TESTING MODELS ON THE EMERGENCE AND NATURE OF MODERN HUMAN BEHAVIOR: MIDDLE STONE AGE FAUNA FROM SIBUDU CAVE (SOUTH AFRICA)

by

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To Matt and μ

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Chapter 1

Introduction

Debates about what it means to be human have a very long history within the field of anthropology. While physical anthropologists look to the fossil record to understand the evolution of our species, one of archaeology's main contributions lies in investigating the evolution of modern human culture. As Kuhn and Hovers (2006:1) stated in a recent publication: "Learning how humans, as a species, came to act the way that we do is probably the greatest contribution that [Paleolithic archaeologists] can make to understanding the human present." This study fits within this framework, focusing on the ways in which evidence for prehistoric food procurement and processing strategies can be utilized to enhance our understanding of the origins of modern human culture.

The period dating from roughly 300,000-30,000 years ago (known as the Middle Stone Age in sub-Saharan Africa and the Middle Paleolithic in Eurasia), was a critical one in human evolution, providing the earliest evidence for both anatomically modern humans (~190 ka; McDougall et al., 2005) and modern human behavior (the material correlates of which include art, jewelry, and advanced technological innovations). However, there is much disagreement about the nature of the transition from archaic to modern behavior during this period.

The traditional model placed the origins of modern human culture in Europe around 40 ka, as part of what is known as the "Upper Paleolithic Revolution" (see Bar-

Yosef, 2002 for a review). As evidence suggesting that our species evolved first in Africa began to accumulate (see McBrearty and Brooks, 2000 for a summary of the fossil evidence and Relethford, 1998 for a summary of the genetic evidence), some of those interested in modern behavioral origins began to shift their attention to that continent. Most famously, Richard Klein proposed that an advantageous genetic mutation in the brain resulted in the shift to a "fully modern behavioral mode" around 50 ka (e.g., Klein, 1995; 2000). He argued that this shift played a role in the evolution of modern language; besides conferring the ability to communicate symbolically, the increase in cognitive capacity promoted technological innovation and more efficient resource use. Under Klein's model, it was the evolution of modern behavior that allowed anatomically modern humans to leave Africa and to successfully out-compete archaic populations such as the Neanderthals. Thus, while the locus of attention had shifted, the origin of modern human culture was still viewed as a revolutionary event.

Others have argued that behavioral modernity was the outcome of a more gradual process, pointing to a growing body of evidence for the appearance of several "modern" traits prior to 50 ka (e.g., d'Errico, 2003; McBrearty and Brooks, 2000; McBrearty and Stringer, 2007). While the scattered appearance of some of the material correlates of modern behavior occurs as early as 300 ka—even prior to evidence for anatomically modern humans—two phases of the southern African MSA have received particular attention from those interested in the evolution of modern behavior (e.g., d'Errico, 2003; Henshilwood and Marean, 2003; McBrearty and Brooks, 2000) These are the Still Bay (~80-70 ka), most famous for its bifacial lanceolate points and for the shell beads and engraved ochre recovered from the site of Blombos Cave (Henshilwood et al., 2002;

d’Errico et al., 2005) , and the Howieson’s Poort (HP; ~68-58 ka), best known for its technological innovations (including geometric backed tools and finely made bone points, some of which may have been used as arrowheads) and for the incised ostrich eggshell recovered from Diepkloof (Parkington et al., 2005; Lombard, 2005b; Wadley, 2008).

One of the most potentially significant—and perplexing—aspects of the MSA record is the fact that all of the classical signatures of modern behavior associated with the Still Bay and the HP have disappeared by the end of the HP, when there is a reversion to the “typical” MSA. When the emergence of modern behavior was attributed solely to changes in cognitive capacity, the evolution of these behaviors was viewed as part of a unidirectional process. And yet, the patchy expression of the material correlates of modern behavior prior to 50 ka clearly demonstrates that the evolution of a fully modern cultural system was *not* unidirectional. The question has thus become, what were the factors that rendered “modern” behaviors advantageous in some contexts, but not in others?

Attention has turned to a series of alternative models, all of which appear to be working from the assumption that the cognitive capacity for modern behavior was in place long before such behaviors were manifested, but that these capacities were exploited in archaeologically visible ways only under certain circumstances. These models have primarily taken three forms: 1) models that link the emergence of modern behaviors to environmental degradation (e.g., McCall, 2007), 2) those that look to population pressure as a major influencing factor (e.g., Bird and O’Connell, 2006), and 3) models that link the emergence of modern behaviors to population increase (without requiring population pressure; Shennan, 2000; 2001). These models will be discussed in detail in Chapter 2.

Under the first two classes of models, modern behaviors represent a form of social and economic intensification in response to stress caused by an imbalance between population and resources. Because subsistence strategies should be particularly sensitive indicators of stress, I sought to test the stress models through a comparative analysis of HP and post-HP MSA fauna from Sibudu Cave (KwaZulu-Natal, South Africa). Sibudu is unique among HP sites because of its meticulous excavation and excellent faunal preservation, and dating indicates that it is one of the few known sites to have been occupied during the transition from the HP (in which modern behaviors are evidenced) to the post-HP MSA (when classic signatures of such behaviors have disappeared) (Wadley, 2006; Wadley and Jacobs, 2006). If the innovations present in the HP reflect a form of social and/or economic intensification in response to stress, then signs of subsistence intensification, including an expansion of dietary breadth and more intensive processing strategies, should be restricted to or more common in the HP. By explicitly testing hypotheses about the emergence and nature of modern behaviors, this work contributes to a broader understanding of modern human origins.

Organization of the volume

Chapter 2 presents the theoretical and analytical framework of the current study. In this chapter, I outline the major schools of thought on modern behavioral origins and discuss the ways in which the archaeological record in sub-Saharan Africa has been particularly important to our understanding of human behavioral evolution. As discussed above, many scholars are now turning to ecological and demographic models to explain the emergence and nature of modern human behaviors; however, these models have yet to be tested. I close the chapter by setting up just such a test, introducing the ways in which the stress models can be tested using faunal data from the site of Sibudu Cave.

In Chapter 3, I introduce the site of Sibudu Cave and discuss the current state of research on the extensive MSA deposits at the site. Since 2002, more than 40 academic papers have been published on various aspects of the MSA record at Sibudu; I focus on those subjects that are most relevant to the current project, including stratigraphy and dating, lithic analyses, and the floral and faunal remains. While I provide an overview of the material remains from all of the MSA horizons at the site, I focus particularly on the HP and post-HP MSA, as these are the periods on which my study is based.

Chapter 4 describes the general characteristics of the HP and post-HP MSA fauna and the basic methodology employed. Because quantification is of key importance, and because there are heated debates about which counting methods most accurately and reliably express the abundance of different animals and/or body parts in the assemblages (e.g., Grayson, 1984; Lyman, 1994a, b, c; Marshall and Pilgram, 1993; Yeshurun et al., 2007), I provide a detailed discussion of the strengths and weaknesses of MNI (minimum number of individuals) and NISP (number of identified specimens), ultimately choosing NISP as the most appropriate quantification unit for the Sibudu assemblage. After introducing the basic results, I close the chapter by discussing some of the potential limitations of the sample.

In considering the resource stress hypothesis, it is important to evaluate the degree to which variability in the faunal assemblage can be attributed to environmental change. As such, Chapter 5 focuses on the paleoecology of the Sibudu region, exploring the ways in which the botanical and faunal records can inform us about conditions in the site region during the HP and post-HP MSA. Archaeomagnetic data indicate that the post-HP MSA encompassed the transition from Oxygen Isotope Stage (OIS) 4 (a glacial) to OIS 3 (an interstadial) (Herries, 2006), and thus it was expected that some shifts in vegetation would be evidenced in the record. In fact, both the botanical and faunal data suggest that the vegetation in the site vicinity underwent marked changes between the HP and the late post-HP MSA. Unfortunately, the limited sample from the early post-HP MSA layers makes it difficult to ascertain whether this transition was sudden or more gradual. In either case, it is clear from this analysis that at least some of the variability in the faunal assemblage is attributable to environmental change; these changes may have resulted in resource stress.

Taphonomic research aims to discern the most influential processes acting on bone assemblages and to distinguish natural forces from human behavior (Bar-Oz and Munro, 2004). Reconstructing the taphonomic history of the assemblage is thus of critical importance in evaluating whether or not patterning in the faunal record is a product of human behavior or is an artifact of other processes such as decay or carnivore activity. Chapter 6 focuses on detailed taphonomic analyses of both the identifiable and non-identifiable fraction of the assemblage. I focus particularly on evidence for variability in burning and fragmentation, the presence and frequency of surface modifications, and density-mediated attrition across the HP and post-HP MSA. These and other analyses are used to identify the agents of accumulation and to evaluate degree of attrition present in the sample, focusing on whether it is the same across the samples and how and to what degree any variability in taphonomy affects our ability to draw inferences about changes in human hunting behavior over time.

In Chapters 7 and 8, I explore the evidence for variability in animal procurement and processing over time. I discuss the methodology employed to study prey selection (e.g., increased diet breath, the relative frequency of dangerous vs. docile game), transport decisions (accessible primarily through element frequency distributions) and processing behavior, highlighting the ways that each of these can reflect the presence of resource stress. In exploring variability in prey selection, I focus in large part on the bovid assemblage, as bovids comprise the majority of the identifiable material.

In Chapter 9, I summarize the results of the analyses conducted in Chapters 5 through 8. I evaluate the resource stress model and discuss the relative impact of environmental change on the results. I conclude with a consideration of the implications of the results to our understanding of the HP, and, on a broader scale, to our understanding of the emergence and nature of modern human behaviors.

Chapter 2

Theoretical and Analytical Framework

For decades, the prevailing view was that modern behavior evolved around 40,000 years ago as part of what is referred to as the "Upper Paleolithic Revolution." This view was based on the European record, in which there was a flowering of evidence for art, ritual, and technological innovation at the time of the transition from the Middle to the Upper Paleolithic (MP and UP, respectively), which also happened to coincide with the earliest appearance of anatomically modern humans on that continent. Under this paradigm, "modern" behaviors were simply those that distinguished the Upper Paleolithic (presumably produced by modern humans) from the Middle Paleolithic (presumably made by Neanderthals). These behaviors included: the production of formalized bone tools, art and ornaments (the latter two representing symbolically mediated behavior); the systematic production of blade and/or microlithic technology; expanded exchange networks; "style" in lithic assemblages; and ritualized burial of the dead (Bar-Yosef, 2002; Mellars, 1973, 2002; White, 1982).

As evidence suggesting that our species evolved first in Africa began to accumulate (see McBrearty and Brooks, 2000, for a review of the fossil evidence and Relethford, 1998, for a review of the genetic evidence) some of those interested in the evolution of modern human behavior began shifting their attention to that continent.

Most famously, Richard Klein (1995, 2000, 2001, 2008) argued that an advantageous genetic mutation in the brain resulted in the shift to a "fully modern behavioral mode" around 50 ka. Under Klein's model, this shift played a role in the evolution of modern language; besides conferring the ability to communicate symbolically, the increase in cognitive capacity promoted technological innovation and more efficient resource use. Klein thus argued that it was the evolution of modern behavior that allowed these populations to leave Africa and successfully out-compete archaic populations like the Neanderthals. Thus, while the locus of attention had shifted, the origin of modern human culture was still viewed as a revolutionary event.

And yet, archaeologists have discovered a growing body of evidence indicating that several modern traits pre-date 50 ka. While much of this evidence is associated with the African Middle Stone Age, including bone points dating to ~95 ka from the site of Katanda (Democratic Republic of the Congo; Yellen et al., 1995) and backed microlithic tools dating to ~65 ka at Klasies River Mouth (KRM, South Africa; Singer and Wymer, 1982), evidence for such behaviors was also found in Eurasia—examples include the production of a standardized blade-based technology dating to ~90 ka at the site of Seclin in France (Clark and Riel-Salvatore, 2006) and engraved flint artifacts from Quneitra and Qafzeh in Israel (dating to ~50 ka and 90-100 ka, respectively; d'Errico et al., 2003a).

There were several different responses to these findings. Particularly for those remains associated with Neanderthals, some tried to explain them away, arguing that the dating was invalid or the significance of the findings was unclear (this was particularly the case for any objects or activities that may have granted Neanderthal symbolic capabilities, such as the burials dating in excess of 50 ka at Kebara and Shanidar, see

Mellars, 1996). Others argued that the broader evolutionary significance of these finds, many of which were related to technological innovations, was uncertain. As such, there was a call to redefine "modernity" in such a way as to exclude these things (e.g., Henshilwood and Marean, 2003; Wadley, 2001). Under these new definitions, the "smoking gun" evidence for modern cognitive ability was symbolically mediated behavior, expressed through such artifacts as art or personal ornamentation.

However, a small group of scholars embraced this evidence. Most notably, McBrearty and Brooks (2000) compiled evidence from the MSA which demonstrated that not only did most of the traits associated with the Upper Paleolithic Revolution appear earlier in Africa than in Europe, but that these behaviors also appeared at sites that were widely separated in space and time. As such, they argued that the evolution of modern behavior occurred in Africa, and that it was the outcome of a gradual process, not a revolution.

While acknowledging an early emergence of modern behavior in Africa, others argued that similar trends are evidenced among Neanderthal populations in Europe and the Near East (d'Errico, 2003; Straus, 2005; Zilhão and d'Errico, 2003). In fact, as early as 1983, Straus recognized that most of the contrasts between the MP and UP as defined by Mellars (1973) and White (1982) were more appropriate for contrasting the Mousterian with the Magdalenian, the chronological poles of the transition. It has become clear that differences between the late Middle Paleolithic (LMP) and early Upper Paleolithic (EUP) are nowhere near as marked. Recent comparisons of LMP and EUP subsistence have shown that hunting strategies and meat processing behaviors did not differ significantly between Neanderthals and modern humans (Bar-Oz and Adler, 2005;

Enloe, 2001; Morin, 2004; Grayson and Delpech, 2003). Furthermore, evidence that Chatelperronian Neanderthals produced personal ornaments and bone tools indicates that they were also capable of symbolic thought (d'Errico et al., 2003b).

A brief aside—what is modern, anyway?

Before continuing, I want to return to a point raised briefly above—to a certain extent, an evaluation of the models relating to the emergence of modern behavior will depend upon what behaviors/traits are considered "modern." As aptly stated by O'Connell and Allen (2007:403):

> Modern humans are characterized by an unusual set of qualities—a capacity for abstract thought and communication, a remarkable degree of behavioral flexibility, and significantly innovative capabilities, notably in the realm of technology.

The question is, how do we recognize this suite of characteristics in the archaeological record? As discussed in the opening paragraph of this chapter, the traditional way of defining modern behavior was to use the list of traits as defined by scholars such as Mellars (1973) and White (1982). However, Henshilwood and Marean (2003) recently argued against the trait list approach, claiming that many of these traits were empirically derived from (and context-specific to) the European record, rendering them problematic when applied to tropical and sub-tropical regions. While recognizing that the trait list approach to defining behavioral modernity can be problematic, I agree with Klein (2003) that the concept retains some utility. He pointed out that the traits were widespread among historic and recent prehistoric hunter-gatherers but not among archaic humans, supporting their association with modernity.

This is not to say that populations which express more of the traits are somehow more "modern" or that those who do not display them are automatically archaic or "nonmodern"—in fact, we know that this is not true, as there were fully modern groups who do not preserve a record of such behaviors (e.g., the early inhabitants of Sahul; O'Connell and Allen, 2007). However, it remains the case that the traits under consideration were relatively uncommon prior to the LSA/UP, and thus their emergence must have some significance. As will be discussed in more detail below, the fact that many of these traits do not see sustained expression until the later Pleistocene can potentially be explained by factors other than a change in cognitive abilities; however, whether or not they are the best, or only, qualifiers of "modernity," I agree with O'Connell and Allen (2007) that the presence of the conventionally defined archaeological markers of modern behavior does indicate modern capabilities, and, as such, I will continue to refer to these traits as modern.

The importance of the MSA record to research on modern behavioral origins

It was against the backdrop of the debate over whether the emergence of modern behavior was an example of revolution or evolution—and whether such behaviors arose first in Europe or Africa—that the major findings at Blombos Cave, an MSA site in the Western Cape region of South Africa, began to be published. In 2002, Christopher Henshilwood and colleagues announced the discovery of engraved ochre artifacts associated with a sub-stage of the MSA known as the Still Bay—a phase that had already received attention for its finely made, bifacially worked points and for its worked bone industry (Henshilwood and Sealy, 1997; Henshilwood et al., 2001a, b; 2002). Optically stimulated luminescence (OSL) dates indicated the age of these artifacts to be in excess of 75,000 years, and thus the Blombos team proposed that the engraved artifacts may have represented the earliest known abstract art and thus served as evidence for modern human behavior (Henshilwood et al., 2002).

Along with the engraved ochre pieces were several ochre "crayons" (Henshilwood et al., 2001). It has been argued that the ochre use, in and of itself, serves as a marker for symbolically mediated behavior (e.g., McBrearty and Stringer, 2007); however, there is a great deal of debate about whether or not ochre can be presumed to have served a symbolic function. Work by Wadley and colleagues (Lombard, 2005a; Lombard, 2007; Wadley, 2005b; Wadley et al. 2004) has demonstrated that incorporation of ochre into mastic can improve the durability of hafted tools; furthermore, ochre can serve as a hide preservative and has an astringent effect, and thus ochre can serve several important utilitarian functions. On the other hand, Watts and colleagues (Watts, 2002; Marean et al., 2007) have demonstrated that the brightest and most saturated reds are disproportionately represented among the utilized ochre present at MSA sites; this selection for color does not appear to be linked to any utilitarian function. Despite this, as Brumm and Moore (2005) argue, in the absence of direct evidence for the artistic use of pigments (in the form of cave paintings or colored artifacts), the presence of ochre should not be held as an unambiguous marker of symbolic behavior.

While some questioned the significance of the markings on the ochre pieces (e.g., Wadley, 2005; Klein 2008), the publication of a collection of more than 40 *Nassarius kraussianus* shell beads from the same the layers at Blombos laid to rest any doubt that the capacity for symbolic behavior predated the purported neural reorganization of the brain at ~50 ka (d'Errico et al., 2005; Henshilwood et al., 2004). Since that finding was published, similar shell beads, some dating even earlier, have been discovered in Still

Bay layers at the site of Sibudu (~71 ka; d'Errico et al., 2008), as well as in Israel (~100-135 ka layers at Skhul; Vanhaeren et al., 2006) and Morocco (~82-85 ka layers at Grotte des Pigeons; Bouzouggar et al., 2007), suggesting that the Blombos finds are not simply an isolated occurrence.

Furthermore, the Still Bay is succeeded by the Howiesons Poort (HP), another sub-stage of the MSA that preserves significant evidence for modern behavior. Because of its wide geographic range and well-defined chronological span, and as a result of the precocious appearance of innovations such as microlithic technology, advanced bone technology, and artifacts of symbolic significance, the HP has figured prominently in recent discussions about the origins of modern human behavior (d'Errico, 2003; Henshilwood and Marean, 2003; Klein 2000; 2001; McBrearty and Brooks 2000; Mellars, 2005; Straus, 2005). Identified across much of southern Africa, the HP is a distinctive artifact horizon characterized by the appearance of geometric backed tools reminiscent of those associated with the LSA (Deacon, 1995). The presence of these tools originally led to the classification of the HP as an intermediate stage between the MSA and LSA; however, excavations at Klasies River Mouth in 1967-68 showed the horizon to be interstratified with typical MSA levels that lack material evidence for modern behavior (Singer and Wymer, 1982). The lack of continuity between the HP and the LSA has been confirmed at several other sites, including Rose Cottage, Boomplaas, Sibudu, and Border Cave, wherein HP assemblages are stratified below a series of later MSA levels (Deacon, 1989; Grün and Beaumont, 2001; Harper, 1997, Wadley and Jacobs, 2004).

Given that the HP is beyond the limits of radiocarbon dating, a variety of methods have been employed to date the phenomenon. Electron spin resonance (ESR) dates from the HP levels at Border Cave provided an age of 79-60 ka (Grün and Beaumont, 2001), while the compilation of amino acid racemization (AAR) dates from HP contexts at Boomplaas, Border Cave, and Apollo 11 suggested an age of 80-56 ka (Miller et al., 1999). Luminescence dates from Rose Cottage, Klasies River Mouth, and Diepkloof showed slightly later dates ranging from 68-54 ka (Feathers, 2002; Gibson, et al. 2004; Rigaud et al., 2006; Valladas et al., 2005).

Jacobs et al. (2008a; Jacobs and Roberts, 2008) recently reported on the results of a systematic study in which 22 samples from eight sites preserving HP deposits were dated using optically stimulated luminescence (OSL). While several of these sites had been dated before, the study aimed to refine the chronology of the HP by measuring all samples on a single instrument using a common set of procedures. The authors found that ages were remarkably consistent across the eight sites, leading them to propose that the period was of shorter duration than previously indicated, perhaps only from ~65-60 ka (with the 95% confidence interval, the range was between 68-57 ka).

These dates are significant for two reasons. First, they show that the various HP assemblages are penecontemporaneous—the Howiesons Poort is thus a regionally and temporally distinct phenomenon. As such, it has been argued that the industry represents one of the earliest cases in which style can be identified in stone tool assemblages (McBrearty and Brooks, 2000; Wurz, 1997). Second, the majority of dates fall squarely within the Last Glacial, during Oxygen Isotope Stage (OIS) 4 (~75-60 ka), with the earlier and later dates spanning the transitions to and from interglacial/interstadial periods

(OIS 5 and 3). As a result of the correlation between the HP and a period of large-scale climatic change, several scholars have posited that environmental change played a causal role in its appearance (discussed in more detail below; see Ambrose and Lorenz, 1990; Deacon, 1989; McCall, 2007).

A number of technological innovations are evidenced in HP assemblages. At most HP sites, there is a lack of traditional MSA hunting technology—stone points are absent (Lombard and Pargeter, 2008). Instead, the lithic assemblages are dominated by the geometric backed tools which define the Industry. Some of these have been classified as microliths (e.g., Ambrose, 2002), making the HP one of the earliest known microlithic industries (but see Barham 2002 for a discussion of microliths dating to ~300ka in Zambia). Studies of microscopic residues on the backed segments from Rose Cottage, Umhlatuzana, and Sibudu indicated these tools were likely hafted, as residues associated with mastic appear on and near the backed edges (Gibson et al., 2004; Lombard, 2007; 2008). Use-trace analysis and impact fractures indicate that the segments were probably used as inserts for hunting weapons (Lombard, 2008; Wurz and Lombard, 2007); experimental work by Pargeter (2007) has shown that these tools act as very effective projectile tips.

Metric analyses of the HP segments from Sibudu (Wadley and Mohapi, 2008) have indicated that the dimension of some of these tools (particularly those made on quartz) fit within the known range of arrow points, and, as such, they proposed that bow and arrow technology may have originated in the HP. Segments made on other raw materials may have served as dart or spear points (Wadley and Mohapi, 2008). In any case, the use of projectile armatures in specialized compound tools implies a high degree of cognitive sophistication (Brooks et al, 2006).

It has also been argued that the HP witnessed an increased use of fine grained and "non-local" resources—while this may be the result of increased range size, the procurement of "exotic" raw materials has also be associated with long-distance exchange (Ambrose and Lorenz, 1990; Wurz, 1997). However, the initial statements about raw material usage in the HP were based upon the assemblage at Klaises River Mouth (KRM), and research on the HP assemblages at Rose Cottage Cave and Sibudu (Soriano et al., 2007; Wadley and Mohapi, 2008) has demonstrated that the majority of tools at these sites were made on raw materials that could have been procured locally. Furthermore, Minichillo (2006) argued that the proportion of exotic raw materials in the KRM assemblage has been overestimated; based on survey work, he argued that materials previously thought to be non-local could have been procured from secondary cobble deposits found near the shelter. Thus, until more research has been undertaken, the argument that non-local raw materials are more common in the HP must be taken with caution.

The HP is also associated with a worked bone industry; Backwell et al. (2008) recently published details on three bone tools from the HP layers at Sibudu Cave, including a finely made point that is virtually indistinguishable from prehistoric and ethnographically documented arrow points. Two similar points were recovered from HP layers at Peers Cave and Klasies River Mouth; however, in both cases the points were dismissed as being intrusive from LSA deposits (e.g., d'Errico and Henshilwood, 2007). The evidence from Sibudu, at which there are no LSA points, suggests that these tools are in fact properly attributable to the HP. In addition to these more formal tools, engraved and notched bones have been recovered from HP contexts (d'Errico and Henshilwood 2007).

Finally, the HP preserves additional evidence for the presence of symbolically mediated behavior. Ochre is nearly ubiquitous at HP sites, although, as previously stated, there is currently a great deal of debate about whether the presence of utilized ochre can be unambiguously associated with symbolic behavior. More than 80 incised ostrich eggshell fragments are associated with HP levels at Diepkloof (Parkington et al., 2005). Although some of the striations on these fragments may have resulted from use wear or trampling, the deeper incisions were clearly intentional and in some cases form abstract designs (see Figure 7 in Parkington et al., 2005). Parkington et al. (2005) propose that the eggshells functioned as containers to store water and suggest that the marks may have served to denote ownership of particular containers.

One of the most potentially significant—and perplexing—aspects of the MSA record is the fact that all of the signatures of modern behavior associated with the HP disappear at the end of the phase, when there is a reversion to the "typical" MSA (Singer and Wymer, 1982; McBrearty and Brooks 2000; Parkington et al. 2005; Wadley, 2006). When the emergence of modern behavior was attributed solely to changes in cognitive capacity, the evolution of these behaviors was viewed as part of a unidirectional process. And yet, the patchy expression of the material correlates of modern behavior prior to the LSA/UP—including discontinuous evidence for symbolically mediated behavior (which appears to be a universally agreed upon sign of modern cognition)—clearly demonstrates that the evolution of a fully modern cultural system was *not* unidirectional. This being the case, what were the factors that rendered modern behaviors advantageous in some contexts but not in others?

Paradigm shift: ecological and demographic models

Under models that envision the emergence of modern behavior as part of a more gradual process, the innate cognitive capacity for modern behavior is believed to have been in place long before these behaviors were manifested—the assumption being that this capacity was exploited in archaeologically visible ways only on the cue of particular stimuli (Hovers and Belfer-Cohen, 2006; McBrearty and Stringer, 2007; Zilhão, 2007). Recent attention has thus begun to focus on the factors that may have influenced the emergence of modern behaviors. Three primary classes of models have been proposed to explain the emergence and nature of modern human behaviors: 1) those that link the emergence of modern behavior to environmental degradation; 2) those that look to population pressure as a prime mover, and 3) models that look to demographic growth more generally (which can occur in the absence of population pressure).

Models linking cultural and technological innovation to environmental and/or demographic stress are certainly not new; archaeologists have employed these models to explain phenomena ranging from the origins of agriculture to the origins of the state (e.g., Binford, 1968; Flannery 1969; Carneiro 1970). Many of the models exploring behavioral adaptations to environmental stress have focused specifically on technology. Fitzhugh (2001) developed a model under which rapid environmental change, such as that caused by a major climatic event, should lead to greater technological innovation, resulting in the development of novel tool classes and new deployment methods. This process could explain the appearance of innovative technology such as microliths. While the production of bone tools and composite weaponry hafted with microliths is more labor intensive than the production of stone or simple organic points, Elston and Brantingham (2002) have argued that these tools are also less likely to fail and are more readily repaired when they do; as such, they are examples of a "reliable" technology—among modern foragers, reliable technological systems are characteristic of foragers living in low productivity environments. A significant decline in environmental productivity may thus have stimulated the development of these technologies.

McCall (2007) built upon this framework to develop an ecological model to explain emergence of both the Still Bay and Howieson's Poort. He linked the emergence of the Still Bay to environmental changes that occurred at the OIS 5/4 transition. These changes would have caused a reduction in the density of food resources, leading to a reorganization of mobility patterns and new strategies of lithic raw material economy and tool design. McCall proposed that stress caused by these changes would have been a strong impetus for the development of new forms of information exchange—this type of exchange would have been facilitated by decorated objects of the type found at Blombos. Under his model, the HP emerged out of the Still Bay as information sharing strategies improved, allowing resources to be more efficiently targeted with task-specific tools. His ecological model also attempts to explain the disappearance of the HP—given that the decline of the HP appears to correspond with the end of OIS 4 and the rise of warmer and wetter conditions during the interstadial period, McCall (2007) argued that the reversion to a "typical" MSA toolkit represents a return to a more flexible, maintainable toolkit in response to denser and more predictable environmental resources.

Deacon and colleagues (Deacon, 1989; Deacon and Wurz, 1996) have also argued in favor of an environmental explanation for the HP, proposing that the HP represents a social mechanism designed to cope with circumstances of environmental stress. Under this model, the backed tools served a symbolic role, functioning as exchange goods in a system of reciprocal exchange designed to enlarge social networks during a period of depressed climate. Following from this, they propose that the return to more productive environmental conditions at the end of the HP relieved the pressures that had required the maintenance of these networks, and thus there was a reversion to earlier technological strategies.

Population density has long been recognized as one of the primary factors stimulating behavioral change, as increasing population densities can lead to heightened competition for both land and resources, leading to various adaptations in the social, economic, and technological spheres (Mellars, 2006a). As a result, it is unsurprising that a number of scholars have turned to demographic factors to explain both the symbolic "revolution" in the UP/LSA and the on-again, off-again presence of the material correlates of modern behavior in the MSA record. Kuhn and Stiner (1998:157) proposed that the changes in material culture associated with the UP may reflect the crossing of an organizational threshold, in which regional populations "reached a level at which new channels of information transmission became necessary to alleviate conflict and to establish boundaries." Bird and O'Connell (2006) make a similar proposition, suggesting that the "explosion" in evidence for symbolic communication after ~50 ka was not driven by a sudden increase in cognitive capacity, but rather by larger population sizes and higher levels of competition for critical resources. They go on to suggest that the intermittent evidence for modern behaviors in the MSA could be read as evidence for earlier (but transient) increases in human population density and competition (see Hovers and Befer-Cohen, 2006, for another version of this argument).

Henshilwood and Marean (2003) attempted to synthesize the environmental and demographic stress models, arguing that many of the traits that have traditionally been associated with behavioral modernity could reflect resource and labor intensification driven by population pressure. This pressure could result either from demographic increase *or* from climatic change that resulted in a decline in the abundance or availability of critical resources. They believe that this model is consistent with the MSA record in Africa, with its "sudden, often regionally isolated expressions of more complex material culture followed by periods of their disappearance (p. 633)" and with a gradual addition and perseverance of such traits over time until they reach sustained expression in the Holocene. Straus (2005) suggested that a similar mechanism underlies the appearance and disappearance of certain cultural traits among Neanderthals.

These mechanisms have also been employed to explain trends evidenced in the later prehistory of Australia and North America. Although it is universally presumed that the first inhabitants of Australia were fully modern humans, the bulk of the Pleistocene record from that continent is strongly reminiscent of MSA/MP, in that a limited range of stone tool production techniques were employed, bone technology is rare, and there is little evidence for symbolically mediated behavior—although, as in the MSA/MP record, ochre is common (Brumm and Moore, 2005; O'Connell, 2006; O'Connell and Allen, 2007). It is not until the early Holocene that classic signatures of modern behavior appear in the record in any frequency—at that time, there was a proliferation of microlithic technology, elaborate art, and ornamentation, an increase in the size of long-distance trade networks, the development of complex technologies to aid in the procurement of aquatic and plant resources. At around the same time as this symbolic "revolution," there is evidence for both population increase and changes in climate that would have favored the adoption of low-ranked resources (Brumm and Moore, 2005; Hiscock and O'Connor, 2006; O'Connell, 2006; O'Connell and Allen, 2007).

As Speth (2004b) highlights, the same basic patterns are apparent in the North American record. Again, we know that the earliest inhabitants of North America were fully modern humans. Although complex stone tool technology is evidenced, the Paleoindian period preserves very little evidence for modern behavior in the form of art, ornaments, or burials. These things become much more common during the course of the Archaic, during which there is also evidence for increasing human population size and resource intensification in the form of broadening diets. Taken together, the data from Australia and North America provide further support for the argument that the emergence (and subsequent disappearance) of the material correlates of modern behavior in the MSA/MP record, and their proliferation and sustained presence in the LSA/UP, does not have to reflect changes in innate behavioral capabilities, but may have rather more to do with demographic and/or ecological factors.

In an important twist to the stress model as developed by Henshilwood and Marean (2003), they argued that behaviors that can be explained by intensification (particularly technological innovations) are not unambiguous indicators of modern behavior, and as such, these should be eliminated from considerations of the emergence of modern behavior. They prefer instead to focus on symbolic behavior as the primary marker of modernity. However, it can be countered that the appearance of material culture reflecting symbolic behavior represents a form of social intensification in response to similar types of stress. For example, James and Petraglia (2005) and Kuhn et al. (2001; see also Kuhn and Stiner, 2007) have argued that signaling identity through the use of ornaments may be adaptive in situations in which population growth has resulted in competition for resources and/or in more frequent contact between previously isolated groups. Others have argued that artifacts with symbolic significance may have arisen as an adaptive response to environmental stresses such as decreased productivity and/or increased variability (e.g., Ambrose, 2002; Deacon, 1989; de Beaune, 2005). Many of these arguments have their basis in ethnographic research among traditional societies, which has shown that the cultivation of social relationships through practices such as the exchange of "exotic" goods or ornaments is a common response to resource stress—this networking provides groups with access to resources in other regions that may be differentially affected by periods of stress (Minnis, 1985; Wiessner, 1983). Thus, contra Henshilwood and Marean (2003), I would argue that the emergence of symbolic behavior can also be modeled as a response to demographic or environmental stress.

The last set of models also focuses on the role that demographic growth plays in the stimulation of innovative behavior, but unlike those discussed above, does not require the presence of population pressure. Simulations conducted by Shennan (2000; 2001) demonstrated that when populations are small, innovations are less likely to be maintained, but as populations increase—either through simple demographic growth or as function of previously isolated groups coming into contact with one another—the probability that innovations will be diffused and maintained is significantly increased. He thus proposed that the rate of successful technological innovations, including those associated with behavioral modernity, could be correlated with increased population sizes and densities. Under this model, then, the origin and spread of model behavior depends primarily upon population increase, but, given the relatively low population densities during the period, demographic growth in an of itself need not lead to stress.

While the shift towards models that link the emergence of modern behaviors to ecological and demographic factors marks a positive step forward, many of these models are beginning to gain acceptance despite the fact that they have yet to be explicitly tested against the archaeological record. Under the first two classes of models, modern behaviors represent a form of social and economic intensification in response to stress caused by an imbalance between population and resources. As such, I will utilize a more general stress model in my test. A generalized model will be more widely applicable, and, in any case, the effects of environmental and demographic stress are often intricately linked—and the nature of the Paleolithic record is not often conducive to teasing the two apart.

Testing the stress model: analytical framework

Because subsistence strategies should be particularly sensitive indicators of stress, I will utilize faunal remains to evaluate the hypothesized link between resource stress and the emergence of modern behaviors. Models of foraging behavior developed in evolutionary ecology have shown that resource intensification can take several forms. Under the prey choice model (Kaplan and Hill, 1992), expansion of dietary breadth is predicted to be one of the earliest responses to dietary stress. Prey choice models predict that top-ranked prey (those that provide a higher energetic yield relative to search, pursuit, and handling costs) will always be taken on encounter; if encounter rates with preferred prey decline, hunters are expected to broaden their diets by including more lower-yield resources in the diet (Bird and O'Connell, 2006; Broughton, 1994; Stiner and Kuhn, 2006).

Expansions in dietary breadth can take several forms. On the most basic level, a broadening diet may be reflected through an increase in taxonomic diversity. In addition, ethnographic and experimental studies have shown that, when acquired individually, rank scales closely with body size, such that larger prey are generally ranked higher than smaller animals (Lupo, 2007; Lupo and Schmitt, 2005). Following from this, increased evenness in the representation of large (high-ranked) and small (low-ranked) prey is often seen as a key indicator of resource stress. However, it is important to keep in mind that pursuit costs can vary widely across taxa within a particular size class, and thus attention must also be paid to differences in predatory defense mechanisms and other behavioral characteristics that may change the costs of pursuing different animals (e.g., Bird and O'Connell, 2006; Lupo, 2007; Lupo and Schmitt, 2005).

Research by Stiner and colleagues on small game exploitation in the Mediterranean region (Stiner and Munro, 2002; Stiner et al., 1999; 2000) demonstrates the utility of a consideration of handling costs among animals of the same size class. Although the relative representation of small- vs. large-bodied prey showed no significant variation between the Middle and Upper Paleolithic, they were able to document a shift in small game exploitation from a focus on slow reproducing, sessile game such as tortoises and shellfish to a focus on quick flight, difficult-to-capture game such as hares and game birds—the latter would have been more costly to procure and thus lower-ranked. As such, the increased focus on the quick-flight game indicated an expansion in dietary breadth. A consideration of handling costs among large game is also potentially meaningful, as capturing aggressive game such as the buffalo or the smaller but fierce suids such as the warthog and bushpig would potentially incur a higher risk than the pursuit of relatively more docile large game such as eland or impala. The inclusion of difficult-to-capture animals, such as dangerous large game or quick-flight small game, can thus reflect significant dietary expansion.

A shift in age structure towards increasing proportions of juvenile and young adult animals can also indicate an expansion of dietary breadth (Munro, 2004; Speth, 2004a; Speth and Clark, 2006). The small size and relatively limited body fat of juveniles means that these animals should typically be lower-ranked than adults. A decrease in the mean age at capture may therefore reflect a decline in the encounter rate with higher- ranked prey.

Beyond measures of subsistence diversification, more intensive carcass use and processing, such as an increased focus on marrow exploitation, should also be evidenced during periods of stress. A primary method of maximizing the nutritional return of an animal is to incorporate body parts with lower meat/marrow utility into the diet (Binford, 1978; Grayson, 1989). In this case, one would expect to find evidence for the increased transport of low-utility elements, along with the more frequent exploitation of elements with low marrow utility, such as the phalanges and the mandible. Given the low rate of return relative to the effort required to extract marrow from the bones of small-bodied animals, evidence that small game were processed for marrow exploitation would be a particularly strong indicator of resource stress.

Bone grease, which is stored within cancellous bone, provides an additional source of fat, but its extraction is both time- and labor-intensive, generally requiring bones to be pulverized and then boiled (Leechman, 1951; Binford, 1978). For a variety of reasons, grease rendering can be notoriously difficult to recognize in the archaeological record (Outram, 2001; Roberts et al., 2002); however, several researchers have proposed new ways of identifying the process (Outram, 2001; Munro and Bar-Oz, 2005; Stiner, 2003). Given the relatively low nutritional yield of bone grease compared to its extraction costs, grease rendering represents a significant form of resource intensification. Methods used to identify grease extraction (and the other forms of intensification described above) will be discussed in more detail in Chapter 8.

The HP/post-HP MSA transition as a test case

Working from the theoretical and analytical framework discussed above, I will investigate the potential relationship between resource stress and the emergence of modern behaviors through an analysis of HP and post-HP MSA fauna from the site of Sibudu Cave (KwaZulu-Natal, South Africa).

If the HP was a period of social and economic intensification in response to stress, then signs of subsistence intensification should be restricted to or more common in the HP, when modern behaviors are evidenced, than in the post-HP MSA, when classical signatures of such behaviors have disappeared. As discussed above, several lines of evidence can potentially be utilized to address the degree of resource intensification, including:

- Expansion of dietary breadth, reflected though any or all of the following: taxonomic diversification; increased exploitation of small game; inclusion of species with higher handling costs within a given size class, such as dangerous large game or quick-flight small game; or increased proportion of juveniles (e.g., Munro, 2004; Stiner, 2004b; Stiner et al., 2000; Speth, 2004a)

- Increased transport/exploitation of low utility parts (e.g., Binford, 1978)
- Development of grease rendering of long bone epiphyses (e.g., Munro and Bar-Oz, 2005; Stiner, 2003)

If there is no significant difference in the presence of the above features between the HP and the post-HP MSA, or if signs of intensification are more prevalent in the latter, the hypothesis that the behavioral innovations evidenced in HP assemblages represent a response to stress would not be supported, requiring the development of alternative hypotheses. For example, if there is no discernable difference between the HP and post-HP MSA, Shennan's (2000; 2001) model may be correct, and signs of population increase in the absence of stress must be sought. However, should the above expectations be met, evidence will indicate that at Sibudu, the behavioral innovations associated with the HP were, at least in part, a response to stress. Further testing in other contexts and cases will be necessary to determine whether or not the Sibudu evidence is reflective of a more general phenomenon.

Chapter 3

Middle Stone Age Research at Sibudu Cave

In this chapter, I review the current state of MSA research at Sibudu. Sibudu has benefited from a tremendous amount of multidisciplinary work, and, as a result, we have a great deal of information about the MSA deposits at the site. I focus on the most relevant data here, including that relating to site accumulation and formation processes. The material culture from the site is also described in detail. Because Chapter 5 is devoted to reconstructing the paleoecology of the Sibudu region, I introduce the botanical remains only briefly. My goal is to put into context the faunal assemblages that are analyzed in detail in Chapters 4-8; to this end, I close the chapter with a consideration of how the previous work at Sibudu sets the stage for the investigation of the HP to post-HP MSA transition.

The setting

Sibudu is situated on a forested cliff above the Tongati River, approximately 40 km north of Durban and 15 km inland from the Indian Ocean in KwaZulu-Natal, South Africa (Figures 3.1, 3.2). Although historically known as Sibudu Cave, geologically speaking, the site is actually a rock shelter. Fluvial erosion carved a series of small pockets into the sandstone and shale cliff; the largest of these erosional events formed the shelter, which is ~55 m long and 18 m in depth (Wadley and Jacobs, 2004). Downcutting

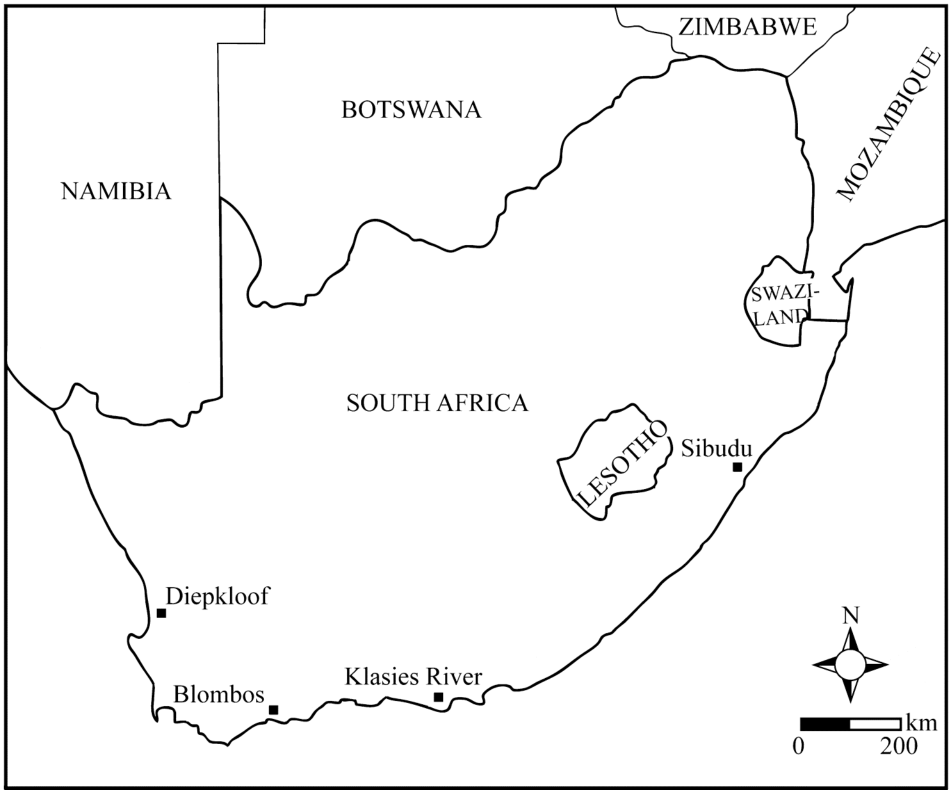


Figure 3.1 Map showing location of Sibudu and other important MSA sites

Figure 3.2 Photo of Sibudu from a distance (arrow points to mouth of shelter)

has continued since the formation of Sibudu, such that the river is currently ~20 m below the site—accessing the shelter requires scaling the nearly vertical cliff face (Allott, 2005). The interior of the shelter lies at approximately 100 m above mean sea level; however, the entrance is about 12 m lower, such that the shelter floor slopes abruptly from north to south (Figure 3.3).

Sibudu is located within the summer rainfall region of South Africa and experiences warm and humid summers, with average temperatures between 22-25 degrees Celsius and approximately 750 mm of rainfall. Winters are mild and drier, with average temperatures of ~17-20 degrees and ~250 mm rain (Allott, 2005; Wadley and Jacobs, 2004). Although much of the natural vegetation around Sibudu has been destroyed by sugar cane farming, a remarkable diversity of vegetation persists on the cliff faces and steep slopes in the vicinity of the site. (Allott, 2005). The southwesterly aspect of the cliff means that it is shaded for much of the day, which creates cooler conditions with less evapotranspiration than on the plateau above the shelter or on the northern facing slopes opposite the site. The cool, moist conditions encourage forest growth (particularly evergreen forest) on the cliff face and in the valley. The Tongati River, a perennial water source, supports much of this vegetation. In contrast, the sunny slopes opposite the shelter are home to a variety of open species such as *Acacia* spp. Under suitable rainfall and temperature regimes, these warmer/drier areas would have supported deciduous woodland and grassland (Wadley, 2006). Wadley (2006) argues that despite shifts in climate over time, a similar mosaic of habitats was almost certainly present throughout the occupation of the site.

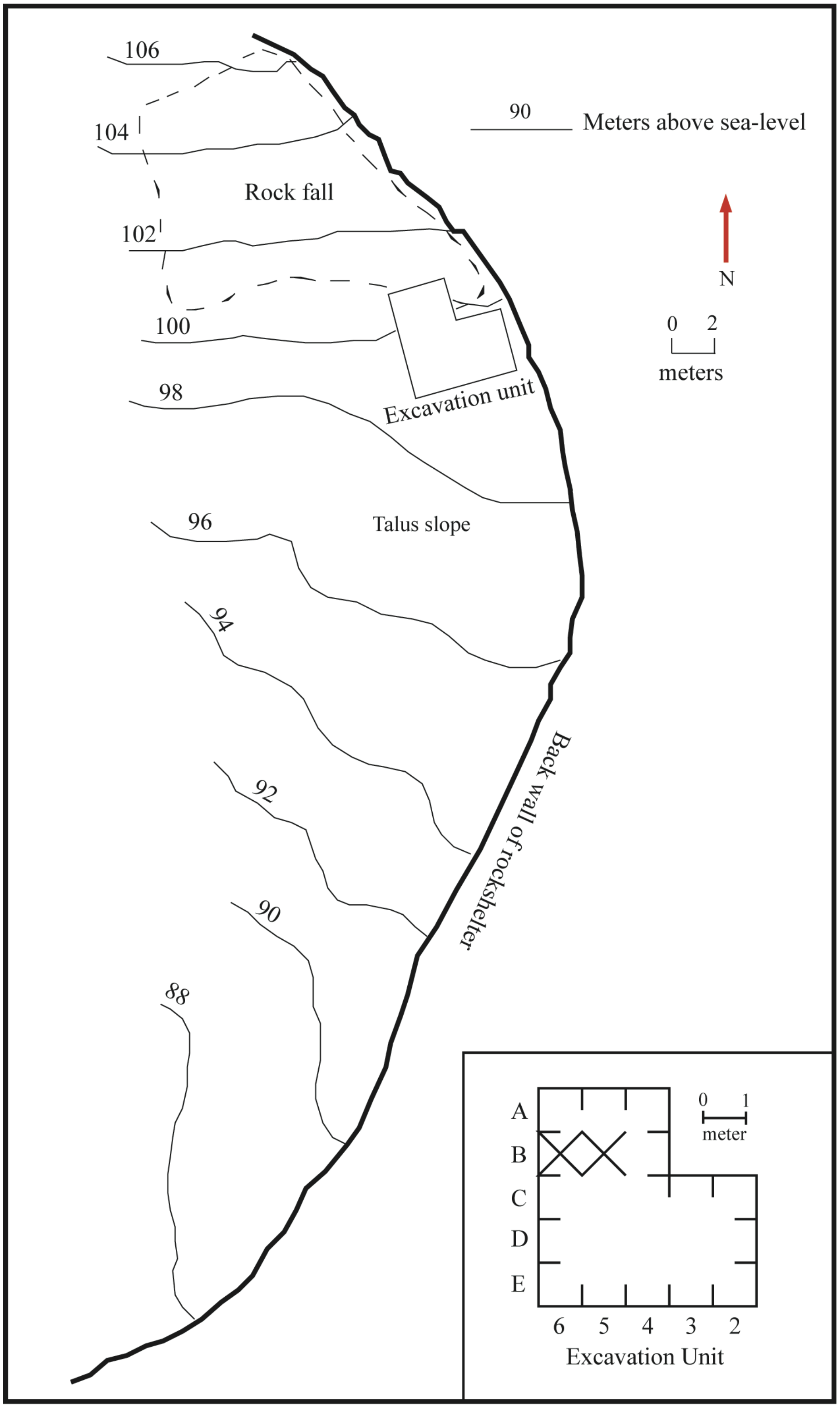


Figure 3.3 Plan map of the shelter/excavation unit (X's on inset show location of Wadley's test trench; adapted from Wadley and Jacobs, 2006)

Background to the excavations

Sibudu was first excavated by Aron Mazel of the Natal Museum, who dug a small trial trench of roughly one meter deep at the site in 1983. His excavations revealed that the upper-most layers of the site contained Iron Age (IA) deposits and that the layers immediately underlying the IA contained MSA remains. The present excavations, directed by Lyn Wadley of the University of the Witwatersrand, have been ongoing since 1998. To date, a total of 21 m^2 of MSA deposits have been excavated, although the lower-most horizons (including the HP and much of the post-HP MSA) have only been reached in a 4 m^2 unit. That unit began as a trial trench in squares B5 and B6 (see Figure 3.3); the trench reached a rock base in 2005 at a depth of ~3 m, although it is not clear as yet whether this rock represents bedrock or simply roof-fall (Wadley and Jacobs, 2006). Since that date, the trench has been expanded into squares C5 and C6.

Deposits are excavated following natural stratigraphy, but where natural layers are thicker than ~10 cm, these are arbitrarily split; this occurred primarily within the deepest layers at the site. Layers at the site were given names rather than numbers—while the lowermost layers were given names that refer to the predominant color and/or matrix (i.e., "Light Brownish Grey," "Pinkish Grey Sand"), this was more difficult in the upper portion of the sequence, wherein layers often displayed complicated mottling (hence names like "Orange Mottled" and "Red Speckled"). In Sibudu publications (and in profile drawings), layers are generally referred to by their abbreviations. A full listing of layer names and their abbreviations, along with OSL ages, can be found in Table 3.1. A permanent datum line was painted on the wall of the shelter, and while profile drawings from the site generally present measurements as depth below surface, a

Phase	**Layer Name**	**Layer Abbreviation**	**OSL age (ka)**
final MSA	Coffee*	Co	38.0 ± 2.6
	Buff*	Bu	39.1 ± 2.5
	Light Brown Mottled*	LBMOD	49.9 ± 2.5
	Milk Chocolate*	MC	
	Espresso*	Es	
	Mousse*	Mou	
	Dark Mousse*	DMou	
late MSA	Polar Bear*	PB	
	Oreo*	Ore, Ore2	
	Cadbury*	Cad	
	Pumpkin*	Pu	
	Mottled Deposit	MOD	49.1 ± 2.1
	Orange Mottled	OMOD	46.6 ± 2.3
	Black lens in OMOD	OMOD-BL	47.6 ± 2.3
	Orange Mottle 2	OMOD2	
	Black lens in OMOD2	OMOD2-BL	
	Grey Mottled	GMOD	
	Brown Mottled	BMOD	
	Red Speckled	RSp	46.0 ± 1.9
	Red Decomposed*	RD	49.4 ± 2.3
	Yellow Speckled	YSp	
post-HP MSA	Brown Speckled	**BSp**, BSp2	57.6 ± 2.1
	Spotty Camel	SPCA	
	Black Layer	BL	
	Orange	Or	
	Midnight	Mi	
	Chestnut	Che	
	Speckled Sunrise	SS	59.6 ± 2.3
	Ebony	Eb	
	Mexican Yellow	MY	
	Mahogany	Ma	
	Flame	Fl	
	Mustard	Mu	
	Burnt Ochre	BO	
	Ivory	Iv	
	Black Magic	BM	
	Pox	P	59.0 ± 2.2
	Orange Pox	OP	
	Brown Pox	BP	
	Sulphur	Su	
	Chocolate	Ch	
	Sulphur 2	Su2	
	Pink 1	P1	
	Grey 1	G1	
	Chocolate 2	Ch2	58.3 ± 2.0
	Yellow 1	Y1	58.6 ± 2.1
	Brown/Grey Mix	**B/G Mix**, B/G Mix2	58.2 ± 2.4
	Brown Organic	Bor	
	Yellow Ash 1	YA1	

Table 3.1 Stratigraphic layers, abbreviations, and OSL ages (OSL ages from Jacobs et al., 2008a; 2008c) (cont'd on next page)

Phase	Layer Name	Layer Abbreviation	OSL age (ka)
	Brown under YA	BuYA	
	Yellow Ash 2	YA2	
	Brown under YA2	BuYA2	
	Reddish Brown	RB	
Howieson's Poort	Grey Rocky	GR, **GR2**	61.7 ± 2.0
	Dark Reddish Grey	DRG, DRG2	
	Grey Sand	GS, **GS2**	63.8 ± 2.8
	Pinkish Grey Sand	PGS	64.7 ± 2.3
Still Bay	Reddish Grey Sand	RGS, RGS2	70.5 ± 2.3
pre-Still Bay	Light Brownish Grey	**LBG**, **LBG2**, LBG3, LBG4	72.5 ± 2.5; 73.2 ±2.7
	Brown Sand	BS	77.3 ± 2.7

*Layers which were only present in the eastern excavation units (not found in trial trench)
Bold indicates layers from which dates were taken

Table 3.1 (cont'd) Stratigraphic layers, abbreviations, and OSL ages (OSL ages from Jacobs et al., 2008a; 2008c)

reference line relating those depths to the datum is included. Units are divided into four 50 cm^2 quadrants, with quadrant "a" located in the northeastern corner. Initially, material was sieved through 2 mm screens; however, since 2003, nested 2 mm and 1 mm sieves have been employed in order to improve the collection of seeds and micromammalian remains. All material from the 2 mm sieves is sorted on site.

Stratigraphy and dating

As information on stratigraphy and dating are reported in detail elsewhere (Wadley and Jacobs, 2004; 2006; Jacobs et al., 2008a; b; c; d), I only summarize the most relevant data here. Sibudu has a rich MSA sequence that includes pre-Still Bay, Still Bay, HP, post-HP MSA, late MSA, and final MSA assemblages; the layers associated with each of these phases are shown in Table 3.1, while a profile drawing from the test trench can be found in Figure 3.4. Horizon designations that begin with lowercase letters (e.g., "late MSA") indicate classifications based on the lithic assemblage; *these are not formally recognized phases*. Work by Wadley's team has confirmed Mazel's findings—

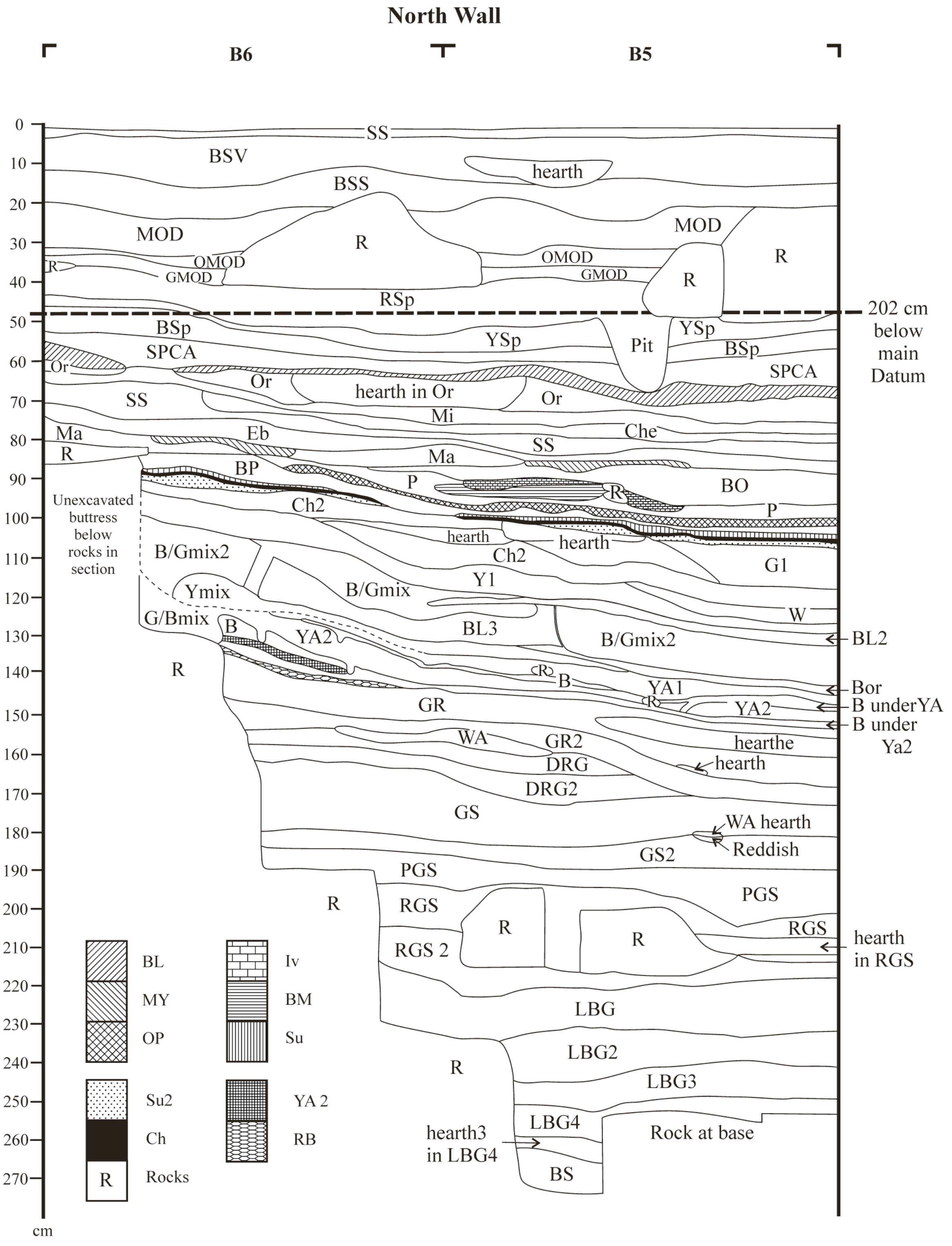


Figure 3.4 Stratigraphic profile drawing from the test trench (Wadley and Jacobs, 2006)

across the site, MSA deposits occur directly below IA layers—no Later Stone Age remains are present. Although there was a significant hiatus between the MSA and IA occupations, this hiatus is not detectable as a sterile unit in the stratigraphy. Today, the shelter floor is scoured by wind in the late winter and early spring; similar circumstances in the past may have prevented the accumulation of sterile deposits (Wadley and Jacobs, 2004).

As indicated in Figure 3.4, the stratigraphy at Sibudu is complex—the lower layers (up to and including the HP) are typically comprised of soft, sandy or silty deposits that are a fairly uniform grey or brownish-grey color. In contrast, the upper portion of the sequence is comprised of a series of thin, distinct, brightly colored layers that include palimpsests of interfingering hearths and ash lenses (Figure 3.5). These are predominantly ashy or silty in composition (Pickering, 2006; Wadley and Jacobs, 2004; 2006).

Burning features are common in the Sibudu sequence. Hearths are discernable as flat, circular patches of ash; thus far, no stone foundations have been located and only rarely do the features show concave bases. The hearths are generally no more than 10-15 cm thick and are often stratified into a basal layer of reddish-brown burnt earth, a central brown-black layer that is rich in charcoal, and an upper layer of off-white or yellow ash. These are well preserved as separate features within the lower portion of the sequence, where burning features are relatively sparsely dispersed (Wadley, 2006; Wadley and Jacobs, 2006). In contrast, the upper sequence shows pervasive evidence for massive burning events; the interfingering nature of the hearths in the younger layers makes it difficult to distinguish individual burning episodes. This is further compounded by the

Figure 3.5 Photograph of the profile showing palimpsests of burning features in the post-HP MSA; more homogenous deposits in the lower portion of the profile are from the HP, Still Bay, and pre-Still Bay

fact that many of these hearths show several focal points, which may indicate repeated use (Allott, 2006a). As a result, multiple layers within a single hearth may have received independent layer designations (for example, Iv and BM were excavated as independent units but may be parts of a hearth within layer P).

As a majority of the MSA deposits at Sibudu fall beyond the range of radiocarbon dating, optically stimulated luminescence (OSL) has been utilized to date the sediments. Ages were obtained from a combination of single aliquot and single-grain analyses of sedimentary quartz. By examining a large number of individual grains for each sample, rigorous statistical procedures could be applied, resulting in reliable age estimates with good precision (OSL ages were presented in Table 3.1; for more details on the methodology, see Jacobs et al., 2008a; b; c; Jacobs and Roberts, 2008). The earliest deposits excavated thus far (the pre-Still Bay) appear to date to ~77-73 ka, while a single date from the Still Bay indicates an age of ~70 ka. Dates were taken from three layers within the HP and range from 65 to 62 ka (although with the range of error, the dates actually fall between 67-60 ka).

Within the upper MSA sequence, OSL dating has indicated the presence of three distinct age clusters, which appear to correspond to three distinct occupational phases. Jacobs et al. (2008c) calculated weighted mean ages for each of these periods, which are 58.5 ± 1.4 ka for the post-HP MSA, 47.7 ± 1.4 ka for the late MSA, and 38.6 ± 1.9 ka for the final MSA. The age distribution suggests that the layers within each cluster may have formed relatively rapidly, with longer duration hiatuses separating the occupations (Wadley and Jacobs, 2006). As was the case for the hiatus between the MSA and IA, these hiatuses are not recognizable geologically.

