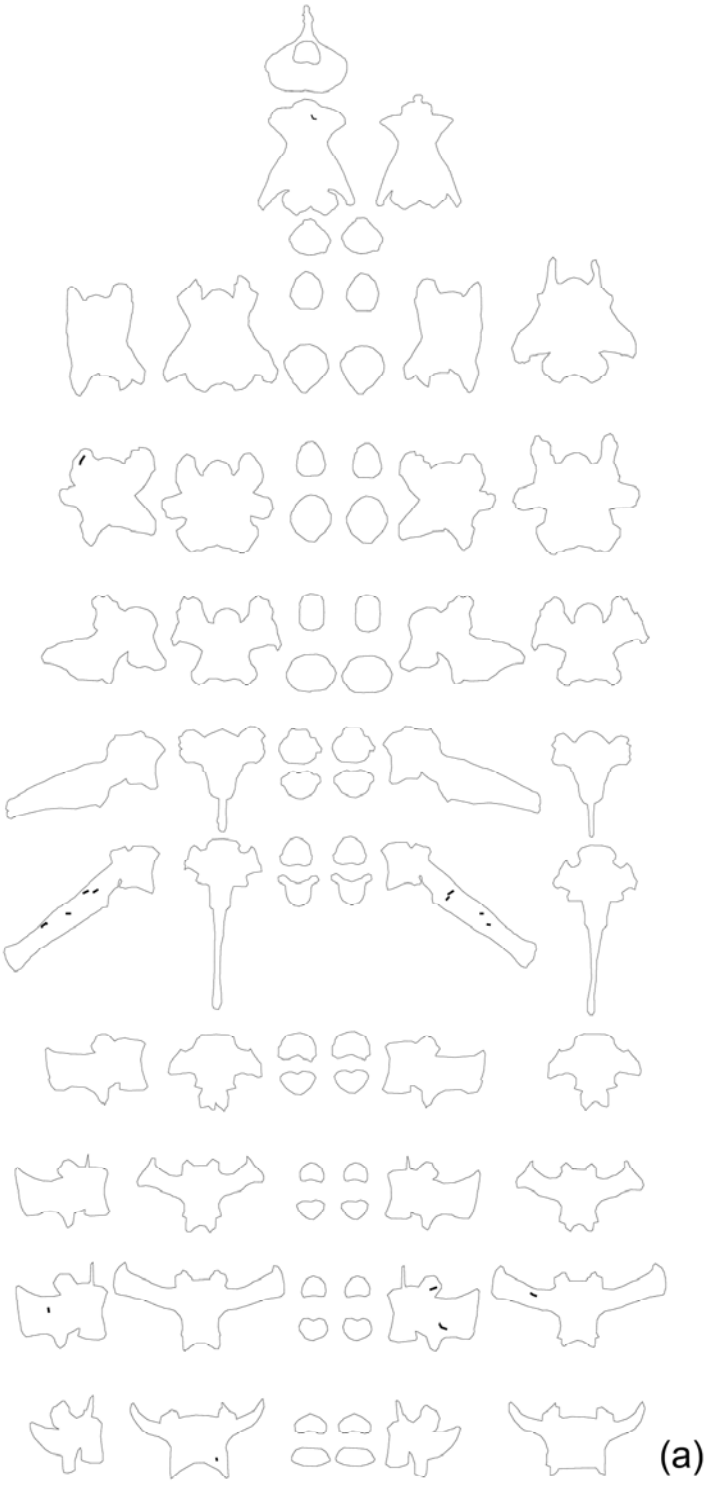


Fig. 59 The locations of percussion marks on vertebrae from Blombos.

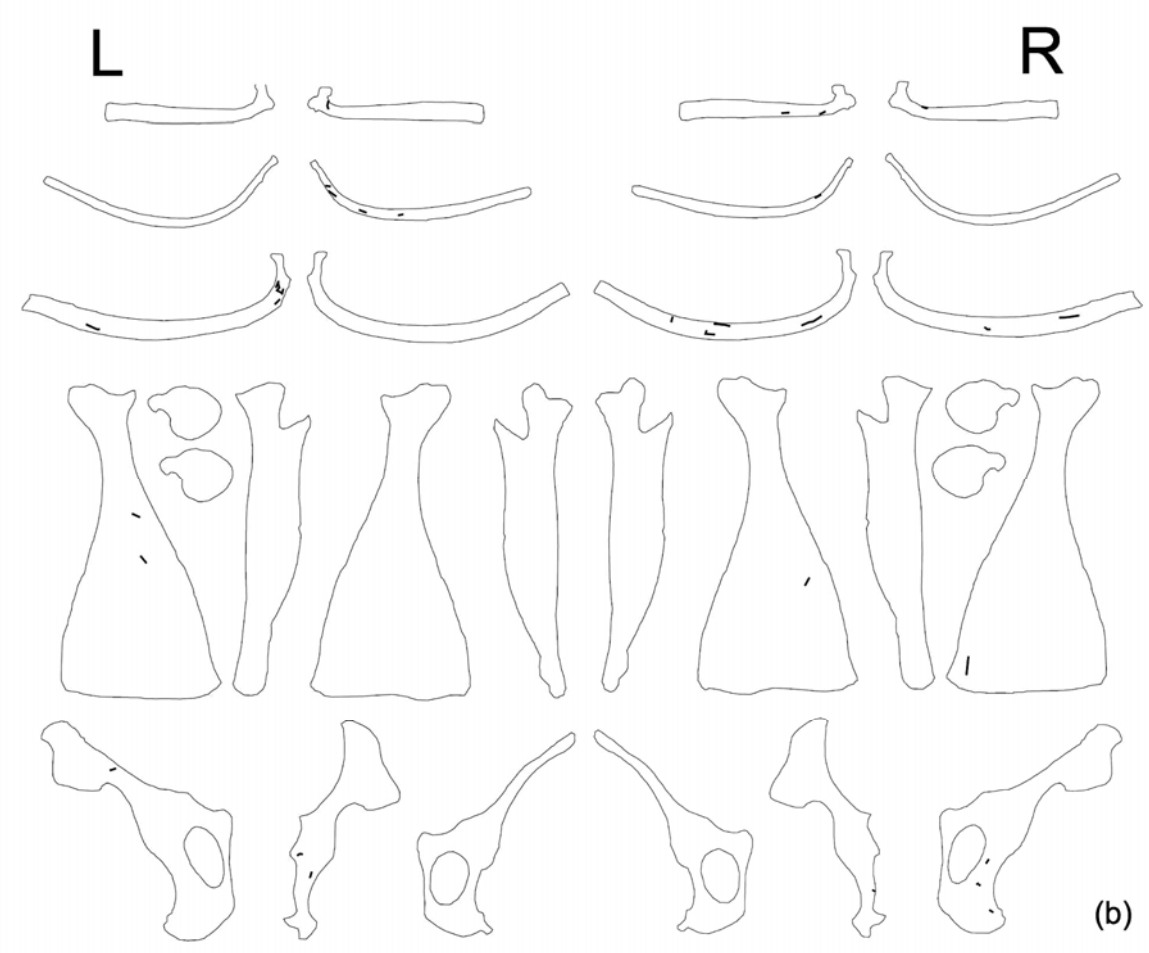


Fig. 59 (cont.) Locations of percussion marks on non-long bones from Blombos.

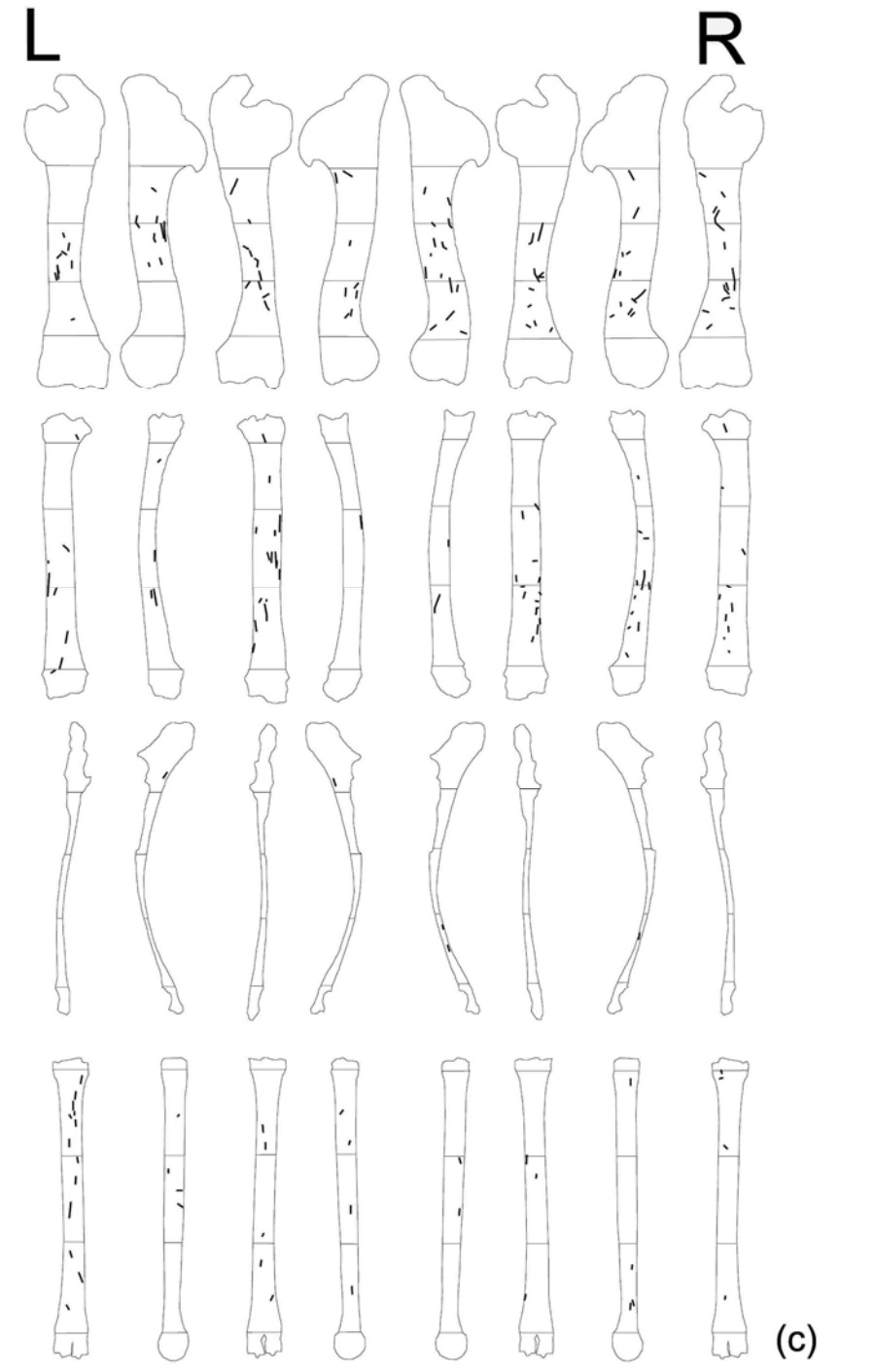


Fig. 59 (cont.) Locations of percussion marks on forelimbs from Blombos.

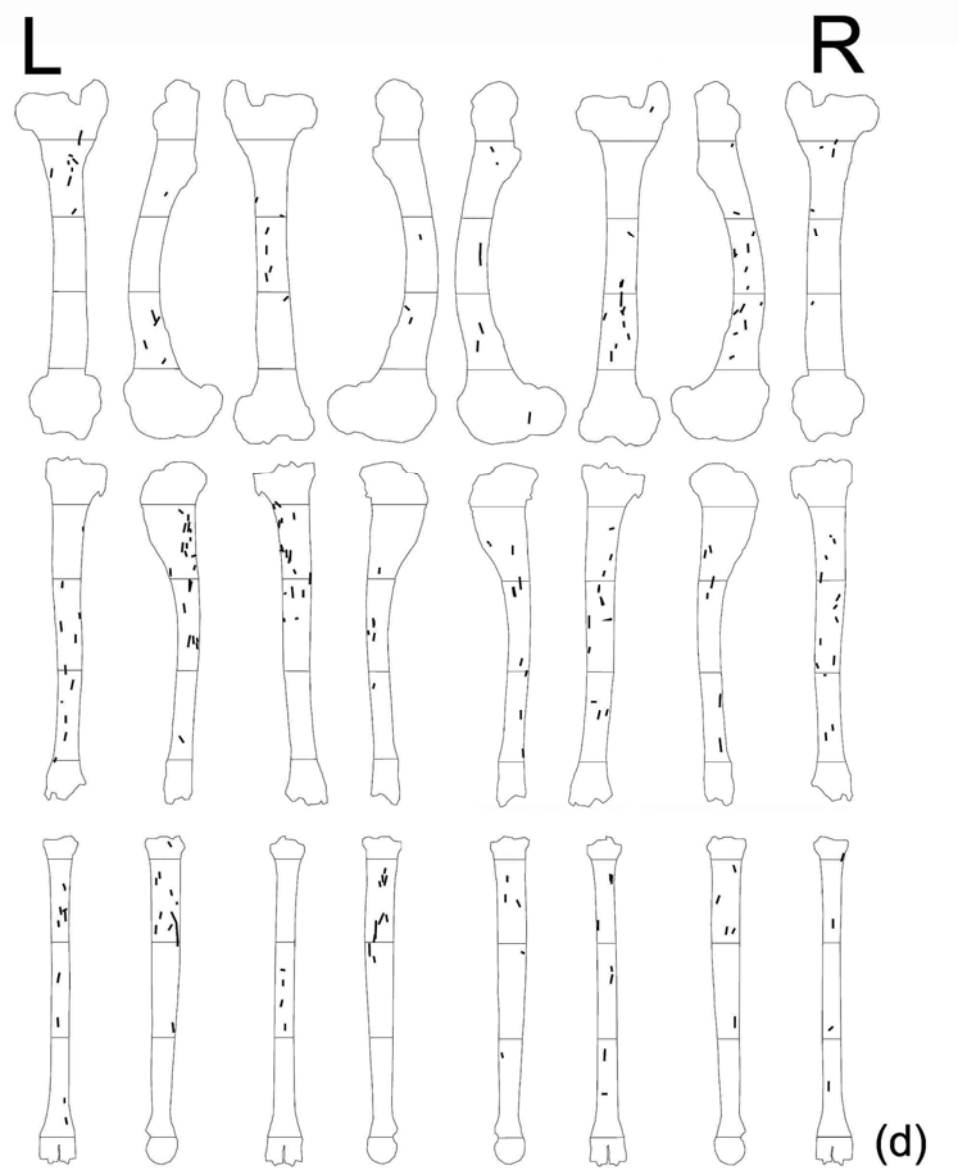


Fig. 59 (cont.) Locations of percussion marks on hindlimbs from Blombos.

Numbers of percussion marks by bone portion are given in Appendix H. The proportions of percussion marks that fall into each bone portion, with subsequent adjustment by surface area, are given in Appendix I and shown in Figure 60.

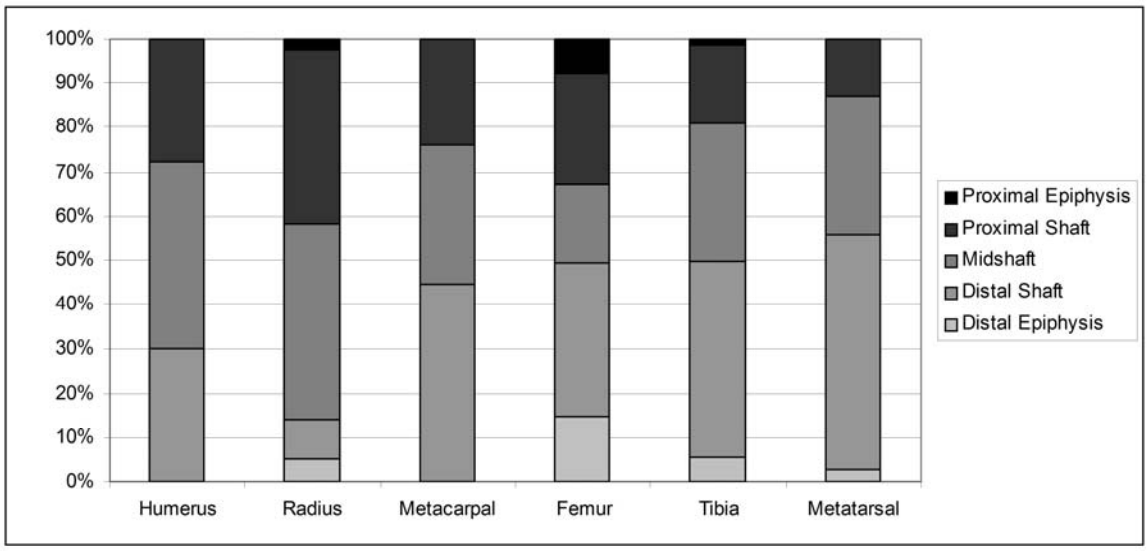


Fig. 60 The incidence of percussion-marking along long bone shafts at Blombos, adjusted by preserved surface area.

Percussion-marked epiphyses are relatively more common on large fauna than small fauna in M1, but the opposite is true in M2 and M3. However, M1 also has the largest sample and the sample of bone portions from large fauna with adequate representation to allow adjustments of percussion mark proportions is so small in M3 that is it unlikely to be informative at all. The pattern of larger fauna retaining more percussion marks on epiphyseal portions suggests that these portions were fragmented for further grease processing more frequently than they are for smaller ungulates, which makes intuitive sense. When faced with the time-consuming task of bone boiling or the digestive task of processing grease in the gut, the return can be maximized by selecting elements that contain more grease (i.e. those from larger ungulates).

Because grease extraction is an intensification strategy that might be expected to occur more frequently during periods of nutritional stress, the incidence of this behavior

can be compared between levels at Blombos to determine if MSA hominins were regularly under different degrees of this stress. The relative incidence of percussion-marking on long bone epiphyses can provide a proxy measure of the relative degree of this behavior. Unfortunately, the sample from Blombos contains so few epiphyses, and so few percussion marks on the ones that are present, that adjustments by bone portion are not often available (Appendix I). As a result, it is difficult to say more about changes in this practice over time except that generally it appears to increase in small ungulates as one goes from M1 to M3, and only makes an appearance that can be documented on large ungulates in M1.

This does not mean that percussion marks are not found on larger fauna in the other time periods (Appendix H), only that the sample of representative bone portions in M2 and M3 is insufficient to provide accurate adjustments by preserved surface area. Indeed, the presence of these marks on epiphyseal and spongy portions speaks to the need for future data collection and analyses that specifically speak to the issue of how to quantify and compare the incidence of bone grease extraction in a taphonomic system that is characterized by extensive density-mediated destruction.

CHAPTER SIX: THE DIE KELDERS CAVE 1 FAUNAL ASSEMBLAGE

Site description

Die Kelders Cave 1 (DK1) s a large site located about 120 km southeast of Cape Town (Figure 61). DK1 is part of a cave complex and is in close physical proximity to the neighboring, but unexcavated, site of DK2. The archaeological deposits benefit from a fortuitous bedrock arrangement in which the cave is formed between acidic base rocks and a limestone of the Bredasdorp Group. This has facilitated good fossil preservation inside the cave, with bone surfaces that are nearly pristine (Marean, pers. comm.., 2008). The site was originally excavated by Schweitzer and colleagues between 1969 and 1973 (Schweitzer, 1970, 1974, 1979; Tankard & Schweitzer, 1974, 1976; Klein, 1975; Butzer, 1979; Volman, 1981; Avery, 1982; Grine *et al.*, 1991). The site was then re-investigated between 1992 and 1995 (Avery *et al.*, 1997; Marean, 2000).

Fig. 61 View of DK1 relative to modern sea level. DK2 is the adjacent opening to the left.

The deposits at DK1 have been divided into 14 natural stratigraphic units, many of which alternate between a heavy and a light anthropogenic input (Marean *et al.*, 2000a;

Goldberg, 2000). There is also a very small sample of fauna from layer 15, which was not a layer reported in Marean *et al.* (2000a). The site has been dated by TL, OSL (Feathers and Bush, 2000), and ESR (Schwarcz and Rink, 2000) to ca. 70 – 60 ka. Dates at the top and bottom of the sequence are statistically indistinguishable, suggesting that the deposits accumulated rapidly during the late MIS 4 cold phase (75 - 64 ka) or early MIS 3. Because the site is only 10 meters above modern sea level, any deposits accumulated prior to MIS 5 would have been removed by rising sea levels during the Last Interglacial (MIS 5). Thus, DK1 offers a window into MSA behavior during a relatively brief interval of time during which other MSA sites such as PP13B and Blombos had been sealed from human occupation by extensive dune systems.

Estimates of global sea level from Chappell and Shackleton (1986) and Chappell (1983) indicate that between 72 – 59 ka the sea would have been approximately between -28 m and -88 m lower than today. If DK1 was occupied throughout the estimated age range of 70 – 60 ka, then the coastline was most likely ca. 15-17 km distant at the start of the MSA occupation and steadily moved to within 4 km by the time the occupation ended (van Andel, 1989). This would not have substantially altered the physiographic configuration of the area immediately local to DK1, although it would have brought the sea to within the 9 km range of marine resource exploitation that has been observed as the general cut-off for how far modern hunter-gatherers will carry marine resources such as shellfish (Bigalke, 1973; Erlandson, 2001). Shellfish are poorly preserved, but marine mammal bones have been recovered in low proportions of between 1 – 6% by NISP from most levels, with Layers 7 and 8 having 0% and Layer 10 having an anomalously high

proportion of 13% (Klein and Cruz-Uribe, 2000). This suggests that the best estimate for the distance of the ancient coastline to DK1 during its MSA occupation was between 4 and 9 km.

The entire faunal assemblage from DK1 has been analyzed for taxonomic abundance (Klein and Cruz-Uribe, 2000). Micromammals and small mammals are abundant (especially in layers where artifacts are not) and tortoises are also very abundant but not reported in full. The fauna from Layers 9 through 15 has been subjected to extensive taphonomic analysis, and 10-11 have been published (Marean *et al.*, 2000b). The larger mammal assemblage is dominated by species that have been historically documented in abundance in the Fynbos ecosystem today. These include grysbok, steenbok, common duiker, angulate tortoise, and a variety of small carnivores – as well as other closed-habitat species such as bushpig and bushbuck (Klein and Cruz-Uribe, 2000). However, much more diversity is indicated by the presence of water-dependent species such as reedbuck and more arid-adapted species such as springbok and black wildebeest. This overview of species representation at DK1 provides a general picture of what resources were available locally, even if it cannot speak more precisely to the relative compositions of those resources.

Because the taphonomic analysis presented by Marean *et al.* (2000b) indicates that the large mammals were predominately hominin-accumulated, the eland and likely most of the species that rely more on grazing indicate that a relatively open environment favored by large ungulate grazers was within the range of hominin transport. The smaller fynbos species had at least a partial hominin accumulator, but with a heavy input from

raptors (Marean *et al.*, 2000b). Therefore, the local environment within the range of raptor transport certainly included a component of bushy, closed habitat. The overall paleoenvironmental picture from DK1 is therefore one in which hominins present at DK1 were well-positioned to exploit a variety of habitats. The cave may have immediately opened up into either bushy or open vegetation, but would have been relatively easy to access and in close proximity to a wealth of different hunting and foraging opportunities. The near-ecotonal location and sources of fresh water from natural seeps and springs also would have contributed to its attractiveness (Marean *et al.*, 2000a).

Taphonomic summary

No primary taphonomic data were collected or analyzed from DK1 for the purposes of this study, but previous work that has been published will be briefly summarized here. A summary of published results for taxonomic abundances and taphonomic patterns is provided in each section. New data that are presented focus on bone portion representation, skeletal element abundances, and cut mark locations as derived from a database of GIS bone fragment entries and cut mark data from Layers 9 – 15.

Marine mammal representation is quite low at DK1, and there is a discrepancy between authors in the proportions of marine mammals that are reported from the site. One set of authors (Klein and Cruz-Uribe, 2000) do not include less identifiable shaft fragments and another (Marean *et al.*, 2000b) do. For Layers 10 and 11 Klein and Cruz-Uribe (2000) report relative proportions of 38% and 21%, respectively, while Marean *et al.* (2000) only report proportions of 14% and 9%. The fact that both sets of data agree in the direction of the difference, with Layer 10 having a greater representation of marine

mammals, is encouraging. It furthermore suggests that there are behavioral and/or environmental differences in marine resource exploitation detectable at DK1, and that it would be very useful to return to this site with improved dating methods to determine if these differences truly did accumulate only over the 10,000-year span suggested by current age estimates.

Small carnivores and mammals such as hyraxes and dune mole rats are common at DK1, as are tortoises (Klein and Cruz-Uribe, 2000). Among the large mammals at the site, carnivores and primates are rare and the faunal assemblage is dominated by large (size 1 – 5) ungulates. Overall taxonomic representation of these ungulates shows that most of them fall into body size class 1 (Klein and Cruz-Uribe, 2000; Figure 62).

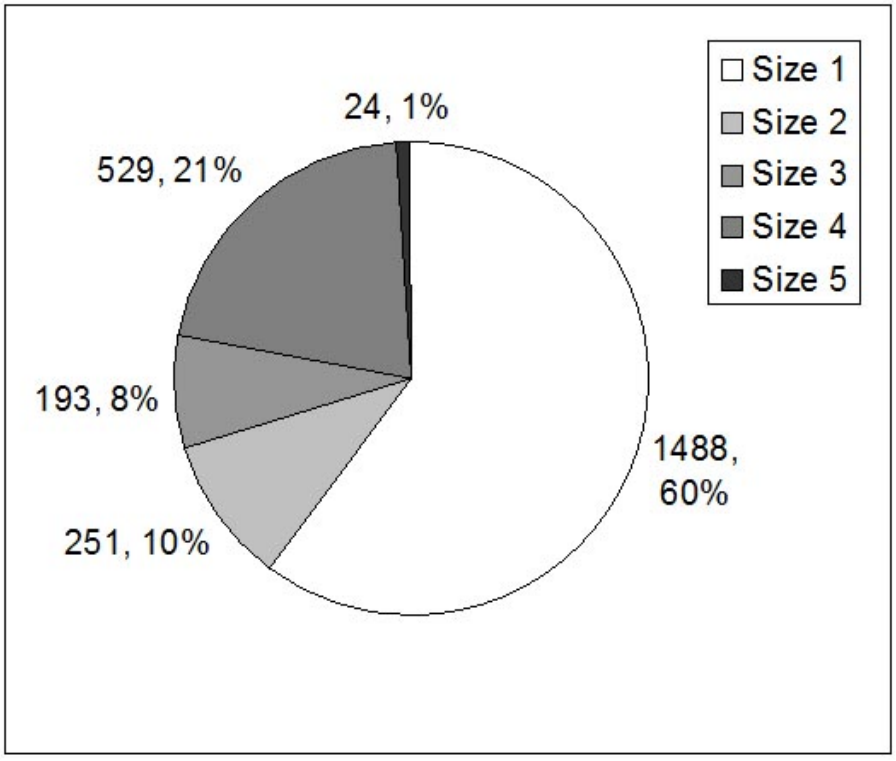


Fig. 62 Body size class representation for ungulates from all layers at DK1 (data from Klein and Cruz-Uribe, 2000).

Klein and Cruz-Uribe (2000) report some differences between layers that may become useful in future interpretations when a more precise series of ages are available for the deposits. However, the summed NISP for specimens identifiable to either species or body size class is very different as reported by Marean *et al.* (2000b) and by Klein and Cruz-Uribe – especially for Layer 10 (Figure 63). This suggests that underlying methodological issues, such as the fact that Klein and Cruz-Uribe do not advocate inclusion of skeletal elements that do not retain some portion of an epiphyseal end (Klein and Cruz-Uribe, 1984) are causing differences that must be resolved before finer-scale interpretations of the species abundances at DK1 take place.

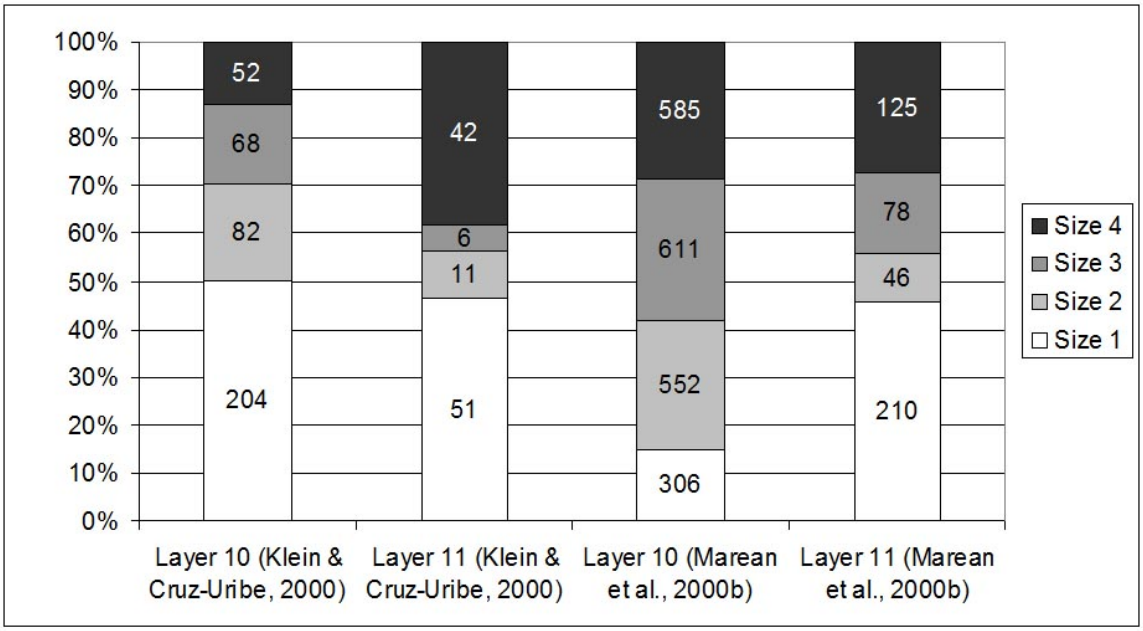


Fig. 63 Comparison of species abundance data from Klein and Cruz-Uribe (2000) and Marean *et al.* (2000b).

These differences in the relative proportions of ungulate body size classes are critical at DK1 in light of the taphonomic data presented by Marean *et al.* (2000b). Size 1 ungulates were found to have been predominately accumulated by raptors, which supports the interpretations of Marean *et al.* (2000a) that Layer 11 represents a period of low occupation for MSA hominins. However, following the 50% representation of size 1 ungulates as reported by Klein and Cruz-Uribe (2000), this would also indicate a relatively low hominin contribution to the fauna from Layer 10.

Marean *et al.* (2000b) found that there were some statistically significant differences in post-depositional breakage between Layers 10 and 11, but that this did not seem to follow any particular pattern with regards to body size. Most of the dry-bone breakage was discovered to have occurred in the wake of many of the fragments having been burned, which weakened the bone and made it more susceptible to post-depositional fragmentation.

The main accumulator of size 2 – 4 ungulates was found to be MSA hominins. There was a relatively low co-occurance of tooth marks and percussion marks on the same midshaft fragment, suggesting that there was an independent carnivore input for some of the fauna. However, most of the tooth marks in the assemblage were attributed to scavenging carnivores entering the site after hominins had discarded the bones.

Layers 10 and 11 at DK1 were also shown to have suffered a relatively high degree of density-mediated destruction, based on the relative representation of epiphyseal ends, near-epiphysis shafts, and midshafts. This can be examined here for the assemblage as a whole using composite MNE images of the major skeletal elements at

DK1 (Figure 64). All images were derived using the GIS program described in the methods section (Marean *et al.*, 2001). Darker areas represent higher MNE estimates, with the best-represented area indicated by an arrow and dotted fill. Diagonal lines indicate areas where there is zero representation in the assemblage.

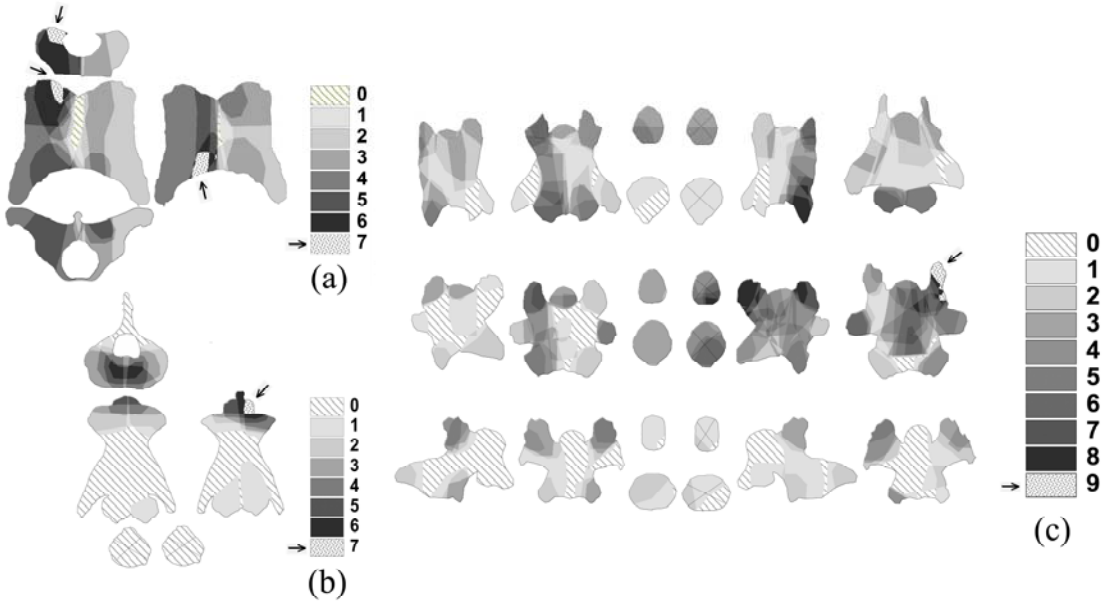


Fig. 64 Composite GIS images of the atlas (a), the axis (b), and cervical vertebrae (c) from all layers at DK1. Darker areas indicate regions from which higher MNE estimates are derived, dotted areas with arrows indicate the zone of the highest MNE, and diagonal lines indicate areas not represented at all in the assemblage.

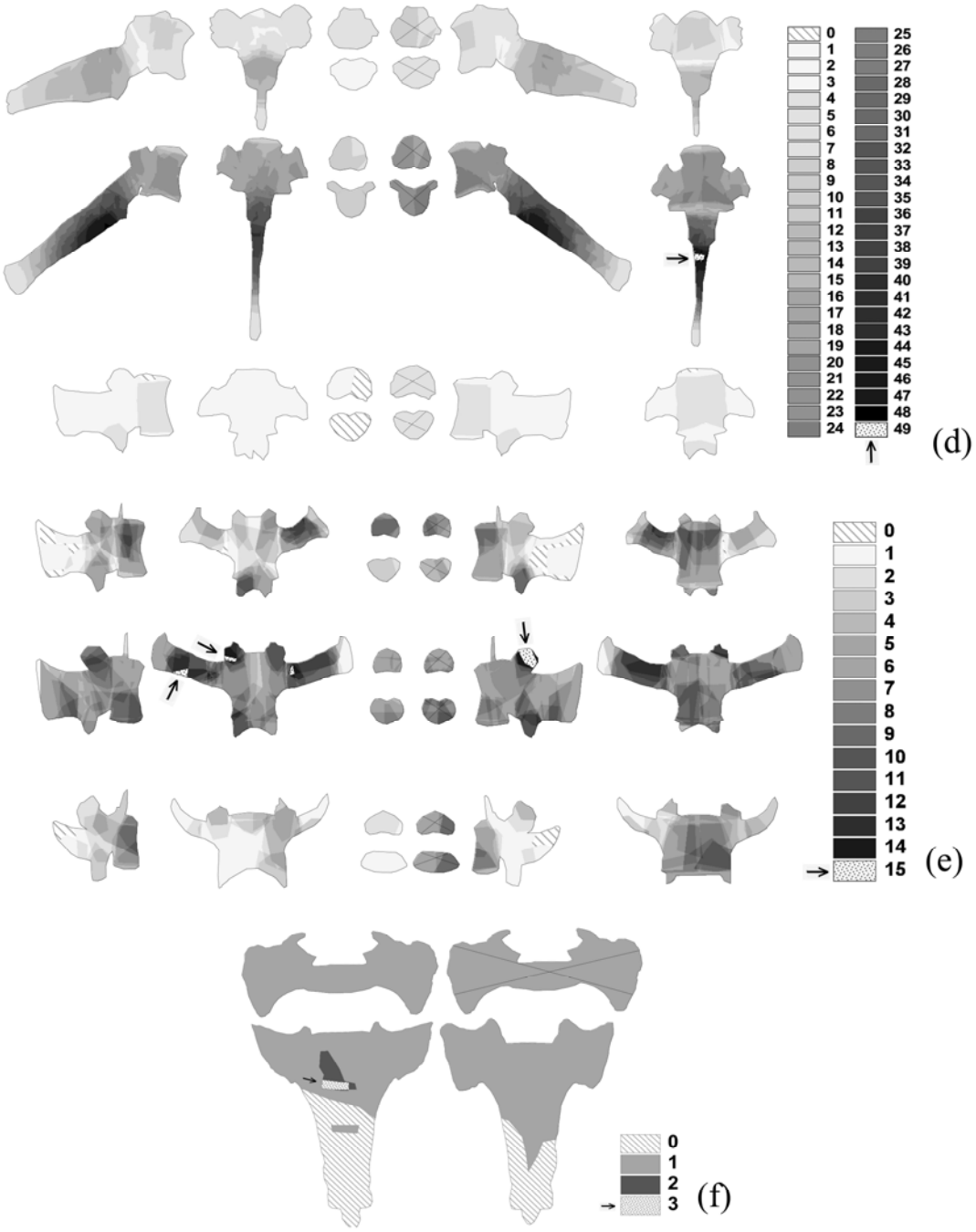


Fig. 64 (cont.) Composite GIS images of thoracic vertebrae (d), lumbar vertebrae (e), and the sacrum (f) from all layers at DK1.

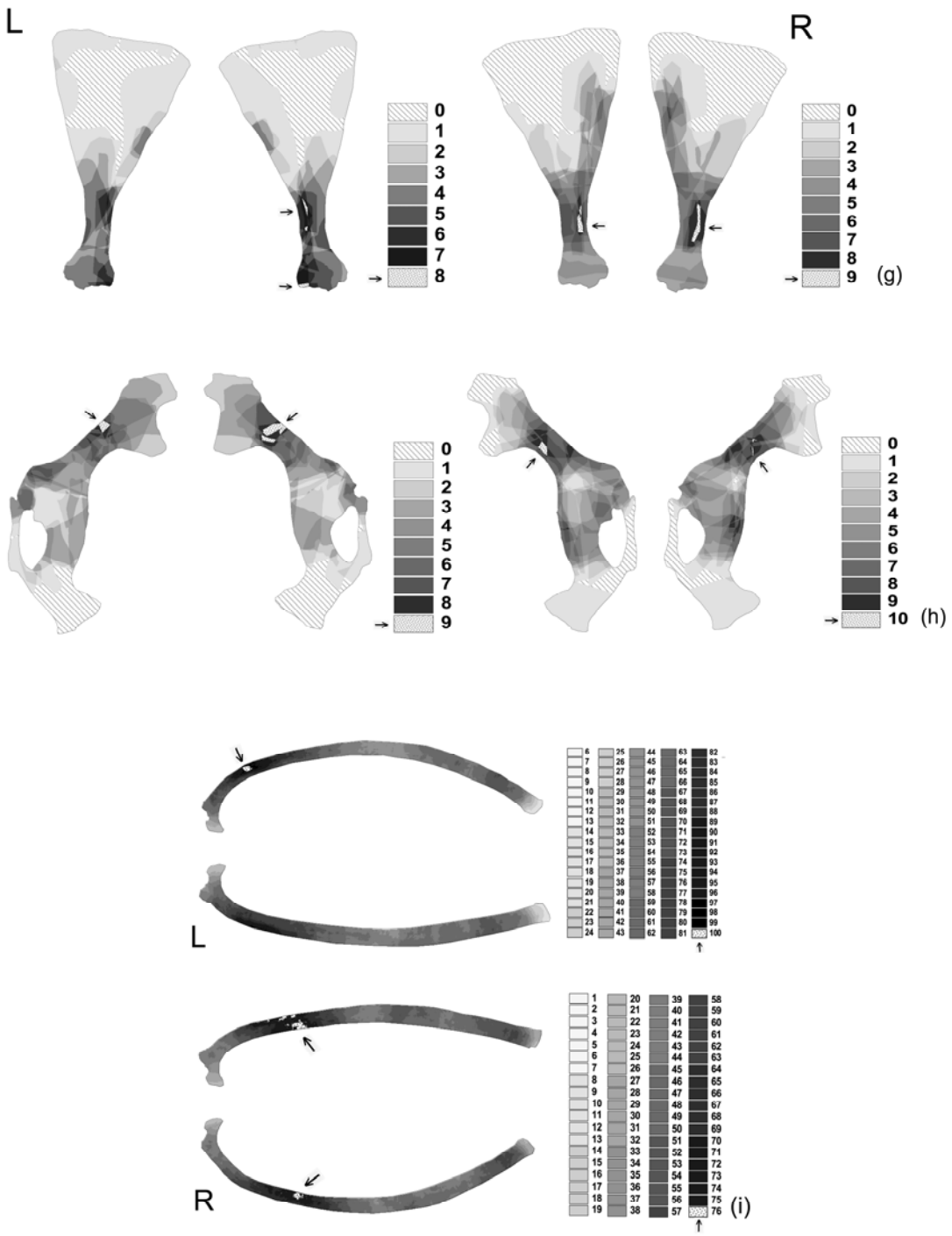


Fig. 64 (cont.) Composite GIS images of scapulae (g), pelves (h), and ribs (i) from all layers at DK1.

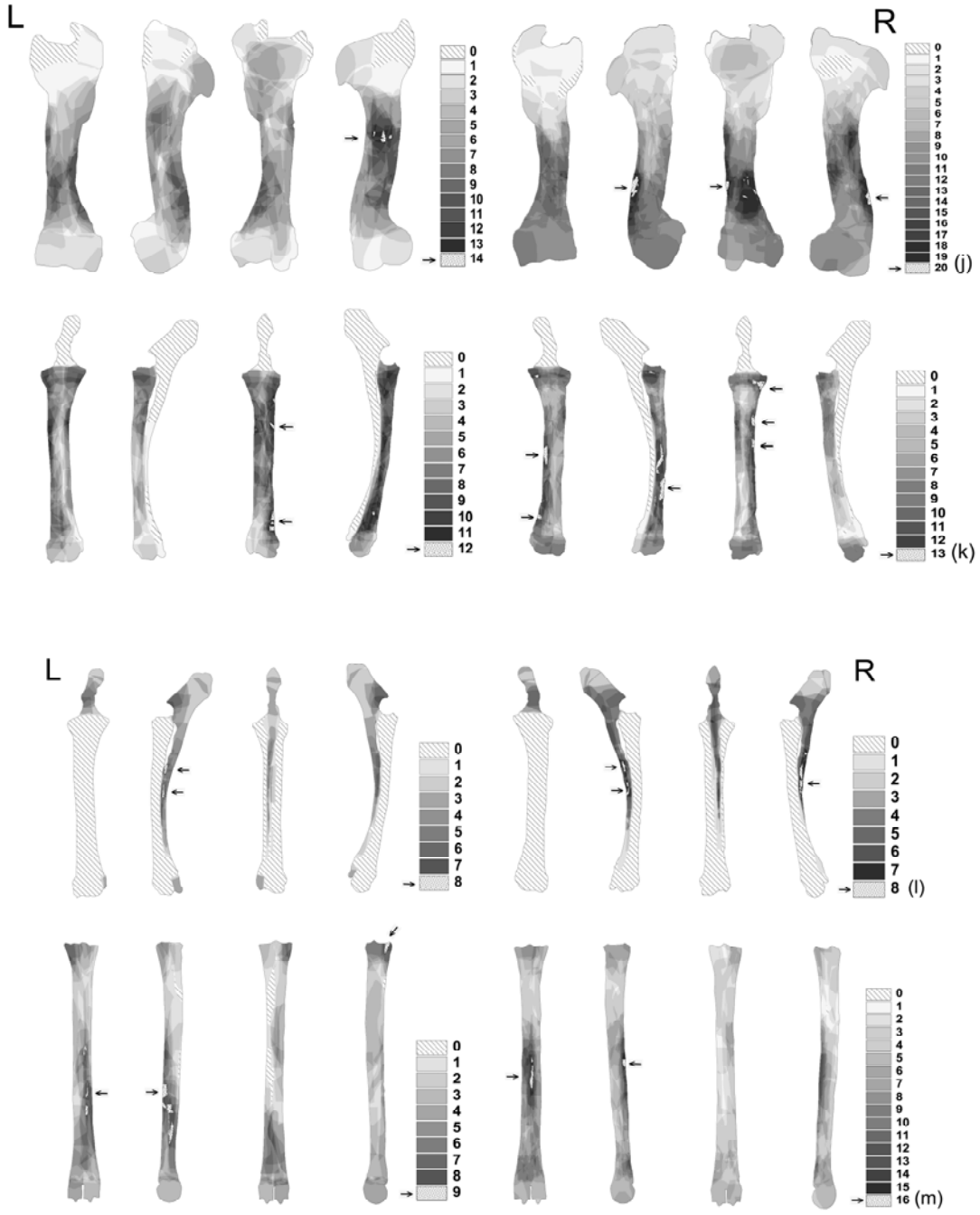


Fig. 64 (cont.) Composite GIS images of the humerus (j), radius (k), ulna (l), and metacarpals (m) from all layers at DK1.