Geoarchaeological research at Sibudu

Sedimentology

Sedimentological analyses based on samples from a number of the upper layers (primarily from the late and final MSA) have indicated that the deposits at Sibudu are predominantly anthropogenic in origin (Pickering, 2006). These layers were found to consist of angular sediment grains as well as angular fragments of bone and charcoal, which points to little or no water-borne transport of the deposits. Because classic sedimentary structures were also absent, and given the high prevalence of *in situ* burning features and the abundance of cultural materials, Pickering (2006) argued humans were primarily responsible for site accumulation.

The clustering of ages, combined with the thickness of the deposits, implies that sediment accumulation rates were relatively rapid (Pickering, 2006). Furthermore, FTIR (Fourier transform infrared) spectroscopy and microscopic analyses by Schiegl and Conard (2006) have demonstrated that the cascade of secondary phosphates observed at other caves sites with a similar sedimentary milieu are almost entirely lacking in the Sibudu deposits, indicating that diagenesis (at least in the form of mineral transformation and dissolution) was only a minor factor. The presence and stability of gypsum and calcite in the deposits also serves as a good indicator of dry conditions within the shelter. Each of these factors contributed to the good preservation of bone and other organic materials at the site, and, taken together, imply that the excavated bone assemblage should reflect the original distribution patterns (Schiegl and Conard, 2006).

The FTIR spectroscopic study also demonstrated the presence of variability in sediment composition between the upper and lower portions of the sequence—there was markedly less variation in sediment composition in the lower horizons (pre-Still Bay, Still Bay, and HP) than that documented in the upper deposits (Scheigl and Conard, 2006). In addition, gypsum inclusions, which occur frequently in the upper layers, are uncommon below the post-HP MSA. This is notable for a number of reasons. Gypsum, a hydrated calcium-sulfate mineral, is post-depositional in nature, and its formation requires moisture; however, once formed, it is relatively soluble in water, dissolving in concentrations of up to 2.5g/litre (Pickering, 2006; Schiegl and Conard, 2006; Schiegl et al., 2004). Its presence thus implies initial humidity followed by comparatively dry conditions. Given that the upper portion of the sequence dates to within Oxygen Isotope Stage (OIS) 3, Pickering (2006) proposed that warmer sea surface temperatures may have led to increased moisture in the form of sea mist, and that this may have supplied the humidity necessary for gypsum formation.

Gypsum inclusions vary in size throughout the upper portion of the sequence, with the largest nodules occurring in the "Pox" layers (P, BP and OP). Because nodule formation is suppressed under high sedimentation rates, the growth of these nodules likely required the presence of stable surfaces (Schiegl and Conard, 2006). Following from this, Herries (2006) proposed that gypsum growth may have been most common during periods when there was little to no deposition or site occupation, and that the layers preserving larger nodules may reflect hiatuses in the sequence. In addition to these nodules, gypsum crystals have formed on bone and stone within the deposits (Figure 3.6). This type of gypsum formation has been known to cause bone fragmentation, as pressure caused by the growing gypsum crystals leads to crack propagation and thus splitting (Schiegl and Conard, 2006). This led Schiegl and Conard (2006) to propose that much of the mechanical bone destruction above the HP is related to gypsum growth. If this were

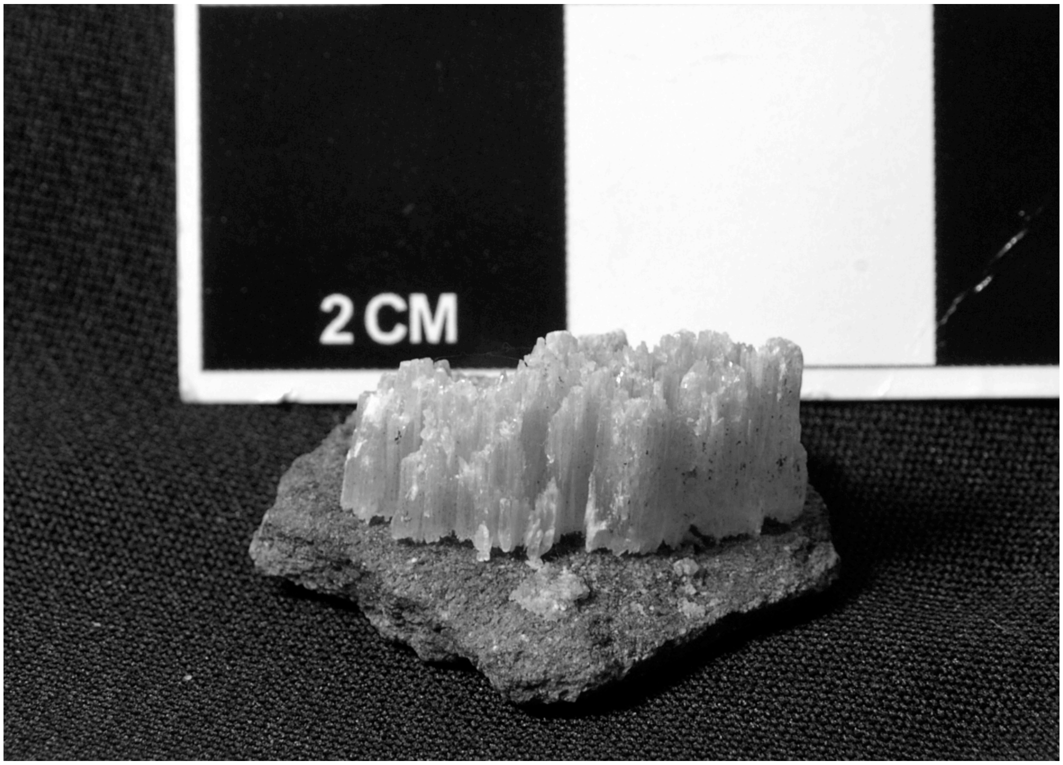


Figure 3.6 Sandstone fragment from the post-HP MSA with gypsum crystal growth

the case, it may account for the slightly better organic preservation in the lower portion of the sequence, as gypsum was absent in those layers. The possible implications of this to our comparison of the fauna from the HP and post-HP MSA will be discussed as part of the consideration of the taphonomic history of the assemblage in Chapter 6.

Sedimentological and phytolith studies focusing on burning features and their surrounding sediments (Schiegl and Conard, 2006; Schiegl et al., 2004) have provided further insight into site use and formation processes at Sibudu. Hearths and ash dumps frequently show sedimentary compositions and phytolith contents similar to those of the sediments around them; according to Schiegl and Conard (2006), this implies that there was even more fire activity than that indicated by the number of burning features. A considerable proportion of the phytoliths analyzed from features in the post-HP, late, and final MSA showed severe morphological changes related to intense heating; phytoliths of similar morphology were produced experimentally by heating a sample of wood ash to 900 degrees Celsius (Schiegl et al., 2004). This does not necessarily imply that the fires at Sibudu reached such an intense temperature, as alkali-rich plant ashes of the sort identified in the deposits can act as natural fluxes that reduce the melting point of silica (Schiegl and Conard, 2006). Even with this caveat, though, it has been argued that the heat energy of small campfires would not be intense enough to have such an extreme effect on phytolith morphology, implying either that fireplaces were extensively reused or that fires were long-burning, perhaps over the course of many days (Schiegl et al., 2004).

Archaeomagnetism: climatic implications

Archaeomagnetic data have been utilized in reconstructing Sibudu's climate history. Herries (2006) reported on the analysis of magnetic susceptibility (MS) and mineral magnetic measurements taken from the section walls of the initial 2 m^2 trial trench; because the final MSA is not represented in the trial trench, his results do not speak to conditions during this period. Furthermore, since the lowest layer sampled was YA2, the pre-Still Bay, Still Bay and HP were also not included in his study. Within the post-HP MSA sequence, the deepest layers (YA2 to G1) showed distinctly different magnetic characteristics and much lower MS values than the upper layers (P1 to BSp—P1 is a small lens that is not visible in the profile illustrated in Figure 3.4; it is located directly above layer G1 where it occurs). Of particular note, layers YA2 to G1 include higher coercivity magnetic minerals—studies of marine and lake sediments across Africa have documented an increase in higher coercivity minerals within colder, glacial sediments. Given these results, Herries proposed that the archaeomagnetic signature in the lower layers of the post-HP MSA reflects the cold, glacial climate of OIS 4. Accordingly, it is argued that the major changes in magnetic mineralogy and the higher MS values beginning with layer P1 represent the transition to OIS 3—and, in fact, as Herries (2006) pointed out, the dating of the post-HP MSA at Sibudu is consistent with the age of the OIS 4 to 3 transition from the Vostok ice core. The late MSA sequence showed yet another considerable increase in mean MS values, suggesting an overall warming in climate as compared to the post-HP MSA.

When considering the results of the archaeomagnetic data, it must be kept in mind that anthropogenic activity, particularly that related to fire use, can affect magnetic susceptibility readings—burnt material is generally associated with high MS values. Although Herries avoided sampling well-defined hearths whenever possible, he recognized that some of the smaller scale warming episodes he identified in the MS profile *may* actually reflect periods of increased fire use. Despite this, there are two primary reasons to believe that the larger trends he identified do reflect climatic change. First, although small amounts of burnt sediment may result in slight magnetic enhancement, wood-ash, the dominant material in MSA hearths, should not cause any thermo-magnetic enhancement because wood itself is non-magnetic (Herries, 2006). That this is the case seems to be demonstrated in the lower layers of the post-HP MSA—while these layers contain some of the most intensely burned bone in the entire sequence (see Chapter 6), they actually show the *lowest* MS values. Finally, *in situ* measurements were taken from three of the four section walls of the trial trench, and all three profiles showed the same patterns, implying that small scale diagenetic effects, local disturbance, and anthropogenic effects were not sufficient to influence the overall signal.

Lithic analyses

The lithic assemblages from Sibudu have been the focus of a great deal of study. In addition to qualitative and quantitative typological/metric analysis (e.g., Villa et al., 2005; Wadley, 2005a; Wadley and Mohapi, 2008), samples have also been subjected to use-wear and micro-residue analyses (e.g., Lombard, 2005; Lombard, 2008; Williamson, 2004). Given that raw material usage can potentially be informative about mobility patterns (e.g., Binford, 1980; Kuhn, 1991; 1995) and because of the interest in the use of "non-local" raw materials in the Still Bay and HP (e.g., Ambrose, 2006; Minichillo, 2006), research has also focused on the nature of raw material use during the MSA at Sibudu.

Raw materials

Although the sandstone that forms the shelter was occasionally used for tool manufacture at Sibudu, the three most common raw materials are hornfels, dolerite, and quartz/quartzite; these are found in varying frequencies throughout the MSA sequence. Hornfels is a fine-grained, metamorphosed shale, while dolerite is an igneous rock that can vary considerably in grain size and mineral composition (Wadley and Mohapi, 2008). In general, dolerite can usually be distinguished from hornfels because of its coarser grain size (Cochrane, 2006). Both milky and crystal quartz (100% silica) are present in the assemblage. Both types probably come from the same source, as fragments with a milky portion adjoining a crystal one have been found (Delagnes et al., 2006).

These raw materials have different properties that likely influenced how they were utilized; for example, crystal quartz tends to fracture irregularly and can be riddled with faults or inclusions, making it difficult to knap; however, tools produced from this material have cutting edges that are notably smoother and sharper than those produced on hornfels or dolerite (Delagnes et al., 2006; Wadley and Mohapi, 2008). Knapping experiments by Cochrane (2006) on local dolerite showed that the material is incredibly hard and can only be fractured when considerable force is applied. This places limitations on the amount of control that can be exercised during manufacture, particularly over the point of impact. As such, Cochrane (2006) expects production errors to be more common when knapping with this raw material. In comparison, hornfels is more brittle and allows a greater degree of control over the flaking product.

Hornfels, dolerite, and quartz/quartzite can all be found as cobbles on the banks of the Tongati River, and while cortical flakes indicate that river cobbles were sometimes used, tabular slabs quarried from outcrops were also utilized (Delagnes et al., 2006; Wadley and Jacobs, 2006). Of the three raw material types, dolerite was the most locally available; a thick dyke of medium- to fine-grained dolerite intrudes into the sandstone cliff a few hundred meters from the shelter (Wadley and Mohapi, 2008). A hornfels outcrop of a quality comparable to that used during the MSA at Sibudu has not yet been located in the immediate vicinity of the site; the closest known outcrop is located about 15 km to the south (Cochrane, 2006). Similarly, while conglomerates with clasts comprised predominately of quartzite (~80 mm in maximum dimensions) can be found near the shelter, the closest known quartz outcrops occur in a granite formation found about 20 km northwest of the site (Delagnes et al., 2006; Wadley and Mohapi, 2008). Thus, while two of the primary raw materials were not available in the immediate vicinity of the site (other than as river cobbles), all of the rock types used at Sibudu were essentially local.

Typology: the lithic assemblages

Details on the oldest lithic assemblage recovered thus far at Sibudu, referred to as the pre-Still Bay, have not yet been published; however, the industry is known to include unifacial points (Wadley and Jacobs, 2006). The Still Bay assemblage has been analyzed in more detail (Lombard, 2006; Wadley, 2007), and includes a number of the thin, bifacial lanceolate points that define the Industry. Bifacially worked pieces constitute 44% of all retouched tools from the Still Bay layers; other tools include two unifacial points and a small sample of scrapers. Although all three raw material types are represented in the assemblage, retouched tools were produced primarily on dolerite (accounting for 48% of all retouched tools and 54% of points and bifacial tools). Quartzite was the least commonly employed, accounting for only 15% of the retouched tools (Wadley, 2007). The presence of debris from all stages of manufacture indicates that dolerite was likely knapped in or near the shelter; however, manufacturing debris was more limited for hornfels and quartz/quartzite, suggesting that these materials may have been knapped elsewhere. Residue and use-trace analysis on a small sample of the bifacial tools indicates that they were hafted, with some used as butchery implements while others functioned as hunting weapons (Lombard, 2006)

The HP assemblage is unique as compared to the remainder of the MSA sequence in that stone points are almost entirely absent; instead, the retouched assemblage consists primarily of backed tools such as segments and trapezes (Wadley, 2006). Although this may be an artifact of the limited spatial extent of the excavations, points are also rare in other HP assemblages (Lombard and Pargeter, 2008), and thus the absence of points may reflect a focus on a different type of hunting technology. Micro-residue analysis by

Lombard (2008) demonstrated that the backed segments in the HP were hafted and used to process animal material; she combined this knowledge with the results of use-wear and macrofracture analysis to argue that the segments served as inserts for composite hunting weapons. Metric analysis by Wadley and Mohapi (2008; see also Wadley, 2008) indicated that the quartz segments found in the HP may have functioned as arrowheads, as their tip-cross-sectional-area (TCSA) and other attributes fit within the range of ethnographically documented arrow points, no matter what hafting configuration was employed.

Cochrane (2006) analyzed the complete sample of post-HP MSA lithics (comprising more than 30,500 objects) from the 2 m^2 trial trench. Retouched artifacts from this phase consist predominately of unifacial points and scrapers that show little standardization of form and were produced predominantly on hornfels (72%). Despite the predominance of hornfels in the retouched sample, the frequency of dolerite and hornfels in the debitage is nearly equal; the reason for this discrepancy is unclear. Although the total representation of quartz/quartzite is low (accounting for only ~6.6% of the assemblage), a distinctive turnover in raw material usage is evidenced when the sample is broken up by layer (Figure 3.7). Quartz and quartzite are the most common raw materials in the lower-most layers of the post-HP MSA—frequencies peak at over 80% in the layer BuYA. Although the proportion of quartz and quartzite begins a slow decline after that point, the contribution of quartz and quartzite falls from more than 10% in Ch2 to less than 1% in Su2; in subsequent layers, hornfels and dolerite completely dominate the assemblage, typically occurring at frequencies in excess of 95%.

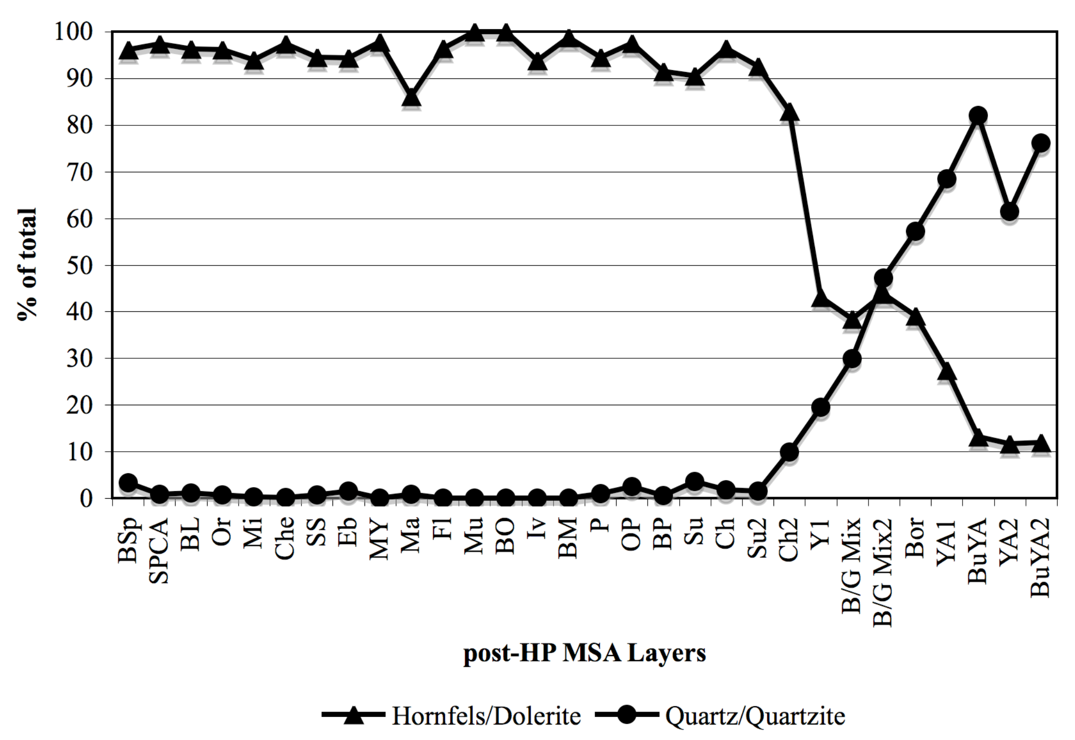


Figure 3.7 Turnover in raw material type during the post-HP MSA (data from Cochrane, 2006)

Despite the variability in raw material types, there is little evidence for other technological or typological changes through time. However, it may be significant that certain tool classes, including grindstones, an anvil, and a hammerstone, were also restricted to the lower-most layers of the post-HP MSA; the uppermost of these tools was recovered from layer Ch2. That the lower layers of the post-HP MSA sequence show evidence for both a different pattern of raw material usage and some unusual artifact types is potentially significant to our understanding of the transition between the HP and the post-HP MSA—this will be discussed in more detail later in the chapter.

Details on the lithic assemblage from the late MSA have only been reported for a single layer within the assemblage—RSp (Villa et al., 2005). This layer yielded a sample of ~14,000 pieces, of which 2,259 were chosen for analysis. The assemblage contains a high proportion of retouched pieces (15%); unifacial points and scrapers are the most common formal tools. Quartz and quartzite were again rare in RSp, accounting for less than 3.5% of the material analyzed. As was the case in the post-HP MSA, formal tools were predominantly made on hornfels, and yet hornfels and dolerite were present in nearly equal proportions in the debitage. Residue, macrofracture, and use-wear analysis of a selection of post-HP and late MSA points indicated that these tools were hafted and served as hunting weapons (Lombard, 2005a); Villa and Lenoir (2006) used metric data to argue that that the artifacts functioned as spear points designed to be thrust or hand-cast.

The youngest MSA lithic assemblage identified at Sibudu, referred to as the final MSA, was recovered only in the eastern-most section of the excavation grid. While bifacial points are slightly more common than unifacial points, the most notable aspect of this assemblage is the presence of a small sample of hollow-based points and backed tools, including segments. Hollow-based points were also found in the upper-most MSA layers at Umhlatuzana Cave, approximately 90 km from Sibudu, and it is possible that the tool type may be indicative of a regional variant of the final MSA (Wadley, 2005a). As in the previous horizons, hornfels was the predominant raw material utilized for most classes of retouched tools (accounting for 66.3% of all retouched material). Quartz/quartzite were the next most common raw materials, accounting for 21.7% of the retouched sample (Wadley, 2005a). The presence of this relatively young expression of the MSA, characterized by a unique combination of tool types, further highlights the importance of Sibudu to our understanding of behavioral variability during the MSA.

Organic materials: flora and fauna

Botanical remains

The potentially rapid accumulation of the Sibudu deposits, combined with the minor degrees of diagenesis and the lack of water disturbance (Pickering, 2006; Schiegl and Conard, 2006), contributed to the excellent preservation of organic remains at Sibudu. Materials present include charred seeds, charcoal, and both macro- and microfauna. Work with the botanical remains has largely focused on reconstructing the paleoecology of the site region; because Chapter 5 is dedicated to paleoecology, I provide only a very brief overview of this research here. While details on the charcoal assemblage from the pre-Still Bay and Still Bay have not yet been published, Allott (2004, 2005, 2006a, 2006b) has analyzed charcoal from the remainder of the sequence. The charcoal data do indicate the presence of major shifts in local vegetation, with evergreen taxa dominating the lower layers of the sequence and deciduous taxa becoming more common in the late and final MSA. Allott (2006a) also noted that while fuel-woods commonly used by modern populations were routinely collected beginning with the post-HP MSA, these "good" fuel-woods were largely absent in the HP—this pattern may reflect changes in local vegetation, but could also indicate a different approach to wood collection and use during the HP.

Carbonized seeds, nuts, and fruit stones have also been identified in the MSA deposits at Sibudu; taxa present include sedges, grasses, shrubs and trees (Sievers, 2006). Sedges (*Cyperaceae*) comprise more than half of all seeds in the assemblage and are present throughout the entire MSA sequence. Their pervasiveness implies that a water source (likely the Tongati River) was present near the shelter during periods of site occupation. Given the continued presence of this water source, it is expected that riverine taxa (both floral and faunal) will be present in some degree throughout the occupational sequence. Because the nutlets from the sedges are invariably whole, Sievers (2006) argues that it is unlikely that they were brought to the shelter as bird droppings; instead, she proposes that sedges may have served as bedding and/or been used for the weaving of mats.

Previous faunal analyses

Because of its extensive sequence and relatively good preservation, Sibudu's faunal assemblages offer an excellent opportunity to explore the range and nature of variability in subsistence behavior during the course of the MSA. Analysis of the small sample of pre-Still Bay and Still Bay fauna is not yet complete; however, preliminary work with the Still Bay assemblage has demonstrated that small game, particularly the blue duiker (*Philantomba monticola*), is predominant (Wadley, 2007). Vervet monkey (*Cercopithecus pygerythrus*) and bushpig (*Potamochoerus larvatus)* are also common—all three of these species are common in forested environments. Marine shell occurs more frequently in the Still Bay than in any other horizon; however, it may have been collected as a raw material rather than for dietary reasons (see discussion below and Plug, 2006).

Clark and Plug (2008) discussed the preliminary analysis of the HP and post-HP MSA fauna excavated from Wadley's trial trench. The HP assemblage was again dominated by small game; the blue duiker was the most commonly identified species. The proportion of medium to large game increased throughout the course of the post-HP MSA; we proposed that the transition may be related to a shift to more open environmental conditions during the post-HP MSA. One of the primary goals of this study is to evaluate the strength of the patterns identified during that initial study—and their implications to our understanding of the HP-post-HP MSA transition.

Plug (2004) analyzed faunal material from the upper portion of the sequence; however, her work was completed before OSL dates were available. Once those dates were published, it became clear that divisions she employed resulted in the mixing of data from multiple horizons—some of the post-HP and late MSA layers were combined, while the final MSA was lumped with the upper layers of the late MSA. Wadley et al. (2008) re-analyzed Plug's original dataset using the updated sub-divisions; details on the late MSA sample were also provided by Wells (2006), who analyzed the full faunal sample from layer RSp. The late MSA fauna is dominated by medium and large ungulates, with zebra well represented. The sample also includes fragmentary teeth identified as belonging to either a hippopotamus or rhinoceros (Plug, 2004; Wadley et al., 2008; Wells, 2006). The range of species present indicates that there was a dry, yet diverse, environment that included both open grassland and a woodland component (Wells, 2006).

The small faunal sample from the final MSA again showed a focus on medium to large game, although some smaller game, including the blue duiker, was also present. A single element was identified as belonging to an elephant (*Loxodonta africana*); hippopotamus (*Hippopotamus amphibius*) was also identified in the sample (Plug, 2004; Wadley et al., 2008). A majority of the microfaunal remains also came from the final MSA (2068 of a total sample of 2700 bones, Glenny, 2006). Given that the units preserving the final MSA are located along the back wall of the shelter, Glenny proposed that the prevalence of microfauna in these layers reflected the presence of raptor roosting sites. Because preliminary taphonomic analysis of the microfauna showed evidence for etching and trampling of the sort associated with owls and owl roosting sites, Glenny (2006) proposed that owls were the major accumulating agent of the mircofaunal assemblage from this period.

To complement the taxonomic analysis published by Plug (2004), Cain (2005, 2006) conducted detailed taphonomic analyses on material from a selection of post-HP and late MSA layers. He focused both on the nature of burning in the MSA horizons (Cain, 2005), and on the identification of the primary agents of accumulation (Cain, 2006). He found that, in most contexts, at least 80% of the bone showed some degree of burning. Given the palimpsests of hearths found in the layers under consideration, he argued this burning was likely the result of anthropogenic (rather than natural) fires. More specifically, Cain (2005) proposed that the burning resulted primarily from bone being systematically discarded into fires as a means of waste disposal. Variability in the presence and intensity of burning in the HP and post-HP MSA assemblage will be considered in greater detail in Chapter 6.

In considering the agents responsible for the accumulation of the macrofauna, Cain (2006) examined a full range of faunal specimens (both identified and non-identified) from the layers under consideration. His results indicated that the non-human contribution to the assemblage was minimal, as the sample preserves abundant signs of human modification, including percussion damage, cut-marks, and the aforementioned burning. Wells' (2006) taphonomic study of the RSp fauna also found that modifications associated with human processing were much more frequent than those associated with non-human carnivores. When considered alongside the results of the sedimentological analyses already discussed, it seems clear that the upper deposits at Sibudu were primarily anthropogenic in origin. Taphonomic analyses of the HP fauna, reported in Chapter 6, will provide a means of evaluating whether this was also the case for the HP.

Worked bone and shell

The Sibudu faunal assemblage also includes a small number of worked bone and shell implements (Backwell et al. 2008; Cain, 2004; d'Errico et al. 2008). Although they are not common, modified bone and shell artifacts are known from a number of MSA sites, including Blombos Cave and KRM (e.g., d'Errico and Henshilwood, 2007; d'Errico et al., 2005), and thus their presence at Sibudu is not unexpected. The HP includes a worked bone industry—at least two bone points have been identified, along with a bone "spatula" (Backwell et al., 2008). Several other pieces that are potentially worked are still awaiting analysis.

Of the two points, one is consistent with a pin or a needle-like implement. The other (illustrated in Figure 3.8) is very similar in morphology to prehistoric and ethnographically documented arrow points, leading Backwell et al. (2008) to argue that bow and arrow technology may have been present in the HP—there are thus two distinct lines of evidence that suggest the presence of this technology during that phase. Among the Bushmen, similar points were used to hunt birds and small game (the point is apparently too small to mortally wound a large animal without poison); because Clark and Plug (2008) found that small game was common in the HP, Backwell et al. (2008)

Figure 3.8 Refitted bone point from layer GS (HP); enlarged images on right show longitudinal striations associated with manufacture (Backwell et al., 2008; image courtesy of L. Backwell)

proposed that this technology may have been part of an adaptation to closed environments in which small prey were common.

In addition to these bone tools, Cain (2004) described a sample of four modified bones from the upper portion of the sequence: two from the post-HP MSA, and one from both the late and final MSA. Only one of these appears to be a formal tool—the specimen from the final MSA is a polished bone pin. The specimens from the post-HP MSA simply show a series of incised notches and the fragment from the late MSA has series of flakes removed from the edge.

In analyzing the marine shell from the Still Bay and pre-Still Bay, Plug (2006) found that many of the shells were beach-worn and thus did not appear to represent food waste, while others were too small to contribute to the diet. She therefore proposed that the shell must have served some other function, perhaps as a raw material. Her supposition has been supported by new findings at the site—d'Errico and colleagues (d'Errico et al., 2008) confirmed the presence of three *Afrolittorina africana* shells that appear to have been perforated by humans, one of which is coated in red pigment. The data thus suggest that the shell beads recovered from the Still Bay layers at Blombos were not an isolated occurrence.

Summary: setting the stage for an investigation of the HP to post-HP MSA transition

In reviewing the current state of MSA research at Sibudu, a number of issues have been raised that are relevant to the comparison of the HP and post-HP MSA fauna; I discuss the most salient of these here. Most obviously, as is the case at other sites preserving the HP and the post-HP MSA, there is marked variability in material culture between the two phases. The backed tools that dominate the HP assemblage disappear in the post-HP MSA, wherein the tool kit consists predominantly of unifacial points and scrapers (Cochrane, 2006; Wadley and Mohapi, 2008). The HP also appears to contain a more formalized bone tool assemblage than does the post-HP MSA (Backwell et al., 2008; Cain, 2004). Noteworthy is the fact that there is a lack of traditional MSA hunting technology in the HP at Sibudu—stone points are absent. It seems possible that the variation in technology evidenced between the HP and post-HP MSA will also be reflected in the faunal remains; the changes may relate to the targeting of a different suite of prey, or perhaps to changes in processing behaviors. I will return to these possibilities in Chapters 7-8.

A number of characteristics distinguish the upper and the lower deposits at Sibudu—this is significant because the HP and the post-HP MSA fall on either side of this boundary. The lower portion of the sequence (pre-Still Bay, Still Bay, and HP) is comprised of thicker, monotonously colored, sandy or silty deposits with sparsely dispersed hearths, while the upper sequence (post-HP, late and final MSA) consists of thin, brightly colored, ashy or silty deposits that contain palimpsests of interfingering hearths and ash layers (Pickering, 2006; Wadley and Jacobs, 2006). The upper deposits are also more variable in sediment composition than are the lower deposits. In addition, while gypsum inclusions are common in the layers above GR (the top-most layer of the HP), they are rare in the deposits below GR—instead, calcite occurs more frequently in these lower layers (Schiegl et al., 2004; 2006). If there were a significant hiatus in occupation between the HP and the post-HP MSA, some of this variability might make more sense, and yet, the available OSL dates indicate that there was not a significant hiatus between the two phases (Jacobs et al. 2008a; b; c; Jacobs and Roberts, 2008).

Although we do not yet understand the processes underlying the variability in sediment composition evidenced between the upper and lower deposits, it should be possible to evaluate whether (and to what degree) the character of the deposits differentially affected faunal preservation in the HP and post-HP MSA. As discussed, gypsum crystal formation can lead to bone fragmentation; if gypsum did play a role in bone fragmentation at Sibudu, one would expect fauna from layers with high concentrations of gypsum to be more heavily fragmented than that from layers with little or no gypsum—this will be evaluated as part of my consideration of the taphonomic history of the assemblage in Chapter 6. Similarly, exposure to heat can make bone more friable, and thus can also lead to increased fragmentation; burning also affects cortical preservation and thus the ability to recognize surface modifications such as cut marks or carnivore damage. The impact of these factors will also be discussed in Chapter 6.

While there are clear differences between the HP and post-HP MSA deposits, there is also evidence for significant variability *within* the post-HP MSA. For this reason, following Clark and Plug (2008), I made the decision to split post-HP MSA into two units: the upper-most layers (BSp to P1), are called the post-HP MSA 1, while the lower layers (G1 to YA2) are referred to as the post-HP MSA 2 (see Figure 3.9 for an enlarged profile drawing of the HP and post-HP MSA that highlights this subdivision). There are a number of reasons the decision was made to split the sequence between G1 and P1.

First, as previously discussed, the archaeomagnetic data indicate that the transition from OIS 4 (a glacial period) to OIS 3 (an interstadial) occurred during the course of the post-HP MSA—Herries (2006) defines the boundary as falling between layers G1 and P1. This division actually corresponds with the turn-over in raw material type during the post-HP MSA. The proportion of quartz/quartzite dropped from 10% to less than 1% between layers Ch2 and Su2, after which hornfels/dolerite completely dominate the assemblage. *G1 and P1 are actually small lenses between these two layers.* It was also the case that Ch2 marked the upper-most occurrence of some of the unusual tool types present in the post-HP MSA lithic assemblage (including hammerstones and grindstones; Cochrane, 2006). Furthermore, while the OSL ages do not indicate a significant hiatus between the deposition of layers G1 and P1, Herries (2006) proposed that the presence of gypsum nodules in layers Ch2 to P1 may reflect a hiatus in the sequence. While any one of these findings may not be significant on its own, the fact that

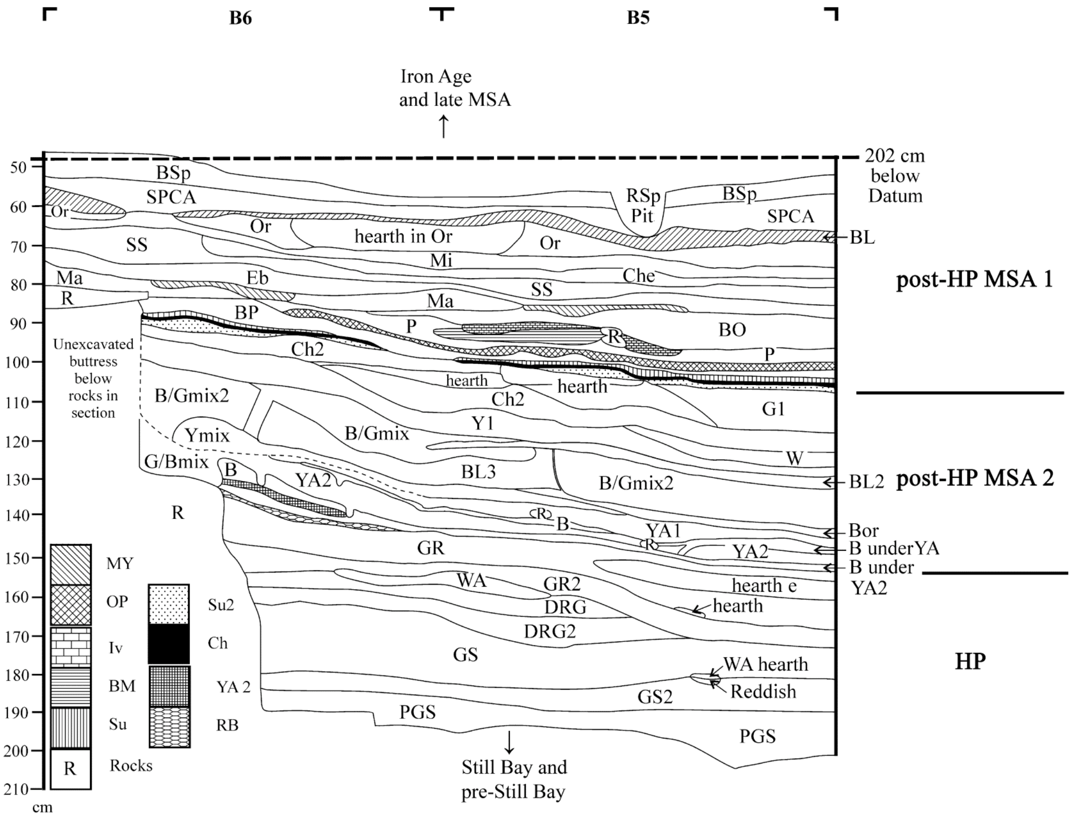


Figure 3.9 Stratigraphic profile drawing showing HP and post-HP MSA, with division into post-HP MSA 1 and 2.

multiple independent classes of data show a consistent pattern suggests that the division of the post-HP MSA into an upper and lower section is warranted. In the analyses presented in Chapters 5-8, we will make use of this division where appropriate.

The splitting of the post-HP MSA into two units is particularly important to our attempts to reconstruct the paleoecology of the Sibudu region. Given that the post-HP MSA sequence appears to preserve the transition from OIS 4 to OIS 3, at least some variability will be expected in the faunal assemblage purely as a result of shifting habitat types. The riverine vegetation supported by the perennial Tongati River would have provided some degree of a buffer against climate change, thus reducing the visibility of such changes in the archaeological record; however, I expect that a major shift such as the transition from a glacial to an interstadial period would be reflected in the fauna (and flora) from the relevant layers. Shifts in the local environment would have obviously created different opportunities—and challenges—for Sibudu's inhabitants, and it is thus important to evaluate the degree to which variability in the faunal assemblage can be attributed to environmental change. Chapter 5, which focuses on paleoecology, begins to address these issues. First, however, it is necessary to introduce the faunal sample itself, the methodology employed, and the particular challenges posed by the available sample—this is the goal of the next chapter.

Chapter 4

Materials and Methods: The HP and post-HP MSA Fauna from Sibudu

This chapter focuses on the initial stages of data collection, particularly as related to identification and quantification; details on the collection of taphonomic data will be presented in Chapter 6. The methods presented here were influenced by the high degree of fragmentation evidenced in the assemblage; this was particularly the case when making decisions about quantification, as heavy fragmentation can reduce the utility of some of the primary quantitative units employed by many zooarchaeologists. Following a discussion of the methodology, I introduce the basic results, including a complete species list. The chapter concludes with a consideration of the most obvious limitations of the current sample and the degree to which these limitations may effect the analyses conducted in later chapters.

The faunal sample: general characteristics

Analysis of the HP and post-HP MSA fauna was undertaken during nine months of data collection which took place between July 2005 and August 2007. Although the upper two layers of the post-HP MSA have been excavated over an area of approximately 21 m^2, the remainder of the post-HP MSA and all of the HP have a much more limited exposure. Because the full suite of layers was represented in the 2 m^2 trial trench, I initially focused only on material from that trench (units B5 and B6), which was excavated between 1998 and 2005. Some of the post-HP MSA fauna from these units was initially identified by Plug (see Plug, 2004); this material was re-analyzed to ensure consistency in identification and in the recording of other attributes.

After reaching bedrock in the test trench in 2005, the exploratory unit was expanded into units C5 and C6, enlarging the available sample. However, the HP layers were not reached in these squares until March 2007. Due to time constraints, only one of the C units could be included in my analysis. Since a portion of the HP sample from C6 was not sorted in the field and had not yet been processed, I chose to analyze the material from C5. In addition to these remains, my study included a small number of bones that were recovered from the wider excavation area (layers BSp and SPCA only) and previously identified by Plug. The sample was thus primarily recovered from an area of 3 m^2, while the total volume of deposits was approximately 4.5 m^3.

My analysis focused only on the macromammalian (> 300 g) assemblage. Work on the remainder of the faunal sample is being carried about by other scholars—data are currently available for the microfauna (< 300 g; Glenny, 2006), aquatic species (Plug, 2006), and the avian remains (Plug and Clark, 2008). Although most of this material has not been subjected to detailed taphonomic analysis, the taxonomic information provided by these faunal classes may be useful for paleoenvironmental reconstruction, and I will thus make use of these data when relevant. It is worth noting that while all three of the aforementioned sources included both HP and the post-HP MSA in their analyses, Plug (2006) lumped the data from the post-HP, late, and final MSA in her analysis of the aquatic species, precluding any direct comparison of the HP and the post-HP MSA.

Methodology: data collection

While zooarchaeologists frequently limit their analyses to material larger than 2 cm in size, I made the decision to include all fragments in this study. There were two primary reasons for this: first, the majority of the assemblage was comprised of bone less than 2 cm in maximum length—this included the identifiable remains. If the less-than-2-cm fraction had been excluded from analysis, the total identified sample would have been much smaller. Second, it was hoped that a consideration of the complete assemblage would allow for a more nuanced understanding of variability in taphonomic processes over time.

The first step in the analysis involved sorting the assemblage into potentially identifiable and non-identifiable classes. The material initially analyzed and reported in Plug (2004) was pre-sorted by students at the University of the Witwatersrand (Wits), with those fragments being considered identifiable submitted to her for study. Given the difficulty in recognizing identifiable material in such a highly fragmented assemblage, in order to be sure that no identifiable bone was missed, and to ensure that all of the material under consideration was sorted in a consistent manner, the non-identifiable bone initially processed by the students at Wits was re-sorted for this study. Since my focus was on the macromammal remains, potentially identifiable material belonging to other taxa (shell, fish, reptiles, amphibians, birds, and micromammals) was set aside for submission to the appropriate specialists.

Once the potentially identifiable fragments were removed, the "non-identifiable" material was then sorted into several fragment categories—skull fragments, enamel, ribs, vertebrae, long bone shaft fragments, and miscellaneous—material less than and greater than 2 cm was sorted separately. In other faunal studies (e.g., Assefa, 2002) some of these categories, particularly long bone shafts, ribs, and/or vertebrae, are assigned to a general size class and considered alongside the identified remains. In this case, however, the degree of fragmentation precluded the assignment of these remains to a size class with any degree of certainty. Material in each fragment category was then sorted into burning categories (from unburned to calcined; these categories are discussed in more detail in Chapter 6), counted, and weighed. Detailed analyses of the non-identified fraction, particularly as related to information on variability in burning and fragmentation over time, will be reported in Chapter 6.

The vast majority of the assemblage (~92%) was comprised of "miscellaneous" bone less than 2 cm in length. Given that this material is of limited analytical value, and because sorting by the degree of burning and then counting each fragment was highly labor intensive, full sorting of the less than 2 cm miscellaneous bone was undertaken only for the B units. For unit C5, only one quadrant per layer was fully sorted and counted; these data were used to calculate the average weight per fragment for that layer. The less than 2 cm miscellaneous bone from the other quadrants in C5 was simply weighed, with the data on average fragment weight used to estimate the total number of fragments.

Specimens were identified with the aid of the large comparative collection housed at the Transvaal Museum (Pretoria, South Africa). Material was considered identifiable if it could be identified to both taxon and skeletal element (or, in some cases, an anatomical region such as "carpal, type unknown"). The taxon could be a species, genus, family, or a more general taxonomic group. While material was identified to the lowest taxonomic level possible, much of the assemblage could only be assigned to higher level

Size Class	Live Weight (kg)	Species (list not all-inclusive)
Bov I	<23	blue duiker, common duiker, klipspringer, steenbok
Bov II	23-84	mountain reedbuck, bushbuck, blesbok, impala
Bov III	85-295	red hartebeest, blue wildebeest, roan antelope, kudu
Bov IV	296-900	African buffalo, eland
Bov V	>900	giant buffalo, giant hartebeest (both extinct)

Table 4.1 Bovid size classes (adapted from Brain, 1974)

taxonomic categories such as “mongoose,” “large carnivore,” or “small mammal.” Bovids were the most common taxon at the site, and when species-level identification was not possible, remains were identified to size class utilizing Brain’s (1974) classificatory scheme, with the addition of the class “Bov V” for the extinct *Pelorovis antiquus* and *Megalotragus priscus* (Table 4.1).

When an assemblage is highly fragmentary, it is important to define the portion of the element represented by each specimen as precisely as possible. This is because portion data are essential to estimating the minimum number of elements (MNE, discussed in more detail below). The importance of including limb bone shaft fragments in zooarchaeological analyses has also been well demonstrated (see Marean and Kim, 1998 for a detailed discussion), and thus limb shafts were identified to element wherever possible. As demonstrated in Pickering et al. (2006), a consideration of cross-sectional geometry can be very useful in identifying long bone shafts to element; however, in their blind tests, only 47.9% of fragments that preserved less than 50% of the shaft circumference and length were successfully identified to skeletal element. Among the limb shaft fragments at Sibudu, the vast majority preserve less than this amount. Thus, the identification of shaft fragments to element generally depended upon the use of diagnostic features such as foramina and muscle attachments.

All identified material was weighed and measured to the nearest centimeter (< 2, 2-3, 3-4, etc). Complete or nearly complete specimens were measured with digital calipers according to the procedures outlined in von den Driesh (1976)—because complete elements were exceptionally rare, most of the material suitable for measurement consisted only of proximal or distal ends, and even these were rarely complete. Where possible, sex was determined from pelvic fragments and horn cores. Age at death (fetal/neonate, juvenile, adult or aged) was estimated based on degree of epiphyseal fusion, the presence of arthritic pathologies, and tooth eruption/wear. Since a majority of the teeth in the assemblage are highly fragmentary, the presence of unerupted enamel often served to identify juveniles while aged animals were identified based on the presence of very heavily worn enamel.

The second stage of data collection involved coding for taphonomic variables, including burning damage, fragmentation patterns, cortical preservation, and surface damage. The methods and criteria utilized for this stage of analysis will be discussed in Chapter 6.

Quantification

Definitions

Before introducing the results, it is important to define the analytical units employed in this study. Because different tests can require the use of different quantitative measures, and because the quantitative units utilized by zooarchaeologists have varying strengths and weaknesses, quantitative data are often expressed in a variety of forms. Two primary units of quantification are utilized in zooarchaeological analyses dealing with taxonomic abundances: the number of identified specimens (NISP), and the minimum number of individuals (MNI). NISP, defined as the number of identified specimens per taxon, is a primary counting unit and serves as the raw data on which many other quantitative measures are based (Lyman, 1994a). It includes all material identifiable to taxonomic category and skeletal element and/or anatomical region. MNI is the minimum number of individual animals necessary to account for a particular set of faunal remains; it can be derived directly from NISP or based on the minimum number of elements (MNE). MNI is usually determined from the most common portion of the most common skeletal element within a taxon (Stiner, 2005).

Analyses of skeletal part frequencies can also utilize NISP, but may be based on MNE, which is an estimate of the minimum number of skeletal elements (usually referring to whole bones) from which the identified fragments could have originated (Stiner, 2005). Like MNI, MNE is derived from NISP counts. The two derived measures share a number of similarities; when I refer to minimum number (MN) counts later in the text, I am referring to *both* MNI and MNE. Analyses of relative skeletal element abundances may also use another derived measure, the minimum number of animal units (MAU), which is calculated by dividing the MNE for each element by the number of times that element occurs in a complete skeleton (Binford, 1984). Grayson and Frey (2004) prefer to use a derivation of NISP known as “normalized NISP,” or nNISP, for analyses of relative element abundances. Simailar to the conversion from MNE to MAU, nNISP values are calculated by dividing the NISP for each element by the number of times that part occurs in a skeleton.

NISP vs. Minimum Number Counts: Strengths and Weaknesses

The various quantitative units have different strengths and weakness. While they are straightforward to calculate, NISP counts do have some drawbacks. The total number of skeletal elements can vary across taxa, meaning that the relative abundance of taxa with more bones will be overemphasized compared to those with fewer bones (Klein and Cruz-Uribe, 1984; Reitz and Wing, 1999). This is most obviously a problem when comparing abundances across classes or phyla (e.g., looking at the abundance of mammals vs. shellfish). Because I focus only on the macromammalian remains, among which the number of skeletal elements is more uniform, this should not be a major complicating factor for my analyses. It has also been argued that NISP is particularly sensitive to variability in transport behaviors, in that NISP counts can overemphasize the importance of species (e.g., those with small body size) that reach a site intact versus those that are dismembered before transport (Klein and Cruz-Uribe, 1984).

The latter critique is related to more general concerns about the sensitivity of NISP to fragmentation. Under low levels of fragmentation, NISP counts will be increased—a humerus that was broken during processing or post-depositionally and recovered as separate proximal and distal ends would be double-counted (presuming no refits could be made or were attempted), resulting in an NISP of 2 even though only one bone was represented. This sort of multiple counting could obviously impact both taxonomic abundances and skeletal part profiles. However, as demonstrated by Marshall and Pilgram (1993), when bones are highly fragmented, identifiability is reduced because a greater proportion of the fragments become too small to identify, and thus NISP counts will actually decrease under high levels of fragmentation.

The use of MN counts was meant to correct for some of the perceived drawbacks of NISP. For example, variation in the number of skeletal elements across taxa should not affect analyses of relative abundance based on MNI. Furthermore, since MNIs are based on the presence of overlapping elements rather than the sheer number of bones, species brought to the site whole and those that arrived partially dismembered should be counted equally. Along the same lines, MNE was introduced as means of correcting for the apparent lack of concordance between NISP measures of skeletal part frequencies, which may be affected by the differential fragmentation of various skeletal elements, and the actual frequencies of those parts (Lyman, 1994c).

It has long been argued that MN counts are less affected by fragmentation than NISP (c.f. Klein and Cruz-Uribe, 1984), with Yeshurun et al. (2007:142) recently going so far as to state that MNE is "immune to fragmentation." However, this is certainly not the case, particularly when fragmentation is high. This is because smaller fragments are "less likely to overlap and thus are less capable of being shown to be independent of one another" (Lyman 1994b:294). Marshall and Pilgram (1993) argue that MN counts are not actually less affected by fragmentation than NISP—because the criteria for calculating MN counts are stricter (again relating to the difficulty of demonstrating independence between small fragments), "[MN counts] will tend be more depressed than NISP at high levels of fragmentation" (265). As a result, Marshall and Pilgram (1993) conclude that MN counts may in fact be less representative than NISP when dealing with highly fragmented assemblages.

MN counts can be problematic for a number of other reasons. When considering the relative abundance of taxa, MNI will overemphasize the importance of rare individuals, as a single specimen always represents at least one individual (Reitz and Wing, 1999). The reduction in sample size that occurs when NISPs are transformed into MN counts, which will especially be a factor among heavily fragmented assemblages, can also make statistical manipulation of the samples more difficult (Grayson, 1984). Perhaps most troubling is the fact that there are several different methods for deriving both MNI and MNE (see Lyman, 1994a for a discussion of the various ways these measures have been defined/calculated). For example, some analysts take into account variables such as age, sex, and body size when calculating MN counts, while others do not. Furthermore, the methods used for deriving MN values are not always made explicit. This means that MN counts provided by different researchers may not be directly comparable—something that should not be an issue when NISP is used.

More seriously, as Grayson (1984) clearly demonstrated, the numerical values for MN counts will vary based on the way in which the faunal material from a given assemblage is aggregated. If each layer/feature is considered independently, the total MN values will be higher than if those units had been combined for analysis. To illustrate this effect, if Layer A contained a right humerus of a bushpig, and Layer B contained the left humerus from the same individual, when the two layers are considered independently, each will have an MNI of 1, for a total MNI of 2. But if the layers are aggregated, the total MNI will only be 1. As Grayson (1984:66) stated:

> It should be clear that minimum numbers are necessarily independent of one another only when one can be sure that the faunal aggregates from which they are defined are totally independent of one another… In many cases, total independence can only be guaranteed by treating an entire site as having provided a single faunal aggregate.

The nature of their derivation means that MN counts must be recalculated from scratch if a different aggregation scheme is used; unlike NISP values, they are not additive. Because it is generally impossible to recalculate MN counts without access to the raw data (which are rarely fully published), one cannot judge how the results of a study would have varied if the layers had been grouped in other ways; moreover, it is not always specified how features and/or layers were combined for analysis. As a general rule, then, it would appear that a maximal splitting of layers will likely result in overestimated MN values, while the aggregation of layers into a single analytical unit will likely result in underestimated MN counts.

Grayson (1984) also found that for any given fauna, MNI values can generally be tightly predicted from NISP counts, which means that the information that resides in MNI counts also resides in the NISP data. Although I recognize that NISP has its own weaknesses, given that the calculation of NISP *is* relatively straightforward, and because the measure is not subject to the aggregation effects that plague MN counts, I have chosen to use NISP as the primary quantitative unit for analyses dealing with taxonomic abundance. The high degree of fragmentation evidenced in the sample raises serious questions about the value of MN counts; however, I present MNI data in the species list in Table 4.2 largely because it is standard to do so.

Element frequency data (discussed in Chapters 6 and 8) are also reported using NISP. MNE/MAU values are also prone to aggregation effects, and as Grayson and Frey (2004:40) demonstrated, NISP-based analyses of skeletal part frequencies “can and do replicate the results of such analyses based on MNE, MAU, and single element MNI values.” Furthermore, as they point out, in cases where fragmentation results in a mismatch between NISP and MNE values, it will not necessarily be clear which statistic provides a more accurate measure of relative skeletal abundance. For these reasons, I will use NISP/nNISP counts rather than MNE/MAU values.

Methods: calculating NISP and Minimum Number counts

Calculating NISP

Although one of the primary benefits in using NISP lies in the fact that specimen counts are straightforward to calculate, there are still some decisions to be made. Of particular relevance here is how to treat material in articulation (for example, teeth in jaws, or articulated carpals/tarsals). Some advocate counting these as a single specimen (see discussion in Reitz and Wing, 1999: 156-157), while Stiner (2005) assigns bone and dental elements that are still in articulation separate NISP counts. She argues that the mechanical reworking of sediments could easily have separated these elements, and thus she counts them independently in an attempt to avoid the biasing effects of variable post-depositional disturbance. For example, if a complete mandible from a given species was present in both Layer A and B, and Layer A was differentially fragmented, resulting in the separation of tooth from jaw, Layer A would show a much higher NISP than Layer B, *if* the articulated mandible and teeth from Layer B were assigned an NISP of 1. This discrepancy could clearly affect analyses of relative taxonomic abundance. While the number of elements in articulation was incredibly small, I chose to follow Stiner's methodology, with information on articulation being coded into the faunal database. A similar issue relates to the treatment of fragmented material that can be refit. While Chaplin (1971) advocated counting fragments that cross-mend as separate specimens, most scholars treat them as a single entity for NISP counts. I assigned fragments that could be refit an NISP of 1.

The final decision related to the calculation of NISP for the Sibudu sample dealt with the treatment of fragmentary teeth. The assemblage contained a large amount of highly fragmented enamel. Unless the fragments were large enough to preserve features that allowed for the identification of a particular tooth type (incisor, upper molar, molar/premolar, etc.), and, for the case of bovids, at least a body size class, the enamel fragments were considered as part of the non-identified assemblage. Refits were attempted on material that was deemed identifiable in an attempt to avoid inflating NISP counts, particularly for those species with very distinctive enamel (e.g., equids and suids). Refitting was undertaken by quadrant and layer. If direct refits were not possible, but it seemed likely that fragments came from a single tooth (i.e., showed fresh breaks and the same degree of wear, burning, enamel thickness, and general texture), the material was assigned an NISP of 1, with the number of fragments specified in the notes for that specimen.

Calculating MNI/MNE

The heavy degree of fragmentation evidenced in the Sibudu assemblage creates several difficulties for the calculation of MN values—my goal was to make the best of a less than ideal situation, which in some cases required the use of slightly unorthodox methods. First, it is important to note that MN counts were calculated based on the total assemblage within each phase. While this likely results in further underestimated MN values, the decision to aggregate in this manner was based on the complex stratigraphy of the post-HP MSA, in which the relationship between layers is often ambiguous (e.g., layers Iv and BM were excavated as independent units but may be parts of a hearth within P; MY may actually be a hearth within Ma, etc.).

Furthermore, a relatively small proportion of the assemblage could be identified to the species level—most of the material could only be assigned to higher level taxonomic categories (e.g., small mammal, Bov I, etc.). This does not seem to be uncommon among highly fragmented assemblages; however, those who deal with similar samples rarely specify exactly how MNIs were derived. It seems relatively standard to exclude *possible* species identifications (such as “cf. *Potamochoerus larvatus*”) from MNI counts unless it is clear that the “cf.” material represents individuals beyond that identified as belonging to that species (e.g., if the “cf.” material included a juvenile but the species-level material comprised only adult remains). I followed this procedure for the derivation of MNI counts for “cf.” material. Otherwise, MNIs were calculated independently for each taxonomic category.

It is true that under a minimalist definition of MNI, one would calculate MNI values for a higher-level taxonomic category such as Bov I only if the sample included individuals beyond those identified for all of the bovid species that fit within that size category (e.g., Reitz and Wing, 1999). The bovid species-level identifications were primarily based on teeth (with the exception of the blue duiker, which was identifiable based on its extraordinarily small size), while the size-class material was predominantly post-cranial. If the size-class data were included only when they provided evidence for individuals beyond those identified to species, the MNI for nearly all bovid size classes would have been 0, despite the fact that some of the samples were fairly large (in part a factor of the heavy fragmentation). While I recognize that the specimens identified to size class may have come from the same individuals identified to the species level, I chose to calculate MN counts independently for the higher level taxonomic categories to provide a more general picture of the degree of fragmentation represented in the assemblage.

MNI values reflect the minimum number of individuals that could account for the MNEs for a given taxon. Thus, the calculation of MNI was dependent on the calculation of MNE. Some scholars use a fraction-summation approach for deriving MNEs (e.g., Assefa, 2002; Klein and Cruz-Uribe, 1984), in which the estimated fraction of each identified portion/feature is recorded and then summed in order to arrive at the MNE. Because the estimated fraction represented by each fragment was not recorded, this methodology could not be used. Furthermore, as a result of the heavy fragmentation, the GIS based approach to determining shaft-based MNEs as developed by Marean et al. (2001) is not applicable to the Sibudu assemblage.

Because portion codes were designed to be as discrete as possible, MNEs were based on the most common portion or feature for that element. For elements such as phalanges and carpals/tarsals, where portions were more vaguely defined, the most logical option seemed to be to choose the most common portion and to assume that the fragments within that portion did not overlap. This may not be ideal, but it seemed to be the best way of dealing with the material. Thus, if the first phalanx of the blue duiker was represented by 42 proximal fragments and 36 distal fragments, the MNE for the first phalanx would be 42. Because there are 8 first phalanges in a bovid skeleton, the MNI that could account for the sample is 6.

Both symmetry and age were taken into account when calculating MNI. Sex was not considered because only a minute fraction of the assemblage could be actually be assigned to sex. If some fragments from a particular skeletal element could be sided but others could not, the non-sided fragments were incorporated as illustrated in the following example: for a given species, if the sample contained 10 left (L) and 5 right (R) tali, along with 10 proximal talus fragments for which data on side was not recorded, 5 of the non-sided fragments would be assigned to the R side in order to make the two sides equal, with the remaining 5 divided equally between the L and R side. This would result in a minimum of 12.5 L (or R) tali, for an MNI of 13 (since you cannot have half a talus).

Basic results

A complete species list, including the total number of non-identified bones for each phase, is presented in Table 4.2 (note that in Table 4.2, as in future Figures and Tables, the data are presented in stratigraphic order rather than chronologically, such that the HP is at the far right of the table). A more detailed list which includes element and portion data can be found in the Appendix. The total assemblage consists of 176,303 fragments in the HP; 115,679 fragments in the post-HP MSA 2; and 255,847 for the post-HP MSA 1. The percent of identifiable bones within the assemblages largely depends upon whether or not the less-than-2 cm fraction of non-identified bone is included. When considering all excavated fauna, regardless of fragment size, the total percentage of identifiable material is 1.92% for the HP; this number declines to less than 0.5% in both units of the post-HP MSA. These values are remarkably low and emphasize the incredibly high degree of fragmentation in the sample. If the non-identified bone that is less than 2 cm (a common cutoff in zooarchaeological analyses) is excluded, those values rise to 26.37% for the HP, 6.35% for the post-HP MSA 2, and 3.20% for the post-HP

	post-HP MSA 1			post-HP MSA 2			HP		
Taxon	**NISP**	**%NISP**	**MNI**	**NISP**	**%NISP**	**MNI**	**NISP**	**%NISP**	**MNI**
Orcyterops afer, aardvark	-	-	-	-	-	-	1	0.0%	1
Procavia capensis, rock hyrax	2	0.3%	2	2	0.4%	1	28	0.8%	5
Lepus cf. saxatilis, cape hare	-	-	-	-	-	-	3	0.1%	2
Pronolagus crassicaudatus, Natal red rock rabbit	-	-	-	-	-	-	2	0.1%	1
Pronolagus sp.	-	-	-	-	-	-	5	0.1%	2
Lepus/Pronolagus	-	-	-	-	-	-	13	0.4%	1
Hystrix africaeaustralis, Cape porcupine	2	0.3%	1	-	-	-	2	0.1%	1
Thryonomys swinderianus, greater canerat	-	-	-	2	0.4%	1	3	0.1%	1
cf. *Thryonomys swinderianus*	-	-	-	-	-	-	1	0.0%	0
Cricetomys gambianus, Gambian giant rat	-	-	-	1	0.2%	1	50	1.5%	2
Rodent large	-	-	-	2	0.4%	1	7	0.2%	2
Papio hamadryas, Chacma baboon	-	-	-	-	-	-	15	0.4%	2
Cercopithecus pygerythrus, Vervet monkey	-	-	-	5	1.0%	1	63	1.9%	4
cf. *Cercopithecus pygerythrus*	1	0.1%	1	-	-	-	-	-	-
Cercopithecus albogularis, Sykes' monkey	-	-	-	-	-	-	23	0.7%	2
Primate: vervet or Sykes' monkey	-	-	-	-	-	-	17	0.5%	2
Primate: Sykes' monkey or baboon	-	-	-	-	-	-	10	0.3%	1
cf. *Genetta tigrina*, large-spotted genet	-	-	-	-	-	-	1	0.0%	1
Felid small (serval/wild cat)	-	-	-	-	-	-	5	0.1%	1
Felid small-medium (serval/caracal)	-	-	-	-	-	-	1	0.0%	1
Felid large (cheetah/leopard)	-	-	-	-	-	-	2	0.1%	1
Viverrid large	1	0.1%	1	-	-	-	2	0.1%	1
Viverrid/Mustelid	-	-	-	-	-	-	1	0.0%	1
Galerella sanguinea, Slender mongoose	-	-	-	-	-	-	2	0.1%	1
Galerella sp.	-	-	-	-	-	-	2	0.1%	2
Atliax palundinosus, Marsh mongoose	-	-	-	-	-	-	3	0.1%	1
Mongoose	-	-	-	-	-	-	13	0.4%	1
Mongoose small	-	-	-	-	-	-	12	0.4%	1
Mongoose medium	-	-	-	-	-	-	2	0.1%	1
Mongoose large	-	-	-	-	-	-	7	0.2%	1
Canid small	-	-	-	-	-	-	1	0.0%	1
Canid small-medium	-	-	-	-	-	-	1	0.0%	1
Canid medium (jackal size)	-	-	-	-	-	-	3	0.1%	1
Canid large	-	-	-	-	-	-	1	0.0%	1
cf. *Ictonyx striatus,* Striped polecat	-	-	-	-	-	-	5	0.1%	1
Mustelid	-	-	-	-	-	-	1	0.0%	1
Carnivore small	-	-	-	-	-	-	7	0.2%	1
Carnivore medium	1	0.1%	1	-	-	-	5	0.1%	1
Carnivore medium-large (hyena size)	2	0.3%	2	-	-	-	3	0.1%	1
Carnivore large	3	0.4%	2	-	-	-	-	-	-
Equus quagga, plains zebra	22	2.8%	2	-	-	-	6	0.2%	1
cf. *Equus capensis,* extinct Cape horse	3	0.4%	1	1	0.2%	1	-	-	-
Equus sp.	12	1.5%	2	7	1.4%	2	1	0.0%	1
Potamochoerus larvatus, bushpig	-	-	-	13	2.6%	1	295	8.7%	7
cf. *Potamochoerus larvatus*	-	-	-	-	-	-	4	0.1%	0
Phacochoerus africanus, Common warthog	5	0.6%	1	4	0.8%	2	-	-	-
Suid	20	2.5%	2	27	5.4%	3	19	0.6%	2
cf. *Giraffa camelopardalis,* giraffe	4	0.5%	1	1	0.2%	1	-	-	-
cf. *Pelorovis antiquus,* giant buffalo	6	0.8%	1	-	-	-	-	-	-
Syncerus caffer, African buffalo	10	1.3%	2	-	-	-	17	0.5%	2
cf. *Syncerus caffer*	8	1.0%	0	2	0.4%	1	2	0.1%	1
Syncerus/Pelorovis	2	0.3%	1	-	-	-	-	-	-
Tragelaphus strepsiceros, kudu	8	1.0%	2	-	-	-	-	-	-
cf. *Tragelaphus strepsiceros*	3	0.4%	0	-	-	-	-	-	-
Tragelaphus scriptus, bushbuck	-	-	-	1	0.2%	1	7	0.2%	2
cf. *Tragelaphus scriptus*	4	0.5%	1	1	0.2%	0	-	-	-
Tragelaphus oryx, eland	-	-	-	1	0.2%	1	5	0.1%	1
cf. *Tragelaphus oryx*	1	0.1%	1	2	0.4%	0	1	0.0%	0
Tragelaphus sp.	1	0.1%	1	-	-	-	-	-	-
Tragelaphine large: kudu or eland	3	0.4%	2	-	-	-	-	-	-
Megalotragus priscus, giant hartebeest	-	-	-	-	-	-	4	0.1%	1

Table 4.2 Taxa identified in the HP and post-HP MSA at Sibudu Cave (macromammals only)

	post-HP MSA 1			post-HP MSA 2			HP		
Taxon	**NISP**	**%NISP**	**MNI**	**NISP**	**%NISP**	**MNI**	**NISP**	**%NISP**	**MNI**
cf. *Megalotragus priscus*	3	0.4%	1	-	-	-	-	-	-
Connochaetes taurinus, blue wildebeest	6	0.8%	2	-	-	-	1	0.0%	1
cf. *Connochaetes taurinus*	3	0.4%	0	2	0.4%	1	-	-	-
cf. *Alcelaphus buselaphus*, red hartebeest	1	0.1%	1	-	-	-	-	-	-
Damaliscus pygargus, blesbok	1	0.1%	1	-	-	-	-	-	-
Alcelaphine medium-large	1	0.1%	1	-	-	-	-	-	-
Alcelaphine large	11	1.4%	2	-	-	-	5	0.1%	1
Hippotragus equinus, roan antelope	-	-	-	-	-	-	5	0.1%	2
Hippotragus sp.	1	0.1%	1	-	-	-	-	-	-
Hippotragus sp./Tragelaphus oryx	-	-	-	-	-	-	4	0.1%	1
Philantomba monticola, blue duiker	2	0.3%	1	14	2.8%	2	1208	35.7%	32
Cephalophus natalensis, red duiker	-	-	-	-	-	-	3	0.1%	1
cf. *Cephalophus natalensis*	-	-	-	-	-	-	1	0.0%	0
Sylvicapra grimmia, common duiker	-	-	-	-	-	-	2	0.1%	2
Cephalophus/Sylvicapra	-	-	-	-	-	-	5	0.1%	1
Redunca fulvorufula, mountain reedbuck	1	0.1%	1	-	-	-	-	-	-
Redunca sp.	2	0.3%	2	-	-	-	1	0.0%	1
Kobus ellipsiprymnus, waterbuck	1	0.1%	1	-	-	-	-	-	-
cf. *Kobus ellipsiprymnus*	1	0.1%	1	-	-	-	-	-	-
Pelea capreolus, grey rhebok	-	-	-	-	-	-	3	0.1%	3
cf. *Pelea capreolus*	-	-	-	-	-	-	2	0.1%	0
Pelea/Redunca	1	0.1%	1	-	-	-	-	-	-
Raphicerus campestris, steenbok	-	-	-	-	-	-	18	0.5%	4
cf. *Raphicerus campestris*	-	-	-	-	-	-	2	0.1%	0
Raphicerus sp.	1	0.1%	1	-	-	-	-	-	-
Raphicerus/Oreotragus	-	-	-	-	-	-	2	0.1%	2
Aepyceros melampus, impala	-	-	-	1	0.2%	1	4	0.1%	1
cf. *Aepyceros melampus*	1	0.1%	1	-	-	-	-	-	-
Oreotragus oreotragus, klipspringer	-	-	-	2	0.4%	1	-	-	-
cf. *Oreotragus oreotagus*	-	-	-	1	0.2%	0	-	-	-
Bov I	31	3.9%	2	60	11.9%	3	367	10.9%	15
Bov I/II	3	0.4%	1	22	4.4%	1	23	0.7%	2
Bov II	190	23.9%	5	184	36.6%	4	574	17.0%	9
Bov II/III	9	1.1%	2	12	2.4%	1	24	0.7%	3
Bov III	276	34.7%	5	72	14.3%	4	271	8.0%	7
Bov III/IV	45	5.7%	3	22	4.4%	1	47	1.4%	3
Bov IV	61	7.7%	4	24	4.8%	2	54	1.6%	3
Bov IV/V	11	1.4%	2	2	0.4%	1	2	0.1%	2
Bov V	4	0.5%	1	-	-	-	-	-	-
Large Ungulate (Bov III/IV or equid)	1	0.1%	1	-	-	-	-	-	-
Mammal small	2	0.3%	1	10	2.0%	1	53	1.6%	4
Mammal medium	2	0.3%	1	3	0.6%	2	15	0.4%	2
Total ID	796	100%	76	503	100%	43	3380	100%	172
Non-identified bone < 2cm*	230993			107756			163485		
Non-identified bone > 2cm	24058			7420			9438		
Total Non-ID	255051			115176			172923		
Grand Total	255847			115679			176303		
% Identifiable against all fragments	0.31%			0.43%			1.92%		
% Identifiable against > 2 cm non-id only	3.20%			6.35%			26.37%		

Note: MNI was estimated for identifications designated as ‘cf.’ only if those specimens must have come from individuals in excess of that represented by the remains verified to come from the species (e.g, if *Syncerus caffer* was represented only by adult remains but cf. *Syncerus* included bones from a juvenile, then cf. *Syncerus* would receive an MNI count), otherwise, MNIs were calculated independently for each taxonomic category

*Counts for a portion of the <2cm fraction from 1 of the 3 analyzed units (C5) was estimated- see text for details

Table 4.2 (cont'd) Taxa identified in the HP and post-HP MSA at Sibudu Cave (macromammals only)

MSA 1. However, these latter numbers are quite misleading, particularly for the HP, in which more than 70% of the identified bone was less than 2 cm. Given the remarkable difference between the two sets of results, it is clear that analysts should specify how the percent of identifiable bone was calculated, as the method employed will affect interpretations regarding the degree of fragmentation in the assemblage.

Potential limitations of the current sample

When considering the interpretations that can be based upon the data presented in Table 4.2, it is important to keep in mind some potentially important limitations of the sample; first, the limited spatial extent from which the remains were excavated; second, the extreme fragmentation of the sample; and third, the uneven sample sizes evidenced between the HP and the post-HP MSA. It is true that the analyzed sample derives from only 3 m^2. As discussed in Clark and Plug (2008), while we cannot fully discount the idea that any patterning in the fauna may reflect a sampling bias—in other words, that we are simply capturing shifts in activity areas over time—MSA sites from which larger horizontal exposures are available (including Rose Cottage Cave, Klasies River Shelter 1B, and Florisbad) do not show clear evidence for the existence of well-defined activity areas (Wadley, 2001). Rather, the evidence suggests the presence of largely unstructured camp organization, although some refuse dumping may be indicated. This suggests that the sample deriving from the exploratory unit is likely to be representative of what was present in the site as a whole; however, this cannot be certain until a larger area is exposed.

Given the extreme fragmentation of the sample, it is reasonable to ask whether differences in the degree of fragmentation across taxa will impact the results of analyses that rely on taxonomic abundances. For example, when looking at the taxonomic information presented in Table 4.2, it becomes clear that the HP assemblage contains a significantly higher proportion of the smallest bovids (including the species-level identification of the blue duiker, with an NISP of 1208). On a theoretical level, one might expect the bones of small animals to be less affected by severe fragmentation than those of larger species. This is in part because larger bones often require more intensive processing before consumption (and are more likely to be processed for marrow), and thus the remains of small animals may be more likely to survive in an identifiable state (Klein, 1989; Lyman, 1994c; Yeshurun et al., 2007). Beyond issues relating to human processing, the greater surface area of large animal remains may also make them more susceptible to post-depositional destruction. In a study of several Paleolithic and Epipaleolithic assemblages from the Levant, Yeshurun et al. (2007) found that the remains of a larger ungulate (fallow deer) were, in fact, more heavily fragmented than those of a smaller ungulate (gazelle), which they argued to be a product of post-depositional attrition.

If the bones of larger animals are more susceptible to fragmentation, this could have two possible effects on analyses of relative abundance—under low degrees of fragmentation, in which identifiability is retained, the proportion of larger animals may be overestimated relative to small game. The opposite would be true under heavy fragmentation, in which the proportion of larger animals may be underestimated relative to smaller game. Following from this, it may in fact be the case that small bovids *are* over-represented in the HP assemblage. However, the same principles would apply throughout the sequence—and despite the high resolution of this analysis, in which even the smallest fragments were analyzed—the blue duiker and other small bovids were identified in only very small quantities in the post-HP MSA. This suggests that the patterning evidenced in the sample is not simply a reflection of preservational bias. The heavy fragmentation and the potential effects of differential fragmentation will be discussed in more detail in Chapter 6.

The final issue deals with the uneven sample size for the HP (NISP 3380) as compared to the post-HP MSA 2 (NISP 503) and post-HP MSA 1 (NISP 796). It has been clearly demonstrated that taxonomic richness and diversity generally correlate with the size of the assemblage—larger assemblages show greater diversity (Grayson, 1984; Grayson and Delpech, 1998; Lyman, 1994c). As a result, analyses of taxonomic diversity must take variation in assemblage size into account. On a more general level, such a large discrepancy in sample sizes will violate the assumptions of many statistical tests. As Reitz and Wing (1999:146) state:

> Quantitative comparison among samples may be done with more confidence when *they are similar in context, recovery method and sample size*…if these conditions are not met, it would be unwise to conduct complex statistical applications and *a more descriptive analysis is justified.* (emphasis added)

When appropriate, the post-HP MSA 1 and 2 can be combined for analysis, allowing for an enlarged sample; however, even as a combined unit, the difference in sample size between the HP and the post-HP MSA remains considerable. In some instances, therefore, it may be necessary to be more qualitative than quantitative.

These are important limitations that cannot be overlooked, and I will return to them again in the upcoming chapters. However, despite these limitations, it is clear that the Sibudu sample has a great deal to offer to our understanding of variability in both paleoenvironment and subsistence behavior during the HP and the post-HP MSA. While Chapters 6-8 focus specifically on the taphonomic history of the assemblage and the evidence for animal procurement and processing, I turn next to an exploration of how the taxonomic data presented in Table 4.2 inform us about paleoenvironmental conditions in the Sibudu region during the HP and post-HP MSA.

Chapter 5

Paleoecology of the Sibudu Region

As discussed in Chapter 3, the archaeomagnetic data indicate that the MSA layers under consideration encompass the transition from a glacial period, OIS 4 (~71-57ka) to the beginning of an interstadial, OIS 3 (~57-24ka). If Herries' (2006) interpretation of the data is correct, the HP and the post-HP MSA 2 fall within OIS 4, while the post-HP MSA 1 falls within OIS 3. Changing temperatures, moisture availability and distance from the coast during OIS 4 and 3 would have influenced both the flora and fauna of the Sibudu region (Wadley, 2006), and, as such, it is expected that the shift from a glacial to an interstadial would be reflected in changes in the local environment. Because it is important to evaluate the degree to which variability in the faunal assemblage can be attributed to environmental change, in this chapter I will explore what the botanical and faunal data suggest about paleoenvironmental conditions during the HP and the post-HP MSA.

The chapter begins with a consideration of the broader evidence for climatic conditions during OIS 4 and 3 in sub-Saharan Africa in general and southern Africa in particular, followed by a review of what the botanical remains (including charcoal, seeds, and pollen) suggest about conditions in the Sibudu region during the period under study. Finally, I turn to the faunal evidence itself, evaluating how it can be used to reconstruct the paleoecology of the site region and how well the results provided by the botanical and faunal data correspond to each other.

African climate during OIS 4 and 3

While it has generally been assumed that most of Africa experienced cooler and drier conditions during glacial/stadial periods and relatively warmer and wetter conditions during interglacials/interstadials (e.g., Barham and Mitchell, 2008; Marean and Assefa, 2005), it is becoming clear that conditions during OIS 4 and OIS 3 (both of which are encompassed within the Last Glacial) were quite variable across the African continent. For example, lake cores from the Awash Valley in Ethiopia have indicated a major decline in lake levels (reflecting high aridity) between 70-60 ka (OIS 4; Assefa, 2002). However, lake core records from Lake Malawi (south-central Africa), Lake Tanganyika (central Africa), and Lake Bosumtwi (west Africa) document a dramatic *rise* in water levels and a shift to more humid conditions over much of tropical Africa after 70ka (Scholz et al., 2007)—the same time that drying was evidenced in the Ethiopian record.

While a lack of high-resolution continental records has hampered our understanding of the influence of global climate transitions on African climate on a broader scale, the problem is particularly acute for southern Africa (Maslin and Christensen, 2007). Not only are conditions in the region not conducive to the preservation of traditional paleoecological data sources (e.g., pollen, insects), but there has also been a lack of suitable deposits for dating—resulting in a data set that is often "vague and confusing" (Chase and Meadows, 2007: 106). Before discussing what we do know (or think we know) about southern Africa's climate during the Last Glacial, it is first important to provide a brief discussion of modern climate regimes in region.

Situated at the interface of the tropical, sub-tropical, and temperate climate systems, as well as the Indian, Atlantic, and Southern Oceans, southern Africa is influenced by a wide variety of atmospheric and oceanic circulation systems (Chase and Meadows, 2007). In the summer rainfall zone (SRZ, see Figure 5.1), conditions are closely linked to seasonal movements of the Intertropical Convergence Zone (ICTZ) and the expansion of moist bodies of air, derived from the Indian Ocean, over the

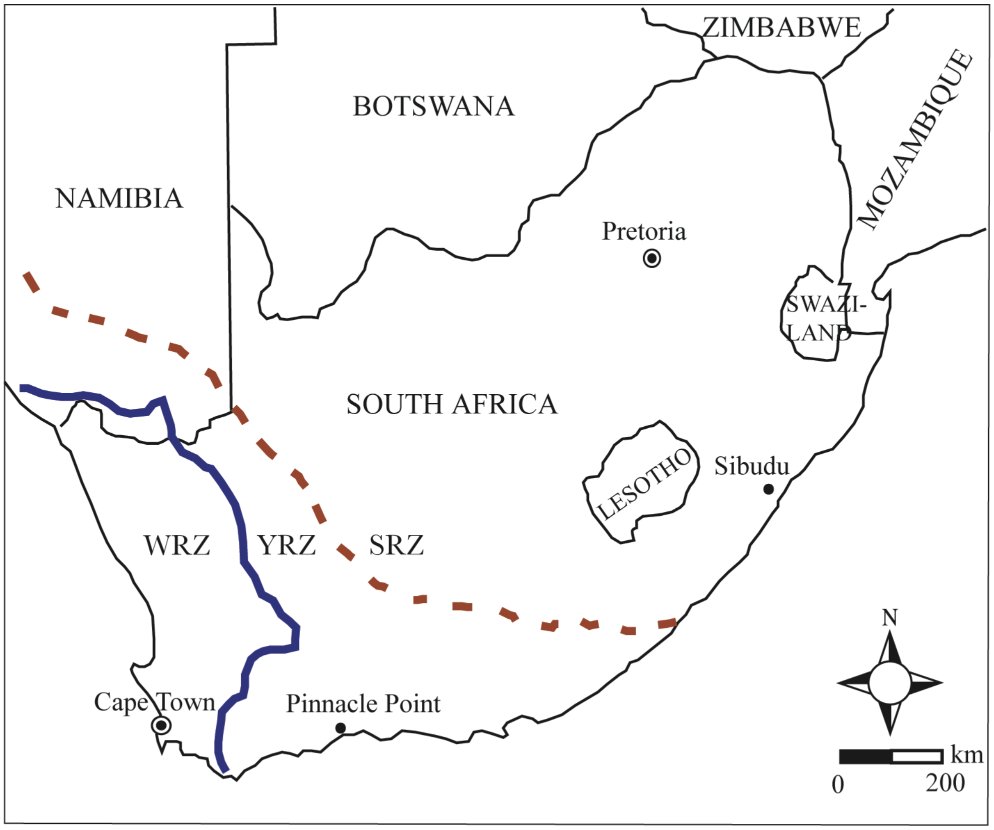


Figure 5.1 Map of southern Africa showing relative locations of the winter rainfall zone (WRZ, bold blue line), the summer rainfall zone (SRZ, located north/east of the dotted red line), and the year-round rainfall zone (YRZ, located between the WRZ and SRZ; adapted from Chase and Meadows, 2007)

subcontinent (Thomas and Shaw, 2002). In the winter rainfall zone (WRZ), conditions are linked to the movement of temperate frontal systems embedded in the westerlies; in between these two lies a narrow zone that receives rain year-round (YRZ; Chase and Meadows, 2007).

While Chase and Meadows (2007) proposed that the winter, summer and year-round rainfall zones likely persisted throughout the glacial-interglacial cycles, the spatial extent and position of these zones may have changed markedly—leading to yet another complication in reconstructing past conditions. Stuut et al. (2002) demonstrated that shifts in the atmospheric circulation system during glacial periods would have resulted in a northward displacement of the westerlies, leading to increased trade-wind intensity and rainfall in extreme southwestern Africa. The same conditions may have also resulted in the north- and east-ward expansion of the WRZ during glacial periods (Chase and Meadows, 2007). At present, dry phases and droughts in the SRZ of the interior region of southern Africa are closely linked to strengthened and expanded westerly circulation, as these systems inhibit the penetration of moist easterly air flows from Indian Ocean. Thus, if the westerlies were strengthened during glacial periods, it may be expected that much of the SRZ would have experienced greater aridity during glacials.

Does the available data match up with these predictions? Chase and Meadows (2007) compiled data on late Quaternary climate from sites across southern Africa and found that the available data does support a model for increased precipitation in SW Africa during periods of the Last Glacial (of which OIS 4 and 3 are both a part). However, they found that conditions were highly variable across the WRZ, with the west and central-southern coasts differentially affected by glacial periods—they thus caution against using the inferred paeloenvironmental trends from the west coast to extrapolate what conditions were like across the WRZ, much less across the whole sub-continent. Conditions also seem to have been highly variable over time, as a high-resolution speleothem sequence from Pinnacle Point (shown on Figure 5.1) showed frequent oscillations between cold/dry and warm/wet conditions between 70-64 ka (Bar-Matthews et al., 2008).

In an attempt to reconstruct the precipitation history of the summer rainfall region (of which KwaZulu-Natal is a part), Partridge et al. (1997) analyzed material from the Pretoria Saltpan, a 200,000 year old closed-basin crater lake on the interior plateau of South Africa. They found evidence for dry conditions from 70-60 ka (during OIS 4), followed by a period of increasing wetness that lasted through 50ka. More recently, Thomas and Shaw (2002) pulled together data from across the interior of southern Africa—they also found evidence for increased aridity during glacial periods. Unfortunately, records from coastal regions in the SRZ are almost entirely lacking (Chase and Meadows indicate only a single data point in the entirety of KwaZulu-Natal), and, given the high amount of diversity present in modern vegetation and climate across the SRZ (Allott, 2005), it seems unwise to extrapolate about conditions in the Sibudu region using data from central southern Africa.

Before moving on to the data from Sibudu itself, one final point deserves mention: Ramsay and Cooper (2002) attempted to create a Late Quaternary sea level curve for South Africa using data from a range of sea level indicators and from a variety of locations, and yet the period from 75-50 ka, which incorporates both the HP and post-

HP MSA, had no data points. As such, they could only extrapolate based on what came before and after this period, ultimately proposing a steady decline in sea level between 75-50 ka (see Figure 5 in Ramsay and Cooper, 2002). This could have had an impact on the relative distance from Sibudu to the shore; however, due to the steep off-shore topography that characterizes much the eastern coast of South Africa, drops in sea level would have had less of an impact on the distance from the rockshelter to the shore than in other regions.

Reconstructing paleoenvironmental conditions at Sibudu: botanical data

The lack of comparative data on conditions during OIS 4 and 3 from coastal regions in the SRZ further highlights the importance of Sibudu's record to our broader understanding of climatic variability during this period. As a result of the careful excavation procedures and excellent organic preservation at the site, several distinct lines of evidence can be utilized to reconstruct the paleoecology of the site region. In this section, I discuss four classes of data deriving from the botanical record that have provided information on paleoclimate during the HP and post-HP MSA: charcoal, seeds, pollen, and the isotopic analysis of charcoal. I will briefly introduce the methodology for each of these analyses, and then break down the data for each phase, beginning with the HP.

Reconstructing paleoenvironments using botanical data: methodology

Allott (2005, 2006a, 2006b) analyzed charcoal samples from the HP and from the post-HP, late, and final MSA. Within the HP and post-HP MSA, she sampled material from 7 distinct layers. Samples were taken from the trial trench (units B5 and B6) and were collected from the sediment matrix—not from hearth contexts (Allott, 2005).

Because charcoal was predominantly introduced to the site as a result of human activity, the samples may not provide an unbiased picture of what was present in the surrounding environment. As a result, Allott primarily focused on combinations of taxa (e.g., species from open vs. closed habitats, deciduous vs. evergreen taxa) rather than focusing on each taxon independently. She based her study on the assumption that the majority of taxa were collected from the area immediately surrounding the site. Given the variety of growing conditions evidenced in the vicinity of the shelter—ranging from the dry, shallow, and well-drained soils on the cliffs, to the wet, poorly-drained soils in the river valley—it was expected that a mosaic of habitats similar to that recognized around the site today was also present during the MSA. As such, wood was likely brought into the site from several different vegetation zones (Allott, 2005, 2006a; Wadley, 2006).

Samples for pollen analysis were also collected from the trial trench (unit B5 only), and were taken from 15 layers, all but two of which came from the post-HP MSA (Renault and Bamford, 2006). However, only six of the post-HP MSA layers actually yielded any recognizable pollen grains, and where present, pollen counts were too low to provide any reliable environmental data. Despite this, even the limited pollen record retains some value, as it can complement the results of other botanical studies by confirming the presence of species identified (or potentially identified) in macrobotanical analyses.

Both Wadley (2004) and Sievers (2006) analyzed seeds recovered from the MSA deposits at Sibudu. While Wadley considered the entire seed assemblage, Sievers focused only on material that was carbonized, as she argued that the uncarbonized seeds are more likely to be intrusive in the deposits (Sievers, 2006). I will primarily focus on the results presented in Sievers (2006), as her study included the HP, which had not yet been excavated at the time of Wadley's work. All carbonized seeds more than half complete were analyzed and all excavation units were included in Sievers' analysis; therefore, the post-HP MSA sample included some material from outside the trial trench.

Finally, Hall et al. (2008) examined stable carbon isotope ratios from archaeological charcoal as another means of obtaining information on paleoenvironmental conditions during the MSA at Sibudu. Their sample was chosen from Allott's identified charcoal, and thus all material came from the trial trench (units B5 and B6). The analysis included charcoal from two HP, one post-HP MSA 1, and two late MSA layers. Although the primary focus of the study was *Podocarpus* charcoal, some *Celtis* charcoal was included for comparison, as *Celtis* is adapted to a wider range of environments (particularly drier ones) than *Podocarpus*.

Hall et al. (2008) first looked at modern samples of *Podocarpus* in order to demonstrate that the $\delta^{13}C$ values of charcoal can provide information on rainfall, temperature, and humidity. They also provided carbon isotope values for samples combusted at a range of temperatures in order to demonstrate the range of variability in isotoptic values that results from the combustion of wood tissue. With these baselines established, Hall et al. (2008) were then able to compare the $\delta^{13}C$ values of the archaeological charcoal to the modern data in order to make inferences about past conditions.

Reconstructing paleoenvironments using botanical data: the HP

Charcoal has been analyzed from three HP layers: GR, GS and PGS (Allott, 2005, 2006a, 2006b). These layers are dominated by evergreen forest taxa, particularly

Podocarpus spp. The prevalence of *Podocarpus* in the HP sample is important because the genus is not currently found in the Sibudu area, nor is it present in any quantity in the layers post-dating the HP (Allott, 2006b). *Podocarpus* can grow in a variety of forest types, but generally occurs in environments that receive at least 900 mm of rainfall per year. However, it is important to note that *Podocarpus* species can survive in drier regions, as long as there are habitat niches in which moisture availability (but not necessarily precipitation) is high (Allott, 2006a).

However, the HP sample also includes some species indicative of more open conditions, including *Kirkia* spp. There are two possible *Kirkia* identifications, both of which are species that occur in deciduous savanna woodland and in warmer/drier habitats than those found around Sibudu today (Allott, 2005). However, this type of open vegetation would not necessarily have been far from the shelter, as *Kirkia* can grow just beyond sheltered kloof (valley) vegetation (Allott, 2006a), and, as previously discussed, open species such as *Acacia* are currently found on the slope opposite the shelter. With the exception of *Kirkia* spp., the HP layers generally show a lack of taxa from savanna woodland or thornveld environments, suggesting again that evergreen forest was the predominant vegetation type (Allott, 2005). While the combination of taxa identified in the HP charcoal assemblage has not been recorded in South Africa today, Allott (2006a) noted the presence of similar vegetation communities in northern KwaZulu-Natal where temperatures and humidity are high throughout the year, suggesting the presence of warm and moist conditions during the HP.

Unfortunately, there is not yet any pollen data for the HP at Sibudu, and the sample of identifiable seeds reported in Sievers (2006) is small. Sedges were the most commonly identified seed type—as discussed in Chapter 3, these are present throughout the MSA sequence and indicate the presence of standing water, likely associated with the Tongati River. Beyond sedges, only three seeds could be identified to genus or species. As a result, the existing sample does not provide sufficient information to aid in reconstructing environmental conditions during the HP.

Podocarpus charcoal from two HP layers (GR and GS) were sampled as part of Hall et al.'s (2008) isotopic analysis. The $\delta^{13}C$ values for the HP charcoal corresponded well with the values obtained from a sample of modern *Podocarpus latifolius* charcoal. The modern sample was collected in Seaton Park, a remnant of indigenous coastal forest preserved in a suburban park near Durban. Hall et al. (2008) suggest that this vegetation community may provide a good analogue for conditions near the site during the HP. Delta ^{13}C values for *Celtis* charcoal from layer GS were notable for their low degree of variability, and although the significance of the low variance is not fully understood, Hall et al. (2008) proposed that it may be reflective of environmental constraints on growth. In other words, the adaptive strategies of this genus may have been limited during the HP. Given that *Celtis* is particularly adapted to drier environments, and because the charcoal data suggested the presence of a moist evergreen forest, the isotopic data may indicate that *Celtis* was at the wet limit of its adaptive capacity during the HP (Hall et al., 2008).

Reconstructing paleoenvironments using botanical data: the post-HP MSA 2

Our knowledge of environmental conditions during the early post-HP MSA is unfortunately rather limited. Allott (2005) did not include material from the post-HP MSA 2 in her analysis, in large part because preliminary work on samples from these layers revealed that charcoal preservation was poor; however, she does plan to focus on this material in the future. Because Hall et al.'s (2008) samples were taken from the material identified by Allott, there is also no isotopic data for this phase.

Both Wadley (2004) and Sievers (2006) included material from the post-HP MSA 2 in their analyses; however, they disagreed on the identification of a particular seed type that was common in the assemblage. Wadley (2004) identified *Erythroxylum emarginatum*, an evergreen tree which occurs as a sub-canopy species in dry or scrub forest, as the dominant seed from layers YA1 to Ch2, indicating a strong forest presence. However, Sievers (2006) believes that the identification of *E. emarginatum* may have been incorrect—while many of the seeds had partially disintegrated since Wadley's study, Sievers felt that most of the fragments were thicker-walled than *E. emarginatum*. Using a larger comparative sample, Sievers argued that many of these seeds belonged to the as-yet unidentified 'Type 5' (possibly *Olea* sp.).

Although these 'Type 5' seeds were present throughout most of the MSA sequence, they were most common in the post-HP MSA 2, despite the fact that the late and final MSA have been excavated over a much larger area (Sievers, 2006). However, because the seeds have not been positively identified to taxon, the implications of this abundance to our understanding of paleoenvironmental conditions cannot be assessed. Sedges were the second most commonly identified seed type in the post-HP MSA 2. The remaining identified seeds came primarily from plants that can occupy a wide range of habitats and thus are not particularly useful for identifying the type of vegetation communities found near the site.

Finally, three layers from the post-HP MSA 2 were sampled for pollen analysis. Although pollen counts were low, sedges were identified, as were some grasses, ferns, and *Acacia* sp. (Renaut and Bamford, 2006). While the available botanical data for the post-HP MSA 2 is quite limited, both riverine and more open grassland vegetation are evidenced, again indicating the presence of a mosaic environment.

Reconstructing paleoenvironments using botanical data: the post-HP MSA 1

The archaeomagnetic data indicated the presence of a variable climate during the post-HP MSA 1, with both cooler and warmer conditions represented—this variability also appears to be reflected in the charcoal data (Herries, 2006; Wadley, 2006). Charcoal was analyzed from three layers within the post-HP MSA 1: Eb, SPCA, and BSp; these samples were distinctive enough that is it worth discussing them separately (Allott, 2005; 2006a). The charcoal from layer Eb suggests the presence of as many as three distinct habitat types in the vicinity of the shelter. The first group of taxa is comprised of species such as *Erica* spp. and *Leucosidea sericea*, which can withstand cool conditions and are associated with high rainfall or high moisture availability. The second group contains species such as *Rapanea* cf. *melanophloeos* and *Bridelia* sp. that are more often found along rivers in evergreen forests. The final group of taxa includes *Acacia* spp. and *Ximenia* sp., which potentially indicate a drier and/or warmer environment with open, woodland vegetation.

While the taxa identified from layer SPCA were quite diverse, the sample was again dominated by taxa from forest and riverine environments (including *Podocarpus*) and indicated a strong evergreen component with few deciduous taxa (Allott, 2006). The co-occurrence of *Leucosidea sericea* and other taxa currently found in the Drakensberg foothills—identified in the assemblages from both Eb and SPCA—led Allott (2005, 2006a) to argue that there may have been a shift in vegetation zones at the end of OIS 4 and the beginning of OIS 3. *Leucosidea sericea*, in particular, is a taxon that generally grows further inland than Sibudu (at present it is not found closer than 30 km from the shoreline) and at higher altitudes. Furthermore, it is frost tolerant, and is often, although not exclusively, found in cooler regions. Although OIS 3 represents an interstadial phase, Allot (2005, 2006a) proposed that the vegetation communities evidenced in layers Eb and SPCA may reflect a lowering of sea levels during the post-HP MSA. While a drop in sea level may not have dramatically changed the profile of the coast due to the relatively steep offshore topography, it may have been enough to reduce the ameliorating influence of the coast on the Sibudu region, enabling taxa currently found farther inland to grow closer to the shelter.

Taxa identified from layer BSp (the upper-most layer of the post-HP MSA) indicate an environment with both evergreen and deciduous components. The absence of *Podocarpus*, combined with the presence of *Acacia* spp., *Ziziphus* spp., and *Calodendrum capense*, suggests a more open environment and perhaps warmer and drier conditions. Because Allott (2005) found more similarities between Eb and SPCA than between either of those layers and BSp, she argued that the increased deciduous component in BSp may reflect the beginnings of a shift to more open conditions, similar to those evidenced during the late MSA.

The seed data from the post-HP MSA 1 was not broken down by layer, but, taken as a whole, the data suggest the presence of a well-developed forest, with canopy species, forest margin species, and understory components all represented (Allott, 2005; Sievers, 2006; Wadley, 2004). The most commonly identified seed type was *Asparagus* sp., which can grow in a wide range of moisture and temperature regimes and is found in habitat types ranging from forest to open woodland (Sievers, 2006). Sedges are the next most common species, followed by the unidentified 'Type 5' seeds. The pollen sample was again quite limited, but sedges, grasses and *Acacia* were identified (Renaut and Bamford, 2006).

Turning to the isotopic data, Hall et al. (2008) found that the $\delta^{13}C$ values for charcoal taken from SPCA were markedly different than the samples analyzed from the HP. Looking first at the *Podocarpus* data, in addition to having a higher mean, the sample from SPCA showed a smaller standard deviation, variance, and range. The $\delta^{13}C$ values for the *Celtis* charcoal were also markedly more positive than those from the HP. Among the modern *Podocarpus* specimens, increased isotopic values were correlated with either reduced rainfall/humidity, an increase in temperature, or both. As discussed for the *Celtis* values in the HP, the significance of limited range of the $\delta^{13}C$ values evidenced for the *Podocarpus* samples from SPCA is currently unclear, but just as *Celtis* may have been at the wet limit of its adaptive capacity in the HP, so too may *Podocarpus* have been at the *dry* limit of its adaptive capacity at the time when SPCA was deposited. Hall et al. (2008) proposed that conditions may have been dry enough that evergreen forest communities were restricted to sheltered areas along the river, where moisture levels would have remained high enough for *Podocarpus* to grow. If this were the case, the absence of *Podocarpus* in the BSp charcoal assemblage may reflect a further intensification of this drying trend, such that its growth was no longer supported.

Summary of the botanical data

The botanical data indicate that riverine vegetation persisted throughout the HP and the post-HP MSA, which is not surprising, given the presence of the Tongati River immediately below the shelter. As Allott (2006a) pointed out, the riverine vegetation zone may have acted as an oasis of sorts and, as a result, shifts in vegetation that occurred in the wider region may be somewhat obscured. Despite this, however, there are some clear differences between the HP and the post-HP MSA assemblages. The combined data from the HP suggest the presence of a humid evergreen forest, one dominated by *Podocarpus*, although it appears that some more open areas were present in the site region. While botanical data from the post-HP MSA 2 is currently limited, the available evidence indicates a mosaic of habitat types was present; however, we cannot make any judgments about relative temperature or humidity. By the time the post-HP MSA 1 was deposited, conditions appear to have been drier and at least occasionally cooler than present. Isotopic data from layer SPCA, combined with the charcoal data from BSp, indicate a decline in the evergreen forest surrounding the site, with a corresponding increase in deciduous taxa. By the end of the post-HP MSA, the vegetation may have been characterized by a small patch of evergreen forest close to the river and larger patches of well-grassed savanna on the neighboring hillsides (Wadley, 2006).

As a whole, then, although data on environmental conditions during the earliest post-HP MSA are limited, the botanical evidence does indicate a shift in the vegetation present in the site region between the HP and the post-HP MSA. These shifts may have occurred in response to changes in climate (for example, changes in moisture availability and distance to the coast) associated with the transition from OIS 4 to OIS 3.

Reconstructing paleoenvironmental conditions at Sibudu: faunal data

I now turn to the faunal data, which serve as yet another means of reconstructing the paleoecology of the Sibudu region during the HP and post-HP MSA. The fauna may have been culturally selected and thus may not be directly reflective of conditions near the site—in other words, changes in fauna could be linked to changes in environment, changes in mobility/targeting strategies, or some combination of both. However, if the fauna indicate a pattern similar to that identified for the botanical data, we can have some confidence that the fauna are providing real environmental information. Although some taxa may be indicator species for a particular habitat type, I follow Allott (2005) in looking primarily at groups of taxa, for example, species that prefer open vs. closed habitats.

Habitat data are presented in Table 5.1 and Figure 5.1. Table 5.1 provides information on the habitat preferences of the identified taxa from the HP and post-HP MSA, along with the NISP counts for each taxa. The table also included information on the feeding behavior (browse vs. graze) of the ungulates in the assemblage. The habitat data are summarized in Figure 5.2, which presents the percentage of taxa that prefer open, closed, or either habitat type for each of the three periods under consideration. The evidence suggests a marked change over time, with a significant decline in the relative abundance of species inhabiting closed or semi-closed environments. The implications of these results will be discussed in detail below; first, however, I will break down the habitat data by phase to explore what the fauna indicates about the paleoecology of the Sibudu region and how this data matches up to the botanical data presented earlier.

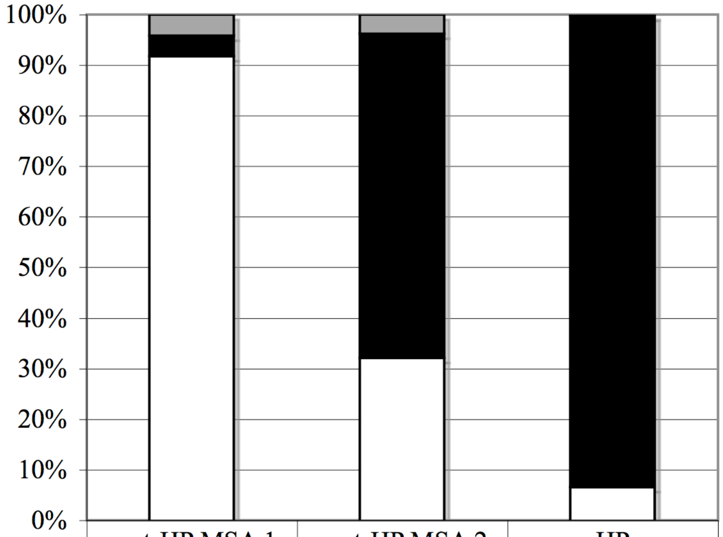
Taxon	Habitat Preference	Primary Habitats	Browse/Graze (Ungulates only)	Present today?*	post-HP MSA 1	post-HP MSA 2	HP
Pronolagus crassicaudatus, Natal red rock rabbit	Open	Rocky areas		Y	-	-	2
Pronolagus sp.		Grassy hillsides			-	-	5
Hystrix africaeaustralis, Cape porcupine	Both	Most (except forest)		Y	2	-	2
Thyronomys swinderianus, greater canerat	Open (w/water)	Tall grassy areas Reed/cane fields		Y	-	2	3
Cricetomys gambianus, Gambian giant rat	Closed	Evergreen forest Woodland savanna		N	-	1	50
Orcyteropus afer, aardvark	Open	Open woodland Grassland		Y	-	-	1
Procavia capensis, rock hyrax	Open	Rocky outcrops		Y	2	2	28
Papio hamadryas, chacma baboon	Open	Woodland savanna		Y	-	-	15
Cercopithecus pygerythrus, vervet monkey	Closed	Riverine woodland Riparian savanna		Y	-	5	63
Cercopithecus albogularis, Sykes' monkey	Closed	Evergreen forest Riverine/coastal forest		Y	-	-	23
Galerella sanguinea, slender mongoose	Open	Open areas		Y	-	-	2
Atilax paludinosus, marsh mongoose	Both	Close to water		Y	-	-	3
Equus quagga, plains zebra	Open	Savanna	Gr	N	22	-	6
Equus sp.		Open woodland			12	7	1
Potamochoerus larvatus, bushpig	Closed	Forest Riparian vegetation	Omnivorous	Y	-	13	295
Phacochoerus africanus, common warthog	Open	Open woodland Bushland	Gr	Y	5	4	-
Syncerus caffer, African buffalo	Open (w/shade)	Open woodland Open vleis	Gr	N	10	-	17
Tragelaphus strepsiceros, kudu	Open (w/shade)	Woodland savanna	Br	N	8	-	-

Table 5.1 Habitat and feeding data (habitat data from Skinner and Chimimba, 2005; feeding data from Wadley et al., 2008)

Taxon	Habitat Preference	Primary Habitats	Browse/Graze (Ungulates only)	Present today?*	post-HP MSA 1	post-HP MSA 2	HP
Tragelaphus scriptus, bushbuck	Closed	Riverine underbrush Thickets	Br	Y	-	1	7
Tragelaphus oryx, eland	Open	Karoo Savanna	Mixed	Y	-	1	5
Connochaetes taurinus, blue wildebeest	Open (w/shade)	Woodland savanna Open woodland	Gr	N	6	-	1
Damaliscus pygargus, blesbok	Open	Grassland	Br	N	1	-	-
Hippotragus equinus, roan antelope	Open	Open savanna	Br	N	-	-	5
Hippotragus sp.		Open grassland			1	-	-
Philantomba monticola, blue duiker	Closed	Forest Thicket	Br	Y	2	14	1208
Cephalophus natalensis, red duiker	Closed	Forest Thicket	Br	Y	-	-	3
Sylvicapra grimmia, common duiker	Semi-closed	Bushland Tall grassland	Br	Y	-	-	2
Redunca fulvorufula, mountain reedbuck	Semi-closed	Rocky slopes	Gr	Y	1	-	-
Kobus ellipsiprymnus, waterbuck	Both	Vlei Floodplain	Gr	N	1	-	-
Pelea capreolus, grey rhebok	Open	Rocky hills/slopes	Br	N	-	-	3
Raphicerus campestris, steenbok	Open	Open grassland Open woodland	Br	Y	-	-	18
Aepyceros melampus, impala	Open (w/shade)	Open woodland Woodland savanna	Mixed	N	-	1	4
Oreotragus oreotragus, klipspringer	Both	Rocky outcrops	Br	N	-	2	-
				Total NISP	**73**	**53**	**1772**

*This column indicates whether the species currently occurs in the region in which the site is located

Table 5.1 Habitat and feeding data (habitat data from Skinner and Chimimba, 2005; feeding data from Wadley et al., 2008)



	post-HP MSA 1	post-HP MSA 2	HP
▨ Either	3	2	5
■ Closed/Semi-closed	3	34	1651
☐ Open	67	17	116

Figure 5.2 Summary of habitat data presented in Table 5.1

Before discussing the results, a few methodological points deserve mention. For this analysis, material identified to genus (e.g, *Pronolagus* sp.) was included only if all of the possible species identifications for that genus have essentially the same habitat preferences. This was done to be as conservative as possible; however, the results were essentially unchanged even when possible identifications ("cf.") and other higher taxonomic categories (e.g., "Primate: Vervet or Samango," as both inhabit closed environments) were included. Furthermore, as discussed in Chapter 4, there are several reasons why NISP was chosen over MNI, not the least of which is the fact that the sample sizes provided by the MNI counts are so small. In any case, the same patterns are manifested even when the analysis is conducted using MNI data—the only difference being that the trends are less marked.

Reconstructing paleoenvironments using faunal data: the HP

Results of the initial faunal analysis presented in Clark and Plug (2008) indicated that the HP fauna was primarily comprised of species that prefer closed (particularly forested) environments; this pattern remains evident in the larger sample considered here. Species that inhabit closed or semi-closed habitats comprise more than 93% (n=1651) of the sample. This meshes well with the charcoal data, which showed a strong evergreen forest signature. As already discussed, the most commonly identified species in the charcoal assemblage for the HP was the evergreen *Podocarpus* (Allott, 2006a); mammals characteristic of modern *Podocarpus* forests include the vervet monkey, blue duiker, red duiker, bushbuck, bushpig, and the banded mongoose (*Mungo mungo*) (Cooper, 1985). With the exception of the banded mongoose, all of these species were identified in the HP—and given that banded mongoose is not represented in the comparative sample at the Transvaal Museum, it seems possible that some of the material identifiable only as "Mongoose" may actually belong to this species. Furthermore, while some of the above mentioned species also occur in the post-HP MSA, this particular combination of taxa was limited to the HP. The presence of the Gambian giant rat, which occurs primarily in evergreen and scrub forest in regions that receive more than 800 mm per annum (Glenny, 2006), may also indicate the presence of increased moisture availability during the HP.

Although their numbers are small (n=116; 6.55%), the HP assemblage does include species more common in (or restricted to) open environments, including African buffalo, blue wildebeest, plains zebra, and the roan antelope. As argued in Clark and Plug (2008), this suite of species implies that hunters had at least some access to more open woodland and/or savanna environments than are found in the region today. Again, this matches with the charcoal data, as the HP sample included some species indicative of an environment more open than at present, particularly *Kirkia* spp., which occurs today in warm/dry habitats in northern South Africa (Allott, 2006b).

Reconstructing paleoenvironments using faunal data: the post-HP MSA

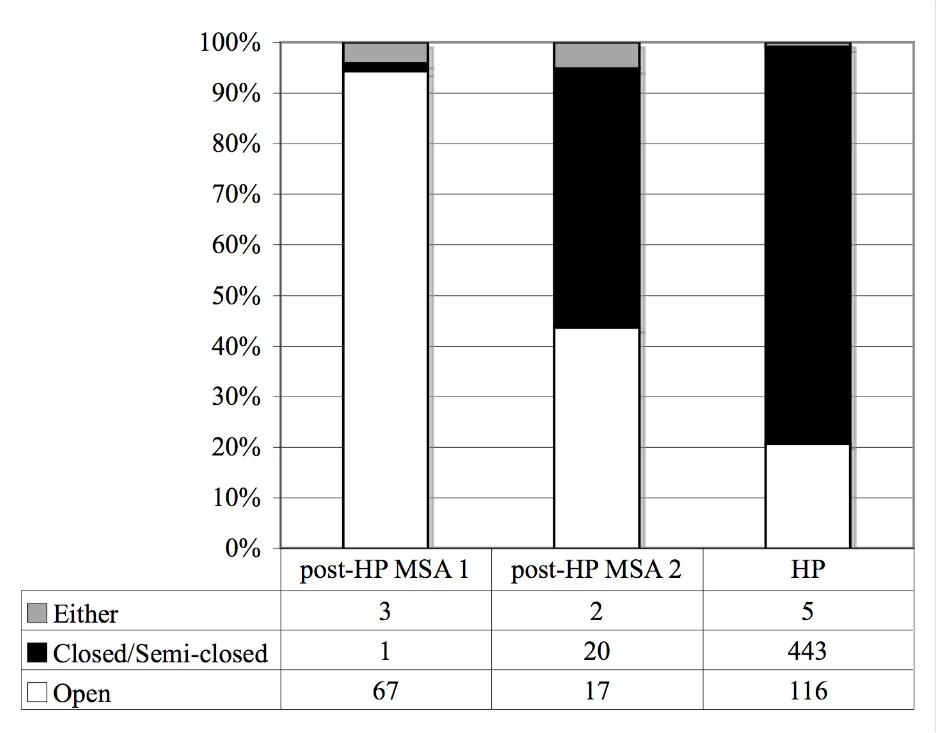
Given the lack of botanical data useful for reconstructing conditions during the post-HP MSA 2, it is unfortunate that the assemblage from this period also contained the smallest sample of faunal material that was identifiable to species (n=53). Although the proportion of animals that preferentially inhabit closed or semi-closed habitats declined relative to the HP, species expected to occur in riverine forest are still well represented, accounting for more than 64% (n=34) of the sample. Species that inhabit more open environments, including warthog and eland, account for ~32% (n=17) of the sample. While these data may indicate the beginning of a shift towards more open woodland/savanna habitats in the vicinity of the site, in the absence of a larger sample it is difficult to make any reliable statements.

Although the sample from the post-HP MSA 1 is also relatively modest (n=73), the available data indicate that a marked shift had occurred, with open-dwelling species now accounting for nearly 92% (n=67) of the assemblage. As argued by Plug (2004), the presence of these species, which include zebra, blesbok, and blue wildebeest, indicates drier conditions and a more open savanna environment than present. The possible identification of giraffe (cf. *Giraffa camelopardalis*) in this phase further supports this argument. The proportion of species that occupy primarily closed or semi-closed habitats has dropped significantly, down to 4.11% (n=3). These data provide a slightly different picture than that provided by the charcoal sample, which, although variable, was dominated by taxa from evergreen and/or riverine forest environments (Allott, 2006a). However, it is important to keep in mind that both the charcoal and isotopic data indicated a decline in the evergreen forest surrounding the site by the end of the post-HP MSA. Furthermore, it would seem reasonable to assume that foragers would range farther afield to obtain meat than firewood, and it could be the case that plenty of fuelwood was available in the immediate vicinity of the site where forest/riverine taxa predominated.

As discussed in Wadley et al. (2008), the near absence of blue duiker in the post-HP MSA requires some explanation. Blue duikers primarily eat fruit and foliage from the highest protein sources, and their stomachs are designed for the absorption of food rich in protein, fat and non-fibrous carbohydrates (Apps, 2000). In a small forest patch, such as that hypothesized in the post-HP MSA 1, the blue duiker may have been unable to compete for high quality food with larger browsers such as kudu.

Reconstructing paleoenvironments using faunal data: summary/discussion

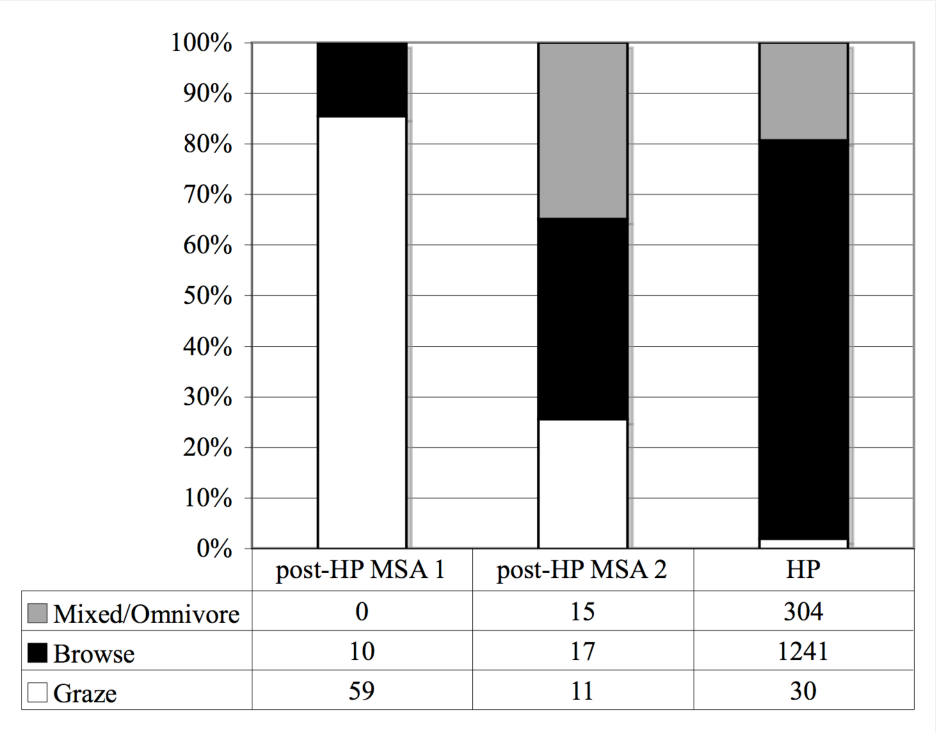
Given the large number of blue duiker in the HP sample (n=1208, or ~68% of the total HP sample that could be identified to genus/species), and the relative rarity of the species in the post-HP MSA (n=14 in the post-HP MSA 2; n=2 in the post-HP MSA 1) it is important to investigate whether the apparent decline in the frequency of animals preferring closed habitats is simply a reflection of changes in the proportion of blue duiker in the three assemblages. I thus re-calculated the percentage of open vs. closed species with blue duiker removed from the sample (Figure 5.3). Even after the removal of blue duiker, the HP assemblage is still predominantly comprised of animals dwelling in closed habitats, and the larger pattern remains very much intact.



	post-HP MSA 1	post-HP MSA 2	HP
▨ Either	3	2	5
■ Closed/Semi-closed	1	20	443
□ Open	67	17	116

Figure 5.3 Summary of habitat data with blue duiker removed from the sample

Researchers have also compared the relative frequency of grazers vs. browsers in an assemblage as a means of exploring change in the relative amount of tree cover (focusing in particular on ungulates, e.g., Klein, 1979). This is because grazers tend to feed on herbs and grasses (indicating less tree cover), while browsers generally feed on the leaves, young shoots, and fruits of shrubs and trees (Chapman and Reiss, 1998). While this is in large part redundant with the analysis already conducted, as demonstrated in Table 5.1, there is not always a one-to-one correlation between open species/grazers and closed species/browsers. As evidenced in Figure 5.4, browsers are significantly more common in the HP, again suggesting greater tree cover during that period. The small sample size and the relatively larger number of mixed feeder/omnivorous species in the post-HP MSA 2 makes the data from that phase difficult to interpret; however, the



	post-HP MSA 1	post-HP MSA 2	HP
▨ Mixed/Omnivore	0	15	304
■ Browse	10	17	1241
□ Graze	59	11	30

Figure 5.4 Summary of feeding data presented in Table 5.1

dominant presence of grazers in the post-HP MSA 1 implies a reduction in tree cover in the site vicinity by the time those layers were deposited.

Taken as a whole, then, the HP faunal assemblage is characterized by a high frequency of species that preferentially inhabit closed or semi-closed environments, data from the post-HP MSA 2 is limited but shows an increase in the presence of species that inhabit open environments, and the post-HP MSA 1 assemblage is comprised predominantly of species occupying open habitats. This pattern lines up well with that identified using the botanical data.

Reconstructing paleoenvironments: other classes of faunal data

It is worth noting here that while my focus was on the macromammalian fauna, three other classes of faunal data are potentially informative on past conditions—the micromammals, the avifauna, and marine species (in this case, marine shell). The micromammal assemblage from the HP and post-HP MSA (described in Glenny, 2006) did not contain a large number of remains that could be identified to species, and of the remains that were identifiable, most came from species with wide habitat tolerance. However, Wadley (2006) did note that the horseshoe bat, which is present only in the HP, prefers sandstone caves with high humidity. Thus, the botanical data, the macrofaunal data (particularly the presence of Gambian giant rat) and the microfaunal data all hint at more humid conditions during the HP.

Unfortunately, the avian remains that were present were also difficult to identify to species, and, as was the case for the micromammals, those that could be identified to species were not particularly useful for discerning changes in the environment over time (Plug and Clark, 2008). The presence/absence and frequency of marine shell have been used as indicators of the relative distance to the coast (e.g., Halkett et al., 2003); this data did show an interesting pattern. While Plug (2006) actually lumped all of the MSA remains that post-dated the HP into a single unit, there are still striking differences in the representation of marine shell, with 216 fragments from 7 taxonomic groupings in the HP and only 31 fragments from 4 taxonomic groupings in the entire assemblage from the post-HP, late, and final MSA. Even if all 31 of those fragments were from post-HP MSA layers, the change is still marked. This could indicate that the distance from site to shore was less during the HP than during the post-HP MSA. It could also reflect a change in mobility patterns that resulted in less frequent visits to the coast during the post-HP MSA. Keep in mind, however, that the particular combination of taxa identified in the charcoal assemblage from the post-HP MSA led Allott (2005) to propose that sea level may have been lower during that phase, and that Ramsay and Cooper (2002) also predicted a steady decline in sea level ~75-50 ka.

Environmental conditions during the HP and post-HP MSA: summary

As a whole, the botanical and faunal data appear to complement each other quite well, and both indicate that a marked shift in the local environment had occurred by the end of the post-HP MSA. During the HP, the flora and fauna both indicate a very strong evergreen forest component, with *Podocarpus* the most frequently identified genus in the charcoal assemblage and the small, forest dwelling blue duiker the most commonly identified animal species. Several lines of evidence also indicate that conditions were relatively humid during this phase, including the prevalence of *Podocarpus*, which generally occurs in areas with rainfall in excess of 900 mm per annum, and the presence of the Gambian giant rat and the horseshoe bat, both of which occur primarily in more humid environments. The relatively low variance in the isotopic values for *Celtis*, a genus adapted to relatively dry conditions, may also indicate wetter conditions during the HP. I should note again here that some of the sedimentological data introduced in Chapter 3 may provide further support for a shift from humid conditions during the HP to drier conditions during the post-HP MSA. The HP deposits were distinctive from those in the post-HP MSA due to presence of calcite and the absence of gypsum. Gypsum is more water-soluble than calcite, and thus absence of gypsum in the HP deposits may be a factor of increased humidity during this period (Wadley, 2006).

Unfortunately, data appropriate for reconstructing the paleoecology of the Sibudu region during the earliest post-HP MSA are limited. An understanding of the local environment during this period is important to our broader understanding of the HP, because if conditions during the post-HP MSA 2 were largely unchanged from that during the HP, the disappearance of the distinctive material culture associated with the HP can perhaps not be linked to environmental change (as proposed by Ambrose and Lorenz, 1990, among others). The available botanical data indicate only that a mosaic of habitats was likely present, which is not surprising given our knowledge of modern conditions. The limited faunal sample shows an increase in the relative proportion of species from more open environments relative to the HP, although species preferring closed or semi-closed habitats still make up a majority of the sample. This *may* indicate the beginning of a shift toward more open conditions, but larger faunal samples, combined with the analysis of the charcoal assemblage, will be necessary before this can be stated with any degree of certainty.

The botanical data from the post-HP MSA 1 indicate that conditions may have been variable during that period, with an overall trend towards drier conditions and a shift to more deciduous/open vegetation by the end of the phase. Wadley (2006) and Hall et al. (2008) used the isotopic data for *Podocarpus* charcoal from layer SPCA, combined with the lack of *Podocarpus* in the BSp charcoal assemblage, to argue that the evergreen forest surrounding the site may have significantly declined in size during this period, proposing that by the end of the post-HP MSA, the vegetation may have been characterized by a small patch of evergreen forest close to the river and larger patches of well-grassed savanna on the neighboring hillsides. The fauna from this period are very distinctive from that in the HP, with a vast majority of the remains coming from species that preferentially inhabit more open environments. Again, this appears to match well with the botanical data, although the charcoal from the earlier layers of the post-HP MSA

1 did show a focus on evergreen/riverine forest species. It was proposed that this distinction may reflect the fact that while sufficient firewood may have been available near the site where riverine forest vegetation predominated, fauna may have been exploited from a wider area that was comprised of more open country.

Again, given the agreement between several different lines of evidence, it does appear that there were marked changes in local conditions between the HP and post-HP MSA. Upon conducting the initial analysis of the faunal assemblage, Clark and Plug (2008) proposed two scenarios that could explain the evidenced patterns. First, they proposed that the size of the forest could have remained relatively stable over time, with the faunal data indicating a marked intensification in the exploitation of the environment in the immediate vicinity of the shelter during the HP. This type of intensification could potentially have resulted from a decline in the productivity of adjacent regions due to increased aridity during OIS 4. Alternatively, they argued that the extent of the riverine forest may simply have been larger during the HP than in the post-HP MSA, with people exploiting animals more or less in proportion to their frequency of occurrence on the landscape.

The data presented here indicate that the latter alternative may be a better fit, both because the evidence suggests that the HP was actually more humid than the post-HP MSA, and because the isotopic data appear to indicate that the forest did decline in size after the HP. A consideration of element frequency patterns may also speak to this issue by providing an indication of the transport distances for various prey; prey transported from larger distances generally arrives at the site less complete than that obtained close to home. This will be explored in Chapter 8. In any case, I think it is clear from this analysis that at least some of the variability in hunting behavior discussed in the following chapters will be attributable to the shifts in the local environment, and this must be kept in mind when evaluating the stress model.

Chapter 6

Taphonomy

Taphonomic research aims to discern the most influential processes acting on bone assemblages and to distinguish natural forces from human behavior (Bar-Oz and Munro, 2004). Reconstructing the taphonomic history of the assemblage is thus of critical importance in evaluating whether or not patterning in the faunal record is a product of human behavior or is an artifact of other processes such as carnivore activity or post-depositional decay. In this chapter I focus on detailed taphonomic analyses of the HP and post-HP MSA fauna from Sibudu, utilizing both the identified and non-identified remains. I will begin by discussing evidence for surface modifications and by identifying the agents responsible for accumulating the faunal assemblage, followed by a consideration of the extent of bone disturbance and loss both before and after deposition. There are two defining characteristics of the Sibudu fauna—it is both highly burned and heavily fragmented. I address each of these factors in detail, attempting to identify the timing (whether pre- or post-depositional) and causes of both. I will also discuss the degree to which these variables ultimately impact our ability to tease out larger patterns relating to human hunting behavior. I turn next to an evaluation of the degree of density-mediated attrition in the assemblage; this is of particular importance to later considerations of the skeletal part data, as it must be demonstrated that the patterns in the data are not simply a factor of differential preservation caused by the destruction of less dense skeletal elements. The chapter closes with a summary of the taphonomic data and an evaluation of the degree to which the three assemblages appear to have been differentially affected by attritional processes.

Surface modifications and the identification of assemblage accumulators

While data on burning intensity was recorded for most of the analyzed material, a smaller subset of the assemblage was subjected to more detailed taphonomic analysis. This smaller sample consisted of all of the identified bone (with the exception of a small number of bones initially analyzed by Plug which could not be relocated) and a sample of the non-identified bone larger than 2 cm (long bone shafts, ribs, vertebrae, and skull fragments from one quadrant per level from B5 and B6). These bones were measured to within a centimeter (< 2 cm, 2-3 cm , 3-4 cm, etc.) and were examined under a Zeiss Stemi 2000 binocular microscope at 8-40 x magnification in order to assess cortical preservation and to identify surface modifications. Cortical preservation was coded as either good (surface well preserved), fair (surface shows some light cracking or peeling or is partially obscured) or poor (little to no preservation of the original bone surface). Classic signatures of weathering as defined by Behrensmeyer (1978) were largely absent, and thus I did not systematically code for this attribute.