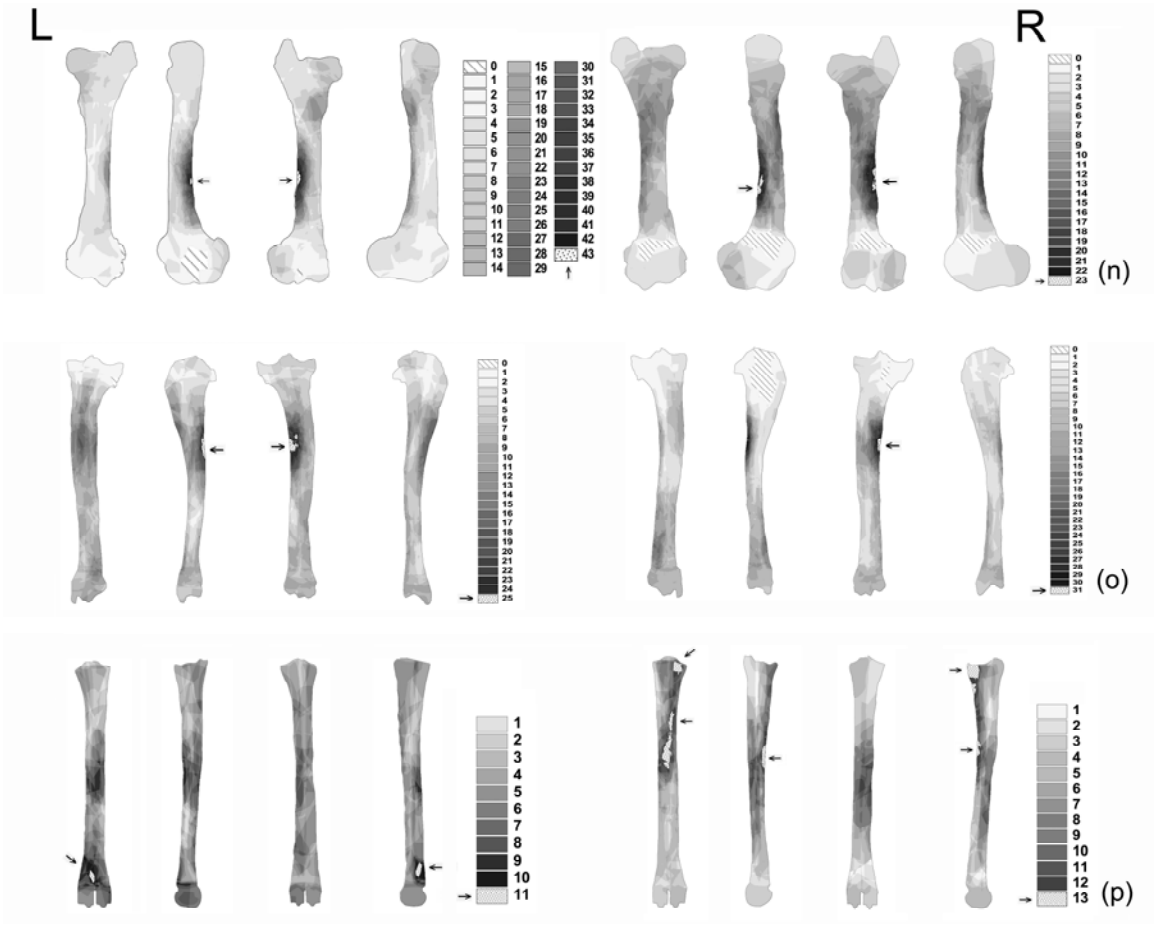


Fig. 64 (cont.) Composite GIS images of the femur (n), tibia (o), and metatarsals (p), from all layers at DK1.

Visual inspection reveals that for each element it is the densest portions that are best represented. The visual assessment is verified quantitatively when MNE values are derived using different portions of the same element. Long bones were divided into the five zones used by Abe *et al.* (2002): proximal epiphysis, proximal shaft, midshaft, distal shaft, and distal epiphysis. The MNE for each bone portion was then derived, and denser

portions such as long bone shafts were found to consistently provide the highest MNE counts (Table 21).

Table 21

MNE estimates from each long bone portion at DK1.

Element	Side	Prox. End	Prox. Shaft	Midshaft	Dist. Shaft	Dist. End
Humerus	Right	7	16	20	20	18
	Left	7	14	14	12	8
Radius	Right	13	13	13	13	11
	Left	11	12	12	12	12
Metacarpal	Right	9	8	9	9	7
	Left	9	10	16	14	12
Femur	Right	10	17	23	23	9
	Left	17	25	43	43	13
Tibia	Right	7	28	31	20	18
	Left	12	25	25	17	16
Metatarsal	Right	13	13	13	11	6
	Left	8	8	10	11	11

Long bone portion representation can also be presented as the %Area preserved for each element using the procedures outlined in Marean *et al.*, (2001) and given in Table 22. Again, it is clear that the highest proportions of preserved area occur on the denser parts of long bones. When these percentages are plotted against bone density as measured by CT of a sheep skeleton (Lam *et al.*, 1998), this relationship is verified (Figure 65).

Table 22

Relative proportions of long bone portion representation at DK1 (all percentages add to 100% for a complete bone).

	Proximal Epiphysis			Proximal Shaft			Midshaft		
	Left	Right	Total	Left	Right	Total	Left	Right	Total
Humerus	15.5%	11.7%	13.0%	21.4%	9.2%	13.3%	25.3%	20.5%	22.1%
Radius	10.3%	13.3%	11.9%	29.3%	23.7%	26.4%	25.3%	25.4%	25.4%
Metacarpal	10.3%	7.2%	8.4%	17.2%	18.3%	17.8%	21.9%	29.6%	26.5%
Femur	17.5%	15.0%	16.3%	22.6%	27.6%	24.9%	25.8%	27.2%	26.5%
Tibia	10.4%	6.7%	8.7%	31.4%	22.1%	27.2%	28.6%	27.4%	28.0%
Metatarsal	9.3%	8.9%	9.1%	22.1%	29.0%	25.7%	27.0%	33.2%	30.3%

	Distal Shaft			Distal Epiphysis		
	Left	Right	Total	Left	Right	Total
Humerus	22.7%	24.1%	23.6%	15.1%	34.6%	28.0%
Radius	21.3%	20.6%	21.0%	13.8%	16.9%	15.4%
Metacarpal	35.2%	29.4%	31.7%	15.5%	15.6%	15.5%
Femur	19.9%	17.4%	18.8%	14.2%	12.8%	13.5%
Tibia	17.6%	27.6%	22.2%	11.9%	16.2%	13.9%
Metatarsal	26.3%	20.7%	23.3%	15.4%	8.2%	11.6%

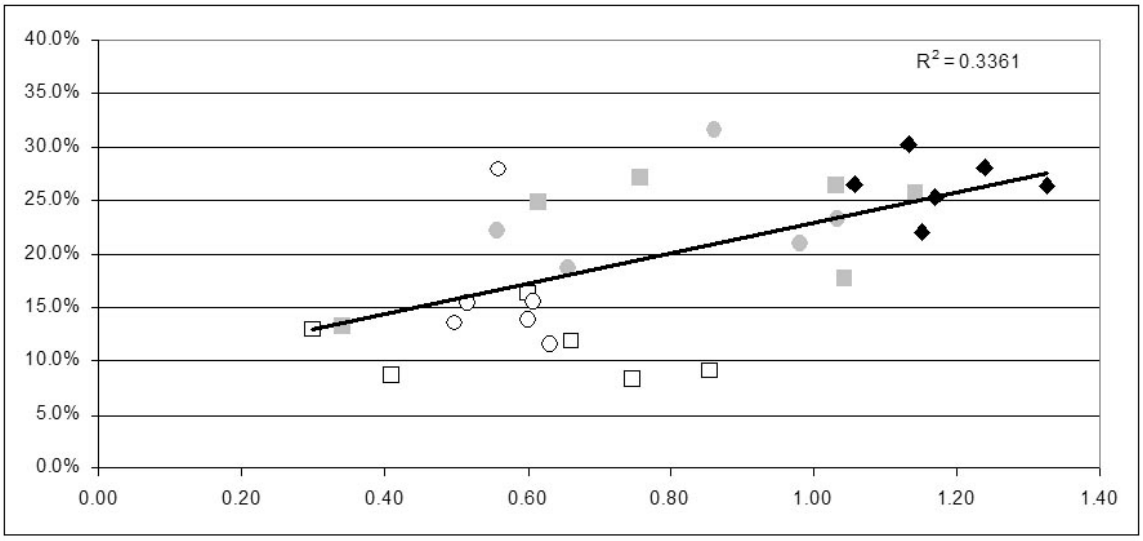


Fig. 65 Long bone portion representation at DK1 versus bone density. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

Using Spearman's Rho, the positive overall relationship between bone density and bone portion representation is statistically very robust at DK1 ($R_s = 0.5520$, $p = 0.002$). However, further examination of this relationship by body size shows some interesting differences – particularly between ungulates of the largest and smallest body sizes (Figure 66).

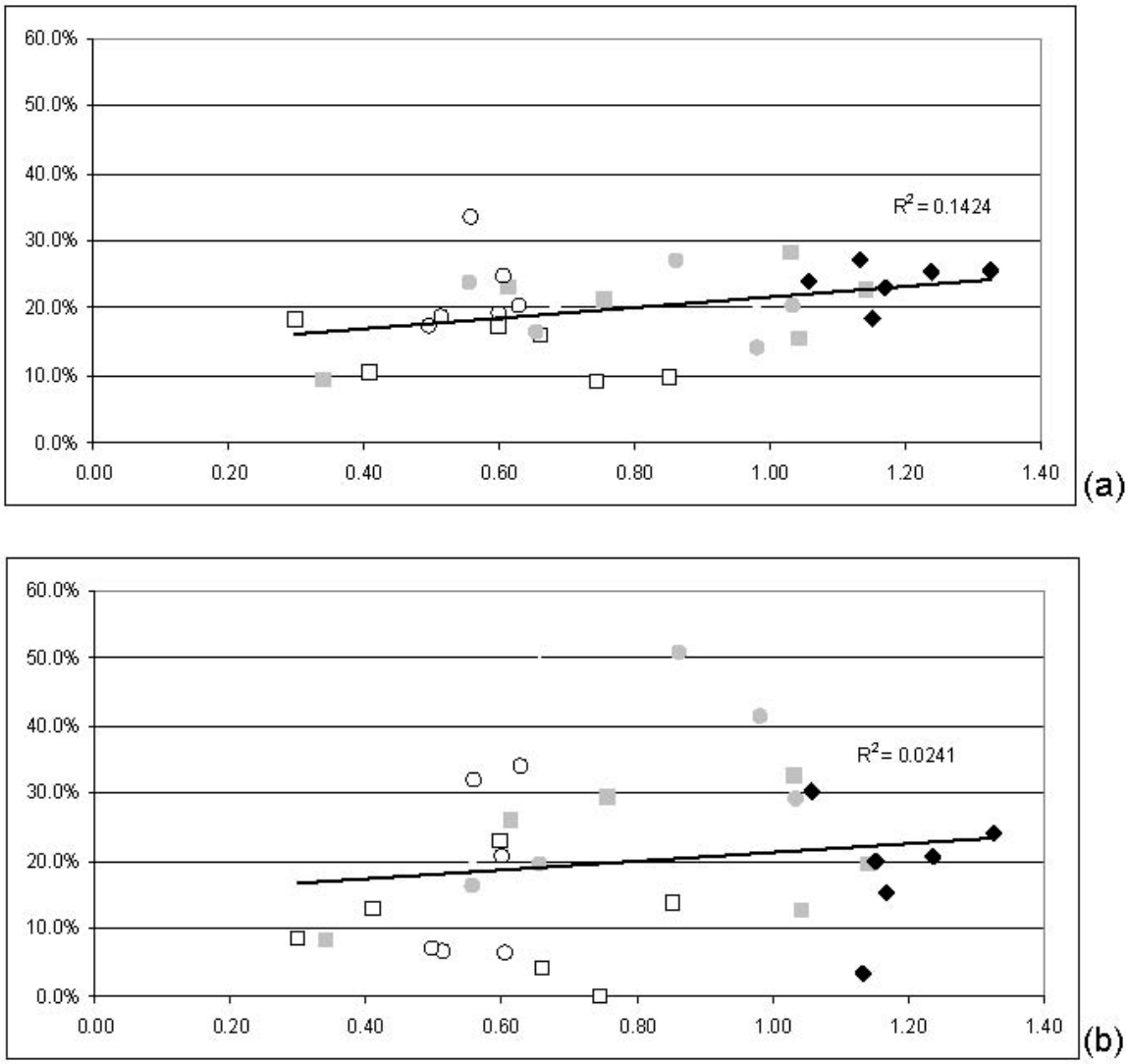
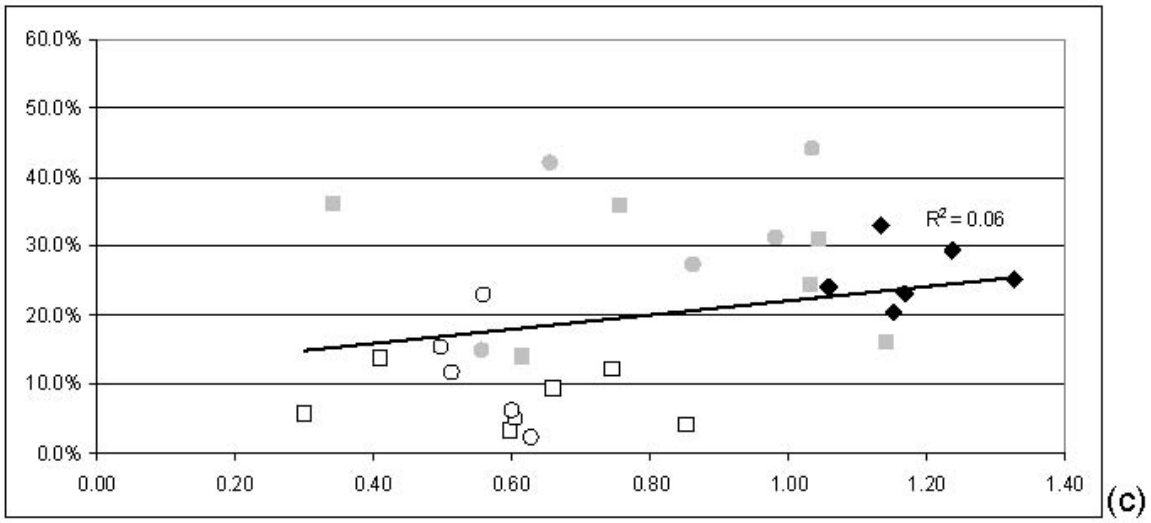


Fig. 66 Long bone portion representation at DK1 versus bone density for size 1 (a) and size 2 (b) fauna. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.



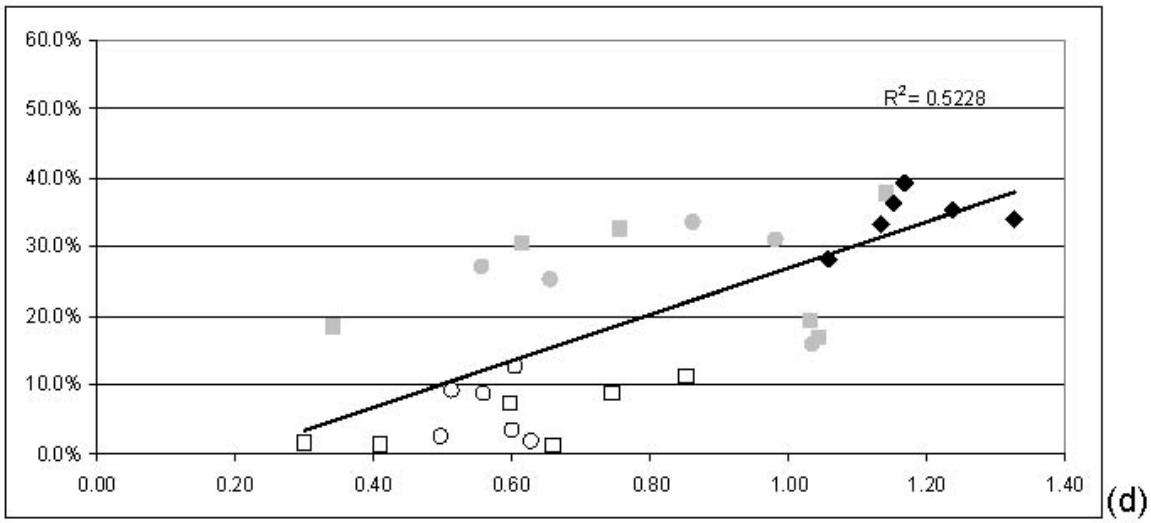


Fig. 66 (cont.) Long bone portion representation at DK1 versus bone density for size 3 (c) and size 4 (d) fauna. Open squares = proximal end, open circles = distal end, gray squares = proximal shaft, gray circles = distal shaft, black diamonds = midshaft.

When broken down by body size class, a tight relationship between long bone portion density and representation is only observed in size 1 and size 4 ungulates. This impression is confirmed statistically using Spearman's Rho (Table 23). Two possible explanations for this pattern are: 1) that these two size classes do not show a pattern that

is as well-defined because they are the same categories for which there is the smallest available sample size; and 2) that these two size classes were those most subject to density-mediated destruction because of the activities of different agents rather than any inherent susceptibility to such destruction for bones of the smallest or largest ungulates.

At modern Kua sites at which both large and small ungulate remains are present, larger ungulates suffer a greater degree of carnivore ravaging (Bartram, 1993). Therefore, after both human marrow processing and carnivore ravaging, small ungulate elements at such archaeological sites should have better representation of epiphyses and near-epiphyses than large ungulate elements (Bartram and Marean, 1999). However, at sites for which only small ungulate remains are available for carnivore ravaging, Bartram and Marean (1999) suggest that carnivores will selectively remove spongy elements and bone portions and the result will be increased evidence of density-mediated destruction within these smaller size classes.

At DK1 the largest and the smallest ungulates suffered the highest degrees of density-mediated destruction, which does not immediately fit either scenario. However, once the important aspect of time-averaging is factored into the equation, the pattern is quite clear. Marean *et al.* (2000b) provide evidence that hominins were not the primary accumulators of the size 1 ungulates, and it follows from this that the raptors accumulating this faunal component were not in residence at the site at the same time as the hominins responsible for accumulating the larger ungulates. This is also supported by Klein and Cruz-Uribe (2000), who showed statistically that common prey of raptors such

as the Cape dune mole rat are much more abundant in layers with very low evidence of hominin occupation.

Following from this, a reasonable conclusion is that size 1 fauna and larger fauna were not often found in the cave together at the same time and thus were subject to different taphonomic pathways in terms of the degree of density-mediated destruction and carnivore interaction with the assemblage. Subsequent to periods of hominin occupation carnivores would have been able to scavenge spongy portions of large ungulates, while during periods of non-human occupation scavenging opportunities would have been more limited to small ungulate remains from raptor kills. Thus, the patterning seen in the density-mediated destruction for both of these groups should appear similar, despite the finding that when presented with both size classes simultaneously carnivores will first focus on epiphyseal portions of the larger ungulates in the assemblage. However, it should be noted that the degree of this destruction is still much higher overall for large ungulates than for small ungulates.

Table 23

Spearman's Rho and p-values for the significance of the correlation between long bone portion representation and bone density.

Ungulate Size	Spearman's Rho	p-value
Size 1	0.4052	0.0263
Size 2	0.1934	0.3058
Size 3	0.3183	0.0865
Size 4	0.7471	<0.0001

Although carnivores have been shown to be common agents behind density-mediated destruction (Marean and Spencer, 1991; Marean *et al.*, 1992), it is also possible that hominins were fragmenting spongy elements in anticipation of grease extraction (Outram, 2001; Church and Lyman, 2003). The pattern seen in the degree of this destruction across body sizes at DK1 therefore may represent the sum of all three processes, with raptors and perhaps carnivores largely responsible for that seen in the size 1 fauna and hominins the major source for it in the size 4 ungulates. Deletion of spongy portions because of hominin grease extraction has been proposed for Middle Paleolithic sites in the Zagros, although it was suggested that this was not the case at DK1 (Marean, 2005). In future work, this possibility can be tested more rigorously by examining the incidence of percussion-marking throughout the skeleton and adjusting for preserved surface area, in the same manner as has been demonstrated for the incidence of percussion-marking (Abe *et al.*, 2002).

Skeletal element transport

Skeletal element representation has been provided by NISP for Layers 10 and 11 at DK1 in Marean *et al.* (2000b:217). Here, skeletal element data using single-element estimates will be provided for Layers 9 – 15. MNE estimates are given in Appendix D, MNI estimates in Table 24, and MAU data in Appendix E.

Table 24

MNI estimates and the element from which the highest MNI was derived at DK1.

	Size 1		Size 2		Size 3	
Layer 9	5	L Humerus	3	L Tibia	3	R Tibia
Layer 10	1	Various	1	Various	3	L Tibia
Layer 11	3	L Femur	1	Various	1	Various
Layer 12	5	Various	4	R Femur	4	R Radius
Layer 13	3	R Pelvis	1	Various	2	Various
Layer 14	22	L Femur	3	L Femur	2	Various
Layer 15	4	Various	1	Various	2	R Metatarsal
DK 1 All (Overlap)	32	L Femur	6	R Femur	7	L Femur
DK 1 All (Count)	68	L Femur	14	L Tibia	18	L Tibia

	Size 4		All Sizes (Overlap)		All Sizes (Count)	
Layer 9	3	L Femur	7	L Femur	10	L Tibia
Layer 10	5	L Femur	6	L Femur	7	L Tibia
Layer 11	2	L Metatarsal	3	L Femur	4	Various
Layer 12	5	L Tibia	11	R Femur	14	R Femur
Layer 13	2	Various	4	R Metacarpal	5	L Tibia
Layer 14	7	R Humerus	24	L Femur	28	L Femur
Layer 15	2	R Metacarpal	4	Various	5	R Radius
DK 1 All (Overlap)	10	R Humerus	43	L Femur	48	L Femur
DK 1 All (Count)	28	R Humerus	91	L Femur	112	L Femur

Published data from Layers 10 and 11 at DK1 show a pattern of relatively high long bone representation: 65% of all non-dental specimens are represented by long bone

fragments (Marean *et al.*, 2000b:217). The MAU data from DK1 as a whole (Layers 9 – 15) support this (Figure 67). It can be seen clearly that skeletal element representation is heavily-influenced by density-mediated destruction, as high-survival elements at the bottom of the chart (humerus - metatarsal) are consistently better-represented than low-survival elements at the top of the chart (atlas – pelvis). Two major anomalies occur, and these are both for size 1 ungulates: a high representation of the femur and a high representation of near-cranial elements such as the axis and atlas. Cranial portions were not examined for this study, but the latter suggests that transport of heads (with the atlas and axis attached) occurred more commonly for this size class than others. This initially points to a whole-body transport strategy for whichever accumulator was most responsible for their presence at the site. As discussed above, this accumulator was most likely raptors and therefore a whole-animal transport strategy makes intuitive sense (Marean *et al.*, 2000b).

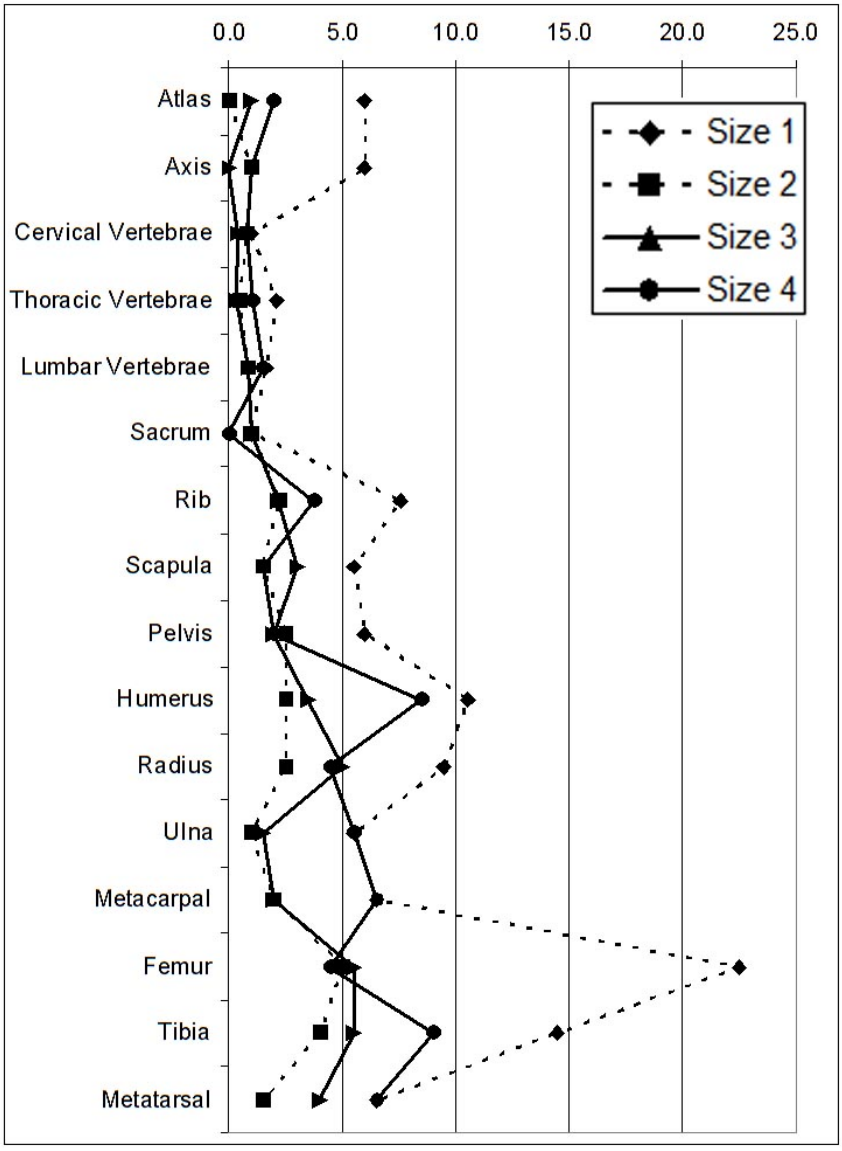


Fig. 67 MAU data from all layers at DK1 showing patterns of skeletal element representation for small (size 1 and 2) and large (size 3 and 4) ungulates.

Figure 68 shows the patterning of skeletal element abundances for small (size 1 and 2) and large (size 3 and 4) ungulates. Data are given as a two pooled groups comprised of the layers considered by Marean *et al.* (2000a) to represent periods of high occupation by hominins (Layers 10, 12, and 14) and periods of low occupation by

hominins (Layers 9, 11, and 13). Layer 15 is not included because the sample is very small and the nature of the deposits or the likely degree of hominin occupation at the time has not been described in any recent publications. The overlapping age ranges of all the dating techniques at DK1 has indicated that the deposits were accumulated quite quickly over the course of about 10 thousand years, and thus pooling the data in the way described above is not likely to capture any major shifts that could unduly influence the patterning.

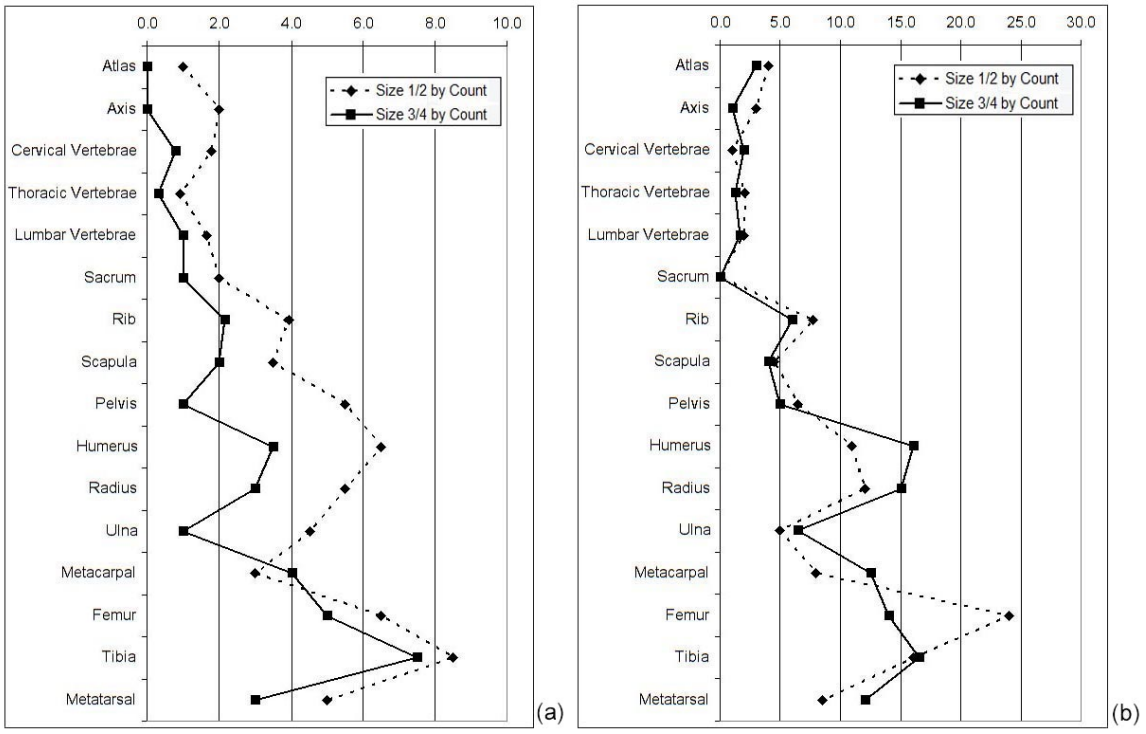


Fig. 68 MAU data from low-occupancy layers (a) and high-occupancy layers (b) showing patterns of skeletal element representation for small (size 1 and 2) and large (size 3, 4 and 5) ungulates.

A clear pattern in the low-occupancy layers is one in which small and large ungulate skeletal element representations follow one another closely. Given that these are low-occupancy layers, it is probable that these data represent the sum pattern of three different accumulative agents: raptors, carnivores, and to a lesser extent MSA hominins. The raptor input is expected to be restricted to the small size classes, and indeed these are most common in these layers as would be expected. The larger ungulates that are present might be the result of either carnivore or hominin accumulation. These two agents may also have played a role in the small ungulate representation. It is therefore interesting and somewhat unexpected that skeletal element representation should be so similar, although this may also be the result of taphonomic processes smoothing over patterns that were previously better-defined.

A similar pattern is observed in the high-occupancy layers, with the additional observation that here both relative and absolute frequencies of skeletal elements are now apparent. One clear consistency is that for both size classes distal limb bones are less commonly represented than proximal limb elements, as was first observed by Marean *et al.* (2000b). However, caution should be used in interpreting this visual pattern for the methodological reasons described in Chapter Two: metapodials are difficult to assign to specific element and therefore are likely to have been under-represented in the GIS. This pattern will be discussed further in Chapter Seven using comparisons of MAU and NISP data.

Observations about skeletal element abundance can be further explored by determining if bone utility had any bearing on hominin transport decisions. The %MAU

was plotted against SFUI, so that if transport was focused on higher-utility bones they should be more abundant and fall within the upper right-hand corner of the plots. The sample from DK1 was sufficient for each body size to be examined separately. Here, the focus lies on interpretation of the high occupation levels only for two reasons. First, low occupation levels have a much smaller sample of faunal remains than do high occupation levels. Second, by definition these layers were not commonly occupied by MSA groups and are therefore less likely to provide insight into the general behavioral patterns. They are also expected to show more influence from random events and individual transport decisions, as suggested above. Following the recommendations of Marean and Cleghorn (2003), high-survival and low-survival elements are plotted separately (Figure 69).

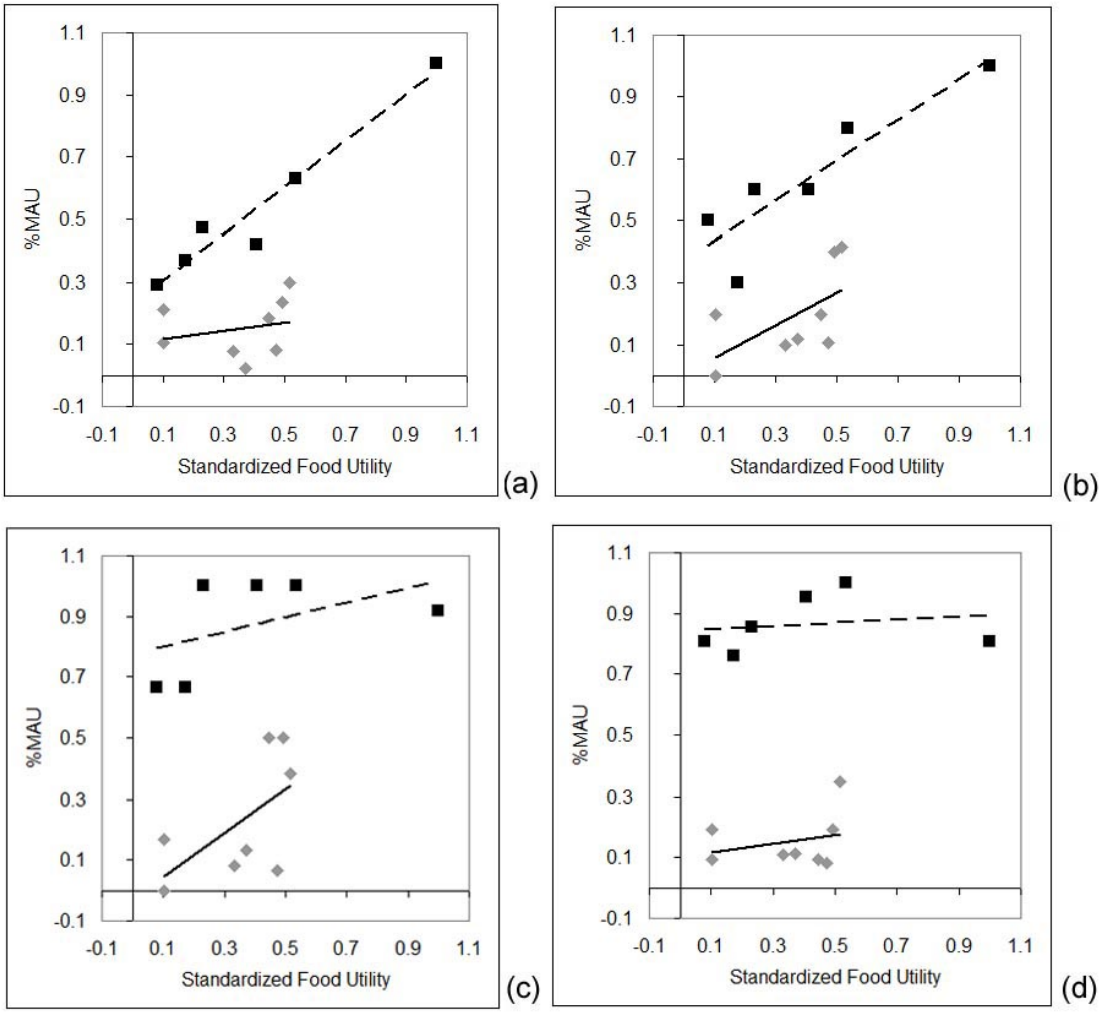


Fig. 69 %MAU versus SFUI in the high-occupancy layers at DK1 for body size 1 (a), 2 (b), 3 (c), and 4 (d). Black squares represent high-survival elements (dashed regression) and gray diamonds represent low-survival elements (solid regression).

The DK1 data show a very clear visual pattern in which both small and large ungulates show evidence of selective transport in accordance with food utility in both the high- and low-survival sets. This general pattern is compelling, but it is most pronounced for small fauna. When these patterns are assessed statistically, the correlations for small ungulates in the high-occupancy layers are found to be significant while those for larger

ungulates are not (Table 25). More importantly, the strength of the correlation is very high for small ungulates and less so for large ungulates. This is puzzling given the Hadza model outlined by Monahan (1998), in which increased selectivity should be most apparent in larger body sizes.

Estimation of the MNE using the GIS system facilitates the generation of values based on shaft fragments (Marean *et al.*, 2001). Values on these portions are expected to be the best representatives of what elements were originally present in an assemblage such as DK1 that has undergone extensive density-mediated destruction. It has been suggested here that small and large ungulates (particularly size 1 and size 4) were subjected to similar degrees of density-mediated destruction because they followed different taphonomic pathways that were sufficiently separated in time for one set to lose its nutritive value before the next was introduced. The GIS procedure should therefore have produced values for all size classes that are more or less comparable to one another.

Table 25

Spearman's Rho and p-values for the strength of the correlation between %MAU and Standardized Food Utility at DK1.

	Group	Body Size	Spearman's Rho	p-value
High Occupation	Low-Survival	1	0.4659	0.2447
	High-Survival	1	0.8987	0.0149
	Low-Survival	2	0.6649	0.0720
	High-Survival	2	0.9276	0.0077
	Low-Survival	3	0.5928	0.1215
	High-Survival	3	0.5555	0.2525
	Low-Survival	4	0.4356	0.2807
	High-Survival	4	0.3703	0.4699
Low Occupation	Low-Survival	1	0.7656	0.0268
	High-Survival	1	0.8117	0.0499
	Low-Survival	2	0.0982	0.8171
	High-Survival	2	0.6473	0.1646
	Low-Survival	3	0.5540	0.1542
	High-Survival	3	0.7590	0.0801
	Low-Survival	4	0.6429	0.0856
	High-Survival	4	-0.0926	0.8615

Given that there should be no taphonomic or methodological reason for this pattern, it is useful to examine the representation of individual elements within each of their respective survival sets. The mean and standard deviation was calculated for the MAU from the high-survival and low-survival sets of elements. A z-score was then derived for each bone so that its individual representation, in terms of standard deviations from the mean, could be visualized relative to other elements in the set (Figure 70). Points falling above the dashed line are represented more often than the mean and points falling below the dashed line are represented less often than the mean.

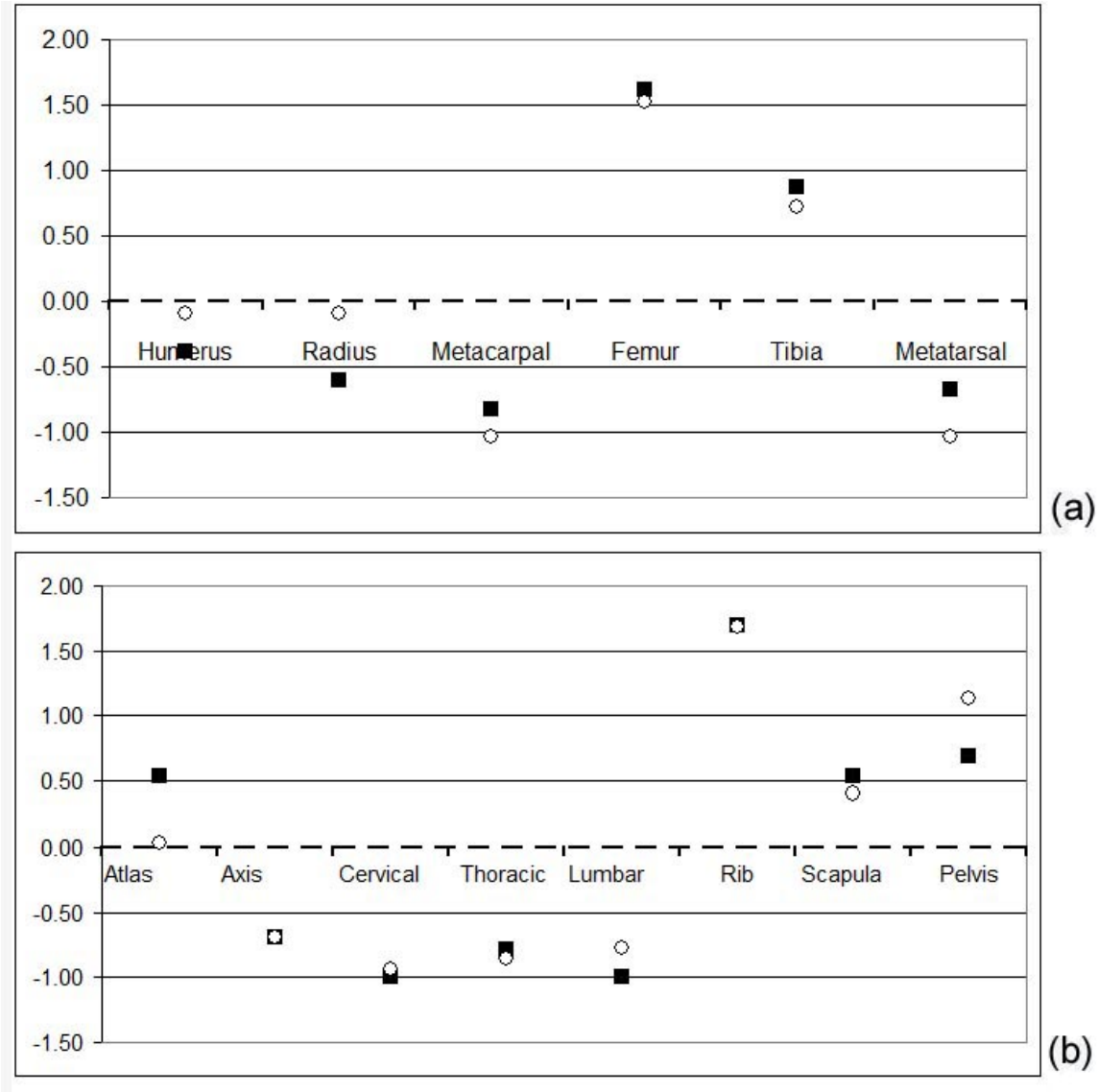


Fig. 70 Z-scores for small (black squares) and large (open circles) ungulates in the high-occupancy layers at DK1. High-survival (a) and low-survival (b) elements are only compared within their respective sets.

The most striking aspect of the distribution of the z-scores is how closely the small and large ungulate data track one another. This is true despite the tendency for larger ungulates to have weaker correlations and higher p-values, and suggests that selective transport in accordance with food utility can be identified as a factor in

decision-making regarding transport for all body size classes. Another notable pattern in the z-scores is confirmation that metapodials are less well-represented than other long bones. Although this could be related to the issues with GIS entry of metapodials, it could also be hinting at increased field processing and discard of these elements, much as in the Hadza model. Unlike the Hadza model, however, there is a disproportionately high representation of ribs, which have been seen to be some of the first of the low-survival elements to be discarded at kill sites (Monahan, 1988; Marean and Cleghorn, 2003).