Data were collected on the presence and orientation of cut/chop marks, percussion damage, rodent gnawing, and carnivore damage. In recording human- and carnivore-induced damage, I followed the diagnostic criteria outlined by Binford (1981), Blumenschine and Selvaggio (1991), Blumenschine et al. (1996), Milo (1994), and Pickering and Egeland (2006). Percussion damage was defined based only on the presence of percussion pits with striae, impact flakes with bulbs of percussion, or

Surface modifications	**Identified bone** **post-HP MSA 1**	 **post-HP MSA 2**	 **HP**	**Non-ID bone** **post-HP MSA 1**	 **post-HP MSA 2**	 **HP**
Cut/Chop marks	1.1%	0.2%	1.2%	0.4%	0.1%	2.3%
Percussion damage	1.1%	0.2%	0.4%	3.4%	1.3%	1.0%
Carnivore damage	-	-	0.2%	0.3%	0.4%	0.8%
Rodent gnawing	-	-	0.1%	-	0.1%	-
Digested?	-	-	0.6%	-	-	-
Chemical weathering?	0.1%	-	0.2%	0.5%	2.3%	3.1%
Crystal growth	-	-	-	2.0%	6.5%	-
Root damage	0.1%	-	0.1%	0.4%	-	0.3%
Total analyzed	**723**	**503**	**3368**	**1578**	**794**	**611**
% of total with poor cortical preservation	27.8%	40.2%	15.3%	44.0%	45.3%	23.9%

Table 6.1: Summary data on surface modifications

negative flake scars. The presence of chemical weathering (described in more detail below), gypsum crystal growth, and root damage was also noted; data on these variables are presented in Table 6.1 along with the data on human- and animal-produced damage.

While I was conservative in my analysis, recording only unambiguous marks, the low frequencies of surface modifications presented in Table 6.1 are no doubt also a reflection of the relatively poor surface preservation evidenced across the assemblage (but particularly in the post-HP MSA 2). It is interesting to note that damage was identified more frequently on the non-identified bone than on the identified bone; this is likely related to the fact that long bone shafts comprised a majority of the non-identified sample subject to analysis, but comprised only a minority of the NISP, and limbs are major meat- and marrow-bearing bones. Carnivore damage was low throughout, never accounting for more than 1% of the sample, and rodent damage was also incredibly rare. Given that some scholars have argued that raptors were responsible for accumulating

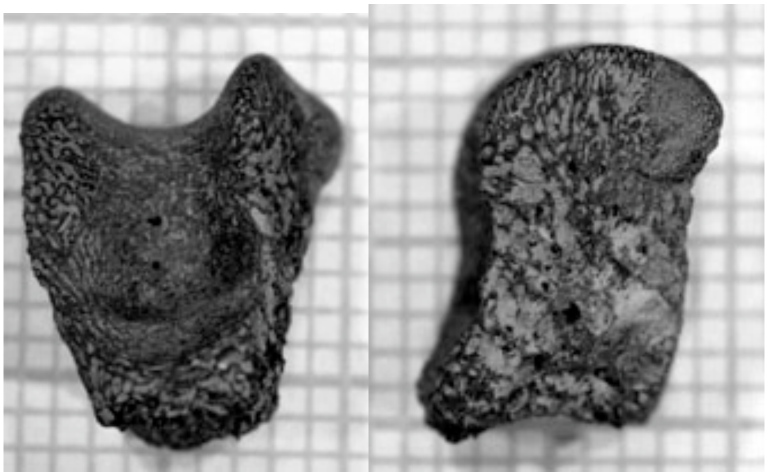


Figure 6.1: Potentially digested blue duiker talus from layer GS (HP)

small bovid remains at other MSA sites (Marean et al., 2000), it is relevant to add that no surface modifications attributable to birds of prey were identified.

Also of note was the presence of a handful of bones whose appearance was consistent with having been digested (n=20, HP only; see Figure 6.1). A majority of the potentially digested remains belonged to the blue duiker and comprised tarsals and phalanges. While these may have been digested by scavenging carnivores, it is also within the realm of possibility that they were consumed and digested by humans; Reinhard et al. (2007) found the remains of many different species of small mammals in coprolites from the Southwest US; while many of the species were smaller than the blue duiker (average mass of ~4 kg), the remains of mammals of comparable size, such as the raccoon (~6 kg) and fox (~5 kg), were also present.

The most frequently identified forms of surface damage appears to be the result of diagenetic processes—more specifically, chemical weathering and crystal growth associated with gypsum formation. Chemical weathering generally took the form of

Figure 6.2: Bone with pitting caused by chemical weathering? (layer GS, HP)

pitting on bone surfaces (see Figure 6.2); the pits generally had irregular edges and were distinguishable from tooth pits by a lack of evidence for crushing and for their sharp/delicate edges. The damage surface inside the pits often appeared fresh. In the post-HP MSA, some of these pits were clearly caused by gypsum crystal formation; some specimens had nodules of gypsum on the bone surface, when light pressure was applied, a small "ball" of gypsum popped out of the bone, leaving a pit like those described above (Figure 6.3). Given the lack of evidence for gypsum growth on bones from the HP deposits (and the fact that sedimentological analyses indicated that gypsum is absent in the HP deposits), the cause of the pitting in the HP is unclear. Some of the damage classified as chemical weathering consisted of smaller, shallower, and distinctly flat-

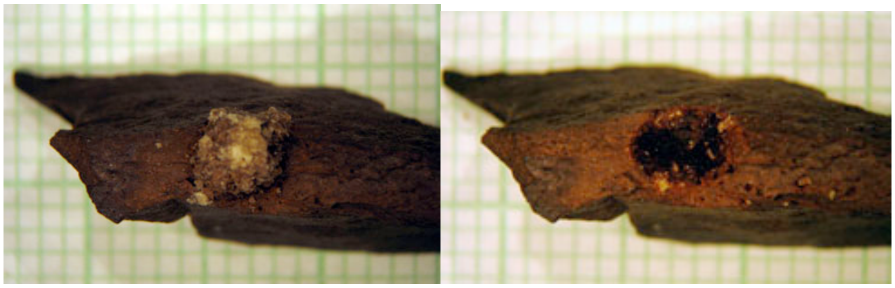


Figure 6.3: Bone shaft with crystalline mass, before/after removal (layer BP, post-HP MSA 1)

bottomed pits. It is possible that this is actually insect damage, but I had no comparative material available and thus could not identify it as such with any degree of certainty.

Identifying the assemblage accumulators

There are a number of reasons to believe that the HP and post-HP MSA fauna at Sibudu was predominantly accumulated by human activity. First, although the number of specimens preserving surface modifications is low, human-produced damage is more common than carnivore damage in all contexts. Very few carnivore remains were recovered, accounting for less than 1% of the total NISP in the post-HP MSA, and less than 2.5% in the HP, and the carnivores in the HP are predominately small species such as mongoose, which would not be significantly contributing to the ungulate assemblage. Furthermore, Lyman (1994c) has argued that small, structurally dense bones such as the carpals/tarsals and sesamoids will be abundant in human accumulated faunas but not in hyena-accumulated assemblages, as hyenas swallow and digestively destroy these elements; these small/compact bones are common in the Sibudu assemblage. As discussed, the fauna is also heavily burned and fragmented, and it is associated with hearths and a rich lithic assemblage—in combination, these lines of evidence are consistent with humans being the primary accumulator of the macromammalian fauna. That said, it is now important to turn to other taphonomic variables in order to determine the extent and nature of bone disturbance and loss.

Burned bone

The identification of burned bone is important for a number of reasons. The distribution of burning damage on identifiable remains can provide information about cooking practices; for example, if burning is greater on epiphyses than on shafts, then the damage may have occurred during roasting, as the joints would have been more directly exposed to heat, not being encased in meat (e.g., Speth and Tchernov, 2001). The opposite pattern (more burning on shafts than epiphyses) would indicate bones were exposed to fire after the meat was removed, perhaps as a result of warming marrow bones prior to marrow extraction (e.g., Speth and Clark, 2006). Bone can also be burned after consumption; it can be discarded into a fire after consumption, perhaps as a means of reducing its attractiveness to carnivores (Gifford-Gonzalez, 1989), and it can also be used as fuel (see Théry-Parisot, 2002 and references therein). Bone can, of course, also be burned naturally, as a result of natural fires or as a result of the proximity of discarded bone to a hearth. In determining what burned bone indicates about human behavior, it is therefore important to attempt to ascertain whether the bone was naturally or intentionally burnt, and whether it was burned pre- or post-consumption.

A consideration of burning is also relevant when reconstructing the taphonomic history of a given assemblage. There are two important reasons for this. First, it has been demonstrated experimentally that burned bones are more fragile/brittle than unburned bones, and it has also been proposed that the mechanical strength of bone varies as a function of the extent to which it is burned (Stiner, 2005; Stiner et al., 1995). Differences in the presence and/or intensity of burning across archaeological horizons may thus result in differential fragmentation, potentially affecting the interpretation of patterning identified in the faunal record. Burning also has a negative impact on the preservation of bone surfaces—even low levels of burning can cause cracking and peeling of the cortical surface, while highly burned/calcined bone often becomes chalky in texture, with no preservation of the original cortical surface (Nicholson, 1993; Schmidt and Symes, 2008). This can obviously negatively impact the preservation of surface damage, including evidence for human processing or carnivore/rodent activity.

Identifying burned bone at Sibudu

Experimental studies have demonstrated that thermally altered bone displays a predictable range of surface color and texture changes, such that the color of a bone can be used to judge the degree of burning intensity (e.g., Bennett 1999; Nicholson, 1993; Shipman et al., 1984). Because the intensity of burning damage is related to both the temperature and the duration of heating, color is a poor indicator of the *precise* temperature to which a bone was heated, but can provide an indication of the *range* of temperatures to which the bone was heated. Lightly heated bones (< 400° C) tend to be yellow to reddish-brown in color; bone exposed to higher temperatures (~400-500° C) carbonizes and turns black, and intensively heated bones (> 600° C) eventually become calcined and are typically blue-grey to white in color (Lyman, 1994c; Shipman et al., 1984).

Given this, bone was initially sorted into a number of burning categories based on color. The non-identified bone (all material greater than 2 cm in length, all of the small-fraction non-identifiable bone from B5 and B6, and the small-fraction non-identified bone from one quadrant per layer for unit C5) was sorted into four categories: not burned (NB), lightly burned (LB, <50% black/carbonized), moderately burned (MB, >50% black/carbonized), and highly burned (HB, >50% grey-white/calcined). Because it was often difficult to ascertain whether the small fragments were lightly burned or oxide stained (see below), the NB/LB categories were combined after the first season of analysis. Identified bone was assigned to one of the seven burning categories defined by

Burning Code	Description
0	Not burned (typically cream/tan in color)
1	Localized burning (<50% black)
2	Moderate burning (>50% black)
3	Carbonized (100% black)
4	Localized calcination (<50% white)
5	Moderate calcination (>50% white)
6	Calcined (typically white or blue/grey)

Table 6.2 Burning categories (modified from Stiner et al., 1995)

Stiner et al. (1995). These categories are defined in Table 6.2. In order to make the data for the identified bones comparable to that available for the non-identified bones, for this analysis, the identified bones were assigned to the same three categories utilized for the non-identified bone: NB/LB (burning codes 0-1), MB (burning codes 2-4), and HB (burning codes 5-6).

However, it is important to note that the use of color categories for the identification of burned bone in the archaeological record is not necessarily as straight-forward as it may seem, as organic and mineral staining can mimic the color changes caused by burning (see Hanson and Cain, 2007; Karkanas et al., 2007; Michel et al., 1996; Shahack-Gross et al. 1997). For example, a blackened bone may have been carbonized by exposure to heat, but the color may also be due to staining by manganese or iron oxides. As a result, researchers have developed a variety of methods for ascertaining whether or not color is an appropriate indicator of burning intensity in a particular assemblage; these methods include chemical analyses (e.g., Shahack-Gross et al., 1997), microscopic studies of bone histology (Hanson and Cain, 2007), and microscopic analyses focusing on the optical properties of the bone matrix, including reflectance and fluorescence (Ligouis et al., in prep). Because these methods are generally quite costly and time-consuming, they are typically only undertaken on a sample of material from a given assemblage.

Based on coloration alone, the HP and post-HP MSA fauna from Sibudu appeared to be highly burned (greater than 95% of the bone in some layers shows at least some degree of burning). However, oxide staining is also common. While this staining is often distinct from burning damage (for example, some of the stains have a metallic sheen, see Figure 6.4), this was not always the case. Thus, in order to confirm that the color changes evidenced in the assemblage actually reflect exposure to heat rather than organic or mineral staining, a sample of 11 bones from the HP and post-HP MSA was sent to Dr. Bertrand Ligouis at the Laboratory for Applied Organic Petrology (University of Tübingen) for more detailed analysis. The sample submitted for analysis included bones that appeared to be lightly, moderately, and heavily burned, those that appeared to be stained, and four bones that were representative of the coloration of a large number of bones but for which the burning status was ambiguous (ranging from deep orange to

Figure 6.4 Blackened bone with oxide staining (staining was black but camera flash brought out the metallic sheen)

maroon in color).

Ligouis produced highly polished thin sections of each sample and examined these using a Leitz DMRX-MPVSP microscope photometer in both incident white-light and UV + violet-light illumination (fluorescence mode). Data were recorded on the color of the bone in reflected light, the preservation of bone structure, the fluorescence properties of the bone matrix, and the reflectance of the bone matrix. Results were compared with samples from multiple fire experiments and from other Paleolithic contexts (both bone and micromorphology samples from Sibudu, Kebara, Hohle Fels, and Pech de l'Aze) in order to ascertain whether the bone was burned, to provide an estimate of the temperature to which the bone had been heated, and to judge whether or not oxides were present. A description of each sample, along with the results of Ligouis' analysis can be found in Table 6.3.

As indicated in the table, with the exception of two bones for which the burning status was unclear, all of the bones that were visually identified as being burned were also classified as such by Ligouis. Ligouis noted that the two ambiguous samples (from SPCA and Chestnut) were difficult to classify because in each case, the color in reflected light and reflectance of the bone matrix indicated burning at high temperatures, while the preservation of the bone structure and fluorescence correlated more with an unburned state. It is interesting to note that some of the bones visually classified as lightly burned because of their reddish-orange coloration were identified as being burned at potentially higher temperatures than some of the blackened or even grayish-white bone— this goes against expectations and may indicate that the duration of heating played more of a role in determining the intensity of burning damage than the maximum temperature to which

Layer	Unit	Visual Classification Color (naked eye)	Burning status	Oxides	Microscopic Analysis Burning Status	Oxides
SPCA	B5a	orangey	Lightly burned (<50% carbonized)	Yes	Unburned or burned at high temperatures (>600°C)	Yes, prob. Mn oxides
Midnight (Hearth)	B5a/b	greyish yellow	Heavily burned (>50% calcined)	Yes	Burned at high temperatures (≥600°C)	Yes, prob. Mn oxides
Chestnut	B5b	greyish brown	Heavily burned? (>50 % calcined)	Maybe?	Unburned or burned at high temperatures (>600°C)	Yes, prob. Mn oxides
Pox	B6a	mottled black/orange/ greyish-brown	Moderately burned (>50% carbonized)	Yes	Burned, probably at very high temperatures (≥800°C)	Yes, prob. Mn oxides
Brown Pox	B6b	black/brown	Moderately burned (>50% carbonized)	No	Burned, probably at low temperatures (~300°C)	None
Grey Rocky I	B5a	black exterior/ orangey interior	Lightly burned (<50% carbonized)	Yes	Burned, probably at moderate temperatures (~300-600°C)	Yes, prob. Mn oxides and Fe oxides
Grey Rocky I (Hearth E)	B5a	greyish white with black and brown mottling	Heavily burned (>50% calcined)	Maybe?	Burned, probably at low temperatures (~300°C)	Yes, prob. Mn oxides and Fe oxides
Grey Rocky II	B5c	yellow	Not burned	Yes	Probably unburned	Yes, prob. Mn oxides
Grey Sand I	B5d	maroon exterior/ orangey interior	Lightly burned? (<50% carbonized)	Yes	Burned, probably at moderate temperatures (~300-600°C)	Yes, prob. Mn oxides
Grey Sand I	C5b	black	Carbonized?	Yes	Burned, probably at low temperatures (~300°C)	Yes, prob. Mn oxides
Pinkish Grey Sand	B5d	mottled maroon/orange/ brown	Lightly burned? (<50% carbonized)	Yes	Burned, probably at moderate temperatures (~300-600°C)	Yes, prob. Mn oxides

Table 6.3 Results from Ligouis' study of a sample of burned bone from HP and post-HP MSA contexts

the bone was exposed. In any case, it would appear that as a rule, color is a valid indicator of burning for the HP and post-HP MSA fauna from Sibudu.

Burned bone in the HP and post-HP MSA

Figure 6.5 summarizes the burning data by period—the data presented here includes all bone sorted into burning categories, both identified and non-identified. More than half the bone in all three assemblages is at least moderately burned (> 50% carbonized), demonstrating the remarkably high levels of burning in the sample. Although burning is prevalent in all three periods, the post-HP MSA 2 shows a much larger proportion of highly burned bone than does the HP or the post-HP MSA 1. While there does not appear to be a straightforward relationship between the intensity of burning and the overall proportion of identifiable bone (the post-HP MSA 1 actually preserved the lowest proportion of identifiable bone), the higher frequency of intensely

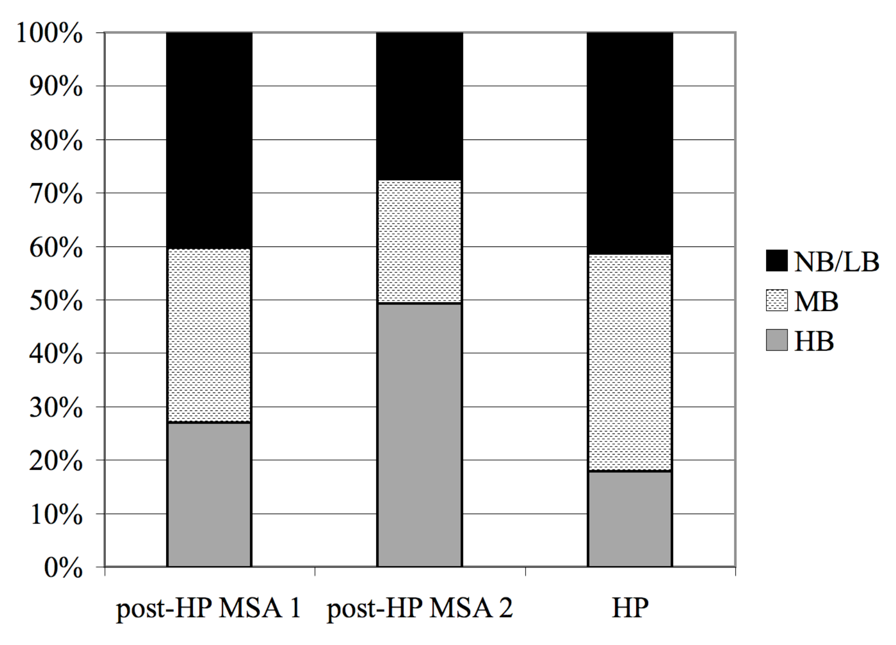


Figure 6.5 Burning data by phase (identified and non-identified bone)

burned bone in the post-HP MSA 2 has potentially important implications relating to variability in fragmentation and in the preservation of surface damage; these issues will be discussed in more detail below.

The Sibudu fauna is also unusual because the high frequencies of burning are not limited to the small fraction non-identified bone. As can be seen in Figure 6.6, the frequency of burned bone is also high among the larger non-identified fragments *and* the identified bones. The fact that the identified bone is also heavily burnt is of particular note, as many other Paleolithic assemblages showing high frequencies of burning among the non-identified bone show markedly lower proportions of burned bone among the identified sample—Table 6.4 compares the results from Sibudu to several of

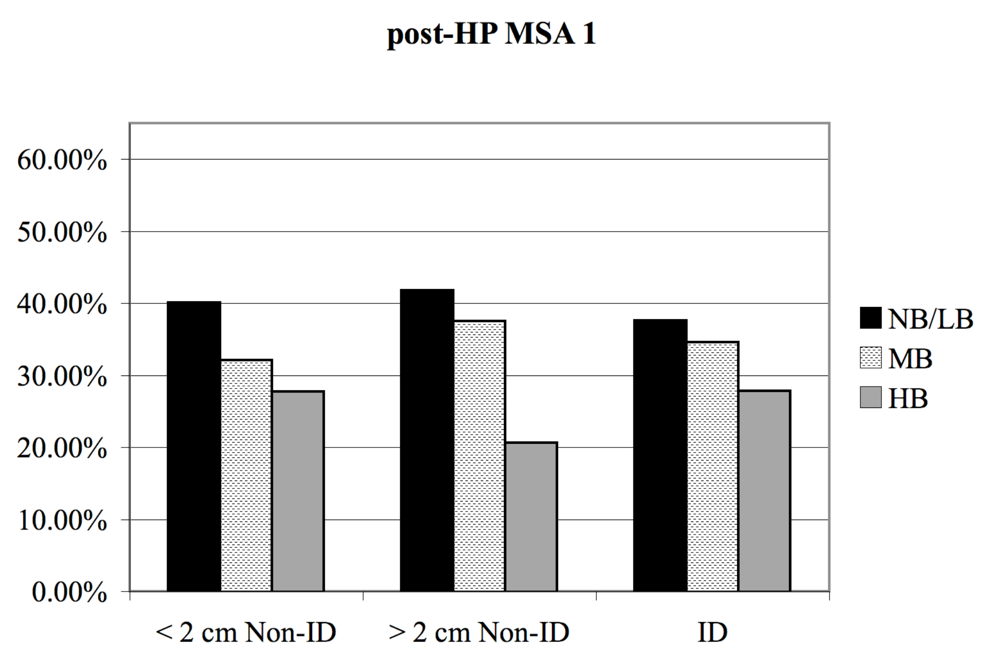
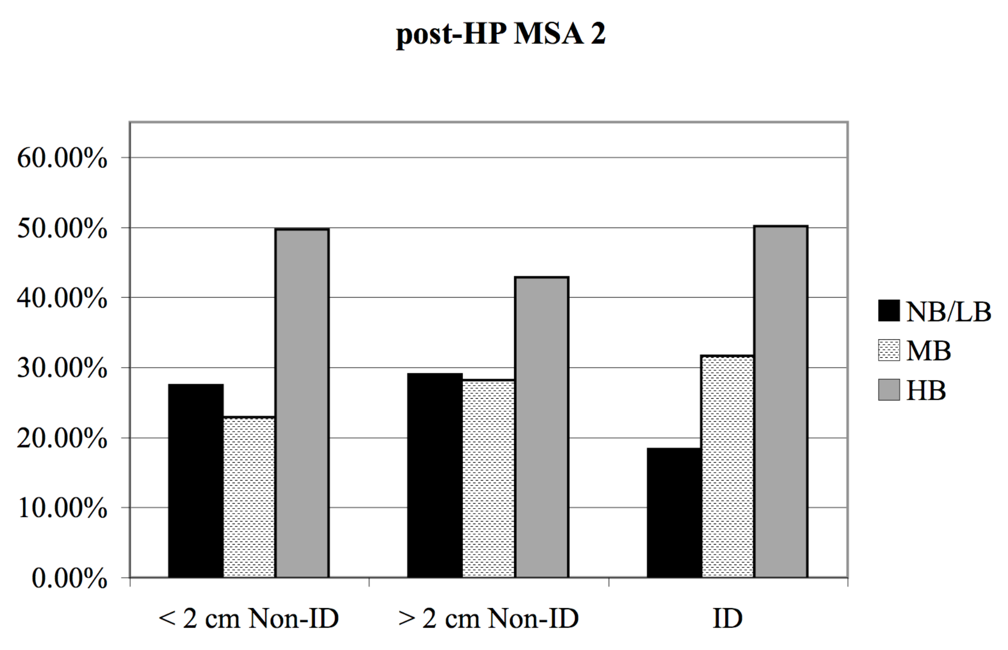


Figure 6.6 Frequency of burning by bone type and phase (cont'd on next page)



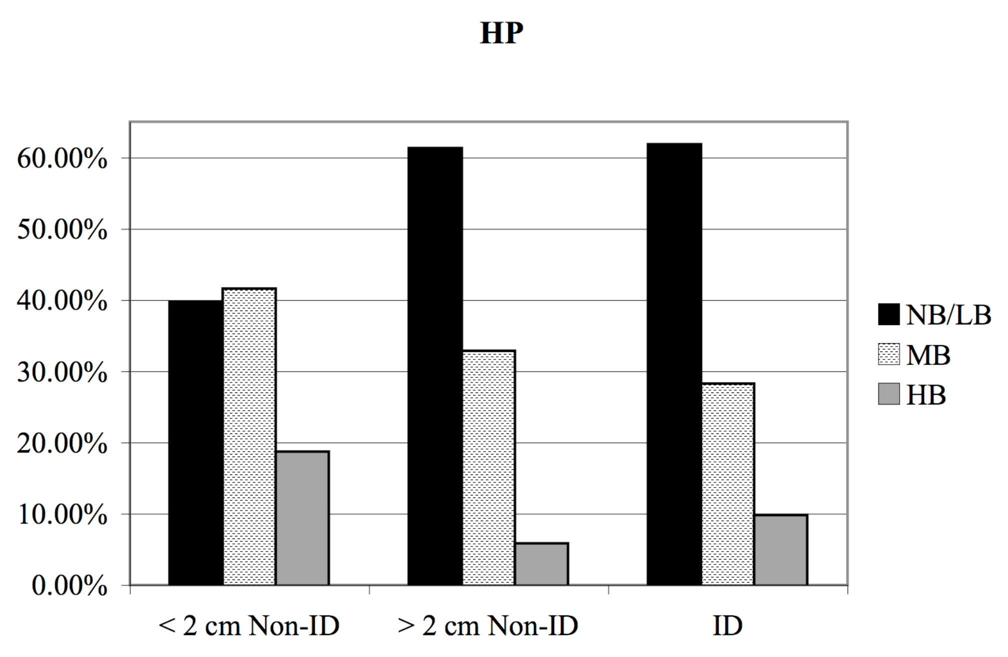


Figure 6.6 (cont'd) Frequency of burning by bone type and phase

Site	Non-ID bones	% Non-ID burned	NISP	% NISP burned	Source
Castanet Auriganian	47454	79.52%	748	3.21%	Villa et al., 2004
Combe Sauniere IV	6378	32.42%	532	1.50%	Villa et al., 2004
Cuzoul layer 23	18554	34.85%	2798	14.87%	Villa et al., 2004
Cuzoul layer 17	4411	32.35%	577	8.84%	Villa et al., 2004
Saint Cesaire Aurignacian I (5)	34202	38.77%	4102	3.66%	Morin, 2004
Saint Cesaire Chatelperronian (8)	27045	27.79%	966	0.21%	Morin, 2004
Saint Cesaire Mousterian (10)	19569	36.22%	867	1.85%	Morin, 2004
Sibudu post-HP MSA 1	145959	59.68%*	723	62.38%*	this study
Sibudu post-HP MSA 2	66668	72.49%*	503	81.71%*	this study
Sibudu HP	118678	59.19%*	3370	38.13%*	this study

*Note: the percentage of burned bone presented for the Sibudu assemblages includes only the moderate and highly burned classes, and thus the true frequency of burning is even higher than the numbers suggest.

Table 6.4 The proportion of burned bone among identified and non-identified bones from several Paleolithic contexts

these other sites. The reasons for this discrepancy are not immediately clear, but it could be due in part to the effort taken to identify the small burned fragments at Sibudu, as these fragments may be more apt to be overlooked when there is a substantial sample of unburned identifiable bones.

Burned bone at Sibudu: identifying the timing and agent of burning

Bone can be burned by a number of processes, both intentional (cooking, disposal of food waste, fuel) and natural/unintentional (brush fires, burned due to proximity to fire structures). There are a number of reasons to think that the burning at Sibudu was not primarily a result of natural (i.e., brush) fires. First and foremost is the association of burned bone with hearths. While burning features were more common in the post-HP MSA, the HP deposits also preserve a number of well-defined hearths. Second is the intensity of the burning; experimental work undertaken by David (1990) indicated that bones exposed to brush fires are often carbonized but rarely calcined, leading him to argue that when bones are calcined over much of their surface area, the presence of anthropogenic fires can be "safely inferred." Finally, the rockshelter is located high on a sandstone cliff and it seems unlikely that brush fires would easily spread within the shelter itself.

Yet, it seems undeniable that at least some of the burning was unintentional. Given the number of burning features, particularly in the post-HP MSA, it seems likely that some bone must have been exposed to heat from overlying hearths after deposition. Work by Stiner et al. (1995) and Bennett (1999) has demonstrated that bone buried in sediment underneath a hearth can be burned; the intensity of the burning damage (ranging from light burning to calcination) depends on the temperature of the fire, the duration of heat exposure and the nature of the surrounding sediments. Cain (2005) argued that incidental burning of this type would cause patchy distributions of burned bone, presumably because it would be expected to occur in direct association with hearth features, and yet burned bone is found throughout the layers. However, geoarchaeological work by Schiegl and colleagues (Schiegl and Conard, 2006; Schiegl et al., 2004) did indicate that the sedimentary composition and phytolith content was similar between hearths/ash dumps and the surrounding sediments, indicating that there was more fire use at Sibudu than indicated by the preserved hearth remains.

Identifying whether bone was burned dry or green may speak to this issue, as one might expect bone burned as a result of post-depositional exposure to heat to be burned dry, while bone burned during cooking, as fuel, or as a means of disposing of food waste would presumably be burned green. Buikstra and Sweagle (1989) found that only defleshed green bone became uniformly "smoked" (i.e., blackened), arguing that dry bone had insufficient organic substance to be uniformly smoked. However, Nicholson (1993) found that mottling was common even among green bone, so it is not clear that this is an appropriate criterion. As a result, I agree with Cain (2005), who, in an analysis of burning in the later MSA layers at Sibudu, argued that it was not possible to differentiate between green and dry burned bone for the Sibudu material. Despite this, I would argue that the sheer quantity of burned bone (again, upwards of 95% in some layers) indicates at least some degree of intentionality.

The distribution of burning damage across bone surfaces has been used as yet another source of information on the timing and mechanism of burning. As previously discussed, scholars have used the distribution of burning on epiphyses vs. shafts to draw inferences about cooking practices (e.g., Speth and Clark, 2006; Speth and Tchernov, 2001). Unfortunately, the nature of the burning at Sibudu, in which material is often burned on all surfaces, precludes this type of analysis. While some burning probably *was* related to food preparation, those signatures appear to have been overprinted by subsequent heat exposure.

It has also been demonstrated that the distribution of burning damage can indicate whether a bone was broken before or after heat exposure (giving some indication of processing strategies), in that bones that were burned after fragmentation are more likely to be burned on both the interior and the exterior surfaces of the bone, while a bone burned complete will show more intensive burning on the exterior surface and lesser degrees of burning on the interior surface (Johnson, 1989 and Knight, 1985, cited in Lyman, 1994c). While I did not record quantitative data on the intensity of burning on each bone surface, the type of banding discussed by Knight (1985) was rare, and, as mentioned above, many fragments were completely burned. This may suggest that the bone was fragmented to some degree prior to exposure to heat; however, it is possible that this type of signature also could have been overprinted by later heat exposure.

Given that much of the burning appears to have occurred after consumption, and that some of the burning likely occurred before the bone ultimately became part of the sedimentary matrix, there remain at least two possibilities to account for the high frequencies of burning damage: bone could have been deliberately used as a source of fuel, or it may have been discarded into the fire as a means of disposing of food waste. Experimental work by Théry-Parisot and colleagues (Costamagno et al., 2005; Théry-Parisot, 2002, Théry-Parisot et al., 2005) has demonstrated that bone can serve as an effective fuel. They found that although the high kindling temperature of bone means that an initial supply of wood is necessary to set bone on fire (but see Kedrowski et al., 2008, who state that bone fires can be built and sustained using only dry grass as kindling), the use of bone as an additional fuel source serves to increase the duration of a fire relative to the use of wood alone. All bone (cancellous vs. cortical, green vs. dry) was shown to have this effect; however, the duration of the fire was longest when spongy bone was used, likely because of the fat contained within trabecular bone (Théry-Parisot et al., 2005).

Based on these results, Costamagno et al. (2005) argued that a preponderance of burned spongy bone (particularly as compared to compact bone) in an archaeological assemblage is strong evidence in favor of the use of bone as fuel. Paleolithic sites such as Abri Pataud and Cuzoul de Vers (both in France) preserve horizons with large quantities of burned spongy bone relative to coritical bone, and preserve relatively small samples of wood charcoal (Théry-Parisot, 2002; Villa et al., 2004). In each of these cases, the authors argued that bone was intentionally used as a fuel source. In making the argument that bone served as a fuel at Cuzoul de Vers, Villa et al. (2004) demonstrated via a chi-squared test that spongy bone was significantly more likely to be burned than cortical bone. While I cannot directly replicate their analysis because my data are not amenable to being divided into "burned" vs. "unburned" categories, I can compare the proportion of ribs/vertebrae (spongy) and long bone shaft fragments (cortical) that were unburned or lightly burned to those that were moderately/highly burned (Table 6.5; data is from the non-identified fraction and includes the less than and greater than 2 cm bone). The difference is highly significant ($\chi^2 = 379.725$; $p < 0.0001$), but in this case, it is the cortical elements that are burned to a greater degree.

Théry-Parisot et al. (2005) argued that if bone were thrown in a hearth as a means of eliminating food waste, all skeletal tissue—both cortical and spongy bone—should be burned. This is in fact the pattern we see at Sibudu, where a majority of all bone fragments are burned to some degree. It is important to keep in mind, however, that spongy elements such as the ribs and vertebrae may be more susceptible to post-depositional destruction as a result of their lower density, particularly after burning, and

	NB/LB	**MB/HB**	**Total**
Ribs/Vertebrae	1983	2021	4004
Shaft fragments	13102	25386	38488
Total	15085	27407	42492

Table 6.5 Data on the intensity of burning for spongy (ribs/vertebrae) vs. cortical bone (long bone shaft fragments); HP and post-HP MSA combined

thus the recovery of these elements may be diminished. However, the sheer quantity of burned cortical bone, combined with the fact that charcoal is abundant throughout the sample (Allott, 2005, 2006a, b), suggests that the preferential selection of spongy bone for fuel is not a sufficient explanation for the heavy burning evidenced in the assemblage. I would thus agree with Cain (2005) that the disposal of food waste in fire seems to be an appropriate interpretation of the burning evidenced at Sibudu; however, even if bone were being discarded in the fire primarily as a means of waste disposal, once in the fire, it would also have acted as a fuel source—and it seems likely that Sibudu's inhabitants would have been aware of this useful secondary function.

Burned bone at Sibudu: taphonomic issues

As previously discussed, several studies have documented that the act of combustion, in and of itself, results in high degrees of fragmentation (Costamagno et al., 1998; Costamagno et al., 2005; Knight, 1985; Stiner et al., 1995). In their bone-as-fuel experiments, Costamagno et al. (2005) demonstrated the degree to which this was the case—on average, whole humeri that were placed into a fire fragmented into 182 pieces, 56.9% of which were less than 2 cm in length. While the severity of fragmentation varied based on whether the bone was burned whole or fragmentary, fresh or dry, all of the bones fragmented to some degree during combustion.

Experimental work by Stiner et al. (1995) also indicated that burned bones are more fragile (and thus more prone to post-depositional destruction) than unburned bones. They went on to propose that the mechanical strength of the burned bone varied as a function of the intensity of burning, with calcined bone being the most fragile. While fragmentation will be discussed in much more detail in the next section of the chapter, the data at hand should allow us to evaluate, at least in part, the hypothesis that more intensely burned bone is more fragile—if this were the case, one would expect the average fragment size to be smaller for the heavily burned material than for the other burning categories.

Table 6.6 provides data on the average fragment size for each burning class, divided by archaeological phase. As you can see, the highly burned fragments do have the smallest average weight for each phase, which lends support to Stiner et al.'s hypothesis. However, for reasons that are not immediately clear, in both of the post-HP MSA assemblages, the moderately burned fragments are actually larger than the unburned or lightly burned fragments, which is counter to Stiner et al.'s expectations. Given that the most intensively burned material does seem to be more heavily fragmented, one might then expect that the fauna from the post-HP MSA 2 will be more fragmentary than that from the HP or post-HP MSA 1, since that phase preserves a higher frequency of intensely burned material. I will return to this issue in the next section of the chapter, but, as discussed earlier, the potentially higher degree of fragmentation does not

Phase	Burning Category	Count	Weight (g)	Average Weight (g) per Fragment
post-HP MSA 1	NB/LB	58843	18606.9	0.316212634
	MB	47724	16430.1	0.344273322
	HB	39392	11845.7	0.300713343
post-HP MSA 2	NB/LB	18342	4346.4	0.236964344
	MB	15479	4050.7	0.261690032
	HB	32847	7457.8	0.227046610
HP	NB/LB	48429	11167.1	0.230587045
	MB	48821	9960.7	0.204024907
	HB	21428	3579.8	0.167061788

Table 6.6: Average fragment weight by phase/burning category

seem to directly relate to the percent of identifiable bone, as the post-HP MSA 2 did not have lowest proportion of identifiable bone.

Burning can also negatively impact cortical preservation, causing cracking and peeling of the cortical surface and eventually the total loss of the original bone surface (Nicholson, 1993; Schmidt and Symes, 2008). That this was a factor for the current assemblage is clearly demonstrated by a consideration of burning status versus cortical preservation (Figure 6.7). Bones with "fair" cortical preservation frequently showed some degree of cortical cracking and/or flaking, but this damage was often only superficial. The damage was very similar to the type of heat damage described by Schmidt and Symes (2008:42) as "[appearing] as a fine mesh of patterned cracks similar to those seen in old china or an aged painting…" Nicholson (1993) described a similar

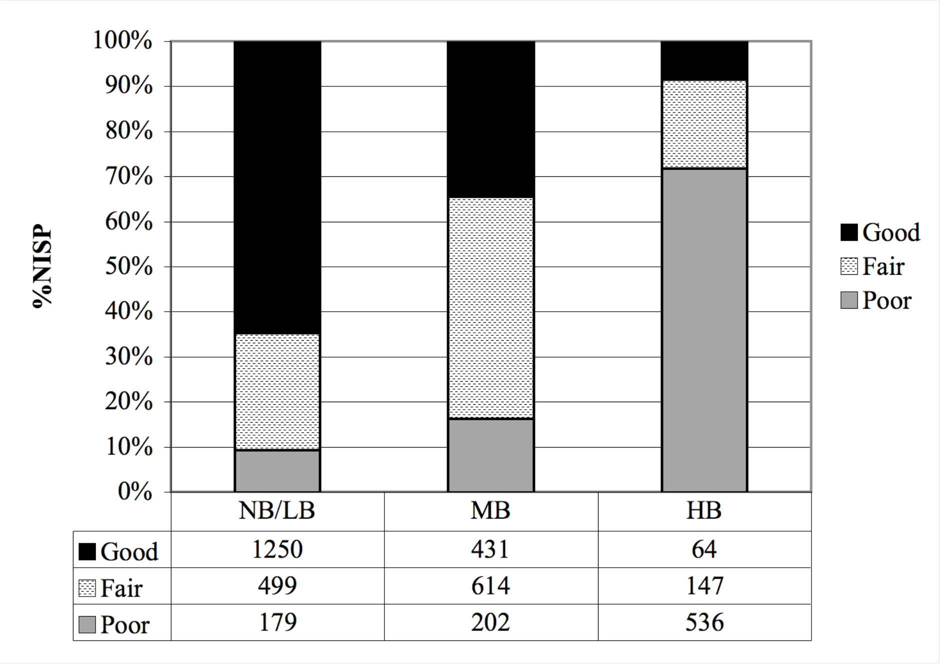


Figure 6.7 Relationship between burning intensity and cortical preservation (identified bone only)

form of damage which she referred to as “peeling surface films,” which occurred among bones heated to ~300-500° C. While this type of damage may not reduce the visibility of surface modifications such as deep tooth punctures and chop marks, lighter forms of damage such as cut marks and tooth scores are unlikely to preserve. Bones with poor cortical preservation often did not preserve any of the original cortical surface, either because it had completely flaked away, or, in the case of the highly burned bone, because the bone had become chalky in texture. In these cases, most forms of surface damage would not be expected to preserve. Again, given that the post-HP MSA 2 showed a much higher proportion of calcined bone, it is not unexpected that surface damage was less common during that period, and thus a consideration of variation in processing behavior based on signatures of human activity such as cutmarks and percussion damage must take this into account.

Burned bone: summary

The ubiquitous presence of burned bone (more than half of the assemblage shows at least moderate burning) is one of the defining characteristics of the HP and post-HP MSA fauna from Sibudu. To date, I have yet to find evidence for another assemblage that shows the same degree and intensity of burning among all fragments, be they the small, non-identified fragments or the identified bones. The association of the burned bone with hearths and other indicators of human activity, the intensity of burning, and the sheer quantity of burned bone suggest that the bone was not burned as a result of brush fires and that it is not explainable solely as the result of unintentional processes. Instead, the evidence appears to indicate that bones were being discarded into fires, perhaps as a means of disposing of food waste (this conclusion was also reached by Cain (2005), who analyzed a small sample of burned bones from the post-HP and late MSA at Sibudu). Although the post-HP MSA 2 showed the highest proportion of calcined bones, this explanation is consistent with the data from all three units under consideration and may thus provide evidence for some degree of behavioral continuity between the HP and post-HP MSA.

Turning to the larger taphonomic implications of the high frequencies of burning; because the combustion of bone does result in fragmentation (Costamagno et al., 1998; Costamagno et al., 2005), it is therefore not surprising that the assemblages are also very heavily fragmented. Given that calcined bone appears to be the most fragile, it is expected that the fauna from post-HP MSA 2 may be more fragmented than that from the HP or the post-HP MSA 1, as the post-HP MSA 2 showed the highest frequency of heavily burned bone. I will explore this possibility in detail in the next section of the chapter. Finally, because heat damage negatively impacts cortical surface preservation, it would appear that the very low occurrence of surface damage in the assemblage as a whole, and especially in the post-HP MSA 2, is, at least in part, a consequence of the heavy burning.

Fragmentation

While the results presented above suggest that much of the fragmentation evidenced in the HP and post-HP MSA fauna may be related to the high incidence of burning, the degree and nature of fragmentation in a given faunal assemblage can provide information on a variety of other processes, both natural (post-depositional destruction) and cultural (variability in processing intensity/techniques). While I focus on processing behavior in greater detail in Chapter 8, in this chapter I explore evidence for variability in fragmentation over time using several basic measures of fragmentation, followed by a specific consideration of the degree of post-depositional destruction.

As discussed by Marean (1991), evaluating the degree of post-depositional destruction is of particular importance for a number of reasons. After faunal material has been deposited, it is subject to a number of chemical and/or mechanical processes that can fragment bone and enamel, lowering its identifiability. These processes can particularly impact the interpretation of patterns in relative element abundances, as less dense bones are more easily fragmented by these processes. As a result, an assemblage with a greater degree of post-depositional destruction should show higher fragmentation among less dense elements (and perhaps a bias against these elements) than an assemblage with a lesser degree of post-depositional destruction (Marean, 1991).

Therefore, prior to addressing higher-order levels of inference about change over time in archaeological faunal assemblages, the relative extent of post-depositional destruction must be compared. If the degree of post-depositional destruction is similar, then comparative analyses are warranted; if it is different, the analyst must recognize that at least some of the patterning evidenced is likely a result of differential post-depositional attrition and thus must be more cautious in interpreting those patterns as reflecting variation in human behavior.

Evaluating the degree/intensity of fragmentation in the HP and post-HP MSA

In Chapter 4, I demonstrated that the percentage of identifiable bones was very low across the three assemblages, indicating a high degree of fragmentation. Table 6.7 provides summary data on the volume of excavated deposits, count and weight of non-identifiable fragments, density of bones per cubic meter of deposit, and percentage of

Phase	Excavated volume (m^3)	Non-Identified Fragments			Density (Non-ID)	Identified Bones		
		Count	Wt. (g)	% < 2cm	Wt./m^3	NISP	%ID	NISP/m^3
post-HP MSA 1	1.664	133530	26144.8	88.92%	15712.0	462	0.34%	277.6
post-HP MSA 2	0.7385	56843	18636.0	93.57%	25234.9	305	0.53%	413.0
HP	0.553*	109788	40391.9	95.14%	73041.4	2438	2.20%	4408.7

*Volumetric data for layer GS2 was estimated

Table 6.7: Summary of fragmentation data (units B5 and B6 only)

identifiable remains for each unit. Because volumetric data was only available for units B5 and B6, the data in Table 6.7 was limited to material from those units.

The table makes a number of points clear: first, despite the fact that the percentage of identifiable bone is very low, the assemblage is still remarkably rich, with a very high density of remains. The table also highlights the fact that the larger number of identified bones in the HP is *not* simply a factor of the relative volume of excavated sediment, as the HP actually had the lowest volume of deposits. The HP actually showed the highest density of both identified and non-identified bone, but while the post-HP MSA 2 had the second highest density of identified bone, it showed a lower density of non-identified remains than did the post-HP MSA 1.

One way of describing the level of fragmentation in an assemblage is to simply chart the frequency of fragments of different sizes. This provides an “instant visual impression of the nature of fragmentation” and of variation in the degree of fragmentation between different assemblages (Outram, 2001:404). This strategy is not designed to identify the agent of fragmentation, but simply to explore similarities or differences in the degree of fragmentation across different assemblages. I first compared the length of the non-identified fragments from each phases (Figure 6.8). Because I

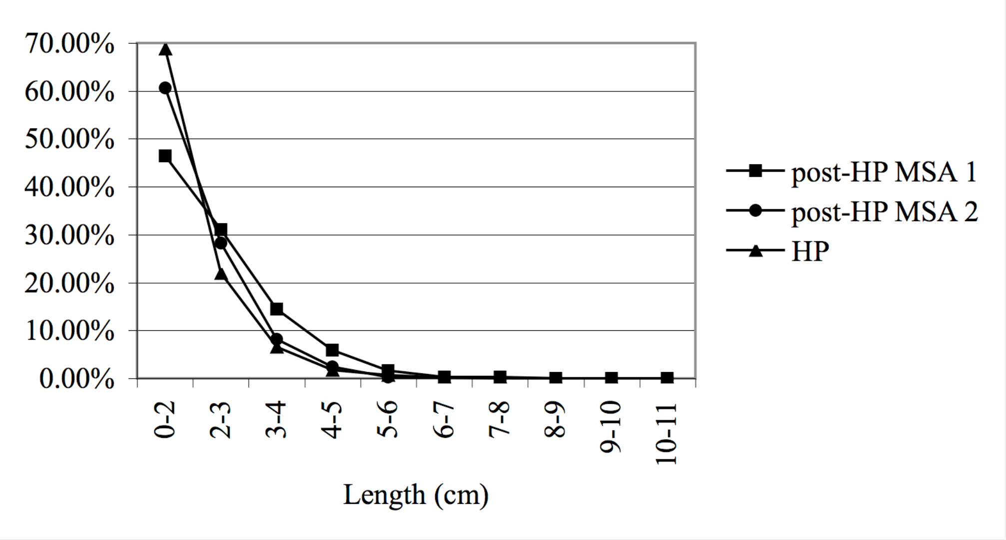


Figure 6.8 Length distribution for non-identified bone subjected to full taphonomic analysis (long bone shaft fragments, ribs, vertebrae and skull fragments)

only measured the greater-than-2 cm bones which were subjected to full taphonomic analysis, the sample is limited to long bone shaft fragments, ribs, vertebrae and skull fragments.

Villa et al. (2004) constructed a similar chart, summed the percentages for the first three size categories, and used the resulting data as a means of comparing the degree of fragmentation between a number of Paleolithic-era assemblages from France (both human- and carnivore-produced). Because all three sites showed similar percentage of small fragments, they concluded that the degree of fragmentation was similar for all sites. The results of the same analysis (conducted using the data presented in Figure 6.8) are presented in Table 6.8.

Chi-squared tests indicate that the proportion of fragments less than 4 cm in size is significantly different in the post-HP MSA 1 as compared to either the post-HP MSA 2 or HP, while there was no significant difference between the HP and the post-HP MSA 2

Fragment Size	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
0-4 cm	2706	1961	1906
> 4 cm	239	57	53
Total	**2945**	**2018**	**1959**
% < 4 cm	91.89%	97.81%	97.29%

Table 6.8 Comparative data on the frequency of small (< 4 cm) fragments (non-identified bone only)

(post-HP MSA 1 vs. post-HP MSA 2; $\chi^2 = 59.769$; $p < 0.0001$; post-HP MSA 1 vs. HP; $\chi^2 = 61.488$; $p < 0.0001$; post-HP MSA 2 vs. HP; $\chi^2 = 0.052$; $p=0.8196$). While all of the assemblages are clearly highly fragmentary, these numbers may suggest that HP and the early post-HP MSA are more heavily fragmented than the post-HP MSA 1; however, the differences may also be linked to the fact that the post-HP MSA 1 contains a much higher proportion of large game than the other two. This possibility will be explored in more detail below.

When the length of identified bones was compared, Villa et al. (2004) found that the hyena den showed a wider distribution of bone lengths than did the human sites in their sample. They found this to be an important distinction, and argued that the generally smaller and more restricted range of length measurements from the human assemblage may have been a result of human activity, such as marrow processing, grease rendering, or the use of bone as fuel. However, the authors did note that size differences between taxa represented at the different sites (i.e., mostly size III/IV ungulates at the hyena site and mostly size II ungulates at the human sites) could affect this type of analysis.

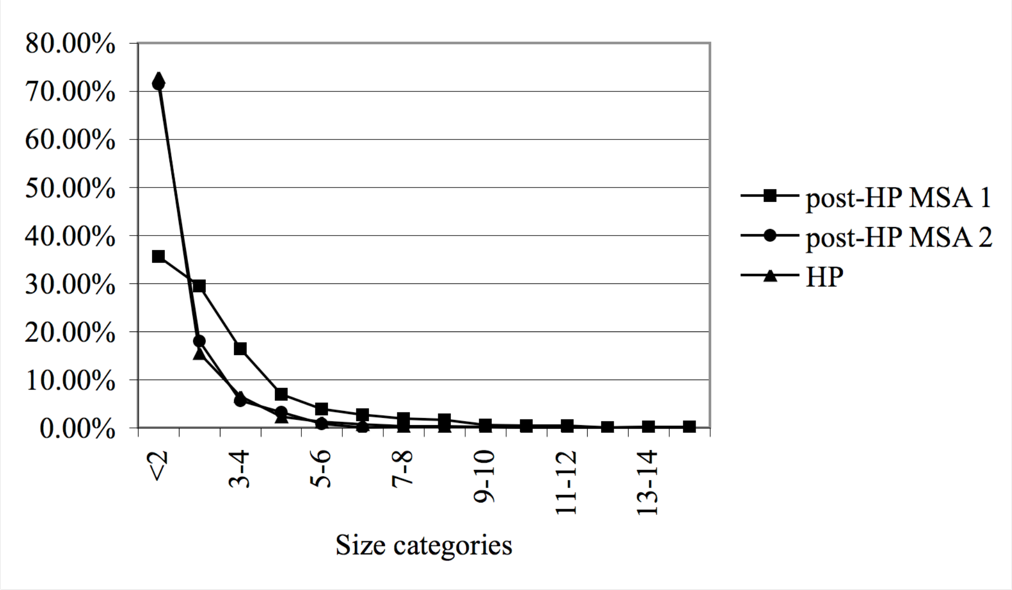
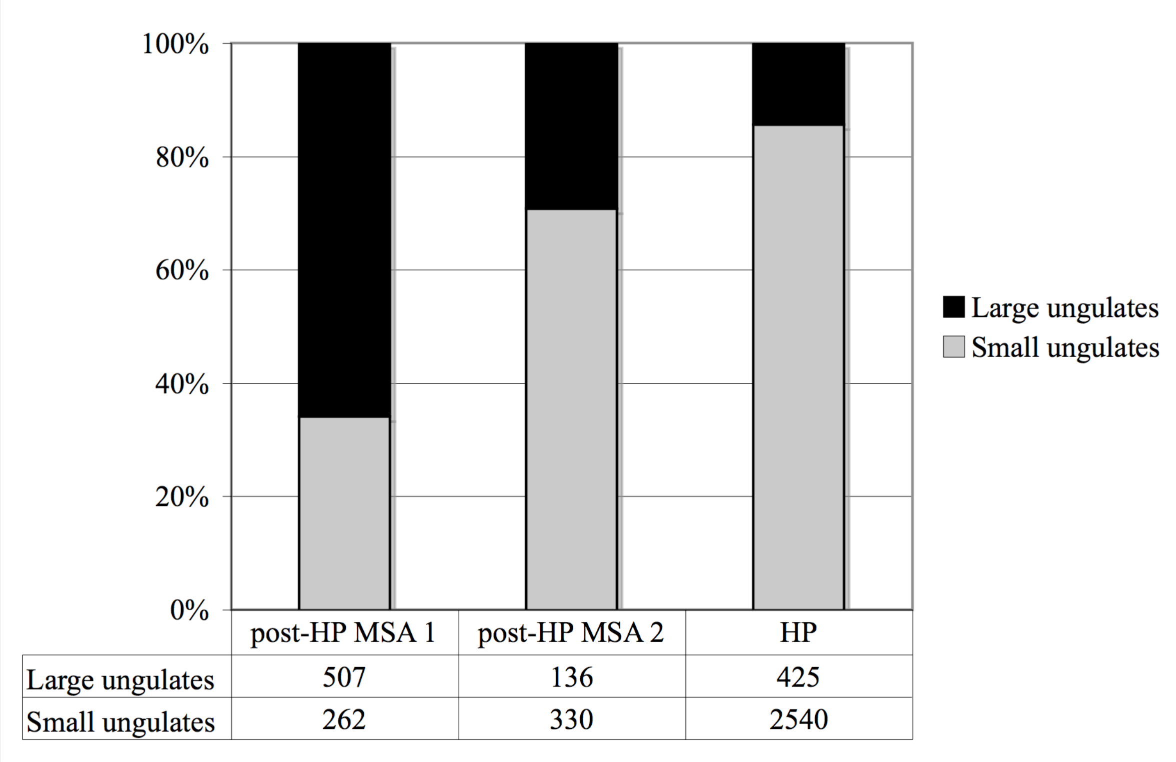


Figure 6.9 Length distribution for identified bone only

Looking at the distribution of length measurements for the identified bone (Figure 6.9), the post-HP MSA 1 shows a broader distribution of NISP lengths than either the post-HP MSA 2 or the HP, while concurrently showing a much lower proportion of specimens in the less-than-2-cm category. I would argue that this is almost entirely an artifact of the size differences of the taxa represented in the three horizons. As demonstrated in Figure 6.10, the post-HP MSA 1 contains a much higher proportion of large ungulates (Bov III or larger, including equids). Obviously, a higher proportion of large game in the assemblage means a greater opportunity for the preservation of large fragments. It is perhaps worth noting that although the post-HP MSA 2 does contain a significantly higher proportion of large game than does the HP (χ^2=64.935; $p < 0.0001$), the distribution of fragment lengths is nearly equal for the two units; this may indicate that the post-HP MSA 2 is more heavily fragmented than the HP.



	post-HP MSA 1	post-HP MSA 2	HP
Large ungulates	507	136	425
Small ungulates	262	330	2540

Figure 6.10 Distribution of large (Bov III + equids) and small (Bov I/II and suids) ungulates by phase

Given that the apparent variability in fragmentation presented in the above analyses could be a factor of size differences in the taxa represented in the three phases, I have employed two alternative methods for comparing the intensity/degree of fragmentation. The first involves a consideration of the length of long bones shaft fragments within a given taxon. For the second, I return to the non-identified sample, exploring differences in average fragment weight among the large-fraction (> 2 cm) non-identified bone.

The mean length of long bone shaft fragments within a given taxon has been cited as a good measure for comparing the intensity of fragmentation across assemblages (Lyman, 1994c). While Villa et al. (2004) were able to focus on the remains of particular species (*Equus caballus*), the Sibudu sample does not preserve a sufficient sample of long bone shaft fragments for any given species. I can, however, use data from a given bovid size class. While I recognize that there is variation in body size within a size class, given the nature of the sample, this was the best available data for this type of analysis. Long bones considered here include the humerus, radius, femur, tibia, metacarpal and metatarsal.

Because measurements were only taken to within a centimeter (i.e., 2-3, 3-4, etc.), in order to calculate average fragment lengths, I used the middle point of the range (i.e., 2.5, 3.5, etc.), with the exception of the less than 2 cm bone, for which I used a value of 1.5. I chose this value because field sorting was primarily aimed at recovering all fragments larger than 1 cm in size, and thus the majority of the fragments in the less than 2 cm category should actually be between 1-2 cm. Sample sizes were sufficient for only the Bov II and Bov III remains; data are presented in Table 6.9. There are a number of reasons for which statistical comparison of the means is not particularly appropriate, including the manipulation of the length data, the fact that the data is not normally distributed, and the presence of unequal sample size and variances. On a qualitative level, the values are quite similar, which may indicate a similar degree of fragmentation across the assemblages.

Phase	**Bov II**		**Bov III**	
	n	**Mean**	***n***	**Mean**
post-HP MSA 1	40	3.450	57	5.196
post-HP MSA 2	10	3.000	9	5.267
HP	72	3.528	41	4.866

Table 6.9 Mean length (in cm) of long bone shaft fragments, identified bone only

If the degree of fragmentation was significantly different across the three assemblages, then one would expect variability in the mean fragment weight, here defined as count vs. weight. For the non-identifiable material, there are essentially three ways in which this could be explored: by looking at the average fragment size for the bone that is less than 2 cm, by comparing the average fragment size for only the greater-than-2-cm bone, and by looking at the total non-identifiable assemblage. I have chosen to use the large-fraction non-identified bone, as the restricted range of possible lengths and masses for the less-than-2-cm bone limits its potential use as an indicator of fragmentation. Furthermore, because the post-HP MSA 1 preserves a much higher proportion of large game, using the entire non-identifiable assemblage is also potentially problematic, as we might expect the post-HP MSA 1 to have a higher ratio of large to small fragments (again, more large animals equals a greater opportunity for large fragments), which would skew the results. Another factor that could skew the results is differential fossilization; however, the degree of fossilization appears to be comparable in all layers.

Although some of the non-identifiable bones larger than 2 cm in maximum dimension may come from small-bodied prey, by removing the small fragments from consideration, the analysis should be less biased by the size differences in the prey animals present in the three assemblages than the comparisons presented earlier. Count and weight data for the greater than 2 cm non-identifiable bone (from units B5, B6 and C5) is presented in Table 6.10 (the *n* in the table is the number of layers in each unit).

Because fragments were not weighed individually, statistical comparison of the means requires a comparison of the average fragment weights for each layer. A Kruskal-

Phase	***n***	**Count**	**Weight (g)**	**Avg. Wt.**
post-HP MSA 1	22	24058	35096.2	1.4588
post-HP MSA 2	12	7420	9916.5	1.3365
HP	7	9438	14467.8	1.5329

Table 6.10: Count/weight data for the > 2 cm non-identified bone

Wallis test did indicate a statistically significant difference in mean fragment weight (H=8.49; p=.0153). Interestingly, while the HP contained the smallest proportion of large game (by a fairly significant margin), the average fragment weight was actually the highest in this phase. If a lower average weight reflects a greater intensity of fragmentation, then the post-HP MSA 2 appears to be more heavily fragmented than the other two units—given the fact that this unit preserved the highest frequency of intensely burned bone, this is perhaps not surprising. In fact, the average fragment weights correlates well with the proportion of highly burned bone among the greater-than-2-cm sample, with the HP showing the lowest proportion of calcined bone and also the highest average fragment size.

While the non-identified material is obviously providing a somewhat gross measure of fragmentation intensity, particularly since I cannot entirely control for the differences in prey size, when the data are broken down by layer, a potentially interesting pattern is revealed. Figure 6.11 presents a scatter-plot of count vs. weight for each layer. While a positive relationship between count and weight is expected (as each fragment will obviously have some mass), the extremely high and consistent correlations (post-HP MSA 1: r^2=.9665; post-HP MSA 2: r^2=.9630; HP: r^2= .9725) and similarities in slope (shown on the figure) were not. If the degree/intensity of fragmentation was different for each of the three units, the slope of the line, in particular, would be expected to vary. I

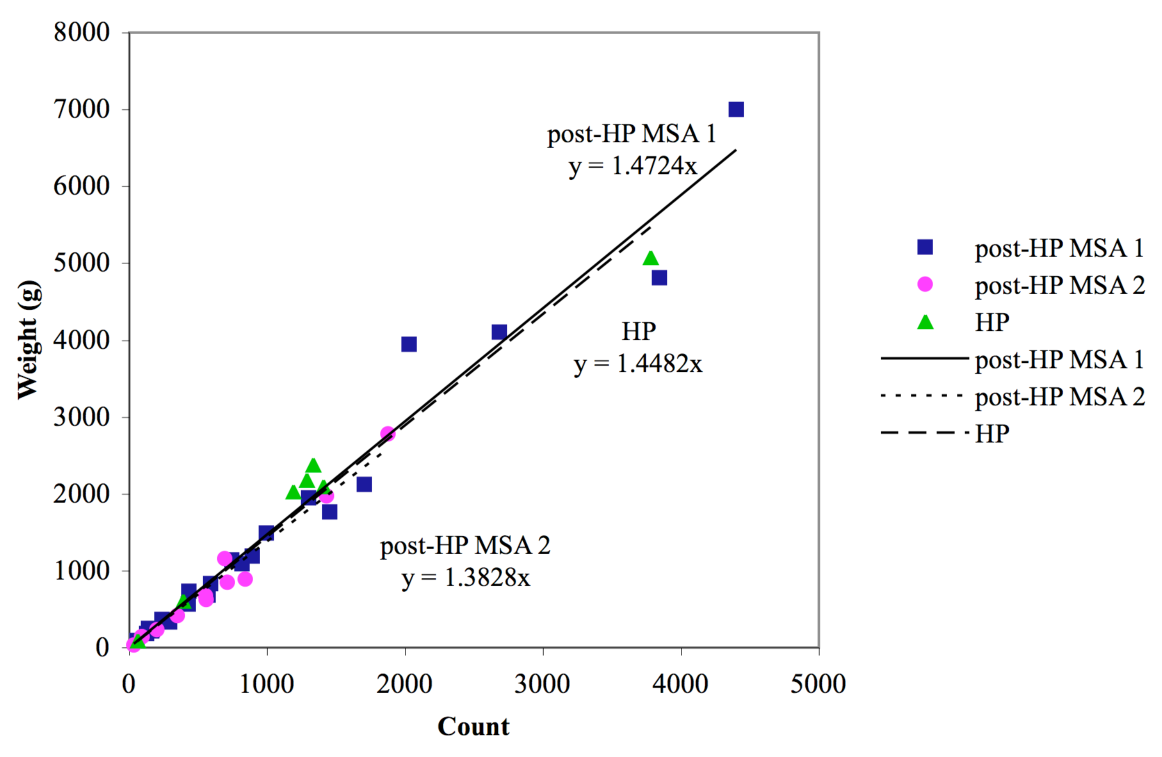


Figure 6.11 Count/weight data for > 2 cm non-identified bone

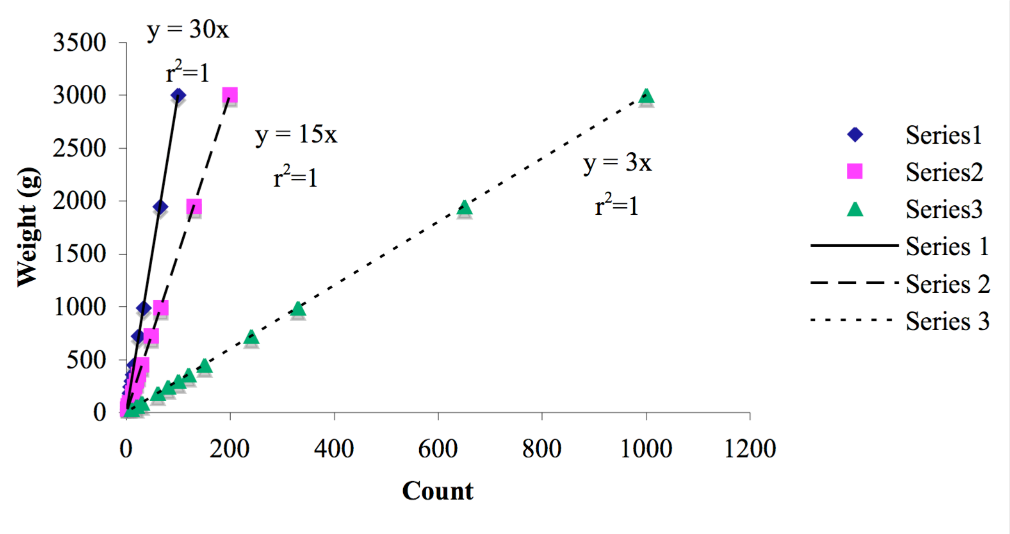


Figure 6.12: Count/weight plot for hypothetical assemblages

have attempted to illustrate why this would be the case in Figure 6.12, which shows a hypothetical distribution of count/weight data for 3 assemblages of 10 layers each.