These data together suggest that DK1 may fit the criteria for having been employed as a central place by MSA foragers. However, one of the major expectations should then be selective transport of large ungulates only. An explanation for the consistent tracking of skeletal element abundances in terms of food utility for both small and large ungulates is again to be found in a model that combines taphonomy with optimal foraging theory. Not only hominins use central places, and the marginal value theorem applies equally to a variety of species when they are faced with the cost of transport versus the return of a resource that is located away from the central place (e.g. Sodhi, 1992; Winterhalder and Smith, 2000; Rogers and Broughton, 2001; Burger et al, 2005). For smaller-bodied carnivore denning at DK1, selective transport of size 1 ungulates (which make up the majority of the small ungulate component) is expected because it removes these elements from the scene of heavy competition with other predators. Therefore, the positive association with food utility in this size class need not be explicable in terms of hominin behavior.

Carcass processing strategies

At DK1 the primary accumulator of the size 2 - 4 ungulates has been shown to be MSA hominins. When examining the incidence of cut-marking throughout the skeleton at DK1, it is therefore assumed that the locations of the marks are the result of conscious decisions by the MSA butchers to process a *complete* carcass in a particular way. Figure 71 shows the distribution of cut marks throughout the ungulate skeleton, with locations of those with unambiguous behavioral correlates as determined by Nilssen (2000) indicated in the key.

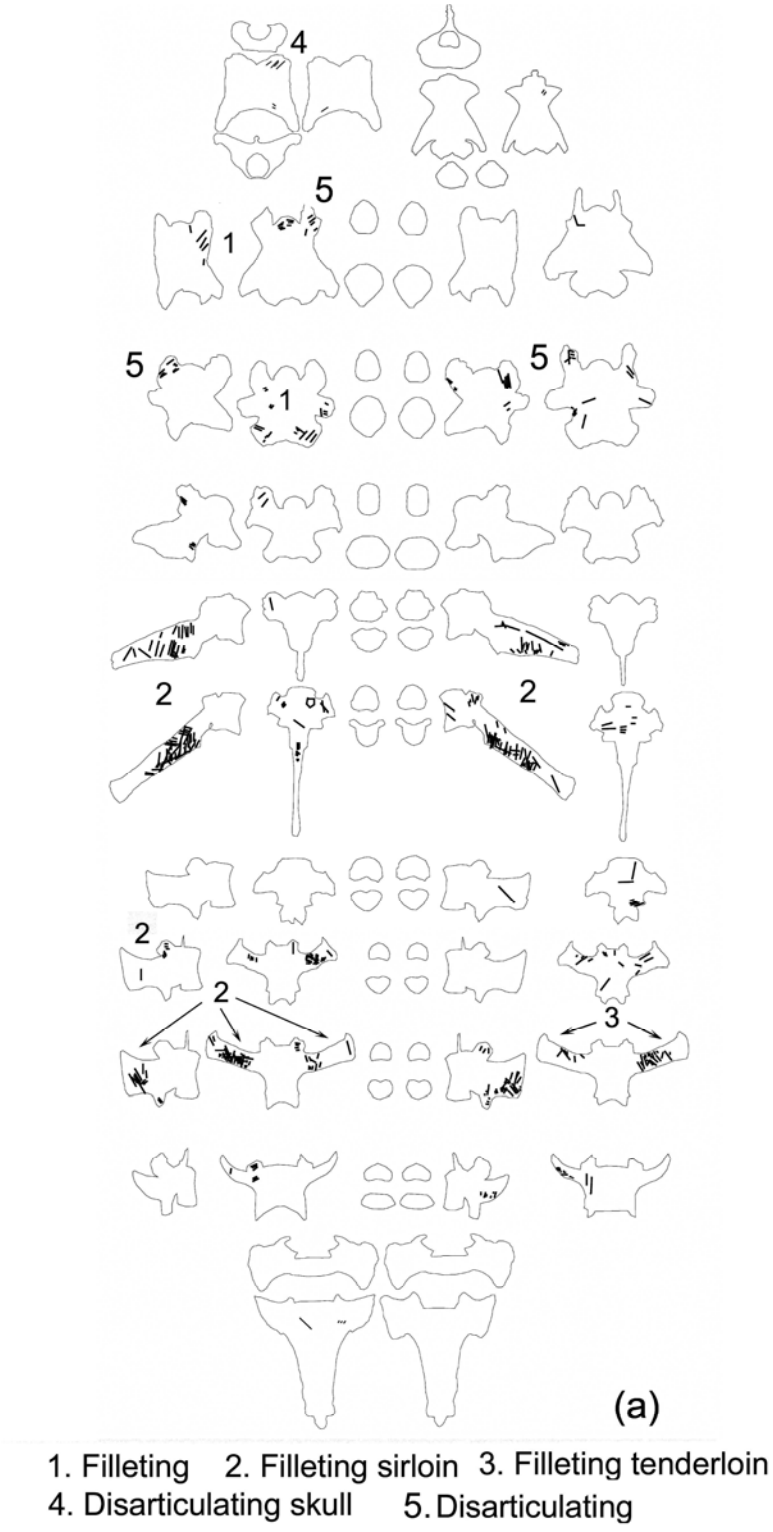


Fig. 71 Locations of cut marks on vertebrae from DK1.

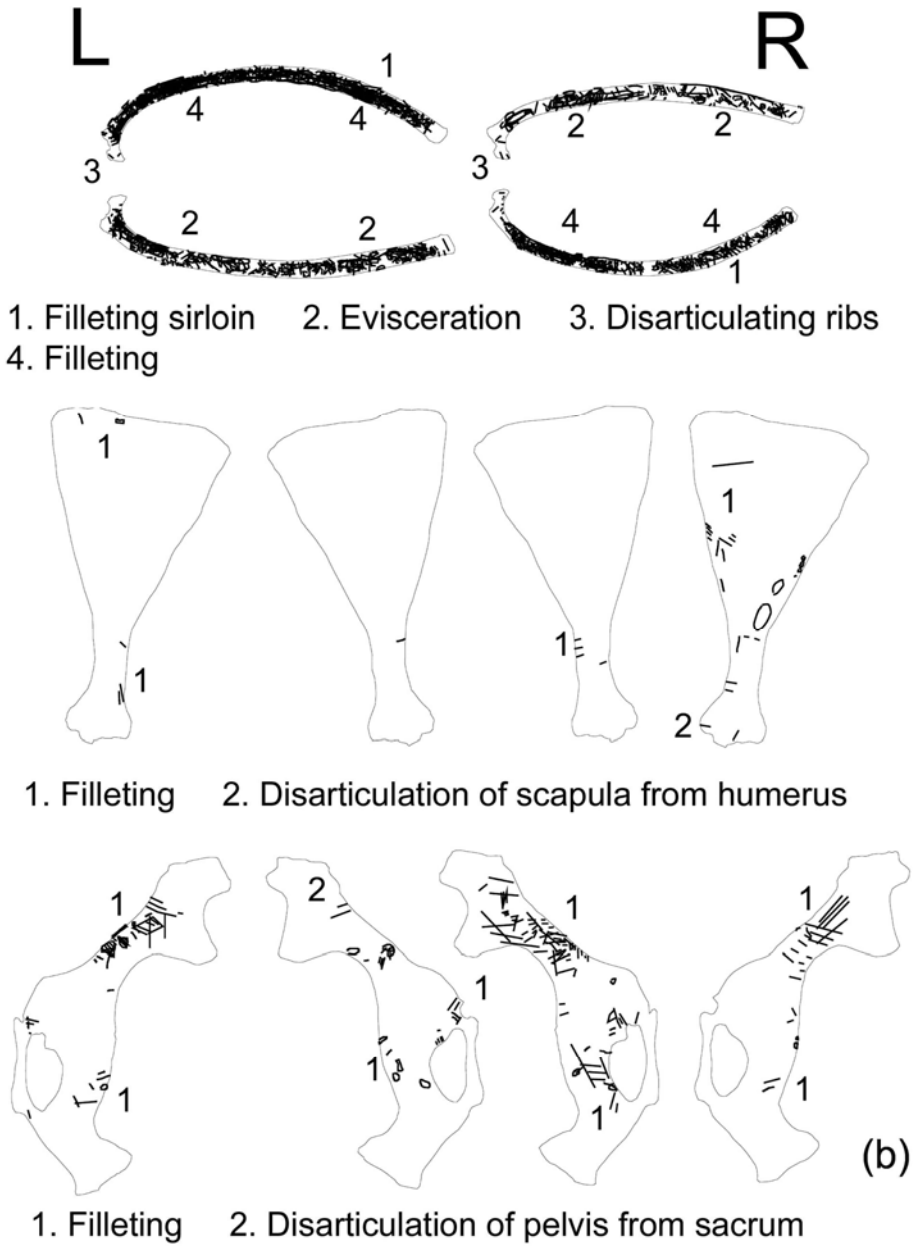


Fig. 71 (cont.) Locations of cut marks on non-long bones from DK1.

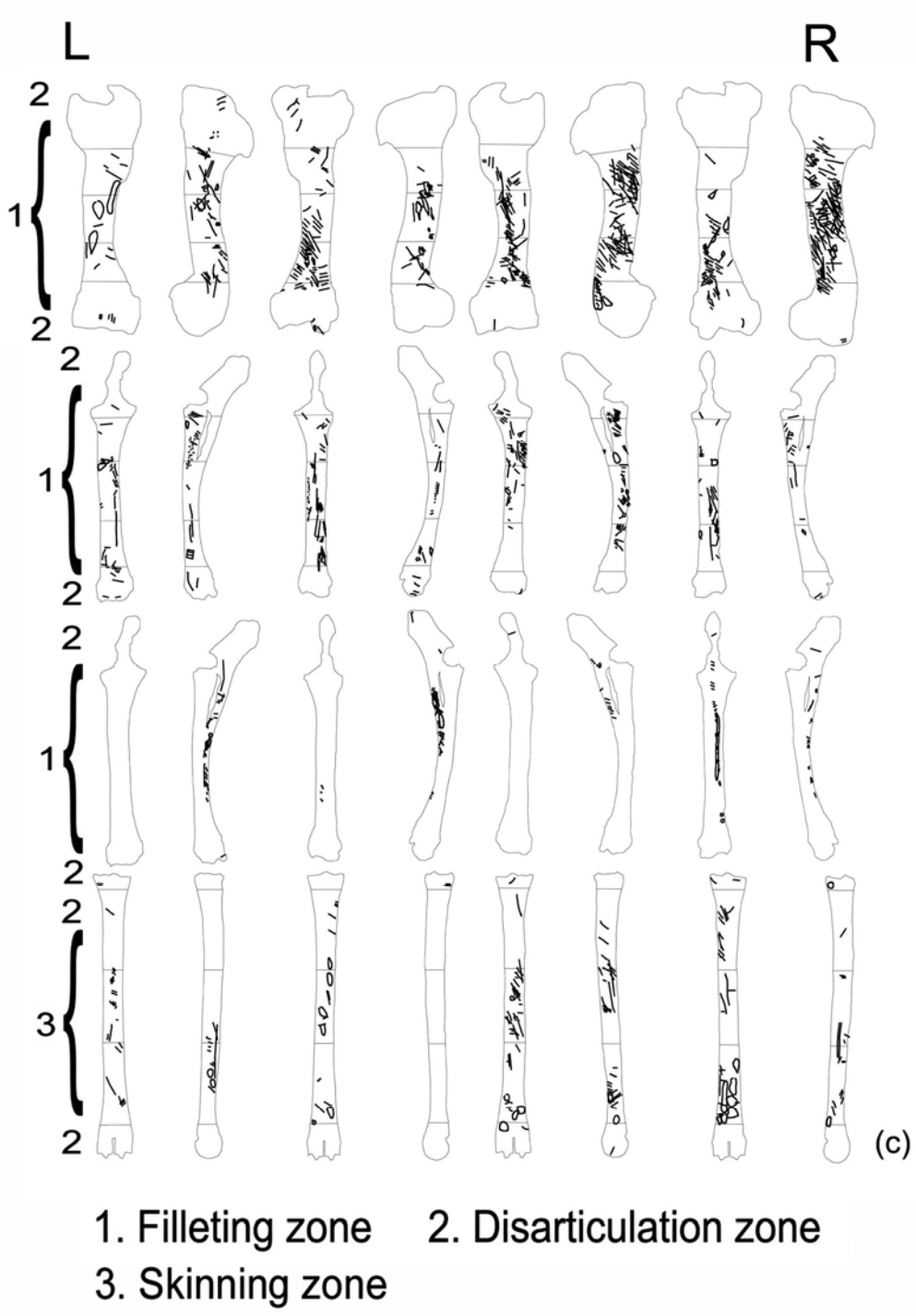


Fig. 71 (cont.) Locations of cut marks on forelimbs from DK1.

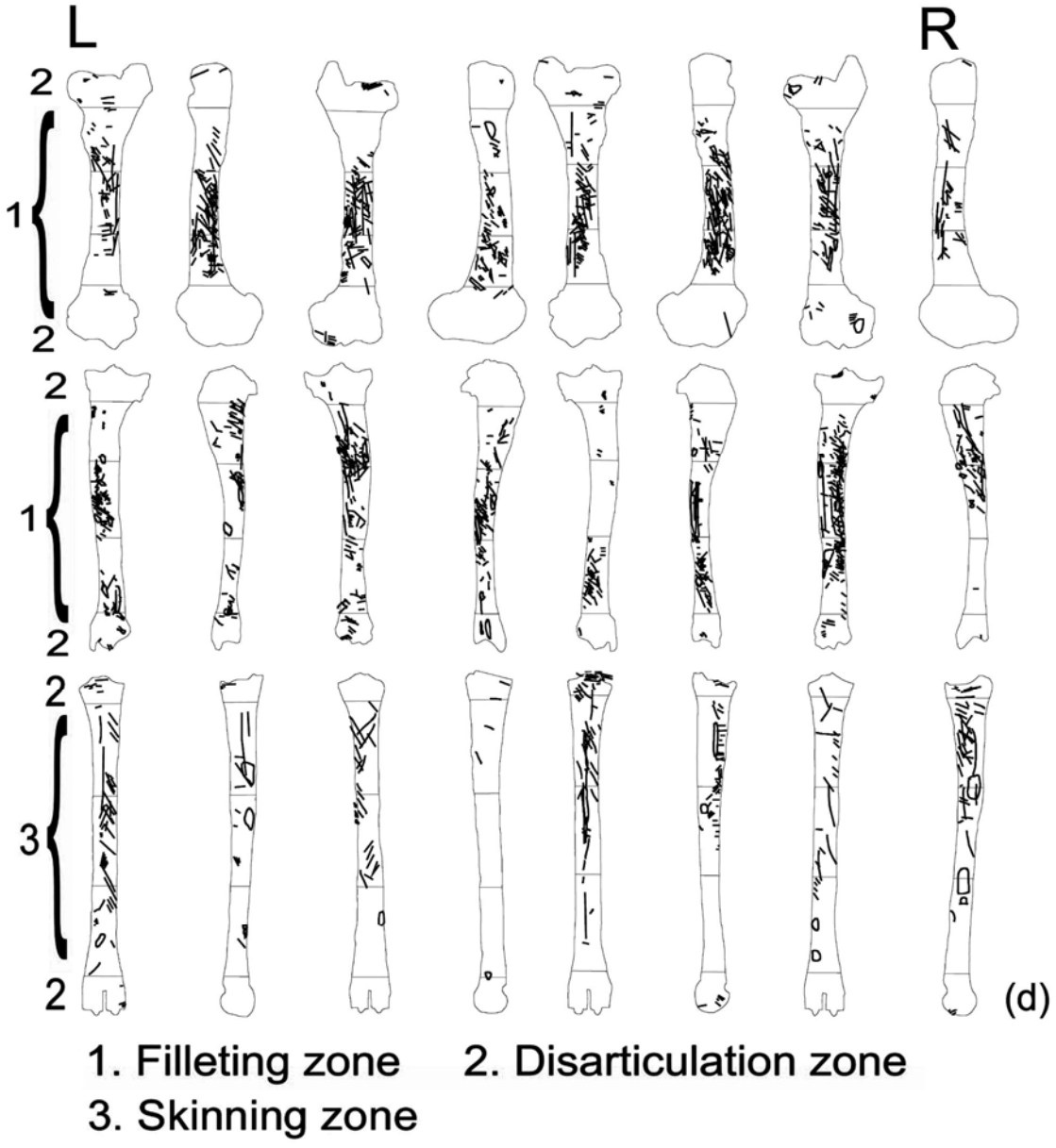


Fig. 71 (cont.) Locations of cut marks on hindlimbs from DK1.

A variety of actions are implicated by the positions of the cut marks, including evisceration, skinning, disarticulation, and filleting of various cuts of meat. A general sequence observed in modern humans can be reasonably applied to these actions (e.g.

Binford, 1978; Nilssen, 2000). First, the skin would have been initially opened along the ventral midline of the prey, resulting in the evisceration marks seen on the ribs. At some point that was likely early in the sequence the skin was removed at the metapodials (cranial elements were not examined for the purposes of this study). The major muscle groups of the back and limbs were removed, and the vertebrae were sometimes disarticulated. The head was also removed at some point in the process, although because these are composite images and the sample of disarticulation marks on the axis and atlas are rare it is difficult to establish any patterning in this behavior.

Most marks on long bones are predominately located along the shaft, but cut marks on the epiphyseal ends and on the pelvis and scapula provide evidence that disarticulation was also a potential element of the strategy. However, the general sequence and the degree to which disarticulation is emphasized can only be qualitatively evaluated using the cut mark maps alone. Using the more quantitative approach of Abe *et al.* (2002), the distribution of cut marks across long bone portions can be examined relative to that found in two ethnoarchaeologically-documented scenarios (Nilssen, 2000).

Abe *et al.* (2002) showed that a disarticulation-to-filleting strategy should result in a greater relative proportion of cut marks on long bone epiphyses than would a filleting-only strategy, and that the overall distribution of marks across these zones can be diagnostic of the primary butchery strategy under which the marks were created. Because DK1 has undergone a relatively high degree of density-mediated destruction, a

further adjustment to accommodate the differential preservation of long bone portions (and the mark they bear) has been made.

These adjusted values, scaled to 100% of the total marks on the bone, are shown in comparison to the two ethnoarchaeologically-documented strategies in Figure 72. All data from DK1 are presented as a sum of all layers because the available dates indicate that the deposits do not represent a span of time that is greater than any divisions used for PP13B or Blombos. The data are divided by body size class because of the strong evidence from DK1 that size 1 ungulates from some layers were not mainly accumulated by hominins. Also, the larger combined sample from DK1 makes it feasible to divide the data in this manner.

Adjusted proportions of where cut marks occur on the major long bones are provided in Appendix G. Because all percentages for each element add to a total of 100%, at least some area had to be represented in each zone in order for them to be calculated. Elements for which all zones were not present at least to some extent are therefore represented with a '-', whereas elements portions on which no cut marks occur, despite at least some representation of that portion, are indicated with a 0%. Raw numbers of marks per portion are provided in Appendix F.

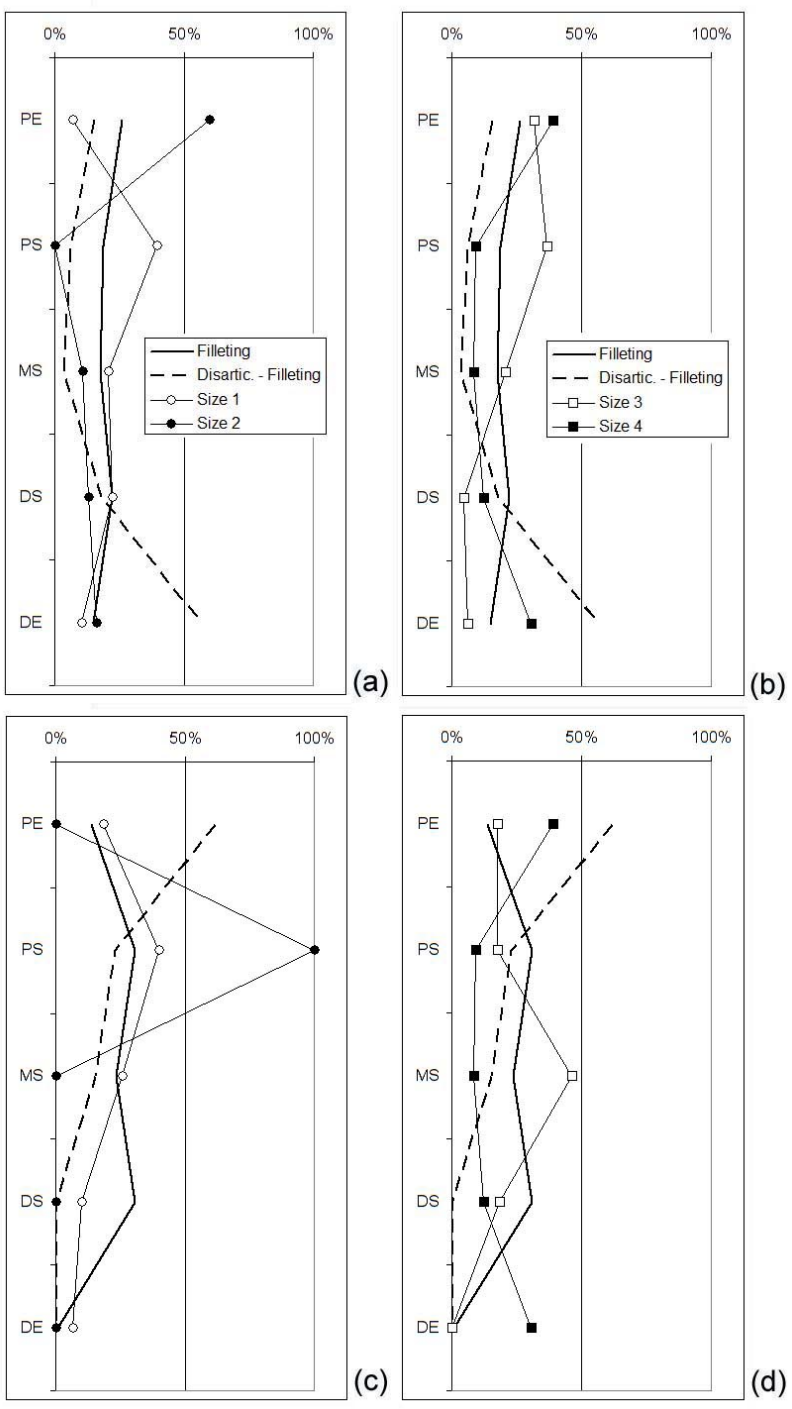


Fig. 72 The distribution of cut marks across long bone zones for the humerus (a, b) and radius (c, d). PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

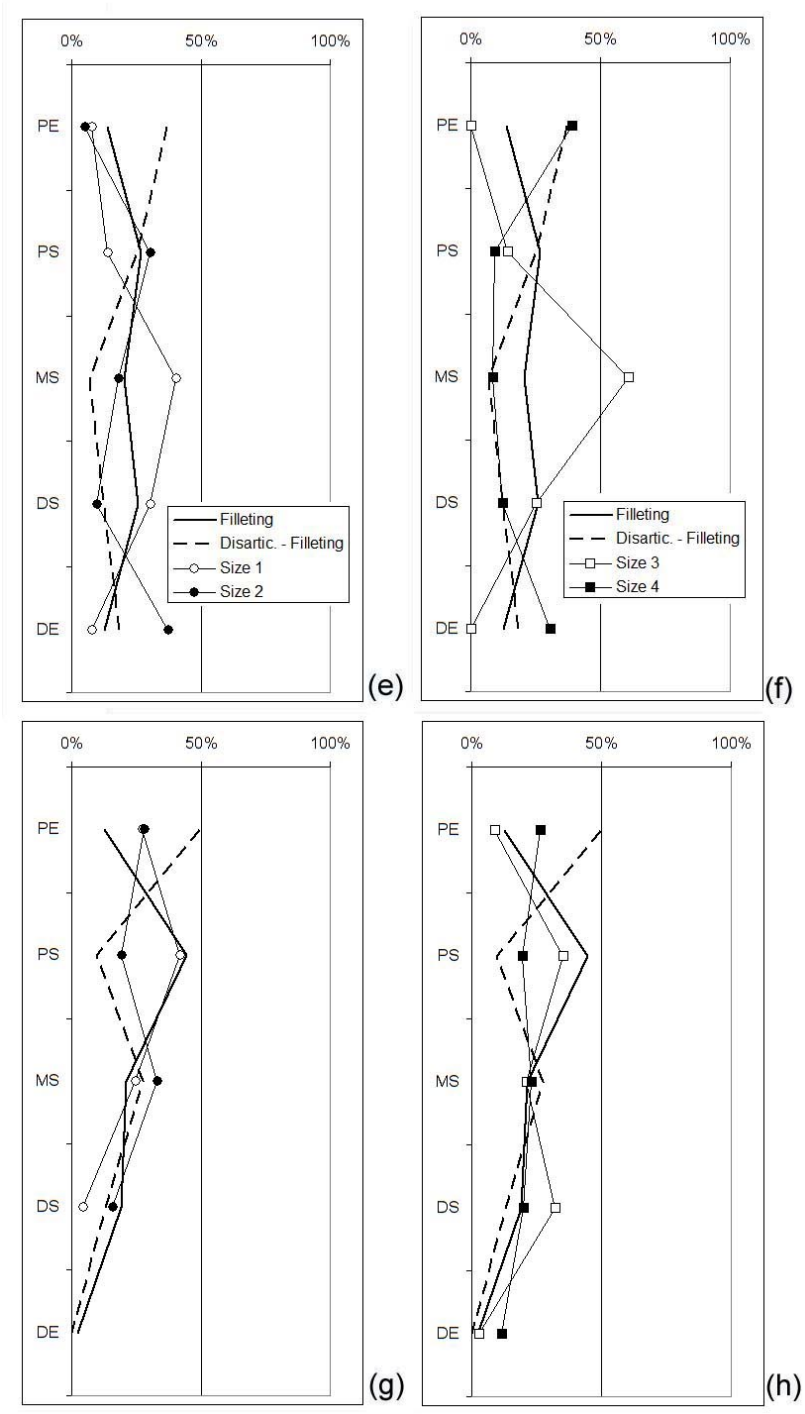


Fig. 72 (cont.) The distribution of cut marks across long bone zones for the femur (e, f) and tibia (g, h). PE = proximal end; PS = proximal shaft; MS = midshaft; DS = distal shaft; DE = distal end.

Despite the finding from Layers 10 and 11 that the majority of the size 1 unguates were accumulated by raptors (Marean *et al.*, 2000b), the fact that cut marks occur on size 1 ungulates indicates that MSA hominins at some point during the occupation of DK1 did acquire these small ungulates and were faced with decisions about how to process them. Cut marks on this body size are weighted toward the proximal shaft, with the exception of the femur where they tend to cluster instead on the midshaft. Size 2 ungulates have relatively more cut marks on the proximal end, again with the exception of the femur. In the case of the size 2 fauna, the femur has relatively more cut marks on the distal portion. When taken together with the preponderance of such marks on the proximal tibia suggests that disarticulation of the joint between these two bones was relatively more common for size 2 ungulates.

Size 3 ungulates consistently show a concentration of marks along the midshaft at the expense of marks on the ends, which suggests that disarticulation was not common for this body size. In contrast, size 4 ungulates show a pattern of a more even distribution across all five zones. They furthermore resemble the ethnoarchaeological scenario in which disarticulation preceded filleting. This suggests that a combination of disarticulation and filleting characterized the treatment of the largest body size commonly represented at DK1, but that this pattern may not be as clear when size 3 and 4 ungulates are combined, as in Abe *et al.* (2002). These patterns can be examined statistically by the application of a chi-squared test comparing the distribution of marks across long bone

zones between the ethnoarchaeological and the archaeological assemblages. The results are provided in Table 26.

Table 26

P-values from chi-squared tests determining if the difference is significant between the distribution of cut marks across each major long bone at DK1 and what would be expected for a filleting or a disarticulation and then filleting butchery strategy.

		Filleting			Disartic. - Fillet.		
		X^2	D. F.	p-value	X^2	D.F.	p-value
Size 1	Humerus	4.874	5	0.4315	16.751	5	0.0050
	Radius	2.260	5	0.8122	3.949	5	0.5568
	Femur	3.907	5	0.5628	20.383	5	0.0011
	Tibia	2.591	5	0.7628	9.995	5	0.0754
	All	24.961	20	0.2029	58.399	20	< 0.0001
Size 2	Humerus	8.811	5	0.1169	14.117	5	0.0149
	Radius	12.845	5	0.0249	12.330	3	0.0063
	Femur	7.087	5	0.2143	11.144	5	0.0486
	Tibia	2.991	5	0.7014	18.311	5	0.0028
	All	55.168	20	< 0.0001	66.669	18	< 0.0001
Size 3	Humerus	7.384	5	0.1936	26.576	5	< 0.0001
	Radius	3.416	5	0.6362	6.346	4	0.1748
	Femur	23.274	5	0.0003	53.201	5	< 0.0001
	Tibia	1.086	5	0.9553	12.038	5	0.0343
	All	49.167	20	0.0003	106.060	19	< 0.0001
Size 4	Humerus	10.911	5	0.0532	10.294	5	0.0673
	Radius	9.260	5	0.0991	2.273	5	0.8102
	Femur	15.323	5	0.0091	37.291	5	< 0.0001
	Tibia	3.715	5	0.5911	5.758	5	0.3305
	All	55.533	20	< 0.0001	94.931	20	< 0.0001

On an element-by-element basis the most of the DK1 data show significant differences from the disarticulation-then-filleting (D-F) strategy. This result differs slightly from that reported by Abe *et al.* (2002), in which a D-F strategy was determined

for the forelimbs, and a filleting only (F-O) strategy was determined for the hindlimbs. When all limb elements are pooled together, all body sizes show a significantly different distribution from both strategies, with the exception of the size 1 ungulates. Here, the cut marks occur along all long bone shafts in a manner that is statistically indistinguishable from how they occur in a filleting-only strategy. This is also the case for three of the four elements examined for the size 3 body size class.

Overall, however, the statistical results support what was observed in the visual patterning: very few of the data from DK1 seem to mimic either ethnoarchaeologically-documented strategy. Although both presentations of the DK1 data show a definite emphasis on filleting and meat removal, no precise analogue seems to be currently available for the behavior recorded in the zooarchaeological record. The relatively small number of disarticulation marks overall is somewhat unexpected, given that the skeletal element transport data indicated that both small and large ungulates were subject to selective transport with regards to food utility and should therefore require some disarticulation in the field. The lack of correspondence to the ethnoarchaeological data suggest the more appropriate comparisons might be made to other zooarchaeological datasets for which corrections for preserved surface area have been made. This possibility is explored further in Chapter Seven.

CHAPTER SEVEN: COMPARISONS BETWEEN THE FAUNAL ASSEMBLAGES FROM PP13B, BLOMBOS, AND DK1

Site configuration and paleoenvironmental context

When making comparisons between the three sites presented here, it is important to do so in light of the context of each site and major stratigraphic division (refer to Chapter Three). Table 27 gives a summary of the major differences found between the sites, arranged in chronological order from older on the left to younger on the right.

Table 27

Summary of the major physical, environmental, and artifactual differences in context between the three study sites.

	PP13B MIS 6	PP13B MIS 5	BBC M3	BBC M2	BBC M1	DK1
Approx. age	178 - 130	130 - 92	104 - 93	90 - 74	76 - 70	70 - 60
Warm/cold	Cold	Warm/cool	Warm	Warm	Cold	Cool
Km to shore	~100 - 5	~20 - 0	Within 9	Within 9	~30	4 - 9
Accessibility	Very	Very except during 5e	Somewhat	Somewhat	Somewhat	Very
Opening	Large	Large	Moderate	Small	Small	Large
Notable lithics	Bladelets	Not reported	None	None	Still Bay	None
Ochre	Present	Present	Present	Abundant	Abundant	Present
Bone tools	None	Likely 1	None	Present	Abundant	None
Other	None	Not reported	None	None	Shell beads	None

The dates from Blombos indicate an early occupation around 100 ka, followed by a hiatus around 84 ka, and subsequent occupation until the cave was sealed around 70 ka (Jacobs *et al.*, 2003a, b, 2006). Thus, the period of time over which the fossils accumulated was potentially much shorter than that documented at PP13B (Marean *et al.*, 2004, 2007) and longer than that documented at DK1. This potentially indicates that patterns in skeletal element transport, cut marks, and percussion marks at DK1 will be less subject to the problems of time-averaging that have been consistently implicated over the development of this study. However, the spans of time that are contained within each sample are still sufficient for several thousand years to have passed undetected with no hominin occupation, and no *a priori* assumptions about the number of hunting, butchering, or transport events per unit of time at each site can necessarily be made.

In spite of this, some general observations about the timing of the occupations at each site and what this might imply for the faunal assemblages can be made. First, there appears to be a tendency for all three sites to have been occupied during periods of climatic amelioration. PP13B has an occupation during MIS 6, which was a very cold period globally. However, it has been arugued to have been less severe along the southwestern coast of South Africa, in the area roughly defined by the distribution of the modern fynbos (Marean *et al*., 2008). Moreover, the exploitation of marine resources is documented at PP13B during MIS 6 (Marean *et al.*, 2007), indicating that the site was occupied during somewhat warmer respites in this relatively harsh climatic period.

There is a similar pattern documented at DK1, where in spite of having an occupation that dates to a relatively cold and potentially arid period of time during MIS 4,

marine resource exploitation is apparent, albeit at very low levels, thoughout the sequence. At Blombos the first occupation in M3 begins during the warm phase of MIS 5c, witnesses a hiatus during the climatic deterioration of MIS 5b, and resumes with M2 during MIS 5a. Occupation by hominins then continues into MIS 4, at which point Blombos Cave was sealed from hominin occupants in much the same manner as did PP13B nearly 22 thousand years earlier.

A second general pattern that appears is one of the relationships between site context, potential resource stress, and the artifactual assemblages that are recovered from each site. As discussed in Chapter Three, Blombos stands out from the other two sites in terms of its relative abundance of ochre, engravings, bone tools, and evidence of personal ornamentation. However, finds from other sites in South Africa such as the engraved ostrich eggshell from Diepkloof (Poggenpoel et al, 2005), the bone tools from Sibudu (Backwell *et al.*, 2008), the engraved ochre from Klein Kliphuis (Mackay and Welz, 2008) and even the abundance of ochre recovered from Hollow Rock Shelter (Evans, 1994) show that evidence of symbolic behavior and complex manufacture of tools on non-lithic materials was not restricted to Blombos.

One commonality that all of these places have is their relative seclusion in comparison to sites such as PP13B and DK1. This suggests that socially-driven factors may have played a role in the selection of such sites for occupation during the MSA. Even so, within the sample of sites studied here there is evidence that patterns in the timing of occupation coincide with shifts in climatically-driven availability of key resources. Given the importance of animal products in the modern human diet (Speth

and Spielman, 1993; Langdon, 2006), it is likely that faunal resources were one of these. Identifying faunal exploitation strategies at PP13B, Blombos, and DK1 may reveal another major variable that drove the decision to select these sites for occupation out of a landscape of potential places to inhabit.

Furthermore, the linking element behind both variables in site selection appears to be climate. Even at sites such as PP13B that do not have unique evidence of symbolic behavior there is rubbed ochre and evidence of a major technological innovation in the form of bladelets (Marean *et al.*, 2007). This evidence is precocious in comparison to previously-reported sites, and it occurs during MIS 6 when fluctuations in global temperature, distance to the shoreline, and related factors of resource availability would have been extreme.

Notably, the levels at Blombos all contain ochre and/or bone tools in varying proportions, and it is not until the first documented cold-period occupation at the site that the shell beads, Still Bay points, and engraved pieces make an appearance. It is within this general pattern of site occupation during relatively mild climatic periods accompanied by behavioral change during periods of increased climatic stress that the faunal assemblages from PP13B, Blombos, and DK1 have likely been deposited. Furthermore, it is within this framework that a summary of comparisons between the three sites will be conducted below.

Taxonomic representation

General patterns in taxonomic representation between sites are summarized in Table 28. Primate and large carnivore representation is very low at all three study sites,

although small carnivores are present in some abundance at Blombos (Henshilwood *et al.*, 2001b) and DK1 (Klein and Cruz-Uribe, 2000). Small mammals and tortoises are very abundant at Blombos and DK1 (Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b, pers. observation). At PP13B small mammals are extremely poorly represented, and tortoise abundances are also relatively low. However, the tortoises from PP13B show much more species diversity than that reported from either Blombos or DK1 (Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b).

Marine mammal representation is low at all three sites and though there is some variability between stratigraphic units and it is in the direction one would expect given distance to the shore at the time, none of these differences is significant. This suggests that the time periods encompassed by the sites, including those designated as 'cold' periods, included several fluctuations in distance to the sea that were sufficient to offer foraging opportunities there from time to time. This further indicates that the deposits were accumulated over periods of climatic change that may appear subtle in the paleoenvironmental record but must have been relatively dramatic to the MSA inhabitants of the sites. In many ways this can explain seeming anomalies in the species identifications, which for Blombos and DK1 often show general trends but occasional representation of animals with very different ecological preferences (Klein and Cruz-Uribe, 2000; Henshilwood *et al.*, 2001b).

Of the larger mammals, ungulates (especially bovids) dominate all the faunal assemblages, but there are differences between sites and between major stratigraphic units. At PP13B overall these ungulates are divided nearly evenly between size classes 1

– 3. When broken down into the chronological and spatial groupings, small fauna (size 1 and 2) are found to be more abundant during MIS 5 and at the front of the cave during both time periods. This is particularly true for size class 1 ungulates.

Table 28

Summary comparison of general patterns in taxonomic representation between sites.

	PP13B MIS 6	PP13B MIS 5	BBC M3	BBC M2	BBC M1	DK1
Marine mammals	Rare	Rare	Rare	Rare	Rare	Rare
Large carnivores	Rare	Rare	Rare	Rare	Rare	Rare
Small mammals	Rare	Rare	Abundant	Abundant	Abundant	Abundant
Tortoises	Rare	Rare	Abundant	Abundant	Abundant	Abundant
Most common body size	Size 1 - 3	Size 1 - 3 (relatively more size 1)	Size 1	Size 1	Size 1-3	Size 1 - 4

At Blombos, size 1 ungulates comprise the majority of the larger mammal faunal assemblage in M2 and M3, with the highest proportion in M2. The situation changes in M1, when size 2 ungulate representation is increased at the expense of the size 1 component. This pattern could be explicable in either environmental or behavioral terms, but when looking at other sites there is a pattern of increased size 1 representation during periods when climates were generally warmer. M1 saw the introduction of a colder climatic period that would certainly have influenced both local environments and hominin behavior to some extent. A reverse pattern, but one that was potentially also climate-related, occurred at PP13B. Here, the shift to a higher representation of small

fauna coincides with a general climatic change from MIS 6 to MIS 5, when climatic conditions improved.

Density-mediated destruction

As is typical at most archaeological sites, there has been a substantial degree of density-mediated destruction at all three sites. This has resulted in a high representation of long bone midshafts relative to epiphyseal ends and spongy elements. The correlation between long bone portion representation and density as measured by CT was found to be positive and significant for nearly all body size classes and all major stratigraphic horizons at PP13B, Blombos, and DK1. Because this relationship was quantified using the same variables, these correlations can be compared to one another between sites to provide a relative degree of density-mediated destruction that has occurred (Figure 73).

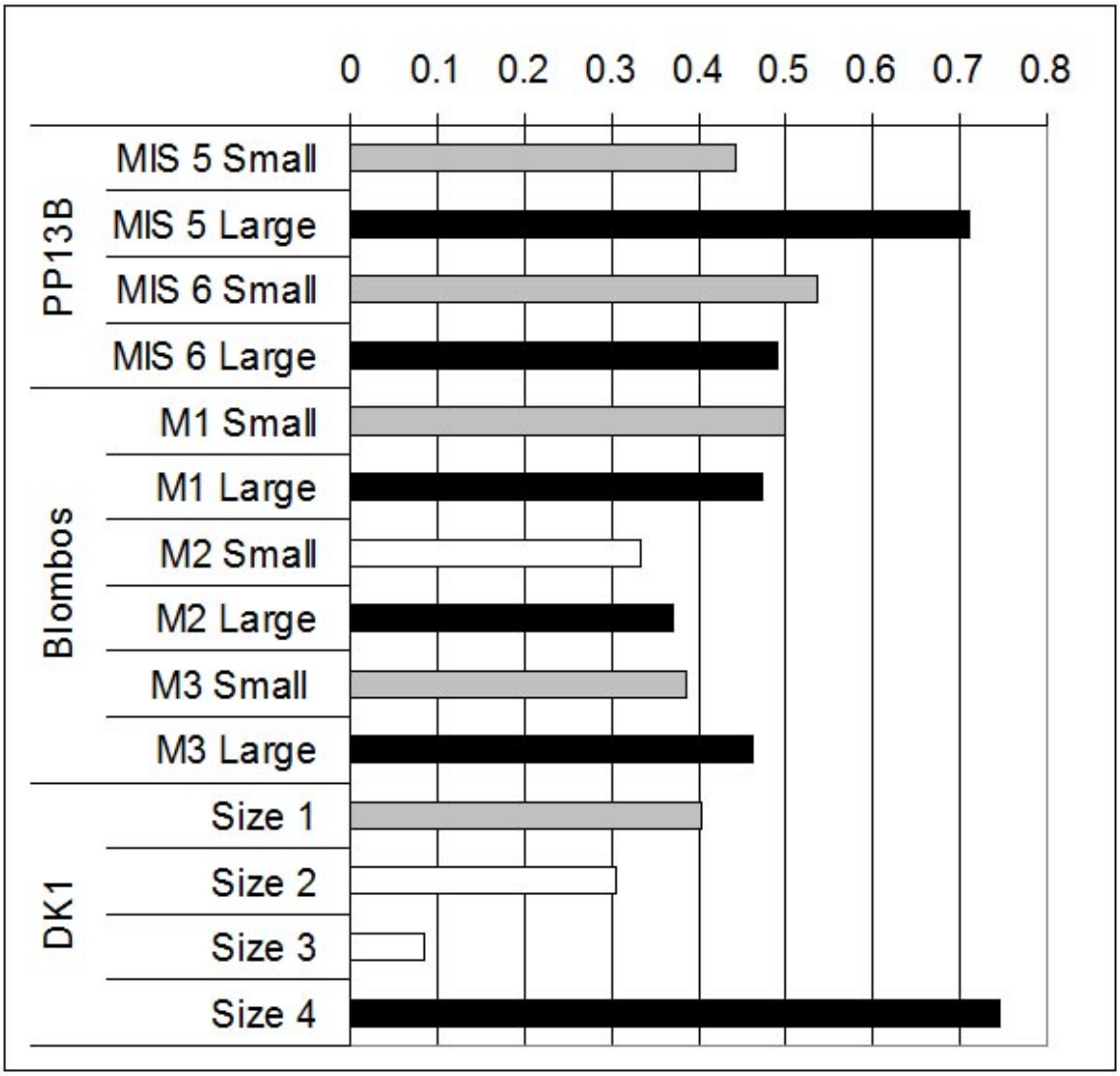


Fig. 73 Values of Spearman's Rho correlations between bone portion representation and bone density. Small fauna (size 1 and 2) = gray bars, large fauna (size 3, 4 and 5) = black bars, correlation not significant where $\alpha < 0.05$ = white bars.

Following Marean *et al.* (2000b), many analyses presented here have divided the datasets into small ungulates (size 1 and 2) and large ungulates (size 3 and 4, and at PP13B and Blombos, also 5). This serves to boost sample sizes, eases presentation and analysis, and when examined in terms of what is known ethnographically about human

butchery and transport strategies it appears that these divisions are often appropriate (Monahan, 1998; Marean and Cleghorn, 2003). However, the results from DK1 suggest that this method of aggregation may tend to average out some of the differential effects of density-mediated destruction on various ungulate size classes.

This is not problematic for analyses such as the locations of cut mark and percussion marks, because in these cases appropriate adjustments have been made to accommodate for this (Abe *et al.*, 2002). It will also not be an issue for examination of fragmentation patterns (which rely on dense shaft and near-epiphyseal shaft portions) or for examination of relative proportions of percussion and tooth marks (which rely on midshafts only). However, at sites such as PP13B and Blombos, where two major potential agents of such destruction have been shown to be operative (carnivore ravaging and human fragmentation of epiphyseal portions), informative patterns that could reveal the individual *processes* behind the overall density-mediated destruction may be blurred by this procedure. It is worth noting that the DK1 dataset differs from the other two sites in that it is a large sample that appears to have been collected quite rapidly and therefore did not require extensive sub-dividing by stratigraphic horizon. At PP13B and Blombos this division was critical, and so aggregates of 'small' and 'large' fauna were often necessary to achieve sufficient sample sizes at risk of sacrificing clarity in other patterns.

If the value of the correlation statistic represents relative degrees of density-mediated destruction, then the general pattern across sites is for larger fauna from the same levels to have been subject to equal or greater degrees of such destruction than was smaller fauna. Bartam (1993) and Bartram and Marean (1999) noted that in fresh

assemblages where both small and large ungulates are present, carnivores will selectively choose to consume epiphyseal portions of larger ungulates first. Thus, greater degrees of density-mediated destruction should occur in larger ungulates for assemblages where both size categories were represented simultaneously. It was argued in Chapter Six that the significant correlations seen in the smallest and largest ungulates occur because these were generally introduced into the site at different times relative to one another – perhaps with raptors bringing in the smallest ungulates and hominins transporting the larger ungulates in alternation.

Overall, when all three sites are compared to one another it becomes apparent that this pattern is much less exaggerated at DK1 than it is at the other two sites. At both Blombos and PP13B the degree of density-mediated destruction on small and large ungulates is relatively similar, except in MIS 5 at PP13B where the pattern is more similar to DK1. This observation highlights the importance of having datasets that are comparable to one another: in isolation DK1 appeared to show one pattern, but when placed into the context of other penecontemporaneous sites the picture looks quite different. Possible reasons for this cross-site patterning are examined in more detail when surface modification and within-bone nutrient extraction strategies are discussed.

Agent of accumulation

Several lines of evidence indicate that MSA hominins were the main accumulator of the size 2 – 4 body size classes at PP13B, Blombos, and DK1. The sample of size 5 fauna from PP13B and Blombos is too small to be informative. At all three sites size 1 fauna had some hominin input, but was also modified to varying degrees by other agents

such as raptors and carnivores. At DK1 Marean *et al.* (2000b) determined that raptors were a major accumulator of this body size class. At PP13B raptors are not implicated, but a relatively substantial independent carnivore input was seen in the co-occurance of tooth and percussion marks on the same midshaft fragement during MIS 6 only. During MIS 5 the proportion of size 1 ungulates increases and with it increases the evidence of hominin exploitation.

At Blombos the size 1 fauna shows approximately equal proportions of percussion marks on midshafts in all three major stratigraphic horizons. However, the difference between these proportions on size 1 fauna and on larger fauna is much greater in M2 and M3. These two layers are the ones with the highest proportion of size 1 ungulates, suggesting that a larger degree of non-hominin input occurred in the lower two layers, and this this was predominately on the smallest ungulates. Raptors are not implicated to a great degree in this input, but the relatively higher co-occurance of tooth and percussion marks on the same midshaft fragments of size 1 fauna does provide evidence that carnivores were involved.

A pattern of increasing proportions of percussion marks with increasing ungulate body size was observed at both PP13B and at Blombos. When these differences are compared between sites, the overall pattern at Blombos remains much closer to that observed at PP13B than that at DK1. Also, proportions of percussion-marked midshafts are invariably higher at Blombos than at DK1, as was the case at PP13B. However, unlike at PP13B where tooth mark proportions were comparable to DK1, these are also almost always higher at Blombos. Fisher's Exact Test was used to make statistical

comparisons between these sites. The 88 two-by-two tables that formed the basis of this analysis are not given in Appendix J with the other tables, but all raw data are available in Tables 6 and 17, and in Marean *et al.* (2000:215). Arrows indicate the direction of the difference of Site/Layer 2 relative to Site/Layer 1 with percussion marks on the left and tooth marks on the right. P-values less than $\alpha = 0.05$ are indicated in gray (Table 29).

Table 29

P-values for Fisher's Exact Test comparisons of proportions of percussion- and tooth-marked midshaft fragments between the study sites.

			PM	TM
Site/Layer 1	Site/Layer 2	Size	p-value	p-value
DK1	BBC M1 ▲▲	1	0.0318	0.0784
DK1	BBC M2 ▲▲	1	0.0015	0.6090
DK1	BBC M3 ▲▲	1	0.0689	0.7553
DK1	BBC M1 ▲▲	2	< 0.0001	0.7263
DK1	BBC M2 ▲▲	2	0.0002	0.0011
DK1	BBC M3 ▲▲	2	< 0.0001	0.3286
DK1	BBC M1 ▲▲	3	< 0.0001	0.1015
DK1	BBC M2 ▲▲	3	< 0.0001	0.0391
DK1	BBC M3 ▲▼	3	< 0.0001	0.8465
DK1	BBC M1 ▲▲	4	< 0.0001	0.2545
DK1	BBC M2 ▲▲	4	< 0.0001	0.6475
DK1	BBC M3 ▲▲	4	< 0.0001	0.0128
PP13B MIS 5	BBC M1 ▼▲	1	0.3038	0.1204
PP13B MIS 5	BBC M2 ▼▲	1	0.9421	0.8272
PP13B MIS 5	BBC M3 ▼▼	1	0.3583	0.8851
PP13B MIS 5	BBC M1 ▼▼	2	0.5995	0.2868
PP13B MIS 5	BBC M2 ▼▲	2	0.0499	0.0221
PP13B MIS 5	BBC M3 ▲▼	2	0.8934	1.0000
PP13B MIS 5	BBC M1 ▼▲	3	0.0059	0.1880
PP13B MIS 5	BBC M2 ▼▲	3	0.6544	0.0736
PP13B MIS 5	BBC M3 ▲▼	3	0.1991	0.5257
PP13B MIS 5	BBC M1 ▲▲	4	0.3155	1.0000
PP13B MIS 5	BBC M2 ▲▼	4	0.0142	1.0000
PP13B MIS 5	BBC M3 ▲▲	4	0.2051	0.0769
PP13B MIS 6	BBC M1 ▲▲	1	0.0245	0.0362
PP13B MIS 6	BBC M2 ▲▲	1	0.0001	0.3850
PP13B MIS 6	BBC M3 ▲▲	1	0.0605	0.6400
PP13B MIS 6	BBC M1 ▲▲	2	0.1646	0.6276
PP13B MIS 6	BBC M2 ▼▲	2	0.7167	0.0003
PP13B MIS 6	BBC M3 ▲▲	2	0.1285	0.3343
PP13B MIS 6	BBC M1 ▼▲	3	0.7647	0.1637
PP13B MIS 6	BBC M2 ▲▲	3	0.1550	0.0658
PP13B MIS 6	BBC M3 ▲▼	3	0.0032	0.6491
PP13B MIS 6	BBC M1 ▲▲	4	0.2379	0.8135
PP13B MIS 6	BBC M2 ▲▼	4	0.0193	0.6851

Table 29 (cont.)

Site/Layer 1	Site/Layer 2	Size	PM p-value	TM p-value
PP13B MIS 6	BBC M3 ▲▲	4	0.1785	0.0804
PP13B MIS 5	DK1 ▼▼	1	0.0022	0.7797
PP13B MIS 6	DK1 ▼▲	1	0.9142	0.8754
PP13B MIS 5	DK1 ▼▼	2	<0.0001	0.0933
PP13B MIS 6	DK1 ▼▲	2	<0.0001	0.9532
PP13B MIS 5	DK1 ▼▼	3	<0.0001	0.5311
PP13B MIS 6	DK1 ▼▼	3	<0.0001	0.6070
PP13B MIS 5	DK1 ▼▼	4	<0.0001	0.3813
PP13B MIS 6	DK1 ▼▲	4	<0.0001	0.4245

At DK1 size 1 ungulates were not primarily accumulated by hominins (Marean *et al.*, 2000b). We would therefore expect that if the size 1 fauna at the other two sites also had a greater non-hominin input (as indicated by several independent lines of evidence), then proportions of percussion-marked midshafts should not be significantly higher than they are at DK1. This is upheld statistically: between DK1 and Blombos, and between DK and PP13B this difference only fails to be significant in the size 1 class. Also in support of this, the proportions of percussion-marked midshafts on size 1 fauna at DK1 is most similar to M3 at Blombos and MIS 6 at PP13B – both stratigraphic divisions that have been shown by independent means to have had the highest non-hominin input.

Despite their abundance at Blombos, size 1 ungulates were not the main prey focus for hominins. This is in contrast to the situation at PP13B where as relative abundances of size 1 fauna increase, so too does evidence for hominin involvement with this category. The early part of the Blombos occupation seems most similar to the MIS 6 deposits at PP13B in that hominins did not put much effort into the capture of less abundant and elusive small antelope but where the sites still received moderate quantities

of these as a combination of both hominin and carnivore efforts. In MIS 5 at PP13B, which overlaps in time only with the M3 deposits at Blombos, hominins seemed to have begun to exploit these small ungulates deliberately and more frequently. Despite being very close in time and despite likely having similar surrounding environments during this time, hominins at PP13B were treating size 1 ungulates differently than were hominins at Blombos.

With only a few exceptions, proportions of tooth-marked midshafts are not found to be significantly different between any of the sites or analytical units under consideration here. Similarly, the overall occurrences of midshaft fragments bearing both a percussion and tooth mark are comparable to published data from DK1. Despite these similarities, the consistently higher proportions of percussion-marked midshafts at PP13B and Blombos relative to DK1 demand an explanation. It is possible that this is the result of inter-analyst differences in mark identification, although it is unlikely given that Blumenschine *et al.* (1996) found that students with only slightly more than 3 hours of training were able to accurately diagnose percussion, cut, and tooth marks with near-95% accuracy on the same blind tests taken by myself and by Marean *et al.* (2000b). Also, similar degrees of fragmentation at all sites indicate that extensive post-depositional fragmentation at DK1 cannot be invoked to explain this difference.

At DK1 no adjustments were made for heavily destroyed bone surfaces or surfaces covered in matrix. Marean (pers. comm.., 2008) has indicated that the surfaces were in excellent condition and did not require such adjustments. This is supported by independent comparisons of two mark types between DK1 and PP13B. Because

elimination of heavily-destroyed surfaces at PP13B should boost proportions of *all* types of surface modification, this confirms that adjusted values from PP13B can be reliably compared to published unadjusted values from DK1 and the observed differences are not methodological artifacts. From these lines of evidence a reasonable conclusion is that the MIS 5/6 inhabitants of PP13B and Blombos were using a more intensive marrow processing strategy than later MIS Stage 4 inhabitants at DK1. These ideas are explored in further detail in the section on MSA butchery strategies.

Carcass transport and processing strategies

Two major patterns are consistenly apparent in the MAU data for all three sites: 1) The relative lack of representation by axial elements such as ribs and vertebrae when compared to long bones; and 2) The disproportionately high representation of proximal to distal limb elements (e.g. the low representation of metapodials). Both patterns are also observed at DK1 for Layers 10 and 11 (Marean *et al.*, 2000b). Based on the fact that it is elements in the low-survival group that are missing, Marean *et al.* (2000b) note that at DK1 they are faced with a situation of equifinality: the lack of axial elements as seen in the first pattern could be attributable to the post-discard destruction of less dense fragments or it could be a direct result of hominin transport decisions.

Less dense axial elements – the low-survival set of Marean and Cleghorn (2003) – are unfortunately also the elements with the highest caloric return rate (Metcalfe and Jones, 1988). They are furthermore the elements that require more intensive processing to extract these calories, and are thus ethnoarchaeologically documented to be the elements most frequently transported away from a kill site (Monahan, 1998).

Furthermore, once transported they are elements that are potential candidates for purposeful hominin fragmentation for grease extraction (Church and Lyman, 2003). This presents a problem in which the elements with the highest caloric return will in almost all cases provide the least reliable estimates of skeletal element abundance, despite the fact that optimal foraging theory would predict them to be the most abundant elements at transport sites such as PP13B, DK1, and Blombos.

Marean and Cleghorn (2003) suggest that nutritive differences between metapodials and other long bones may be sufficient and their relative representation may allow for inferences about hominin transport decisions within the high-survival set only. Similarly, Marean *et al.* (2000b) used ethnoarchaeological data from the modern Hadza in East Africa to build an argument that the relative lack of metapodials at DK1 was attributable to these elements being the most frequently field-processed long bones, and are therefore the least likely to be transported away from a kill or butchery site (Monahan 1998). The relative lack of metapodials at DK1 was termed "atypical for South African MSA sites, and cave and rockshelter sites in general" (Marean *et al.*, 2000b: 221).

This is supported by visual examination of the MAU data not only at DK1 but at the other two sites. However, as was seen in the z-scores for all sites there can be substantial variation in the relative representation of metacarpals and metatarsals, and the initial visual pattern may be misleading. It is therefore useful to examine the ratio of proximal: distal limb elements more quantitatively. If complete limbs were transported without bias against distal portions (metapodials), each forelimb should contain one humerus and radius for every metacarpal. Similarly, the hindlimb should contain one femur and one

tibia for every metatarsal. The overall ratio between these bones in a complete-transport strategy should therefore be 2:1, and the proximal limb elements of the humerus, radius, femur, and tibia, should account for 67.6% of the total. MAU values for proximal limb elements were summed separately from distal limb elements for large and small ungulates from each layer from Blombos, the low- and high-occupation layers at DK1, and the grouped analytical units that comprise MIS 5 and MIS 6 at PP13B. These can then be displayed against the expected figure to determine if they truly do appear to be underrepresented (Figure 74).

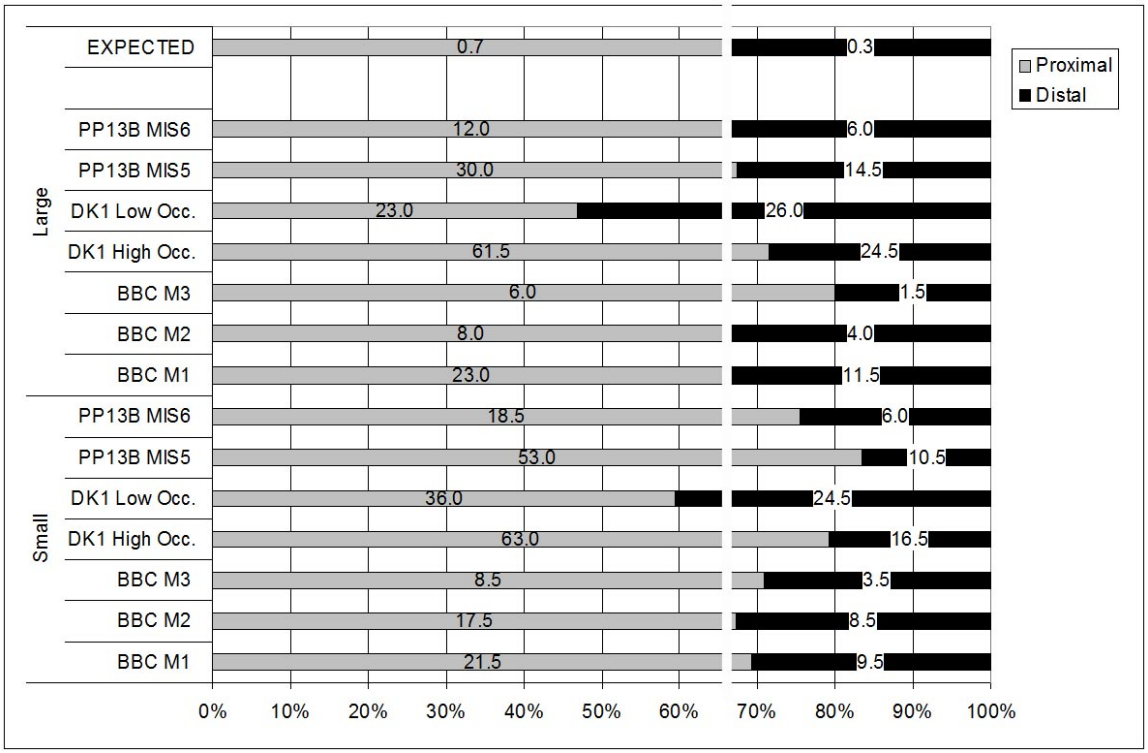


Fig. 74 Ratio of proximal to distal limb elements (by MAU) in each major stratigraphic horizon from each site compared to the expected proportion in a whole-limb transport strategy (top). Metapodial representation is less than expected if it falls to the right of the white bar and more than expected if it falls to the left.

Figure 74 reveals that the pattern observed at DK1 in Layers 10 and 11 is not ubiquitous throughout the site. In fact, metapodial representation in the low--occupation layers at DK1 is higher than expected and more in line with what has been reported from other cave and rockshelter sites. In the high-occupation layers metapodial representation is relatively low, but only falls quite short of what would be expected for small ungulates. This implies that: 1) The suggestive patterning at DK1 is an artifact of small sample size; or 2) There have been some key methodological differences in the ways in which assemblages have been investigated and reported; or 3) The sample of zooarchaeological assemblages from this time period is insufficient to determine what the 'typical' pattern really is.

A combination of the latter two possibilities is considered here to be behind the inconsistency in the results from Marean *et al.* (2000b) and the dataset presented here. The GIS image-analysis approach to estimating MNE values has likely resulted in some differences in metapodial patterning, although not in the expected direction given the conservative criteria used in selecting which fragments to include in the analysis. Indeed, given that only fragments that could be confidently assigned to either metacarpal or metatarsal were used here, it is surprising that metapodials are so well-represented and it suggests that their true representation is actually greater than that shown here. Also, the high- and low-occupation layers (10 and 11) were combined by Marean *et al.* (2000b), and the present analysis shows that there may be some significant differences between metapodial representation in these two layer classes.

The third possibility is also implicated when the other two sites have been examined. Substantial variability is present in relative distal limb representation both between sites and between analytical units within sites. Most of this variability occurs at a lower-than-expected frequency of metapodials, as was originally suggested to be the case at DK1. Much of it also records subtle differences in the representation of distal limbs between body sizes with in the same layer and analytical unit. However, it is also important to know if any of these differences in relative proportions are statistically distinguishable from what would be expected under a whole-limb transport strategy.

Fisher's Exact Test (Appendix J:[j]) was used to determine the statistical robusticity of the observed pattern versus the expected pattern. Expected values were obtained by taking the sum of the proximal and distal limb MAU and standardizing it by the ratio 2:1 (67.7% and 33.3%, respectively). These tests were conducted for all layers shown in Figure 74, as well as for individual layers at DK1 (Table 30). The tests found that only three p-values were significant below the $\alpha = 0.05$ level. Two of the significant values were in Layer 15 at DK1, from which the sample size is very small (Marean, pers. comm.). This indicates that although all three sites visually appeared to be impoverished in metapodials, they are in fact represented in the proportions that would be expected relative to proximal limbs given a whole-limb transport strategy.

Table 30

P-values for Fisher's Exact Test comparing the observed ratio of proximal to distal limbs to the expected ratio given a whole-limb transport strategy.

Site/Layer	Size	p-value
BBC M1	Small	1.0000
BBC M2	Small	1.0000
BBC M3	Small	1.0000
DK1 9	Small	0.7140
DK1 10	Small	1.0000
DK1 11	Small	1.0000
DK1 12	Small	0.7906
DK1 13	Small	1.0000
DK1 14	Small	0.1295
DK1 15	Small	0.0465
PP13B MIS 5	Small	0.0376
PP13B MIS 6	Small	0.7516
DK 1 High-Occ.	Small	0.1044
DK 1 Low-Occ.	Small	0.5701
BBC M1	Large	1.0000
BBC M2	Large	1.0000
BBC M3	Large	0.5593
DK1 9	Large	1.0000
DK1 10	Large	1.0000
DK1 11	Large	1.0000
DK1 12	Large	1.0000
DK1 13	Large	1.0000
DK1 14	Large	0.5472
DK1 15	Large	0.0008
PP13B MIS 5	Large	0.8983
PP13B MIS 6	Large	1.0000
DK 1 High-Occ.	Large	0.6178
DK 1 Low-Occ.	Large	0.0656

This is initially confusing, as some of the highest-ranked long bones are the femur, tibia, and humerus, which require processing of both meat and marrow to extract their maximum value. The metapodials carry virtually no meat and thus most of their

nutritive value lies in the marrow, which can be directly extracted by removing the periosteum and percussing the shaft with a hammerstone. Thus, if the goal of the hunter was to minimize field-processing effort and maximize the nutritive value of animal resources that were being transported, it makes more sense that it is the metapodials that would be left behind at the kill locality. Indeed, this has been shown to be the case in the modern Hadza (Bunn *et al.*, 1998; O'Connell *et al.*, 1988, 1990). It is further confusing that in general when there is a tendency for metapodials to be less well-represented, this is mainly the case for the small ungulates where selective transport is not predicted (Monahan, 1998).

Marrow varies in its composition both within the skeleton and in accordance with the age and nutritional status of the animal from which it is derived. Young animals tend to have marrow lower in fat content, and animals under nutritional stress deplete the fat reserves in their marrow in a predictable sequence (Sinclair and Duncan, 1972; deCalesta *et al.*, 1977; Brooks *et al.*, 1977; Dunham and Murray, 1982). Moreover, carnivores appear capable of picking up on these subtle differences and will shift their 'typical' sequence of carcass portion consumption to take these variables into account – effectively reorganizing their ranking in bone choice in a way that is paleontologically invisible except possibly in the case of neonates (Blumenschine, 1986).

Based on interviews with the Nunamiut about their food preferences, Binford (1978) proposed that there is a preference for marrow with higher oleic acid content, and that marrow with higher proportions of such unsaturated fats can be easily identified using visual cues. In a recent study, Morin (2007:77) developed an Unsaturated Marrow

Index (UMI), and suggested that this variable is one that might influence long bone transport decisions independently of the total nutritive value of a skeletal element as measured by SFUI. This model stands in contrast to that proposed by Jones and Metcalfe (1988), who indicate that simple marrow volume is an effective measure of long bone ranking with regards to this resource. Interestingly, distal limb elements such as the metapodials are the most enriched in oleic acid content. Elements become progressively more impoverished in this unsaturated fat as one moves proximally through the same bone and even more proximally through the entire limb.

The UMI index therefore predicts a correlation with long bone abundance that is generally the reverse of what would be predicted by food utility, which places the metapodials at the lowest ranking. The only reason it is not the exact reverse is that the amount of unsaturated fat is multiplied by the overall marrow volume as emphasized by Jones and Metcalfe (1988). This has resulted in a weak (although insignificant) positive correlation with food utility for the major long bones (Spearman's Rho = 0.4857; $p = 0.3287$).

Thus, the UMI is convenient for zooarchaeologists because when combined with the SFUI index a ready explanation becomes available for either a pattern of distal limb impoverishment or enrichment in an archaeological assemblage. In many ways, this risks failing to identify subtle strategies of bone preference and transport in the archaeological record that may not be attributable to either food utility or marrow quality. It also places certain key elements of the hindlimbs (owing to their high marrow volume) in positions where they can have an extreme influence over the general pattern of skeletal element

representation when it is plotted versus UMI. Given the lack of standardization in methods used to identify and quantify these elements as was discussed in Chapter Two, this is potentially problematic in a way that may not be immediately apparent – especially to the non-specialist.

Furthermore, it is less certain what such a preference for unsaturated marrow should mean in terms of transport. Given the relative ease of processing, the ready access to the marrow in comparison with other long bones, and the higher content of oleic acid in their marrow, it seems that the UMI in fact should predict greater emphasis on field processing of metapodials to extract this resource immediately – with the result being lower representation of these elements at the transport site. This appears to have been the case at PP13B, and particularly for small ungulates during MIS 5, when the ratio of proximal to distal limbs is significantly lower than expected.

One seeming inconsistency in the data is that between the z-scores and the ratio of proximal: distal limb elements at all sites. At PP13B the overall pattern of skeletal element transport in the high-survival set seemed to be one in which elements were not transported with strict accordance to their food utility or even with regard to marrow quality. One possibility was that this is the result of time-averaging of individual prey acquisition and transport events over the course of thousands of years. However, a consistent indication of active carcass portion choice in the low-survival set indicated that some decisions were made with regards to food utility. Thus, the conclusion was that when making transport decisions MSA hominins at PP13B did not consider the relative utilities of limb units but that elements in the high-survival set that required additional

processing may have been preferentially transported back to the site. This would have been particularly true if spongy elements were further processed for grease, which is an intense process that may have been more effectively practiced away from a kill site and in the company of the rest of the social group. It was also argued that in the case of PP13B, the Hadza model may not be the most appropriate analogue for understanding overall transport decisions.

The same general arguments were made for the patterning at Blombos. At this site, the data suggested that carcass segments were transported as a series of individual transport events, each of which was defined by its own set of contingent variables. This in turn suggested that group size was relatively small and that site use may have been somewhat sporadic. In contrast, the data from DK1 suggested that it may have been an MSA approximation of a central place for hominin foraging, as is seen in many modern hunter-gatherer groups (e.g. Binford, 1980; Kelly, 1995; Lupo, 2001). Central place foraging is a strategy that is not by any means restricted to hominins (Sodhi, 1992), and although it occurs in modern humans it is not necessarily a hallmark of the condition of being 'modern'. However, it is interesting that patterning suggestive of such a strategy is not apparent at earlier sites such as PP13B or Blombos – and it becomes tempting to ascribe this overall pattern between siites to more general changes in MSA foraging group size, transport strategies, and partitioning of faunal resources. Future work with larger available samples should include the suggestions provided by Faith and Gordon (2007), in which both the evenness of skeletal element representation and the correlations with food utility are examined for all sites. A summary of patterns and general

interpretations of the transport data from the present study is provided in Table 31, organized chronologically with the earliest deposits on the left and the latest on the right.

Table 31

Summary of transport data and potential patterns identified at PP13B, Blombos, and DK1.

	PP13B MIS 6	PP13B MIS 5	BBC M3	BBC M2	BBC M1	DK1
Overall transport	Long bones were transported at random, axial elements were subject to some selection		The combined influence of several individual prey acquisition and transport events likely left little patterning in the datasets			Selective transport likely; small and large fauna likely not present simultaneously
Transport according to utility	In accordance in low-survival set, not in high-survival set		No transport according to utility or the sporadic accumulation of fauna precludes identification of patterning			All ungulates in general accordance with utility
Elements more frequently transported (relative to other elements in the same survival set)	Small: humerus, femur, tibia, mandible, rib, atlas; Large: metacarpal, tibia, mandible, lumbar	Small: humerus, metacarpal, mandible, rib; Large: tibia, metatarsal, mandible, rib	Small: humerus, tibia, atlas, pelvis; Large: tibia, rib	Small: humerus, pelvis; Large: humerus, metacarpal, axis, pelvis	Small: humerus, metatarsal, pelvis; Large: femur, tibia, pelvis	Small: femur, tibia, rib; Large: femur, tibia, rib, pelvis
Elements less frequently transported (relative to other elements in the same survival set)	Small: radius, metacarpal; Large: humerus, femur, axis, atlas	Small: radius, metatarsal, axis; Large: femur, metacarpal, axis, atlas	Small: scapula, axis; Large: axis, atlas, pelvis	Small: tibia; Large: femur, metatarsal, atlas, scapula	Small: radius, metacarpal; Large: scapula	Small: metacarpal, metatarsal, vertebrae; Large: metacarpal, metatarsal, vertebrae
Relative distal limb (metapodial) representation	Even for large , low for small	Even for large , low for small	Low for large , even for small	Even for all sizes	Even for all sizes	Even for large , low for small

At all sites a variety of butchery activities are implicated in the distribution of cut marks throughout the ungulate skeleton. These include evisceration, skinning, filleting of the sirloin and tenderloin, occasional disarticulation of the ribs and vertebrae, occasional disarticulation of the head, and occasional disarticulation of the long bones both from the girdle elements and from one another. At PP13B there is additional evidence for removal of the tongue. PP13B and Blombos were also examined for evidence of within-bone nutrient extraction, and both the removal of marrow and the fragmentation of spongy elements (likely to extract bone grease) was documented.

These actions normally follow a logical order, although there can be variation in the timing of specific steps. Unfortunately, knowing where each step occurred – at the kill site, at the transport site, or elsewhere – is difficult to determine. For example, cut marks on vertebrae and ribs can demonstrate that evisceration occurred (Nilssen, 2000), but these marks will be retained on any elements subsequently transported away from the site where evisceration was performed.

A more quantitative examination of the long bones was used to compare the distribution of cut marks across different elements to ethnoarchaeologically-documented distributions of marks that were the result of two different carcass processing strategies. These two strategies were a disarticulation-then-filleting strategy and a filleting only strategy (Nilssen, 2000; Abe *et al.*, 2002). The former was one that was employed by modern butchers to segment carcasses and remove different cuts of meat, while the latter was employed with the primary goal of producing strips of meat for drying.

None of the sites showed any similarity to the D-F strategy, and all showed a definite emphasis on filleting of meat from bones. In most single-element comparisons to the F-O there were mixed results, with some bones within the same dataset having statistically indistinguishable distributions while others looked very different. However, when all bones were pooled and compared to the different strategies, there was only one instance of similarity to one of the ethnoarchaeological strategies. This was for size 1 ungulates at DK1, which closely resembled a filleting strategy.

In the case of PP13B and Blombos, the relative lack of disarticulation marks aligned well with the interpretations of the transport data, where it seemed that there was little selective transport among the long bones. However, at DK1 there was evidence for such a transport strategy, and this would have necessitated more disarticulation than at the other two sites. It was therefore suggested that the two ethnoarchaeologically-documented strategies may not provide the best analogues for the behavior recorded in the zooarchaeological datasets, but that comparison to other MSA faunal assemblages may be informative. This could be because of the effects of time-averaging of individual strategies per carcass acquisition event or it could be because strategies that were employed during the MSA have not been quantitatively documented in the modern day.

The final stages of carcass processing can be examined with more confidence. Midshafts from which the marrow had been removed would not be transported away from the site where this activity occurred, given that they no longer would have held any nutritive value. Relative abundances of percussion-marked midshafts therefore provide a measure of the intensity of long bone percussion between sites but not an indication of

where this activity more commonly took place. The proportions of percussion-marked midshafts at Blombos and PP13B are consistently higher than at DK1. Between Blombos and PP13B there is more variability, with a general pattern for greater proportions of percussion-marked midshafts at Blombos. Both sites show the same pattern of increasing proportions of percussion marks with increasing body size. This suggests that marrow extraction strategies were most intensive at Blombos and least intensive at DK1, either in terms of the number of elements that were percussed or in terms of the number of times a single element was struck.

The data also indicate that percussion of spongy elements, taken as a proxy for grease extraction, occurred both at PP13B and at Blombos. The incidence of percussion-marking across long bones differed between the two sites. At Blombos the strategy was more focused on percussion of long bones for marrow, indicating that fragmentation of spongy portions for grease extraction was more commonly an activity that took place on-site at PP13B. This suggests that carcasses were more extensively processed off-site at Blombos than at PP13B. There was a moderately low level of grease processing at PP13B during MIS 6 and a moderate level during MIS 5, while at Blombos it was practiced at a low level through MIS 5 and then at slightly elevated levels going into MIS 4. However, there is also a tendency for larger fauna to retain more percussion-marked epiphyseal portions than smaller fauna, and at Blombos smaller fauna is relatively more abundant than at PP13B. The observed differences may therefore owe more to a generally practiced method of processing small ungulates than to a need or desire to extract within-bone nutrients from spongy portions at a particular time or place.

No evidence for processing of spongy or epiphyseal portions for within-bone nutrients has ever previously been systematically documented at any MSA site. However, the two datasets presented here show that the evidence is likely to be present if workers include microscopic examination of these fragments in their research agenda. As with several other aspects of this study, these results from PP13B and Blombos will likely achieve their greatest potential utility when comparable data have been collected from other sites and both variability and uniformity in MSA behavior can begin to be explored in more detail.

A summary of the overall observations and interpretations of the carcass data is provided in Table 32. The sites are arranged in chronological order with the oldest deposits on the left and the youngest deposits on the right.

Table 32

Summary of carcass processing data and potential patterns identified at PP13B, Blombos, and DK1.

	PP13B MIS 6	PP13B MIS 5	BBC M3	BBC M2	BBC M1	DK1
Behaviors recorded by cut marks at all sites	Evisceration, filleting of sirloin and tenderloin, general filleting of axial elements and long bones, skinning, some disarticulation of ribs, vertebrae, and long bones					
Additional behaviors recorded by cut marks	Tongue removal		Disarticulation of head			Disarticulation of head
Closest ethnoarchaeological strategy	Filleting, minor disarticulation	Filleting, very low evidence for disarticulation	Filleting, very low evidence for disarticulation	Filleting, very low evidence for disarticulation	Filleting, very low evidence for disarticulation	Filleting, relatively more evidence of disarticulation
Appropriateness of ethnoarchaeological filleting-only model	Small: reasonable; Large: possible match	Small: reasonable; Large: not a close match	Small: reasonable; Large: possible match	Small: reasonable; Large: not a close match	Small: possible match; Large: reasonable	Reasonable match except for size 4
Within-bone nutrient extraction emphasis	Primarily marrow	Combination marrow and grease	Primarily marrow	Primarily marrow	Primarily marrow	Not examined
Relative indication of grease processing	Low	Moderate	Low	Low	Low	Not examined

CHAPTER EIGHT: MSA HOMININS AS MEMBERS OF THE CARNIVORE GUILD

Rationale and implications for zooarchaeology

The earliest evidence of animal husbandry presently comes from the Zagros Mountains on the border of Iraq and Iran (Zeder and Hesse, 2000; Zeder, 2001). The dates for this basic animal management imply that prior to at least 10 ka all hominin access to animal resources was through hunting, scavenging, or a combination of both. Anatomically and behaviorally modern humans have therefore been members of the predatory guild for almost the entire duration of their existence, and certainly throughout the course of most biological, behavioral, and technological evolution. In modern ecosystems humans are dominant predators who engage in varying degrees of direct competition with other members of the large-bodied predatory guild (Treves and Naughton-Treves, 1999) and within the modern human origins debate the timing of hominin establishment as a dominant predator has been a topic of much discussion (e.g. Klein, 1978a, 2000; Binford, 1984; Milo, 1998; Marean and Assefa, 1999).

Brantingham (1998) has suggested an approach to understanding early hominin meat acquisition during the late Pliocene that uses ecological principles of co-evolution and character displacement to characterize the early hominin hunting/scavenging niche. For later hominins such as the MSA occupants of the sites under consideration here, a similar approach provides a useful way to examine hominin-accumulated faunal assemblages on a landscape in which hominins would have been interacting with carnivores in the dual roles of prey and potential competitors for at least 1.5 million years (Treves and Palmqvist, 2007).

Today, carnivore guilds that lack a human component are very rare and almost always exist only in areas where substantial tracts of land have been set aside for their preservation (Woodroffe and Ginsberg, 2005). As a result, after millions of years of evolution with hominins competing for the same animal resources, it is difficult to consider these predatory guilds that lack hominins using traditional hunting technology as 'intact'. This makes modern observations useful but not precisely analogous to the situation as it would have existed in the late Middle and early Upper Pleistocene when hominin hunters were a part of these communities.

Despite this, modern observations of competitive behavior, territoriality, and sociality in carnivores provide three potential avenues for examining MSA zooarchaeological assemblages. First, they allow predictions to be made about what species, body sizes, and skeletal elements would be expected to be recovered from accumulations by a large-bodied social carnivore. Deviations from these predications that may be revealed in zooarchaeological assemblages can then be illuminated. Second, they provide a theoretical framework in which the special challenges and potential limitations faced by MSA hunters can be evaluated at the time the first early modern human behavior is thought to have arisen.

Finally, ecological principles of niche exclusion revealed in the ecological literature may provide a useful starting point for understanding how one single small population of early modern humans was able to expand and eventually replace closely-related populations with similar feeding niches to their own. This then makes

understanding how less closely-related populations were replaced in other parts of the Old World more easily accessible (e.g. Marean, 2005).

Intra-guild competition

In order to understand the potential ecological consequences of MSA hominin predation and how this would have impacted zooarchaeological assemblages it is important to review how competition between carnivore species structures the modern-day predatory guild. Several decades of ecological studies have established the importance of two salient observations about carnivore-carnivore interactions and the effects these have on resource availability, population densities, and relative reproductive success.

Observation One: The dietary overlap of medium- and large-bodied carnivores is generally quite high, and this leads to exploitation competition between predatory species (Sinclair *et al.*, 2003). Some partitioning in prey body size can occur when a larger-bodied or more sociable species is able to routinely exploit prey larger than its fellow guild members. Prey may also be partitioned according to the activity patterns during which various carnivores are active, or different methods of hunting (e.g. stalking and ambush versus flat-out running) that favor certain prey ecologies over others. As a general ecological principle, communities are structured by niches that are already filled. Before potential competitors will begin to infiltrate a niche, all similar empty niches will first be filled (Brown 1995a). New niches may be created by disparate use of resources from several other niches. However, in general predator diets are nested within one

another rather than being strictly partitioned, and this leads to substantial dietary overlap (Sinclair *et al.*, 2003).

Sinclair *et al.* (2003) found that despite substantial niche overlap in East Africa there is no evidence that as certain carnivores are reduced in number within an ecosystem the remaining predators immediately rush to fill the gaps. Similarly, Woodroffe and Ginsberg (2005) were unable to find more than anecdotal evidence that when one carnivore population becomes depressed there are immediately discernable changes in diet or daytime activity in sympatric carnivores. However, prey population densities have been observed to increase as predation pressure is released, and as prey populations increase so do predator populations (Sinclair *et al.* 2003). At this point more direct forms of inter-species competition complicate the picture, as predator populations of different species do not increase uniformly in synch with an increased prey biomass. For example, intra-guild avoidance has developed to such an extent in wild dogs that as prey density increases, dog home range sizes actually increase with it (Woodroffe and Ginsberg, 2005). This partially explains why in areas in which lions (*Panthera leo*) and spotted hyenas are resident, wild dogs and cheetahs (*Acinonyx jubatus*) both have larger home ranges than would be predicted by their metabolic requirements alone (Gittleman and Harvey, 1982).

Observation Two: Intra-guild competition, including direct aggression, has a substantial impact on the ecology, behavior, and population densities of other carnivores. Under most conditions, populations will stand close to their carrying capacity (K) in an ecosystem, with K normally limited by a single resource. One such resource is food

density (Wrangham *et al.*, 1993). However, in a carnivore guild that contains several species of medium- to large-bodied carnivores, there is always a smaller subset that accounts for most of the prey biomass taken in an area. These dominant carnivores may cause less successful carnivore species to remain at populations below well below the K of the ecosystem. The most widely acknowledged role of carnivores in an ecosystem is the regulation of prey species (e.g. Mills, 2005). Less obvious is the regulation of other carnivore populations, either through exploitation competition for the same basic prey resource, direct competition at kills, or even predation upon one another (e.g. Palomares and Caro, 1999).

As an example, of observed cheetah kills, about 10% are stolen by hyenas, lions, wild dogs, and even leopards – all of which have been reported to kill cheetahs if given the opportunity (Kingdon, 1977; Caro, 1987). Cheetahs do not return to kills and unlike other big cats they tear off big chunks of meat rather than eating with the meat gripped between their paws (Adamson, 1969). This may be a way for cheetahs to eat large amounts quickly and then move on before other predators arrive on the scene. Wild dog diet overlaps substantially with that of lions and spotted hyenas, particularly the latter, which have been observed trailing behind dogs as they initiate hunts (Creel and Creel, 2002). As a result, there is often interference competition for wild dog kills, with spotted hyenas capitalizing on the efforts of the dogs. Although the dogs are usually proficient at mobbing hyenas and taking back their prey, wild dog populations fare much better in areas where inter-specific competition with hyenas is rare, and did so prior to when their populations began a sharp decline in recent decades (Estes and Goddard, 1967).

All forms of intra-guild competition lead to substantial behavioral and ecological modification on the part of carnivores to avoid sympatric predators. For example, some species place their territories at the very margins of a competitor's home range. Neither cheetahs nor wild dogs commonly scavenge meals from other predators, and they avoid lions and hyenas by seeking out areas of low prey density that are less desirable to larger-bodied competitors. Creel and Creel (2002:267) describe wild dogs as a 'fugitive species' with several adaptations that help minimize the risk of encounter with lions and hyenas. Wild dogs are always found in low population densities relative to other local large-bodied carnivores, normally by 1 – 2 orders of magnitude (Creel *et al.*, 2004), and as with cheetahs their population densities seem to correspond negatively to the population densities of larger-bodied carnivores. Less quantitative evidence suggests that this was also the case before wild dogs gained their current status as being highly endangered (Frame and Frame, 1967; Frame *et al.*, 1979).

Direct predation by lions and sometimes spotted hyenas is also a limiting factor for less-dominant species such as cheetahs and wild dogs (Creel and Creel, 1996; Mills and Gorman, 1997; Durant, 1998; Hunter *et al.*, 2007). In the Serengeti ecosystem heavy predation on cheetahs by lions was found to have serious repercussions on their population dynamics within the study area (Laurenson, 1994, 1995; Durant *et al.*, 2004). Cubs in particular suffer from inter-specific predation to such an extent that cheetah mother's vigilance can be accounted for both in terms of looking for prey and looking out for predators (Caro, 1987). There is also evidence that an increase in lion populations has a negative effect on cheetah reproductive success in the same area even if resident

cheetah populations still appear to be below the potential carrying capacity for this species (Kelly *et al.*, 1998). In wild dogs there is frequent predation by lions away from kills, with up to 50% of all adult wild dog deaths attributable to lion predation (Creel and Creel, 2002). There is less predation by hyenas on adult dogs, but they are a common threat to wild dog pups that are old enough to have left a defended den but that are not yet fully-grown.

Berger (2005) has examined the evidence that modern human hunters fill precisely the same niche as other large-bodied carnivores. In an overview that includes several different ecosystems and a variety of traditional and non-traditional hunting technologies, he cites ample evidence that modern humans and carnivores play similar roles in prey species overlap, areas from which prey are taken, prey mortality rates, and prey functional response. However, he argues that simple niche overlap is insufficient evidence for predator redundancy within an ecosystem, and as modern hunting is currently practiced there is little evidence that humans are functionally redundant with large-bodied carnivores.

Berger (2005) suggests that several modifications of modern hunting behavior would more closely replicate predation by other large-bodied carnivores: killing at close range, taking of a disproportionate number of neonates, year-round harvesting, and approximation of biomass removal by carnivores. These characteristics are similar to hunting behavior in ethnographically-known subsistence hunters using non-modern technology, which provides strong evidence that once humans became an established part of the carnivore guild they would have been capable of playing the same regulatory roles

both on prey populations and carnivores as did other large-bodied predators. This would have brought them into frequent and direction competition with other predators (Treves and Palmqvist, 2007).

In considering the problem of how MSA hominins were situated within the carnivore guild, potential redundancy and direct competition with other carnivores could mean the restructuring of local carnivore populations or even the local extinctions of competing predators. This would have been particularly the case as modern human populations began to recover and expand after a genetic bottleneck that has been identified about 141 ka (Fagundes *et al.*, 2007). It could further mean that changes in MSA hunting efficiency or prey selection would have a paleontologically observable impact on local carnivore populations. Mapping and careful dating of paleontological sites relative to archaeological sites, and documentation of both predator and prey species that were present on the landscape, would provide a way to examine patterns in hominin-carnivore interaction over time. If one large-bodied carnivore is eradicated in a region it might be theoretically possible that other large-bodied carnivores with overlapping niches, such as early modern humans, would be able to take over the main regulatory top-down role without substantial disruption of the ecosystem.

Woodroffe and Ginsberg (2005) found that when a carnivore guild begins to collapse it is typically the most wide-ranging animals that are the first to be lost - possibly because of enforced proximity to competing members of the same guild. Wild dogs would be the first to be affected, with cheetahs second and leopards remaining at a generally low but ubiquitous population density (Creel *et al.* 2001). Spotted hyenas and

lions, which generally take on the dominant predatory role in those modern ecosystems that have been studied, would be expected to be displaced only when modern human predation became prevalent and efficient enough, and modern human populations became large enough, to project them into the upper echelon of the hierarchy. Therefore, changes in the effects of hominin hunting on prey populations through a combination of factors such as improved technology, increased reciprocity, and extension of social networks, (and their eventual increase in population densities) may be monitored by their impact on existing lion and spotted hyena populations. This can be observed paleontologically, as suggested above, or by proxy through shifts in human faunal accumulations to incorporate more of the prey favored by these species.