Each of the hypothetical assemblages initially contained the same number of complete bones of a single bone type; this bone weighs 30 grams when complete. In Series 1, the bones were always complete. In Series 2, each of those bones was broken in half. As a result, the total weights were the same as in Series 1, but the relationship between count and weight is different, and thus so is the slope. In Series 3, each bone was broken into 10 pieces. Again, the weights remained the same, but the counts were different, and so again is the slope. While this is obviously a gross simplification, I think the point raised is a valid one, and the similarities in correlation coefficient and slope for the HP and post-HP MSA assemblages presented in Figure 6.11 suggest that the nature of fragmentation within and between the three assemblages is similar. Of course, these analyses do not provide an indication as to whether the fragmentation was primarily pre- or post-depositional; I will turn to this issue in the next section.

Evaluating the degree of post-depositional destruction: Marean's Completion Index for compact bones

As discussed in the beginning of this section, the relative extent of post-depositional destruction must be compared across the assemblages prior to conducting higher order analyses, particularly those dealing with element frequency data. Because experimental studies have indicated that carpals and tarsals (excluding the calcaneus) are unlikely to be fragmented during human processing or carnivore ravaging, Marean (1991) argued that the degree of fragmentation among these bones provides insight into the degree of post-depositional destruction. As such, he developed a "Completeness Index" (CI) for evaluating the degree of post-depositional destruction. As defined by Marean, calculating the CI requires data on the percentage of the total bone represented by each carpal/tarsal fragment. Because I did not record data in this way, I follow Villa et al.

(2004), who relied on a less precise but more easily calculated index, in which the number of complete and almost complete bones are added together and then divided by the total number of fragments.

Given that the goal in calculating the CI is to judge the degree of post-depositional destruction, carpals and tarsals showing possible evidence for pre-depositional fragmentation in the form of human processing (percussion damage) or carnivore damage (gnaw marks, tooth punctures) are typically removed prior to analysis; in this case, none of the compact bones preserved such damage. Villa et al. (2004) also excluded bones showing evidence for burning, arguing that burned bones were fragmented pre-depositionally. While I have already discussed how burning can promote fragmentation, it is not clear that one can automatically equate the burning of small, compact bones with pre-depositional fragmentation; and, in any case, given that the vast majority of the assemblage at Sibudu is burned to some degree, removing burned bones was not an option. As a result, I recognize that some fragmentation may have occurred during burning, but feel that the CI should still provide some indication of the degree of post-depositional fragmentation for the assemblages under consideration.

In addition to the carpals and tarsals (with the exception of the calcaneus), I also included sesamoids in my analysis. While sesamoids were not addressed in Marean's 1991 experimental study, they are also small, compact bones that are unlikely to be fragmented as a result of human or carnivore processing. Table 6.11 presents the data by phase and by bovid size class (note: bones belonging to fetal/neonates or young juveniles were removed from the sample prior to analysis). The smallest and largest bovids (Bov I and Bov V, respectively) were not included because the sample sizes were so small—

	Carpals/Tarsals			Sesamoids only			All compact bones		
	CO+ ACO	Frag.	CI*	CO+ ACO	Frag	CI*	CO+ ACO	Frag	CI*
Bov II									
post-HP MSA 1	6	15	0.2857	12	5	0.7059	18	20	0.4737
post-HP MSA 2	10	19	0.3448	33	6	0.8462	43	25	0.6324
HP	20	33	0.3774	63	25	0.7159	83	58	0.5887
Bov III									
post-HP MSA 1	1	10	0.0909	20	16	0.5556	21	26	0.4468
post-HP MSA 2	2	6	0.2500	3	11	0.2143	5	17	0.2273
HP	0	13	0.0000	14	19	0.4242	14	32	0.3043
Bov IV									
post-HP MSA 1	0	0	0.0000	12	8	0.6000	12	8	0.6000
post-HP MSA 2	0	2	0.0000	4	2	0.6667	4	4	0.5000
HP	0	2	0.0000	13	3	0.8125	13	5	0.7222

Table 6.11 Completion Indices for the small, compact bones (CO+ACO= complete and almost complete specimens; Frag.= fragmentary specimens)

while the HP had over 200 compact bones from Bov I, the sample from post-HP MSA 2 comprised only nine bones, and the post-HP MSA 1 had only three; only one Bov V carpal or tarsal was identified in the entire assemblage.

Looking first at the CI values for the total sample of compact bones, it seems that all of the assemblages have been affected by post-depositional destruction. A chi-squared test was conducted for each bovid size class to test the null hypothesis that the proportion of complete bones was no difference across the three horizons. In each case, there was no significant difference (at $\alpha = .05$) between the three values (Bov II: $\chi^2 = 2.568$; p = 0.2769; Bov III: $\chi^2 = 3.823$; p = 0.1479; Bov IV: $\chi^2 = 1.315$; p = 0.5181). The same tests were also conducted using the carpals/tarsals and sesamoids independently (the Bov IV carpals/tarsals were excluded from analysis because of the small sample size), again, no differences were significant at the $\alpha = 0.05$ level. Taken as a whole, then, these data suggest that the degree of post-depositional fragmentation was not significantly different between the three horizons under consideration. Given the relationship between heavy burning/fragmentation identified in the previous section of the chapter, this result is perhaps surprising. For example, although greater than 50% of the compact bones from the Bov II size class from both post-HP MSA assemblages were highly burned (compared to 17% for the HP), the CI values were not significantly different. This suggests that the post-HP MSA 2 did not necessarily suffer from a greater degree of post-depositional fragmentation, despite the fact that a larger percentage of the material from that horizon was calcined.

The data presented in Table 1 raise two additional points. First, the CI values indicate that the sesamoids were less fragmentary than the carpals/tarsals. Samples from all three archaeological phases were pooled to test whether this was the case; the small number of Bov IV carpals/tarsals again precluded their use. The results for both the Bov II and Bov III remains were highly significant (Bov II: $\chi^2 = 39.616$; $p < 0.0001$; Bov III: $\chi^2 = 12.617$; $p = 0.0004$); it would thus appear that the sesamoids were less fragmented. If post-depositional destruction has a greater affect on less dense bones, it may be the case that the carpals/tarsals are simply less dense than the sesamoids; unfortunately, I could not find any density studies in which measurements were provided for sesamoids. A more detailed consideration of the potential effects of post-depositional destruction, particularly as related to density mediated attrition, will be discussed later in the chapter.

The second additional point raised by Table 6.11 relates to an issue discussed in Chapter 4— the possibility that large animals are more prone to post-depositional fragmentation than smaller game (c.f., Yeshurun et al. 2007). When the proportion of complete/almost complete compact bones is compared between size classes (again, limited to Bov II and III), there is a significant difference when the samples from all three assemblages are pooled (χ^2= 17.363; p < 0.0001). When the same comparison is made within each period, the differences are still significant for the HP and the post-HP MSA 2 (HP: χ^2=11.230; p = 0.0008; post-HP MSA 2: χ^2=10.959; p = 0.0009), but there is no significant difference for the post-HP MSA 1 (χ^2=0.061; p = 0.8049). The reason why the post-HP MSA 1 shows a different pattern is not immediately clear and perhaps deserves future attention.

Assessing the degree of post-depositional fragmentation: fracture patterns

Protocol developed by Villa and Mahieu (1991) allows for the distinction of fresh from post-depositional breaks through the analysis of fracture patterns on long bone shafts. Although their methodology was originally developed for use on human remains, it has been shown to be valid for archaeofaunal assemblages (Assefa, 2002; Marean et al., 2000; Pickering et al., 2005). The most commonly utilized measures focus on the characterization of fracture angles (defined as the angle formed by the fracture surface and the inner table of the bone) and the fracture outline (the shape of the fracture). Green bone fractures are commonly associated with obtuse or acute fracture angles and curved or v-shaped fracture outlines (both of these types would be classified as oblique fracture planes by Pickering et al. 2005); while dry bone fractures are associated with right angles and transverse fracture outlines. It is important to keep in mind that Villa and Mahieu's (1991) results showed that these attributes have diagnostic value at the *assemblage level only*, not at the level of individual bones.

Because it can be incredibly time-consuming and difficult to define the boundaries of the various fracture planes on highly fragmentary long bone shafts of incomplete diameter in any replicable way (see Pickering et al., 2005, Figure 2, for a photograph of a specimen with six fracture planes), many scholars choose to restrict this type of analysis to shaft fragments with epiphyses attached (c.f., Munro and Bar-Oz, 2005). I had initially planned on including an analysis of fracture patterns as part of the assessment as to whether bones were primarily fragmented pre- or post-depositionally; however, the available sample of shaft fragments with attached epiphyses was remarkably low (the sample for the post-HP MSA 1 comprised only 4 bones; the post-HP MSA 2 preserved only 7). Furthermore, given that the assemblage is so highly burned, and that burned bone, even when only lightly heated, displays fracture patterns associated with dry bones (Cáceres et al., 2002), this line of evidence was unlikely to be particularly informative, as "fresh" fracture patterns would have been overprinted by fragmentation related to burning.

Causes of post-depositional destruction

It should be kept in mind that the apparent similarity in the degree of post-depositional fragmentation across the three assemblages does not necessarily mean the same processes were responsible for that fragmentation. In fact, we know that to some degree, different factors account for the post-depositional fragmentation in the HP and post-HP MSA, as bone in the post-HP MSA was fragmented at least in part by gypsum growth—this was demonstrated by micromorphological studies (Schiegl and Conard 2006) and in the analysis of surface damage reported earlier in the chapter, in which bones from the post-HP MSA showed damage related to gypsum crystal growth. Why then does the HP show a similar degree of post-depositional fragmentation? Studies of the sediments in the lower deposits at the site (including the HP) suggest that these horizons may have been more heavily trampled than the later deposits (Wadley, personal communication). The fact that different means have resulted in similar fragmentation patterns may suggest that once bone is weakened due to heat exposure, it is apt to fracture in similar ways, even in the face of different proximal causes of that fragmentation.

Fragmentation data: summary

I began this section of the chapter by revisiting the data on the percent of identifiable remains, demonstrating that while the fauna is highly fragmentary, the HP and post-HP MSA deposits are still remarkably rich, with a very high density of both identifiable and non-identifiable remains. When basic descriptive measures for comparing degree of fragmentation were utilized, the post-HP MSA 1 initially appeared to be less fragmentary than the other two units. However, this was found to be largely an artifact of the differential representation of large ungulates, which were much more common in the post-HP MSA 1 than in the HP or in the lower post-HP MSA. Alternative methods for comparing the degree of fragmentation that attempted to correct for the differences in prey size—one using long bone shaft fragments within a given taxon, and the other using the non-identified bone—indicated that the intensity of fragmentation was fairly similar across the assemblages. There did seem to be some correlation between the intensity of burning and the degree of fragmentation, with the post-HP MSA 2, which had the greatest proportion of highly burned bone, appearing somewhat more fragmentary than the other units.

However, these potential differences did not appear to significantly impact the degree of post-depositional destruction. While the degree of fragmentation among the small, compact bones indicated that all of the assemblages suffered from some degree of post-depositional fragmentation, there were no significant differences in the Completion

Indices between the three units under consideration. Because post-depositional destruction often results in density-mediated attrition, I turn next to a consideration of density-mediated attrition in the HP and post-HP MSA at Sibudu.

Density-mediated attrition

Experimental and ethnoarchaeological data have indicated that several taphonomic processes are mediated by the structural density of bones (e.g., Behrensmeyer, 1975; Brain, 1981; Marean and Spencer, 1991). Lyman (1994c: 239-258) provides an excellent discussion of this phenomenon; to summarize, bones (or portions of bones) with the lowest bulk density also have the highest porosity (i.e., spongy bone), which also means that they have greater surface area to volume rations. As a result, mechanical and chemical attrition have a greater impact on these bones. A consideration of the relationship between element representation and bone mineral density thus provides a frame of reference for assessing skeletal part frequencies in a given assemblage; this is of particular importance because these data provide one of the primary means of studying variation in transport and processing behaviors, topics covered in Chapter 8.

While some have used analyses of density-mediated attrition primarily as a way of assessing the degree of *in situ* attrition (e.g., Stiner, 2005), it is important to keep in mind that a variety of other processes, both natural (consumption of low density parts by carnivores) and cultural (grease rendering) can also favor the removal/destruction of less dense bones (Lyman, 1994c; Miracle, 1995). As a result, if there is a significant correlation between element frequency and structural density, these results must be considered alongside other classes of data on carnivore activity, post-depositional fragmentation, and processing behaviors in order to tease out the processes responsible for the density mediated attrition.

Density-mediated attrition: methodology

Density data have now been published for a wide range of species, from bison (Kreutzer, 1992) to marmot (Lyman et al., 1992); for this analysis, I have chosen to use the bone mineral density (BMD_2) values provided by Lam et al. (1999) for the blue wildebeest, as the species is present in our assemblage, and because I could not locate density data for any other African bovid species. Bov I remains were excluded from this analysis because the blue duiker, the most common small bovid in the assemblage, is nearly two orders of magnitude smaller than the wildebeest, and, as such, I was uncertain as to whether wildebeest served as an appropriate analog. Because of their lesser density, juvenile and fetal/neonate remains were also removed from study. Given the small sample sizes for the largest bovid size classes, I have combined all of the Bov III or larger remains into one group and thus data will be presented for two size categories, Bov II and Bov III+.

Because most bones are not of uniform density, elements are typically divided into a number of different scan sites; the data presented are based on the representation of these scan sites. The portion-of-element codes that I used were aligned to the scan sites as closely as possible; the utilized portions, their associated scan sites, and the density measurements for each scan site are presented in Table 6.12. For some elements, the coding system I employed was not directly comparable to a scan site—for example, during the first season of analysis, I did not code the specific portion for talus fragments (I simply used "indeterminate talus fragment"), and thus I calculated the average density

Element	Portion	Scan Site	BMD
Mandible	Incisivum	DN1	0.52
	Diasthema	DN2	1.09
	Corpus (horizonal ramus)	Avg. of DN3, 4, 5, 6	0.9925
	Ascending ramus and/or condyle	DN7	0.97
Hyoid	Any fragment		0.26
Atlas	Anterior articulation	AT3	0.66
Axis	Collar/Dens	AX1	0.87
Rib	Proximal complete	RI1, RI2	0.48, 0.47
Sacrum	Proximal (or subset thereof)	SC1	0.35
Innominate	Acetabulum (or fragment thereof)	AC1	0.64
	Acetabulum + Ilium	AC1, IL2	0.64, 0.96
	Acetabulum + Ischium	AC1, IS1	0.64, 0.92
	Acetabulum + Pubis	AC1, PU1	0.64, 0.40
	Iliac blade	IL1	0.39
	Ischium	IS2	0.31
	Pubis	PU2	0.56
Scapula	Glenoid	SP1	1.02
	Neck	SP2	1.01
	Spine	SP3	0.74
	Cranial Edge	SP3	0.74
	Caudal Edge	SP4	0.98
	Blade*	SP5	0.5
Humerus	Proximal end (or subset thereof)	HU1	0.32
	Proximal shaft	HU2	0.49
	Shaft	HU3	1.1
	Distal shaft (flare)	HU4	1.03
	Distal end (or subset thereof)	HU5	0.51
Radius	Proximal end (or subset thereof)	RA1	0.51
	Shaft- ulnar scar	RA2	1.02
	Shaft	RA3	1.07
	Distal shaft	RA4	0.96
	Distal end (or subset thereof)	RA5	0.47
Ulna	Olecranon	UL1	0.46
	Anconaeus	UL2	0.85
Femur	Head or Head/Neck	FE1	0.41
	Major Trochanter	FE7	0.31
	Minor Trochanter	FE3	0.92
	Shaft	FE4	1.16
	Distal shaft	FE5	0.66
	Distal end (or subset thereof)	FE6	0.38

Table 6.12 Portion codes, scan sites and density measurements (density measurements from Lam et al., 1999)

Element	Portion	Scan Site	BMD
Patella	Any fragment	PA1	0.44
Tibia	Proximal end (or subset thereof)	TI1	0.42
	Proximal shaft/crest	TI2	0.91
	Shaft	TI3	1.12
	Distal shaft	TI4	1.09
	Distal end (or subset thereof)	TI5	0.59
2nd/3rd Carpal	Any fragment		0.67
4th Carpal	Any fragment		0.77
Intermediate Carpal	Any fragment		0.70
Radial Carpal	Any fragment		0.76
Ulnar Carpal	Any fragment		0.79
Calcaneum	Tuberculum	CA1	0.57
	Corpus	CA2	0.92
	Sustenaculum	CA3	0.67
	Distal Projection	CA4	0.75
Talus	Any fragment	Avg. of AS1, 2, 3	0.717
2nd/3rd Tarsal	Any fragment		0.84
Metacarpal III/IV	Proximal end (or subset thereof)	MC1	0.72
	Proximal shaft	MC2	1.12
	Shaft	MC3	1.15
	Distal shaft	MC4	0.83
	Complete distal end	MC5, MC6	0.56, 0.62
	Isolated Distal Condyle	MC6	0.62
Metatarsal III/IV	Proximal end (or subset thereof)	MR1	0.83
	Proximal shaft	MR2	1.11
	Shaft	MR3	1.14
	Distal shaft	MR4	0.84
	Complete distal end	MR5, MR6	0.54, 0.65
	Isolated Distal Condyle	MR6	0.65
MC/MT	Shaft	Avg. of MC3, MR3	1.115
	Isolated Distal Condyle	Avg. of MC6, MR6	0.635
First Phalanx	Proximal end (or subset thereof)	P11	0.54
	Shaft	P12	1.02
	Distal end (or subset thereof)	P13	0.80
Second Phalanx	Proximal end (or subset thereof)	P21	0.47
	Distal end (or subset thereof)	P22	0.56
Phalanx 1 or 2	Distal fragment	Avg. of P13, P22	0.68
Third Phalanx	Any fragment		0.53

*Scapula blade fragments not used in nNISP calculations (see text for details)

Table 6.12: (cont'd) Portion codes, scan sites, and density measurements (density measurements from Lam et al., 1999.)

for all three talus scan sites and used that value for the fragments. Along similar lines, because I generally did not specify where exactly a fragment from the border of the mandibular corpus derived, I used an average of the measurements from the scan sites located along the length of the corpus for these fragments. Shaft fragments were often identified based on particular landmarks (nutrient foramina, the deltoid tuberosity, etc.). These features are often located near the center of a shaft, and thus I utilized the scan site at the center of the shaft in these cases. Since I am working at the level of element portions, if a fragment was complete enough that it incorporated multiple scan sites, that fragment would count as one NISP for each scan site present. As mentioned in the previous section, density measurements were not available for the sesamoids and thus they could not be included.

Analyses of density mediated attrition typically depend upon some sort of derived counting measure as a means of accounting for the fact that elements are not present in the skeleton in equal frequency. Some analysts use MAU (e.g., Miracle, 1995; 2005; Yeshurun et al., 2007), while others use %MAU (e.g., Niven, 2007). %MAU was originally defined by Binford (1981) as the MAU of a given element divided by the maximum MAU for the assemblage, times 100. Still others use %Survivorship (e.g., Munro and Bar-Oz, 2005). I want to first note that using MAU and %MAU will give the same results, as the frequency of all of the elements relative to each other is the same in either case. %Survivorship is a different measure, and is calculated for a given taxon as below (from Lyman, 1994c):

$$\frac{\text{(MNE for a given element)} * 100}{\text{MNI} * \text{(the number of times that element occurs in a skeleton)}}$$

Basically, %Survivorship is aimed at discovering how many elements survived versus the number that would have originally been present, given the total MNI for that taxon. Inherent in this calculation is the assumption that whole carcasses were transported to the site, but ethnographic and ethnoarchaeological work indicates that this is unlikely to be a safe assumption, particularly for large game (e.g., Monahan, 1998; O'Connell et al., 1990). Furthermore, I have already discussed why MNI counts are unlikely to be representative for the given assemblage. I am thus more apt to follow the example of scholars who instead use a measure like MAU—although in this case, given the problems inherent in using minimum number counts, I use nNISP (again, calculated by dividing NISP values by the number of times a given part occurs in the skeleton). As discussed in Chapter 4, nNISP has been found to provide results consistent with those provided by MN counts (Grayson and Frey, 2004).

Because I am working at the level of scan sites, nNISP values were based on the number of times any given portion of an element would occur in a complete skeleton (so, 2 proximal humeri, 2 distal humeri, 8 proximal first phalanges, etc). While there is a possibility that some of the shaft fragments may overlap, because I attempted to identify shafts on the basis of distinctive landmarks, I make the assumption that each shaft fragment is from a unique element, and thus shaft scan sites are also divided by 2, with the exception of generic MC/MT shaft fragments, which are divided by 4. Scapula blade fragments were excluded because they are difficult to refit and I was not comfortable simply dividing the number of these fragments by 2. Once the calculations were made, nNISP values were compared against BMD using Spearman's rank correlation coefficent. Figure 6.13 shows the plots of nNISP vs. BMD for each period/size class, while Table

6.13 shows the results of the statistical testing.

As demonstrated in Table 6.13, only one case showed a statistically significant result (at α=.05), and in this case, there was actually a *negative* correlation—in other words, the less dense bone was actually more frequent than the dense bone. The cases in which there were no significant results seem to suggest that the patterns in element frequency data are not primarily a factor of density-mediated attrition. Given that post-depositional destruction is expected to result in density-mediated attrition, this was unexpected, as the results presented earlier indicated that post-depositional fragmentation did affect the assemblages under consideration. Lyman (1994) briefly mentioned a study in which no significant correlation was found between MAU and bone density (Grayson, 1989; an assemblage of marmot bones); he pointed out that Grayson's marmot bones were highly fragmentary, and proposed that the degree of fragmentation may have influenced the results. Lyman did not address why heavy fragmentation would result in a lack of correlation between MAU and bone density, but it may have something to do with the fact that when highly fragmented, dense shaft fragments are less likely to be identifiable to skeletal element than epiphyses, which generally have more distinctive

Phase	**Bovid Size Class**	***n****	**Spearman's ρ**	**p value (2-tailed)**
post-HP MSA 1	Bov II	47	0.0547	0.7131
	Bov III+	41	0.2881	0.0676
post-HP MSA 2	Bov II	33	-0.3531	**0.0440**
	Bov III+	32	0.2385	0.1871
HP	Bov II	63	0.0678	0.5980
	Bov III+	54	0.0605	0.6690

**n* is the number of portion types with nNISP greater than 0

Table 6.13 Spearman's correlation statistics

morphologies.

The one significant (negative) correlation also deserves explanation. While this does not appear to be a common pattern in Paleolithic faunal assemblages, if bones were being intensely processed for marrow and yet the epiphyses were not being fragmented (i.e., no grease rendering), limb bone shafts may be more heavily fragmented and thus less identifiable.

Density mediated attrition: summary

Given the apparent evidence for post-depositional fragmentation, the lack of correlation between element frequencies and bone mineral density is a bit perplexing. This is because the mechanical/chemical processes that result in post-depositional destruction *should* have a greater impact on less dense bones, particularly if those less dense bones are burned, making them even more susceptible to *in situ* attrition. While I do not have an explanation for this phenomenon at present, the lack of correlation between element frequency and bone density, combined with the evidence for a similar degree of post-depositional fragmentation across the three assemblages under consideration, suggests that any patterning in the element frequency data will not solely be a result of variability in post-depositional destruction but may reflect real differences in transport and processing behaviors.

Taphonomic data: summary

Reconstructing the taphonomic history of the assemblage is of critical importance in evaluating whether or not patterning in the faunal record is a product of human behavior or is an artifact of other processes such as carnivore activity or post-depositional decay. In this chapter, I have explored the taphonomic history of the HP and post-HP

MSA assemblages in detail, demonstrating first that the assemblages do appear to have been primarily accumulated by human activity. Looking to the variables that have most directly impacted the assemblage, I first explored the data on burning—the remarkably high frequencies and intensity of burning in the Sibudu assemblage make it unique among similarly dated sites. Evidence suggests that while some of the burning likely occurred post-depositionally (due to exposure to heat from overlying fire structures), the bone was likely discarded into fire as a means of disposing of food waste; this would account for the very high frequencies of calcined bone, in particular. Because combustion promotes fragmentation, and given that as bone becomes more fragile as it is more intensively burned, the heavy burning is no doubt partly responsible for the high degrees of fragmentation evidenced in the assemblage. As burning also negatively impacts surface preservation, the burning likely also played a role in the relatively low frequency of surface modifications, particularly in the post-HP MSA 2.

Analyses relating to the degree and intensity of fragmentation indicated that while post-HP MSA 2 may be slightly more fragmentary than the HP and post-HP MSA 1, likely because of its high frequency of calcined bone, as a whole, the degree of fragmentation seemed quite similar across the three units. This similarity extended to the consideration of post-depositional destruction—Completion Indices for the small, compact bones indicated that while all three assemblages were affected by post-depositional fragmentation, there were no significant differences between the units in terms of the degree of post-depositional destruction.

Post-depositional fragmentation often results in a bias against less dense skeletal parts, which can skew interpretations of skeletal element frequencies. As such, the relationship between element frequencies and bone mineral density was explored; however, there were no significant positive correlations between the two, which seems to indicate that density mediated attrition has not significantly biased the skeletal part data. As a whole, the fact that the assemblages appear to be fragmented to a fairly similar degree, both in a general sense and as it relates to *in situ* attrition, and because evidence for density mediated attrition was absent, it would seem that patterning in the element frequency data are in fact real patterns that are potentially informative about variability in human behavior, rather than reflecting variation in the taphonomic history of the assemblages.

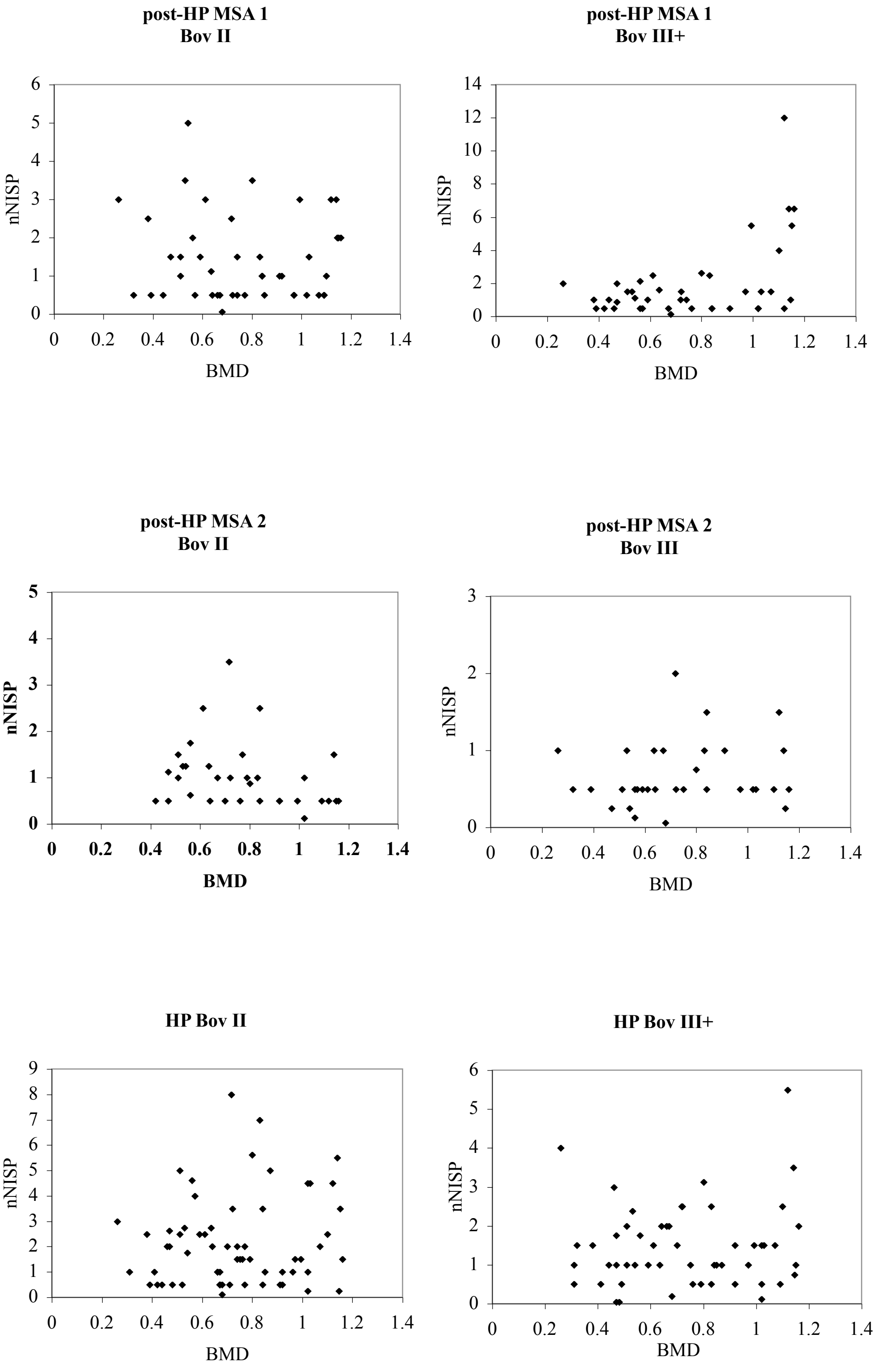


Figure 6.13 Plots of nNISP vs. BMD

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Chapter 7

Animal Procurement and Processing: Prey Selection/Diet Breadth

In Chapter 2, I introduced the expectations for the resource stress model, focusing on the ways in which resource intensification can be identified in the faunal record. In the next two chapters, I will turn to the archaeological record in order to explore the evidence for variability in animal procurement and processing behaviors—in this chapter, I will provide an analysis of prey selection during the HP and post-HP MSA, focusing in particular on evidence for changes in dietary breadth, while in the following chapter I will look at evidence relating to transport and processing strategies. If the HP was in some way a response to resource stress, then that phase should show evidence for wider dietary breadth, reflected through any or all of the following: greater taxonomic diversification; greater evenness in the relative abundance of high- vs. low-ranking game; more frequency exploitation of small game; the inclusion of species with higher handling costs within a give size class; or an increased proportion of juveniles. I begin the chapter with a brief recap of the logic behind these expectations, followed by a discussion of the specific methods zooarchaeologists have used to measure changes in dietary breadth over time (and possible problems in the application of these methods to the Sibudu fauna). I then turn to the record at Sibudu in order to evaluate whether the evidence indicates any changes in dietary breadth over time.

Prey selection: diet breadth

As discussed in Chapter 2, models of foraging behavior developed in evolutionary ecology provide a framework for identifying resource intensification. Under the prey choice model (Kaplan and Hill, 1992; Pianka, 1978; Stephens and Krebs, 1986), high-ranking prey (those that will provide a higher energetic yield relative to search, pursuit and handling costs) will always be taken on encounter. An abundance of high-ranking prey thus fosters a narrow diet focused upon a few select resources. As the encounter rate with high-ranking prey declines, the model predicts that prey will be sequentially added to the diet in order of decreasing rank (Broughton, 1994).

Ethnographic and empirical data have demonstrated that when prey are acquired individually, larger-sized animals are generally higher ranked than smaller ones (Broughton and Grayson, 1993; Hawkes et al., 1982; Kelly, 1995; Lupo and Schmitt, 2005). This makes sense, as the energetic value provided by an animal is more or less proportional to its weight—larger prey provide greater returns with respect to nutritional variables (energy, protein, fat) and have the added benefit of providing more raw materials for tools/clothing (hides, fur, bones) (Broughton, 1994). It must be kept in mind, however, that there is a point of diminishing returns, with the very largest prey (e.g., elephants, whales) generally having handling costs that outweigh their returns (Nagaoka, 2001). These species aside, when given the opportunity, hunters should focus exclusively on large animals, and, as the abundance of large game declines, they should broaden their diet by either taking previously unexploited smaller game or by exploiting smaller animals with greater regularity (Ugan, 2005).

However, several scholars have argued that focusing on body size alone potentially overlooks important differences in prey handling costs between animals of similar body size (Lupo and Schmitt, 2005; Stiner, 2003; Stiner and Munro, 2002; Stiner et al. 1999; 2000). This research has primarily focused on variation in defense and escape mechanisms and the way these affect pursuit costs and thus relative prey rank. As discussed in Chapter 2, Stiner and colleagues (Stiner and Munro 2002; Stiner et al. 1999; 2000) were able to document a shift in small game exploitation from a focus on slow reproducing, sessile game such as tortoise and shellfish during the Middle Paleolithic to a focus on quick flight, difficult to capture game such as hares and game birds during the Upper Paleolithic. The latter would have been more costly to procure and therefore lower ranked; as such, it was argued that increasing frequencies of these species indicated a significant expansion in dietary breadth. While Sibudu does not have a rich small game assemblage, a consideration of handling costs among larger game is also potentially meaningful (c.f., Hill et al., 1987). For example, capturing aggressive large game such as the buffalo and/or the smaller but fierce suids would potentially incur a higher risk (and thus higher costs) than the pursuit of more docile game such as the eland or the impala.

It has also been argued that increased focus on the exploitation of juveniles and young adults can indicate an expansion of dietary breadth in response to resource stress (Miracle, 1995; Munro, 2004; Speth, 2004a; Speth and Clark, 2006). The small size and relatively limited body fat of juveniles means that these animals should be comparatively low-ranked resources. Again, under optimal foraging models, the incorporation of low-ranking resources into the diet should occur not when the numbers of low-ranked prey increase, but rather when the abundance of high-ranking prey declines. Thus, Speth and Clark (2006) argued that an increase in the number of juveniles does not necessarily reflect a seasonal indicator of their abundance on the landscape, but rather a possible sign of resource intensification.

Measuring changes in diet breadth over time

Taxonomic Diversity/Richness

On a broad level, evidence of increased dietary breadth is expected to take the form of a larger number of species in the diet (increasing taxonomic richness) and/or a greater proportional evenness between high- and low- ranked prey items in response to the declining availability of preferred types (Stiner, 2003; 2005). Taxonomic richness is often explored through a comparison of the number of taxa (NTAXA) identified in assemblages under consideration (Grayson and Delpech, 1998; Lyman, 2008). However, there are a number of potential difficulties with using NTAXA as a means of comparing diet breadth across archaeological assemblages (see Grayson and Delpech, 1998 for a detailed discussion).

Because archaeological faunal assemblages are generally comprised of a number indistinguishable collecting events, NTAXA reflects the *maximum* diet breadth over a given time period, rather than the average dietary breadth. Differential time sampling can thus affect NTAXA values, as the longer an assemblage takes to accumulate, the greater the chances are that it will incorporate a low probability dietary event. Along similar lines, taxonomically richer faunas are often larger than less taxonomically rich faunas, and thus the relationship between sample size and NTAXA must be explored before interpreting the results. Changes in climate and technology can also cause the numbers and kinds of taxa that enter the diet to change. The ways in which these factors potentially impact the Sibudu assemblages will be discussed below.

In any case, it is also important to pay attention to the composition of the assemblages, as two faunal samples could have the same NTAXA but be comprised of completely different species. Following Lyman (2008), I will use the Sorenson index (S), as a means of comparing the degree of similarity between two assemblages. The index (S) is calculated as:

$$S = 100(2c)/(a+b)$$

where a is the total number of taxa in fauna A, b is the total number of taxa in fauna B, and c is the number of taxa common to both A and B. If all taxa are shared, the value of the index would be 100, if no taxa were held in common, the value would be 0. The composition of two or more faunal assemblages can also be compared through a consideration of the degree of nestedness; this concept will be discussed in more detail later in this section.

Even if two assemblages are found to share the same taxa, there may still be significant differences in proportional abundances of low- and high- ranked taxa. It is thus critical to combine measures of taxonomic richness with other measures of dietary breadth such as evenness. It is this type of combined analysis that is most likely to provide real information on changes in dietary breadth over time (see Grayson and Delpech, 1998 for one such study).

Evenness

The relative frequency with which high- and low- ranked prey are selected can provide an index of foraging efficiency, and thus measures of taxonomic evenness have

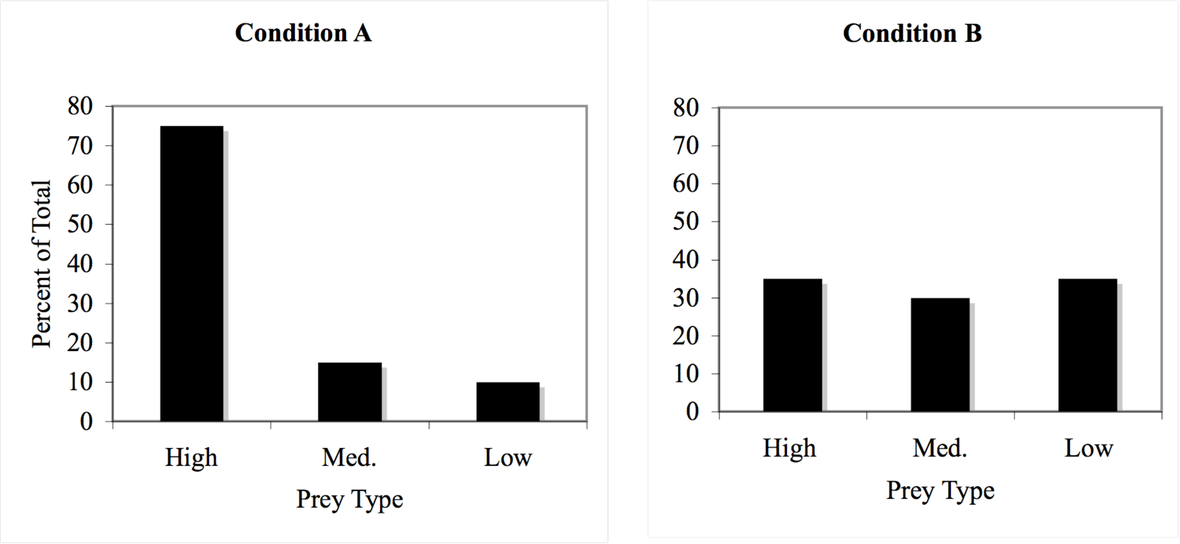


Figure 7.1 Predicted difference in evenness when highly ranked prey is abundant (Condition A), and when the availability of that prey has declined (Condition B) (based on Stiner 2005)

also been employed in analyses of variation in diet breadth (Broughton, 1994). To use Stiner's (2005) example, a predator can afford to ignore low-ranked prey when more highly ranked prey are abundant on the landscape, fostering a narrow diet that emphasizes preferred prey types (Condition A in Figure 7.1). As the supply of preferred prey declines, the predator's returns are maximized by broadening the diet to include common but lower-yield resources. This results in a more diverse diet in the sense that the predator's focus is now spread more evenly between two or more prey types (Condition B in Figure 7.1). Because of the general relationship between body size and prey rank, I will explore potential variation in evenness using body size as the determining factor of prey rank.

Zooarchaeologists have primarily employed two measures of evenness. The first is known as the Shannon index of evenness (Magurran, 1988) and is calculated as follows:

$$\frac{-\sum P_i (\ln P_i)}{\ln \mathrm{S}}$$

where P is the proportion of taxon i in the assemblage and S is the number of types. The Shannon index is constrained to fall between 0 and 1, with a value of 1 indicating that all taxa are equally abundant. Another frequently used measure of evenness is known as the reciprocal of Simpson's index. This is often calculated using the formula:

$$1/\sum p_i^2$$

with p again denoting the proportion of taxon i in the assemblage. However, this formula is based on the assumption that the population is infinitely large, and because the sample of remains in an archaeological deposit is finite, I follow Jones (2004) and Lyman (2008) in calculating Simpson's index as follows:

$$1/\mathrm{D}, \text{ where } \mathrm{D} = \sum \frac{n_i(n_i - 1)}{N(N-1)}$$

where n is the number of specimens of the ith taxon and N is the total number of specimens of all taxa. Simpson's index is known as D because it is more sensitive to the dominance of a single taxon than is the Shannon index. The lower the value of the index, the more the assemblage is dominated by a single taxon; thus, 1/D increases as evenness increases.

As was the case with measures of richness, measures of evenness can also be influenced by sample size, and, as such, the relationship between evenness and sample size must be explored. Nagaoka (2001) highlighted another potential issue with evenness values—the indices do not take into account the position of prey in a rank order set. As a result, the evenness of an assemblage can remain unchanged even when the diet itself is changing. To use her example, during one period 80% of the assemblage may be comprised of Prey A, a high-ranked resource, with the remaining 20% from Prey B, a low-ranking source. Later, Prey #2 may increase to 80% of the assemblage while Prey #1 declines to 20%. The evenness value will be the same in either case, even though the diet is markedly different. Thus, it is also important to take into consideration the composition of the fauna when comparing evenness values.

Nestedness

Both Jones (2004) and Lyman (2008) also advocate a consideration of nestedness when exploring evidence for variation in diet breadth, although they propose using it in slightly different ways. Lyman (2008:167-170) provides a detailed discussion of the concept of nestedness; to summarize briefly, in a perfectly nested faunal assemblage, taxa which are absent from a large sample are also expected to be absent from all smaller samples, while taxa present in a small faunal assemblage are expected to be present in all larger samples. In poorly or weakly nested faunal assemblages, some taxa may occur unexpectedly in small or large samples but not in midsized assemblages, and other taxa which occur in midsized or small assemblages may not occur in large ones. If a series of fauna are strongly nested, then it is probable that the samples derive from the same population, but if they are weakly nested, it is more likely that they derive from different populations.

Lyman (2008) focuses primarily on the value of the nestedness concept as a means of looking at sample size effects. If a small faunal sample should approximate a random sample of a larger assemblage, then when two or more assemblages of differing size are compared, they should be nested (if they derive from the same population). If they are nested, rarefaction analyses can then be conducted as a means of comparing samples of different sizes. If they are not nested (and thus do not appear to be from the same population), Lyman (2008) argues that rarefaction analysis is no longer appropriate.

Jones (2004) turned to nestedness as a means of looking for evidence of increasing dietary breadth over time. If encounter rates with high-ranked prey were declining, one would expect earlier assemblages to be nested subsets of later ones (in other words, while high-ranked taxa would be present throughout, later assemblages would show an increasing number of species as taxa were added to the diet in order of decreasing rank). Keep in mind, however, that this assumes that the samples were derived from the same population.

In looking at the degree of nestedness of the HP and post-HP MSA fauna at Sibudu, I will follow Jones (2004) and Lyman (2008) in using Atmar and Patterson's Nestedness Calculator (1995; see Atmar and Patterson, 1993 for a discussion of the theory behind the program), which provides a measure of the degree of nestedness using a presence-absence matrix. The Calculator provides a system "temperature," with 0 degrees indicating a perfectly nested subset (also known as a "cold" system), and 100 degrees indicating a completely random order, or a "hot" system. In addition, the Calculator includes a Monte Carlo simulation that provides a measure of the probability that the assemblages would be drawn randomly.

Measuring changes in diet breadth at Sibudu: complicating factors

When exploring evidence for changes in dietary breadth in the HP and post-HP MSA, a number of the aforementioned caveats must be taken into account. First, the number of identified remains is much higher in the HP than in post-HP MSA (HP= 3380;

post-HP MSA 2= 503; post-HP MSA 1= 796). OSL dating also indicates that the HP may have accumulated over a slightly longer period of time than did the post-HP MSA (~7,000 years for the HP vs. ~6,000 years for the post-HP MSA; Jacobs et al., 2008a; 2008c). This is particularly relevant to comparisons of taxonomic richness, as both factors may result in a higher NTAXA in the HP. Thus, increased richness in the HP will not necessarily indicate an expansion in diet breadth—this is why using other measures of dietary breadth is so important.

In many parts of the world, changes in the abundance and distribution of mammalian prey are correlated with climate change; shifts in habitat types can increase or decrease the breadth of resources that are potentially exploitable (Grayson and Cannon, 1999). This is important because the botanical and faunal data both provide fairly strong evidence for climate change between the HP and the post-HP MSA. This could also negatively impact the utility of taxonomic richness as a measure of diet breadth, as the use of such measures presumes that the same populations were being exploited—an assumption that will not be met if the available taxa varied due to climate change.

It is relevant to mention that variability in the relative frequency with which high- and low-ranked prey are selected (evenness) may also be linked to changes in climate (Lupo, 2007). For instance, large grazing animals will occur more commonly in open environments than in forested habitats. While this does not detract from the ultimate utility of evenness as a means of identifying variability in diet breadth over time, the impact of climate on the measure should be kept in mind, and I will come back to this issue later in the chapter.

Variability in procurement technology can also affect prey rankings (Nagaoka, 2002). With more efficient technology, the handling costs related to the pursuit and capture of a given species may decline; the resulting improvement in net returns for that prey may increase its relative rank. For example, nets may allow small prey that were previously taken individually to be taken *en masse*, which can increase their return rates dramatically (Grayson and Cannon, 1999). The possibility that snares, nets, or traps were used in the HP has been raised (Wadley, 2006; Clark and Plug, 2008); however, these are made of perishable materials and thus direct evidence for such technology is lacking. In any case, the technological innovations necessary to reduce the handling costs of small prey often result in an increased investment of time and labor in tool production (Stiner, 2005), leading some to argue that changes in technology associated with the more intensive exploitation of low-ranked prey are in and of themselves a reflection of increased dietary breadth (Ugan, 2005).

Projectile technology such as the bow and arrow may reduce costs associated with the pursuit of dangerous prey. As discussed in Chapter 3, the HP assemblage lacks traditional MSA stone points but does include backed microliths and finely made bone points—Wadley and Mohapi (2008) and Backwell et al. (2008) have proposed that each of these tool classes were used to tip arrows. The post-HP MSA, on the other hand, is dominated by traditional MSA stone points; metric data indicate that these were used to tip spears that were either thrust or hand-cast (Villa and Lenoir, 2006).

Hypothetically speaking, if the HP inhabitants of Sibudu were using the bow and arrow, while the post-HP MSA populations were using primarily hand-thrust spears, this would potentially create problems with the use of prey handling costs as a means of exploring evidence for increased dietary breadth, as the bow and arrow would presumably reduce the costs associated with the pursuit of dangerous game by increasing the kill distance. In this case, an increased frequency of this game would thus not necessarily indicate a wider dietary breadth. However, the presence of the bow and arrow in the HP is still speculative, and the spears utilized in the post-HP MSA may have been used as projectile (rather than thrusting) weapons. Thus while it is important to keep in mind the potential impact of differences in hunting technology, we cannot at present take these differences as a given.

As a whole, I think it is fairly clear that the application of measures of diet breadth to the Sibudu assemblage is by no means straightforward. However, I do not believe that the measures are therefore useless; I think they can be informative about changes in subsistence behaviors as long as the aforementioned caveats are taken into account. Furthermore, as is so often the case, an argument in favor of increased dietary breadth will be strongest when several different lines of evidence point to a similar conclusion. In the following section, I will turn to the record from the HP and post-HP MSA in order to evaluate whether the HP shows evidence of wider diet breadth than does the post-HP MSA.

Diet breadth in the HP and post-HP MSA

Richness

In exploring evidence for variation in diet breadth during the HP and post-HP MSA, I first look at taxonomic richness, expressed as NTAXA. I chose to focus on the ungulate remains because while it seems clear that the ungulate fauna were accumulated predominantly by human activity (see Chapter 6), the agents responsible for the

	post-HP MSA 1		post-HP MSA 2		HP	
	n	% total	*n*	% total	*n*	% total
Ungulates	780	97.99%	478	95.03%	2989	88.43%
Non-Ungulates	16	2.01%	25	4.97%	391	11.57%
Total	796	100%	503	100%	3380	100%

Table 7.1: Relative frequency of ungulate vs. non-ungulate macrofauna

accumulation of the remainder of the macrofauna is less clear. The sample of non-ungulate fauna (comprised of rare medium/large carnivore remains and a variety of small game) was relatively small (Table 7.1), and none of these remains preserved cutmarks or percussion damage, although an ulna belonging to a vervet monkey was clearly worked (submitted to L. Backwell for analysis). The percentage of moderately to highly burned bone is comparable to that for the total identified sample, which may indicate human involvement, but, as discussed in Chapter 6, at least some of the burning appears to be post-depositional. Based on the avian fauna, Plug and Clark (2008) proposed that the HP deposits may have preserved more episodes of less intensive human occupation than did the later MSA deposits. If this were the case, it may partially account for the increased frequency of non-ungulate fauna in the HP, as most of the species represented have been known to occur in rockshelters. For the present purposes, because the accumulating agent of this fauna is ambiguous, it makes more sense to focus on the ungulate remains.

Ungulate data are presented in Table 7.2. Following Grayson and Delpech (1998) “cf.” material was included. Species are listed in order of body size, from largest to smallest. I included the “other ungulate” category, which comprises all of the ungulate remains not identifiable to species, because the total number of analyzed ungulate bones is relevant when looking for potential sample size effects. The table raises several points of note. First, there is not a straightforward relationship between sample size and

Ungulate Species	Avg. weight (kg)		post-HP MSA 1	post-HP MSA 2	HP
	F	M			
cf. *Giraffa camelopardalis*	828	1192	4	1	-
cf. *Pelorovis antiquus*	*extinct*		6	-	-
Megalotragus priscus	*extinct*		3	-	4
Syncerus caffer	433	631	18	2	19
Tragelaphus oryx	460	650	1	3	6
Equus quagga	302	313	22	-	6
cf. *Equus capensis*	*extinct*		3	1	-
Hippotragus equinus	230*	270*	-	-	5
Kobus ellipsyprimnus	180*	260*	2	-	-
Connochaetes taurinus	183	250	9	2	1
Tragelaphus strepsiceros	152	287	11	-	-
cf. *Alcelaphus buselaphus*	120	152	1	-	-
Potamochoerus larvatus	70	72	-	13	299
Damaliscus pygargus	65*	75*	1	-	-
Phacocoerus africanus	57	80	5	4	-
Aepyceros melampus	41*	60*	1	1	4
Tragelaphus scriptus	36*	60*	4	2	7
Redunca fulvorufula	31	27	1	-	-
Pelea capreolus	25^	25^	-	-	5
Sylviacapra grimmia	17	16	-	-	2
Cephalophus natalensis	12	12	-	-	4
Oreotragus oreotragus	13	11	-	3	-
Raphicerus campestris	11	11	-	-	20
Philantomba monticola	5	4	2	14	1208
Other ungulate remains	n/a	n/a	686	432	1399
Total NISP			**780**	**478**	**2989**
NTAXA (not including "other")			**17**	**11**	**14**

*weight data from Bothma (2002)

^data on avg. weight for both sexes, from Estes (1992)

Table 7.2 Ungulate data from HP and post-HP MSA (unless otherwise specified, weight data from Skinner and Chimimba, 2005)

NTAXA. Despite the fact that the HP had the largest sample and was accumulated over a longer period of time, it does not have the largest number of taxa—the post-HP MSA 1 does. If the “cf.” material were to be removed, the HP *would* have the highest NTAXA, but only by one (14 vs. 13 in the post-HP MSA 1)—considering that the HP sample is nearly four times larger than the post-HP MSA 1, these data still suggests that sample size is not the primary factor in determining NTAXA.

	post-HP MSA 1	post-HP MSA 2	HP
post-HP MSA 1	-	64.29	51.61
post-HP MSA 2	-	-	56.00
HP	-	-	-

Table 7.3 Sorenson Index values of similarity

The second point raised by Table 7.2 relates to the composition of the fauna. As discussed above, climate change can cause both the number and kind of taxa that enter the diet to vary—under these circumstances, NTAXA may not be a valid indicator of dietary breadth. Because the botanical and faunal data strongly indicated that an environmental shift occurred during the period under consideration, it was expected that the composition of the fauna would not necessarily be the same in all three assemblages. I used the Sorenson index as a means of exploring the degree of similarity between each of the assemblages; results of the pair-wise comparisons are presented in Table 7.3. Remembering that the value of the index will be 100 if all taxa are shared, it is clear from Table 7.3 that none of the faunal assemblages are particularly similar to each other. As expected given the environmental data, the HP and the post-HP MSA 1 assemblage were the least similar. Note that the analysis included all species listed in Table 7.2, including the "cf." identifications. However, the results remain largely unchanged if the "cf." material is excluded—the values changed slightly, but the relative order remained the same (HP/post-HP MSA 1 the least similar, the two post-HP MSA assemblages the most similar).

A consideration of the degree of nestedness can also serve as a means of evaluating whether the samples were likely to have derived from the same population. Once the presence-absence data are entered into Atmar and Patterson's Nestedness

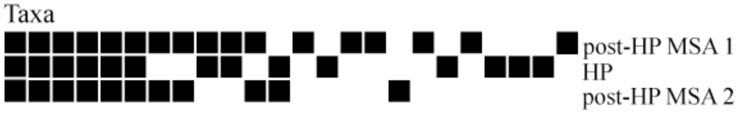


Figure 7.2 Nestedness matrix for the HP and post-HP MSA assemblages

Calculator, the matrix is maximally packed (based on NTAXA and degree of similarity) and then the degree of nestedness is calculated. The matrix for the three assemblages is presented in Figure 7.2; because the assemblages are ordered by NTAXA, the order of the assemblages, from top to bottom, is post-HP MSA 1, HP, post-HP MSA 2. The figure highlights the fact that a relatively small number of taxa are shared between the three assemblages—half of the taxa appear in only one of the three units. The nested temperature is 35.83 degrees, indicating a relatively low degree of nestedness. The Monte Carlo derived probability that the matrix was randomly generated is .788, and thus the degree of nestedness is not significantly different (at α=.05) than that which would be expected given random chance. (for comparison, see Lyman, 2008: 170, Figure 4.12 for a matrix derived from a series of assemblages that are significantly nested).

In short, these analyses indicate that the three assemblages under consideration do not appear to have derived from the same population. Again, given the evidence for environmental change in the vicinity of Sibudu, this is not particularly surprising. What it does mean, however, is that NTAXA does not serve as good indicator of diet breadth, and thus we must turn to other measures, such as the degree of evenness in the representation of high- vs. low-ranked game.

Evenness

As discussed above, archaeologists have used increasing evenness in the representation of high- and low-ranked prey as a sign of expanded dietary breadth. Since I am using body size as a proxy for rank, I will explore evidence for changes in evenness in terms of the representation of large vs. small game. Table 7.4 presents the size class data (including between-class remains) for the HP and post-HP MSA; Figure 7.3 presents the same data in graphical form. For this analysis, the species-level identifications have been combined with those remains identifiable only to size class—this is why the numbers are different from the species list presented in Chapter 4.

Note that although the size classes are based on the categories derived for bovid remains, the remaining ungulates have been added as well. Suids were added to the Bov II size class, and the giraffe falls within the Bov V category. The equids were a bit more difficult to assign to size class. The average body weight for the plains zebra (*Equus quagga*) is just above 295 kg, and thus the species would technically fit within the Bov IV category. However, other equids occurring in southern Africa have an average weight of less than 295 kg, and, in other analyses (e.g., Wadley et al., 2008), all zebra species are grouped with the Bov III remains. Because it is not clear to which species all of the equid remains belong, I decided to add all of the equids to the Bov III/IV size class.

	post-HP MSA 1	**post-HP MSA 2**	**HP**
Bov I	34	77	1608
Bov I/II	3	22	23
Bov II (+ suids)	225	231	909
Bov II/III	11	12	24
Bov III	311	74	282
Bov III/IV (+ equids)	86	30	58
Bov IV	80	29	79
Bov IV/V	13	2	2
Bov V (+ cf. giraffe)	17	1	4
Grand Total	**780**	**478**	**2989**

Table 7.4 Size class data (NISP)

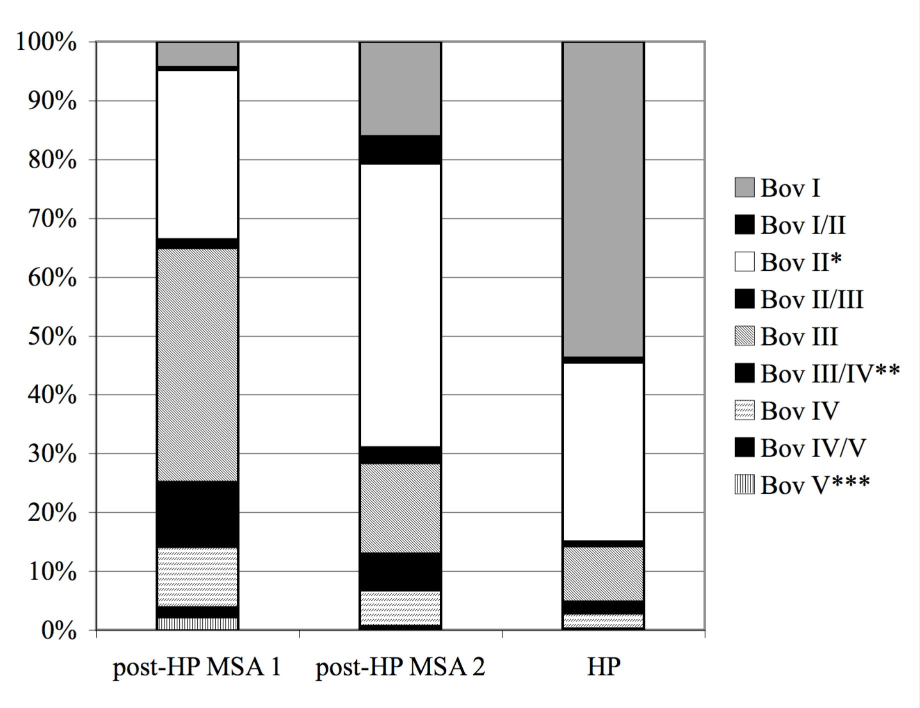


Figure 7.3 Size class data in graphical form

As evidenced in Figure 7.3 (and as first discussed in the previous chapter), there is a marked change in the representation of large vs. small game over time, with the post-HP MSA showing a much higher frequency of medium and large game. Given that larger ungulates of the type that dominate the post-HP MSA 1 assemblage tend to occur more frequently in open habitats, this pattern is no doubt at least partly a reflection of the changes in the local environment.

In comparing the evenness in the representation of high- and low-ranked game, I divided the remains into three classes: small game (Bov I)/low-ranked, medium game (Bov II and suids)/medium-ranked, and large game (Bov III+, including equids)/high-ranked. Data on the NISP and the relative abundance of each class are presented in Table 7.5, which also provides measures of the evenness of each assemblage, using both the Shannon index and the Reciprocal of Simpson's index. Note that for this analysis, while

	post-HP MSA 1		post-HP MSA 2		HP	
Body Size/Relative Prey Rank	***n***	***p***	***n***	***p***	***n***	***p***
Small (Bov I)/Low	34	0.0444	77	0.1734	1608	0.5466
Medium (Bov II, incl. suids)/ Medium	225	0.2937	231	0.5203	909	0.3090
Large (Bov III+, incl. equids)/ High	507	0.6619	136	0.3063	425	0.1445
Evenness						
Shannon Index	0.7020		0.9159		0.8853	
Reciprocal of Simpson's Index	1.90		2.54		2.41	

Table 7.5 Relative abundance data by size class/prey rank, with evenness values

The remains identifiable as only Bov III/IV and IV/V were subsumed within the large size class, the Bov I/II and Bov II/III remains were not included.

The results indicate that while the HP and post-HP MSA 2 display a similar (and high) degree of evenness, the post-HP MSA 1 assemblage is distinctly less even, indicating a reduction in dietary breadth over time. Given that the post-HP MSA 1 is more heavily dominated by large game, which presumably would have been the highest ranking prey, the relationship between evenness and dietary breadth for this period seems straightforward. On the other hand, while the HP and post-HP MSA 2 show a similar degree of evenness, a consideration of the composition of the two assemblages indicates that this measure may be obscuring variability in diet breadth in just the way Nagaoka (2001; 2002) warned of. The evenness values ended up being very similar because the three relative abundance values on which the indices are calculated are roughly the same. However, in the HP, ~85% of the remains come from small or medium game, while in the post-HP MSA ~83% of the remains come from *medium or large* game. This suggests that if prey size is a valid proxy for prey rank, diet breadth was actually widest in the HP.