Group size and other factors influencing hunting effectiveness

There are several ways to measure hunting effectiveness. Per capita meat consumption is often used (e.g. Creel and Creel, 2002), although for species that cache food (such as leopards), prey body size may also be an appropriate measure. A large prey body size has also been argued by Kaplan *et al.* (2000) and Hawkes *et al.* (1991) to be the preferred choice for modern hunter-gatherers, as well as for MSA hominins (Marean *et al.*, 2000b). Both measures will be discussed here, although it is important to keep in mind that the preferable measure for archaeological purposes is that of prey body size, which can be more directly measured in zooarchaeological assemblages.

A survey of the carnivore literature found that there is an allometric relationship between predator and prey body size, with prey size increasing with carnivore body weight (Gittleman 1985). It is intuitive that larger predators would be capable of taking

larger prey, but they would not be expected to do so unless the costs of acquiring sufficient smaller prey exceeded the costs of acquiring the same nutritional gain from larger prey. There is also a relationship between predator body size and prey diversity. Gittleman (1985) posits that this is because larger animals can travel over a larger area and increase the potential range of prey. Even within a smaller area, large predators are able to utilize both large and small prey while smaller-bodied predators are limited to smaller prey. Wilson (1975) argues that this confers a competitive advantage on carnivores with a larger body size, as they are able to utilize resources out of the grasp of smaller carnivores and thus have access to a broader range of dietary options in times where there are fluctuations in prey populations.

Another factor that may be found to influence hunting success in both MSA hominins and non-human carnivores is the degree of sociality in the predator. Thus, it is useful to examine the ecological literature for trends in predator sociality, group size, and hunting effectiveness. For organisms across a variety of orders there are advantages to group living that often supercede the potential costs. Although groups may be more apparent to predators or prey, individuals can benefit from the increased vigilance of other group members, attention can be diverted away from oneself by other individuals, and group members can have increased defense support in the event of an attack (Caro, 1994). Similarly, though social animals may face more intra-group competition for the same resource they are better equipped to displace other species or smaller groups of the same species from a communal resource, and to subsequently defend these resources while they make use of them. Sharing of access to mates is another potential

disadvantage to group living, but at the same time more potential mates may be immediately available without the need to invest energy into long-range searches.

As a large-bodied social predator, hominins would be subject to many of the same advantages and disadvantages of group living as have been identified in other species. Today, modern human hunting takes place in a range of group sizes, from individual hunters to whole-family groups driving small prey into nets (Kelly, 1995). The degree to which MSA hominins hunted socially is unknown, as is the general population density at which they lived. However, an examination of the ecological principles that structure group size and range size in other large-bodied social predators can provide ways to predict what these parameters might have been in the MSA. Because these factors influence the body sizes and abundances of prey species, the zooarchaeological records from PP13B, Blombos, and DK1 can therefore be examined not only for potential hunting group sizes but for relative group sizes as s whole.

Within the order Carnivora, 85-90% of species aggregate only during the breeding season (Gittleman 1986). However, there are several examples of large-bodied carnivores that clearly benefit from group living. With prey species the majority of studies have focused on the benefits the group living in terms of predator avoidance. With carnivores, these studies have instead been slanted towards understanding advantages in food acquisition: lowering the risks of prey capture, increasing the diversity and size of prey that can be obtained, improved hunting success, and increased efficiency at defending resources and young against conspecifics and sympatric carnivores (Caro, 1994). It has been further suggested that group living is so common in

both predator and prey species that groups rather than individuals make a more appropriate unit of ecological analysis (Fryxell *et al.*, 2007).

Much ecological work has been done on carnivores outside of Africa, and most of the literature referred to here contains citations leading to supporting studies on other continents. However, for the sake of brevity all points will be made here using examples that refer to medium- to large-bodied African species. These are also the species that have spent at least the last two million years jostling for meat resources with modern humans and their ancestors, and which would have experienced feeding niche pressure as hominins underwent the transition to fully modern hunters and dominant predators. Of these species lions, wild dogs, and spotted hyenas are traditionally considered to be social carnivores, while cheetahs and leopards are often portrayed as the quintessential solitary hunter. However, a closer look reveals that carnivore sociality is much more variable and consists of many more gradations than this simple division would imply.

Several authors have argued that group living confers sufficient benefit to carnivore species that selection would consistently favor it (e.g. Alexander, 1974; Kruuk, 1975; Kruuk and McDonald, 1985). Therefore, the extent of carnivore sociality should mainly be regulated by its costs. Wrangham *et al.* (1993) have argued that exploitation competition is a major regulating factor in group size, and that foraging group size should be considered separately from total group size. Exploitation competition is a non-aggressive form of competition in which access to resources is reduced simply by other individuals using the resource. In a group living situation, exploitation competition occurs among all animals when a group has to travel further per day than a lone forager

in order to satisfy the group's energetic requirements. Therefore, group size should correlate positively with both food density and travel efficiency. Group size should also correlate positively with population density, which is in turn often regulated by food density (Wrangham *et al.*, 1993).

Many ecologists consider body mass to be a key variable for understanding group size and population density, as it has a predictable relationship to physiological, life history, and ecological parameters (Smallwood *et al.*, 1996). Carnivores typically have larger home ranges than omnivores or herbivores of a similar body size, and within carnivores those with a larger proportion of flesh in their diets have especially large home ranges (Gittleman and Harvey, 1982). Carnivore home range size is best predicted by group mass (as a proxy for body size and metabolic requirements), secondly by defense behavior, and thirdly by diet (Grant *et al.* 1992). Body mass has also been touted as a good predictor for species density in a given study area, with a consistently negative regression slope when $\log_{10}$ body mass is plotted against $\log_{10}$ density (e.g. Damuth, 1981,1987; Peters, 1983; Peters and Wassenberg, 1983; Peters and Raelson, 1984).

However, population density is not always highest in animals of the smallest body size (Blackburn *et al.* 1990; Johnson, 1999). In a comprehensive overview of available data for carnivore species, Smallwood *et al.* (1996) found that this allegedly firm relationship between body mass and density may rather be explicable in terms of a third variable: researcher choice of study area. Put simply, body mass (and home range) may have determined the spatial extent of studies, with density estimates derived from these studies then relating back to body mass in a negative relationship (Smallwood and

Schonewald, 1996, 1998). This result was also replicated for mammalian primary consumers (Blackburn and Gaston, 1996).

Smallwood and Jones (1996) found that once the effects of spatial scale were removed from the analysis, carnivores with females that normally weigh more than 11 kg still occur at an average density that is less than one-third that of smaller carnivore species. The authors hasten to add that study sites are often chosen because of a relatively high density of individuals, and that these sites are frequently resource-rich patches embedded within a landscape that has overall a much lower average density of the species in question. Estimated density is therefore a function of the patchiness of habitat, and as the spatial extent of a study area decreases the details of these patches become more and more apparent.

Territoriality also has an effect on home range size and therefore density as measured in individuals per unit area, with undefended home ranges on average 4.5 times larger than defended ranges (Grant *et al.* 1992). This is because a defended home range requires effort to maintain, and the cost of this maintenance is not as effectively spread over a larger area. When a territory is well-defended against exploitation competition this is not problematic, as a smaller defended home range can still provide the same amount of resource per individual as a larger undefended range. Defended home ranges also support larger groups of individuals, and they tend to occur in areas of high resource abundance (Grant *et al.*, 1992).

Creel and Creel (2002) examined foraging success and group size in 14 different studies that included terrestrial, arboreal, avian, and aquatic predators. They found that

cooperative hunting was beneficial under a broad range of ecological situations, but particularly those in which hunting strategies did not require a great deal of stealth. These authors found that per capita food intake is usually higher for group rather than solitary hunters, though Caro (1994) argues that this relationship is not a linear one and group sizes in a range of carnivores do not match the expected numbers for maximizing per capita food intake (*contra* Nudds, 1978). This has led to some debate over the universality of cooperative hunting as the sole driving force behind carnivore sociality and a recognition that carnivores are subject to the same requirements to maintain a territory, escape predation, and secure access to mates, as other mammals (Caraco and Wolf, 1975; Caro, 1994:340).

Although cooperative hunting may be an advantage of group living, it has been argued that it is not necessarily the driving force behind the evolution of sociality in carnivores (e.g. Gittleman, 1989; Caro, 1994). Cheetahs have highly variable degrees of sociality, and might live either alone or in groups within three different age-sex classes: females and mothers with cubs, independent adolescents, and males. This differs from most other felids, which are solitary – lions being a notable exception. Caro (1994) found that the principle advantage to group living in male cheetahs was their ability to gain access to territories and defend them against conspecific males. This defense was most critical in securing a mate as female cheetahs were drawn to the prey aggregated in such territories. Where females also aggregate, as in lions, the main advantage conferred upon males living in groups was an enhanced ability to gain access to female prides, hold

prides for longer, and occupy several prides during their reproductive years (Packer, 1986; Packer and Ruttan, 1988; Packer *et al.*, 1990).

A survey across felids suggests that high female density and extensive range overlap are both important in favoring formation of male alliances (Caro, 1994:330). High densities of females, in turn, appear to be most directly tied to the distribution and predictability of prey. In lions, as with other carnivores, larger-bodied prey are more often pursued and taken when there are larger group sizes of hunters (Scheel and Packer, 1991). However, per capita foraging success did not increase with group size in the Serengeti lions (Packer *et al.*, 1990). In the more open habitat of Etosha National Park, Namibia, lions had greater success rates in larger groups (Stander and Albon, 1993), but did not appear to congregate according to the most efficient group sizes – likely because maximizing per capita food intake is not the only force that structures the sizes of their groups (Caro, 1994).

In Namibia large groups of cheetahs numbering from 10 – 14 individuals were often sighted. The Namibian cheetahs were able to kill larger prey such as adult kudus and wildebeests (up to approximately 250 kg, size 3). The ranges in Namibia where cheetahs form large groups differ from other study areas in that they have been fenced off and are largely devoid of other large carnivores such as lions and hyenas. This makes cheetahs the dominant predator on the landscape and indicates that the cheetah's social organization and favored prey size are at least in part determined by competition with other predators (McVittie, 1979). Cheetah will take smaller prey such as hares and small antelope (Caro, 1994), but they rarely kill antelope heavier than about 50 kg, or their own

body weight (Estes, 1991:378). However, male coalitions are much more successful at claiming and maintaining a territory (Caro and Collins, 1987), as well as hunting larger prey (Foster and Kearney, 1967). Overall, for both cheetahs and lions there was no firm evidence found to suggest that group size was directly related to optimal foraging returns, although larger prey were able to be taken (Caro, 1994).

Wild dogs are specialized pack hunters that typically take prey up to 45 kg, but that occasionally take prey up to 65 kg, or twice an individual dog's body weight (Estes, 1991:410). The basis of the wild dog social system is cooperative hunting and food-sharing, with sharing being extremely equitable and kills normally divided without aggression (Ewer, 1973). Pups are sequestered in a den along with their lactating mother, who is directly provisioned by the pack until the pups are weaned at around five weeks. Pups and lactating females are highly dependent on provisioning by other pack members and if all pack members were allowed to breed pup mortality would soar (Estes, 1991). A single breeding pair therefore normally contains the only direct reproducers in a pack, and male helpers are vital to pup-rearing and provisioning for a full 12 – 14 months at a time. Because females emigrate at sexual maturity existing packs are highly dependent on large litters consisting mainly of males – and indeed there is a sex bias towards males at birth. Males who remain with the pack are always related to the new pups, and this cooperation can comfortably be described as a form of kin-selection (Malcolm and Marten, 1982).

Larger packs are more viable than smaller packs, with the extra provisioning resulting in far less pup mortality (Schaller, 1972), and there appears to be a critical

minimum pack size below which these obligate cooperators are prone to extinction (Courchamp and Macdonald, 2001). The number of pups born and the number of pups raised to independence both increase as the number of adult pack members increases (Creel *et al.*, 2004). In terms of hunting efficiency, larger packs kill larger prey, chase prey over shorter distances, are more likely to make a kill, and make more multiple kills (Creel *et al.* 2001, Creel and Creel, 1995, Fanshawe and Fitzgibbon, 1993, Fuller *et al.*, 1995). Because prey are brought down by large groups of dogs pulling from different directions, it is extremely difficult for a lone dog to accomplish a successful hunt of an ungulate with a body size of 2 or greater (Estes and Goddard, 1967). However, these kills now need to be divided among that many more hungry dogs.

Using the number of kilograms of meat per individual dog/km traveled per day as a measure of foraging success, wild dog pack size reaches a local optimum of efficiency when there are 12 – 14 dogs and then eventually climbs to maximum efficiency at around 20 individuals. Through a series of further calculations of the efficiency of hunting and pack size, Creel and Creel (2002) concluded that cooperative hunting confers substantial benefits on a pack of wild dogs, and that natural selection would have maintained this high level of sociality. However, there are other factors that influence pack size apart from cooperative hunting. Although wild dogs have been observed in packs as large as 60 or more animals (Kingdon, 1977), the mean is between five and nine dogs across five ecosystems, and wild dog packs do not normally conform to the optimal size (Frame *et al.*, 1979; Creel and Creel, 2002).

This illuminates the conflict between individual reproductive interests and the benefits conferred on the group as a whole. Despite the clear advantages to group living, pack sizes may be limited by young adults of both sexes being the first age class to disperse from larger packs. This is presumably because in a larger pack their chances of ever obtaining a direct opportunity to breed are much smaller than if they fission off to form a new pack on their own – and individual reproductive success is greater by parenting of a litter than by assisting with kin (Creel and Creel, 2002). Wild dogs therefore provide a further example of the interplay between sociality, individual reproductive success, and the impact these other factors have on optimal foraging returns. Table 33 shows a summary of the general effects that body size, group size, and territoriality have on various aspects of carnivore ecology and behavior.

Table 33

Summary of the effects that body size, group size, and territoriality have on various aspects of carnivore ecology.

	Large body size	High territoriality	Large foraging group size
Population density	Indeterminate effect	High density	High density
Per capita food intake	No effect	High in patch	Local maxima
Prey size	Larger	No effect	Larger
Effectiveness of direct competition with conspecifics	Effective	Effective	Effective
Protection against predators	Effective	Effective	Effective
Ability to access multiple resources	More able	Indeterminate	More able

The sum of the evidence indicates that in terms of hunting efficiency for predators not relying on stealth, a larger group size is always favorable up to an optimum, after which point per capita hunting success decreases. This is also effectively what allows predators to take prey of a much larger body size than their own. In the case of MSA hominins, this suggests that where zooarchaeological assemblages contain a high proportion of prey that is best obtained by stealth (including those with an anti-predator strategy of fleeing in open territory, such as springbok or zebra [*Equus* spp.]) a larger group size would *not* have been beneficial. In the absence of long-range killing technology, situations in which large groups would have been most critical would have been where large-bodied ungulates were the main focus of predation.

The degree to which such technology was available to MSA hominins has been debated, and a full review is beyond the scope of this study (e.g. Lombard, 2005). However, there is other evidence for increased group size during the later part of the MSA, and this would have influenced both the nutritive requirements of the group as well as hunting strategies. One way of mediating larger aggregations and improving success in hunting is through information sharing and more complex within- and between-group social interactions. As discussed in the introduction to the modern human origins debate, likely archaeological proxy measures for this sort of social complexity and external symboling make thier first appearance during the MSA – particularly during MIS 5.

However, Sernland *et al.* (2004) found that information sharing about patchy resources that can be facilitated by a larger group size does not in itself raise per capita food intake, and the costs of having a larger foraging group size need to be outweighed

by benefits obtained in other ways. Such a benefit could be access to a large, productive, and reliable patch of resources such as shellfish or tortoises that can be collected by all members of the group as a way to offset variance in hunting success.

A larger group with access to reliable resources would not only be expected to show signs of external symbolic expression but would also have an edge over smaller groups competing for the same resources. Given some trends in the ecological literature, some potential expectations for the zooarchaeological record that could indicate a larger group size with a higher degree of social integration and complexity are: 1) where intensification practices such as grease extraction were employed; 2) where access to alternative sources of fat and protein are available; and 3) where among larger mammals an emphasis on the procurement of large-bodied terrestrial ungulates is observed.

CHAPTER NINE: IMPLICATIONS FOR THE MODERN HUMAN ORIGINS DEBATE

Significance of animal resources

Where conditions of preservation are good, large mammal bones are one of the most commonly recovered ecofact classes recovered at MSA sites. Tortoises (as well as other reptiles), small mammals, micromammals, and shellfish are also often recovered, sometimes in great abundance. However, most studies of MSA subsistence have relied heavily on interpretations of the large mammal fauna (e.g. Klein, 1976, 1978; Klein and Cruz-Uribe, 2000; Marean *et al.*, 2000b; Henshilwood et al, 2001; Halkett *et al.*, 2003; Clark and Plug, 2008). This may be because of its high visibility relative to the other categories, or even because of an underlying assumption that the MSA occupants were mainly involved in the accumulation of the large mammals but not other faunal components.

However, this high visibility cannot be taken at face value to be representative of the actual importance that MSA hominins placed on large mammal resources, or even animal resources in general. The first order of inquiry is therefore to determine if reliable access to animal products was an essential component of the MSA diet. Although the MSA hominin skeletal record is scant, there are few indications that their anatomies were substantially different from our own. In particular, we know they were in possession of a large brain that would have required maintenance with the fats and proteins found most effectively in animal resources (Speth and Spielman, 1983; Aiello and Wheeler, 1995). In modern hunter-gatherers these macronutrients are highly valued, and they are essential for proper growth and nutrition (Eaton and Konner, 1997; Milton, 1999; Kaplan *et al.*,

2000). This is particularly true for infants, juveniles, and nursing mothers who require docosahexaenoic fatty acids (DHA) such as those recovered from the marrow and brain cavities and from marine resources for optimal neurologic development and maintenance (Broadhurst *et al.*, 2002; Langdon, 2006).

Given their key role, animal products have the high social value that would be expected (e.g. Hawkes *et al.*, 1991; Hawkes and Bird, 2002) - and no modern humans obtain this resource through scavenging only. This study makes the baseline assumption that the metabolic and nutritive requirements of MSA hominins were not substantially different from what is seen in modern humans. If this assumption is true, then animal resources are important to the diet and the null hypothesis must be that hunting was the primary mode of large mammal resource acquisition. This is because hunting is the only way to obtain these resources *reliably* in the absence of sensory abilities to detect carcasses or locomotor abilities to arrive at them quickly.

However, it is important to note that hunting of large ungulates is not the only way to obtain fats and proteins. In environments rich in easily-collected resources such as shellfish or tortoises, or with technology such as net-hunting or snares, acquisition of this component of the diet is more akin to gathering and is an activity in which all members of a group can participate. Furthermore, aquatic resources are high in DHA and comprise an important part of the diverse diet proposed to be most nutritionally beneficial during the evolution of our ancestors (Broadhurst *et al.*, 2002) – and the type of diet that would provide a reproductive and competitive edge to all populations with access to it (Hockett and Haws, 2003). In many modern hunter-gatherer groups, collectors contribute to the

diet in the form of roots, nuts, seeds, and other gathered resources. Patches of these resources are often more reliable and predictable than terrestrial mammal resources (Burger *et al.*, 2005). Despite this, the contribution of hunters is often considered more valuable and carries a higher status than the contribution of the gatherers (Hawkes and Bird, 2002). Some authors have suggested that this is because hunting is a more dangerous way to acquire resources, and thus by doing so they are engaging in costly signaling, or 'showing off' in order to enhance their reproductive success (Hawkes and Bird, 2002; but see Wood, 2006).

In environments such as those considered for this study, where both marine resources and tortoises are available for collection, MSA hominins did not have to be either hunters or scavengers of large ungulates in order to obtain critical animal resources. This in turn has implications for the social structuring of the group, as the role and status of juveniles, the elderly, pregnant females, or females with young will be much different in a society in which they also contribute animal resources than one in which animal resource procurement falls largely to males in the form of active hunting (Hawkes and Bird, 2002).

If fats and proteins were normally obtained through efforts similar to gathering, then we would expect a relatively equitable social hierarchy and little sex-specific division of labor in MSA groups (Hawkes, 1996). Under this scenario, scavenging of large mammal resources could feasibly act as a supplement to the MSA diet rather than a critical mode of resource acquisition, as the majority of animal resources would be obtained in other ways. This basic difference in the acquisition of animal products therefore has further

implications for group size, mobility, territoriality, and the expression of symbolic behavior. Though these latter implications will not be explored in depth here, it is clear that understanding the main mode of animal resource acquisition is an absolutely essential step in understanding the emergence of modern humans for many reasons other than simply the fact that obligate scavenging is not observed in modern groups today.

Question one: pattern of hunting behavior

There has been much debate over if MSA groups obtained large mammal resources through hunting, scavenging, or some combination of these strategies (Bartram and Marean 1999, Binford 1984, Klein 1989, 1995, Marean and Assefa 1999, Marean *et al.*, 2000b, Milo 1998). Obligate scavengers for which animal resources comprise a major portion of the diet have specialized adaptations for ranging widely to find carcasses, locating them, stripping them of remaining nutrients, and avoiding other predators at the kill site. These adaptations may be olfactory, locomotor, behavioral, or include biological solutions for breaking into bones or digesting tough carcass components left by carnivores with earlier access.

Although technological solutions such as hammerstones to break open bones and fire to cook otherwise indigestible components solve many of these problems for hominins, their lack of biological adaptations for encountering carcasses on a more than opportunistic basis renders them an unlikely candidate to be obligate scavengers if frequent access to animal resources played a necessary role in the MSA diet. If frequent access to animal resources was not critical, then obligate scavenging could more feasibly be a supplementary strategy to a predominately vegetarian diet.

Two critical aspects of this problem can be addressed using the datasets presented in this study. First, it can be determined if the ungulates recovered from PP13B and Blombos were hunted or scavenged. Second, the work at PP13B provides the first of several essential analyses of MSA small fauna assemblages that will assist in understanding the role this component played in the overall diet. Isotope work on MSA skeletal material would be extremely useful in this regard, but the scarcity of human fossil material from this time period in southern Africa makes it unlikely that the desired samples could be easily obtained. In the absence of isotope data zooarchaeological data can provide an indication of the dietary significance of various items, but only when data from large mammals, small mammals, and tortoises have been combined with shellfish data can a more complete picture of where and how MSA hominins obtained critical fats and proteins be constructed from food remains.

Once this is done, the social implications of MSA faunal resource procurement can be examined in greater detail and more reliably linked to the emergence of symbolic behaviors such as those documented at Blombos. At present, with large mammal taphonomy done for only three sites and small fauna taphonomy done for one, this picture can only be touched on by addressing the hypotheses outlined in Chapter Three. These are addressed in turn below.

The first hypothesis was that hunting was the main mode of meat acquisition. Examining the relative abundances of high- and low-utility skeletal elements has been an initial approach to determining whether hunting or scavenging was the primary mode of meat acquisition during the MSA. Binford (1984) based his interpretation that MSA

hominins were predominately scavengers on skeletal element abundance data that showed very low representation of high-return elements. This was taken to indicate scavenging and transport of the dregs of a carcass that had already had the choicest portions removed by the primary predator. However, Binford did not take into account the differential survivorship of skeletal elements and skeletal element portions (e.g. Marean and Frey, 1995; Marean and Kim, 1998; Marean *et al.*, 2000b), as was documented and corrected for in the sites used in this study.

Bone representation and food utility are not positively correlated in all cases, and for some analytical units and body sizes it is actually negative. However, it also does not fit the 'reverse utility' curves observed by Binford (1984) in which high-utility elements appeared to be lacking at MSA and Middle Paleolithic sites. Instead, the data indicate a consistent strategy of increased transport according to increased food utility of elements within the low-survival set of Marean and Cleghorn (2003), and a much less selective strategy of long bone transport. This seems to have especially been the case for the human-accumulated portion of the assemblages at PP13B, and to a lesser degree at Blombos. At DK1 a more selective transport strategy was identified.

From this, three observations emerge: 1) correcting for the effects of density-mediated destruction does not result in clear reverse utility curves for any of the sites examined here; and 2) high-return axial elements were available to MSA hominins in sufficient quantities for them to consistently make transport decisions with regards to their relative utility.

Surface modification analysis has also been used as a way to diagnose hunting versus scavenging in the zooarchaeological record. On the basis of microscopic examination of bone surfaces at Klasies River, Milo (1998) argued that MSA hominins were fully modern hunters. Cain (2006) suggested that at Sibudu there is no evidence that MSA hominins were 'less-effective' hunters of less dangerous prey such as was proposed by Klein (1976, 1978, 2000). Marean *et al.* (2000b) also showed that at DK1 hominin versus carnivore modification was present in the abundances that would be expected given the 'hominin-first' scenarios replicated in actualistic studies. This study shows that this was also the case at PP13B and at Blombos. Furthermore, the cut mark data from all sites show filleting of the sirloin and tenderloin in the axial region and a heavy emphasis on a filleting strategy of long bones. None of this is compatible with a scenario in which hominins had secondary access to partially-defleshed carcasses, and this conclusion has now been taphonomically verified at three separate MSA sites in the Western Cape – four if Klasies River is included despite its having suffered from excavator bias against less identifiable long bone fragments.

Milo (1998) supported his conclusions from the surface modification analysis with an example of what he considered to be 'smoking gun' evidence, in the form of a cervical vertebra from the very large extinct Cape buffalo (*Pelorovis antiquus*), complete with the embedded tip of an MSA stone tool – although this could as easily represent a peri-mortem break that occurred during butchery. PP13B also has similar direct evidence of killing and/or butchery in the cervical and thoracic region of ungulates. Three cases of embedded fragments of stone tools were recorded, one on a vertebral centrum, one on a

cervical vertebra zygopophysis, and one on a rib (Figure 75). All include entry points in the bone that indicate a very hard thrust with a stone tool, either as part of a killing or butchery apparatus. This is further supported by evidence from MSA sites that pointed lithic forms may have been hafted (Lombard, 2005; Bird *et al.*, 2007).

The fragment embedded in the zygopophysis closely resembles the actual tip of an MSA point, although because all examples are on quartzite it is difficult to tell for certain. Density-mediated destruction prevents us from examining axial element transport in detail, these fragments do provide further direct evidence that butchered vertebrae and ribs were brought to the site by MSA hominins. Although such evidence is compelling, it does not speak to the ubiquity of the action. It also does not rule out the possibility that the stone tool point embedded in the vertebra was in fact used for butchering rather than killing.

However, because these elements rank highest, this provides additional support to the result from the surface modification analysis that hominins had primary, hunted, access to carcasses. The plots of low-survival skeletal element representation versus food utility further emphasize this by showing a nearly-universal pattern of increasing representation with increasing nutritive value within the axial skeleton. These lines of evidence all together indicate a fully developed hunting ability for the occupants of Blombos and PP13B, with active hunting as the main mode of faunal acquisition for ungulates (Marean and Assefa, 1999).

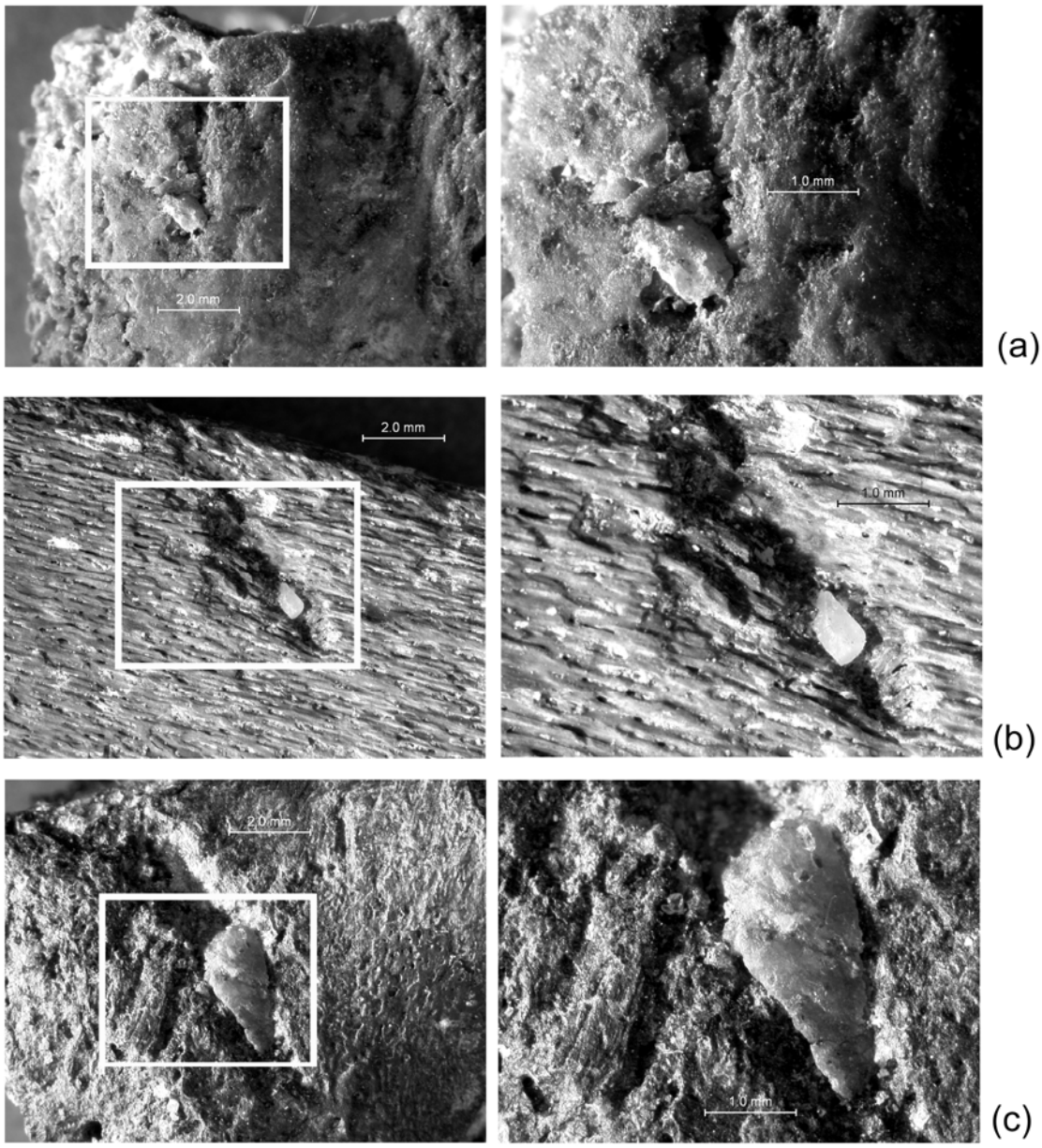


Fig. 75 Tips of stone tools embedded in a vertebral centrum (a), a rib (b), and the zygopophysis of a cervical vertebra (c).

The second hypothesis was that prey selection was focused on high return animals. Although hunting may have been the main mode of meat acquisition, this observatsion does not position the role of larger mammal hunting in its greater dietary

context. As discussed above, marine resource exploitation can provide many of the same nutrients as those available in large terrestrial mammal resources. The shellfish data are not yet available, but marine mammal representation is low at all three sites and fish remains a rare discovery at most MSA localities. Hominin modification has been located on fragments of small mammal and tortoise fossils at both PP13B and Blombos, but this has only been quantified at PP13B and shown at that site to be negligible.

Kaplan *et al.* (2000) have argued that over the course of human evolution a reliance on large, nutrient-dense resource packages became the preferred and most efficient form a resource could take. This is also borne out in the modern ethnographic record (e.g. Hawkes *et al.*, 1991). Marean *et al.* (2000b) showed that by about 70 ka large ungulates were likely the main focus of MSA faunal exploitation efforts at DK1. Large ungulates at PP13B and Blombos consistently show the highest degree of hominin modification. This is true starting in the MIS 6 deposits at PP13B and continues across both space and time to the observations made by Marean *et al.* (2000b) at DK1. Overall, this indicates that animal resources in large packages were indeed important enough to MSA groups to justify the amount of time and effort that must be allocated to their acquisition. When one includes training and practice for the maintenance of skill as well as the manufacture of suitable hunting weapons in this time and effort budget, the importance of this particular resource becomes even more apparent.

Despite the evidence that at PP13B, Blombos, and DK1 size 1 ungulates had the highest non-hominin input, there is some variability in the degree of this evidence. For example, at PP13B small ungulate representation increases during MIS 5 and with it so

does evidence for hominin exploitation of this body size class. At Blombos (which is within 200 km of PP13B) and during M3 times (which overlap with the MIS 5 deposits at PP13B), small ungulates are also relatively common in the deposits but are not implicated as the main hominin prey choice. This potentially speaks to variability in small ungulate exploitation strategies and the overall role these played in MSA diet, all within quite a constrained space and time interval.

The third hypothesis was that MSA assemblages would have prey body size profiles that are most similar to those taken by the dominant mammalian predators in an ecosystem. The ecological literature reviewed in the previous chapter indicates that the dominant mammalian predators on the landscape are those that normally take larger-bodied prey. Prey body size also increases with cooperative group hunting and the absence of potential competitor species. The data from DK1, the PP13B MIS 6 deposits, and the M1 and M3 deposits at Blomobs indicate an emphasis on large-bodied prey. This is in spite of the overall species abundances, which if taken at face value without any taphonomic analysis would have indicated much higher levels of small ungulate exploitation at all three sites.

The taxonomic and surface modification data further show a conspicuous absence of large-bodied carnivores that may have been sympatric with MSA hominins. This could be indicative of a high degree of inter-species avoidance between MSA hominins and carnivore species that could potentially be competitors for the same animal resources. Body size data differ at Blombos during M2 and at PP13B during MIS 5, which is slightly older. In these analytical units, there is a much higher representation of human-

accumulated small fauna. However, this is accompanied by the same lack of evidence for other large-bodied carnivore use of the same site. The most parsimonious interpretation is that although large ungulates were important to MSA hominin groups from MIS 6 onward, and although MSA hunters were fully capable of exploiting this resource, the overall strategy was a flexible one that was adjusted to suit the local terrain and community structure of available fauna. This does not detract from the implication that MSA hominins had a modern capacity for hunting, and in fact this flexible and successful response to changes in local conditions is one that is observed in the incredible variety of modern hunting practices seen today (e.g. Kelly, 1995).

At PP13B, Blombos, and DK1 the representation of large carnivore fossil remains is negligible. This indicates that despite the shelter provided by both sites these were not places that were chosen for lairing and the raising of offspring for large-bodied carnivores. Scavenging of human food refuse has been documented at both sites, as has a low independent input of size 1 ungulates. However, ungulates in this body size are not the normal prey of spotted hyenas or lions in South Africa. Instead, smaller and more solitary carnivores such as leopards, caracals (*Felis caracal*), and brown hyenas (*Parahyaena brunea*) are implicated (Estes, 1991).

Further evidence for this lies in the relatively low degree of tooth-marked versus percussion-marked midshafts, as Domínguez-Rodrigo and Barba (2007) have noted that bone-crunching carnivores such as canids and spotted hyenas leave much lower frequencies of tooth marks than do felids. The high degree of density-mediated destruction that has been documented at all three sites seems somewhat anomalous in

light of these observations, but at Blombos and PP13B a degree of hominin fragmentation of these portions has also been recorded. Lower-density portions may therefore have been deleted via several different avenues, with the combined effect of being equifinite to a pattern of purely carnivore destruction.

Overall, the taphonomic patterns and prey choice behaviors observed at PP13B and Blombos are in accordance with an ecosystem in which hominins were the dominant large-bodied predator on the landscape. Further work must be done at penecontemporaneous paleontological and archaeological sites to determine if this suggestive pattern is one that was ubiquitious throughout the late Middle and early Upper Pleistocene of Southern Africa.

Question two: carcass processing and transport strategies

The first hypothesis was that meat drying would be identified as a potential strategy for MSA hominins. Food hoarding behavior has a clear competitive advantage over non-hoarding. Not only can cached food be used at a later date, but the ability to take advantage of food-getting opportunities as they arise and cache the surplus can result in hoarders having access to a disproportionately large portion of a resource relative to competitors for the same resource. Several species, including insects, hoard or cache food for future use (Vander Wall, 1990). This clearly indicates that a large brain and advanced technological ability is not a prerequisite for food storage behavior. However, MSA groups with individuals who planned ahead for specific contingencies would have had an edge during times of stress over groups without these individuals.

Over time, subtle behavioral advantages such as this could have made the difference in reproductive success that eventually resulted in one or a few groups outcompeting and displacing adjacent populations. This is the general process aregued here to have led to the emergence of modern humans in Africa and their eventual ability to replace other, less closely related hominins outside the continent. Therefore, identifying certain advantageous behaviors such as food storage in the archaeological record is an important documentary step in the overall modern human origins debate.

Food caching in other large-bodied African predators is generally quite rare. Burying has been reported in African wild dogs (*Lycaon pictus*), but only on occasion and only during the breeding season when they are tied to dens with pups (Malcolm, 1980). Leopards (*Panthera pardus*) drag prey into trees to store them, which other felids have not been observed doing (Vander Wall, 1990), and they also engage in surplus killing because they are able to effectively protect their cached prey from other carnivores (Stuart, 1986). Spotted hyenas will cache chunks of meat or bones in still muddy water, which keeps other predators and scavengers from smelling it. They normally return within a day to retrieve it, apparently remembering the location by using visual landmarks (Kruuk, 1972).

In a survey by Creel and Creel (2002), which found that per capita food intake is usually higher for group rather than solitary hunters, leopards were not included. Interestingly, leopards are solitary carnivores that are unusual among other large-bodied African predators in that they cache food in trees to eat later. Other carnivores may experience higher per capita food intake while hunting in groups, but this intake must

take place quickly and in large quantities after the kill. A single lion or hyena taking a single medium-sized prey item is unlikely to be able to finish the entire carcass alone before the remainder of the kill is stolen by other predators. By caching their prey out of the reach of competitors, a single leopard ensures that it will have access to the entire carcass, which may compensate for the costs of solitary hunting.

Foragers in risky environments employ one of two strategies to maintain their populations through extended periods of scarcity: 1) food storage; or 2) hunting in group sizes that are influenced by both the mean foraging success of the group and its variance (Housten *et al.*, 1988). Therefore, the results of simple optimality and stochastic models are likely to coincide as in Packer *et al.* (1990). Variance of food intake declines with increasing group size, leading to shorter periods between meals – even if individual meals are not as large as they might otherwise be (Pulliam and Caraco, 1984; Housten *et al.* 1988).

The latter strategy is very much in evidence among modern humans such as the Hadza, where even though most hunting events do not include the entire group, everyone is allowed access to the resource after it has been acquired (Hawkes *et al.*, 1991). Large ungulate hunting success is highly variable, despite the returns being high when prey are acquired (Hawkes *et al.*, 1991). Therefore, hunters accomplish two things by sharing large game: they reduce the number of days without animal resources and they obviate the need for engaging in time-consuming food storage behaviors (Hawkes *et al.*, 1991). Therefore, in both modern human and carnivore examples from the tropics and subtropics, food storage and the degree of sociality seem to be negatively correlated

variables. This is not what one would expect given that planning and foresight have been implicated as possible hallmarks of modern human behavior, though this possibility is weakened in light of non-human primates also displaying a measure of foresight (Suddendorf, 2008).

The incidence of food storage changes as one moves into environments with more marked seasonality, and the practice takes on a critical role even in the face of highly variable group sizes (e.g. Binford, 1978; Helm, 1993; Abe, 2005). Such food-storage behavior is the type that can provide an individual or a group with sustenance through long periods of time, whereas in the tropics such periods are usually days or perhaps weeks without hunting success. Thus, the incidence of food storage may also be closely related to climatic stress, and could be a response to reducing variance in the acquisition of critical resources over prolonged periods (Housten *et al.*, 1988). For hominins with a relatively varied diet and for which variance in *hunting* success does not necessiarly equate to starvation, food storage of animal products is likely to be most beneficial when it is in a form that allows humans to access a regular source of fats and protein over a longer period of time. Meat drying is one such method.

Nilssen's (2000) ethnoarchaeological study of modern butchery includes a large dataset of the locations and forms of cut marks where the overall butchery strategy was aimed at the production of biltong (dried meat). The filleting only strategy described in Abe *et al.* (2002) is derived from this dataset. At all three sites discussed here, the main emphasis for long bone butchery was seen to be on filleting. Although this does not prove the meat drying was a strategy, it certainly supports the possibility.

Tortoises also provide an excellent source of transportable, storeable, easily-collectable fat and protein. The extremely slow metabolism of a tortoise allows it to be stored alive on its back for weeks at a time before it is consumed, and this practice is observed in modern hunter-gatherers (Hill pers. comm., 2007). PP13B showed evidence for tortoise processing in the form of percussion marks, cut marks, and burning. However, the sample was extremely small and at this site tortoise exploitation does not appear to have made an important contribution to the MSA diet. This provides yet another reason that tortoise taphonomy at sites where they are superabundant will make an important contribution to studies of MSA faunal resource behavior.

Question three: variability in MSA faunal exploitation behavior

Several lines of evidence have shown that the faunal accumulations at PP13B and Blombos, as well as published Layers 10 and 11 from DK1, were primarily the result of active hominin hunting and transport behavior. This is especially true for large fauna, with some variability in the degree to which size 1 ungulate transport was emphasized at each site. This means that on the landscapes around the sites, faunal acquisition effort would have been allocated to a strategy designed to maximize the chances of encountering and obtaining potential prey rather than a strategy targeted at obtaining scavenged resources. Despite both sites being the same in this regard, differences in topography and physical context between Blombos and PP13B suggest that these strategies should not have been identical.

Because carcass processing and transport occurs in several stages, each of which represents a series of decisions by the butcher, human-modified faunal assemblages can

be used to understand MSA decision-making with regards to subsistence, and how these decisions may have been modified to suit the particular context of a given site. Blombos stands out from the other two in terms of its artifactual assemblage, and there are distinct changes through time in these assemblages (Henshilwood *et al.*, 2001b). This indicates that there was more variability in MSA behavior than has commonly been portrayed, but until the faunal assemblages were closely examined it was not clear if such variability could also be detected in MSA subsistence strategies. The very different site contexts observed between Blombos and the other two sites discussed in this study indicate that comparisons between these sites are a good place to begin examining the evidence for such variability.

The first hypothesis was that Blombos would show a greater emphasis on small ungulate transport than PP13B or DK1. An overall examination of body size representation by NISP shows that the Blombos faunal assemblage fits this expectation in comparison to all analytical units combined at PP13B and published data from DK1. More variability is seen when the data are broken down by layer or analytical unit, but even a layer-by-layer examination of the data indicates that small ungulates are indeed more highly represented at Blombos. Small (size 1 and 2) ungulates in each major layer at Blombos still comprise a larger proportion of those sub-assemblages than is seen in either MIS 5 or MIS 6 at PP13B, or in Layer 10 or 11 at DK1. The smallest proportion of small ungulates at Blombos is in M1 (65%), which approximates but is still higher than the largest proportion seen at PP13B (62%).

The fragmentation data indicate that this high representation of small ungulates is not attributable to a greater degree of fragmentation in this body size class, and indeed there is less percussion activity on the midshafts of small ungulates than there is on larger ungulates. Small ungulates do appear to have suffered slightly lower degrees of density-mediated destruction at Blombos, which could lead to elevated representation of these body size classes. However, the other two sites also show this general pattern and owing to this the two should remain comparable. Finally, it is important to note that slightly elevated input from non-human accumulators (likely carnivores) was observed for size 1 fauna during MIS 6 at PP13B and during M3 at Blombos. Therefore, the pattern of higher representation of small ungulates at Blombos appears to be true, but not to the extent implied by taking body size abundances at face value.

The second hypothesis was that Blombos would have evidence that individuals with a body size of three or higher were more extensively processed off-site than they were at PP13B or DK1. The degree to which carcasses were actually processed off- versus on-site remains unknown from the surface modification data, but can be inferred to a certain extent from the degree of selective transport as shown by estimates of skeletal element abundance. Owing to the presence of bone marrow all long bones have nutritive value, but that of metapodials is less relative to the upper limb portions because they are not also a meat-bearing element (Metcalfe and Jones, 1988). Relative representation of metapodials is therefore predicted to be higher for small animals because they can be more easily transported whole (Metcalfe and Barlow, 1992), and lower for large animals as these elements can be quickly processed and discarded off-site. The ratio of proximal

to distal limbs initially seemed to be quite biased against metapodials, but when analyzed statistically was shown to approximate a whole-limb transport strategy for all body size classes at all sites – the same result as was obtained in the cut mark analysis. In support of this, the %MAU versus SFUI data also failed to show convincing evidence for selective transport of long bones in accordance with their utility at any of the sites.

The general lack of patterning and statistical significance within the low-survival set is also seen in the low-survival set at Blombos, but is countered by the consistently positive correlation between food utility and bone representation in the low-survival set at PP13B and DK1. This fits well with the implication that more processing of spongy bones was taking place at PP13B than at Blomobs, given that in the modern Hadza axial elements are transported for further processing that includes the careful removal of bits of flesh adhering to vertebral processes (Marean and Cleghorn, 2003) as well as grease rendering by boiling (Lupo, 1995). However, this result is not in accordance with the hypothesis that more extensive carcass-processing of larger ungulates should take place off-site. Indeed, with the exception of body size representation, none of the expectations of a maximization strategy for bone transport are met at Blombos.

One question that arises from these results is that posed by Marean and Cleghorn (2003:39), who ask if after proper taphonomic adjustments have been made, "[i]s this high survival set sufficiently diverse and behaviorally sensitive to allow us to ask interesting foraging theory questions?". The answer is likely yes, provided the sample size is sufficiently large and the amount of time over which a faunal assemblage was accumulated is sufficiently small. Maximization predications from optimal foraging

theory with regards to skeletal element abundance are predictions that should be true overall for any animal with initial access to complete, fleshed carcasses. This includes both 'modern' and 'non-modern' hominins.

In fact, the data presented above imply that the failure to identify a clear and consistent pattern of transport based on a maximization strategy at any site is potentially attributable to other factors related to the decision-making process that are currently not identified in the MSA hominin behavioral repertoire. It is possible that these data are simply indicating that the sites were occupied at such a low intensity over an extended period of time that the faunal assemblages reflect different individual transport decisions, each of which was based on so many unknowable variables that very little patterning remains. This in turn suggests that the 'speleo-centric' view of caves as living sites or home bases to which MSA hominins regularly returned with transported resources is entirely attributable to these sites acting as preservational loci for human behavioral debris rather than any actual preference for these sites on the parts of the hominins in question.

Conclusions

Understanding the timing and nature of the emergence of 'modern human behavior' has historically been a sort of Holy Grail for archaeologists, and in many ways just as elusive. The empirical record that forms the essential basis of such research has grown slowly and in a piecemeal fashion, offering many surprises and forcing reconsiderations of what was thought to be evidentiary fact only a few decades ago. Theoretical and epistemological approaches to interpreting this newly available record remain in flux as an increasing research focus in the relevant time period - the MSA - continues to produce new evidence.

The study presented here inserts several important datapoints into this growing body of research. A detailed taphonomic examination of two new coastal MSA sites corroborates what was previously suggested for the later site of DK1 regarding MSA prey choice and hunting ability. This indicates that at least in the Western Cape, South Africa, MSA hominins had a fully developed hunting economy in place by MIS 6, and were dominant predators in their respective ecosystems. However, subtle differences over time and between sites were observed to such an extent that variability and flexibility in the details of faunal exploitation seem to have characterized overall subsistence strategies during a time period traditionally considered to be rather static and homogenous. It is within this variability that new innovations and strategies would potentially have emerged and provided advantages for some MSA groups over others as they competed on the landscape on for the same resources. A summary of the major findings of this research is provided in Table 34.

Table 34

Summary of the major findings of the study in light of research questions relevant to the modern human origins debate

Pattern of faunal acquisition	- MSA hominins were the primary accumulators of the large mammals at all three sites - MSA hunters had regular access to complete, fleshed carcasses - Focus was on larger (size 3 – 4) ungulates at all sites - Smaller (size 1 – 2) ungulates were taken variably over time, perhaps more when local environments favored their abundance - At PP13B small vertebrates were not commonly used as sources of fats and proteins - An emphasis on large mammal hunting suggests that valuable animal resources were primarily acquired by able-bodied hunters (males?) - Focus on large ungulate hunting implies food sharing within the group
Carcass processing and transport	- Carcasses were fully processed, from initial evisceration to grease extraction - Meat drying may have been a strategy (based on evidence for filleting) - Grease extraction has not been previously documented in the MSA and may have been advantageous during periods of extreme climate - Small and large ungulates were not differentially transported in any discernable pattern over time - All three assemblages likely represent a variety of individual processing and transport decisions and therefore do not show a consistent pattern
Variability in MSA behavior	- MSA subsistence strategies vary subtly over time and space - The most obvious variability is in taxonomic abundances, which may directly reflect climate as well as prey choice - It is difficult to assign particular strategies to particular time periods or localities - Variability cannot be explained in terms of simple optimization - Major shifts or 'revolutions' in subsistence strategies are not apparent at any point between ca. 175 and 65 ka, nor are gradual innovations - Basic strategies seem to have been in place prior to the end of MIS 6

New datasets are particularly needed for the less-commonly examined components of MSA faunal assemblages, which include the tortoises and small mammals. All of these potential contributions to the MSA diet must then be combined with shellfish data to obtain a complete picture of potential strategies for obtaining critical lipids and proteins. It is equally important to derive a sample of comparably-studied MSA faunal assemblages from other areas of Southern Africa – and eventually further afield – in order to determine how the near-coastal or coastal placement of the sites considered here potentially influenced MSA subsistence strategies. For example, an even greater emphasis on the hunting of large terrestrial mammals concurrent with an opportunistic exploitation of scavenged brain and marrow resources may be expected at inland sites, where access to DHA through marine sources or storeable and transportable fats and proteins in the form of tortoises may not have been as immediately available.

Despite the fact that the modern human origins debate cannot be resolved without an adequate empirical basis, it is also not a problem that can be resolved simply through the generation of multiple large datasets. These datasets must be employed carefully, and in ways that are comparable to one another. The case studies presented here highlight the need for workers to continue building the empirical record with standardized data collection methods, and to carefully assess the taphonomic histories of faunal assemblages prior to interpreting them in light of hominin behavior. It is only through the wedding of solid data collection techniques, comparable analytical methods rooted in

actualistic observations, and the innovative development of theory that the emergence of modern human behavior can be most confidently understood.

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APPENDIX A

TAXONOMIC ABUNDANCES BY NISP AT PP13B AND BLOMBOS

	Size Indet.						
PP13B Analytical Unit	1	2	3	4	5	6	7
Class Mammalia							
Mammal	198	785	1145	469	529	40	689
Marine Mammal	1	5	7	6	0	0	8
Terrestrial Mammal	72	196	221	113	130	59	357
Order Carnivora	0	0	0	0	0	0	0
Fam. Hyenidae	0	0	0	0	0	0	0
Fam. Otariidae/Phocidae	0	0	0	0	0	0	0
Order Primates	0	0	0	0	0	0	0
Superorder Ungulata	1	10	7	2	5	0	13
Order Artiodactyla	0	0	0	0	0	0	0
Fam. Bovidae	17	70	192	20	73	2	34
Fam. Suidae	0	0	0	0	0	0	0
Fam. Hippopotamidae	0	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0	0
Fam. Equidae	0	0	0	0	0	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0	0
Totals	289	1066	1572	610	737	101	1101

	Size 1						
PP13B Analytical Unit	1	2	3	4	5	6	7
Class Mammalia							
Mammal	32	145	294	88	31	6	71
Marine Mammal	1	4	5	0	0	0	5
Terrestrial Mammal	49	170	410	134	40	44	276
Order Carnivora	0	0	8	1	7	0	2
Fam. Hyenidae	0	0	0	0	0	0	0
Fam. Otariidae/Phocidae	0	1	0	0	1	0	0
Order Primates	0	15	0	0	0	0	0
Superorder Ungulata	5	4	34	10	4	2	13
Order Artiodactyla	0	73	9	3	0	0	2
Fam. Bovidae	20	0	187	59	34	11	30
Fam. Suidae	0	0	0	0	0	0	0
Fam. Hippopotamidae	0	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0	0

Fam. Equidae	0	0	0	0	0	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0	0
Totals	107	412	947	295	117	63	399

	Size 2						
PP13B Analytical Unit	1	2	3	4	5	6	7
Class Mammalia							
Mammal	20	78	167	38	31	4	46
Marine Mammal	1	0	4	0	0	1	1
Terrestrial Mammal	44	162	405	128	64	39	342
Order Carnivora	2	2	6	1	3	0	0
Fam. Hyenidae	0	0	0	0	3	0	0
Fam. Otariidae/Phocidae	0	7	7	1	1	0	0
Order Primates	1	23	0	0	1	0	0
Superorder Ungulata	4	4	47	8	7	2	17
Order Artiodactyla	3	101	16	1	4	0	10
Fam. Bovidae	22	1	173	50	44	6	57
Fam. Suidae	0	0	0	1	1	0	0
Fam. Hippopotamidae	0	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0	0
Fam. Equidae	0	0	0	0	0	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0	0
Totals	97	378	825	228	159	52	473

	Size 3					
PP13B Analytical Unit	1	2	3	4	5	6
Class Mammalia						
Mammal	15	76	147	20	24	2
Marine Mammal	0	3	3	0	2	0
Terrestrial Mammal	56	206	495	74	112	26
Order Carnivora	0	0	2	0	0	0
Fam. Hyenidae	0	0	0	0	0	0
Fam. Otariidae/Phocidae	0	1	4	0	1	0
Order Primates	0	39	0	0	0	0
Superorder Ungulata	7	2	46	9	16	3
Order Artiodactyla	0	88	11	3	2	1
Fam. Bovidae	19	0	175	17	37	5
Fam. Suidae	0	0	0	0	0	0

Fam. Hippopotamidae	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0
Fam. Equidae	0	0	0	0	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0
Totals	97	415	883	123	194	37

				Size 4			
PP13B Analytical Unit	1	2	3	4	5	6	7
Class Mammalia							
Mammal	6	31	38	5	8	0	17
Marine Mammal	0	0	0	0	0	0	0
Terrestrial Mammal	10	74	102	9	23	7	61
Order Carnivora	0	0	0	0	0	0	0
Fam. Hyenidae	0	0	0	0	0	0	0
Fam. Otariidae/Phocidae	0	0	0	0	0	0	0
Order Primates	0	12	0	0	0	0	0
Superorder Ungulata	9	0	17	1	9	1	13
Order Artiodactyla	0	40	1	0	1	0	0
Fam. Bovidae	11	0	16	3	13	0	8
Fam. Suidae	0	0	0	0	0	0	0
Fam. Hippopotamidae	0	0	0	0	0	0	0
Order Perissodactyla	0	1	0	0	1	0	0
Fam. Equidae	1	0	1	1	3	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0	0
Totals	37	158	175	19	58	8	99

				Size 5			
PP13B Analytical Unit	1	2	3	4	5	6	7
Class Mammalia							
Mammal	3	14	3	1	3	0	1
Marine Mammal	0	0	0	1	0	0	1
Terrestrial Mammal	4	13	13	3	3	0	11
Order Carnivora	0	0	0	0	0	0	0
Fam. Hyenidae	0	0	0	0	0	0	0
Fam. Otariidae/Phocidae	0	0	0	0	0	0	0
Order Primates	0	4	0	0	0	0	0
Superorder Ungulata	0	0	2	0	5	0	1

Order Artiodactyla	0	1	0	1	0	0	0
Fam. Bovidae	4	0	2	0	4	0	1
Fam. Suidae	0	1	0	0	0	0	0
Fam. Hippopotamidae	0	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0	0
Fam. Equidae	0	1	0	0	0	0	0
Fam. Rhinocerontidae	0	0	0	0	0	0	0
Totals	11	34	20	6	15	0	15

	Size Indet.			Size 1		
BBC Layer	M1	M2	M3	M1	M2	M3
Class Mammalia						
Mammal	503	321	191	170	196	71
Marine Mammal	35	4	3	3	3	0
Terrestrial Mammal	226	144	120	685	740	287
Order Carnivora	0	0	0	11	8	5
Family Canidae	0	0	0	0	1	2
Family Felidae	0	0	0	6	1	3
Family Otariidae/Phocidae	1	0	0	18	8	12
Superorder Ungulata	0	1	0	16	25	10
Order Artiodactyla	0	0	0	2	6	3
Family Bovidae	3	1	1	255	323	151
Family Hippopotamidae	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0
Family Equidae	0	0	0	0	0	0
Family Rhinocerontidae	0	0	0	0	0	0
Totals	768	471	315	1166	1311	544

	Size 2			Size 3		
BBC Layer	M1	M2	M3	M1	M2	M3
Class Mammalia						
Mammal	173	59	28	182	56	30
Marine Mammal	26	4	3	27	5	4
Terrestrial Mammal	423	166	96	308	140	94
Order Carnivora	3	3	0	0	0	0
Family Canidae	0	0	0	0	0	0
Family Felidae	2	0	0	0	0	0

Family Otariidae/Phocidae	47	13	22	18	3	0
Superorder Ungulata	22	7	3	67	25	7
Order Artiodactyla	5	10	5	11	1	0
Family Bovidae	152	62	16	146	47	20
Family Hippopotamidae	0	0	0	0	0	0
Order Perissodactyla	0	0	0	0	0	0
Family Equidae	0	0	0	0	0	0
Family Rhinocerontidae	0	0	0	0	0	0
Totals	853	324	173	759	277	155

	Size 4			Size 5		
BBC Layer	M1	M2	M3	M1	M2	M3
Class Mammalia						
Mammal	52	11	9	12	2	9
Marine Mammal	1	0	0	0	0	0
Terrestrial Mammal	105	26	24	14	0	1
Order Carnivora	0	0	0	0	0	0
Family Canidae	0	0	0	0	0	0
Family Felidae	0	0	0	0	0	0
Family Otariidae/Phocidae	0	0	0	0	0	0
Superorder Ungulata	29	13	9	6	1	1
Order Artiodactyla	0	0	0	0	0	0
Family Bovidae	79	18	10	17	3	4
Family Hippopotamidae	0	0	0	4	0	0
Order Perissodactyla	0	0	0	0	0	0
Family Equidae	7	2	0	0	0	0
Family Rhinocerontidae	0	0	0	4	0	1
Totals	273	70	52	57	6	16

APPENDIX B

FRAGMENTATION DATA BY NISP AT PP13B AND BLOMBOS

	Size 1						
	PP13B Analytical Unit						
Fracture Angle	1	2	3	4	5	6	7
Oblique	53	130	451	153	57	56	363
Oblique/Right	1	5	7	5	3	1	8
Right	23	41	99	30	16	28	139
Total	77	176	557	188	76	85	510

	PP13B Analytical Unit						
Fracture Outline	1	2	3	4	5	6	7
Curved/V-Shaped	59	133	465	153	59	54	376
Intermediate	0	0	1	1	0	0	3
Transverse	17	39	83	31	17	30	124
Transverse/Curved	1	4	8	3	0	1	7
Total	77	176	557	188	76	85	510

	Size 2						
	PP13B Analytical Unit						
Fracture Angle	1	2	3	4	5	6	7
Oblique	64	251	522	181	113	45	503
Oblique/Right	0	9	17	6	1	2	13
Right	24	53	159	38	34	24	170
Total	88	313	698	225	148	71	686

	PP13B Analytical Unit						
Fracture Outline	1	2	3	4	5	6	7
Curved/V-Shaped	70	251	529	188	116	48	506
Intermediate	0	2	3	0	0	1	2
Transverse	17	53	151	33	29	22	160
Transverse/Curved	1	7	15	4	3	0	18
Total	88	313	698	225	148	71	686

	Size 3						
	PP13B Analytical Unit						
Fracture Angle	1	2	3	4	5	6	7
Oblique	66	298	654	99	133	35	460
Oblique/Right	2	9	28	2	4	2	12
Right	15	84	197	36	50	16	120
Total	83	391	879	137	187	53	592

	PP13B Analytical Unit

Fracture Outline	1	2	3	4	5	6	7
Curved/V-Shaped	62	302	657	107	135	40	458
Intermediate	1	0	4	0	2	0	1
Transverse	18	82	196	28	47	11	122
Transverse/Curved	2	7	22	2	3	2	11
Total	83	391	879	137	187	53	592

	Size 4						
	PP13B Analytical Unit						
Fracture Angle	1	2	3	4	5	6	7
Oblique	25	123	128	11	36	6	84
Oblique/Right	1	4	7	1	2	0	3
Right	0	28	29	3	6	3	16
Total	26	155	164	15	44	9	103

	PP13B Analytical Unit						
Fracture Outline	1	2	3	4	5	6	7
Curved/V-Shaped	23	118	121	9	35	5	86
Intermediate	1	0	1	0	1	0	0
Transverse	2	33	39	6	7	4	16
Transverse/Curved	0	4	3	0	1	0	1
Total	26	155	164	15	44	9	103

	Size 5						
	PP13B Analytical Unit						
Fracture Angle	1	2	3	4	5	6	7
Oblique	5	17	14	6	6	0	16
Oblique/Right	0	0	3	0	1	0	0
Right	5	8	3	0	0	0	7
Total	10	25	20	6	7	0	23

	PP13B Analytical Unit						
Fracture Outline	1	2	3	4	5	6	7
Curved/V-Shaped	6	18	15	5	4	0	19
Intermediate	0	0	0	0	0	0	0
Transverse	4	7	5	1	2	0	4
Transverse/Curved	0	0	0	0	1	0	0
Total	10	25	20	6	7	0	23

	Size 1			Size 2		
	BBC	BBC	BBC	BBC	BBC	BBC
Fracture Angle	M1	M2	M3	M1	M2	M3

Oblique	816	812	399	502	184	134
Oblique/Right	27	28	3	25	6	7
Right	343	459	85	215	102	35
Total	1186	1299	487	742	292	176

	Size 1			Size 2		
Fracture Outline	BBC M1	BBC M2	BBC M3	BBC M1	BBC M2	BBC M3
Curved	875	902	398	546	215	142
Intermediate	8	4	1	7	1	2
Transverse	275	359	79	158	74	28
Transverse/Curved	28	34	9	31	2	4
Total	1186	1299	487	742	292	176

	Size 3			Size 4		
Fracture Angle	BBC M1	BBC M2	BBC M3	BBC M1	BBC M2	BBC M3
Oblique	412	196	155	141	33	33
Oblique/Right	24	16	3	18	3	2
Right	127	67	25	51	15	8
Total	563	279	183	210	51	43

	Size 3			Size 4		
Fracture Outline	BBC M1	BBC M2	BBC M3	BBC M1	BBC M2	BBC M3
Curved	424	207	151	149	38	31
Intermediate	9	1	0	1	1	1
Transverse	111	61	26	50	10	9
Transverse/Curved	19	10	6	10	2	2
Total	563	279	183	210	51	43

	Size 5		
Fracture Angle	BBC M1	BBC M2	BBC M3
Oblique	8	2	5
Oblique/Right	1	0	0
Right	4	0	2
Total	13	2	7

	Size 5		
Fracture Outline	BBC M1	BBC M2	BBC M3
Curved	8	2	7

Intermediate	1	0	0
Transverse	3	0	0
Transverse/Curved	1	0	0
Total	13	2	7

APPENDIX C

SKELETAL ELEMENT ABUNDANCES BY NISP AT PP13B AND BLOMBOS

Element	Carnivore/Primate							Mammal						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Horn Core	0	0	0	0	0	0	0	0	0	3	0	2	0	0
Cranial	0	0	0	0	0	0	0	25	168	333	99	65	6	86
Hyoid	0	0	0	0	0	0	0	0	0	4	1	0	0	4
Maxilla	0	0	0	0	0	0	0	1	0	2	1	1	0	0
Mandible	0	0	0	0	1	0	0	2	23	26	8	14	0	10
Alveolus	0	0	0	0	0	0	0	11	41	61	19	30	2	18
Isolated Tooth	2	1	3	1	10	0	1	96	358	290	245	388	15	249
Atlas	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Axis	0	0	0	0	0	0	0	0	2	2	1	0	0	0
Cervical	0	0	0	0	0	0	0	10	21	62	9	2	1	8
Thoracic	0	0	0	0	0	0	0	5	20	52	10	6	0	9
Lumbar	0	0	0	0	0	0	0	14	38	65	9	8	1	19
Sacrum	0	0	0	0	0	0	0	2	0	1	1	0	0	0
Caudal Vertebra	0	0	0	0	0	0	0	1	4	11	4	1	0	4
Indet.	0	0	0	0	0	0	0	25	87	272	67	24	3	67
Sternum	0	0	0	0	0	0	0	0	2	3	0	0	0	0
Rib	0	0	0	0	0	0	0	62	274	462	109	49	13	260
Costal Cartilage	0	0	0	0	0	0	0	4	20	22	5	9	2	4
Humerus	0	1	1	1	0	0	0	0	0	1	1	0	0	0
Radius	1	0	1	0	0	0	1	1	1	1	0	0	0	1
Ulna	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Metacarpal	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Femur	0	0	0	0	0	0	0	1	0	1	0	1	0	1
Tibia	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Metatarsal	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Metapodial	0	0	3	0	0	0	0	0	0	0	1	0	0	0
Long Bone Frag.	0	0	0	0	0	0	0	6	34	73	19	13	8	99
Long Bone Flake	0	0	0	0	0	0	0	2	7	8	3	4	1	28
Phalanx 1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Phalanx 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalanx 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalanx Indet.	0	0	0	0	0	0	0	1	0	3	0	0	0	2
Scapula	0	0	0	0	0	0	0	1	4	1	0	2	0	2

Innominate	0	0	2	0	0	0	0	1	8	3	2	1	0	9
Small Carpals	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Astragalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcaneus	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Small Tarsals	0	0	0	0	2	0	0	0	1	0	0	0	0	0
Compact/Sesamoid	0	0	0	0	0	0	0	3	15	29	6	6	0	7
Patella	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Element	Marine Mammal							Terrestrial Mammal						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Horn Core	0	1	0	0	0	0	0	0	0	1	5	0	0	5
Cranial	0	0	0	0	0	0	0	0	2	1	1	0	0	7
Hyoid	0	0	0	0	0	0	0	0	0	2	2	0	0	1
Maxilla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mandible	0	0	0	0	0	0	1	0	0	3	0	0	0	1
Alveolus	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Isolated Tooth	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Atlas	0	0	0	0	0	0	0	0	1	2	0	0	0	0
Axis	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cervical	0	0	1	0	0	0	0	0	5	7	2	1	0	1
Thoracic	0	0	0	0	0	0	0	0	14	28	4	4	0	3
Lumbar	0	0	0	0	0	0	0	4	20	30	20	5	1	15
Sacrum	1	0	0	0	0	0	0	0	1	1	0	0	0	0
Caudal Vertebra	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Indet.	0	2	3	1	0	0	0	0	1	3	0	0	1	1
Sternum	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Rib	1	7	8	4	0	1	8	13	90	155	22	8	2	31
Costal Cartilage	0	1	0	1	1	0	0	0	3	12	2	4	0	0
Humerus	0	1	0	0	0	0	0	1	5	14	3	1	0	3
Radius	0	0	0	0	0	0	0	0	1	1	1	1	0	1
Ulna	0	0	1	0	0	0	0	0	0	1	1	0	0	0
Metacarpal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Femur	0	1	0	0	0	0	0	0	3	6	3	3	1	3
Tibia	0	0	0	0	0	0	0	2	12	22	2	4	1	11
Metatarsal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metapodial	0	0	1	0	1	0	0	0	0	5	1	1	0	2
Long Bone	0	0	4	2	1	0	6	155	494	101	306	263	15	931

Frag.										0			0	
Long Bone														
Flake	1	0	0	0	0	0	1	49	139	261	71	64	19	321
Phalanx 1	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Phalanx 2	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Phalanx 3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Phalanx														
Indet.	0	6	8	0	2	0	0	2	9	12	2	1	0	3
Scapula	0	0	0	0	0	0	0	3	5	20	8	7	0	4
Innominate	0	1	0	0	0	0	0	5	9	33	3	3	0	3
Small														
Carpals	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcaneus	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Small														
Tarsals	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Compact/S														
esamoid	0	0	2	0	0	0	0	1	3	9	0	2	0	4
Patella	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Element	Ungulate						
	1	2	3	4	5	6	7
Horn Core	16	71	188	17	74	0	35
Cranial	2	7	7	3	4	0	1
Hyoid	0	0	0	0	0	0	0
Maxilla	1	5	8	2	2	0	0
Mandible	3	22	40	5	7	0	9
Alveolus	0	0	1	1	0	0	0
Isolated							
Tooth	10	27	47	13	33	5	15
Atlas	0	2	2	1	0	0	1
Axis	0	0	3	0	0	0	0
Cervical	1	1	4	0	1	0	1
Thoracic	2	10	10	5	4	1	2
Lumbar	0	1	3	1	0	0	1
Sacrum	0	0	0	0	0	0	0
Caudal	0	0	1	0	0	0	0
Vertebra							
Indet.	0	1	0	0	0	0	0
Sternum	1	2	0	0	0	0	1
Rib	7	16	37	3	8	1	11
Costal							
Cartilage	0	1	0	0	0	0	0

Humerus	6	25	58	15	14	0	15
Radius	5	27	77	21	10	2	12
Ulna	1	15	33	8	7	4	9
Metacarpal	3	12	20	3	4	1	7
Femur	2	21	23	15	11	0	9
Tibia	8	30	52	11	10	2	31
Metatarsal	3	19	22	0	10	1	10
Metapodial	9	27	59	9	15	1	13
Long Bone Frag.	5	14	14	9	4	3	25
Long Bone Flake	0	6	6	1	4	1	8
Phalanx 1	5	15	52	7	4	4	11
Phalanx 2	2	20	26	4	3	3	9
Phalanx 3	6	11	12	0	4	2	4
Phalanx Indet.	0	0	3	2	3	0	5
Scapula	3	13	16	0	5	0	6
Innominate	6	24	42	10	8	1	7
Small Carpals	5	8	17	7	7	0	4
Astragalus	1	6	5	0	1	0	0
Calcaneus	2	5	8	4	0	0	1
Small Tarsals	3	3	10	5	1	0	4
Compact/Sesamoid	3	22	27	7	4	1	13
Patella	2	1	3	0	1	0	1

Element	Carnivore			Mammal			Mar. Mamm.		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
Atlas	0	0	0	1	0	0	0	0	0
Axis	1	0	0	1	0	0	0	0	0
Cervical	1	0	0	50	33	11	10	1	0
Thoracic	0	0	0	39	29	17	9	0	0
Lumbar	0	1	0	29	19	12	3	1	0
Sacrum	0	0	0	3	1	1	0	0	0
Caudal	0	0	0	3	2	1	0	1	0
Vertebra Indet.	0	0	0	213	98	47	9	2	1
Sternum	0	0	0	1	1	2	0	1	0

Rib	0	0	0	338	231	86	35	5	8
Costal Cartilage	0	0	0	102	32	16	3	0	0
Humerus	2	1	1	5	5	0	7	1	2
Radius	3	3	1	7	1	0	1	0	1
Ulna	1	0	0	2	3	1	3	0	0
Metacarpal	0	1	0	0	0	0	0	0	2
Femur	1	1	0	6	4	0	4	0	0
Tibia	0	1	0	2	1	0	2	0	0
Metatarsal	2	0	0	0	0	0	2	0	0
Metapodial	4	0	5	1	4	0	5	0	0
Long Bone Frag.	0	0	0	163	97	74	21	3	2
Long Bone Flake	0	0	0	48	47	59	2	2	0
Phalanx 1	1	0	0	0	0	0	0	1	0
Phalanx 2	2	0	0	0	0	0	0	0	0
Phalanx 3	0	0	1	0	0	0	6	4	3
Phalanx Indet.	1	0	1	5	3	1	34	15	20
Scapula	1	0	0	4	5	1	9	1	1
Innominate	0	0	0	15	6	1	8	1	1
Small Carpals	0	0	1	0	0	0	0	1	2
Astragalus	0	1	0	0	0	0	0	0	0
Calcaneus	0	0	0	2	0	1	0	0	0
Small Tarsals	2	4	0	0	1	0	2	0	1
Compact/Sesamoid	0	0	0	52	22	7	1	0	0
Patella	0	0	0	0	0	0	0	0	0

Element	Terr. Mamm			Ungulate		
	M1	M2	M3	M1	M2	M3
Atlas	0	0	0	4	2	4
Axis	0	0	0	4	2	0
Cervical	8	3	1	6	4	2
Thoracic	15	12	8	21	11	6
Lumbar	11	16	1	8	6	5
Sacrum	2	1	0	0	1	1
Caudal	2	0	0	0	0	1
Vertebra Indet.	4	7	4	1	0	0
Sternum	1	0	0	0	0	0
Rib	64	52	18	7	15	4
Costal Cartilage	0	3	1	0	0	0
Humerus	19	16	4	69	44	12
Radius	5	1	1	35	35	10
Ulna	0	0	0	15	12	2
Metacarpal	0	0	0	34	30	7
Femur	10	9	5	49	31	15

Tibia	37	25	14	88	34	17
Metatarsal	0	0	0	45	20	9
Metapodial	1	4	0	152	72	37
Long Bone Frag.	##	833	351	2	7	0
Long Bone Flake	##	172	194	0	0	0
Phalanx 1	6	6	4	66	66	16
Phalanx 2	1	0	0	40	37	18
Phalanx 3	1	0	0	25	16	14
Phalanx Indet.	24	27	8	2	0	3
Scapula	13	12	0	23	7	8
Innominate	26	11	3	38	27	12
Small Carpals	0	0	0	18	22	14
Astragalus	0	2	0	4	5	2
Calcaneus	1	0	0	12	3	4
Small Tarsals	0	0	0	22	13	10
Compact/Sesamoid	9	4	5	34	21	6
Patella	0	0	0	1	2	2

APPENDIX D

GIS-DERIVED MNE VALUES FROM PP13B, BLOMBOS, AND DK1

Light Brown Sand 1 (1)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		0		0		0		0		0		0	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	2		1		1		1		1		3		6	
Thoracic Vertebrae	2		1		1		1		0		3		5	
Lumbar Vertebrae	2		2		2		0		1		3		7	
Sacrum	1		2		0		0		0		3		3	
Mandible	0	0	0	0	1	1	0	0	0	0	1	1	1	1
Rib	1	3	0	1	0	1	1	2	0	0	1	3	2	7
Scapula	0	0	0	1	0	2	0	0	0	0	0	3	0	3
Humerus	1	0	1	1	0	0	1	1	0	0	2	1	3	2
Radius	0	0	1	0	0	1	0	2	0	0	1	2	1	3
Ulna	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Metacarpal	0	0	0	0	2	0	0	0	0	1	2	1	2	1
Pelvis	2	0	1	0	1	1	0	0	0	0	3	1	4	1
Femur	0	0	1	0	0	0	0	0	0	0	1	0	1	0
Tibia	0	1	0	1	1	0	0	1	0	0	1	2	1	3
Metatarsal	0	0	0	0	0	0	1	0	0	0	1	0	1	0

Upper Dark Brown Sand/LC-MSA Upper (2)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		1		0		0		0		1		1	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	5		2		2		1		1		6		11	
Thoracic Vertebrae	5		3		4		5		0		13		17	
Lumbar Vertebrae	8		3		5		2		1		12		19	
Sacrum	1		0		0		0		0		1		1	
Mandible	5	2	1	2	1	1	0	1	0	0	5	4	7	6
Rib	8	1	3	4	4	5	2	1	1	1	10	14	18	22

		1												
Scapula	3	1	2	0	5	0	0	0	0	0	6	1	10	1
Humerus	1	2	3	2	1	2	1	1	0	0	4	5	6	7
Radius	1	3	3	2	2	1	0	0	0	0	5	4	6	6
Ulna	0	0	4	3	1	0	0	0	0	0	4	3	5	3
Metacarpal	0	1	2	2	0	2	1	0	0	0	3	3	3	5
Pelvis	2	2	1	3	2	1	0	1	0	0	3	3	5	7
Femur	1	3	3	1	2	1	0	1	0	0	5	5	6	6
Tibia	1	1	0	3	0	2	3	1	0	1	6	5	4	8
Metatarsal	0	0	2	2	1	2	1	2	0	0	2	3	4	6

Shelly Brown Sand/Upper Roof Spall (3)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		2		0		0		0		2		2	
Axis	0		1		1		0		0		2		2	
Cervical Vertebrae	10		5		4		1		1		20		21	
Thoracic Vertebrae	17		6		5		3		1		24		32	
Lumbar Vertebrae	8		8		8		1		0		15		25	
Sacrum	0		1		1		0		0		2		2	
Mandible	2	4	2	3	1	3	0	0	0	0	4	8	5	10
Rib	0	8	3	5	4	4	2	1	0	0	14	13	19	18
Scapula	3	2	0	2	1	1	0	0	0	0	4	3	4	5
Humerus	3	4	3	4	3	3	0	1	0	0	6	9	9	12
Radius	4	4	4	4	3	4	0	0	0	0	4	9	11	12
Ulna	2	1	2	1	2	3	0	1	0	0	4	4	6	6
Metacarpal	1	1	1	2	2	2	0	0	0	0	3	3	4	5
Pelvis	4	4	1	1	3	2	0	0	0	0	5	5	8	7
Femur	1	1	2	3	1	2	0	1	0	0	2	4	4	7
Tibia	3	4	2	1	4	3	1	0	0	0	7	4	10	8
Metatarsal	1	1	2	1	3	3	0	4	0	0	3	4	6	9

Lower Roof Spall (4)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L

Atlas	0		1		0		0		0		1	
Axis	0		0		0		0		0		0	
Cervical Vertebrae	3		1		1		0		0		5	
Thoracic Vertebrae	6		3		1		1		0		8		11	
Lumbar Vertebrae	5		2		2		1		1		7		11	
Sacrum	1		0		0		0		0		1		1	
Mandible	1	1	1	0	1	0	0	0	0	0	3	1	3	1
Rib	2	3	1	1	1	1	1	1	0	0	2	3	5	6
Scapula	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humerus	1	2	2	0	1	1	0	0	0	0	3	3	4	3
Radius	2	2	1	2	1	1	0	0	0	0	3	4	4	5
Ulna	0	3	1	2	0	0	0	0	0	0	1	3	1	5
Metacarpal	1	0	0	1	1	0	0	0	0	0	1	1	2	1
Pelvis	4	2	1	1	0	0	0	0	0	0	3	2	5	3
Femur	2	2	0	2	1	0	0	0	0	0	3	4	3	4
Tibia	1	1	0	2	1	1	0	0	0	0	1	3	2	4
Metatarsal	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Lower Dark Brown Sand Units (5)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	1		0		0		0		0		1		1	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	1		0		1		1		0		3		3	
Thoracic Vertebrae	3		2		2		2		0		4		9	
Lumbar Vertebrae	1		1		2		1		1		3		6	
Sacrum	0		0		0		0		0		0		0	
Mandible	0	1	1	0	0	0	0	0	0	0	1	1	1	1
Rib	0	1	1	0	1	2	1	0	0	1	2	4	3	4
Scapula	1	0	0	0	0	0	0	0	0	0	1	0	1	0
Humerus	1	0	2	2	1	3	1	1	0	0	2	4	5	6
Radius	1	1	1	2	0	1	0	0	0	0	1	3	2	4
Ulna	2	1	0	0	1	0	0	0	0	0	2	1	3	1
Metacarpal	0	0	0	1	1	0	1	0	1	0	2	1	3	1
Pelvis	0	0	1	1	2	1	0	1	0	0	2	2	3	3

Femur	0	1	0	3	1	1	0	0	0	0	1	3	1	5
Tibia	0	2	0	0	1	1	1	1	0	0	2	2	2	4
Metatarsal	0	0	2	1	0	1	2	0	0	1	3	2	4	3

LC-MSA Middle (6)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		0		0		0		0		0		0	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	1		0		0		0		0		1		1	
Thoracic Vertebrae	0		1		0		0		0		1		1	
Lumbar Vertebrae	0		0		1		0		0		1		1	
Sacrum	0		0		0		0		0		0		0	
Mandible	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rib	0	1	0	1	0	0	0	0	0	0	0	1	0	2
Scapula	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radius	0	0	1	0	0	0	0	0	0	0	1	0	1	0
Ulna	1	1	0	0	0	1	0	0	0	0	1	1	1	2
Metacarpal	0	0	0	0	0	1	0	0	0	0	0	1	0	1
Pelvis	0	0	0	0	0	1	0	0	0	0	0	1	0	1
Femur	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tibia	0	1	1	0	0	0	0	0	0	0	1	1	1	1
Metatarsal	0	0	1	0	0	0	0	0	0	0	1	0	1	0

LC-MSA Lower (7)

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	1		0		0		0		0		1		1	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	2		1		2		0		0		3		5	
Thoracic Vertebrae	2		2		1		1		0		3		6	
Lumbar Vertebrae	3		2		3		2		0		5		10	

Sacrum	0		0		0		0		0		0		0	
Mandible	0	1	2	1	1	1	0	0	0	0	3	1	3	3
Rib	2	3	1	1	3	1	2	2	0	0	4	4	8	7
Scapula	1	2	1	0	1	1	0	0	0	0	3	3	3	3
Humerus	1	1	3	0	1	2	0	0	0	0	3	2	5	3
Radius	1	0	1	1	1	1	0	0	0	0	2	2	3	2
Ulna	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Metacarpal	0	0	2	1	0	0	0	0	0	0	2	1	2	1
Pelvis	0	0	1	1	1	2	0	0	0	0	1	2	2	3
Femur	2	1	0	2	1	0	0	0	0	0	2	2	3	3
Tibia	0	1	1	3	2	2	1	0	0	0	3	4	4	6
Metatarsal	0	0	2	2	1	1	0	0	0	0	2	3	3	3

PP13B All Analytical Units

	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	2		3		0		0		0		4		5	
Axis	0		1		1		0		0		2		2	
Cervical Vertebrae	16		7		7		2		2		31		34	
Thoracic Vertebrae	31		7		10		9		1		52		58	
Lumbar Vertebrae	20		10		19		4		3		35		56	
Sacrum	2		3		1		0		0		5		6	
Mandible	7	6	5	4	4	3	0	1	0	0	9	10	16	14
	1	2				1								
Rib	6	2	6	7	8	2	6	5	1	2	24	34	37	48
Scapula	6	5	2	2	5	3	0	0	0	0	11	10	13	10
Humerus	5	7	8	7	3	5	2	1	0	0	13	16	18	20
Radius	4	7	9	5	4	6	0	2	0	0	13	12	17	20
Ulna	3	5	4	3	2	4	0	1	0	0	7	9	9	13
Metacarpal	1	2	4	4	4	4	2	0	1	1	7	7	12	11
Pelvis	8	5	2	4	4	4	0	2	0	0	11	10	14	15
Femur	5	6	4	5	4	2	0	2	0	0	9	13	13	15
					1									
Tibia	3	5	2	6	2	4	3	2	0	1	13	11	20	18
Metatarsal	1	1	6	4	4	5	3	3	0	1	9	8	14	14

BBC M1	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	2		0		2		1		0		4		5	
Axis	3		0		0		0		1		4		4	
Cervical Vertebrae	5		6		11		2		0		21		24	
Thoracic Vertebrae	16		3		14		1		0		30		34	
Lumbar Vertebrae	5		2		3		3		0		8		13	
Sacrum	4		0		0		0		0		4		4	
Rib	6	9	5	5	8	5	4	3	0	0	15	16	23	22
Scapula	5	5	3	2	0	0	1	0	0	0	8	7	9	7
Humerus	5	3	3	2	4	6	2	0	0	0	8	6	14	11
Radius	3	2	1	2	3	2	1	1	0	0	5	4	8	7
Ulna	0	2	1	2	2	0	2	1	0	0	2	4	5	5
Metacarpal	1	2	1	2	4	2	1	2	1	0	6	5	8	8
Pelvis	1	5	3	3	3	2	0	1	0	0	6	7	7	11
Femur	3	3	3	1	2	8	2	1	0	0	7	11	10	13
Tibia	3	2	4	3	4	5	2	3	0	0	8	8	13	13
Metatarsal	3	3	5	2	2	3	3	2	1	0	7	5	14	10

BBC M2	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	2		0		0		0		0		2		2	
Axis	1		0		0		1		1		2		3	
Cervical Vertebrae	4		2		2		2		0		7		10	
Thoracic Vertebrae	12		3		5		1		0		14		21	
Lumbar Vertebrae	9		1		3		1		0		9		14	
Sacrum	3		0		0		0		0		3		3	
Rib	6	9	2	1	2	2	1	1	0	0	7	9	11	13
Scapula	1	1	0	2	0	0	0	0	0	0	1	3	1	3
Humerus	4	4	2	1	2	1	1	1	0	0	8	4	9	7
Radius	3	4	1	1	1	2	0	1	0	0	4	6	5	8
Ulna	2	2	1	1	0	0	0	0	0	0	3	2	3	3
Metacarpal	2	5	1	1	2	2	1	0	0	0	4	6	6	8

Pelvis	2	3	2	2	1	2	0	0	0	0	4	3	5	7
Femur	5	3	0	1	1	1	1	0	0	0	6	5	7	5
Tibia	2	3	1	0	2	1	0	1	0	0	3	3	5	5
Metatarsal	1	4	1	2	0	1	0	2	0	0	2	8	2	9

BBC M3	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	3		0		0		0		0		3		3	
Axis	0		0		0		0		0		0		0	
Cervical Vertebrae	2		1		1		0		0		4		4	
Thoracic Vertebrae	7		1		2		1		1		8		12	
Lumbar Vertebrae	4		1		1		0		1		4		7	
Sacrum	1		0		1		0		0		1		2	
Rib	3	3	1	2	2	1	1	1	0	0	5	5	7	7
Scapula	1	1	1	0	0	0	1	0	0	0	2	1	3	1
Humerus	1	4	0	1	0	0	0	0	1	0	2	4	2	5
Radius	0	2	0	1	1	0	0	1	0	0	1	2	1	4
Ulna	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metacarpal	0	2	0	0	0	1	1	0	0	0	1	2	1	3
Pelvis	5	3	0	1	0	0	0	0	0	0	5	3	5	4
Femur	0	1	0	0	1	0	1	0	0	0	2	1	2	1
Tibia	1	4	1	1	2	1	0	1	1	0	2	5	5	7
Metatarsal	1	3	0	1	0	0	1	0	0	0	2	4	2	4

Blombos All Layers	Size 1		Size 2		Size 3		Size 4		Size 5		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	7		0		3		1		0		8		11	
Axis	4		0		0		1		1		5		6	
Cervical Vertebrae	10		8		12		2		0		29		32	
Thoracic Vertebrae	33		4		18		2		1		49		58	
Lumbar Vertebrae	13		2		7		3		1		19		26	
Sacrum	7		0		1		0		0		7		8	
	1	1			1									
Rib	3	4	6	8	0	7	5	3	0	0	24	23	34	32

Scapula	7	7	3	4	0	0	1	0	0	0	11	10	11	11
Humerus	9	8	4	2	4	6	3	0	1	0	12	12	20	16
Radius	6	5	2	3	4	4	1	2	0	0	9	9	13	14
Ulna	2	4	2	2	1	0	2	1	0	0	5	6	7	7
Metacarpal	3	8	2	3	6	4	2	2	1	0	9	11	13	17
Pelvis	8	8	4	4	4	3	0	1	0	0	11	11	16	16
Femur	8	4	3	2	3	9	4	1	0	0	13	15	18	16
Tibia	5	6	5	3	6	5	2	1	1	0	11	14	18	15
Metatarsal	4	10	4	3	2	3	4	3	1	0	9	15	14	19