Another way of getting at this issue is to use the relative abundance index (AI), originally introduced by Bayham (1979, cited in Ugan, 2005), which is simply calculated as the ratio of large bodied animals to the sum of the large and small ones (*Large/(Large+Small)*). Again, given the general correspondence between body size and return rates, declines in this index imply reduced foraging returns (Ugan, 2005). In the North American literature, this index often takes the form of the "Artiodactyl Index," in which the relative proportion of artiodactyls (large game) and lagomorphs (small game) is compared (c.f., Byers and Broughton, 2004). In this case, I would argue that the smallest bovids (Bov I) are suitable for use as the "small game" in the index, particularly since the most common small bovid, the blue duiker, has an average mass of only ~4 kg (which is comparable to many lagomorphs—for example, the Natal red rock rabbit has an average mass of 2.6 kg, data from Skinner and Chimimba, 2005). The "large game" in the index would thus be all ungulate remains larger than Bov I. As evidenced in Table 7.6, the index is lowest in the HP and rises steadily over time, suggesting an increase in foraging efficiency (and a reduction in diet breath) in the post-HP MSA.

Prey characteristics

Earlier, I proposed that an increased focus on aggressive/dangerous game may serve as a potential indicator of expanded dietary breadth, as the procurement costs associated with these species should be higher than those associated with the pursuit of

	Abundance Index
post-HP MSA 1	0.9564
post-HP MSA 2	0.8389
HP	0.5771

Table 7.6 Results of abundance index (large/(large+small)), where small=Bov I remains

more docile game. I turned to Skinner and Chimimba (2005) and Estes (1992) for information on the defense and escape strategies of the identified species (refer back to Table 7.2 for species and NISP counts, analysis included “cf.” identifications). In terms of the “fight or flight” dichotomy, most of the identified species employ some variation of the “flight” strategy—some will freeze and flee, while others (particularly those that inhabit closed environments) will first hide and then flee if the perceived source of danger comes too close. Three species are well known to be aggressive/confrontational: the African buffalo, the warthog, and the bushpig. An additional four species will generally flee but can be aggressive and dangerous: giraffe (size/speed/good vision make these difficult to track and kill in any case, but they are known to kick in defense), waterbuck (males are known to confront predators), roan antelope (while these are often cited as being aggressive, Estes (1992) claims that evidence is mostly anecdotal), and bushbuck (cornered/wounded males are said to be incredibly aggressive and dangerous).

In exploring potential evidence for changes in the representation of these species over time, there are two factors that must be taken into consideration. Certain species (particularly the bushbuck) have rather specific habitat requirements, and thus variation in the presence of these species is likely to have more to do with environmental change than variation in diet breadth. The sample sizes for roan antelope, waterbuck, and giraffe are incredibly small (the highest NISP for any of these is 5), negating any real comparison of their frequency of occurrence over time.

Sample sizes are slightly larger for the African buffalo, and while the species does prefer more open habitats, the other species in the same size class (the relatively more docile eland) also prefers open environments, and thus the relative proportion of buffalo

	post-HP MSA 1	**post-HP MSA 2**	**HP**
Syncerus caffer (African buffalo)	18	2	19
Tragelaphus oryx (Eland)	4	2	7
% Buffalo	81.81%	50.00%	73.07%

Table 7.7 Data on the relative representation of African buffalo and eland (NISP)

to eland may be informative. These data are presented in Table 7.7. A chi-squared analysis finds no significant difference in this ratio between the three assemblages (χ^2=1.93, p = 0.3810), although these results are potentially problematic given that more than 20% of the expected frequencies are less than 5. If we remove the post-HP MSA 2 because of its small sample size, the difference between the HP and the post-HP MSA 1 remains insignificant (χ^2= 0.515, p = 0.4730).

The other two species known to be highly aggressive are suids. Suid remains are very distinctive, particularly when compared to bovids, with species-level identification for bovids generally requiring a complete or nearly complete tooth (the blue duiker being a notable exception, as the species was identifiable based on its very small size). It is thus perhaps most appropriate to look at the proportion of suid remains (including the generic "suid" category) as compared to the other medium-sized game (in this case, Bov II). As demonstrated in Table 7.8, suids are best represented in the HP and show a clear decline in frequency over time; the difference is highly significant (χ^2=37.601, $p < 0.0001$).

Because the warthog and the bushpig frequent different habitats (open vs. closed), changes in the frequency of occurrence should not primarily be a factor of environmental

	post-HP MSA 1	post-HP MSA 2	HP
Suids	25	44	318
Other similar sized ungulates (Bov II)	225	231	909
% Suid	11.11%	19.05%	34.98%

Table 7.8 Data on the representation of suids vs. other similar sized ungulates (NISP)

change. The difference may thus indicate the diet breadth was relatively wider during the HP, as predicted by the stress models. However, there are two things to keep in mind. First, while the two species do occur in different habitats, their density on the landscape may have varied. It is possible that the bushpig (only identified in the HP and the post-HP MSA 2) may have been present at higher densities than the warthog (only identified in the two post-HP MSA assemblages).

It is also relevant to keep in mind that the degree of danger involved in the procurement of these species will be (at least in part) a factor of the hunting technology employed. While dangerous to hunt at close distances (such as those required by use of a hand-thrust spear), the increased striking distance afforded by projectile weaponry, whether that be the bow and arrow, a spear thrower, or even a hand-cast spear, should mitigate the danger, as would remote capture technology such as traps or snares. Again, while there is some evidence suggesting that more advanced projectile technology may have been present during the HP (Backwell et al., 2008; Wadley and Mohapi, 2008), the presence of that technology remains speculative.

Presence of juveniles

The final line of evidence dealing with prey selection relates to the presence of juveniles in the assemblage. As discussed above, some scholars (e.g., Speth 2004; Speth and Clark, 2006) have argued that a decline in the mean age at capture may indicate an expansion of diet breadth. Calculating the mean age of prey at capture would require a sufficient sample of ageable teeth, which the Sibudu assemblages do not have. Instead, I can look for changes in the relative frequency of young animals. Table 7.9 provides data on the number of fetal/neonate, juvenile, and aged remains for the ungulate assemblage. Keep in mind that the number of juvenile remains must be taken as minimums, as some mid-shaft fragments may actually belong to juveniles (the same can be argued for the aged remains).

For the present purposes, we are interested in variation in the frequency of the juvenile remains—fetal/neonate remains will not be considered because these likely reflect the taking of pregnant females rather than the targeting of newly born infants. If the percentage of juveniles in the total ungulate assemblage is compared across the three units using chi-squared analysis, the difference is not significant at $\alpha=0.05$ ($\chi^2=4.836$; $p=0.0891$). When the data is broken down by animal type, however, some interesting

	post-HP MSA 1			**post-HP MSA 2**			**HP**		
	F/N	**Juv**	**Aged**	**F/N**	**Juv**	**Aged**	**F/N**	**Juv**	**Aged**
Bov I	0	1	0	0	3	0	10	175	11
Bov I/II	0	0	0	0	0	0	0	2	0
Bov II	1	11	0	0	9	0	15	29	1
Bov II/III	0	2	0	0	0	0	1	1	0
Bov III	2	29	2	0	5	0	9	20	1
Bov III/IV	0	7	0	0	0	0	0	2	0
Bov IV	2	10	0	0	1	0	2	4	2
Bov IV/V	0	0	0	0	0	0	1	1	0
Bov V	0	0	0	0	0	0	0	4	0
Suid	0	6	0	1	5	0	12	26	7
Equid	0	3	0	0	5	0	0	0	0
Total	**5**	**69**	**2**	**1**	**28**	**0**	**50**	**264**	**22**
% of total ungulate assemblage	0.64%	8.85%	0.26%	0.21%	5.86%	0.00%	1.67%	8.83%	0.74%

Table 7.9 Age data for HP and post-HP MSA (in NISP)

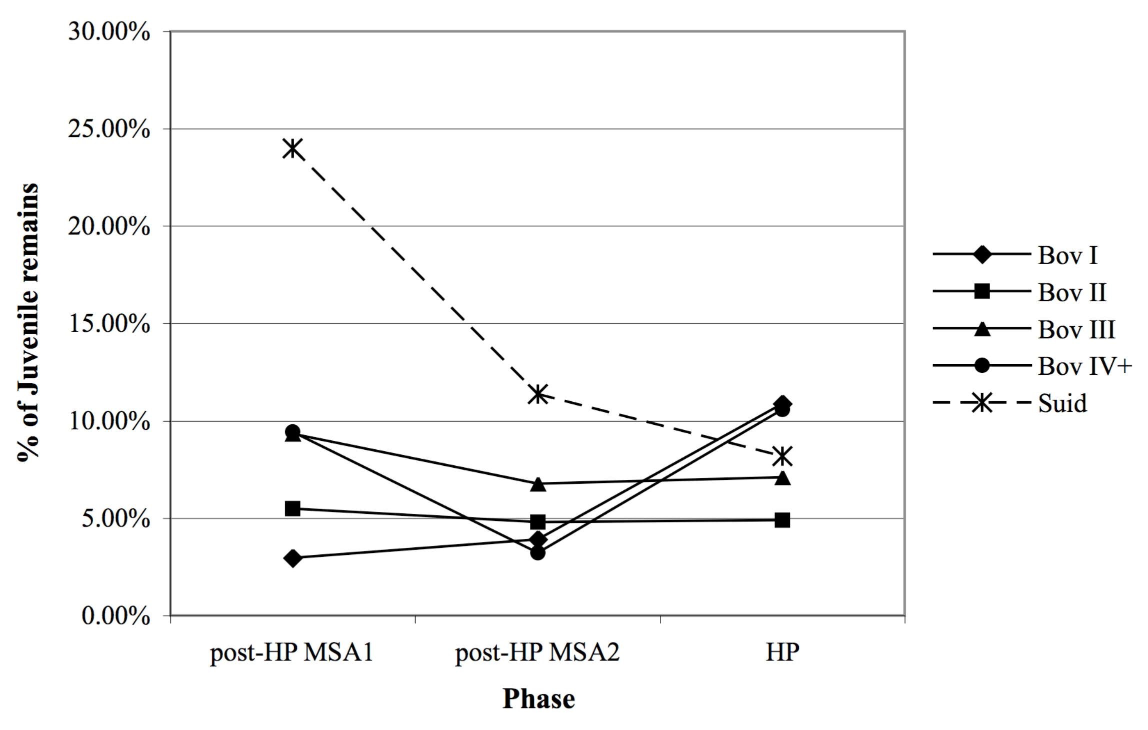


Figure 7.4 Proportion of juvenile remains by phase

patterns emerge. Figure 7.4 plots the percentage of juveniles as compared to the total number of remains for the major bovid sizes classes (due to small samples, the largest size classes (Bov IV+) were combined for analysis) and suids (equids are not included on the chart because of the extremely low sample sizes for the HP and the post-HP MSA 2).

The first and most obvious difference lies in the proportion of juvenile suid remains, which rises steadily over time (the difference is significant, with χ^2=6.861 and p = 0.0088, however, there is again a potential issue because 20% of the expected frequencies are less than 5). Juvenile suids were also taken more frequently than juvenile bovids in the post-HP MSA—this difference is especially marked in the post-HP MSA 1. While this pattern would appear to be opposite from what would be expected if resource stress were more common in the HP, it may be that the increase in suid remains in the post-HP MSA is actually related to changes in procurement technology. As discussed in the previous section, if the HP inhabitants of Sibudu *did* have the bow and arrow, or perhaps some form of remote capture technology, procuring adult suids would have been relatively less dangerous. If the post-HP MSA inhabitants of Sibudu no longer had this technology, the focus may have shifted to juvenile suids, which are much more susceptible to predation than the adults (Skinner and Chimimba, 2005).

Another potentially interesting pattern relates to the proportion of juvenile remains in the various bovid size classes. In general, the relative frequency of juvenile remains increases in tandem with body size. There are only two deviations from this pattern—the lower than expected representation of Bov IV juveniles in the post-HP MSA 2, and higher than expected representation of Bov I juveniles in the HP. The broader pattern makes logical sense; juveniles of larger bodied animals will provide more resources and thus should be higher ranked than juveniles of small-bodied animals. It may be that this is a taphonomic signature, with the bones of small-bodied juveniles being more fragile and thus less likely to survive, and yet in both the HP and the post-HP MSA 2, Bov I juveniles are more common than Bov IV juveniles. It will be interesting to see whether this pattern will hold as the sample sizes are increased.

As far as the deviations from this general pattern are concerned, there is a marked drop in the representation of juveniles of the largest bovids in the post-HP MSA 2; however, the small sample of juveniles for this phase (see Table 7.9) makes interpretation of this pattern difficult. Given the much larger sample sizes in the HP, the higher than expected representation of Bov I juveniles in the HP is more likely to reflect a real pattern. There are at least two possible explanations for this. First, the increased focus on juveniles of even the smallest bovids may reflect a real expansion in dietary breadth, as a juvenile blue duiker (again, the most common Bov I species in the HP) would provide very little nutritional value. However, the pattern may also be a reflection of the procurement technology employed by the HP inhabitants of Sibudu.

Studies of modern foraging populations from central Africa who regularly prey on blue duiker have demonstrated that the age profile of capture duikers varies depending on the procurement method employed, with immature duikers more likely to be taken in nets than when traps or snares are employed (Lupo and Schmitt, 2002). Unfortunately, I could locate no data on the proportion of juveniles taken when spears are used, although optimal foraging theory would say that, when taken individually, adults should be preferentially targeted due to their larger body size. In the absence of nets, however, the higher frequency of small bodied juveniles in the HP assemblage may serve as an indication of resource stress during that period.

Diet breadth in the HP and post-HP MSA: summary

In this chapter, I have explored the evidence for variation in diet breadth during the HP and post-HP MSA. In so doing, I discovered that taxonomic diversification, as measured by NTAXA, was not an appropriate measure of diet breadth at Sibudu. This is because analyses of similarity and nestedness indicated that the faunal assemblages from the HP and post-HP MSA were not derived from the same population—not surprising given the fairly strong evidence for climate change presented in Chapter 5.

A consideration of variation in evenness in the representation of high- and low-ranked prey (here defined by body size) was more useful. Both measures of evenness employed for this analysis (the Shannon index and the reciprocal of Simpson's index) indicated that the post-HP MSA 1 assemblage was the least even. Given that this assemblage was dominated by highly-ranked large game, these results suggest that diet breadth was narrowest during this phase. The HP and post-HP MSA 2 showed similar evenness values, but this measure was found to be slightly misleading; while relative abundance values on which the evenness was calculated were similar, the composition of the prey was different, with the HP dominated by small and medium game and the post-HP MSA 2 dominated by medium and large game. This suggests that diet breadth was actually widest during the HP. I also calculated the Abundance Index, which is based on the ratio of large to small game. The index increased over time, again indicating an increase in foraging returns (and a reduction of dietary breadth) after the HP. The increase in large, highly-ranked prey in the post-HP MSA may be linked to the apparent changes in the local environment, as these species tend to occur more frequently in open environments than in forested habitats.

Because a focus on body size alone can obscure important differences in prey handling costs among animals within a given size class, I also looked for variation in the presence of dangerous game, which would have been more costly to procure and thus lower-ranked. Of the seven species that can potentially be aggressive/dangerous, only three were appropriate for consideration: the African buffalo, warthog, and the bushpig, which are, in any case, the three most aggressive species represented in the Sibudu ungulate fauna. There was no clear change over time in the representation of buffalo vs. other similar-sized game (eland), but there was a statistically significant reduction in the exploitation of suids over time. If this is not a reflection of technological changes that would have lowered the risk (and thus the cost) associated with the procurement of this game, then these data mesh with the earlier results and suggest that diet breadth was widest during the HP and declined steadily over time.

I last looked at evidence for the changes in the relative abundance of juvenile remains. While there was no significant difference in terms of the frequency of juveniles at the level of the total ungulate assemblage, breaking the data down revealed some particularly interesting patterns. The frequency of juvenile suids actually increased in the post-HP MSA—so, not only did the total proportion of suids decline over time, but the focus also shifted to increased capture of juveniles, which are much more susceptible to predation than adults—this could be related to the changes in procurement technology. The HP also showed a greater than expected focus on juveniles from the smallest bovids, both as compared to the post-HP MSA, and as compared to other bovid size classes. While larger sample sizes will be necessary for establishing the validity of this pattern, it may be a further indicator of increased dietary breadth during the HP.

As a whole, then, the various lines of evidence that speak to diet breadth appear to correlate well with each other, and indicate that, as predicted by the resource stress model, dietary breadth was widest during the HP and narrowed throughout the post-HP MSA. In the next chapter I will turn to the data on carcass transport and processing strategies to evaluate whether these lines of evidence provide similar results as those presented here.

Chapter 8

Animal Procurement and Processing: Carcass Transport and Processing Strategies

In the previous chapter, I explored evidence for temporal changes in dietary breadth, concluding that signs of expanded dietary breadth did appear to be more common in the HP, as was predicted by the resource stress models. In this chapter, I turn to evidence on carcass transport and processing strategies. Beyond measures of subsistence diversification, more intensive carcass use and processing should be evidenced during periods of stress. Signs of subsistence stress can include increased transport of low utility parts, greater transport distance for high-ranked prey, the exploitation of parts with lower marrow utility, the processing of small game for marrow, and the development (or use) of grease rendering. I will first look to the evidence on part selection and transport strategies, followed by a consideration of evidence for intensified processing.

Part selection and transport

While data on transport patterns can provide valuable information on resource intensification, this data set can be difficult to work with for a variety of reasons. Because these analyses are based on relative element frequencies, taphonomic factors (particularly those that result in the destruction of less dense elements) that can bias element frequency data are a real problem. As such, a number of scholars have argued that analyses should focus only on the more dense elements which are less susceptible to taphonomic processes (see Cleghorn and Marean, 2004; Marean and Cleghorn, 2003). In cases in which there is no clear evidence for density-mediated attrition, analyses of part selection and transport that include all elements should complement the results of those conducted using only the high density remains.

Beyond this, a number of variables can play a role in decision making about element transport, including the number in the hunting party and/or available to help with transport, the distance from the kill site to the consumption site, the condition of the animal, and even the time of day (Lupo, 2006; Miracle, 1995). Unfortunately, many of these factors cannot be well accounted for archaeologically. In general, though, when carcasses require butchery before transport, archaeologists work from the assumption that people will discriminate between parts for transport/processing on the basis of food utility (c.f., Binford, 1978; Munro and Bar-Oz, 2004). As such, *if all else can be held equal,* an increase in the transport of low utility elements has been cited as evidence for resource stress. However, if transport distances varied, prey choice models predict that the greater the transport distance, the more likely it is that low utility elements will be discarded at the kill site (Bird and O'Connell, 2006; Ugan, 2005). If HP populations had to travel larger distances to procure large, open dwelling species, one may thus expect a greater focus on high utility elements among the larger bovids during the HP.

Given that ethnoarchaeological research among hunter-gatherer populations such as the Hadza has demonstrated that smaller prey (Bov I and II size) are usually transported whole (Oliver, 1993), one may expect there to be little change over time in the transport of these animals. For the larger animals, interpretation of transport strategies will be more difficult. As discussed above, if HP populations had to travel longer distances to procure high-ranked prey, we may expect a greater focus on high utility elements from these animals during the HP, and yet, if populations were under sufficient stress, an effort may have been made to transport relatively complete carcasses even at long distances. A variety of methods have been developed to study transport strategies and transport distance, which, in combination, should allow for an evaluation of whether animals were introduced to the site relatively complete, whether they traveled long or short distance to the site, and how transport strategies may have changed over time.

Methods for studying transport strategies

Characterizing transport strategies using "high survival" elements

Using data collected from the Nunamiut, Binford (1978) proposed that a number of distinct transport strategies could be identified based on the patterning evidenced on scatterplots of element frequency versus utility (Figure 8.1). Binford defined these as: 1) bulk strategy, in which the quantity of high and moderate utility bones is maximized, with only the lowest utility parts abandoned at the kill site; 2) the gourmet strategy, in which quality is maximized, with low and moderate utility parts abandoned at the kill site; and 3) the unbiased strategy, in which elements are selected for transport in direct proportion to their utility. To this list, Faith and Gordon (2007) added the "unconstrained strategy," in which skeletal elements are transported in relation to their abundance in a complete animal, regardless of economic utility.

Faith and Gordon (2007) recently developed a quantitative method for distinguishing between these transport strategies. Their method, which is based on the

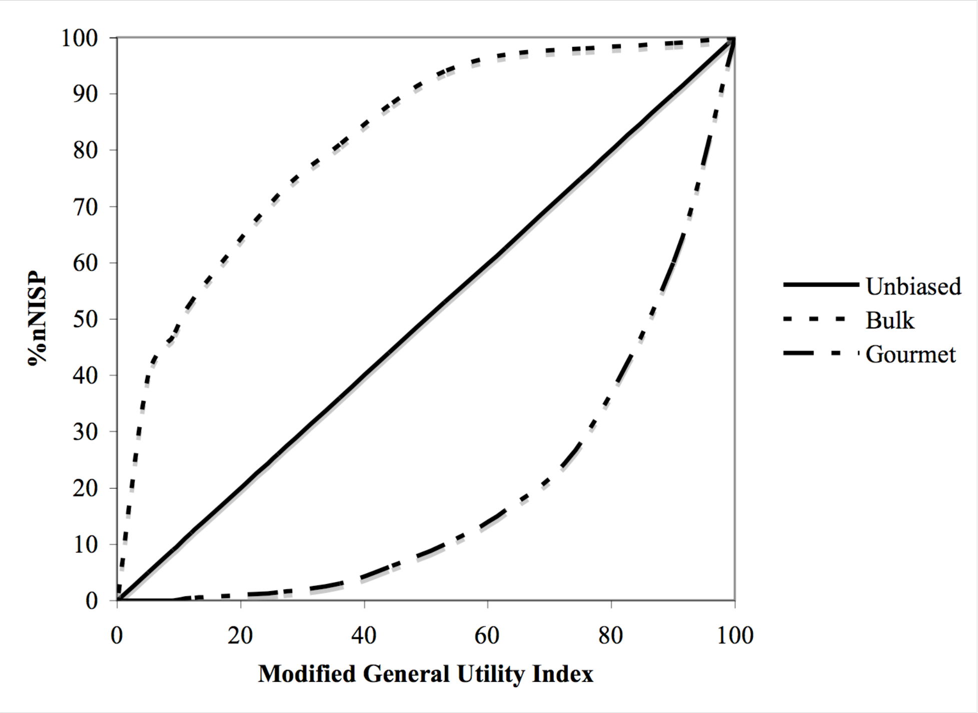


Figure 8.1 Hypothetical utility curves for three transport strategies (based on Binford, 1978)

representation of a selection of "high survival" elements (dense elements which are less sensitive to taphonomic processes), involves a consideration of both the correlation between element frequency and utility (using Spearman's rank correlation coefficient) and the degree of evenness in the representation of high and low utility parts (using the Shannon index). Faith and Gordon were able to demonstrate that, at sufficient sample sizes, a combination of the evenness value and Spearman's rho could effectively separate simulated assemblages drawn from populations characterized by the four hypothetical transport strategies. For example, the gourmet strategy is characterized by high correlation but low evenness, while the unconstrained strategy will have the highest evenness but virtually no correlation between element frequency and utility. Based on their similar evenness values, the bulk and unconstrained strategies are most likely to be mistaken for each other, but the two strategies produce different correlation coefficients, with high positive values for the bulk strategy and range of negative and positive values, centering around zero, for the unconstrained strategy. To aid in the application of their method, Faith and Gordon provided the mean values and middle 95% range of values for each strategy for a variety of sample sizes (Table 4 in Faith and Gordon, 2007).

Exploring evidence for changing transport strategies using all elements

Given that taphonomic analyses indicated that density-mediated attrition was not a significant factor in the assemblages under consideration, I expanded the analysis of part selection/transport to include all major elements, with the exception of the ribs and vertebrae, which are exceptionally difficult to assign to size class when highly fragmentary. In analyses of element frequencies that use the complete skeleton, the skeleton is usually divided into a number of distinct anatomical units. One of the more commonly cited systems is that of Stiner (2002), who advocated the use of nine distinct anatomical regions: horn/antler, head, neck (cervical vertebrae), axial (thoracic/lumbar vertebrae, ribs, pelvis and sacrum), upper front limb (scapula and humerus), lower front limb (radius, ulna, carpals and metacarpals), upper and lower hind limb (femur only; tibia, tarsals and metatarsals), and feet (phalanges and sesamoids). This particular system has been critiqued because it combines relatively high ranking elements with low ranked ones (particularly for the lower limbs), which can potentially skew behavioral interpretations based on these data (Pickering et al., 2003). For my analysis, I chose to divide the skeleton into five anatomical units: skull (cranium, mandible, and hyoid, no teeth/horn), forelimb (scapula, humerus, radius, and ulna), hindlimb (pelvis, femur, patella, and tibia), distal limb (carpals, tarsals, and metapodials), and feet (phalanges, sesamoids). Using this scheme, the hindlimb and forelimb will be the highest utility, followed by the distal limbs and the skull and feet.

Methods for studying transport distance

Element frequency data have also been used to evaluate transport distance. Miracle (1995) proposed using the representation of feet (as compared to the rest of the carcass) as a means of studying variability in transport distance. This method is based on the assumption that feet, as low utility elements, are likely to be discarded at the kill site. In working with the Nunamiut, Binford (1978) found that there *was* a strong negative relationship between the frequency of phalanges at hunting stands and the distance between the initial kill site and the hunting stand. Miracle (1995) thus argued that a consideration of the relative representation of foot elements can provide a rough indicator of transport distance. He chose to divide the MAU for the feet (based on the first phalanx) by the maximum MAU for the carcass to arrive at a %MAU value for the feet, with a decline in this index indicating increasing transport distance. I will use a more simplified index, in which I compare the proportion of foot elements relative to the rest of the skeleton (using NISP) for each size class, looking for evidence of change over time using a chi-squared analysis. It is worth noting again here that this index, along with those discussed below, is more likely to be useful for studying variation in transport distance among larger game, as small/medium game is more likely to be transported complete.

The proportion of heads that are transported to habitation sites is also known to decline with increasing body size and with increasing distance (e.g., O’Connell et al., 1988). This makes sense, as heads have relatively low utility and are quite bulky. As a result, the relative frequency of heads to post-crania can provide another rough indicator of transport distance. Others have looked at the proportion of crania to mandibles (including dental remains), as the mandible can be removed from the cranium fairly easily and may be transported for the marrow it contains, while the head is left behind (Speth and Clark, 2006; Speth and Tchernov, 2007). In both cases, as transport distance increases, one would expect the relative frequency of heads to decline.

Of course, as alluded to at the beginning of the chapter, these measures are not necessarily as straightforward as they may seem, as the head and the feet are also among those parts that are more likely to be exploited during periods of stress. Heads can provide an important starvation food because of the relatively high fat content of the brains and tongue, and thus crania may be more likely to be transported during periods of resource scarcity (Miracle, 1995; Stiner and Kuhn, 1992). Along a similar vein, the phalanges provide small packages of marrow, and that marrow is relatively labor intensive to extract, yet it is also high in fat and may have been an important source of additional nutrients during times of stress (Binford, 1978; Miracle, 1995; Morin, 2007). Thus, while these measures may provide information on variability in transport distance, if the HP inhabitants of Sibudu were under sufficient stress, they may have made an effort to transport low utility elements even if they had to travel farther in order to procure large game. In any case, these measures are still useful in evaluating whether low utility elements are in fact more common in the HP.

Studying transport strategies at Sibudu: some additional points of note

Before turning to the evidence for part selection and transport during the HP and post-HP MSA, there are two methodological points that need to be raised. First, in considering the transport strategies practiced by the Hadza, Lupo (2006) pointed out that grouping material into size classes can obscure important taxonomic differences in carcass treatment—she found particular differences in the treatment of equids as compared to similar-sized bovids. For this reason, I will limit my analysis to the bovid remains, which should help to mitigate this problem. The second issue relates to sample size. Once the samples are broken down into size classes and then into specific elements/body sections, sample sizes for the post-HP MSA assemblages often became quite small, making statistical manipulation of the data difficult. For this reason, the two post-HP MSA assemblages were combined for these analyses.

Part selection/transport during the HP and post-HP MSA

Using "high survival" elements

I began my analysis of part selection and transport strategies by applying the methodology of Faith and Gordon (2007), with a couple of notable exceptions. Following Cleghorn and Marean (2004), Faith and Gordon defined the high survival elements as the cranium, mandible, humerus, radius, metacarpal, femur, tibia, and metatarsal (note: teeth and horns were not included in counts for the cranium and mandible). They excluded the ulna, perhaps because measures of general utility tend to provide a single value for the "radius/ulna" (see Emerson, 1993; Metcalfe and Jones, 1988). Because the radius and ulna are unlikely to be disarticulated during butchery, and because small sample sizes make me unwilling to discard any potentially informative data, I chose to include the ulna in my analysis, assigning it the same utility value as the radius.

While Faith and Gordon initially advocated the use of MNE/MAU counts, in a later application, Faith (2007) utilized NISP/nNISP counts; I follow the latter method here. In calculating nNISP values, Faith (2007) chose to divide the number of cranial elements by 1, presumably because there is only one cranium. However, virtually every cranial part identified in my assemblage is paired—even when fragments came from an unpaired cranial element such as the frontal or the occipital, the particular fragments identified are in fact paired (left vs. right orbital fragments, occipital condyles). Thus, I also corrected for the number of cranial parts by dividing by 2. This means that all elements under consideration are converted to nNISP values by dividing by 2, and thus whether NISP or nNISP are used, the relative frequencies will be the same.

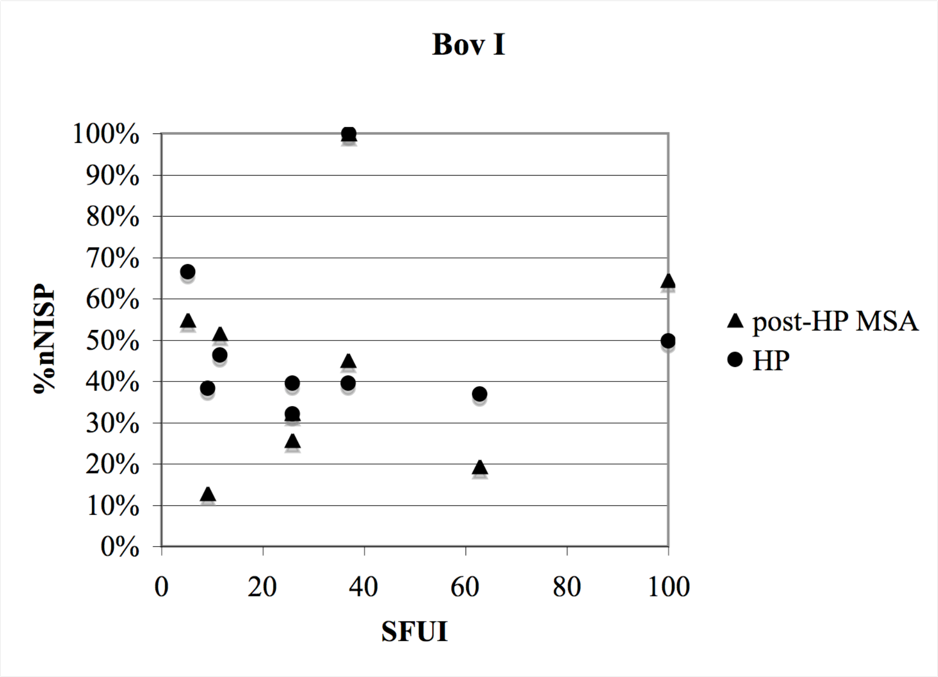
It is also worth making a note here about the utility model employed by Faith and Gordon (2007). They used Metcalfe and Jones' (1988) standardized food utility index (SFUI), a simplified alternative to Binford's modified general utility index (MGUI; Binford, 1978). The SFUI was calculated using Binford's data on the meat, marrow and bone grease content of single caribou. Because there is variation in meat/marrow/bone grease content by species, age, sex, and even season of death, the application of a model based on a single individual to a wide variety of different species has been criticized (e.g., Lupo, 2006); despite this, derivatives of Binford's model have been successfully applied to a variety of archaeological assemblages (e.g., Enloe, 2004; Speth, 1983). While Faith (2007) recognizes potential difficulties in using this model for bovid remains, Faith and Gordon (2007) nonetheless applied the SFUI in their consideration of a series of African MSA assemblages and were able to identify variation in transport strategies. Although they do not specify the reason for their choice, it may be because the most accessible comparable data from a bovid species (Emerson, 1993) does not provide separate values for the cranium and mandible, but rather provides a "skull" value which may or may not include the brain and tongue. In any case, in applying Faith and Gordon's methodology, I chose to use the SFUI; however, in a later consideration of transport in which the frequency of limb elements is compared to their marrow utility, I will use data derived from bovid species.

Table 8.1 data on the representation of the high survival elements. It also provides evenness values and the Spearman's rank correlation coefficient for SFUI vs. element frequency, followed by the most likely transport strategy given those values. Figure 8.2 provides scatterplots of frequency vs. utility for the Bov I, II and III remains; the very large bovids (Bov IV+) were not included because of the small sample sizes for this class. The first thing to note is that there was a statistically significant relationship (at α = .05) between element frequency and SFUI in only one case—for the Bov III size class in the HP. This may indicate a greater focus on higher utility elements during the HP, as would be expected if hunters had to travel longer distances to procure large game.

		Bov I		**Bov II**		**Bov III**		**Bov IV+**	
Element	**SFUI**	**post-HP MSA**	**HP**	**post-HP MSA**	**HP**	**post-HP MSA**	**HP**	**post-HP MSA**	**HP**
Cranium	9.1	2	56	6	11	18	8	6	3
Mandible	11.5	8	68	10	7	14	5	5	1
Humerus	36.8	7	58	13	23	10	9	6	4
Radius	25.8	5	58	9	25	13	9	0	0
Ulna	25.8	4	47	10	18	8	12	0	2
Metacarpal	5.2	8.5	97.5	21.5	31	20.5	8	7	4
Femur	100	10	73	14	17	12	15	2	1
Tibia	62.8	3	54	15	17	29	14	3	0
Metatarsal	37	15.5	146.5	27.5	41	22.5	15	10	0
Total		**63**	**658**	**126**	**190**	**147**	**95**	**39**	**15**
Evenness		0.9304	0.9682	0.9654	0.9516	0.9665	0.9761	n/a	n/a
Spearman's rho		0.2427	0.0126	0.3908	0.0420	-0.0251	***0.8772****	-0.2447	-0.5409
Transport Strategy		U?	U?	U?	U?	U?	B	n/a	n/a

B= Bulk transport; U= Unconstrained transport; *Significant at $p < 0.005$

Table 8.1 Data on SFUI and NISP counts for the "high survival" elements, with measures of evenness, Spearman's rho values, and possible transport strategies



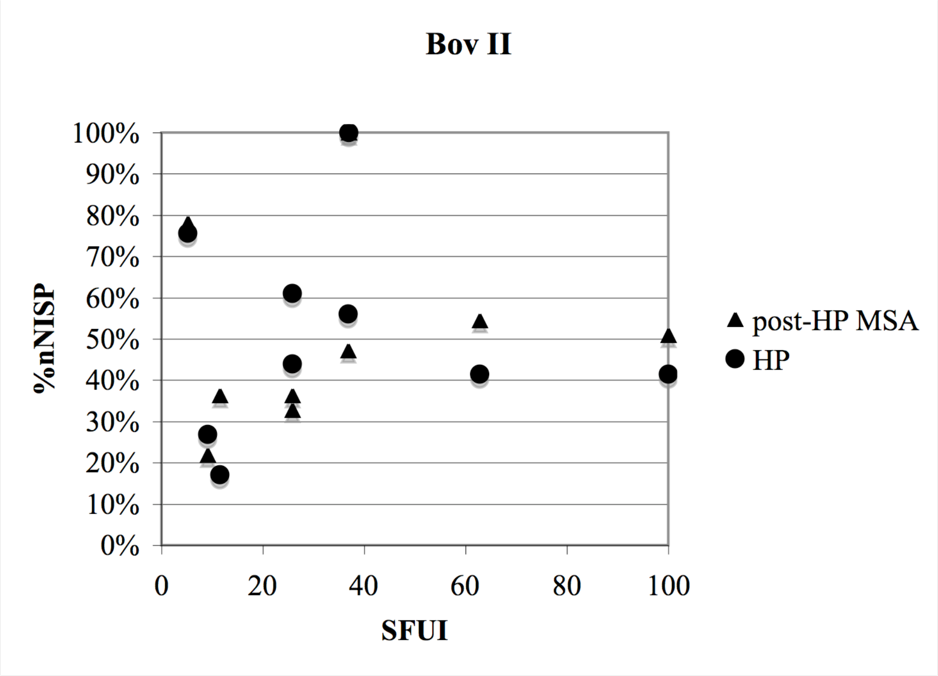


Figure 8.2 Element frequency vs. standardized food utility (cont'd on next page)

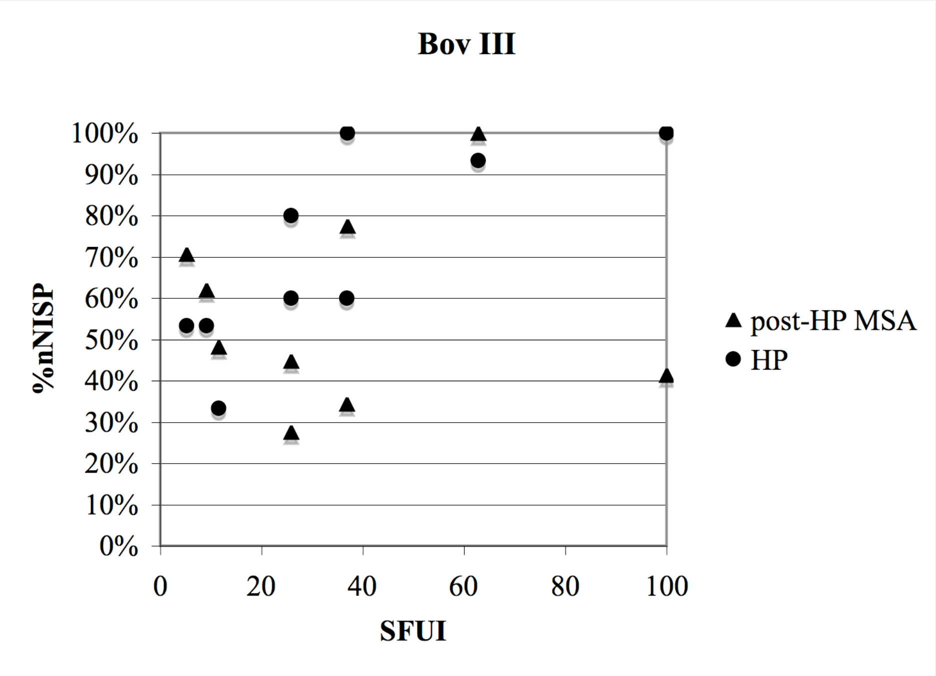


Figure 8.2 (cont'd) Element frequency vs. standardized food utility

In all cases, the assemblages were highly even. As discussed earlier, it can be remarkably difficult to distinguish between bulk and unconstrained transport strategies using evenness values alone; however, bulk transport strategies generally have high and significant positive correlations between utility and element frequency, as was the case for the large bovids from the HP. It would thus appear that in both the HP and post-HP MSA, the small and medium bovids were brought to the site relatively intact (as expected), and that even large bovids were transported as complete or nearly complete carcasses during the post-HP MSA. While the transport strategy appears to have been somewhat different for the large bovids during the HP, the bulk strategy is still one in which the quantity of elements is maximized (as opposed to gourmet and unbiased strategies, where quality is maximized), and, as such, bulk strategies have also been associated with the transport of relatively complete carcasses. I now turn to two alternative methods of exploring variation in transport strategies—a consideration of the relationship between limb bone frequency and marrow utility, and a comparison based on all elements—in order to evaluate whether these lines of evidence show the same patterns as do the high survival elements.

Exploring transport strategies using alternative utility indices: limb frequency vs. marrow rank

As discussed above, the SFUI was calculated using data on from a caribou (a cervid), and while Faith and Gordon (2007) applied the measure to bovid assemblages, there do appear to be some differences in the relative utility of cervid and bovid remains (compare Binford, 1978 with Emerson, 1993; see Miracle, 1995: 390-391 for a discussion). As a result, I compared the relative frequency of limb bones to their marrow utility as another means of exploring variation in transport strategies. Scholars have calculated a variety of marrow utility indices, based on everything from the number of kilocalories provided by a given element, to the marrow cavity volume, to the content of unsaturated fatty acids (e.g., Binford, 1978; Emerson, 1993; Metcalfe and Jones, 1988). The relative rank of the limb elements using a variety of utility measures is indicated in Table 8.2 (1=highest rank, 6=lowest rank); the first two measures are based on cervid remains (in this case, caribou), and the remainder are based on a variety of bovid species. Note that in this case, the ulna is not included since it does not contain a marrow cavity.

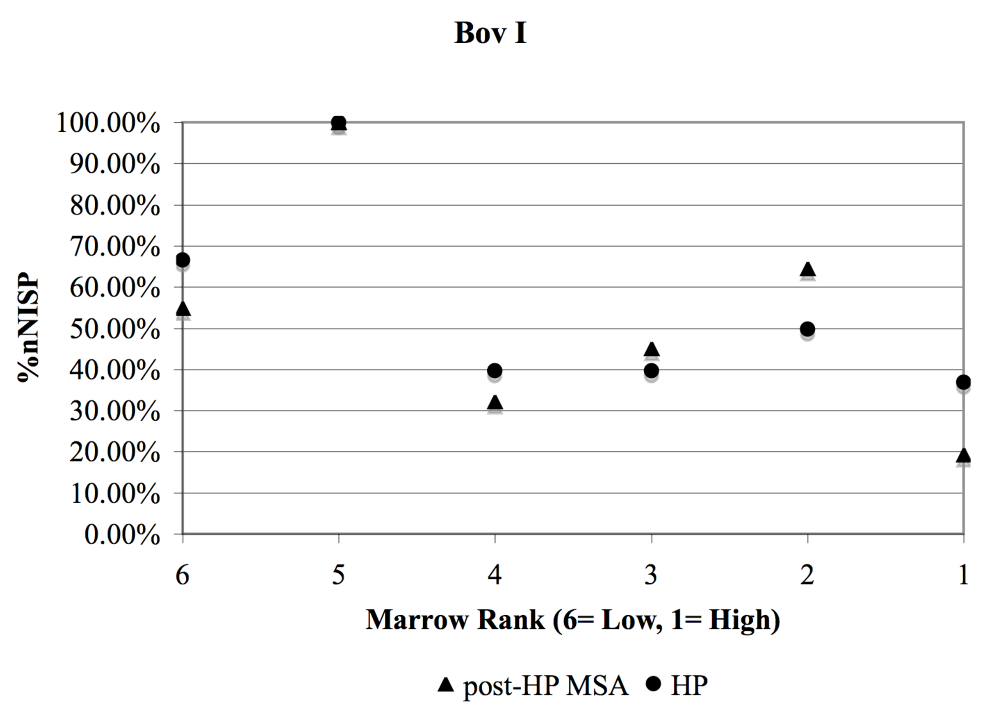
The table raises two interesting points. First, while the relative ranking of caribou parts varied slightly using two different measures of utility, the rankings for three different bovids, using three different methods, were consistent and unchanging. Second,

	Humerus	Radius	Metacarpal	Femur	Tibia	Metatarsal	Source
Caribou- based on marrow cavity volume	4	5	6	2	1	3	Metcalfe and Jones, 1988, data from Binford, 1978
Caribou- Unsaturated Marrow Index	5	4	6	3	1	2	Morin, 2007
Bison- Marrow Fat Model	3	4	6	2	1	5	Emerson, 1993
Gazelle- based on kCal	3	4	6	2	1	5	Bar-Oz and Munro, 2007
Wildebeest- based on return rates	3	4	6	2	1	5	Lupo, 1998

Table 8.2 Limb bone rankings by marrow utility, using different indices of utility

there do appear to be some real differences in the rank order of the cervid and bovid remains—while the highest (tibia) and lowest (metacarpal) elements are the same for both taxa, the metatarsal is lower ranked for the bovids than for caribou, while the humerus and radius are generally higher ranked among bovids than among caribou.

Figure 8.3 plots the relative frequency of the various limb bones (using the data presented in Table 8.2) versus their marrow rank by size class and time period. Again, there was generally a lack of correlation between utility and frequency; only one case showed a statistically significant correlation (Table 8.3)—the Bov II remains from the HP—and in that case, the correlation was actually negative. The significance of this negative correlation is unclear. Within each size class, the relative frequency of the various elements was actually quite similar in the HP and post-HP MSA, although this similarity was most marked among the small and medium bovids. The results indicate that elements were not selected for transport on the basis of their marrow utility, and



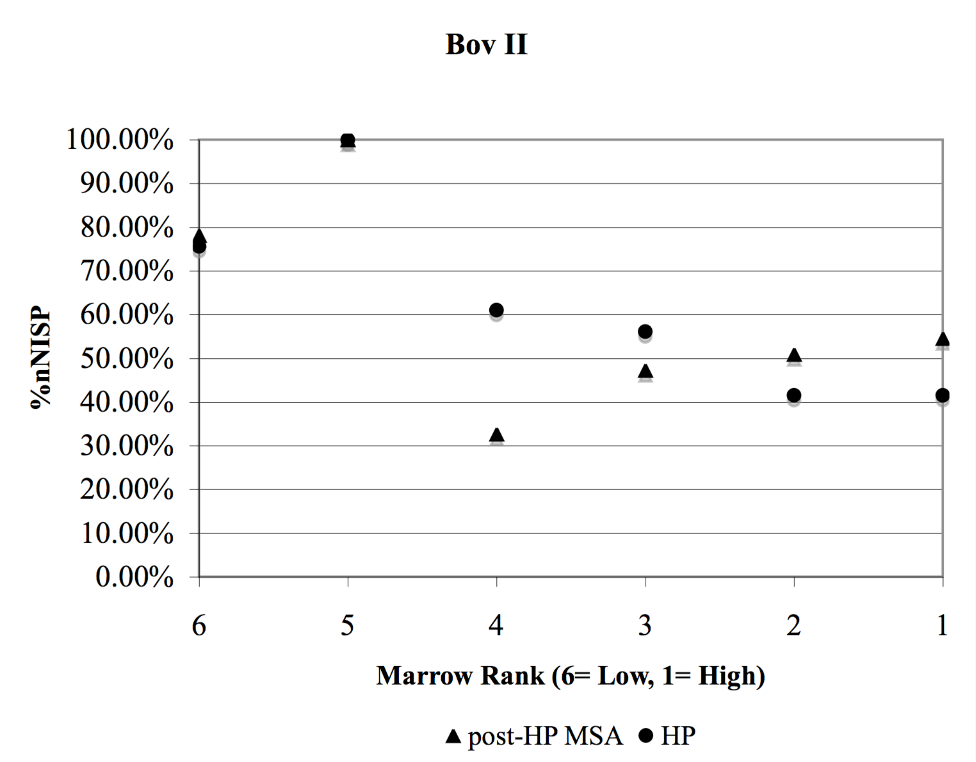


Figure 8.3 Element frequency vs. marrow utility (limb bones only)

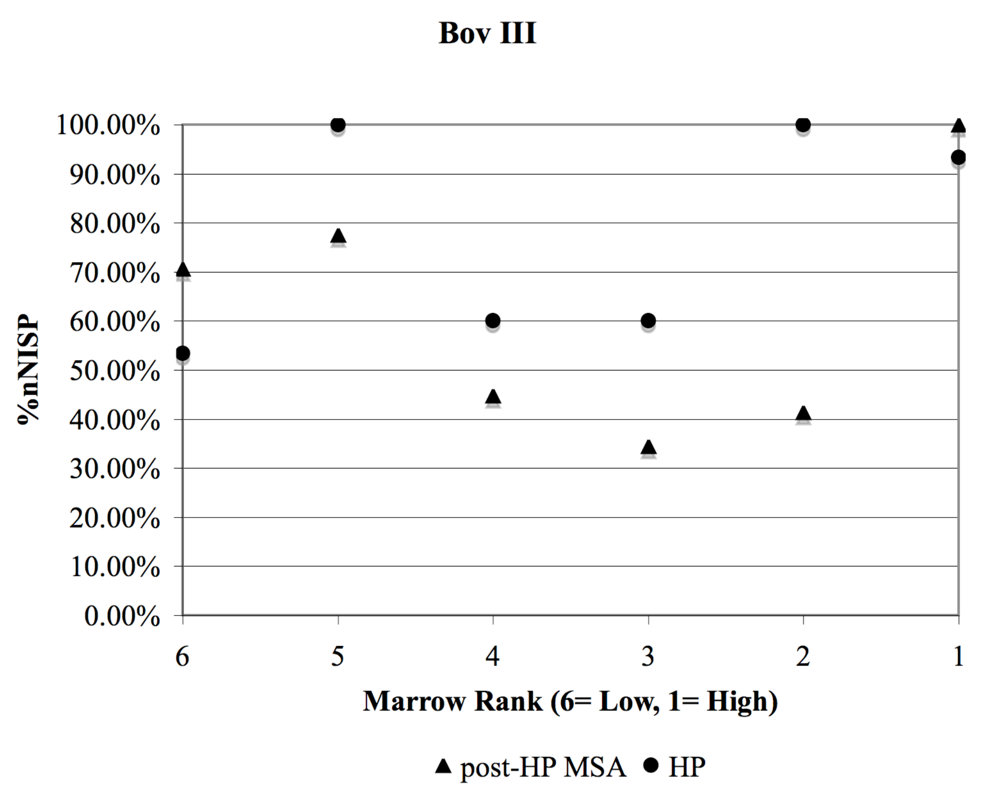


Figure 8.3 (cont'd) Element frequency vs. marrow utility (limb bones only)

again suggest that transport patterns were quite similar in the HP and the post-HP MSA, for both large and small bovids.

Exploring transport strategies using all elements

Given that taphonomic analyses indicated that density mediated attrition was not a significant factor in the assemblages under consideration, I expanded the analysis of part selection and transport to include all major elements, with the exception of the ribs and

	Spearman's rho		
	Bov I	**Bov II**	**Bov III**
post-HP MSA	-0.4857	-0.3714	-0.0286
HP	-0.7537	***-0.9276****	0.4414

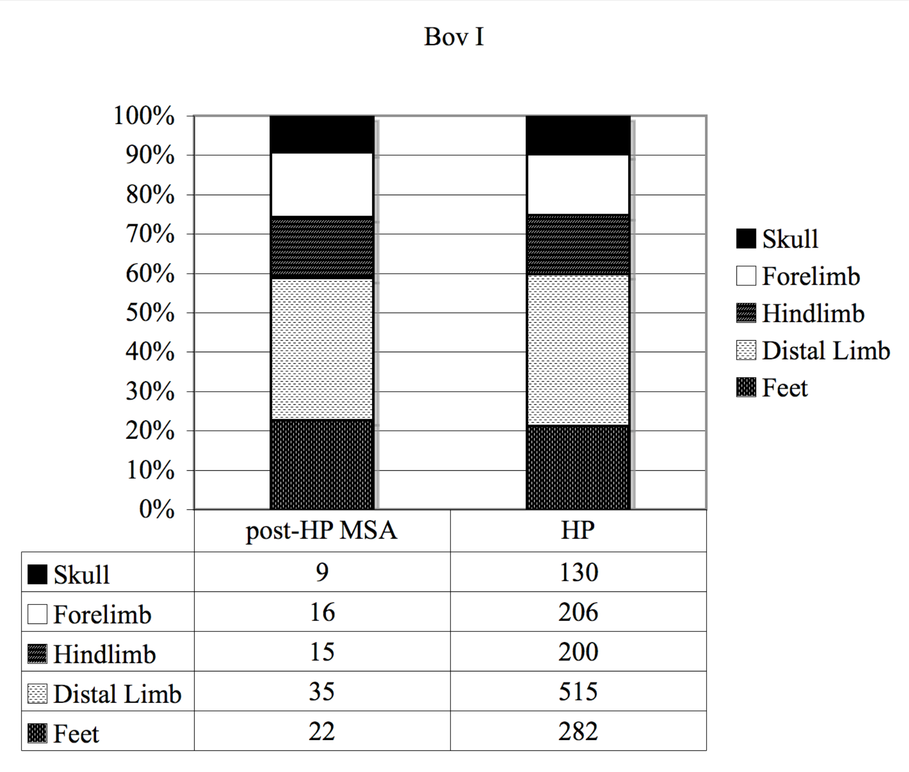
*significant at p < .05

Table 8.3 Spearman's rank correlation coefficient values for marrow utility vs. element frequency

Body Section	Elements Included
Skull	Cranium, mandible, hyoid (no teeth/horn)
Forelimb	Scapula, humerus, radius, ulna
Hindlimb	Pelvis, femur, patella, tibia
Distal Limb	Carpals, tarsals, metapodials
Feet	Phalanges, sesamoids

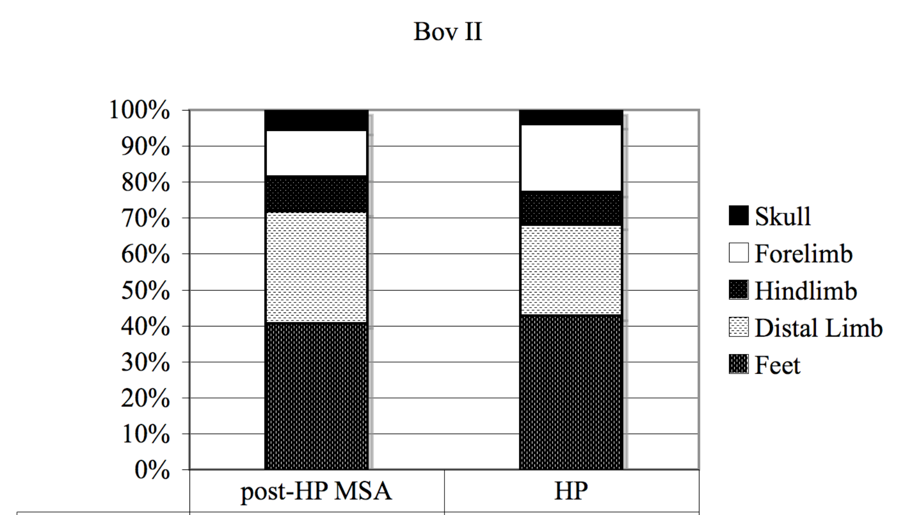
Table 8.4 Anatomical units utilized for analysis of part selection/transport

vertebrae, which are exceptionally difficult to assign to size class when highly fragmentary. The skeleton was divided into five anatomical units: skull, forelimb, hindlimb, distal limb, and feet (refer to Table 8.4 for elements contained within each group). Because I am interested in comparing transport strategies within each size class across time, data for each size class are presented independently in Figure 8.4. Keep in mind that these figures are based on raw NISP counts (included in the data tables)—they



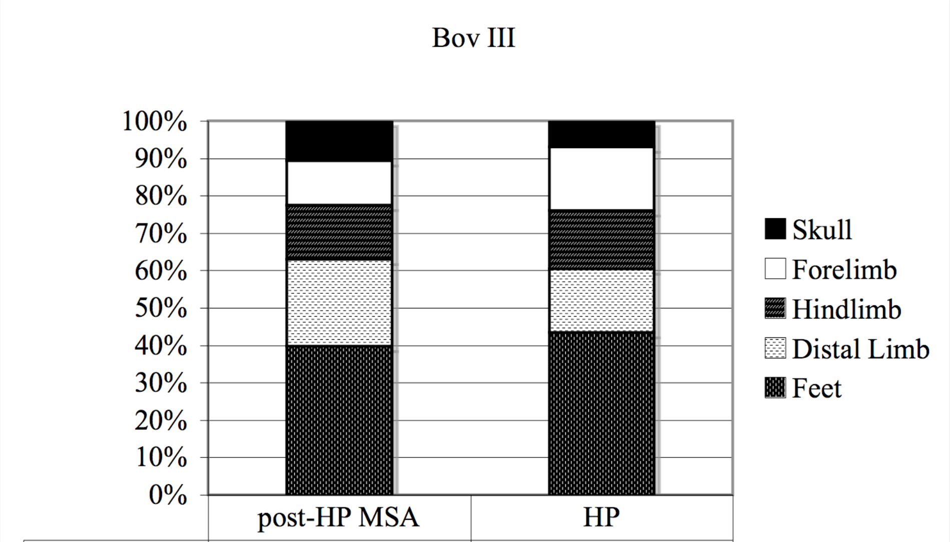
	post-HP MSA	HP
■ Skull	9	130
□ Forelimb	16	206
▨ Hindlimb	15	200
░ Distal Limb	35	515
▩ Feet	22	282

Figure 8.4 Data on anatomical part frequencies by size class and period



Bov II

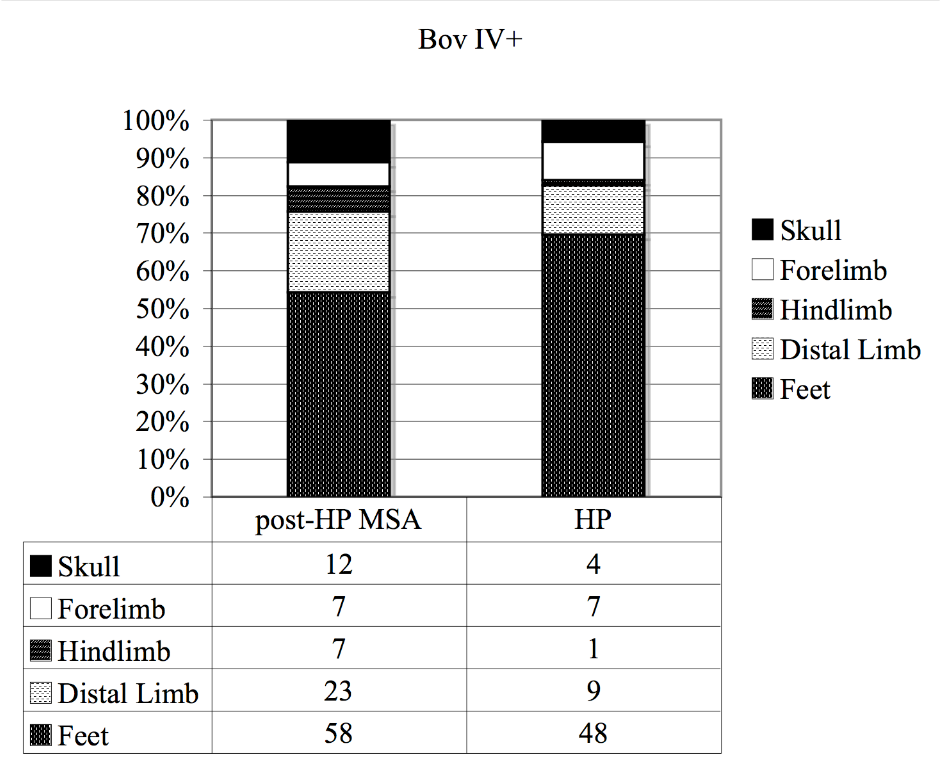
	post-HP MSA	HP
■ Skull	19	21
□ Forelimb	45	103
▩ Hindlimb	33	49
░ Distal Limb	108	137
▦ Feet	140	232



Bov III

	post-HP MSA	HP
■ Skull	31	16
□ Forelimb	35	39
▤ Hindlimb	43	36
░ Distal Limb	68	39
▦ Feet	117	100

Figure 8.4 (cont'd) Data on anatomical part frequencies by size class and period



	post-HP MSA	HP
■ Skull	12	4
☐ Forelimb	7	7
▨ Hindlimb	7	1
░ Distal Limb	23	9
▩ Feet	58	48

Figure 8.4 (cont'd) Data on anatomical part frequencies by size class and period

have not been corrected based on the number of times a given part occurs in the skeleton or for the number of elements within each anatomical unit. Given that change over time is the primary interest, these corrections are not necessary.

When the distribution of the various anatomical units was compared using a chi-squared analysis, no differences were significant at the $\alpha = .05$ level (Table 8.5), although

Size Class	**χ^2 value**	**p**
Bov I	0.35	0.9864
Bov II	8.82	0.0658
Bov III	7.1	0.1307
Bov IV+	7.72*	0.1024*

*at least 20% of expected frequencies less than 5

Table 8.5 Chi-squared results for anatomical unit comparison

the results for the largest bovids (Bov IV+) must be taken cautiously, as at least 20% of the expected frequencies were less than 5, meaning the use of chi-squared may not be appropriate in that case. The potential variation in transport strategies for the large bovids that was identified using Faith and Gordon's methodology is not apparent in this data set, as the lower utility elements (head, feet, distal limbs) are present in similar frequencies in both the HP and the post-HP MSA. The lack of any significant differences across the two time periods again suggests remarkably similar transport strategies over time—this is true for both the small and large bovids.

Evidence for variation in transport distance

A variety of methods have been used for exploring variation in transport distance, many of which involve comparisons of the relative frequencies of certain low utility elements. Because low utility elements are more likely to be transported during times of resource stress, in this case these indices may not serve as valid indicators of changes in transport distance; however, they do provide another means of evaluating whether lower utility elements were in fact more commonly transported during the HP. The first measure looks at the representation of foot bones relative to the rest of the body.   Given the data presented in Figure 8.4, it was not surprising to find that there was no significant variation in the proportion of foot elements between the HP and post-HP MSA for the Bov I, II and III size classes (Table 8.6). The only significant difference was among the largest bovids (Bov IV+), with the HP showing a higher incidence of foot elements. This may indicate that hunters were actually traveling longer distances to procure the largest prey during the post-HP MSA, which would seem to be counter to the expectations of the stress models. Alternatively, it could indicate that the post-HP MSA hunters were under

	Bov I		**Bov II**		**Bov III**		**Bov IV+**	
	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP
Foot elements	22	282	140	232	117	100	58	48
Other	75	1051	205	310	177	130	49	21
% Feet	22.68%	21.16%	40.58%	42.80%	39.80%	43.48%	54.21%	69.57%
χ^2	0.126		0.428		0.721		4.131	
p-value	0.7226		0.513		0.3958		***0.0421***	

Table 8.6 Foot elements vs. remainder of body, in NISP, with chi-squared results, using data from Figure 8.4

less stress and thus could afford to be more selective, choosing to leave the low-utility foot remains behind. Given the relatively small sample sizes, I cannot at present determine which interpretation is more likely to be correct.