Layer 9	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		0		0		0		0		0	
Axis	0		1		0		0		1		1	
Cervical Vertebrae	3		3		1		2		6		9	
Thoracic Vertebrae	6		2		1		2		6		11	
Lumbar Vertebrae	4		2		1		1		5		8	
Sacrum	1		1		1		0		3		3	
Rib	10	9	2	2	2	2	3	4	11	13	17	17
Scapula	2	1	1	0	0	0	1	1	2	2	4	2
Humerus	2	5	0	1	1	0	1	1	2	5	4	7
Radius	3	3	1	0	1	1	1	1	3	3	6	5
Ulna	4	3	0	0	0	0	0	1	4	3	4	4
Metacarpal	2	1	0	0	1	1	1	2	2	2	4	4
Pelvis	3	0	0	1	0	1	0	0	3	1	3	2
Femur	0	4	1	1	1	1	0	3	2	7	2	9
Tibia	4	3	0	3	3	2	2	2	7	4	9	10
Metatarsal	2	2	1	0	2	0	1	0	3	2	6	2

Layer 10	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		0		0		0		0		0	
Axis	0		0		0		0		0		0	
Cervical	0		1		1		2		3		4	

Vertebrae Thoracic Vertebrae	1		1		0		3		3		5	
Lumbar Vertebrae	0		1		0		2		2		3	
Sacrum	0		0		0		0		0		0	
Rib	2	1	1	1	2	6	0	9	2	13	5	17
Scapula	0	1	0	0	1	2	0	0	1	2	1	3
Humerus	1	0	1	0	2	1	2	2	2	2	6	3
Radius	1	0	1	0	1	0	3	1	5	1	6	1
Ulna	0	0	0	0	0	0	2	1	2	1	2	1
Metacarpal	0	0	0	0	1	1	3	1	3	1	4	2
Pelvis	0	0	0	0	0	0	1	0	1	0	1	0
Femur	0	0	0	0	2	1	2	5	4	6	4	6
Tibia	0	1	0	1	1	3	3	2	4	5	4	7
Metatarsal	0	0	0	0	2	2	2	4	2	4	4	6

Layer 11	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	0		0		0		0		0		0	
Axis	0		0		0		0		0		0	
Cervical Vertebrae	0		0		0		1		1		1	
Thoracic Vertebrae	1		0		0		1		1		2	
Lumbar Vertebrae	1		1		1		1		1		4	
Sacrum	0		0		0		0		0		0	
Rib	4	7	1	1	2	1	4	3	6	11	11	12
Scapula	1	2	0	0	0	1	0	0	1	2	1	3
Humerus	1	1	0	0	0	1	1	0	2	1	2	2
Radius	1	0	0	0	1	0	1	0	2	0	3	0
Ulna	0	1	0	1	0	0	0	0	0	2	0	2
Metacarpal	0	1	0	0	0	0	0	1	0	2	0	2
Pelvis	1	1	0	1	0	0	0	0	1	2	1	2
Femur	1	3	0	0	0	0	1	1	1	3	2	4
Tibia	2	1	0	1	0	1	0	1	2	2	2	4
Metatarsal	1	0	0	0	0	0	1	2	2	2	2	2

Layer 12	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L

Atlas	0		0		1		2		3		3	
Axis	1		0		0		1		2		2	
Cervical Vertebrae	0		1		2		3		4		6	
Thoracic Vertebrae	8		2		2		6		12		18	
Lumbar Vertebrae	5		1		2		4		6		12	
Sacrum	0		0		0		0		0		0	
Rib	11	13	8	6	6	8	11	20	26	37	36	47
Scapula	1	2	0	0	2	1	0	1	2	3	3	4
Humerus	5	5	2	1	2	3	4	3	8	6	13	12
Radius	5	5	0	2	4	3	3	3	7	8	12	13
Ulna	2	2	1	1	1	1	2	2	6	4	6	6
Metacarpal	3	2	1	3	2	1	5	3	7	6	11	9
Pelvis	1	4	1	1	1	2	0	2	2	5	3	9
Femur	5	4	4	1	1	3	4	3	11	5	14	11
Tibia	4	3	2	2	2	2	2	5	7	10	10	12
Metatarsal	3	4	2	1	1	2	3	3	6	8	9	10

Layer 13	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	1		0		0		0		1		1	
Axis	1		0		0		0		1		1	
Cervical Vertebrae	3		0		0		0		3		3	
Thoracic Vertebrae	3		0		0		0		3		3	
Lumbar Vertebrae	1		1		1		1		4		4	
Sacrum	0		0		0		0		0		0	
Rib	7	6	1	1	2	2	1	2	9	9	11	11
Scapula	0	0	0	0	0	1	0	0	0	1	0	1
Humerus	2	1	0	0	0	0	2	0	3	1	4	1
Radius	1	2	0	0	0	0	0	0	1	2	1	2
Ulna	0	0	0	0	0	0	0	1	0	1	0	1
Metacarpal	2	0	0	0	0	0	2	0	4	0	4	0
Pelvis	3	0	1	0	0	0	0	1	3	1	4	1
Femur	1	2	0	0	2	1	0	0	3	2	3	3
Tibia	1	1	0	1	0	2	1	1	2	3	2	5
Metatarsal	2	1	1	0	0	0	0	0	2	1	3	1

Layer 14	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	4		0		0		0		4		4	
Axis	1		1		0		0		1		2	
Cervical Vertebrae	2		1		1		1		3		5	
Thoracic Vertebrae	11		4		3		2		20		20	
Lumbar Vertebrae	4		1		1		1		4		7	
Sacrum	0		0		0		0		0		0	
Rib	22	25	8	3	4	4	5	3	31	31	39	35
Scapula	2	1	2	0	0	0	0	1	4	2	4	2
Humerus	4	1	2	0	2	2	7	2	11	4	15	5
Radius	4	3	2	1	2	2	4	4	5	4	12	10
Ulna	3	1	0	0	0	1	1	2	3	2	4	4
Metacarpal	3	3	0	1	2	1	2	3	5	5	7	8
Pelvis	3	1	1	1	2	1	1	0	4	3	7	3
Femur	7	22	2	3	2	2	2	1	10	24	13	28
Tibia	11	5	2	1	2	2	5	4	15	9	20	12
Metatarsal	3	4	0	0	1	0	2	2	4	5	6	6

Layer 15	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	2		0		0		1		2		3	
Axis	3		0		0		0		3		3	
Cervical Vertebrae	2		1		1		1		2		5	
Thoracic Vertebrae	3		1		0		2		6		6	
Lumbar Vertebrae	2		1		1		0		2		4	
Sacrum	0		0		0		0		0		0	
Rib	3	4	1	0	2	0	1	1	5	4	7	5
Scapula	1	0	0	0	0	0	1	1	1	1	2	1
Humerus	4	2	0	1	0	1	1	1	4	3	5	5
Radius	4	1	0	0	0	0	1	0	4	1	5	1
Ulna	0	0	0	0	0	0	0	0	0	0	0	0
Metacarpal	1	1	1	1	0	0	2	1	3	2	4	3
Pelvis	2	0	0	0	0	0	1	0	3	0	3	0
Femur	1	1	0	1	0	1	0	0	1	1	1	3

Tibia	1	2	0	0	0	1	1	1	1	3	2	4
Metatarsal	0	0	0	0	2	1	1	1	2	1	3	2

DK1 All Layers	Size 1		Size 2		Size 3		Size 4		All (Overlap)		All (Count)	
Element	R	L	R	L	R	L	R	L	R	L	R	L
Atlas	6		0		1		2		7		9	
Axis	6		1		0		1		7		8	
Cervical Vertebrae	5		4		2		4		9		15	
Thoracic Vertebrae	27		6		4		14		49		51	
Lumbar Vertebrae	10		5		5		9		15		29	
Sacrum	1		1		1		0		3		3	
Rib	48	50	17	12	12	16	13	36	76	100	90	114
Scapula	6	5	2	1	3	3	1	2	9	8	12	11
Humerus	15	6	3	2	3	4	10	7	20	14	31	19
Radius	10	9	3	2	5	5	4	5	13	12	22	21
Ulna	8	3	1	1	1	2	6	5	8	8	16	11
Metacarpal	9	4	1	3	2	2	8	5	16	9	20	14
Pelvis	6	6	3	2	2	2	2	2	10	9	13	12
Femur	13	32	6	4	4	7	4	5	23	43	27	48
Tibia	17	12	3	5	6	5	9	9	31	25	35	31
Metatarsal	7	6	2	1	5	3	8	5	13	11	22	15

APPENDIX E

MAU VALUES FOR PP13B, BLOMBOS, AND DK1

PP13B Light Brown Sand (1)

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Mandible	0.0	0.0	1.0	0.0	0.0	1.0	1.0
Atlas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.4	0.2	0.2	0.2	0.2	0.6	1.2
Thoracic Vertebrae	0.2	0.1	0.1	0.1	0.0	0.2	0.4
Lumbar Vertebrae	0.3	0.3	0.3	0.0	0.2	0.5	1.2
Sacrum	1.0	2.0	0.0	0.0	0.0	3.0	3.0
Rib	0.3	0.1	0.1	0.2	0.0	0.3	0.7
Scapula	0.0	0.5	1.0	0.0	0.0	1.5	1.5
Humerus	0.5	1.0	0.0	1.0	0.0	1.5	2.5
Radius	0.0	0.5	0.5	1.0	0.0	1.5	2.0
Ulna	0.5	0.0	0.0	0.0	0.0	0.5	0.5
Metacarpal	0.0	0.0	1.0	0.0	1.0	1.5	1.5
Pelvis	1.0	0.5	1.0	0.0	0.0	2.0	2.5
Femur	0.0	0.5	0.0	0.0	0.0	0.5	0.5
Tibia	0.5	0.5	0.5	0.5	0.0	1.5	2.0
Metatarsal	0.0	0.0	0.0	0.5	0.0	0.5	0.5

PP13B Upper Dark Brown Sand/LC-MSA Upper (2)

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Mandible	3.5	1.5	1.0	0.5	0.0	4.5	6.5
Atlas	0.0	1.0	0.0	0.0	0.0	1.0	1.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	1.0	0.4	0.4	0.2	0.2	1.2	2.2
Thoracic Vertebrae	0.4	0.2	0.3	0.4	0.0	1.0	1.3
Lumbar Vertebrae	1.3	0.5	0.8	0.3	0.2	2.0	3.2
Sacrum	1.0	0.0	0.0	0.0	0.0	1.0	1.0
Rib	1.5	0.5	0.7	0.2	0.2	1.8	3.1

Scapula	2.0	1.0	2.5	0.0	0.0	3.5	5.5
Humerus	1.5	2.5	1.5	1.0	0.0	4.5	6.5
Radius	2.0	2.5	1.5	0.0	0.0	4.5	6.0
Ulna	0.0	3.5	0.5	0.0	0.0	3.5	4.0
Metacarpal	0.5	2.0	1.0	0.5	0.0	3.0	4.0
Pelvis	2.0	2.0	1.5	0.5	0.0	3.0	6.0
Femur	2.0	2.0	1.5	0.5	0.0	5.0	6.0
Tibia	1.0	1.5	1.0	2.0	1.0	5.5	6.0
Metatarsal	0.0	2.0	1.5	1.5	0.0	2.5	5.0

PP13B Shelly Brown Sand/Upper Roof Spall (3)

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Mandible	3.0	2.5	2.0	0.0	0.0	6.0	7.5
Atlas	0.0	2.0	0.0	0.0	0.0	2.0	2.0
Axis	0.0	1.0	1.0	0.0	0.0	2.0	2.0
Cervical Vertebrae	2.0	1.0	0.8	0.2	0.2	4.0	4.2
Thoracic Vertebrae	1.3	0.5	0.4	0.2	0.1	1.8	2.5
Lumbar Vertebrae	1.3	1.3	1.3	0.2	0.0	2.5	4.2
Sacrum	0.0	1.0	1.0	0.0	0.0	2.0	2.0
Rib	1.4	0.6	0.6	0.2	0.0	2.1	2.8
Scapula	2.5	1.0	1.0	0.0	0.0	3.5	4.5
Humerus	3.5	3.5	3.0	0.5	0.0	7.5	10.5
Radius	4.0	4.0	3.5	0.0	0.0	6.5	11.5
Ulna	1.5	1.5	2.5	0.5	0.0	4.0	6.0
Metacarpal	1.0	1.5	2.0	0.0	0.0	3.0	4.5
Pelvis	4.0	1.0	2.5	0.0	0.0	5.0	7.5
Femur	1.0	2.5	1.5	0.5	0.0	3.0	5.5
Tibia	3.5	1.5	3.5	0.5	0.0	5.5	9.0
Metatarsal	1.0	1.5	3.0	2.0	0.0	3.5	7.5

PP13B Lower Roof Spall (4)

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Mandible	1.0	0.5	0.5	0.0	0.0	2.0	2.0
Atlas	0.0	1.0	0.0	0.0	0.0	1.0	1.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical	0.6	0.2	0.2	0.0	0.0	0.6	1.0

Vertebrae							
Thoracic Vertebrae	0.5	0.2	0.1	0.1	0.0	0.6	0.8
Lumbar Vertebrae	0.8	0.3	0.3	0.2	0.2	1.2	1.8
Sacrum	1.0	0.0	0.0	0.0	0.0	1.0	1.0
Rib	0.4	0.2	0.2	0.2	0.0	0.4	0.8
Scapula	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humerus	1.5	1.0	1.0	0.0	0.0	3.0	3.5
Radius	2.0	1.5	1.0	0.0	0.0	3.5	4.5
Ulna	1.5	1.5	0.0	0.0	0.0	2.0	3.0
Metacarpal	0.5	0.5	0.5	0.0	0.0	1.0	1.5
Pelvis	3.0	1.0	0.0	0.0	0.0	2.5	4.0
Femur	2.0	1.0	0.5	0.0	0.0	3.5	3.5
Tibia	1.0	1.0	1.0	0.0	0.0	2.0	3.0
Metatarsal	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PP13B Lower Dark Brown Sand Units (5)

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Mandible	0.5	0.5	0.0	0.0	0.0	1.0	1.0
Atlas	1.0	0.0	0.0	0.0	0.0	1.0	1.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.2	0.0	0.2	0.2	0.0	0.6	0.6
Thoracic Vertebrae	0.2	0.2	0.2	0.2	0.0	0.3	0.7
Lumbar Vertebrae	0.2	0.2	0.3	0.2	0.2	0.5	1.0
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.1	0.1	0.2	0.1	0.1	0.5	0.5
Scapula	0.5	0.0	0.0	0.0	0.0	0.5	0.5
Humerus	0.5	2.0	2.0	1.0	0.0	3.0	5.5
Radius	1.0	1.5	0.5	0.0	0.0	2.0	3.0
Ulna	1.5	0.0	0.5	0.0	0.0	1.5	2.0
Metacarpal	0.0	0.5	0.5	0.5	1.0	1.5	2.0
Pelvis	0.0	1.0	1.5	0.5	0.0	2.0	3.0
Femur	0.5	1.5	1.0	0.0	0.0	2.0	3.0
Tibia	1.0	0.0	1.0	1.0	0.0	2.0	3.0
Metatarsal	0.0	1.5	0.5	1.0	1.0	2.5	3.5

PP13B LC-MSA Middle (6)

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Mandible	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atlas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.2	0.0	0.0	0.0	0.0	0.2	0.2
Thoracic Vertebrae	0.0	0.1	0.0	0.0	0.0	0.1	0.1
Lumbar Vertebrae	0.0	0.0	0.2	0.0	0.0	0.2	0.2
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.1	0.1	0.0	0.0	0.0	0.1	0.2
Scapula	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humerus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Radius	0.0	0.5	0.0	0.0	0.0	0.5	0.5
Ulna	1.0	0.0	0.5	0.0	0.0	1.0	1.5
Metacarpal	0.0	0.0	0.5	0.0	0.0	0.5	0.5
Pelvis	0.0	0.0	0.5	0.0	0.0	0.5	0.5
Femur	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tibia	0.5	0.5	0.0	0.0	0.0	1.0	1.0
Metatarsal	0.0	0.5	0.0	0.0	0.0	0.5	0.5

PP13B LC-MSA Lower (7)

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Mandible	0.5	1.5	1.0	0.0	0.0	2.0	3.0
Atlas	1.0	0.0	0.0	0.0	0.0	1.0	1.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.4	0.2	0.4	0.0	0.0	0.6	1.0
Thoracic Vertebrae	0.2	0.2	0.1	0.1	0.0	0.2	0.5
Lumbar Vertebrae	0.5	0.3	0.5	0.3	0.0	0.8	1.7
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.4	0.2	0.3	0.3	0.0	0.6	1.2
Scapula	1.5	0.5	1.0	0.0	0.0	3.0	3.0

Humerus	1.0	1.5	1.5	0.0	0.0	2.5	4.0
Radius	0.5	1.0	1.0	0.0	0.0	2.0	2.5
Ulna	0.5	0.0	0.0	0.0	0.0	0.5	0.5
Metacarpal	0.0	1.5	0.0	0.0	0.0	1.5	1.5
Pelvis	0.0	1.0	1.5	0.0	0.0	1.5	2.5
Femur	1.5	1.0	0.5	0.0	0.0	2.0	3.0
Tibia	0.5	2.0	2.0	0.5	0.0	3.5	5.0
Metatarsal	0.0	2.0	1.0	0.0	0.0	2.5	3.0

PP13B All Analytical Units

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Mandible	6.5	4.5	3.5	0.5	0.0	9.5	15.0
Atlas	2.0	3.0	0.0	0.0	0.0	4.0	5.0
Axis	0.0	1.0	1.0	0.0	0.0	2.0	2.0
Cervical Vertebrae	3.2	1.4	1.4	0.4	0.4	6.2	6.8
Thoracic Vertebrae	2.4	0.5	0.8	0.7	0.1	4.0	4.5
Lumbar Vertebrae	3.3	1.7	3.2	0.7	0.5	5.8	9.3
Sacrum	2.0	3.0	1.0	0.0	0.0	5.0	6.0
Rib	2.9	1.0	1.5	0.8	0.2	4.5	6.5
Scapula	5.5	2.0	4.0	0.0	0.0	10.5	11.5
Humerus	6.0	7.5	4.0	1.5	0.0	14.5	19.0
Radius	5.5	7.0	5.0	1.0	0.0	13.5	18.5
Ulna	4.0	3.5	3.0	0.5	0.0	8.0	11.0
Metacarpal	1.5	4.0	4.0	1.0	2.0	7.0	11.5
Pelvis	6.5	3.0	4.0	1.0	0.0	10.5	14.5
Femur	5.5	4.5	3.0	1.0	0.0	11.0	14.0
Tibia	4.0	4.0	8.0	2.5	1.0	12.0	19.0
Metatarsal	1.0	5.0	4.5	3.0	1.0	8.5	14.0

BBC M1

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	2.0	0.0	2.0	1.0	0.0	4.0	5.0
Axis	3.0	0.0	0.0	0.0	1.0	4.0	4.0

Cervical Vertebrae	1.0	1.2	2.2	0.4	0.0	4.2	4.8
Thoracic Vertebrae	1.2	0.2	1.1	0.1	0.0	2.3	2.6
Lumbar Vertebrae	0.8	0.3	0.5	0.5	0.0	1.3	2.2
Sacrum	4.0	0.0	0.0	0.0	0.0	4.0	4.0
Rib	1.2	1.1	0.8	1.0	1.0	0.7	0.5
Scapula	0.8	0.4	0.0	0.1	0.0	1.2	1.2
Humerus	4.0	2.5	5.0	1.0	0.0	7.0	12.5
Radius	2.5	1.5	2.5	1.0	0.0	4.5	7.5
Ulna	1.0	1.5	1.0	1.5	0.0	3.0	5.0
Metacarpal	1.5	1.5	3.0	1.5	1.0	5.5	8.0
Pelvis	3.0	3.0	2.5	0.5	0.0	6.5	9.0
Femur	3.0	2.0	5.0	1.5	0.0	9.0	11.5
Tibia	2.5	3.5	4.5	2.5	0.0	8.0	13.0
Metatarsal	3.0	3.5	2.5	2.5	1.0	6.0	12.0

BBC M2

	Size 1	Size 2	Size 3	Size 4	Size 5	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	2.0	0.0	0.0	0.0	0.0	2.0	2.0
Axis	1.0	0.0	0.0	1.0	1.0	2.0	3.0
Cervical Vertebrae	0.8	0.4	0.4	0.4	0.0	1.4	2.0
Thoracic Vertebrae	0.9	0.2	0.4	0.1	0.0	1.1	1.6
Lumbar Vertebrae	1.5	0.2	0.5	0.2	0.0	1.5	2.3
Sacrum	3.0	0.0	0.0	0.0	0.0	3.0	3.0
Rib	1.2	0.8	0.2	0.2	0.3	0.2	0.2
Scapula	0.2	0.2	0.0	0.0	0.0	0.3	0.3
Humerus	4.0	1.5	1.5	1.0	0.0	6.0	8.0
Radius	3.5	1.0	1.5	0.5	0.0	5.0	6.5
Ulna	2.0	1.0	0.0	0.0	0.0	2.5	3.0
Metacarpal	3.5	1.0	2.0	0.5	0.0	5.0	7.0
Pelvis	2.5	2.0	1.5	0.0	0.0	3.5	6.0
Femur	4.0	0.5	1.0	0.5	0.0	5.5	6.0
Tibia	2.5	0.5	1.5	0.5	0.0	3.0	5.0
Metatarsal	2.5	1.5	0.5	1.0	0.0	5.0	5.5

BBC M3

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Atlas	3.0	0.0	0.0	0.0	0.0	3.0	3.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.4	0.2	0.2	0.0	0.0	0.8	0.8
Thoracic Vertebrae	0.5	0.1	0.2	0.1	0.1	0.6	0.9
Lumbar Vertebrae	0.7	0.2	0.2	0.0	0.2	0.7	1.2
Sacrum	1.0	0.0	1.0	0.0	0.0	1.0	2.0
Rib	0.5	0.3	0.2	0.3	0.2	0.2	0.2
Scapula	0.2	0.1	0.0	0.1	0.0	0.2	0.3
Humerus	2.5	0.5	0.0	0.0	1.0	3.0	3.5
Radius	1.0	0.5	0.5	0.5	0.0	1.5	2.5
Ulna	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metacarpal	1.0	0.0	0.5	0.5	0.0	1.5	2.0
Pelvis	4.0	0.5	0.0	0.0	0.0	4.0	4.5
Femur	0.5	0.0	0.5	0.5	0.0	1.5	1.5
Tibia	2.5	1.0	1.5	0.5	1.0	3.5	6.0
Metatarsal	2.0	0.5	0.0	0.5	0.0	3.0	3.0

BBC All Layers

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	Size 5 MAU	All (Overlap) MAU	All (Count) MAU
Atlas	7.0	0.0	3.0	1.0	0.0	8.0	11.0
Axis	4.0	0.0	0.0	1.0	1.0	5.0	6.0
Cervical Vertebrae	2.0	1.6	2.4	0.4	0.0	5.8	6.4
Thoracic Vertebrae	2.5	0.3	1.4	0.2	0.1	3.8	4.5
Lumbar Vertebrae	2.2	0.3	1.2	0.5	0.2	3.2	4.3
Sacrum	7.0	0.0	1.0	0.0	0.0	7.0	8.0
Rib	2.1	1.5	1.1	1.4	1.3	0.9	0.6
Scapula	1.1	0.5	0.0	0.1	0.0	1.6	1.7
Humerus	8.5	3.0	5.0	1.5	1.0	12.0	18.0
Radius	5.5	2.5	4.0	1.5	0.0	9.0	13.5
Ulna	3.0	2.0	0.5	1.5	0.0	5.5	7.0
Metacarpal	5.5	2.5	5.0	2.0	1.0	10.0	15.0

Pelvis	8.0	4.0	3.5	0.5	0.0	11.0	16.0
Femur	6.0	2.5	6.0	2.5	0.0	14.0	17.0
Tibia	5.5	4.0	5.5	1.5	1.0	12.5	16.5
Metatarsal	7.0	3.5	2.5	3.5	1.0	12.0	16.5

DK1 Layer 9

	Size 1	Size 2	Size 3	Size 4	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	0.0	0.0	0.0	0.0	0.0	0.0
Axis	0.0	1.0	0.0	0.0	1.0	1.0
Cervical Vertebrae	0.6	0.6	0.2	0.4	1.2	1.8
Thoracic Vertebrae	0.5	0.2	0.1	0.2	0.5	0.8
Lumbar Vertebrae	0.7	0.3	0.2	0.2	0.8	1.3
Sacrum	1.0	1.0	1.0	0.0	3.0	3.0
Rib	1.5	0.3	0.3	0.5	1.8	2.6
Scapula	1.5	0.5	0.0	1.0	2.0	3.0
Humerus	3.5	0.5	0.5	1.0	3.5	5.5
Radius	3.0	0.5	1.0	1.0	3.0	5.5
Ulna	3.5	0.0	0.0	0.5	3.5	4.0
Metacarpal	1.5	0.0	1.0	1.5	2.0	4.0
Pelvis	1.5	0.5	0.5	0.0	2.0	2.5
Femur	2.0	1.0	1.0	1.5	4.5	5.5
Tibia	3.5	1.5	2.5	2.0	5.5	9.5
Metatarsal	2.0	0.5	1.0	0.5	2.5	4.0

DK1 Layer 10

	Size 1	Size 2	Size 3	Size 4	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	0.0	0.0	0.0	0.0	0.0	0.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.0	0.2	0.2	0.4	0.6	0.8
Thoracic Vertebrae	0.1	0.1	0.0	0.2	0.2	0.4
Lumbar Vertebrae	0.0	0.2	0.0	0.3	0.3	0.5

Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.2	0.2	0.6	0.7	1.2	1.7
Scapula	0.5	0.0	1.5	0.0	1.5	2.0
Humerus	0.5	0.5	1.5	2.0	2.0	4.5
Radius	0.5	0.5	0.5	2.0	3.0	3.5
Ulna	0.0	0.0	0.0	1.5	1.5	1.5
Metacarpal	0.0	0.0	1.0	2.0	2.0	3.0
Pelvis	0.0	0.0	0.0	0.5	0.5	0.5
Femur	0.0	0.0	1.5	3.5	5.0	5.0
Tibia	0.5	0.5	2.0	2.5	4.5	5.5
Metatarsal	0.0	0.0	2.0	3.0	3.0	5.0

DK1 Layer 11

	Size 1	Size 2	Size 3	Size 4	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	0.0	0.0	0.0	0.0	0.0	0.0
Axis	0.0	0.0	0.0	0.0	0.0	0.0
Cervical Vertebrae	0.0	0.0	0.0	0.2	0.2	0.2
Thoracic Vertebrae	0.1	0.0	0.0	0.1	0.1	0.2
Lumbar Vertebrae	0.2	0.2	0.2	0.2	0.2	0.7
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.8	0.2	0.2	0.5	1.3	1.8
Scapula	1.5	0.0	0.5	0.0	1.5	2.0
Humerus	1.0	0.0	0.5	0.5	1.5	2.0
Radius	0.5	0.0	0.5	0.5	1.0	1.5
Ulna	0.5	0.5	0.0	0.0	1.0	1.0
Metacarpal	0.5	0.0	0.0	0.5	1.0	1.0
Pelvis	1.0	0.5	0.0	0.0	1.5	1.5
Femur	2.0	0.0	0.0	1.0	2.0	3.0
Tibia	1.5	0.5	0.5	0.5	2.0	3.0
Metatarsal	0.5	0.0	0.0	1.5	2.0	2.0

DK1 Layer 12

	Size 1	Size 2	Size 3	Size 4	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	0.0	0.0	1.0	2.0	3.0	3.0
Axis	1.0	0.0	0.0	1.0	2.0	2.0
Cervical	0.0	0.2	0.4	0.6	0.8	1.2

Vertebrae						
Thoracic						
Vertebrae	0.6	0.2	0.2	0.5	0.9	1.4
Lumbar						
Vertebrae	0.8	0.2	0.3	0.7	1.0	2.0
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	1.8	1.1	1.1	2.4	4.8	6.4
Scapula	1.5	0.0	1.5	0.5	2.5	3.5
Humerus	5.0	1.5	2.5	3.5	7.0	12.5
Radius	5.0	1.0	3.5	3.0	7.5	12.5
Ulna	2.0	1.0	1.0	2.0	5.0	6.0
Metacarpal	2.5	2.0	1.5	4.0	6.5	10.0
Pelvis	2.5	1.0	1.5	1.0	3.5	6.0
Femur	4.5	2.5	2.0	3.5	8.0	12.5
Tibia	3.5	2.0	2.0	3.5	8.5	11.0
Metatarsal	3.5	1.5	1.5	3.0	7.0	9.5

DK1 Layer 13

	Size 1	Size 2	Size 3	Size 4	All (Overlap)	All (Count)
Element	MAU	MAU	MAU	MAU	MAU	MAU
Atlas	1.0	0.0	0.0	0.0	1.0	1.0
Axis	1.0	0.0	0.0	0.0	1.0	1.0
Cervical						
Vertebrae	0.6	0.0	0.0	0.0	0.6	0.6
Thoracic						
Vertebrae	0.2	0.0	0.0	0.0	0.2	0.2
Lumbar						
Vertebrae	0.2	0.2	0.2	0.2	0.7	0.7
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	1.0	0.2	0.3	0.2	1.4	1.7
Scapula	0.0	0.0	0.5	0.0	0.5	0.5
Humerus	1.5	0.0	0.0	1.0	2.0	2.5
Radius	1.5	0.0	0.0	0.0	1.5	1.5
Ulna	0.0	0.0	0.0	0.5	0.5	0.5
Metacarpal	1.0	0.0	0.0	1.0	2.0	2.0
Pelvis	1.5	0.5	0.0	0.5	2.0	2.5
Femur	1.5	0.0	1.5	0.0	2.5	3.0
Tibia	1.0	0.5	1.0	1.0	2.5	3.5
Metatarsal	1.5	0.5	0.0	0.0	1.5	2.0

DK1 Layer 14

	Size	Size	Size	Size	All	All

Element	1 MAU	2 MAU	3 MAU	4 MAU	(Overlap) MAU	(Count) MAU
Atlas	4.0	0.0	0.0	0.0	4.0	4.0
Axis	1.0	1.0	0.0	0.0	1.0	2.0
Cervical Vertebrae	0.4	0.2	0.2	0.2	0.6	1.0
Thoracic Vertebrae	0.8	0.3	0.2	0.2	1.5	1.5
Lumbar Vertebrae	0.7	0.2	0.2	0.2	0.7	1.2
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	3.6	0.8	0.6	0.6	4.8	5.7
Scapula	1.5	1.0	0.0	0.5	3.0	3.0
Humerus	2.5	1.0	2.0	4.5	7.5	10.0
Radius	3.5	1.5	2.0	4.0	4.5	11.0
Ulna	2.0	0.0	0.5	1.5	2.5	4.0
Metacarpal	3.0	0.5	1.5	2.5	5.0	7.5
Pelvis	2.0	1.0	1.5	0.5	3.5	5.0
Femur	14.5	2.5	2.0	1.5	17.0	20.5
Tibia	8.0	1.5	2.0	4.5	12.0	16.0
Metatarsal	3.5	0.0	0.5	2.0	4.5	6.0

DK1 Layer 15

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	All (Overlap) MAU	All (Count) MAU
Atlas	2.0	0.0	0.0	1.0	2.0	3.0
Axis	3.0	0.0	0.0	0.0	3.0	3.0
Cervical Vertebrae	0.4	0.2	0.2	0.2	0.4	1.0
Thoracic Vertebrae	0.2	0.1	0.0	0.2	0.5	0.5
Lumbar Vertebrae	0.3	0.2	0.2	0.0	0.3	0.7
Sacrum	0.0	0.0	0.0	0.0	0.0	0.0
Rib	0.5	0.1	0.2	0.2	0.7	0.9
Scapula	0.5	0.0	0.0	1.0	1.0	1.5
Humerus	3.0	0.5	0.5	1.0	3.5	5.0
Radius	2.5	0.0	0.0	0.5	2.5	3.0
Ulna	0.0	0.0	0.0	0.0	0.0	0.0
Metacarpal	1.0	1.0	0.0	1.5	2.5	3.5
Pelvis	1.0	0.0	0.0	0.5	1.5	1.5
Femur	1.0	0.5	0.5	0.0	1.0	2.0

Tibia	1.5	0.0	0.5	1.0	2.0	3.0
Metatarsal	0.0	0.0	1.5	1.0	1.5	2.5

DK1 All Layers

Element	Size 1 MAU	Size 2 MAU	Size 3 MAU	Size 4 MAU	All (Overlap) MAU	All (Count) MAU
Atlas	6.0	0.0	1.0	2.0	7.0	9.0
Axis	6.0	1.0	0.0	1.0	7.0	8.0
Cervical Vertebrae	1.0	0.8	0.4	0.8	1.8	3.0
Thoracic Vertebrae	2.1	0.5	0.3	1.1	3.8	3.9
Lumbar Vertebrae	1.7	0.8	0.8	1.5	2.5	4.8
Sacrum	1.0	1.0	1.0	0.0	3.0	3.0
Rib	7.5	2.2	2.2	3.8	13.5	15.7
Scapula	5.5	1.5	3.0	1.5	8.5	11.5
Humerus	10.5	2.5	3.5	8.5	17.0	25.0
Radius	9.5	2.5	5.0	4.5	12.5	21.5
Ulna	5.5	1.0	1.5	5.5	8.0	13.5
Metacarpal	6.5	2.0	2.0	6.5	12.5	17.0
Pelvis	6.0	2.5	2.0	2.0	9.5	12.5
Femur	22.5	5.0	5.5	4.5	33.0	37.5
Tibia	14.5	4.0	5.5	9.0	28.0	33.0
Metatarsal	6.5	1.5	4.0	6.5	12.0	18.5

APPENDIX F

NUMBERS OF CUT MARKS BY BONE PORTION AT PP13B, BLOMBOS, AND DK1

Size 1 and 2 Ungulates - MIS 5						
		PE	PS	MS	DS	DE
Humerus	Left	0	3	8	9	5
	Right	0	3	4	5	0
	Total	0	6	12	14	5
Radius	Left	3	8	4	1	0
	Right	2	6	1	7	0
	Total	5	14	5	8	0
Metacarpal	Left	0	0	0	2	0
	Right	0	2	7	2	0
	Total	0	2	7	4	0
Femur	Left	2	5	3	1	0
	Right	0	12	15	4	0
	Total	2	17	18	5	0
Tibia	Left	0	6	15	18	6
	Right	2	6	1	0	0
	Total	2	12	16	18	6
Metatarsal	Left	3	2	1	0	0
	Right	0	1	0	0	0
	Total	3	3	1	0	0

Size 3, 4, and 5 Ungulates - MIS 5						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	2	2	0
	Right	0	1	14	8	0
	Total	0	1	16	10	0
Radius	Left	1	0	1	2	0
	Right	0	5	11	3	1
	Total	1	5	12	5	1
Metacarpal	Left	0	6	1	0	0
	Right	0	0	0	0	0
	Total	0	6	1	0	0
Femur	Left	0	4	0	2	0
	Right	0	0	9	9	0
	Total	0	4	9	11	0
Tibia	Left	0	5	1	8	0
	Right	0	11	15	2	4
	Total	0	16	16	10	4
Metatarsal	Left	1	1	3	4	0
	Right	0	1	23	1	0
	Total	1	2	26	5	0

Size 1 and 2 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	1	0	0
	Right	0	1	17	12	0
	Total	0	1	18	12	0
Radius	Left	1	5	0	0	0
	Right	0	0	0	0	0
	Total	1	5	0	0	0
Metacarpal	Left	0	2	0	1	0
	Right	0	1	0	0	0
	Total	0	3	0	1	0
Femur	Left	1	0	3	2	0
	Right	0	1	0	0	0
	Total	3	0	0	0	0
Tibia	Left	0	1	10	5	0
	Right	0	0	3	0	0
	Total	0	1	13	5	0
Metatarsal	Left	0	0	0	0	0
	Right	1	1	0	0	0
	Total	1	1	0	0	0

Size 3, 4, and 5 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	0	0	0
	Right	0	0	0	1	0
	Total	0	0	0	1	0
Radius	Left	0	0	0	0	0
	Right	0	0	0	0	0
	Total	0	0	0	0	0
Metacarpal	Left	0	0	0	1	0
	Right	0	0	0	0	0
	Total	0	0	0	1	0
Femur	Left	0	0	0	0	0
	Right	0	0	0	0	0
	Total	0	0	0	0	0
Tibia	Left	0	0	0	0	0
	Right	0	8	19	1	0
	Total	0	8	19	1	0
Metatarsal	Left	0	0	0	0	0
	Right	0	0	0	0	0
	Total	0	0	0	0	0

Size 1 and 2 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0	8	5	1	2
	Right	0	3	5	3	4
	Total	0	11	10	4	6
Radius	Left	0	0	0	4	1
	Right	0	1	1	5	0
	Total	0	1	1	9	1
Metacarpal	Left	0	2	2	4	0
	Right	0	0	1	2	0
	Total	0	2	3	6	0
Femur	Left	0	0	1	1	1
	Right	1	5	4	4	2
	Total	1	5	5	5	3
Tibia	Left	0	3	2	7	2
	Right	0	8	8	2	3
	Total	0	11	10	9	5
Metatarsal	Left	2	2	2	0	0
	Right	0	2	4	3	0
	Total	2	4	6	3	0

Size 3, 4, and 5 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0	2	2	6	0
	Right	0	0	2	3	0
	Total	0	2	4	9	0
Radius	Left	0	0	0	1	0
	Right	0	0	2	3	0
	Total	0	0	2	4	0
Metacarpal	Left	0	1	0	0	0
	Right	0	1	0	2	0
	Total	0	2	0	2	0
Femur	Left	1	4	4	2	0
	Right	0	0	0	2	0
	Total	1	4	4	4	0
Tibia	Left	0	9	15	5	0
	Right	0	5	7	2	1
	Total	0	14	22	7	1
Metatarsal	Left	0	4	0	2	0
	Right	2	1	2	0	0
	Total	2	5	2	2	0

Size 1 and 2 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	0	7	8	5	0
	Right	0	1	6	10	2
	Total	0	8	14	15	2
Radius	Left	2	2	3	4	0
	Right	0	1	3	3	1
	Total	2	3	6	7	1
Metacarpal	Left	0	2	0	0	0
	Right	0	0	0	1	0
	Total	0	2	0	1	0
Femur	Left	0	4	7	0	0
	Right	0	0	2	12	0
	Total	0	4	9	12	0
Tibia	Left	0	3	1	2	0
	Right	0	1	5	8	0
	Total	0	4	6	10	0
Metatarsal	Left	0	2	1	0	0
	Right	3	5	2	2	0
	Total	3	7	3	2	0

Size 3, 4, and 5 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	2	1	0
	Right	0	4	2	0	1
	Total	0	4	4	1	1
Radius	Left	0	0	0	0	0
	Right	0	2	1	0	1
	Total	0	2	1	0	1
Metacarpal	Left	0	1	0	1	0
	Right	0	7	0	2	0
	Total	0	8	0	3	0
Femur	Left	0	0	0	0	0
	Right	0	0	0	2	0
	Total	0	0	0	2	0
Tibia	Left	0	0	0	3	1
	Right	0	2	3	2	0
	Total	0	2	3	5	1
Metatarsal	Left	0	5	2	0	0
	Right	0	0	0	0	0
	Total	0	5	2	0	0

Size 1 and 2 Ungulates - BBC M3

		PE	PS	MS	DS	DE
Humerus	Left	0	1	2	3	0
	Right	0	0	0	0	3
	Total	0	1	2	3	3
Radius	Left	0	3	0	0	0
	Right	0	0	0	0	0
	Total	0	3	0	0	0
Metacarpal	Left	0	0	1	0	0
	Right	0	0	0	0	0
	Total	0	0	1	0	0
Femur	Left	0	0	0	0	1
	Right	0	15	6	0	0
	Total	0	15	6	0	1
Tibia	Left	0	4	2	2	2
	Right	0	2	0	0	0
	Total	0	6	2	2	2
Metatarsal	Left	0	0	2	1	0
	Right	0	0	0	0	0
	Total	0	0	2	1	0

Size 3, 4, and 5 Ungulates - BBC M3						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	0	0	0
	Right	0	1	2	1	0
	Total	0	1	2	1	0
Radius	Left	0	0	0	0	0
	Right	0	0	1	4	0
	Total	0	0	1	4	0
Metacarpal	Left	1	0	0	0	0
	Right	1	3	0	0	0
	Total	2	3	0	0	0
Femur	Left	0	0	0	0	0
	Right	0	0	2	0	0
	Total	0	0	2	0	0
Tibia	Left	0	6	7	3	0
	Right	0	0	3	5	0
	Total	0	6	10	8	0
Metatarsal	Left	0	0	0	0	0
	Right	0	5	0	0	0
	Total	0	5	0	0	0

DK 1 - Size 1						
		PE	PS	MS	DS	DE
Humerus	Left	4	7	11	15	6
	Right	1	24	25	30	12
	Total	5	31	36	45	18
Radius	Left	6	15	11	4	4
	Right	2	25	12	2	3
	Total	8	40	23	6	7
Metacarpal	Left	0	4	9	4	0
	Right	2	4	8	1	0
	Total	2	8	17	5	0
Femur	Left	5	13	40	20	6
	Right	9	20	69	39	2
	Total	14	33	109	59	8
Tibia	Left	0	14	22	5	6
	Right	1	13	35	30	2
	Total	1	27	57	35	8
Metatarsal	Left	0	0	0	0	0
	Right	8	22	5	2	0
	Total	8	22	5	2	0

DK 1 - Size 2						
		PE	PS	MS	DS	DE
Humerus	Left	3	0	0	1	0
	Right	0	0	3	5	4
	Total	3	0	3	6	4
Radius	Left	0	2	0	0	0
	Right	0	7	0	0	0
	Total	0	9	0	0	0
Metacarpal	Left	0	0	1	0	0
	Right	0	0	0	7	0
	Total	0	0	1	7	0
Femur	Left	0	16	12	2	0
	Right	3	5	2	4	4
	Total	3	21	14	6	4
Tibia	Left	1	12	5	12	6
	Right	0	2	3	0	6
	Total	1	14	8	12	12
Metatarsal	Left	0	0	0	0	0
	Right	1	0	0	0	5
	Total	1	0	0	0	5

DK 1 - Size 3

		PE	PS	MS	DS	DE
Humerus	Left	2	11	6	2	2
	Right	0	20	5	0	0
	Total	2	31	11	2	2
Radius	Left	0	3	0	2	0
	Right	2	4	19	9	0
	Total	2	7	19	11	0
Metacarpal	Left	0	0	1	0	0
	Right	0	11	6	7	0
	Total	0	11	7	7	0
Femur	Left	0	2	22	13	0
	Right	0	2	16	14	0
	Total	0	4	38	27	0
Tibia	Left	2	16	6	1	1
	Right	2	21	15	17	0
	Total	4	37	21	18	1
Metatarsal	Left	0	0	0	0	0
	Right	4	0	3	6	0
	Total	4	0	3	6	0

DK 1 - Size 4

		PE	PS	MS	DS	DE
Humerus	Left	3	13	24	40	9
	Right	4	27	58	81	32
	Total	7	40	82	##	41
Radius	Left	0	9	19	19	9
	Right	2	15	12	5	0
	Total	2	24	31	24	9
Metacarpal	Left	5	4	8	12	1
	Right	2	5	27	39	6
	Total	7	9	35	51	7
Femur	Left	2	10	47	28	5
	Right	1	16	37	12	0
	Total	3	26	84	40	5
Tibia	Left	3	37	74	36	9
	Right	2	37	37	44	1
	Total	5	74	111	80	10
Metatarsal	Left	0	0	0	0	0
	Right	20	62	40	3	3
	Total	20	62	40	3	3