The remaining two methods explore variation in the relative frequency of heads. The first looks at the proportion of heads (crania and mandibles, teeth and horns excluded) versus postcrania. Using chi-squared analysis, there proved to be no significant difference in the relative frequency of heads over time (Table 8.7), this was true for all size classes. The final method looked at the relative frequency of cranial vs. mandible fragments (teeth and horns included); again, there were no significant differences in the occurrence of cranial parts over time for any size class (Table 8.8). These results imply that even if the HP populations at Sibudu had to travel longer distances to procure high-ranked prey than did hunters who occupied the shelter during the post-HP MSA, transport strategies remained relatively stable over time.

	Bov I		**Bov II**		**Bov III**		**Bov IV+**	
	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP
Heads	9	130	19	21	31	16	12	4
Postcrania	92	1203	326	521	263	214	95	65
% Heads	9.28%	9.75%	5.51%	3.87%	10.54%	6.96%	11.21%	5.80%
χ^2	0.134		1.305		2.034		1.49	
p-value	0.7143		0.2533		0.1538		0.2222	

Table 8.7 Head elements vs. post-cranial elements, in NISP, with chi-squared results, using data from Figure 8.4

	Bov I		**Bov II**		**Bov III**		**Bov IV+**	
	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP	post-HP MSA	HP
Cranium	4	163	9	19	37	16	16	8
Mandible	11	181	14	17	31	18	15	2
% Cranial	26.67%	47.38%	39.13%	52.78%	54.41%	47.06%	51.61%	80.00%
χ^2	2.48		1.048		0.491		2.51*	
p-value	0.1153		0.3060		0.4835		0.1131*	

*at least 20% of expected frequencies less than 5

Table 8.8 Cranial fragments vs. mandibular fragments (including horns/teeth), in NISP, with chi-squared results

Part selection/transport during the HP and post-HP MSA: summary

Several different methods for studying variation in transport strategies were discussed. Although an analysis based only on the "high survival" elements indicated some variability in transport strategies among the large bovids (Bov III), when the analysis was expanded to include all elements, I could not identify any significant differences in part selection and transport over time. In part because the environmental data suggested that HP populations may have had to travel longer distances to procure large, open dwelling prey, several methods aimed at discerning change in transport distance were also applied. However, these methods typically rely on exploring changes in the representation of low utility elements, which are the same elements that would be exploited more frequently during times of resource stress. In any case, there was once again no significant variation in the occurrence of these parts over time, which indicates that either transport distances remained relatively stable over time, *or* that HP populations made an effort to transport even the low utility elements despite longer transport times (and thus higher transport costs), which could indicate resource stress. As sample sizes are enlarged, I should be better able to choose between these alternatives.

Processing strategies as indicators of resource intensification

Extraction of marrow from low utility parts

More intensive carcass use and processing may also be expected during periods of resource stress. Evidence for more intensive processing might include marrow extraction from parts with low marrow utility, the processing of small game for marrow, and the development of grease rendering. Just as it has been argued that people will make decisions about transport on the basis of food utility, so too has it been argued that people will choose elements for processing on the basis of their food utility (Binford, 1978; Grayson, 1989). A primary method of maximizing the nutritional return of an animal is to incorporate body parts with lower meat/marrow utility into the diet. Among the marrow bearing bones, the phalanges, the pelvis and the mandible contain relatively small marrow deposits. Given the low returns relative to the effort required to extract marrow from these bones, the exploitation of marrow from these elements has been considered a sign of subsistence stress (Miracle, 1995). For the same reasons, evidence that the bones of small prey were processed for marrow should also serve as an indicator of resource stress.

Miracle (1995) employed a relatively basic means of exploring variability in the exploitation of marrow from the first and second phalanges—he simply compared completion indices across assemblages, as complete phalanges were obviously not processed for marrow. Because phalanges are relatively small/dense elements, they are more suited to this method than the mandible or the pelvis, which are often fragmented. Evidence for percussion damage (particularly in the form of percussion pits with striae) on these elements can indicate marrow exploitation, and thus the relative frequency of this damage can be compared over time, with the expectation being that evidence for marrow processing should be more common in the HP than the post-HP MSA. The same criteria can be applied to the bones of small prey.

Development of grease rendering

Bone grease, which is stored within cancellous bone, provides an additional source of fat, but its extraction is both time and labor intensive as compared to the exploitation of meat or marrow. Extracting grease generally requires bones to be broken up and then boiled, with the fatty components skimmed off the top and stored (Binford, 1978; Leechman, 1951; Stiner, 2003). Given the relatively low nutritional yield of bone grease relative to its extraction costs, it has been argued that grease rendering represents a significant form of resource intensification (Church and Lyman, 2003; Lupo and Schmitt, 1997; but see Prince, 2007, who argues that grease rendering is not always linked to stress). Because bone grease is stored primarily in cancellous tissue, highly fragmented/pulverized spongy bone is a key signature of grease processing; unfortunately, as discussed by Munro and Bar Oz (2005), a plethora of taphonomic processes are known to cause the fragmentation of cancellous bone. Stiner (2003, 2005) argued that in addition to highly comminuted spongy bone, the presence of large quantities of heat fractured/heat scarred stone, and large, pitted stone anvils are characteristic of grease processing, and thus that when occurring in concert, these things serve as good evidence for grease rendering.

Evaluating the degree of processing intensity during the HP and post-HP MSA

Unfortunately, due to the nature of fragmentation and the heavy burning present in the Sibudu assemblage, it is not possible to adequately address questions relating to processing intensity using the current sample. For example, virtually all the phalanges in the assemblage are fragmented (among the bovid remains larger than Bov I size, there were only three complete phalanges in the entire assemblage), meaning that completion indices cannot be compared. As discussed in Chapter 6, the heavy burning has negatively impacted surface preservation, and thus evidence for surface damage is sparse. As such, comparing the number of low utility bones (or bones of small bovids) preserving percussion damage is not possible (again, to illustrate, only four low-utility bones and two Bov I bones preserve direct evidence of percussion damage). Along similar lines, it is not currently possible to judge whether bones were processed for grease at Sibudu. While spongy bone may be underrepresented (see Chapter 6 for discussion), the cause of the destruction of this bone cannot be attributed to grease processing—it may have more to do with the intensity of burning. However, fire-cracked rock of the type that would be expected if hot-stone boiling were being practiced is largely absent, as are large anvil stones, which may indicate that grease rendering, at least in the form evidenced among later Upper Paleolithic and historic foragers, was not practiced at Sibudu.

Carcass transport and processing: summary

In this chapter, I focused on evidence for resource stress in terms of carcass transport and processing strategies. Under the stress models, it was expected that the HP would show signs of more intensive carcass use and processing than evidenced during the post-HP MSA. Keeping in mind the relatively small sample sizes (particularly for the post-HP MSA) and the potentially confounding variables, the available data seem to indicate a remarkable degree of consistency in decision making about element transport between the HP and post-HP MSA, which appears to go against the predictions of the resource stress model. Because ethnographic data have indicated that small and medium bovids are often transported whole, the apparent lack of change in the treatment of the small and medium bovids was not unexpected. However, during both periods, it also appears as though even the large bovids may have been introduced to the site relatively complete. If the HP inhabitants of Sibudu were required to travel longer distances to procure high-ranked large game, this may indicate resource intensification, as transport costs would have significantly increased; however, with the current data set it is not possible to adequately address the issue of transport distance. Unfortunately, due to the nature of fragmentation and burning in the assemblage, it was also not possible to evaluate whether more intensive processing strategies were being practiced during the HP. Thus, while data on prey selection and diet breadth provided support for the resource stress model, data on transport and processing during the HP and post-HP MSA at Sibudu are much more equivocal. In the final chapter, I will pull the faunal data together in order to more fully evaluate the resource stress model and to address the implications of the variability evidenced in the Sibudu assemblage.

Chapter 9

Testing the Stress Model: Summary and Conclusions

In this chapter, I summarize the results of my work, followed by an evaluation of the stress model. I conclude with a discussion of the implications of the current study to our understanding of the HP and to our understanding of the evolution of modern human culture.

A growing body of evidence has suggested that the evolution of a fully modern cultural system was not a revolutionary event, nor was it part of a unidirectional process. In particular, the patchy expression of modern traits during the MSA—which includes discontinuous evidence for symbolically mediated behavior (universally considered to be a signature of modern cognition)—implies that the emergence of such behaviors is not solely attributable to changes in cognitive capacity. The question has thus become, what were the factors that rendered modern behaviors advantageous in some contexts but not in others? A small but growing number of scholars have proposed that the emergence of these behaviors may be linked to ecological or demographic factors. These new models have taken three forms—1) those that link the emergence of modern behaviors to environmental degradation, 2) those that point to population pressure as a prime mover, and 3) those which cite demographic growth as a prime factor (without requiring pressure).

Under the first two of these models, modern behaviors represent a form of social and economic intensification in response to stress caused by an imbalance between population and resources. Because subsistence strategies should be particularly sensitive indicators of periods of stress, I sought to test these models through a comparative analysis of HP and post-HP MSA fauna from Sibudu Cave (KwaZulu-Natal, South Africa). If the innovations present in the HP reflect a form of social and/or economic intensification in response to stress, then signs of subsistence intensification, including expanded dietary breadth and more intensive processing strategies, should be restricted to or more common in the HP than in the post-HP MSA.

Sibudu was ideally suited to such an analysis because of its meticulous excavation and good faunal preservation; furthermore, OSL dating indicates that it is one of the few known sites to have been occupied during the transition from the HP to the post-HP MSA (Wadley and Jacobs, 2006; Wadley, 2006). Sibudu has also been the focus of a remarkable amount of multidisciplinary work, and thus the faunal data can be considered within a rich context. Previous work has raised two points, in particular, which are relevant to a consideration of variability in subsistence behavior in the HP and post-HP MSA. The first relates to procurement technology—the HP lithic assemblage is unique as compared to the remainder of the MSA sequence in that stone points are almost entirely absent; instead, the retouched assemblage consists primarily of geometric backed tools such as segments and trapezes (Wadley, 2006). This appears to reflect a focus on a different type of hunting technology, with metric analyses indicating that some of the backed segments may have functioned as arrow points (Wadley and Mohapi, 2008; Wadley, 2008). A bone point recovered from the HP layers was found to be virtually indistinguishable from prehistoric and ethnographically documented arrow points, providing an additional line of evidence that the bow and arrow may have been employed during the HP (Backwell et al., 2008). In contrast, the post-HP MSA assemblage is dominated by traditional MSA stone points; metric data indicate that these were used to tip spears that were thrust or perhaps hand-cast (Villa and Lenoir, 2006). It was expected that the variation in technology evidenced between the HP and post-HP MSA may also be reflected in the faunal remains, perhaps relating to a shift to the exploitation of a different suite of prey in the post-HP MSA.

The age of the HP and post-HP MSA deposits is consistent with the dating of the transition from OIS 4 (a glacial) to OIS 3 (an interstadial) from the Vostok ice core, and archaeomagnetic data indicated that this transition may have been captured within the post-HP MSA, with the lower deposits having characteristics consistent with those expected during a glacial period (Herries, 2006). Because the timing of this transition coincided with a shift in raw material usage and with the disappearance of some unusual tool types, the decision was made to split the post-HP MSA into an upper and lower unit. Given that the post-HP MSA sequence appears to preserve the transition from OIS 4 to OIS 3, at least some variability in the faunal assemblage was expected purely as a function of shifting habitat types. In order to evaluate to what degree variability in the faunal assemblage could be attributed to environmental change, I integrated botanical and faunal data in order to reconstruct the paleoecology of the Sibudu region during the HP and post-HP.

As a whole, the two data sets complemented each other quite well, with both indicating that a marked shift in the local environment had occurred by the end of the post-HP MSA. The flora and fauna indicated the presence a strong evergreen forest component during the HP, with several lines of evidence also suggesting that conditions were humid during this phase (Allott 2006a, b; Clark and Plug, 2008; Hall et al., 2008). Unfortunately, data speaking to conditions during the phase immediately post-dating the HP were incredibly limited, although the available sample may indicate the beginnings of a shift towards more open conditions. The botanical data from the post-HP MSA 1 suggested a trend toward drier conditions and a clear shift towards more deciduous/open vegetation. The size of the evergreen forest surrounding the site appears to have declined significantly—by the end of the phase, the vegetation may have been characterized by a small patch of evergreen forest along the river with larger patches of well-grassed savanna on the surrounding slopes (Allott, 2005; 2006b; Hall et al., 2008; Wadley, 2006). The faunal sample from the post-HP MSA 1 was also quite distinct from the HP, with a vast majority of the remains now coming from species that preferentially inhabit more open environments. Future work on the charcoal assemblage and an expanded faunal sample from the post-HP MSA 2 is planned so as to allow for an evaluation of whether the changes in climate were more gradual or abrupt; in any case, given the magnitude of change, it is clear at least some variability in hunting behavior will be attributable to shifts in the local environment.

Before exploring the evidence for variability in human hunting behavior over time, it was first necessary to reconstruct the taphonomic history of the site in order to demonstrate that patterning in the faunal record was a product of human behavior rather being an artifact of carnivore activity or post-depositional decay. Although the incidence of surface damage was low, signs of human involvement (cut/chop marks and percussion damage) were more frequent than carnivore/rodent damage; furthermore, carnivore remains were rare and the faunal remains were associated with hearths and a rich lithic assemblage. All of these lines of evidence indicate that the fauna was accumulated predominantly by human activity. Two additional characteristics indicating human involvement were the high degree of burning and fragmentation. Detailed analysis aimed at identifying the nature and extent of burning indicated that much of the burning was probably the result of bones being discarded into fire as a means of disposing of food waste—this was true for both the HP and post-HP MSA. All three assemblages were highly fragmentary; since burning promotes fragmentation, this was not surprising. A variety of methods were used to characterize the nature of the fragmentation, from which I found that the extent of fragmentation was quite similar across the three units.

After faunal material has been deposited, it can be fragmented by a variety of chemical and/or mechanical processes. These processes can impact the interpretation of patterns in relative element abundances, as less dense bones are more susceptible to post-depositional attrition—if the degree of post-depositional destruction varies across assemblages, changes in the element frequency data may reflect taphonomic processes rather than variation in human behavior. Two stages were involved in this analysis; first, I applied a modified version of Marean's (1991) Completion Index in order to compare the degree of post-depositional fragmentation across the three assemblages. In so doing, I found that while all of the assemblages appear to have suffered from some post-depositional fragmentation, there were no significant differences in the degree of that fragmentation. Next, I turned to a standard series of density measures (provided by Lam et al., 1999) in order to evaluate the relative impact of density-mediated attrition on the assemblage. I found that there were no significant positive correlations between element frequency and density for any size class or time period, indicating that the assemblages were not significantly biased by density-mediated attrition. This implies that patterning in the element frequency data should be reflecting variability in human transport and/or processing behaviors.

Having established that the faunal assemblages were accumulated primarily by human activity, and because there did not appear to be any significant differences in the degree of fragmentation or post-depositional attrition, I turned next to the data on animal procurement and processing. Under the resource stress model, it was expected that signs of expanded dietary breadth, including greater taxonomic diversity, increased evenness in the representation of high- and low- ranked prey, and a greater focus on dangerous game, would be more common in the HP than in the post-HP MSA.

While taxonomic diversification was not found to be an appropriate measure of diet breadth at Sibudu, a consideration of variation in evenness in the representation of high- and low- ranked prey (here defined by body size) was more useful. Two different measures of evenness indicated that the post-HP MSA 1 was the least even (indicating the narrowest diet), which is the expected condition when high-ranking prey are abundant. Evenness values for the HP and post-HP MSA were quite similar; however, this was in large part because the measures of evenness employed consider only relative abundance values and not the prey rank. In fact, the HP was dominated by small and medium game, while the post-HP was dominated by medium and large game—this suggests that diet breadth was in fact widest during the HP. The Abundance Index, which is based on the relative proportion of large vs. small game (in this case "small" being defined as the smallest bovids), also indicated a steady increase in foraging returns after the HP. While these results do meet the expectations of the stress models, it is relevant to note that the shift from small to large game may well be a reflection of the changes in the local environment, as larger bovids of the type that dominate the post-HP MSA 1 assemblage also tend to be those occurring in more open habitats.

Because a focus on body size alone can obscure important differences in prey handling costs among animals within a given size class, I also looked at variation in the presence of dangerous game, as this prey would have been more costly to procure and thus lower-ranked than more docile game. Three species identified in the assemblage are widely known to be aggressive/confrontational—the African buffalo, the warthog, and the bushpig. While there was no clear change over time in the representation of the buffalo (as compared to other similar sized game), suids were most common in the HP, and there was a statistically significant reduction in the exploitation of suids (relative to similar sized bovids) over time. If the higher occurrence of suids in the HP is not a reflection of technological changes that would have lowered the risk (and thus the costs) associated with the procurement of these species, then these data also suggest that diet breadth was widest during the HP and narrowed over time.

Because of their small size and limited body fat, juveniles should be comparative low-ranked resources, and, as such, should be more commonly exploited during times of stress. At the level of the total ungulate assemblage, there was no statistically significant difference in the relative abundance of juveniles over time. However, breaking down the data by animal type revealed some potentially meaningful patterns. There was actually an increase in the frequency of juvenile suids over time, which means that not only were fewer suids exploited in the post-HP MSA, but the focus shifted to juveniles, which are much more susceptible to predation. This could actually be a reflection of the changes in hunting technology—if the risks associated with the capture of suids were higher during the post-HP MSA, the decision to focus on the least dangerous individuals (the juveniles) makes sense. More relevant to our consideration of diet breadth, the HP also showed a greater than expected focus on juveniles from the smallest bovids, both as compared to the post-HP MSA and as compared to other bovid size classes. This could be an additional sign of subsistence intensification during the HP, although larger sample sizes will be necessary to confirm the validity of this pattern.

I next turned to evidence for resource stress in terms of carcass transport and processing strategies. Decision making on transport depends upon a number of independent variables, many of which cannot be adequately addressed archaeologically; however, archaeologists generally work from the assumption that people will discriminate between parts for transport on the basis of utility. Following from this, if all else can be held equal, the increased transport of low-utility skeletal parts has been considered to be evidence of resource stress. However, if HP populations were required to travel longer distances in order to procure large, open dwelling game (resulting in increased transport costs), prey choice models actually predict that there should be a greater focus on high-utility elements among those species during the HP.

As a result of the relatively small sample sizes, in exploring variation in transport strategies over time, the post-HP MSA 1 and 2 were combined into a single unit. While this may obscure some temporal trends, the available data indicated a remarkable degree of consistency in decision making about element transport between the HP and post-HP

MSA, counter to the expectations of the stress model. During both periods, it also appears as though even the large bovids may have been introduced to the site relatively complete. If large game was being transported over greater distances during the HP, this may indicate the presence of resource intensification, as transport costs would have increased hand in hand with transport distance. At present, however, the available data do not allow me to judge whether (or how much) transport distances varied over time.

I turned last to evidence relating to processing strategies; under the stress model, it was expected that signs of intensified processing would be more common in the HP than in the post-HP MSA. Classic signs of subsistence intensification include the extraction of marrow from low utility elements (such as the phalanges) and from small game, as well as the development of grease rendering. Unfortunately, the highly burned and fragmented nature of the assemblage made it impossible to evaluate the degree of processing intensity during either the HP or post-HP MSA.

Testing the stress model

Table 9.1 summarizes the results of the test of the stress model. While measures of diet breadth generally agreed in indicating the presence of resource intensification during the HP, the transport data are more equivocal and suggested no difference between the two periods, which was counter to the expectations. Unfortunately, the current dataset was not appropriate for addressing questions relating to variability in processing intensity. Although all of the expectations were not met, when present, signs of subsistence intensification were more common in the HP—the faunal data thus provide tentative support for the stress models.

Lines of Evidence	Expectations	Results	Expectations Met?
Diet Breadth			
Taxonomic Diversity	Higher in HP	N/A	N/A
Evenness	Higher in HP	Higher in HP	Yes
Small Game	More common in HP	Most common in HP	Yes
Dangerous Game	More common in HP	Suids more common in HP	Possibly?
Juveniles	More common in HP	No difference overall, but Bov I juveniles over-represented in HP?	Possibly?
Part Selection/Transport			
Transport of Low Utility Parts?	More common in HP?	No difference	No
Transport Distance?	Greater for high ranked prey in HP?	No difference	No
Processing			
Marrow Processing	More processing of low utility parts in HP	N/A	N/A
Grease Processing	More common in HP	N/A	N/A

Table 9.1 Results of the test of the stress model

It is worth noting here that the lithic assemblage may provide an additional data set against which the stress model can be evaluated, as the development of complex weaponry has also been viewed as an indicator of expanded dietary breadth (e.g., Hawkes and O'Connell, 1992; Kuhn and Stiner, 2001; O'Connell, personal communication; Ugan, 2005). There are a variety of reasons for this. As technological complexity increases, the amount of time and energy expended in making and maintaining artifacts also increases (Kuhn and Stiner, 2001). As a result, a large animal taken with a relatively low-cost weapon (such as a single component spear) would be of higher rank than the same animal taken with a more expensive system (such as the bow and arrow). On the basis of the available evidence, the technology evidenced in the HP would appear to be much higher cost than that evidenced in the post-HP MSA. Not only is the production of bone points much more time- and labor-intensive than the manufacture of stone points (Knecht, 1997), but it has also been documented that projectile weapons equipped with microlithic inserts are significantly more expensive to produce than same weapons using other stone or simple organic points (Bird and O'Connell, 2006; Elston and Brantingham, 2002). The lithic data thus provide an additional line of evidence for wider diet breadth in the HP, suggesting again that the stress models do have merit.

Following from this line of reasoning, as average return rates fall, the payoffs from more efficient handling begin to increase, such that broader diets should be accompanied by greater investments in handling technology (see Bird and O'Connell, 2006 and O'Connell, 2006 for a discussion)—this seems to have been the case during the HP at Sibudu. As high-ranked prey became more abundant during the post-HP MSA, the payoffs provided by the more costly weaponry system may have declined, promoting the return to a simpler and more cost-effective hunting technology. Could this really explain why a seemingly more efficient technology such as the bow and arrow may have been abandoned? Here I quote Bird and O'Connell (2006:153):

> It is often said that the adoption of more expensive subsistence technology marks an improvement in this aspect of food procurement: better tools make the process more efficient. This is true in the sense that such technology often enables its users to extract more nutrients per unit weight of resource processed or area of land harvested. If, on the other hand, the key criterion is the cost/benefit ratio, the rate of nutrient gained relative to the effort needed to acquire it, *then the use of more expensive tools will often be associated with declines in subsistence efficiency*. Increased investment in handling associated with the use of high-cost projectile weapons, in plant foods that require extensive tech-related processing, and in more intensive agriculture all illustrate this point. (emphasis added)

If Bird and O'Connell (2006) are correct, then there is no need to invoke a model of a population crash (e.g., Cochrane, 2008) or a population extinction (e.g., Bar-Yosef, 2002) to explain the loss of the more advanced, but also more costly, technology of the HP. This is not to say that population instability could not also have played a role in the reversion to a more typical MSA pattern—we do not have sufficient data available to judge whether or not this was the case—but simply to say that other factors could also explain the evidenced patterning.

As a whole, the data from the HP and post-HP MSA at Sibudu indicate that the same stress models that have been invoked to explain the emergence of classical signatures of modern behavior among much later populations whom we know to have been fully modern (e.g., late Pleistocene populations in Australia and North America; see O'Connell and Allen, 2007; Speth, 2004b) may also apply to the much earlier emergence of these traits in the late Pleistocene. If, as seems to be the case, the cognitive capacity for modern behavior was already in place in the HP, the implication is that this capacity was also present during the post-HP MSA—and, as such, that the absence of traditional signatures of modern behavior in that period cannot serve as evidence that such capabilities were lacking (the old "absence of evidence is not evidence of absence" adage).

What does this mean for our understanding of behavioral and cultural evolution? It may mean that the absolute origins of modern human capabilities will be impossible to track archaeologically (O'Connell and Allen, 2007). But it may also be the case that we need to find new ways of defining what it is to be modern—and how these traits can be identified in the archaeological record. Work by Stiner and Kuhn (2001), who have attempted to characterize the limits of variation among recent hunter-gatherers, and then to use those observations as a baseline of assessing behavioral variation in the past, seems like a step in the right direction.

Future directions and food for thought

Although the present test was designed for a general stress model, in this case, the advanced behaviors associated with the HP do appear to be linked to a period of lowered environmental productivity—the material culture associated with the HP may thus reflect an adaptation to a specific set of environmental circumstances. Data that speaks to conditions during the HP and post-HP MSA at other sites will be necessary in determining whether this model applies further afield; it is interesting to note that preliminary results from Diepkloof (located in the Western Cape) show a similar pattern, with small game such as molerat, hyrax and hare occurring more commonly in the HP while large grazing animals are more frequent in the post-HP MSA (Parkington et al., 2005). Of course, while the environment seems to be an important factor in this case, I am certainly not proposing it as a universal model. The factors influencing the appearance (and disappearance) of "modern" behaviors likely varied, and population growth was no doubt important in the longer term.

In thinking about the implications of this work to our understanding of the HP to post-HP MSA transition, I would argue that the variability in diet and technology at Sibudu reflects an ability to successfully adapt to long term changes in the environment. The data clearly indicate that both the HP and post-HP MSA inhabitants of Sibudu were capable hunters who focused on a wide variety of game, both dangerous and docile, large and small. Despite the variation in hunting technology and subsistence behaviors, there are some striking incidences of behavioral continuity. In both periods, it appears as though bone was systematically discarded into fire as a means of disposing of waste, a practice that is by no means universal among modern hunter-gatherer populations. Even more striking was the apparent consistency in decision making relating to part selection and transport. Recognizing this continuity is important, as some have argued that the HP disappeared because its makers suffered a population extinction (Bar-Yosef, 2002), while others have proposed that it was the makers of the HP who migrated out of Africa (Mellars, 2006b)—both of these models imply discontinuity between the HP and post-HP MSA inhabitants of southern Africa.

In moving forward, it is clear that we still have much to learn about the nature and extent of variability in human behavior during the periods immediately preceding the emergence of a fully modern cultural system—this is true for both the African Middle Stone Age and the Eurasian Middle Paleolithic. It is my hope that this study has made a contribution to a deeper understanding of this variation, and its potential significance to larger questions about cultural evolution.

Appendix

Element Frequency Data

Notes:
CO/ACO = Complete or Almost Complete
(#) = the number of juvenile or fetal/neonate remains

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Orcyterops afer	Phalanx, Type Unknown	Distal end (or subset thereof)			1
Procavia capensis	Os Petrosum				1
	Upper Molar			1	3
	Mandible w/ teeth	Corpus			1
	Mandible w/o teeth	Ascending ramus			1
	Lower P4				1
	Lower M1				1
	Lower M2				1
	Molar				1
	Molar/Premolar			1	
	Premolar				1
	Scapula	Glenoid + Neck + Blade			1
	Humerus	Distal shaft	(1)		
		Distal end (or subset thereof)			5
	Radius	Proximal end (or subset thereof)			2
		Shaft			1
		Distal end (or subset thereof)			1
	Ulna	Anconaeus	1		1
	Tibia	Proximal end (or subset thereof)			(1)
		Distal end (or subset thereof)			1
	Calcaneum	Indet Fragment			1
	Talus	CO/ACO			1
	Phalanx, Type Unknown	CO/ACO			1
		Proximal end (or subset thereof)			1
Lepus cf. *saxatilis*	Radius	Shaft			1
	Ulna	Olecranon + Anconaeus			(1)
	Tibia	Proximal end (or subset thereof)			1
Pronolagus crassicaudatus	Radius	Distal end (or subset thereof)			1
	Femur	Shaft			1
Pronolagus sp.	Scapula	Glenoid			1
	Ulna	Olecranon + Anconaeus			1
	Innominate	Acetabulum + Ilium			1
	Femur	Shaft			1
	Tibia	Proximal end (or subset thereof)			(1)
Lepus/Pronolagus	Scapula	Caudal Edge			1
	Humerus	Distal end (or subset thereof)			1
		Distal shaft			1
	Ulna	Anconaeus			1
		Shaft			1
	Innominate	Acetabulum + Pubis			1
	Femur	Head or head/neck			1
		Shaft			1
		Distal end (or subset thereof)			1
	Tibia	Proximal shaft/crest			1
		Distal shaft			1
	Metatarsal, Type Unknown	Shaft			2

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Hystrix africaeaustralis	Molar		1		
	Innominate	Indet Fragment	1		
	MC/MT (generic metapod)	CO/ACO			1
	Phalanx, Type Unknown	Distal end (or subset thereof)			1
Thryonomys swinderianus	Upper Incisor			1	1
	Incisor				1
	Molar			1	
	Phalanx, Type Unknown	Distal end (or subset thereof)			1
cf. *Thryonomys swinderianus*	Radius	Proximal end (or subset thereof)			1
Cricetomys gambianus	Maxilla w/ teeth				1
	Upper M1				1
	Upper M2				2
	Upper M3				2
	Mandible w/ teeth	Corpus			2
	Lower M1				3
	Lower M2				3
	Lower M3				1
	Incisor				2
	Axis				2
	Scapula	Glenoid			1
	Humerus	Proximal end (or subset thereof)			1
	Radius	Proximal end (or subset thereof)			3
		Distal end (or subset thereof)			2
	Ulna	Olecranon + Anconaeus		1	3
		Anconaeus			1
	Tibia	Proximal end (or subset thereof)			1
		Proximal shaft/crest			1
		Distal end (or subset thereof)			3
	Talus	CO/ACO			1
	Tarsal, Type Unknown				2
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			1
	MC/MT (generic metapod)	Complete distal end			1
	First Phalanx	CO/ACO			1
	Phalanx, Type Unknown	CO/ACO			4
		Distal end (or subset thereof)			1
		Proximal end (or subset thereof)			4
Rodent large	Maxilla w/ teeth				1
	Upper Incisor				1
	Incisor				2
	Enamel Fragment			2	
	Scapula	Glenoid			2
	Ulna	Olecranon + Anconaeus			(1)
Papio hamadryas	Upper Canine				1
	Upper P3				1
	Upper Premolar				1
	Fibula	Distal end (or subset thereof)			1
		Proximal end (or subset thereof)			2
	Calcaneum	Tuberculum and Corpus			1
	Talus	CO/ACO			1
		Indet Fragment			1
	Tarsal, Type Unknown				1
	First Phalanx	Distal end (or subset thereof)			1
	Second Phalanx	Proximal end (or subset thereof)			2
	Phalanx, Type Unknown	Distal end (or subset thereof)			1
		Proximal end (or subset thereof)			1
Cercopithecus pygerythrus	Upper Premolar			1	1
	Upper Molar				1
	Mandible w/ teeth	Corpus			1

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Cercopithecus pygerythrus	Lower I1				1
	Lower Canine				1
	Lower M1				1
	Lower M3				2
	Lower P3				1
	Lower P4				2
	Incisor				1
	Premolar				2
	M2				1
	M3				1
	Molar				2
	Deciduous Molar				(1)
	Deciduous Premolar				(1)
	Clavicle				1
	Humerus	Distal shaft			1
		Distal end (or subset thereof)			1
	Radius	Proximal end (or subset thereof)			1
	Ulna	Shaft			1
	Patella			2	
	Talus	Indet Fragment			1
	Tarsal, Type Unknown				1
	Metacarpal V	Complete distal end			1
	Metacarpal, No. Unknown	Proximal end (or subset thereof)			2
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			2
	MC/MT (generic metapod)	Isolated distal condyle			1
	First Phalanx	CO/ACO			1
		Proximal end (or subset thereof)			1
		Distal end (or subset thereof)		1	5
	Second Phalanx	Distal end (or subset thereof)			2
	Third Phalanx	CO/ACO		1	3
	Phalanx, Type Unknown	Proximal end (or subset thereof)			5
		Distal end (or subset thereof)			13
cf. *Cercopithecus pygerythrus*	Cranial		1		
Cercopithecus albogularis	Basicranium				1
	Os Petrosum				1
	Maxilla w/o teeth				1
	Upper Canine				1
	Upper M3				1
	Mandible w/ teeth	Corpus			1
	Lower P4				1
	Lower M1				1
	Lower M2				1
	Ulna	Olecranon + Anconaeus			1
	Patella				3
	Fibula	Distal end (or subset thereof)			1
	Cuboid				1
	Metacarpal, No. Unknown	Proximal end (or subset thereof)			1
	Metatarsal, Type Unknown	CO/ACO			1
		Proximal end (or subset thereof)			1
	First Phalanx	CO/ACO			1
		Proximal end (or subset thereof)			1
		Distal end (or subset thereof)			1
	Second Phalanx	CO/ACO			1
	Phalanx, Type Unknown	Shaft			1
Primate: Vervet or Sykes' monkey	Upper dm1				(1)
	Lower Molar				1
	Molar				1
	Ulna	Olecranon + Anconaeus			1

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Primate: Vervet or Sykes' monkey	Tibia	Distal shaft			1
	Metacarpal, No. Unknown	CO/ACO			1
		Proximal end (or subset thereof)			1
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			2
	First Phalanx	Distal end (or subset thereof)			1
	Second Phalanx	Distal end (or subset thereof)			1
	Third Phalanx	CO/ACO			3
	Phalanx, Type Unknown	Shaft			1
		Distal end (or subset thereof)			2
Primate: Sykes' monkey or Baboon	Upper P3				1
	Upper P4				1
	Mandible w/ teeth	Corpus			1
	Lower P4				1
	Tibia	Distal end (or subset thereof)			1
	First Phalanx	Proximal end (or subset thereof)			1
	Second Phalanx	Proximal end (or subset thereof)			1
	Third Phalanx	CO/ACO			1
	Phalanx, Type Unknown	Distal end (or subset thereof)			2
cf. *Genetta tigrina*	Scapula	Glenoid			1
Felid small (serval/wild cat)	I2				1
	Patella				1
	Carpal, Type Unknown				1
	Calcaneum	Tuberculum and Corpus			1
	MC/MT (generic metapod)	Complete distal end			1
Felid small-medium (caracal/serval)	Lower P3				1
Felid large (cheetah/leopard)	Carpal, Type Unknown				2
Viverrid large	Mandible w/o teeth	Condyle			1
	Fibula	Proximal end (or subset thereof)			1
	MC/MT (generic metapod)	Complete distal end	1		
Viverrid/Mustelid	Metacarpal, No. Unknown	CO/ACO			1
Galerella sanguinea	Radius	Distal end (or subset thereof)			1
	Metatarsal, Type Unknown	CO/ACO			1
Galerella sp.	Humerus	Proximal end (or subset thereof)			1 (1)
Atliax palundinous	Incisor				(1)
	Ulna	Shaft			(1)
	Innominate	Acetabulum + Ischium			(1)
Mongoose	Maxilla w/o teeth				1
	Lower Premolar				1
	Humerus	Distal end (or subset thereof)			1
	Femur	Distal end (or subset thereof)			1
	Tibia	Proximal end (or subset thereof)			1
	Calcaneum	CO/ACO			1
		Tuberculum and Corpus			1
	Talus	CO/ACO			1
		Indet Fragment			1
	Tarsal, Type Unknown				1
	Metacarpal III/IV	Proximal end (or subset thereof)			1
	Metatarsal, Type Unknown	CO/ACO			1
		Proximal end (or subset thereof)			1
Mongoose small	Mandible w/o teeth	Ascending ramus			1
	Scapula	Glenoid			1
	Humerus	Proximal end (or subset thereof)			1
	Radius	Proximal end (or subset thereof)			3
	Ulna	Distal end (or subset thereof)			1
	Carpal, Type Unknown				1
	Innominate	Acetabulum + Pubis			1
	Tarsal, Type Unknown				1

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Mongoose small	MC/MT (generic metapod)	Isolated distal condyle			1
	Metatarsal, Type Unknown	CO/ACO			1
Mongoose medium	Radius	Shaft			1
	Femur	Shaft			1
Mongoose large	Maxilla w/o teeth				2
	Radius	Proximal end (or subset thereof)			3
	Metacarpal, No. Unknown	CO/ACO			1
	Phalanx, Type Unknown	CO/ACO			1
Canid small	MC/MT (generic metapod)	Complete distal end			1
Canid small-medium	Upper P1				(1)
Canid medium (jackal size)	P1				1
	Patella				1
	MC/MT (generic metapod)	Isolated distal condyle			1
Canid large	Ulna	Anconaeus			1
cf. *Ictonyx striatus*	Metacarpal, No. Unknown	CO/ACO			1
	MC/MT (generic metapod)	Complete distal end			1
	Tarsal, Type Unknown				1
	First Phalanx	CO/ACO			1
	Phalanx, Type Unknown	CO/ACO			1
Mustelid	MC/MT (generic metapod)	Complete distal end			1
Carnivore small	Premolar				1
	Molar/Premolar				1
	Carpal, Type Unknown				1
	Talus	Indet Fragment			1
	Tarsal, Type Unknown				1
	Metacarpal, No. Unknown	Proximal end (or subset thereof)			1
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			1
Carnivore medium	Canine				2
	Upper I3				1
	Sacrum				1
	Ulna	Anconaeus	1		
	Fibula	Distal end (or subset thereof)			1
Carnivore medium-large (hyena size)	Cervical Vertebra		(1)		
	Scapula	Blade	1		1
	Carpal, Type Unknown		1		
	MC/MT (generic metapod)	Isolated distal condyle			1
	Second Phalanx	Distal end (or subset thereof)			1
Carnivore large	Canine		1		
	Radius	Shaft	1		
	Innominate	Indet Fragment	(1)		
Equus quagga	Upper M2		1		
	Upper M3		1		
	Upper Premolar		1		
	Upper tooth		2		
	Mandible w/o teeth	Corpus	(1)		
	dp2		(1)		
	Molar/Premolar		3		1
	Enamel Fragment		6		5
	Innominate	Iliac blade	1		
	Femur	Shaft	1		
	Tibia	Shaft	1		
	MC/MT (generic metapod)	Proximal end (or subset thereof) Shaft	1 2		
cf. *Equus capensis*	Canine		1		
	Distal Sesamoid		1		
	First Phalanx	Distal end (or subset thereof)		1	
	Second Phalanx	Distal end (or subset thereof)	1		
Equus sp.	Os Petrosum		1		

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Equus sp.	Upper M1			(1)	
	Mandible w/o teeth	Corpus		1	
	Lower Deciduous Premolar			(3)	
	Incisor			(1)	
	Deciduous Premolar		(1)		
	Molar/Premolar		1		
	Enamel Fragment		2		1
	Os Centroquartale		1		
	Innominate	Iliac blade	1		
	Femur	Shaft	3		
	MC/MT (generic metapod)	Proximal end (or subset thereof)	1		
	Proximal Sesamoid		1		
	Second Phalanx	Distal end (or subset thereof)		1	
Potamochoerus larvatus	Cranial				2
	Maxilla w/o teeth				1
	Upper P4				1
	Upper Molar				1
	Mandible w/ teeth	Corpus			1
	Mandible w/o teeth	Corpus			1
	Lower dp4				(1)
	M2			1	
	Incisor				2
	Tusk Fragment				15
	Premolar				2
	Molar			1	35 (2)
	Molar/Premolar			2	7
	Deciduous Premolar				(2)
	Deciduous tooth				(2)
	Enamel Fragment				7 (2)
	Scapula	Glenoid + Neck + Blade			(1)
		Blade			2
	Humerus	Distal shaft			1
		Distal end (or subset thereof)			2 (1)
	Radius	Proximal end (or subset thereof)			3
	Ulna	Anconaeus			2 (1)
		Shaft			(2)
	Radial Carpal				6
	Intermediate Carpal				2 (1)
	4th carpal				1
	Accessory Carpal				5
	Carpal, Type Unknown				5
	Innominate	Acetabulum + Ischium			1
	Femur	Major trochanter			1
	Patella				(2)
	Tibia	Proximal end (or subset thereof)			1
		Distal end (or subset thereof)			1
	Fibula	Shaft			2
	Calcaneum	CO/ACO			(1)
		Tuberculum and Corpus			1
	Tarsal, Type Unknown				6
	Metacarpal III/IV	Proximal end (or subset thereof)			1
	Metacarpal V	Proximal end (or subset thereof)			1
	Metacarpal, No. Unknown	CO/ACO			2
		Proximal end (or subset thereof)			2
		Shaft			1
	Metatarsal III	Proximal end (or subset thereof)			1
	Metatarsal IV	Proximal end (or subset thereof)			1
	Metatarsal V	CO/ACO			2

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Potamochoerus larvatus	Metatarsal V	Proximal end (or subset thereof)			2
		Distal end (or subset thereof)			(1)
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			2
	MC/MT (generic metapod)	Proximal end (or subset thereof)		1	2
		Shaft			1 (9)
		Complete distal end			2
		Isolated distal condyle		1	12
	Proximal Sesamoid				9
	First Phalanx	CO/ACO			2
		Half			2
		Proximal end (or subset thereof)		1	12 (3)
		Shaft			1
		Distal end (or subset thereof)		2	16
	Second Phalanx	CO/ACO		1	19 (3)
		Half			2
		Proximal end (or subset thereof)			12 (1)
		Shaft			4 (1)
		Distal end (or subset thereof)			3
	Third Phalanx	CO/ACO		1	10
		Proximal end (or subset thereof)		2	12
		Plantar			(1)
	Phalanx 1 or 2	Proximal end (or subset thereof)			1
		Distal end (or subset thereof)			3
	Phalanx, Type Unknown	CO/ACO			1
cf. *Potamochoerus larvatus*	Radius	Proximal end (or subset thereof)			1
	Fibula	Proximal end (or subset thereof)			1
	First Phalanx	Distal end (or subset thereof)			2
Phacochoerus africanus	Lower Molar			1	
	Molar		1		
	Enamel Fragment		4	2 (1)	
Suid	Os Petrosum			2	
	Cranial		1		
	Tusk Fragment		1		
	Enamel Fragment			(1)	
	Humerus	Proximal end (or subset thereof)	1		
		Distal end (or subset thereof)		2	1
	Ulna	Shaft	1		
	Accessory Carpal			1	
	Carpal, Type Unknown			1	
	Femur	Head or head/neck	1		
	Patella				(1)
	Fibula	Proximal end (or subset thereof)		1	
		Shaft			1
		Distal end (or subset thereof)	1		
	Metacarpal, No. Unknown	Proximal end (or subset thereof)		1	
	MC/MT (generic metapod)	CO/ACO		(1)	
		Distal shaft	(1)		
		Complete distal end	(1)		
		Isolated distal condyle		3	
	Proximal Sesamoid		1	2	9
	First Phalanx	CO/ACO	1 (2)	1	
		Proximal end (or subset thereof)	(1)		
		Shaft		1 (1)	
		Distal end (or subset thereof)	1	3	2
	Second Phalanx	CO/ACO	1	1	1
		Proximal end (or subset thereof)	2 (1)	1 (2)	1
		Distal end (or subset thereof)			1
	Third Phalanx	CO/ACO	1	1	

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Suid	Third Phalanx	Proximal end (or subset thereof)	1	1	1
	Phalanx 1 or 2	Proximal end (or subset thereof)			1
cf. *Giraffa camelopardalis*	Enamel Fragment		1		
	Vertebra spine or Rib		1		
	Long Bone	Shaft	1		
	Proximal Sesamoid		1		
	First Phalanx	Distal end (or subset thereof)		1	
cf. *Pelorovis antiquus*	Mandible w/ teeth	Corpus	1		
	Lower P3		1		
	Lower M2		1		
	Patella		1		
	Metatarsal III/IV	Shaft	1		
	Proximal Sesamoid		1		
Syncerus caffer	Horn		1		
	Upper P2				1
	Upper P3		1		
	Upper P3/P4		1		
	Upper M1				1
	Upper M2		1		1
	Upper M2/M3		(1)		
	Upper Molar				(1)
	Lower M1/M2		(1)		
	Lower M2		1		
	Lower Molar		1		
	Premolar				1
	Molar				1
	2nd and 3rd carpal				1
	Proximal Sesamoid				2
	First Phalanx	Proximal end (or subset thereof)			(1)
		Distal end (or subset thereof)	1		
	Second Phalanx	Proximal end (or subset thereof)			2
		Half			2
		Distal end (or subset thereof)	1		
	Third Phalanx	Plantar			1
		Distal end (or subset thereof)			2
cf. *Syncerus caffer*	Os Petrosum		1		
	Upper I2				1
	Lower P3/P4		2		
	Incisor			1	1
	Molar/Premolar		1 (1)		
	Metatarsal III/IV	Shaft	1		
	MC/MT (generic metapod)	Isolated distal condyle	1		
	Distal Sesamoid		1		
	First Phalanx	Distal end (or subset thereof)		1	
Syncerus/Pelorovis	Lower P4		1		
	First Phalanx	Proximal end (or subset thereof)	1		
Tragelaphus strepsiceros	Lower I2		1		
	Lower M1/M2		(1)		
	Lower Molar		1		
	Molar		1 (1)		
	Molar/Premolar		1		
	Proximal Sesamoid		1		
	Distal Sesamoid		1		
cf. *Tragelaphus strepsiceros*	Upper P4		1		
	Lower P3		1		
	Lower dp4		(1)		
Tragelaphus scriptus	Upper Deciduous Premolar				(1)
	Talus	CO/ACO			1

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Tragelaphus scriptus	Third Phalanx	CO/ACO			5
		Distal end (or subset thereof)		1	
cf. *Tragelaphus scriptus*	Molar/Premolar		1		
	Os Malleolare			1	
	Third Phalanx	CO/ACO	1		
		Proximal end (or subset thereof)	1		
		Distal end (or subset thereof)	1		
Tragelaphus oryx	Upper Molar				1
	First Phalanx	Proximal end (or subset thereof)			1
		Distal end (or subset thereof)			1
	Second Phalanx	Half			2
		Distal end (or subset thereof)		1	
cf. *Tragelaphus oryx*	Lower P3/P4				1
	Molar/Premolar		1		
	MC/MT (generic metapod)	Isolated distal condyle		1	
	Second Phalanx	Distal end (or subset thereof)		1	
Tragelaphus sp.	Upper Molar		1		
Tragelaphine large: kudu or eland	Cranial base		(1)		
	Occipital Condyle		(1)		
	Lower Molar		1		
Megalotragus priscus	Os Petrosum				(1)
	Sphenoid				(1)
	Femur	Head or head/neck			(1)
	Second Phalanx	Proximal end (or subset thereof)			(1)
cf. *Megalotragus priscus*	Upper M2/M3		1		
	Lower M3		1		
	Molar		1		
Connochaetes taurinus	Horn		1		
	Upper M2		1		
	Upper Molar		1		
	Lower P3		1		
	Lower P3/P4		1		
	Molar				(1)
	Third Phalanx	CO/ACO	1		
cf. *Connochaetes taurinus*	Upper M1		1	1	
	Upper M2		1		
	Upper M2/M3		1		
	Tibia	Shaft		1	
cf. *Alcelaphus buselaphus*	Upper P2		1		
Damaliscus pygargus	Upper M2		1		
Alcelaphine medium-large	Third Phalanx	CO/ACO	1		
Alcelaphine large	Upper M2		1		
	Upper Molar		1		1
	Upper Molar/Premolar				1
	Lower dp4		(1)		
	Molar		3		2 (1)
	Molar/Premolar		2 (2)		
	First Phalanx	Distal end (or subset thereof)	1		
Hippotragus equinus	Mandible w/ teeth	Corpus			1
	Lower M1				1
	Lower M2				1
	Lower M3				2
Hippotragus sp.	Lower M1		1		
Hippotragus sp. / *Tragelaphus oryx*	First Phalanx	Distal end (or subset thereof)			2
	Second Phalanx	Half			1
		Distal end (or subset thereof)			1
Philantomba monticola	Horn				16
	Os Petrosum				3

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Philantomba monticola	Occipital Condyle				10
	Basicranium				1
	Maxilla w/ teeth				4 (1)
	Maxilla w/o teeth				3
	Upper P2			1	5
	Upper P3				4
	Upper P3/P4				1
	Upper P4				4
	Upper M1				10 (1)
	Upper M1/M2			1	3
	Upper M2				7 (1)
	Upper M3				7
	Upper dp2				(6)
	Upper dp3				(5)
	Upper dp4				(9)
	Upper Premolar				1
	Upper Molar				9
	Upper Molar/Premolar				1
	Mandible w/ teeth	Corpus			6 (4)
		Diasthema			1
	Mandible w/o teeth	Corpus			9
		Diasthema		1	5
		Ascending ramus			2
		Condyle		1	14
	Lower P2				2
	Lower P3			2	9
	Lower P3/P4				3
	Lower P4				4
	Lower M1				17 (4)
	Lower M2				8 (4)
	Lower M3				9
	Lower dp2				(4)
	Lower dp3				(9)
	Lower dp4				(11)
	Incisor				2
	Lower Premolar				1
	Lower Molar				10
	M2/M3				1
	M3				3
	dp4				(1)
	Premolar				1
	Molar				13 (1)
	Molar/Premolar				1
	Deciduous Premolar				(1)
	Hyoid				4
	Axis				11
	Thoracic Vertebra				1
	Scapula	Glenoid			8
		Glenoid + Neck + Blade			5 (1)
		Spine			6
		Caudal Edge			2
	Humerus	Proximal end (or subset thereof)			17
		Proximal shaft			(1)
		Distal shaft		1	1
		Distal end (or subset thereof)			17 (1)
	Radius	Proximal end (or subset thereof)		1	28 (1)
		Proximal shaft			(1)
		Shaft			3

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Philantomba monticola	Radius	Distal shaft			(1)
		Distal end (or subset thereof)		1	10 (2)
	Ulna	Olecranon		1	3 (1)
		Olecranon + Anconaeus			6
		Anconaeus			16
		Shaft			1 (1)
	Radial Carpal				22 (1)
	Intermediate Carpal				13
	Ulnar Carpal				5
	2nd and 3rd carpal				26 (1)
	4th carpal				13 (1)
	Innominate	Acetabulum			22
		Acetabulum + Ilium			4
		Acetabulum + Pubis			3
		Ischium			1 (1)
		Pubis			(1)
	Femur	Head or head/neck			17 (1)
		Major trochanter			1
		Shaft	1		16
		Distal end (or subset thereof)			10 (1)
	Patella				17 (2)
	Tibia	Proximal end (or subset thereof)		(1)	5 (2)
		Proximal shaft/crest			3
		Shaft			4
		Distal shaft			(5)
		Distal end (or subset thereof)			18 (3)
	Os Malleolare				8
	Calcaneum	CO/ACO			8
		Tuberculum			7 (4)
		Tuberculum and Corpus			12
		Sustenaculum			6
		Susteanculum and Corpus			1
		Corpus and Distal Projection			1
		Distal Projection			3
	Talus	CO/ACO			22 (1)
		Half			2
		Proximal end (or subset thereof)		1	6
		Distal end (or subset thereof)			8 (1)
		Indet Fragment			20 (1)
	Cuneiform				2
	2nd and 3rd tarsal				7
	Os Centroquartale				31 (2)
	Metacarpal III/IV	Proximal end (or subset thereof)			20
		Shaft			5
		Distal shaft			1
		Complete distal end			4
		Isolated distal condyle			2 (1)
	Metatarsal III/IV	Proximal end (or subset thereof)			25
		Proximal shaft			1
		Shaft	1	1	40
		Complete distal end			3 (2)
		Isolated distal condyle			3
	MC/MT (generic metapod)	Proximal end (or subset thereof)			1
		Shaft			6
		Distal shaft			(1)
		Paired condyles			3 (1)
		Isolated distal condyle			70 (7)
	First Phalanx	CO/ACO			16 (3)

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Philantomba monticola	First Phalanx	Proximal end (or subset thereof)			19 (2)
		Shaft			6
		Distal end (or subset thereof)			36 (5)
	Second Phalanx	CO/ACO			30 (1)
		Half			2 (1)
		Proximal end (or subset thereof)			4 (1)
		Shaft			(5)
		Distal end (or subset thereof)			28
	Third Phalanx	CO/ACO		1	41 (3)
		Proximal end (or subset thereof)			12
		Distal end (or subset thereof)			2
	Dew Claw				2
Cephalophus natalensis	Mandible w/ teeth	Corpus			1
	Lower P4				1
	Lower M1				1
cf. *Cephalophus natalensis*	2nd and 3rd carpal				1
Sylvicapra grimmia	Upper M1				1
	Upper dp3				(1)
Cephalophus/Sylvicapra	Maxilla w/ teeth				1
	Upper M2				1
	Upper M3				1
	Lower M1				1
	Lower M3				1
Redunca fulvorufula	Second Phalanx	CO/ACO	1		
Redunca sp.	Lower P4		1		
	First Phalanx	Proximal end (or subset thereof)	(1)		
	Second Phalanx	CO/ACO			1
Kobus ellipsiprymnus	Lower M1		1		
cf. *Kobus ellipsiprymnus*	Upper M1		(1)		
Pelea capreolus	Horn				1
	Lower M1				1
	MC/MT (generic metapod)	Isolated distal condyle			(1)
cf. *Pelea capreolus*	Mandible w/o teeth	Corpus			1
	First Phalanx	Proximal end (or subset thereof)			1
Pelea/Redunca	Second Phalanx	Proximal end (or subset thereof)	1		
Raphicerus campestris	Horn				1
	Upper P2				1
	Upper P3				1
	Mandible w/ teeth	Corpus			(2)
	Lower P4				(1)
	Lower M1				(2)
	Lower M2				1
	Lower dp2				(2)
	Lower dp3				(2)
	Lower dp4				(3)
	Axis				1
	Second Phalanx	Proximal end (or subset thereof)			1
cf. *Raphicerus campestris*	Upper P3				1
	Upper Molar				1
Raphicerus sp.	Third Phalanx	CO/ACO	1		
Raphicerus/Oreotragus	Upper M1				1
	Lower M2/M3				1
Aepyceros melampus	Horn				1
	Lower M2				1
	Lower M2/M3				1
	Radial Carpal				1
	Third Phalanx	CO/ACO		1	
cf. *Aepyceros melampus*	Upper P2		1		

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Oreotragus oreotragus	MC/MT (generic metapod)	Paired condyles		1	
	Third Phalanx	Proximal end (or subset thereof)		1	
cf. *Oreotragus oreotragus*	Metatarsal III/IV	Proximal end (or subset thereof)		1	
Bov I	Horn				3
	Orbital				1
	Occipital Condyle				7 (2)
	Os Petrosum			1	23
	Cranial		1		
	Upper P3				1
	Upper Molar				3
	Mandible w/o teeth	Corpus	2		
		Diasthema		1	4
		Ascending ramus		2	5
		Condyle	1		10 (3)
	Incisor		1		
	Lower M3				1
	Lower Molar		1		1
	Molar		1		4
	Molar/Premolar		1		1
	Hyoid				2
	Atlas				2
	Axis			2	8
	Sternum				1
	Scapula	Glenoid			5 (1)
		Glenoid + Neck + Blade			(1)
		Spine			4
		Caudal Edge			7 (1)
		Blade			2
	Humerus	Proximal end (or subset thereof)		1	5 (1)
		Proximal shaft			(1)
		Shaft	1	1	3 (1)
		Distal shaft		1	5 (3)
		Distal end (or subset thereof)	1	1	2
	Radius	Proximal end (or subset thereof)	2	1	4
		Shaft			1
		Distal end (or subset thereof)			7
	Ulna	Olecranon		1	9
		Anconaeus		2	5
		Shaft			2 (1)
		Distal end (or subset thereof)			1 (1)
	Radial Carpal				1
	Intermediate Carpal				4 (1)
	Ulnar Carpal				1
	2nd and 3rd carpal		1		
	4th carpal				1 (1)
	Accessory Carpal				1
	Innominate	Acetabulum			9 (1)
		Acetabulum + Ilium			3 (1)
		Iliac blade			1 (2)
		Ischium			2
		Pubis			1
		Indet Fragment	1		
	Femur	Head or head/neck	(1)	(1)	5 (2)
		Major trochanter		1	
		Minor trochanter			3
		Shaft	2	1	6
		Distal shaft	1		2
		Distal end (or subset thereof)		2	8 (1)

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Bov I	Patella		1		2
	Tibia	Proximal end (or subset thereof)			3 (2)
		Proximal shaft/crest	1		5
		Shaft	1		1
		Distal shaft			1
		Distal end (or subset thereof)			2
	Os Malleolare				2
	Calcaneum	Tuberculum	1	1	5 (1)
		Tuberculum and Corpus			1
		Sustenaculum			2
		Distal Projection		1	2
	Talus	Half			1
		Proximal end (or subset thereof)		1	1
		Indet Fragment	1	1	3
	Cuneiform			2	
	2nd and 3rd tarsal			1	2 (1)
	Os Centroquartale				4
	Metacarpal III/IV	Proximal end (or subset thereof)	1	3	3
		Shaft		2	3 (1)
		Isolated distal condyle			1
	Metatarsal III/IV	Proximal end (or subset thereof)		1	5
		Proximal shaft			2
		Shaft	1	8	9
	Metapod II or V	CO/ACO			2
	MC/MT (generic metapod)	Proximal end (or subset thereof)			2
		Proximal shaft			1
		Shaft			2 (1)
		Distal shaft		(1)	1 (1)
		Isolated distal condyle	1	2	16
	Proximal Sesamoid		1		8
	Distal Sesamoid			2	5
	First Phalanx	Proximal end (or subset thereof)	1		4 (3)
		Shaft			1 (2)
		Distal end (or subset thereof)	1	5	17
	Second Phalanx	CO/ACO			1
		Proximal end (or subset thereof)		2	6
		Shaft		2	(1)
		Distal end (or subset thereof)	1	1	6
	Third Phalanx	Proximal end (or subset thereof)	1	2	8
		Distal end (or subset thereof)			1 (1)
	Dew Claw			2	
	Sesamoid, Carpal/Tarsal Region?			1	
Bov I/II	Horn				2
	Orbital		1		
	Os Petrosum				2
	Upper Molar		1		
	Mandible w/o teeth	Condyle			1
	Lower Molar				1
	Molar			1	
	Scapula	Glenoid			(1)
	Ulna	Shaft			1
	Intermediate Carpal				(1)
	Femur	Head or head/neck		1	
		Shaft		2	
		Distal end (or subset thereof)			1
	Talus	Proximal end (or subset thereof)			1
	Cuneiform				1
	Metacarpal III/IV	Proximal end (or subset thereof)		1	

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Bov I/II	Metatarsal III/IV	Shaft	1	2	
	Metapod II or V	CO/ACO		1	1
	MC/MT (generic metapod)	Isolated distal condyle		4	
	Proximal Sesamoid			2	4
	Distal Sesamoid			3	2
	First Phalanx	Distal end (or subset thereof)		2	2
	Third Phalanx	CO/ACO		1	
		Distal end (or subset thereof)			1
		Proximal end (or subset thereof)		1	1
	Dew Claw			1	
Bov II	Horn				5
	Orbital		1		2
	Occipital Condyle				1
	Os Petrosum		2	3	6
	Premaxilla				1
	Maxilla w/o teeth				1
	Upper P3/P4		1		
	Mandible w/o teeth	Corpus	6	1	2
		Diasthema	1	1	
		Incisivum			1
		Ascending ramus			1
		Condyle	1		2
	I1		1		
	I2			1	
	Lower M3			1	
	Lower dp3				(1)
	Lower dp4				(1)
	Incisor				2
	Lower Molar		1	1	4
	Lower Premolar				1
	P3/P4			1	
	Molar		2	1	2 (1)
	Molar/Premolar		1	1 (1)	
	Deciduous Premolar				(1)
	Hyoid		3		3
	Atlas				1
	Axis				5
	Scapula	Glenoid	1	2	9
		Neck			(1)
		Spine	1		2
		Caudal Edge	3 (1)		3
		Cranial Edge			2
		Blade	4	1	20
	Humerus	Proximal end (or subset thereof)	1 (2)		(1)
		Shaft	2		5
		Distal shaft	3		9 (1)
		Distal end (or subset thereof)	3	2	5 (2)
	Radius	Proximal end (or subset thereof)	2 (1)	3	10 (1)
		Shaft-ulnar scar			2
		Shaft	1		4
		Distal shaft			2
		Distal end (or subset thereof)		1 (1)	4 (2)
	Ulna	Olecranon			4
		Olecranon + Anconaeus			(1)
		Anconaeus	1		2
		Shaft	4	3	6
		Distal end (or subset thereof)	1	1	5
	Radial Carpal			1 (1)	2

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Bov II	Intermediate Carpal			1 (1)	4 (1)
	Ulnar Carpal			2	3
	2nd and 3rd carpal		1	2 (1)	2
	4th carpal		1	3 (1)	4
	Accessory Carpal		2	1	4
	Innominate	Acetabulum	1	1	3 (1)
		Acetabulum + Ischium			1 (1)
		Iliac blade	1		1 (1)
		Ischium			2 (1)
	Femur	Head or head/neck	(1)		2
		Minor trochanter		1	
		Shaft	4 (1)	1	5 (3)
		Distal shaft	1		(2)
		Distal end (or subset thereof)	5		5
	Patella		1		(3)
	Tibia	Proximal end (or subset thereof)		1 (1)	1
		Proximal shaft/crest	2		1
		Shaft	6	1	9
		Distal shaft	1		(1)
		Distal end (or subset thereof)	3		5
	Os Malleolare		2		3 (1)
	Calcaneum	CO/ACO			1
		Tuberculum	1		6
		Tuberculum and Corpus			1
		Corpus	1	1	
		Susteanculum and Corpus	1		
		Distal Projection			2
	Talus	Half			1
		Proximal end (or subset thereof)			6
		Distal end (or subset thereof)	1	1	1
		Indet Fragment	4	6	8
	Cuneiform		2	1	1
	2nd and 3rd tarsal		2	5 (1)	7
	Os Centroquartale		6	5	5
	Metacarpal III/IV	Proximal end (or subset thereof)	1	2	7
		Shaft	4	1	7 (2)
	Metatarsal III/IV	Proximal end (or subset thereof)	3	2	14
		Shaft	6	3	11
		Isolated distal condyle			1
	Metapod II or V	CO/ACO	1		
	MC/MT (generic metapod)	Shaft	8		1 (1)
		Distal shaft			(1)
		Paired condyles	1		2 (3)
		Isolated distal condyle	8	10	20 (1)
	Proximal Sesamoid		9	25	53 (1)
	Distal Sesamoid		3 (1)	9	33
	First Phalanx	CO/ACO			(1)
		Half			1
		Proximal end (or subset thereof)	10 (2)	10 (1)	12
		Shaft		1	1 (1)
		Distal end (or subset thereof)	7	7	44
	Second Phalanx	Half			1
		Proximal end (or subset thereof)	1 (1)	9	20 (1)
		Shaft		5	(1)
		Distal end (or subset thereof)	3	14	36
	Third Phalanx	Proximal end (or subset thereof)	3	8	12
		Plantar			2
		Distal end (or subset thereof)	1		3