APPENDIX G

ADJUSTED PROPORTIONS OF CUT MARKS BY BONE PORTION AT PP13B, BLOMBOS, AND DK1

Size 1 and 2 Ungulates - MIS 5						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	72.9%	14.0%	6.5%	6.5%
	Right	0.0%	40.1%	30.9%	29.0%	0.0%
	Total	0.0%	42.4%	29.2%	18.6%	9.7%
Radius	Left	17.4%	45.1%	29.3%	8.1%	0.0%
	Right	10.5%	35.6%	5.5%	48.4%	0.0%
	Total	13.8%	40.9%	15.5%	29.8%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	25.7%	50.4%	24.0%	0.0%
	Total	0.0%	25.7%	45.3%	28.9%	0.0%
Femur	Left	18.9%	45.2%	25.2%	10.8%	0.0%
	Right	0.0%	49.0%	32.6%	18.4%	0.0%
	Total	7.3%	43.7%	34.1%	15.0%	0.0%
Tibia	Left	0.0%	9.9%	23.3%	58.7%	8.1%
	Right	29.6%	61.4%	9.0%	0.0%	0.0%
	Total	3.5%	23.1%	28.3%	37.2%	7.9%
Metatarsal	Left	-	-	-	-	-
	Right	0.0%	100.0%	0.0%	0.0%	0.0%
	Total	30.7%	36.0%	33.3%	0.0%	0.0%

Size 3, 4, and 5 Ungulates - MIS 5						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	0.0%	55.9%	44.1%	0.0%
	Right	0.0%	20.3%	55.7%	24.0%	0.0%
	Total	0.0%	10.4%	60.4%	29.1%	0.0%
Radius	Left	12.4%	0.0%	13.4%	74.3%	0.0%
	Right	0.0%	27.1%	43.5%	16.1%	13.4%
	Total	4.4%	19.3%	37.2%	27.3%	11.8%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	0.0%	72.7%	0.0%	27.3%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	12.1%	23.5%	64.4%	0.0%
Tibia	Left	0.0%	47.0%	7.5%	45.4%	0.0%
	Right	0.0%	44.4%	37.9%	6.0%	11.7%
	Total	0.0%	43.0%	29.0%	18.7%	9.2%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 1 and 2 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	0.0%	8.7%	41.5%	49.8%	0.0%
	Total	0.0%	6.9%	40.7%	52.4%	0.0%
Radius	Left	21.6%	78.4%	0.0%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	25.0%	75.0%	0.0%	0.0%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	85.4%	0.0%	14.6%	0.0%
Femur	Left	17.5%	0.0%	60.5%	22.0%	0.0%
	Right	-	-	-	-	-
	Total	49.4%	0.0%	32.8%	17.8%	0.0%
Tibia	Left	0.0%	13.2%	63.5%	23.4%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	7.8%	70.3%	21.9%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	44.5%	55.5%	0.0%	0.0%	0.0%
	Total	44.7%	55.3%	0.0%	0.0%	0.0%

Size 3, 4, and 5 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	0.0%	0.0%	100.0%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	0.0%	0.0%	100.0%	0.0%
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	-	-	-	-	-
	Right	0.0%	33.9%	58.2%	8.0%	0.0%
	Total	0.0%	24.8%	60.9%	14.3%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 1 and 2 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	53.1%	28.4%	12.3%	6.3%
	Right	0.0%	41.8%	42.1%	6.5%	9.5%
	Total	0.0%	50.4%	34.3%	7.2%	8.1%
Radius	Left	0.0%	0.0%	0.0%	76.9%	23.1%
	Right	0.0%	12.1%	11.6%	76.4%	0.0%
	Total	0.0%	6.5%	8.6%	68.4%	16.6%
Metacarpal	Left	0.0%	42.0%	20.9%	37.1%	0.0%
	Right	0.0%	0.0%	65.4%	34.6%	0.0%
	Total	0.0%	37.6%	26.3%	36.2%	0.0%
Femur	Left	-	-	-	-	-
	Right	8.9%	20.6%	10.9%	16.3%	43.2%
	Total	5.3%	15.3%	8.1%	14.0%	57.3%
Tibia	Left	0.0%	21.3%	15.4%	46.0%	17.3%
	Right	0.0%	27.7%	40.0%	7.6%	24.7%
	Total	0.0%	27.7%	30.5%	22.4%	19.4%
Metatarsal	Left	14.1%	21.4%	64.5%	0.0%	0.0%
	Right	0.0%	40.2%	30.6%	29.1%	0.0%
	Total	8.8%	27.5%	36.9%	26.8%	0.0%

Size 1 and 2 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	34.6%	41.9%	23.4%	0.0%
	Right	0.0%	12.1%	33.8%	45.0%	9.1%
	Total	0.0%	25.9%	36.1%	32.8%	5.2%
Radius	Left	6.8%	39.0%	31.8%	22.4%	0.0%
	Right	0.0%	16.0%	59.0%	19.2%	5.7%
	Total	5.5%	25.7%	43.3%	21.0%	4.5%
Metacarpal	Left	0.0%	100.0%	0.0%	0.0%	0.0%
	Right	0.0%	0.0%	0.0%	100.0%	0.0%
	Total	0.0%	71.2%	0.0%	28.8%	0.0%
Femur	Left	0.0%	70.8%	29.2%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	63.6%	18.0%	18.4%	0.0%
Tibia	Left	0.0%	50.1%	13.2%	36.7%	0.0%
	Right	0.0%	10.2%	28.1%	61.7%	0.0%
	Total	0.0%	24.6%	22.8%	52.5%	0.0%
Metatarsal	Left	0.0%	60.4%	39.6%	0.0%	0.0%
	Right	21.5%	41.9%	14.3%	22.2%	0.0%
	Total	14.9%	44.1%	22.8%	18.2%	0.0%

Size 1 and 2 Ungulates - BBC M3						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	59.8%	18.8%	16.4%	4.9%
	Right	-	-	-	-	-
	Total	0.0%	58.1%	13.3%	12.7%	15.9%
Radius	Left	0.0%	100.0%	0.0%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	0.0%	0.0%	100.0%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	58.1%	10.0%	15.7%	16.1%
	Right	-	-	-	-	-
	Total	0.0%	62.7%	8.6%	14.2%	14.5%
Metatarsal	Left	0.0%	0.0%	61.3%	38.7%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	0.0%	68.3%	31.7%	0.0%

Size 3, 4, and 5 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	14.0%	16.2%	69.8%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	12.8%	19.7%	67.4%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	0.0%	42.1%	57.9%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	46.0%	0.0%	54.0%	0.0%
	Total	0.0%	54.0%	0.0%	46.0%	0.0%
Femur	Left	51.6%	21.2%	16.4%	10.8%	0.0%
	Right	0.0%	0.0%	0.0%	100.0%	0.0%
	Total	32.1%	24.1%	21.1%	22.6%	0.0%
Tibia	Left	0.0%	43.6%	36.8%	19.6%	0.0%
	Right	0.0%	37.4%	29.6%	19.8%	13.2%
	Total	0.0%	41.8%	34.7%	19.9%	3.5%
Metatarsal	Left	0.0%	75.7%	0.0%	24.3%	0.0%
	Right	-	-	-	-	-
	Total	16.3%	39.9%	24.3%	19.5%	0.0%

Size 3, 4, and 5 Ungulates - BBC M2

		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	0.0%	47.8%	40.2%	0.0%	12.0%
	Total	0.0%	37.2%	46.2%	7.3%	9.3%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	0.0%	0.0%	49.2%	50.8%
	Right	-	-	-	-	-
	Total	0.0%	23.4%	14.7%	27.2%	34.7%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 3, 4, and 5 Ungulates - BBC M3

		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	44.1%	36.1%	19.7%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	34.1%	34.1%	31.8%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

DK 1 - Size 1						
		PE	PS	MS	DS	DE
Humerus	Left	14.9%	19.7%	17.2%	28.2%	20.1%
	Right	2.0%	50.7%	21.0%	18.6%	7.8%
	Total	6.9%	39.6%	20.8%	22.2%	10.4%
Radius	Left	30.2%	23.8%	22.2%	11.7%	12.2%
	Right	7.5%	56.6%	25.9%	6.4%	3.6%
	Total	18.3%	39.8%	25.6%	9.8%	6.5%
Metacarpal	Left	0.0%	34.2%	58.2%	7.6%	0.0%
	Right	14.3%	39.5%	39.2%	7.1%	0.0%
	Total	4.4%	39.1%	43.7%	12.7%	0.0%
Femur	Left	6.1%	15.3%	41.7%	24.2%	12.8%
	Right	10.3%	12.2%	37.7%	36.0%	3.8%
	Total	7.8%	13.8%	40.5%	30.2%	7.7%
Tibia	Left	0.0%	31.1%	43.4%	15.3%	10.3%
	Right	3.2%	30.4%	42.2%	22.8%	1.3%
	Total	1.9%	27.3%	42.0%	24.7%	4.1%
Metatarsal	Left	-	-	-	-	-
	Right	18.5%	57.1%	11.0%	13.4%	0.0%
	Total	19.1%	65.2%	9.9%	5.8%	0.0%

DK 1 - Size 2						
		PE	PS	MS	DS	DE
Humerus	Left	93.0%	0.0%	0.0%	7.0%	0.0%
	Right	-	-	-	-	-
	Total	59.6%	0.0%	10.9%	13.1%	16.3%
Radius	Left	0.0%	100.0%	0.0%	0.0%	0.0%
	Right	0.0%	100.0%	0.0%	0.0%	0.0%
	Total	0.0%	100.0%	0.0%	0.0%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	0.0%	59.8%	33.5%	6.7%	0.0%
	Right	9.2%	13.2%	5.0%	12.5%	60.1%
	Total	5.1%	30.4%	17.9%	9.4%	37.2%
Tibia	Left	4.4%	25.1%	12.7%	42.4%	15.4%
	Right	-	-	-	-	-
	Total	4.2%	27.9%	19.4%	32.9%	15.6%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	22.9%	0.0%	0.0%	0.0%	77.1%

DK 1 - Size 3

		PE	PS	MS	DS	DE
Humerus	Left	45.1%	17.1%	15.8%	5.3%	16.8%
	Right	0.0%	73.2%	26.8%	0.0%	0.0%
	Total	31.7%	36.8%	20.7%	4.8%	6.0%
Radius	Left	0.0%	80.8%	0.0%	19.2%	0.0%
	Right	21.3%	10.7%	47.5%	20.5%	0.0%
	Total	17.5%	17.8%	46.5%	18.2%	0.0%
Metacarpal	Left	0.0%	0.0%	100.0%	0.0%	0.0%
	Right	0.0%	35.3%	24.8%	39.9%	0.0%
	Total	0.0%	43.0%	28.7%	28.4%	0.0%
Femur	Left	0.0%	13.7%	66.0%	20.3%	0.0%
	Right	0.0%	14.4%	53.4%	32.2%	0.0%
	Total	0.0%	14.2%	60.4%	25.4%	0.0%
Tibia	Left	14.4%	49.8%	22.2%	6.8%	6.8%
	Right	7.1%	31.9%	20.4%	40.6%	0.0%
	Total	8.9%	35.4%	20.9%	32.2%	2.6%
Metatarsal	Left	-	-	-	-	-
	Right	76.1%	0.0%	8.8%	15.2%	0.0%
	Total	64.5%	0.0%	13.4%	22.1%	0.0%

		DK 1 - Size 4				
		PE	PS	MS	DS	DE
Humerus	Left	37.3%	9.2%	11.7%	18.5%	23.2%
	Right	52.0%	7.9%	5.5%	7.7%	26.9%
	Total	39.1%	9.2%	8.6%	12.4%	30.6%
Radius	Left	0.0%	23.3%	22.6%	22.8%	31.4%
	Right	50.3%	32.1%	11.4%	6.2%	0.0%
	Total	40.2%	22.8%	13.3%	11.7%	12.1%
Metacarpal	Left	7.8%	11.2%	17.6%	32.8%	30.6%
	Right	3.3%	17.9%	32.6%	39.0%	7.2%
	Total	5.9%	14.6%	29.4%	40.8%	9.3%
Femur	Left	3.9%	10.9%	36.9%	14.0%	34.3%
	Right	13.3%	20.4%	35.4%	30.8%	0.0%
	Total	5.2%	10.9%	26.1%	16.3%	41.5%
Tibia	Left	29.6%	16.7%	25.1%	14.3%	14.3%
	Right	24.2%	24.1%	19.8%	28.5%	3.5%
	Total	26.3%	19.5%	23.0%	19.8%	11.3%
Metatarsal	Left	-	-	-	-	-
	Right	11.2%	28.7%	17.9%	3.5%	38.7%
	Total	14.7%	39.5%	22.9%	3.9%	18.9%

APPENDIX H

NUMBERS OF PERCUSSION MARKS BY LONG BONE PORTION AT PP13B AND BLOMBOS

Size 1 and 2 Ungulates - Back						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	3	2	0
	Right	0	2	2	1	0
	Total	0	2	5	3	0
Radius	Left	1	4	1	0	0
	Right	0	1	1	2	0
	Total	1	5	2	2	0
Metacarpal	Left	0	0	0	2	0
	Right	0	0	0	0	0
	Total	0	0	0	2	0
Femur	Left	1	1	1	2	0
	Right	0	0	2	0	0
	Total	1	1	3	2	0
Tibia	Left	0	4	10	6	0
	Right	0	0	0	0	0
	Total	0	4	10	6	0
Metatarsal	Left	0	1	1	0	0
	Right	0	2	0	0	0
	Total	0	3	1	0	0

Size 3, 4, and 5 Ungulates - Back						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	8	1	0
	Right	0	1	1	3	0
	Total	0	1	9	4	0
Radius	Left	0	1	0	0	0
	Right	0	0	1	1	0
	Total	0	1	1	1	0
Metacarpal	Left	0	1	1	1	0
	Right	0	2	0	1	0
	Total	0	3	1	2	0
Femur	Left	0	0	2	1	0
	Right	1	1	1	1	0
	Total	1	1	3	2	0
Tibia	Left	0	1	2	2	1
	Right	1	4	4	4	0
	Total	1	5	6	6	1
Metatarsal	Left	0	1	5	1	0
	Right	1	2	2	1	0
	Total	1	3	7	2	0

Size 1 and 2 Ungulates - Front						
		PE	PS	MS	DS	DE
Humerus	Left	0	1	4	3	0
	Right	0	5	5	16	3
	Total	0	6	9	19	3
Radius	Left	0	6	2	11	1
	Right	1	6	8	7	0
	Total	1	12	10	18	1
Metacarpal	Left	0	6	1	1	0
	Right	0	2	4	5	0
	Total	0	8	5	6	0
Femur	Left	0	1	7	3	0
	Right	0	2	3	2	0
	Total	0	3	10	5	0
Tibia	Left	0	7	15	11	3
	Right	1	8	4	0	0
	Total	1	15	19	11	3
Metatarsal	Left	0	4	1	0	0
	Right	1	2	1	4	0
	Total	1	6	2	4	0

Size 3, 4, and 5 Ungulates - Front						
		PE	PS	MS	DS	DE
Humerus	Left	1	4	7	4	0
	Right	0	0	2	4	0
	Total	1	4	9	8	0
Radius	Left	0	0	6	3	0
	Right	1	5	7	3	0
	Total	1	5	13	6	0
Metacarpal	Left	0	5	0	3	0
	Right	0	0	0	3	0
	Total	0	5	0	6	0
Femur	Left	0	3	1	1	0
	Right	0	0	2	0	0
	Total	0	3	3	1	0
Tibia	Left	0	2	9	4	0
	Right	0	3	3	8	0
	Total	0	5	12	12	0
Metatarsal	Left	0	1	2	2	0
	Right	0	1	7	1	0
	Total	0	2	9	3	0

Size 1 and 2 Ungulates - MIS 5

		PE	PS	MS	DS	DE
Humerus	Left	0	1	6	5	0
	Right	0	3	5	16	3
	Total	0	4	11	21	3
Radius	Left	0	9	3	11	1
	Right	1	6	7	9	0
	Total	1	15	10	20	1
Metacarpal	Left	0	3	1	3	0
	Right	0	2	2	3	0
	Total	0	5	3	6	0
Femur	Left	0	1	7	3	0
	Right	0	2	3	1	0
	Total	0	3	10	4	0
Tibia	Left	0	9	15	12	3
	Right	1	8	3	0	0
	Total	1	17	18	12	3
Metatarsal	Left	0	5	2	0	0
	Right	1	1	1	0	0
	Total	1	6	3	0	0

Size 3, 4, and 5 Ungulates - MIS 5

		PE	PS	MS	DS	DE
Humerus	Left	1	4	9	5	0
	Right	0	1	3	7	0
	Total	1	5	12	12	0
Radius	Left	0	1	4	3	0
	Right	1	5	5	2	0
	Total	1	6	9	5	0
Metacarpal	Left	0	7	1	2	0
	Right	0	1	0	3	0
	Total	0	8	1	5	0
Femur	Left	0	3	2	2	0
	Right	1	1	3	1	0
	Total	1	4	5	3	0
Tibia	Left	0	3	9	6	1
	Right	1	6	11	9	0
	Total	1	9	20	15	1
Metatarsal	Left	0	2	7	2	0
	Right	1	3	4	2	0
	Total	1	5	11	4	0

Size 1 and 2 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	1	0	0
	Right	0	4	2	1	0
	Total	0	4	3	1	0
Radius	Left	1	0	0	0	0
	Right	3	1	2	0	0
	Total	4	1	2	0	0
Metacarpal	Left	0	3	0	0	0
	Right	0	0	2	2	0
	Total	0	3	2	2	0
Femur	Left	1	1	1	2	0
	Right	0	0	2	1	0
	Total	1	1	3	3	0
Tibia	Left	0	2	10	5	0
	Right	0	0	1	0	0
	Total	0	2	11	5	0
Metatarsal	Left	0	0	0	0	0
	Right	0	3	0	4	0
	Total	0	3	0	4	0

Size 3, 4, and 5 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	4	0	0
	Right	0	0	0	0	0
	Total	0	0	4	0	0
Radius	Left	0	0	2	0	0
	Right	0	0	3	2	0
	Total	0	0	5	2	0
Metacarpal	Left	0	0	0	1	0
	Right	0	1	0	1	0
	Total	0	1	0	2	0
Femur	Left	0	0	1	0	0
	Right	0	0	0	0	0
	Total	0	0	1	0	0
Tibia	Left	0	0	2	0	0
	Right	0	1	6	3	0
	Total	0	1	8	3	0
Metatarsal	Left	0	0	0	1	0
	Right	0	0	5	0	0
	Total	0	0	5	1	0

Size 1 and 2 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0	4	7	3	0
	Right	0	3	3	8	0
	Total	0	7	10	11	0
Radius	Left	0	1	3	1	1
	Right	0	2	4	9	0
	Total	0	3	7	10	1
Metacarpal	Left	0	1	1	3	0
	Right	0	1	1	0	0
	Total	0	2	2	3	0
Femur	Left	0	1	0	1	0
	Right	0	7	1	2	0
	Total	0	8	1	3	0
Tibia	Left	0	11	8	1	0
	Right	0	7	5	6	0
	Total	0	18	13	7	0
Metatarsal	Left	0	8	4	0	0
	Right	0	1	3	1	0
	Total	0	9	7	1	0

Size 3, 4, and 5 Ungulates - BBC M1						
		PE	PS	MS	DS	DE
Humerus	Left	0	1	6	0	0
	Right	0	0	3	6	0
	Total	0	1	9	6	0
Radius	Left	0	0	0	0	0
	Right	0	1	1	8	0
	Total	0	1	1	8	0
Metacarpal	Left	0	1	1	0	0
	Right	0	1	2	2	0
	Total	0	2	3	2	0
Femur	Left	1	3	3	3	0
	Right	1	1	1	7	1
	Total	2	4	4	10	1
Tibia	Left	0	2	5	2	0
	Right	0	3	7	1	0
	Total	0	5	12	3	0
Metatarsal	Left	1	2	0	2	0
	Right	1	5	1	1	0
	Total	2	7	1	3	0

Size 1 and 2 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	0	3	4	1	0
	Right	0	7	11	7	0
	Total	0	10	15	8	0
Radius	Left	1	1	5	6	0
	Right	1	0	4	6	0
	Total	2	1	9	12	0
Metacarpal	Left	0	3	0	0	0
	Right	0	0	0	2	0
	Total	0	3	0	2	0
Femur	Left	0	7	3	1	0
	Right	0	0	2	2	1
	Total	0	7	5	3	1
Tibia	Left	2	10	3	1	0
	Right	0	0	2	1	0
	Total	2	10	5	2	0
Metatarsal	Left	0	4	2	0	0
	Right	0	2	1	0	0
	Total	0	6	3	0	0

Size 3, 4, and 5 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	2	3	0
	Right	0	1	1	3	0
	Total	0	1	3	6	0
Radius	Left	0	0	5	1	0
	Right	0	0	0	0	0
	Total	0	0	5	1	0
Metacarpal	Left	0	6	1	1	0
	Right	0	1	1	1	0
	Total	0	7	2	2	0
Femur	Left	0	0	0	2	0
	Right	0	0	1	1	0
	Total	0	0	1	3	0
Tibia	Left	0	2	0	3	0
	Right	0	0	3	2	0
	Total	0	2	3	5	0
Metatarsal	Left	0	7	0	0	0
	Right	0	0	0	0	0
	Total	0	7	0	0	0

Size 1 and 2 Ungulates - BBC M3

		PE	PS	MS	DS	DE
Humerus	Left	0	1	2	3	0
	Right	0	0	0	0	0
	Total	0	1	2	3	0
Radius	Left	1	0	1	2	0
	Right	0	0	0	0	0
	Total	1	0	1	2	0
Metacarpal	Left	0	1	3	2	0
	Right	0	0	0	0	0
	Total	0	1	3	2	0
Femur	Left	0	0	0	0	0
	Right	1	0	5	3	0
	Total	1	0	5	3	0
Tibia	Left	0	1	2	1	1
	Right	0	2	1	0	0
	Total	0	3	3	1	1
Metatarsal	Left	0	0	5	0	0
	Right	0	1	0	2	0
	Total	0	1	5	2	0

Size 3, 4, and 5 Ungulates - BBC M3						
		PE	PS	MS	DS	DE
Humerus	Left	0	0	0	0	0
	Right	0	0	2	0	0
	Total	0	0	2	0	0
Radius	Left	0	0	0	1	0
	Right	0	0	3	2	0
	Total	0	0	3	3	0
Metacarpal	Left	0	0	0	0	0
	Right	0	0	0	0	0
	Total	0	0	0	0	0
Femur	Left	0	0	0	0	0
	Right	0	0	2	2	0
	Total	0	0	2	2	0
Tibia	Left	0	1	4	0	0
	Right	0	2	3	1	0
	Total	0	3	7	1	0
Metatarsal	Left	0	0	0	0	0
	Right	0	3	0	0	0
	Total	0	3	0	0	0

APPENDIX I

ADJUSTED PROPORTIONS OF PERCUSSION MARKS BY BONE PORTION AT PP13B AND BLOMBOS

Size 1 and 2 Ungulates - Back						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	0.0%	51.8%	48.2%	0.0%
	Right	0.0%	60.6%	24.5%	15.0%	0.0%
	Total	0.0%	43.6%	31.8%	24.7%	0.0%
Radius	Left	23.5%	57.8%	18.7%	0.0%	0.0%
	Right	0.0%	16.2%	10.9%	72.9%	0.0%
	Total	13.8%	39.9%	16.8%	29.5%	0.0%
Metacarpal	Left	0.0%	0.0%	0.0%	100.0%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	0.0%	0.0%	100.0%	0.0%
Femur	Left	31.8%	27.1%	16.1%	25.0%	0.0%
	Right	0.0%	0.0%	100.0%	0.0%	0.0%
	Total	27.0%	17.0%	34.9%	21.2%	0.0%
Tibia	Left	0.0%	23.0%	43.2%	33.8%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	19.0%	43.5%	37.5%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	0.0%	100.0%	0.0%	0.0%	0.0%
	Total	0.0%	57.7%	42.3%	0.0%	0.0%

Size 3, 4, and 5 Ungulates - Back						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	0.0%	88.6%	11.4%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	14.0%	57.9%	28.1%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	68.4%	0.0%	31.6%	0.0%
	Total	0.0%	39.7%	25.8%	34.5%	0.0%
Femur	Left	0.0%	0.0%	47.3%	52.7%	0.0%
	Right	-	-	-	-	-
	Total	30.0%	6.3%	19.2%	44.5%	0.0%
Tibia	Left	0.0%	22.5%	35.4%	23.1%	19.0%
	Right	57.6%	14.9%	8.9%	18.6%	0.0%
	Total	44.9%	17.9%	13.9%	18.4%	4.8%
Metatarsal	Left	0.0%	11.0%	79.0%	10.0%	0.0%
	Right	-	-	-	-	-
	Total	4.3%	16.5%	65.4%	13.9%	0.0%

Size 1 and 2 Ungulates - Front

		PE	PS	MS	DS	DE
Humerus	Left	0.0%	54.6%	36.5%	9.0%	0.0%
	Right	0.0%	32.3%	18.1%	42.2%	7.3%
	Total	0.0%	43.1%	25.0%	25.0%	6.8%
Radius	Left	0.0%	28.5%	10.4%	43.4%	17.7%
	Right	3.8%	25.3%	37.7%	33.3%	0.0%
	Total	1.9%	27.4%	25.3%	42.3%	3.2%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	61.2%	16.7%	22.1%	0.0%
Femur	Left	0.0%	3.9%	53.1%	43.1%	0.0%
	Right	0.0%	41.9%	14.6%	43.5%	0.0%
	Total	0.0%	11.4%	36.7%	51.9%	0.0%
Tibia	Left	0.0%	21.6%	37.4%	33.4%	7.5%
	Right	7.7%	66.1%	26.2%	0.0%	0.0%
	Total	1.9%	37.2%	37.9%	18.6%	4.5%
Metatarsal	Left	0.0%	74.0%	26.0%	0.0%	0.0%
	Right	10.1%	52.4%	12.7%	24.8%	0.0%
	Total	6.0%	45.8%	16.2%	32.0%	0.0%

Size 3, 4, and 5 Ungulates - Front

		PE	PS	MS	DS	DE
Humerus	Left	84.0%	6.0%	6.7%	3.4%	0.0%
	Right	0.0%	0.0%	45.3%	54.7%	0.0%
	Total	76.4%	7.9%	9.4%	6.3%	0.0%
Radius	Left	0.0%	0.0%	45.4%	54.6%	0.0%
	Right	9.9%	31.1%	33.1%	25.8%	0.0%
	Total	7.8%	21.1%	36.9%	34.2%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	0.0%	24.5%	62.7%	12.9%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	37.9%	43.1%	19.0%	0.0%
Tibia	Left	0.0%	8.8%	45.6%	45.6%	0.0%
	Right	0.0%	17.7%	53.3%	29.1%	0.0%
	Total	0.0%	14.0%	53.1%	32.8%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 1 and 2 Ungulates - MIS 5

	PE	PS	MS	DS	DE

Humerus	Left	0.0%	63.3%	27.3%	9.4%	0.0%
	Right	0.0%	21.0%	20.2%	48.5%	10.3%
	Total	0.0%	31.8%	30.1%	31.4%	6.6%
Radius	Left	0.0%	29.5%	12.8%	52.0%	5.7%
	Right	3.7%	25.2%	27.1%	44.0%	0.0%
	Total	1.8%	28.0%	19.8%	47.7%	2.7%
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	33.8%	18.9%	47.3%	0.0%
	Total	0.0%	50.6%	15.3%	34.1%	0.0%
Femur	Left	0.0%	9.0%	58.7%	32.3%	0.0%
	Right	0.0%	42.3%	33.8%	23.9%	0.0%
	Total	0.0%	19.9%	49.0%	31.1%	0.0%
Tibia	Left	0.0%	18.2%	28.7%	48.1%	5.0%
	Right	12.0%	66.3%	21.7%	0.0%	0.0%
	Total	1.9%	34.4%	33.5%	26.1%	4.1%
Metatarsal	Left	-	-	-	-	-
	Right	19.1%	26.5%	54.4%	0.0%	0.0%
	Total	5.6%	39.6%	54.8%	0.0%	0.0%

Size 3, 4, and 5 Ungulates - MIS 5						
		PE	PS	MS	DS	DE
Humerus	Left	46.8%	20.0%	23.1%	10.1%	0.0%
	Right	0.0%	38.1%	22.4%	39.5%	0.0%
	Total	46.7%	21.0%	18.2%	14.1%	0.0%
Radius	Left	0.0%	8.3%	29.7%	61.9%	0.0%
	Right	14.7%	40.1%	29.3%	15.9%	0.0%
	Total	5.3%	28.0%	33.7%	33.0%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	0.0%	47.0%	29.4%	23.5%	0.0%
	Right	-	-	-	-	-
	Total	58.3%	11.8%	12.8%	17.2%	0.0%
Tibia	Left	0.0%	19.7%	47.4%	23.8%	9.2%
	Right	18.3%	25.0%	28.7%	28.1%	0.0%
	Total	11.5%	23.6%	35.3%	27.4%	2.3%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 1 and 2 Ungulates - MIS 6						
		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-

	Right	0.0%	79.3%	11.2%	9.5%	0.0%
	Total	0.0%	71.2%	17.5%	11.3%	0.0%
Radius	Left	#####	0.0%	0.0%	0.0%	0.0%
	Right	63.6%	9.5%	26.8%	0.0%	0.0%
	Total	66.4%	9.9%	23.6%	0.0%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	60.1%	19.4%	20.6%	0.0%
Femur	Left	24.9%	15.0%	28.7%	31.4%	0.0%
	Right	-	-	-	-	-
	Total	15.3%	10.8%	40.8%	33.1%	0.0%
Tibia	Left	0.0%	23.3%	56.1%	20.6%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	16.2%	61.3%	22.6%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	0.0%	57.3%	0.0%	42.7%	0.0%
	Total	0.0%	42.8%	0.0%	57.2%	0.0%

Size 3, 4, and 5 Ungulates - MIS 6

		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	0.0%	100.0%	0.0%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	40.0%	0.0%	60.0%	0.0%
	Total	0.0%	31.2%	0.0%	68.8%	0.0%
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	0.0%	100.0%	0.0%	0.0%
	Right	0.0%	9.1%	39.5%	51.4%	0.0%
	Total	0.0%	4.3%	35.7%	60.0%	0.0%
Metatarsal	Left	0.0%	0.0%	0.0%	100.0%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	0.0%	76.8%	23.2%	0.0%

Size 1 and 2 Ungulates - BBC M1

		PE	PS	MS	DS	DE
Humerus	Left	0.0%	25.8%	38.5%	35.7%	0.0%
	Right	0.0%	49.4%	29.9%	20.6%	0.0%
	Total	0.0%	37.2%	39.8%	22.9%	0.0%
Radius	Left	0.0%	9.7%	67.3%	10.5%	12.6%
	Right	0.0%	11.6%	22.3%	66.1%	0.0%
	Total	0.0%	11.3%	34.8%	44.2%	9.6%
Metacarpal	Left	0.0%	35.4%	17.7%	46.9%	0.0%
	Right	0.0%	80.9%	19.1%	0.0%	0.0%
	Total	0.0%	51.3%	23.9%	24.7%	0.0%
Femur	Left	-	-	-	-	-
	Right	0.0%	72.6%	6.9%	20.5%	0.0%
	Total	0.0%	71.0%	4.7%	24.3%	0.0%
Tibia	Left	0.0%	53.5%	42.1%	4.5%	0.0%
	Right	0.0%	33.6%	34.7%	31.6%	0.0%
	Total	0.0%	44.2%	38.8%	17.0%	0.0%
Metatarsal	Left	0.0%	39.9%	60.1%	0.0%	0.0%
	Right	0.0%	38.1%	43.5%	18.4%	0.0%
	Total	0.0%	54.3%	37.8%	7.9%	0.0%

Size 3, 4, and 5 Ungulates - BBC M1

		PE	PS	MS	DS	DE
Humerus	Left	0.0%	12.6%	87.4%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	6.7%	46.4%	46.9%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	0.0%	28.0%	11.1%	60.9%	0.0%
Metacarpal	Left	-	-	-	-	-
	Right	0.0%	28.8%	37.5%	33.7%	0.0%
	Total	0.0%	33.3%	38.4%	28.3%	0.0%
Femur	Left	53.7%	16.6%	12.8%	16.9%	0.0%
	Right	8.9%	6.1%	22.2%	27.4%	35.3%
	Total	30.9%	11.6%	10.2%	27.3%	20.0%
Tibia	Left	0.0%	32.5%	41.2%	26.3%	0.0%
	Right	0.0%	36.2%	47.8%	16.0%	0.0%
	Total	0.0%	35.2%	44.7%	20.1%	0.0%
Metatarsal	Left	15.9%	51.3%	0.0%	32.9%	0.0%
	Right	-	-	-	-	-
	Total	14.4%	49.2%	10.7%	25.7%	0.0%

Size 1 and 2 Ungulates - BBC M2

		PE	PS	MS	DS	DE

Humerus	Left	0.0%	36.7%	51.8%	11.6%	0.0%
	Right	0.0%	47.4%	34.9%	17.7%	0.0%
	Total	0.0%	36.5%	43.7%	19.8%	0.0%
Radius	Left	3.1%	17.8%	48.5%	30.6%	0.0%
	Right	7.8%	0.0%	62.0%	30.3%	0.0%
	Total	4.8%	7.5%	56.5%	31.3%	0.0%
Metacarpal	Left	0.0%	100.0%	0.0%	0.0%	0.0%
	Right	0.0%	0.0%	0.0%	100.0%	0.0%
	Total	0.0%	65.0%	0.0%	35.0%	0.0%
Femur	Left	0.0%	89.1%	9.0%	1.9%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	84.1%	7.5%	3.5%	4.8%
Tibia	Left	10.4%	66.6%	15.7%	7.3%	0.0%
	Right	0.0%	0.0%	59.3%	40.7%	0.0%
	Total	19.9%	54.2%	16.7%	9.2%	0.0%
Metatarsal	Left	0.0%	60.4%	39.6%	0.0%	0.0%
	Right	0.0%	70.0%	30.0%	0.0%	0.0%
	Total	0.0%	62.4%	37.6%	0.0%	0.0%

Size 3, 4, and 5 Ungulates - BBC M2						
		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	0.0%	12.3%	20.7%	67.1%	0.0%
	Total	0.0%	10.6%	39.6%	49.8%	0.0%
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	58.9%	0.0%	41.1%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	35.8%	22.5%	41.7%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

Size 1 and 2 Ungulates - BBC M3						
		PE	PS	MS	DS	DE
Humerus	Left	0.0%	62.9%	19.8%	17.3%	0.0%

	Right	-	-	-	-	-
	Total	0.0%	69.1%	15.8%	15.0%	0.0%
Radius	Left	33.2%	0.0%	34.8%	32.0%	0.0%
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	0.0%	6.0%	54.2%	39.9%	0.0%
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	35.9%	24.7%	19.5%	20.0%
	Right	-	-	-	-	-
	Total	0.0%	53.4%	22.1%	12.1%	12.4%
Metatarsal	Left	0.0%	0.0%	100.0%	0.0%	0.0%
	Right	0.0%	64.4%	0.0%	35.6%	0.0%
	Total	0.0%	12.7%	63.7%	23.7%	0.0%

Size 3, 4, and 5 Ungulates - BBC M3						
		PE	PS	MS	DS	DE
Humerus	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Radius	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Metacarpal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Femur	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-
Tibia	Left	0.0%	26.3%	73.7%	0.0%	0.0%
	Right	-	-	-	-	-
	Total	0.0%	38.0%	53.2%	8.8%	0.0%
Metatarsal	Left	-	-	-	-	-
	Right	-	-	-	-	-
	Total	-	-	-	-	-

APPENDIX J

TWO-BY-TWO TABLES EMPLOYED IN FISHER'S EXACT TEST

Terrestrial versus Marine Mammals at PP13B

	Terrestrial	Marine	p-value
MIS 5	8742	62	0.3463
MIS 6	4057	22	

(b) Size 1 versus Other Sizes at PP13B

	Other Sizes	Size 1	p-value
Back/MIS 5	1227	519	0.0002
Back/MIS 6	426	117	

	Other Sizes	Size 1	p-value
Front/MIS 5	2279	1242	<0.0001
Front/MIS 6	1135	462	

	Other Sizes	Size 1	p-value
Front/MIS 5	2279	1242	<0.0001
Back/MIS 5	1227	519	

	Other Sizes	Size 1	p-value
Front/MIS 6	1135	462	0.0008
Back/MIS 6	426	117	

(c) Gastrically Etched Bone at PP13B

	Not Etched	Etched	p-value
Size 1	2810	211	<0.0001
Size 2	1331	19	

	Not Etched	Etched	p-value
Size 1	2810	211	<0.0001
Size 3	1178	13	

	Not Etched	Etched	p-value
Size 1	2810	211	<0.0001

Size 4	390	5	

	Not Etched	Etched	p-value
Size 2	1131	19	0.2867
Size 3	1178	13	

	Not Etched	Etched	p-value
Size 2	1131	19	0.8137
Size 4	390	5	

	Not Etched	Etched	p-value
Size 3	1178	13	0.7854
Size 4	390	5	

(d) Large Mammals versus Small Mammals at PP13B

	Large Mammals	Small Mammals	p-value
Front	8514	238	0.1165
Back	4388	101	

	Large Fauna	Small Fauna	p-value
Front	8514	2141	0.0646
Back	4388	1020	

(e) Percussion-Marked Midshafts versus Body Size at PP13B (All Analytical Units)

	PM No	PM Yes	p-value
Size 2	435	364	<0.0001
Size 1	397	187	

	PM No	PM Yes	p-value
Size 3	416	409	<0.0001
Size 1	397	187	

	PM No	PM Yes	p-value
Size 1	397	187	<0.0001
Size 4	80	94	

	PM Yes	PM No	p-value
Size 1	187	397	<0.0001
Size 5	18	9	

	PM No	PM Yes	p-value

Size 2	435	364	0.1118
Size 3	416	409	

	PM No	PM Yes	p-value
Size 2	435	364	0.0446
Size 4	80	94	

	PM Yes	PM No	p-value
Size 2	364	435	0.0478
Size 5	18	9	

	PM No	PM Yes	p-value
Size 3	416	409	0.3169
Size 4	80	94	

	PM Yes	PM No	p-value
Size 3	409	416	0.1162
Size 5	18	9	

	PM Yes	PM No	p-value
Size 4	94	80	0.2980
Size 5	18	9	

(f) Percussion-Marked Size 1 Midshafts at PP13B

	PM No	PM Yes	p-value
Front	311	164	0.0063
Back	86	23	

	PM No	PM Yes	p-value
MIS 5	212	126	0.0016
MIS 6	185	61	

Tooth-Marked Size 1 Midshafts at PP13B

	TM No	TM Yes	p-value
Front	430	45	0.1186
Back	93	16	

	TM No	TM Yes	p-value
MIS 5	300	38	0.4956
MIS 6	223	23	

(g) Percussion Flakes at PP13B

	PM No	PM Yes	p-value
Front	472	186	0.3142
Back	172	60	

	PM No	PM Yes	p-value
Front/MIS 6	248	94	0.1859
Back/MIS 6	45	10	

(h) Gastically-etched bone at Blombos

	Not Etched	Etched	p-value
M2	1226	85	0.0100
M1	1109	57	

	Not Etched	Etched	p-value
M1	1109	57	<0.0001
M3	475	69	

	Not Etched	Etched	p-value
M2	1226	85	<0.0001
M3	475	69	

(i) Percussion-Marked Midshafts versus Body Size at Blombos (All Layers)

	PM No	PM Yes	p-value
Size 1	702	377	0.0010
Size 2	184	151	

	PM No	PM Yes	p-value
Size 1	702	377	<0.0001
Size 3	163	154	

	PM No	PM Yes	p-value
Size 1	702	377	<0.0001
Size 4	40	82	

	PM No	PM Yes	p-value
Size 2	184	151	0.3883
Size 3	163	154	

	PM No	PM Yes	p-value
Size 2	184	151	<0.0001
Size 4	40	82	

	PM No	PM Yes	p-value
Size 3	163	154	0.0004
Size 4	40	82	

Tooth-Marked Midshafts versus Body Size at Blombos (All Layers)

	TM No	TM Yes	p-value
Size 1	940	139	0.5797
Size 2	288	47	

	TM No	TM Yes	p-value
Size 1	940	139	0.7760
Size 3	274	43	

	TM No	TM Yes	p-value
Size 1	940	139	0.2046
Size 4	101	21	

	TM No	TM Yes	p-value
Size 2	288	47	0.9098
Size 3	274	43	

	TM No	TM Yes	p-value
Size 2	288	47	0.4574
Size 4	101	21	

	TM No	TM Yes	p-value
Size 3	274	43	0.3654
Size 4	101	21	

(j) Proximal versus Distal Limb Representation - Small Ungulates

	BBC M1 Obs.	BBC M1 Expect.	p-value
Proximal	21.5	20.7	1.0000
Distal	9.5	10.3	

	BBC M2 Obs.	BBC M2 Expect.	
Proximal	17.5	17.3	1.0000
Distal	8.5	8.7	

	BBC M3 Obs.	BBC M3 Expect.	
Proximal	8.5	8.0	1.0000
Distal	3.5	4.0	

	DK1 9 Obs.	DK1 9 Expect.	
Proximal	15.5	13.0	0.7140
Distal	4.0	6.5	

	DK1 10 Obs.	DK1 10 Expect.	
Proximal	3.0	2.0	1.0000
Distal	0.0	1.0	

	DK1 11 Obs.	DK1 11 Expect.	
Proximal	5.5	4.3	1.0000
Distal	1.0	2.2	

	DK1 12 Obs.	DK1 12 Expect.	
Proximal	25.0	23.0	0.7906
Distal	9.5	11.5	

	DK1 13 Obs.	DK1 13 Expect.	
Proximal	6.0	6.0	1.0000
Distal	3.0	3.0	

	DK1 14 Obs.	DK1 14 Expect.	
Proximal	35.0	28.0	0.1295
Distal	7.0	14.0	

	DK1 15 Obs.	DK1 15 Expect.	
Distal	16.5	8.5	0.0465
Proximal	9.0	17.0	

	PP13B MIS5 Obs.	PP13B MIS5 Expect.	
Proximal	53.0	42.3	0.0376
Distal	10.5	21.2	

	PP13B MIS6 Obs.	PP13B MIS6 Expect.	
Proximal	18.5	16.3	0.7516
Distal	6.0	8.2	

	DK1 High Occ. Obs.	DK1 High Occ. Expect.

Proximal	63.0	53.0	0.1044
Distal	16.5	26.5	

	DK1 Low Occ. Expect.	DK1 Low Occ. Obs.	
Proximal	40.3	36.0	0.5701
Distal	20.2	24.5	

Proximal versus Distal Limb Representation - Large Ungulates

	BBC M1 Obs.	BBC M1 Expect.	p-value
Proximal	23.0	23.0	1.0000
Distal	11.5	11.5	

	BBC M2 Obs.	BBC M2 Expect.	
Proximal	8.0	8.0	1.0000
Distal	4.0	4.0	

	BBC M3 Obs.	BBC M3 Expect.	
Proximal	6.0	5.0	0.5593
Distal	1.5	2.5	

	DK1 9 Obs.	DK1 9 Expect.	
Proximal	10.5	9.7	1.0000
Distal	4.0	4.8	

	DK1 10 Expect.	DK1 10 Obs.	
Proximal	15.7	15.5	1.0000
Distal	7.8	8.0	

	DK1 11 Obs.	DK1 11 Expect.	
Proximal	4.0	4.0	1.0000
Distal	2.0	2.0	

	DK1 12 Obs.	DK1 12 Expect.	
Proximal	23.5	22.3	1.0000
Distal	10.0	11.2	

	DK1 13 Obs.	DK1 13 Expect.	
Proximal	4.5	3.7	1.0000
Distal	1.0	1.8	

	DK1 14 Obs.	DK1 14 Expect.

Proximal	22.5	19.3	0.5472
Distal	6.5	9.7	

	DK1 15 Expect.	DK1 15 Obs.	
Distal	19.0	7.7	0.0008
Proximal	4.0	15.3	

	PP13B MIS5 Obs.	PP13B MIS5 Expect.	
Proximal	30.0	29.7	0.8983
Distal	14.5	14.8	

	PP13B MIS6 Obs.	PP13B MIS6 Expect.	
Proximal	12.0	12.0	1.0000
Distal	6.0	6.0	

	DK1 High Occ. Obs.	DK1 High Occ. Expect.	
Proximal	61.5	57.3	.6178
Distal	24.5	28.7	

	DK1 Low Occ. Expect.	DK1 Low Occ. Obs.	
Proximal	32.7	23.0	.0656
Distal	16.3	26.0	