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Bov II	Phalanx 1 or 2	Shaft	(1)		
		Distal end (or subset thereof)	1		2
	Dew Claw		8	6	15
	Humerus OR Femur	Shaft			1
	Carpal/Tarsal				(1)
	Sesamoid, Carpal/Tarsal Region?		5	4	1
	Sesamoid, Type Unknown			1	1
Bov II/III	Horn		1	1	1
	Os Petrosum			1	1
	Upper Molar/Premolar		1		
	Molar/Premolar		1		
	Axis			1	
	Humerus	Distal shaft		2	1
	2nd and 3rd carpal				1
	4th carpal				1
	Innominate	Ischium			(1)
	Femur	Shaft			1
	Tibia	Shaft	2		1
	Talus	Distal end (or subset thereof)			1
		Indet Fragment		1	
	2nd and 3rd tarsal		(1)		
	Os Centroquartale		(1)		
	Metatarsal III/IV	Proximal end (or subset thereof)			1
		Shaft	1		
	MC/MT (generic metapod)	Isolated distal condyle		2	
	Proximal Sesamoid				6
	Distal Sesamoid			1	1
	First Phalanx	Distal end (or subset thereof)	1	1	
	Second Phalanx	CO/ACO			(1)
		Distal end (or subset thereof)			1
	Third Phalanx	Distal end (or subset thereof)		1	1
	Dew Claw			1	4
Bov III	Horn		1	1	1
	Nasal				1
	Orbital		3		
	Occipital Condyle			1	
	Os Petrosum		4	5	5
	Cranial base		(1)		
	Cranial		2		
	Maxilla w/o teeth	(blank)	2		2
	Upper P2				2
	Upper P3				1
	Upper P4		1		
	Upper Molar		2		2
	Upper Molar/Premolar		1	1	
	Mandible w/o teeth	Corpus	7		1
		Diasthema			1
		Ascending ramus	3 (2)		1
		Coronid process	(1)		
		Condyle	(1)		1
	Lower P3				1
	Lower P3/P4		1 (1)		
	Lower P4				1
	Lower M3		1		
	Lower dp4		(1)		
	Canine				1
	Incisor				5
	Lower Premolar		2		4

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Bov III	Lower Molar		2		1
	Premolar				1
	Molar		9 (1)	2	5 (2)
	Molar/Premolar		5 (1)	(1)	
	Deciduous incisor		(1)		
	Hyoid		1		3
	Atlas				2
	Axis				1
	Scapula	Glenoid	1		2
		Cranial Edge	2		
		Blade	1		7
	Humerus	Proximal end (or subset thereof)	(1)	(1)	3
		Proximal shaft			1
		Shaft	5	1	
		Distal shaft	1	1	3
		Distal end (or subset thereof)			1 (1)
	Radius	Proximal end (or subset thereof)	3		2 (1)
		Shaft-ulnar scar	1	1	1
		Shaft	3		3
		Distal shaft	(1)		
		Distal end (or subset thereof)	4		2
	Ulna	Olecranon	1		6
		Olecranon + Anconaeus	(1)		
		Anconaeus			(1)
		Shaft	4 (1)	1	4
		Distal end (or subset thereof)			1
	Radial Carpal		1		
	Intermediate Carpal				3
	2nd and 3rd carpal		(1)	2	3 (1)
	Accessory Carpal		1		1
	Carpal, Type Unknown				1
	Innominate	Acetabulum			4
		Iliac blade	1		
		Ischium			(1)
	Femur	Head or head/neck			1 (3)
		Major trochanter			2
		Minor trochanter			3
		Shaft	10		2 (1)
		Distal end (or subset thereof)	2		3
	Patella		1		2
	Tibia	Proximal end (or subset thereof)	1		(1)
		Proximal shaft/crest	1	1	
		Shaft	20	2	11
		Distal end (or subset thereof)	2	1	2
	Os Malleolare		(1)	1	
	Calcaneum	Tuberculum	1	1	
		Corpus			1
		Distal Projection			1
	Talus	Distal end (or subset thereof)	1 (1)	1	
		Indet Fragment	1	2	3
	Cuneiform		1	(1)	
	2nd and 3rd tarsal		1	2	1
	Os Centroquartale		5		2
	Metacarpal III/IV	Proximal end (or subset thereof)	2	1	3
		Proximal shaft	1		
		Shaft	8		1
	Metatarsal III/IV	Proximal end (or subset thereof)	5	1	4
		Proximal shaft			(1)

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Bov III	Metatarsal III/IV	Shaft	7	1	6
	Metapod II or V	CO/ACO			1
	MC/MT (generic metapod)	Proximal end (or subset thereof)	1		
		Shaft	1		3
		Isolated distal condyle	10	5	5
	Proximal Sesamoid		13	5	15 (2)
	Distal Sesamoid		15	7 (2)	18 (3)
	First Phalanx	Proximal end (or subset thereof)	6 (1)	1	6 (3)
		Shaft			1 (1)
		Distal end (or subset thereof)	12 (1)	4	13 (2)
	Second Phalanx	Half	1		
		Proximal end (or subset thereof)	6 (2)	2	7 (1)
		Shaft	1 (1)	1	
		Distal end (or subset thereof)	12 (1)	2	9 (2)
	Third Phalanx	Proximal end (or subset thereof)	6	3	9
		Plantar	2 (1)		1
		Distal end (or subset thereof)	2		3
	Phalanx 1 or 2	Distal end (or subset thereof)	2	1	3
	Dew Claw		9	4	10
	Long Bone	Shaft	1		1
	Sesamoid, Carpal/Tarsal Region?		6	2	
Bov III/IV	Horn				4
	Os Petrosum		2	1	1
	Maxilla w/o teeth			2	
	Upper Molar		1		
	Upper Molar/Premolar		1		
	Lower Molar			1	
	Lower Premolar		(1)		
	Incisor		1	1	2
	Molar		2 (2)	1	1
	Molar/Premolar		8	1	
	Hyoid				1
	Rib				1
	Humerus	Proximal end (or subset thereof)		1	
		Shaft			1
		Distal end (or subset thereof)			3
	Radius	Proximal shaft			1
	Ulna	Anconaeus			1
		Shaft	1		
	Radial Carpal				1
	2nd and 3rd carpal		1		
	Innominate	Acetabulum		1	
		Ischium			1
	Femur	Shaft	1	1	2
	Tibia	Shaft	2		
	Talus	Distal end (or subset thereof)		1	
		Indet Fragment			2
	Cuneiform			1	
	Os Centroquartale				1
	Metacarpal III/IV	Shaft	1		
	Metatarsal III/IV	Proximal end (or subset thereof)	(1)		1
		Shaft	1		1
	Metapod II or V	CO/ACO			2
	MC/MT (generic metapod)	Proximal shaft			(1)
		Shaft	2		
		Distal shaft			(1)
		Isolated distal condyle	2		3
	Proximal Sesamoid		2	2	4

Taxon	Element	Portion	post-HP MSA 1	post-HP MSA 2	HP
Bov III/IV	Distal Sesamoid		10 (1)	4	5
	First Phalanx	Distal end (or subset thereof)	2		2
	Second Phalanx	Proximal end (or subset thereof)			2
	Third Phalanx	Plantar		2	
		Distal end (or subset thereof)		1	
	Dew Claw			1	2
Bov IV	Occipital Condyle		(1)		
	Os Petrosum			1	
	Cranial		(1)		
	Maxilla w/o teeth				1
	Upper Molar		1		
	Upper Molar/Premolar		1		
	Mandible w/o teeth	Ascending ramus		1	
		Corpus	3		1
	Lower dp4		(1)		
	Incisor		2		3
	Premolar		1		
	Molar		1		
	Molar/Premolar		1		
	Hyoid		1	1	
	Scapula	Glenoid			1
		Blade	1		
	Humerus	Shaft	1		4
		Distal shaft	1		
		Distal end (or subset thereof)		1	
	Ulna	Anconaeus			1
	Ulnar Carpal				1
	2nd and 3rd carpal		(1)		(1)
	Innominate	Iliac blade		1	
	Femur	Shaft	1		
	Tibia	Proximal shaft/crest		1	
		Shaft	1		
	Calcaneum	Corpus	(1)		
		Distal Projection		1	1
	Talus	Indet Fragment	(1)		
	2nd and 3rd tarsal			1	
	Os Centroquartale			1	
	Metacarpal III/IV	Proximal end (or subset thereof)	1		2
		Shaft	2 (1)		1
		Distal shaft			1
	Metatarsal III/IV	Proximal end (or subset thereof)		1	
		Shaft	3	1	
	MC/MT (generic metapod)	Shaft	1	1	
		Isolated distal condyle		2	
	Proximal Sesamoid		9	4	11
	Distal Sesamoid		10 (1)	2	3
	First Phalanx	Proximal end (or subset thereof)	1 (1)	1 (1)	1
		Distal end (or subset thereof)	4	1	7
	Second Phalanx	Proximal end (or subset thereof)			2 (1)
		Shaft			(2)
		Distal end (or subset thereof)	3		3
	Third Phalanx	Proximal end (or subset thereof)	1	1	1
		Plantar			2
	Dew Claw		1		
	Humerus OR Femur	Shaft			2
	Long Bone	Shaft			1
Bov IV/V	Os Petrosum		2		
	Ulna	Anconaeus			(1)

Taxon	**Element**	**Portion**	**post-HP MSA 1**	**post-HP MSA 2**	**HP**
Bov IV/V	Femur	Shaft	1		
	Os Centroquartale				(1)
	Proximal Sesamoid		3	1	
	Distal Sesamoid		3		
	First Phalanx	Proximal end (or subset thereof)	1		
		Distal end (or subset thereof)	1		
	Third Phalanx	Proximal end (or subset thereof)		1	
Bov V	Humerus	Distal shaft	1		
		Shaft	2		
	Tibia	Shaft	1		
Large Ungulate	Humerus	Distal end (or subset thereof)	1		
Mammal small	Maxilla w/o teeth			1	
	Mandible w/o teeth	Corpus			2
	Sternum				2
	Humerus	Proximal end (or subset thereof)			3
		Distal shaft		1	
	Radius	CO/ACO		1	
		Proximal end (or subset thereof)		1	5
		Distal shaft			(1)
Mammal small	Ulna	Olecranon + Anconaeus			1
		Anconaeus			1
		Shaft		1	1
	Carpal, Type Unknown				1
	Femur	CO/ACO		(1)	
		Head or head/neck			4
		Major trochanter			1
		Shaft			1
		Distal end (or subset thereof)			2
	Patella			1	1
	Talus	CO/ACO			2
	Tarsal, Type Unknown				2
	Metacarpal, No. Unknown	Proximal end (or subset thereof)			2
	Metatarsal, Type Unknown	Proximal end (or subset thereof)			4
	MC/MT (generic metapod)	Proximal end (or subset thereof)	2		1 (1)
		Complete distal end			4 (1)
		Isolated distal condyle			2 (1)
	Phalanx, Type Unknown	CO/ACO		1	2
		Proximal end (or subset thereof)			1
		Shaft			(1)
		Distal end (or subset thereof)		2	1
	Carpal/Tarsal				2
Mammal medium	Cranial				1
	Incisor				1
	Carpal, Type Unknown				1 (1)
	Patella				1
	Proximal Sesamoid			1	8
	Distal Sesamoid		1	(1)	
	Second Phalanx	CO/ACO			1
	Dew Claw		1		
	Carpal/Tarsal				1
	Sesamoid, Type Unknown			(1)	
Grand Total			**796 (77)**	**471 (32)**	**3048 (332)**

Works Cited

Allott, Lucy F. 2004. Changing environments in Oxygen Isotope Stage 3: reconstructions using archaeological charcoal from Sibudu Cave. *South African Journal of Science* 100:179-184.

—. 2005. Paleoenvironments of the Middle Stone Age at Sibudu Cave, KwaZulu-Natal, South Africa: an analysis of archaeological charcoal. Unpublished PhD thesis, University of the Witwatersrand.

—. 2006a. Archaeological charcoal as a window on palaeovegetation and wood-use during the Middle Stone Age at Sibudu Cave. *Southern African Humanities* 18:173-201.

—. 2006b. "Evidence for *Podocarpus* forest and changes in anthropogenic wood use at Sibudu Cave, KwaZulu-Natal, South Africa." *Fifth International Workshop for African Archaeobotany, London, England, 2006.*

Ambrose, Stanley H. 2002. "Small Things Remembered: Origins of Early Microlithic Industries in Sub-Saharan Africa," in *Thinking Small: Global Perspectives on Microlithization*, *Archaeological Papers of the American Anthropological Association, 12*. Edited by R. G. Elston and S. L. Kuhn: American Anthropological Association.

—. 2006. Howiesons Poort lithic raw material procurement patterns and the evolution of modern human behavior: A response to Minichillo (2006). *Journal of Human Evolution* 50:365-369.

Ambrose, Stanley H., and Karl G. Lorenz. 1990. "Social and Ecological Models for the Middle Stone Age in Southern Africa," in *The Emergence of Modern Humans: An Archaeological Perspective*. Edited by P. Mellars, pp. 3-33. Ithica, NY: Cornell University Press.

Apps, P. 2000. *Smithers' Mammals of Southern Africa: A Field Guide*. Cape Town: Struik.

Assefa, Zelalem. 2002. Investigations of Faunal Remains from Porc-Epic: A Middle Stone Age Site in Southeastern Ethiopia. unpublished PhD thesis, State University of New York, Stony Brook.

Atmar, W., and B.D. Patterson. 1993. The measure of order and disorder in the distribution of species in fragmented habitats. *Oecologia* 96:373-382.

— 1995. "The nestedness temperature calculator: a visual basic program, including 294 presence-absence matricies." University Park, NM and The Field Museum: AICS Research, Inc.

Backwell, Lucinda, Francesco d'Errico, and Lyn Wadley. 2008. Middle Stone Age bone tools from the Howiesons Poort layers, Sibudu Cave, South Africa. *Journal of Archaeological Science* 35:1566-1580.

Bar-Matthews, Miryam, Curtis W. Marean, Panagiotis Karkanas, Zenobia Jacobs, Erich Fisher, Andy I.R. Herries, and Avner Ayalon. 2008. "A high resolution and continuous isotopic speleothem record of paleoclimate and paleoenvironment from 92-55 ka from Pinnacle Point, South Africa." *Paleoanthropology Society Annual Meetings, Vancouver, B.C., Canada, 2008.*

Bar-Oz, Guy, and Daniel S. Adler. 2005. Taphonomic history of the Middle and Upper Paleolithic faunal assemblage from Ortvale Klde, Georgian Republic. *Journal of Taphonomy* 3:185-212.

Bar-Oz, Guy, and Natalie D. Munro. 2004. Beyond cautionary tales: a multivariate taphonomic approach for resolving equifinality in zooarchaeological studies. *Journal of Taphonomy* 2:201-222.

—. 2007. Gazelle bone marrow yields and Epipaleolithic carcass exploitation strategies in the southern Levant. *Journal of Archaeological Science* 34:946-956.

Bar-Yosef, Ofer. 2002. The Upper Paleolithic Revolution. *Annual Review of Anthropology* 31:363-393.

Barham, Lawrence, and Peter Mitchell. 2008. *The First Africans: African Archaeology from the Earliest Toolmakers to the Most Recent Foragers*. Cambridge: Cambridge University Press.

Barham, Lawrence S. 2002. Backed tools in Middle Pleistocene central Africa and their evolutionary significance. *Journal of Human Evolution* 43:585-603.

Bayham, F. 1979. Factors influencing the Archaic pattern of animal exploitation. *Kiva* 44:219-235.

Behrensmeyer, Anna K. 1975. The taphonomy and paleoecology of Plio-Pleistocene vertebrate assemblages east of Lake Rudolpf, Kenya. *Bulletin of the Museum of Comparative Zoology* 146:473-578.

—. 1978. Taphonomic and ecological information from bone weathering. *Paleobiology* 4:150-162.

Bennett, Joanne L. 1999. Thermal alteration of buried bone. *Journal of Archaeological Science* 26:1-8.

Binford, Lewis R. 1968. "Post-Pleistocene Adaptations," in *New Perspectives in Archaeology*. Edited by L. R. Binford and S. R. Binford, pp. 313-341. Chicago: Aldine.

—. 1978. *Nunamiut ethnoarchaeology*. New York: Academic Press.

—. 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45:4-20.

—. 1981. *Bones: Ancient Men and Modern Myths*. New York: Academic Press.

—. 1984. *Faunal Remains from Klasies River Mouth*. New York: Academic Press.

Bird, Douglas W., and James F. O'Connell. 2006. Behavioral ecology and archaeology. *Journal of Archaeological Research* 14:143-188.

Blumenschine, Robert J., Curtis W. Marean, and Salvatore D. Capaldo. 1996. Blind test of inter-analyst correspondence and accuracy in the identification of cut marks, percussion marks and carnivore tooth marks on bone surfaces. *Journal of Archaeological Science* 23:493-507.

Blumenschine, Robert J., and Marie Selvaggio. 1991. "On the marks of marrow bone processing by hammerstones and hyaenas: their anatomical patterning and archaeological implications," in *Cultural Beginnings: Approaches to*

Understanding Early Hominid Lifeways in the African Savanna. Edited by J. D. Clark, pp. 17-32. Bonn: Dr. R. Habelt GMBH.

Bothma, J. du P. 2002. "Antelope and other smaller herbivores," in *Game Ranch Management*, 4th edition. Edited by J. d. P. Bothma, pp. 149-175. Pretoria: Van Schaik Publishers.

Bouzouggar, A., N. Barton, M. Vanhaeren, F. d'Errico, S. Collcutt, T. Higham, E. Hodge, S. Parfitt, E. Rhodes, J. L. Schwenninger, C. Stringer, E. Turner, S. Ward, A. Moutmir, and A. Stambouli. 2007. 82,000-year-old shell beads from North Africa and implications for the origins of modern human behavior. *Proceedings of the National Academy of Sciences of the United States of America* 104:9964-9969.

Brain, C. K. 1974. Some Suggested Procedures in the Analysis of Bone Accumulations from Southern African Quaternary Sites. *Annals of the Transvaal Museum* 29:1-7.

Brain, C.K. 1981. *The Hunters or the Hunted? An Introduction to African Cave Taphonomy*. Chicago: University of Chicago Press.

Brooks, Alison S., Lisa Nevell, John E. Yellen, and Gideon Hartman. 2006. "Projectile Technologies of the African MSA," in *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Edited by E. Hovers and S. L. Kuhn, pp. 233-255. New York: Springer.

Broughton, Jack M. 1994. Declines in foraging efficiency during the late Holocene: the archaeological mammal evidence from San Francisco Bay, California. *Journal of Anthropological Archaeology* 13:371-401.

Broughton, Jack M., and Donald K. Grayson. 1993. Diet breadth, adaptive change and the White Mountain fauna. *Journal of Archaeological Science* 20:331-336.

Brumm, Adam, and Mark W. Moore. 2005. Symbolic revolutions and the Australian archaeological record. *Cambridge Archaeological Journal* 15:157-175.

Buikstra, Jane E., and M. Sweagle. 1989. "Bone modification due to burning: experimental evidence," in *Bone Modification*. Edited by R. Bonnichsen and M. H. Sorg, pp. 247-258. Orono: University of Main Center for the Study of the First Americans.

Byers, D., and Jack M. Broughton. 2004. Holocene environmental change, artiodactyl abundances, and human hunting strategies in the Great Basin. *American Antiquity* 69:235-256.

Cáceres, Isabel, P. Bravo, M. Esteban, I. Expósito, and P. Saladié. 2002. "Fresh and heated bone breakage: an experimental approach," in *Current Topics on Taphonomy and Fossilization*. Edited by M. De Rienzi, M. V. Pordo Alonso, M. Belinchón, E. Peñalver, P. Montoya, and A. Márquez-Aliasa, pp. 471-481. Valencia, Spain: Ayuntamiento de Valencia.

Cain, Chester R. 2004. Notched, flaked and ground bone artefacts from Middle Stone Age and Iron Age layers of Sibudu Cave, KwaZulu-Natal, South Africa. *South African Journal of Science* 100:195-197.

—. 2005. Using burned animal bone to look at Middle Stone Age occupation and behavior. *Journal of Archaeological Science* 32:873-884.

—. 2006. Human activity suggested by the taphonomy of 60 ka and 50 ka faunal remains from Sibudu Cave. *Southern African Humanities* 18:241-260.

Carneiro, Robert L. 1970. A theory of the origin of the state. *Science* 169:733-738.

Chaplin, Raymond E. 1971. *The Study of Animal Bones from Archaeological Sites*. New

York: Seminar Press.

Chapman, Jenny L., and Michael J. Reiss. 1998. *Ecology: Principles and Applications*, 2nd edition. UK: Cambridge University Press.

Chase, B. M., and M. E. Meadows. 2007. Late Quaternary dynamics of southern Africa's winter rainfall zone. *Earth-Science Reviews* 84:103-138.

Church, Robert R., and R. Lee Lyman. 2003. Small fragments make small differences in efficiency when rendering grease from fractured artiodactyle bone by boiling. *Journal of Archaeological Science* 30:1077-1084.

Clark, Geoffrey A., and Julien Riel-Salvatore. 2006. "Observations on Systematics in Paleolithic Archaeology," in *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Edited by E. Hovers and S. L. Kuhn, pp. 29-56. New York: Springer.

Clark, Jamie L., and Ina Plug. 2008. Animal exploitation strategies during the South African Middle Stone Age: Howiesons Poort and post-Howiesons Poort fauna from Sibudu Cave. *Journal of Human Evolution* 54:886-898.

Cleghorn, Naomi, and Curtis W. Marean. 2004. Distinguishing selective transport and in situ attrition: a critical review of analytical approaches. *Journal of Taphonomy* 2:43-67.

Cochrane, Grant G.W. 2008. The transition from Howieson's Poort to post-Howieson's Poort industries in southern Africa. *South African Archaeological Society Goodwin Series* 10:157-167.

Cochrane, Grant W.G. 2006. An analysis of lithic artefacts from the ~60 ka layers of Sibudu Cave. *Southern African Humanities* 18:69-88.

Cooper, Keith H. 1985. *The Conservation Status of Indigenous Forests in Transvaal, Natal, and Orange Free State, South Africa*. Durban, South Africa: Wildlife Society of South Africa, Conservation Division.

Costamagno, Sandrine, C. Griggo, and V. Mourre. 1998. Approche expérimentale d'un problème taphonomique: utilisation de combustible osseux au Paléolithique. *Préhistoire Européenne* 13:167-194.

Costamagno, Sandrine, Isabelle Théry-Parisot, Jean-Philip Brugal, and Raphaele Guibert. 2005. "Taphonomic consequences of the use of bones as fuel. Experimental data and archaeological applications," in *Biosphere to Lithosphere: New studies in vertebrate taphonomy (Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham 2002)*. Edited by T. O'Connor, pp. 51-62. Oxford: Oxbow Books.

d'Errico, Francesco. 2003. The Invisible Frontier: A Multiple Species Model for th Origin of Behavior Modernity. *Evolutionary Anthropology* 12:188-202.

d'Errico, Francesco, and Christopher Henshilwood. 2007. Additional evidence for bone technology in the southern African Middle Stone Age. *Journal of Human Evolution* 52:142-163.

d'Errico, Francesco, Christopher Henshilwood, Graeme Lawson, Marian Vanhaeren, Anne-Marie Tiller, Marie Soressi, Frederique Bresson, Bruno Maureille, April Nowell, Joseba Lakarra, Lucinda Backwell, and Michele Julien. 2003a. Archaeological evidence for the emergence of language, symbolism and music--an alternative multidisciplinary perspective. *Journal of World Prehistory* 17:1-70.

d'Errico, Francesco, Christopher Henshilwood, Marian Vanhaeren, and Karen van

Niekerk. 2005. *Nassarius kraussianus* shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age. *Journal of Human Evolution* 48:3-25.

d'Errico, Francesco, Michele Julien, Despina Liolios, Marian Vanhaeren, and Dominique Baffier. 2003b. "Many awls in our argument: Bone tool manufacture and use in the Chatelperronian and Aurignacian levels of the Grotte du Renne at Arcy-sur-Cure," in *The Chronology of the Aurignacian and of the Transitional Technocomplexes: Dating, Stratigraphy and Cultural Implications*, vol. 33, *Trabalhos de Arqueologia*. Edited by J. Zilhao and F. d'Errico, pp. 247-270. Lisbon: Instituto Portugues de Arqueologia.

d'Errico, Francesco, Marian Vanhaeren, and Lyn Wadley. 2008. Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. *Journal of Archaeological Science* 35.

David, B. 1990. "How was this bone burnt?," in *Problem Solving in Taphonomy*, vol. 2. Edited by S. Solomon, I. Davidson, and D. Watson, pp. 65-79.

de Beaune, Sophie A. 2005. Comment on "Modern Human Origins and the Evolution of Behavior in the Later Pleistocene Record of South Asia". *Current Anthropology* 46:S16-S17.

Deacon, H.J. 1989. "Late Pleistocene Palaeoecology and Archaeology in the Southern Cape, South Africa," in *The Human Revolution: behavioral and biological perspectives on the origins of modern humans.* Edited by C. Stringer and P. Mellars, pp. 547-564. Princeton, NJ: Princeton UP.

Deacon, H.J., and Sarah Wurz. 1996. "Klasies River Main Site, Cave 2: a Howiesons Poort occurrence," in *Aspects of African Archaeology*. Edited by G. Pwiti and R. Soper, pp. 213-218. Harare: University of Zimbabwe Publications.

Deacon, Janette. 1995. An unsolved mystery at the Howieson's Poort name site. *South African Archaeological Bulletin* 50:110-120.

Delagnes, Anne, Lyn Wadley, Paola Villa, and Marlize Lombard. 2006. Crystal quartz backed tools from the Howiesons Poort at Sibudu Cave. *Southern African Humanities* 18:43-56.

Elston, Robert G., and P.G. Brantingham. 2002. "Microlithic technology in northern Asia: A risk-minimizing strategy of the late Paleolithic and early Holocene," in *Thinking Small: Perspectives on Microlithization*, *Archaeological Papers of the American Anthropological Association 12*. Edited by R. G. Elston and S. L. Kuhn, pp. 104-117. Washington, D.C.: American Anthropological Association.

Emerson, Alice M. 1993. "The Role of Body Part Utility in Small-Scale Hunting Under Two Strategies of Carcass Recovery," in *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*, vol. 21, *Occasional Paper*. Edited by J. Hudson, pp. 200-227. Carbondale, IL: Southern Illinois University, Center for Archaeological Investigations.

Enloe, James G. 2001. "Investigating Human Adaptations in the Early Upper Paleolithic," in *Questioning the Answers: Re-Solving Fundamental Problems of the Early Upper Paleolithic*, vol. 1005, *British Archaeological Reports International Series*. Edited by M. A. Hayes and P. Thacker, pp. 21-26. Oxford: Archaeopress.

—. 2004. "Taphonomy and Site Structure of a Late Paleolithic Open Air Site," in *Processual Archaeology: Exploring Analtyical Strateges, Frames of Reference and Culture Process*. Edited by A. L. Johnson, pp. 61-87. Westport, CT: Greenwood Publishing Group.

Estes, Richard. 1992. *The Behavior Guide to African Mammals: Including Hoofed Mammals, Carnivores and Primates*. Los Angeles: University of California Press.

Faith, J. Tyler. 2007. Changes in reindeer body part representation at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 34:2003-2011.

Faith, J. Tyler, and Adam D. Gordon. 2007. Skeletal element abundances in archaeofaunal assemblages: economic utility, sample size, and assessment of carcass transport strategies. *Journal of Archaeological Science* 34:872-882.

Feathers, James K. 2002. Luminescence Dating in Less than Ideal Conditions: Case Studies from Klasies River Main Site and Duneifontein, South Africa. *Journal of Archaeological Science* 29:177-194.

Fitzhugh, Ben. 2001. Risk and invention in human technological evolution. *Journal of Anthropological Archaeology* 20:125-167.

Flannery, Kent V. 1969. "Origins and Ecological Affects of Early Domestication in Iran and the Near East," in *The Domestication and Exploitation of Plants and Animals*. Edited by P. J. Ucko and G. W. Dimbleby, pp. 73-100. London: Duckworth.

Gibson, NE, Lyn Wadley, and B.S. Williamson. 2004. Microscopic residues as evidence of hafting on backed tools from the 60000 to 68000 year-old Howiesons Poort layers of Rose Cottage Cave, South Africa. *Southern African Humanities* 16:1-11.

Gifford-Gonzalez, D.P. 1989. "Ethnographic analogues for interpreting modified bones: some cases from East Africa.," in *Bone modification*. Edited by R. Bonnichsen and M. H. Sorg, pp. 179-246. Orono: University of Maine Center for the Study of the First Americans.

Glenny, Wayne. 2006. Report on the micromammal assemblage analysis from Sibudu Cave. *Southern African Humanities* 18:279-288.

Grayson, Donald K. 1984. *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Orlando: Academic Press.

—. 1989. Bone transport, bone destruction, and reverse utility curves. *Journal of Archaeological Science* 16:643-652.

Grayson, Donald K., and M.D. Cannon. 1999. "Human paleoecology and foraging theory in the Great Basin," in *Models for the Millennium: Great Basin Anthropology Today*. Edited by C. Beck, pp. 141-150. Salt Lake City: University of Utah Press.

Grayson, Donald K., and Francoise Delpech. 1998. Changing diet breadth in the early Upper Paleolithic of southwestern France. *Journal of Archaeological Science* 25:1119-1129.

—. 2003. Ungulates and the Middle-to-Upper Paleolithic transition at Grotte XVI (Dordogne, France). *Journal of Archaeological Science* 30:1633-1648.

Grayson, Donald K., and Carol J. Frey. 2004. Measuring skeletal part representation in archaeological faunas. *Journal of Taphonomy* 2:27-42.

Grün, Rainer, and Peter Beaumont. 2001. Border Cave revisited: a revised ESR chronology. *Journal of Human Evolution* 40:467-482.

Halkett, D., T. Hart, R. Yates, T. P. Volman, J. E. Parkington, J. Orton, R. G. Klein, K. Cruz-Uribe, and G. Avery. 2003. First excavation of intact Middle Stone Age layers at Ysterfontein, Western Cape Province, South Africa: Implications for Middle Stone Age ecology. *Journal of Archaeological Science* 30:955-971.

Hall, G., S. Woodborne, and M. Scholes. 2008 Stable carbon isotope ratios from archaeological charcoal as palaeoenvironmental indicators. *Chemical Geology* 247:384-400.

Hanson, Megan, and Chester R. Cain. 2007. Examining histology to identify burned bone. *Journal of Archaeological Science* 34:1902-1913.

Harper, P.T. 1997. The Middle Stone Age sequences at Rose Cottage Cave: a search for continuity and discontinuity. *South African Journal of Science* 93:470-475.

Hawkes, Kristen, Kim Hill, and James F. O'Connell. 1982. Why hunters gather: optimal foraging and the Ache of eastern Paraguay. *American Ethnologist* 9:379-398.

Hawkes, Kristen, and James F. O'Connell. 1992. On optimal foraging models and subsistence transitions. *Current Anthropology* 33:63-66.

Henshilwood, Christopher, Francesco d'Errico, Marian Vanhaeren, Karen van Niekerk, and Zenobia Jacobs. 2004. Middle Stone Age shell beads from South Africa. *Science* 304:404.

Henshilwood, Christopher, Francesco d'Errico, R. Yates, Zenobia Jacobs, C. Tribolo, G.A.T. Duller, N. Mercier, J. Sealy, H. Valladas, I. Watts, and A. Wintle. 2002. Emergence of Modern Human Behavior: Middle Stone Age engravings from South Africa. *Science* 295:1278-1280.

Henshilwood, Christopher, and Curtis W. Marean. 2003. The Origin of Modern Human Behavior: Critique of the Models and Their Test Implications. *Current Anthropology* 44:627-651.

Henshilwood, C., and J. Sealy. 1997. Bone artefacts from the Middle Stone Age at Blombos Cave, Southern Cape, South Africa. *Current Anthropology* 38:890-895.

Henshilwood, Christopher S., Francesco d'Errico, Curtis W. Marean, Richard G. Milo, and Royden Yates. 2001a. An early bone tool industry from the Middle Stone Age at Blombos Cave, South Africa: implications for the origins of modern behaviour, symbolism, and language. *Journal of Human Evolution* 41:631-678.

Henshilwood, C. S., J. C. Sealy, R. Yates, K. Cruz-Uribe, P. Goldberg, F. E. Grine, R. G. Klein, C. Poggenpoel, K. Van Niekerk, and I. Watts. 2001b. Blombos Cave, Southern Cape, South Africa: Preliminary report on the 1992-1999 excavations of the Middle Stone Age Levels. *Journal of Archaeological Science* 28:421-448.

Herries, Andrew I.R. 2006. Archaeomagnetic evdience for climate change at Sibudu Cave. *Southern African Humanities* 18:131-147.

Hill, Kim, H. Kaplan, Kristen Hawkes, and A.M. Hurtado. 1987. Foraging decisions among Ache hunter-gatherers: new data and implications for optimal foraging models. *Ethology and Sociobiology* 8:1-36.

Hiscock, Peter, and Sue O'Connor. 2006. An Australian perspective on modern behaviour and artefact assemblages. *Before Farming* 2:1-10.

Hovers, Erella, and Anna Belfer-Cohen. 2006. "Now You See it, Now you Don't" Modern Human Behavior in the Middle Paleolithic," in *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Edited by E. Hovers and S. L. Kuhn, pp. 295-304. New York: Springer.

Jacobs, Zenobia, and Richard G. Roberts. 2008. Testing times: old and new chronologies for the Howieson's Poort and Still Bay Industries in environmental context. *South*

African Archaeological Society Goodwin Series 10:9-34.

Jacobs, Zenobia, Richard G. Roberts, Rex F. Galbraith, Hilary J. Deacon, Rainer Grun, Alex Mackay, Peter Mitchell, Ralf Vogelsang, and Lyn Wadley. 2008a. Ages for the Middle Stone Age of Southern Africa: Implications for Human Behavior and Dispersal. *Science* 322:733-735.

Jacobs, Zenobia, Ann G. Wintle, Richard G. Roberts, and Geoff A.T. Duller. 2008b. Equivalent dose distributions from single grains of quartz at Sibudu Cave, South Africa: context, causes and consequences for optical dating of archaeological deposits. *Journal of Archaeological Science*:1808-1820.

Jacobs, Zenobia, Ann G. Wintle, Geoff A. T. Duller, Richard G. Roberts, and Lyn Wadley. 2008c. New ages for the post-Howiesons Poort, late and final Middle Stone Age at Sibudu Cave, South Africa. *Journal of Archaeological Science*:1790-1807.

James, Hannah V.A., and Michael D. Petraglia. 2005. Modern Human Origins and the Evolution of Behavior in the Later Pleistocene Record of South Asia. *Current Anthropology* 46:S3-S27.

Johnson, E. 1989. "Human modified bones from early southern Plains sites," in *Bone Modification*. Edited by R. Bonnichsen and M. H. Sorg, pp. 431-471. Orono: University of Maine Center for the Study of the First Americans.

Jones, Emily L. 2004. Dietary evenness, prey choice, and human-environment interactions. *Journal of Archaeological Science* 31:301-317.

Kaplan, Hillard, and Kim Hill. 1992. "The Evolutionary Ecology of Food Acquisition," in *Evolutionary Ecology and Human Behavior*. Edited by E. Smith and B. Winterhalder, pp. 167-201. Hawthorne, NY: Aldine.

Karkanas, Panagiotis, Ruth Shahack-Gross, Avner Ayalon, Mira Bar-Matthews, Ran Barkai, Amos Frumkin, Avi Gopher, and Mary C. Stiner. 2007. Evidence for habitual use of fire at the end of the Lower Paleolitihic: site formation processes at Qesem Cave, Israel. *Journal of Human Evolution* 53:197-212.

Kedrowski, B.L., B.A. Crass, J.A. Behm, J.C. Leutke, A.L. Nichols, A.M. Moreck, and C.E. Holmes. 2008. GC/MS analysis of fatty acids from ancient hearth residues at the Swan Point archaeological site. *Archaeometry* in press:doi: 10.1111/j.1475-4754.2008.00384.x.

Kelly, Robert L. 1995. *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Washington, D.C.: Smithsonian Institution Press.

Klein, Richard G. 1979. Environmental and ecological implications of large mammals from Upper Pleistocene and Holocene sites in southern Africa. *Annals of the South African Museum* 81:223-283.

—. 1989. Why does skeletal part representation differ between smaller and larger bovids at Klasies River Mouth and other archaeological sites? *Journal of Archaeological Science* 6:363-381.

—. 1995. Anatomy, behavior, and modern human origins. *Journal of World Prehistory* 9:167-198.

—. 2000. Archeology and the Evolution of Human Behavior. *Evolutionary Anthropology* 9:17-36.

—. 2001. Southern Africa and modern human origins. *Journal of Anthropological Research* 57:1-16.

—. 2003. Comment on "The Origins of Modern Human Behavior: Critique of the Models and Their Test Implications". *Current Anthropology* 45:640-641.

—. 2008. Out of Africa and the Evolution of Human Behavior. *Evolutionary Anthropology* 17:267-281.

Klein, Richard G., and Kathryn Cruz-Uribe. 1984. *The Analysis of Animal Bones from Archaeological Sites*. Chicago: University of Chicago Press.

Knecht, H. 1997. "Projectile points of bone, antler, and stone: experimental explorations of manufacture and use," in *Projectile Technology*. Edited by H. Knecht, pp. 191-212. New York: Plenum Press.

Knight, J.A. 1985. Differential preservation of calcined bone at the Hirundo Site, Alton, Maine. Unpublised M.S. thesis, University of Maine at Orono.

Kreutzer, L.A. 1992. Bison and deer bone mineral densities: comparisons and implications for the interpretation of archaeological faunas. *Journal of Archaeological Science* 19:271-294.

Kuhn, Steven L. 1991. "Unpacking" reduction: lithic raw material economic of the Mousterian in west-central Italy. *Journal of Anthropological Archaeology* 10:76-106.

—. 1995. *Mousterian Lithic Technology*. Princeton, NJ: Princeton UP.

Kuhn, Steven L., and Erella Hovers. 2006. "General Introduction," in *Transtions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Edited by E. Hovers and S. L. Kuhn, pp. 1-11. New York: Springer.

Kuhn, Steven L., and Mary C. Stiner. 1998. "Middle Paleolithic 'Creativity': Reflections on an oxymoron?," in *Creativity in Human Evolution*. Edited by S. Mithen, pp. 143-164. New York: Routledge.

—. 2001. "The antiquity of hunter gatherers," in *Hunter-Gatherers: An Interdisciplinary Perspective*. Edited by C. Panter-Brick, R. H. Layton, and P. Rowley-Conwy, pp. 99-142. Cambridge: Cambridge University Press.

—. 2007. Paleolithic Ornaments: Implications for Cognition, Demography and Identity. *Diogenes* 214:40-48.

Kuhn, Steven L., Mary C. Stiner, David S. Reese, and Erksin Gulec. 2001. Ornaments of the earliest Upper Paleolithic: New insights from the Levant. *Proceedings of the National Academy of the Sciences* 98:7641-7646.

Lam, Y.M., Xingbin Chen, and O.M. Pearson. 1999. Intertaxonomic variability in patterns of bone density and the differential representation of bovid, cervid and equid elements. *American Antiquity* 64:343-362.

Leechman, Douglas. 1951. Bone grease. *American Antiquity* 16:355-356.

Lombard, Marlize. 2005. Evidence of hunting and hafting during the Middle Stone Age at Sibudu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. *Journal of Human Evolution* 48:279-300.

—. 2005. The Howiesons Poort of South Africa: What we know, what we think we know, what we need to know. *Southern African Humanities* 17:33-55.

—. 2006. First impressions of the functions and hafting technology of Still Bay pointed artefacts from Sibudu Cave. *Southern African Humanities* 18:27-41.

—. 2007. The gripping nature of ochre: The association of ochre with Howiesons Poort adhesives and Later Stone Age mastics from South Africa. *Journal of Human Evolution* 53:406-419.

—. 2008. Finding resolution for the Howiesons Poort through the microscope: micro-residue analysis of segments from Sibudu Cave, South Africa. *Journal of Archaeological Science* 35:26-41.

Lombard, Marlize, and Justin Pargeter. 2008. Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools. *Journal of Archaeological Science* 35:2523-2531.

Lupo, Karen D. 1998. Experimentally derived extraction rates for marrow: implications for body part exploitation strategies of Plio-Pleistocene hominid scavengers. *Journal of Archaeological Science* 25:657-675.

—. 2006. What explain the carcass field processing and transport decisions of contemporary hunter-gatherers? Measures of economic anatomy and zooarchaeological skeletal part frequencies. *Journal of Archaeological Method and Theory* 13:19-66.

—. 2007. Evolutionary foraging models in zooarchaeological analysis: recent applications and future challenges. *Journal of Archaeological Research* 15:143-189.

Lupo, Karen D., and Dave N. Schmitt. 1997. Experiments in bone boiling: nutritional returns and archaeological reflection. *Anthropozoologica* 25-26:137-144.

—. 2002. Upper Paleolithic net-hunting, small prey exploitation, and women's work effort: a view from the ethnographic and ethnoarchaeological record of the Congo Basin. *Journal of Archaeological Method and Theory* 9:147-179.

—. 2005. Small prey hunting technology and zooarchaeological meaures of taxonomic diversity and abundance: Ethnoarchaeological evidence from Central African forest foragers. *Journal of Anthropological Archaeology* 24:335-353.

Lyman, R. Lee. 1994a. Quantitative Units and Terminology in Zooarchaeology. *American Antiquity* 59:36-71.

—. 1994b. Relative abundances of skeletal specimens and taphonomic analysis of vertebrate remains. *Palaios* 9:288-298.

—. 1994c. *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.

—. 2008. *Quantitative Paleozoology*. New York: Cambridge University Press.

Lyman, R. Lee, L.E. Houghton, and A.L. Chambers. 1992. The effect of structural density on marmot skeletal part representation in archaeological sites. *Journal of Archaeological Science* 19:557-573.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement*. Princeton: Princeton University Press.

Marean, Curtis W. 1991. Measuring the post-depositional destruction of bone in archaeological assemblages. *Journal of Archaeological Science* 18:677-694.

Marean, Curtis W., Yoshiko Abe, Carol J. Frey, and Robert C. Randall. 2000. Zooarchaeological and taphonomic analysis of the Die Kelders Cave 1 Layers 10 and 11 Middle Stone Age larger mammal fauna. *Journal of Human Evolution* 38:197-233.

Marean, Curtis W., Yoshiko Abe, Peter J. Nilssen, and Elizabeth C. Stone. 2001. Estimating the minimum number of skeletal elements (MNE) in zooarchaeology: a review and a new image-analysis GIS approach. *American Antiquity* 66:333-348.

Marean, Curtis W., and Zelalem Assefa. 2005. "The Middle and Upper Pleistocene

African Record for the Biological and Behavioral Origins of Modern Humans," in *African archaeology: a critical introduction*. Edited by A. B. Stahl, pp. 93-129. Malden, MA: Blackwell Publishing Ltd.

Marean, Curtis W., Miryam Bar-Matthews, Jocelyn Bernatchez, Erich Fischer, Paul Goldberg, Andy I.R. Herries, Zenobia Jacobs, Antonieta Jeradino, Panagiotis Karkanas, Tom Minichillo, Peter J. Nilssen, Erin Thompson, Ian Watts, and Hope M. Williams. 2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature* 449:905-908.

Marean, Curtis W., and Naomi Cleghorn. 2003. Large mammal skeletal element transport: applying foraging theory in a complex taphonomic system. *Journal of Taphonomy* 1:15-42.

Marean, Curtis W., and Soo Yeun Kim. 1998. Mousterian large-mammal remains from Kobeh Cave: behavioral implications for Neanderthals and Early Modern Humans. *Current Anthropology* 39:S79-S114.

Marean, Curtis W., and L.M. Spencer. 1991. Impact of carnivore ravaging on zooarchaeological measures of element abundance. *American Antiquity* 56:645-658.

Marshall, Fiona, and Tom Pilgram. 1993. NISP vs. MNI in quantification of body-part representation. *American Antiquity* 58:261-269.

Maslin, M. A., and B. Christensen. 2007. Tectonics, orbital forcing, global climate change, and human evolution in Africa: introduction to the African paleoclimate special volume. *Journal of Human Evolution* 53:443-464.

McBrearty, Sally, and Alison S. Brooks. 2000. The revolution that wasn't: a new interpretation of the origin of modern human behavior. *Journal of Human Evolution* 39:453-563.

McBrearty, Sally, and Chris Stringer. 2007. The coast in colour. *Nature* 449:793-794.

McCall, Grant S. 2007. Behavioral ecological models of lithic technological change during the later Middle Stone Age of South Africa. *Journal of Archaeological Science* 34:1738-1751.

McDougall, Ian, Francis H. Brown, and John G. Fleagle. 2005. Stratigraphic placement and age of modern humans from Kibish, Ethiopia. *Nature* 433:733-736.

Mellars, Paul. 1973. "The Character of the Middle-Upper Paleolithic Transition in Southwest France," in *The Explanation of Cultural Change*. Edited by C. Renfrew, pp. 255-276. London: Duckworth.

—. 1996. *The Neanderthal Legacy: An Archaeological Perspective from Western Europe*. Princeton: Princeton University Press.

—. 2002. Archaeology and the Origins of Modern Humans: European and African Perspectives. *Proceedings of the British Academy* 106:31-47.

—. 2005. The Impossible Coincidence. A Single-Species Model for the Origins of Modern Human Behavior in Europe. *Evolutionary Anthropology* 14:12-27.

—. 2006a. "Foreword: Challenges and Approaches in the Study of Middle Paleolithic Behavioral Change," in *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Edited by E. Hovers and S. L. Kuhn, pp. vii-xvii. New York: Springer.

—. 2006b. Why did modern human populations disperse from Africa ca. 60,000 years ago? A new model. *Proceedings of the National Academy of the Sciences*

103:9381-9386.

Metcalfe, Duncan, and Kevin T. Jones. 1988. A reconsideration of animal body-part utility indices. *American Antiquity* 53:486-504.

Michel, Véronique, Hervé Bocherens, Isabelle Théry-Parisot, Karel Valoch, and Patricia Valensi. 2006. Coloring and preservation state of faunal remains from the Neanderthal levels of Kulna Cave, Czech Republic. *Geoarchaeology* 21:479-501.

Miller, G.H., P.B. Beaumont, H.J. Deacon, A.S. Brooks, P.E. Hare, and A.J.T. Jull. 1999. Earliest modern humans in southern Africa dated by isoleucine epimerization in ostrich eggshell. *Quaternary Science Reviews* 18:1537-1548.

Milo, Richard G. 1994. Human-animal interactions in southern African prehistory: A microscopic study of bone damage signatures. unpublished PhD thesis, University of Chicago.

Minichillo, Tom. 2006. Raw material use and behavioral modernity: Howiesons Poort lithic foraging strategies. *Journal of Human Evolution* 50:359-364.

Minnis, Paul E. 1985. *Social Adaptation to Food Stress: A Prehistoric Southwestern Example*. *Prehistoric Archaeology and Ecology Series*. Chicago: University of Chicago Press.

Miracle, Preston T. 1995. Broad-Spectrum Adaptations Re-Examined: Hunter-Gatherer Repsonses to Late Glacial Environmental Changes in the Eastern Adriatic. Unpublished PhD thesis, University of Michigan.

—. 2005. Late Mousterian subsistence and cave use in Dalmatia: the zooarchaeology of Mujina Pećina, Croatia. *International Journal of Osteoarchaeology*:84-105.

Monahan, Christopher M. 1998. The Hadza Carcass Transport Debate Revisited and its Archaeological Implications. *Journal of Archaeological Science* 25:405-424.

Morin, Eugene. 2004. Late Pleistocene Population Interaction in Western Europe and Modern Human Origins: New Insights Based on the Faunal Remains from Saint-Cesaire, Southwestern France. Unpublished PhD thesis, University of Michigan.

—. 2007. Fat composition and Nunamiut decision-making: a new look at the marrow and bone grease indices. *Journal of Archaeological Science* 34:69-82.

Munro, Natalie D. 2004. Zooarchaeological Measures of Hunting Pressure and Occupation Intensity in the Natufian: Implications for Agricultural Origins. *Current Anthropology* 45:S5-S33.

Munro, Natalie D., and Guy Bar-Oz. 2004. Debating Issues of Equifinality in Ungulate Skeletal Part Studies. *Journal of Taphonomy* 2:1-13.

—. 2005. Gazelle bone fat processing in the Levantine Epipaleolithic. *Journal of Archaeological Science* 32:223-239.

Nagaoka, L. 2001. Using diversity indices to measure change in prey choice at Shag River Mouth Site, southern New Zealand. *International Journal of Osteoarchaeology* 11:101-111.

—. 2002. Explaining subsistence change in southern New Zealand using foraging theory models. *World Archaeology* 34:84-102.

Nicholson, Rebecca A. 1993. A morphological investigation of burnt animal bone and an evaluation of its utility in archaeology. *Journal of Archaeological Science* 1993:411-428.

Niven, Laura. 2007. From carcass to cave: large mammal exploitation during the Aurignacian at Vogelherd, Germany. *Journal of Human Evolution* 53:362-382.

O'Connell, James F. 2006. "How did modern humans replace Neanderthals?," in *When Neanderthals and Modern Humans Met*. Edited by N. J. Conard, pp. 43-64. Tuebingen: Kerns Verlag.

O'Connell, James F., and Jim Allen. 2007. "Pre-LGM Sahul (Pleistocene Australia-New Guinea) and the Archaeology of Early Modern Humans," in *Rethinking the Human Revolution: New Behavioural and Biological Perspectives on the Origin and Dispersal of Modern Humans*. Edited by P. Mellars, K. Boyle, O. Bar-Yosef, and C. Stringer, pp. 395-410. Cambridge, UK: McDonald Institute for Archaeological Research, Cambridge University.

O'Connell, James F., Kristen Hawkes, and N.G. Blurton Jones. 1988. Hadza Hunting, Butchering, and Bone Transport and Their Archaeological Implications. *Journal of Anthropological Research* 44:113-162.

—. 1990. Reanalysis of Large Mammal Body Part Transport Among the Hadza. *Journal of Archaeological Science* 17:301-316.

Oliver, James S. 1993. "Carcass Processing by the Hadza: Bone Breakage from Butchery to Consumption," in *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*, vol. 21, *Occasional Paper*. Edited by J. Hudson, pp. 200-227. Carbondale, IL: Southern Illinois University, Center for Archaeological Investigations.

Outram, Alan K. 2001. A new approach to identifying bone marrow and grease exploitation: Why the "indeterminate" fragments should not be ignored. *Journal of Archaeological Science* 28:401-410.

Pargeter, Justin. 2007. Howiesons Poort segments as hunting weapons: experiments with replicated projectiles. *South African Archaeological Bulletin* 62:147-153.

Parkington, John E., Cedric Poggenpoel, Jean-Philippe Rigaud, and Pierre-Jean Texier. 2005. "From tool to symbol: the behavioural context of intentionally marked ostrich eggshell from Diepkloof, Western Cape," in *From Tools to Symbols: From Early Hominids to Modern Humans*. Edited by F. d'Errico and L. Backwell, pp. 475-492. Johannesburg: Witwatersrand University Press.

Partridge, T.C., P.B. Demenocal, S.A. Lorentz, M.J. Paiker, and J.C. Vogel. 1997. Orbital forcing of climate over South Africa: a 200,000-year rainfall record from the Pretoria Saltpan. *Quaternary Science Reviews* 16:1125-1133.

Pianka, E.R. 1978. *Evolutionary Ecology*, 2nd edition. New York: Harper and Row.

Pickering, Robin. 2006. Regional geology, setting and sedimentology of Sibudu Cave. *Southern African Humanities* 18:123-129.

Pickering, Travis Rayne, Manuel Dominguez-Rodrigo, Charles P. Egeland, and C.K. Brain. 2005. The Contribution of Limb Bone Fracture Patterns to Reconstructing Early Hominid Behavior at Swartkrans Cave (South Africa): Archaeological Application of a New Analytical Method. *International Journal of Osteoarchaeology* 15:247-260.

Pickering, Travis R., and Charles Egeland. 2006. Experimental patterns of hammerstone percussion damage on bones and zooarchaeological inferences of carcass processing intensity by humans. *Journal of Archaeological Science* 33:459-469.

Pickering, Travis Rayne, Charles P. Egeland, Amy G. Schnell, Daniel L. Osbone, and Jake Enk. 2006. Success in identification of experimentally fragmented limb bone shafts: implications for estimates of skeletal element abundance in archaeofaunas.

Journal of Taphonomy 4:97-108.

Pickering, Travis Rayne, Curtis W. Marean, and Manuel Dominguez-Rodrigo. 2003. Importance of limb bone shaft fragments in zooarchaeology: a response to "On in situ attrition and vertebrate body part profiles" (2002), by M.C. Stiner. *Journal of Archaeological Science* 30:1469-1482.

Plug, Ina. 2004. Resource exploitation: animal use during the Middle Stone Age at Sibudu Cave, KwaZulu-Natal. *South African Journal of Science* 100:151-158.

—. 2006. Aquatic animals and their associates from the Middle Stone Age levels at Sibudu. *Southern African Humanities* 18:289-299.

Plug, Ina, and Jamie L. Clark. 2008. In the air: a preliminary report on the birds from Sibudu Cave, KwaZulu-Natal, South Africa. *South African Archaeological Society Goodwin Series* 10:133-142.

Prince, Paul. 2007. Determinants and implications of bone grease rendering: a Pacific Northwest example. *North American Archaeologist* 28:1-28.

Ramsay, Peter J., and J. Andrew Cooper. 2002. Late Quaternary sea-level change in South Africa. *Quaternary Research* 57:82-90.

Reinhard, K.J., J.R. Ambler, and C.R. Szuter. 2007. Hunter-gatherer use of small animal food resources: coprolite evidence. *International Journal of Osteoarchaeology* 17:416-428.

Reitz, Elizabeth J., and Elizabeth S. Wing. 1999. *Zooarchaeology*. Cambridge: Cambridge University Press.

Relethford, J. H. 1998. Genetics of modern human origins and diversity. *Annual Review of Anthropology* 27:1-23.

Renaut, Ray, and Marion K. Bamford. 2006. Results of a preliminary palynological analysis at Sibudu Cave. *Southern African Humanities* 18:235-240.

Rigaud, Jean-Philippe, Pierre-Jean Texier, John E. Parkington, and Cedric Poggenpoel. 2006. Le mobilier Stillbay et Howiesons Poor de l'abri Diepkloof: La Chronologie du Middle Stone Age sud-africain et ses implications. *Comptes Rendus Palevol* 5:839-849.

Roberts, S.J., C.I. Smith, A. Mallard, and M.J. Collins. 2002. The taphonomy of cooked bone: characterizing boiling and its physico-chemical effects. *Archaeometry* 44:485-494.

Schiegl, Solveig, and Nicholas J. Conard. 2006. The Middle Stone Age sediments at Sibudu: results from FTIR spectroscopy and microscopic analyses. *Southern African Humanities* 18:149-172.

Schiegl, Solveig, Philipp Stockhammer, Christine Scott, and Lyn Wadley. 2004. A mineralogical and phytolith study of the Middle Stone Age hearths in Sibudu Cave, KwaZulu-Natal, South Africa. *South African Journal of Science* 100:185-194.

Schmidt, Christopher, and Stephen Symes. 2008. *The Analysis of Burned Human Remains*. New York: Academic Press.

Scholz, Christopher, Thomas C. Johnson, Andrew S. Cohen, John W. King, John A. Peck, Jonathan T. Overpeck, Michael R. Talbot, Erik T. Brown, Leonard Kalindekafe, Philip Y.O. Amoako, Robert P. Lyons, Timothy M. Shanahan, Isla S. Castaneda, Clifford W. Heil, Steven L. Forman, Lanny R. McHargue, Kristina R. Beuing, Jeanette Gomez, and James Pierson. 2007. East African megadroughts between 135 and 75 thousand years ago and bearing on early modern human origins. *Proceedings of the National Academy of the Sciences* 104:16416-16421.

Shahack-Gross, Ruth, Ofer Bar-Yosef, and Steve Weiner. 1997. Black-coloured bones in Hayonim Cave, Israel: differentiating between burning and oxide staining. *Journal of Archaeological Science* 24:439-446.

Shennan, Stephen. 2000. Population, culture history, and the dynamics of culture change. *Current Anthropology* 41:811-835.

—. 2001. Demography and cultural innovation: a model and its implications for the emergence of modern human culture. *Cambridge Archaeological Journal* 11:5-16.

Shipman, Pat, Giraud Foster, and Margaret Schoeninger. 1984. Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. *Journal of Archaeological Science* 11:307-325.

Sievers, Christine. 2006. Seeds from the Middle Stone Age layers at Sibudu Cave. *Southern African Humanities* 18:203-222.

Singer, Ronald, and John Wymer. 1982. *The Middle Stone Age at Klasies River Mouth in South Africa*. Chicago: University of Chicago Press.

Skinner, John D., and Christian T. Chimimba. 2005. *The Mammals of the Southern African Sub-region*, 3rd edition. Singapore: Cambridge University Press.

Soriano, Sylvain, Paola Villa, and Lyn Wadley. 2007. Blade technology and tool forms in the Middle Stone Age of South Africa: the Howiesons Poort and post-Howiesons Poort at Rose Cottage Cave. *Journal of Archaeological Science* 34:681-703.

Speth, John D. 1983. *Bison Kills and Bone Counts: Decision Making by Ancient Hunters. Prehistoric Archaeology Ecology Series*. Chicago: University of Chicago Press.

—. 2004a. "Hunting Pressure, Subsistence Intensification, and Demographic Change in the Levantine Late Middle Paleolithic," in *Human Paleoecology in the Levantine Corridor*. Edited by N. Goren-Inbar and J. D. Speth, pp. 149-166. Oxford: Oxbow.

—. 2004b. News flash: negative evidence convicts Neanderthals of gross mental incompetence. *World Archaeology* 36:519-526.

Speth, John D., and Jamie L. Clark. 2006. Hunting and overhunting in the Levantine late Middle Paleolithic. *Before Farming* 3:1-42.

Speth, John D., and Eitan Tchernov. 2001. "Neandertal Hunting and Meat-Processing in the Near East: Evidence from Kebara Cave (Israel)," in *Meat-Eating and Human Evolution*. Edited by C. B. Stanford and H. T. Bunn, pp. 52-72. Oxford: Oxford University Press.

—. 2007. "The Middle Paleolithic Occupations at Kebara Cave: A Faunal Perspective," in *Kebara Cave, Mt. Carmel, Israel: The Middle and Upper Paleolithic Archaeology Part I*, vol. 49, *American School of Prehistoric Research Bulletin*. Edited by O. Bar-Yosef and L. Meignen, pp. 165-260. Cambridge, MA: Peabody Museum Press, Harvard University.

Stephens, D.W., and J.R. Krebs. 1986. *Foraging Theory*. Princeton: Princeton University Press.

Stiner, Mary C. 2002. On in situ attrition and vertebrate body part profiles. *Journal of Archaeological Science* 29:979-991.

—. 2003. Zooarchaeological evidence for resource intensification in Algarve, Southern

Portugal. *promontoria* 1:27-61.

—. 2004a. A comparison of Photon Densitometry and Computer Tomography parameters of bone density in ungulate body part profiles. *Journal of Taphonomy* 2:117-145.

—. 2004b. "Population Ecology, Predator-Prey Dynamics, and Paleolithic Society," in *Processual Archaeology: Exploring Analytical Strategies, Frames of Reference, and Culture Process*. Edited by A. L. Johnson, pp. 218-260. London: Praeger.

—. 2004. A comparison of Photon Densitometry and Computer Tomography parameters of bone density in ungulate body part profiles. *Journal of Taphonomy* 2:117-145.

—. 2005. *The Faunas of Hayonim Cave, Israel: A 200,000-Year Record of Paleolithic Diet, Demography, and Society. American School of Prehistoric Research Bulletin 49*. Cambridge, MA: Peabody Museum Press, Harvard University.

Stiner, Mary C., and Steven L. Kuhn. 1992. Subsistence, Technology, and Adaptive Variation in Middle Paleolithic Italy. *American Anthropologist* 94:306-339.

—. 2006. Changes in the 'connectedness' and resilience of Paleolithic societies in Mediterranean ecosystems. *Human Ecology* 34:693-712.

Stiner, Mary C., Steven L. Kuhn, Stephen Weiner, and Ofer Bar-Yosef. 1995. Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone. *Journal of Archaeological Science* 22:223-237.

Stiner, Mary C., and Natalie D. Munro. 2002. Approaches to Prehistoric Diet Breadth, Demography, and Prey Ranking Systems in Time and Space. *Journal of Archaeological Method and Theory* 9:181-214.

Stiner, Mary C., Natalie D. Munro, and Todd A. Surovell. 2000. The tortoise and the hare: small-game use, the broad spectrum revolution, and Paleolithic demography. *Current Anthropology* 41:39-73.

Stiner, Mary C., Natalie D. Munro, Todd A. Surovell, Eitan Tchernov, and Ofer Bar-Yosef. 1999. Paleolithic population growth pulses evidenced by small animal exploitation. *Science* 283:190-194.

Straus, Lawrence Guy. 1983. "From Mousterian to Magdalenian: Cultural evolution viewed from Vasco-Cantabrian Spain and Pyrenean France," in *The Mousterian Legacy*, vol. 164, *British Archaeological Reports International Series*. Edited by E. Trinkaus, pp. 73-111.

—. 2005. A mosaic of change: the Middle-Upper Paleolithic transition as viewed from New Mexico and Iberia. *Quaternary International* 137:47-67.

Stuut, Jan-Berend W., Maarten A. Prins, Ralph R. Schneider, Gert Jan Weltje, J.H. Fred Jansen, and George Postma. 2002. A 300-kyr record of aridity and wind strength in southwestern Africa: inferences from grain-size distributions of sediments on Walvis Ridge, SE Atlantic. *Marine Geology* 180:221-233.

Théry-Parisot, Isabelle. 2002. Fuel management (bone and wood) during the lower Aurignacian in the Pataud rock shelter (Lower Paleolithic, Les Eyzies de Tayac, Dordogne, France). Contribution of experimentation. *Journal of Archaeological Science* 29:1415-1421.

Théry-Parisot, Isabelle, Sandrine Costamagno, Jean-Philip Brugal, P. Fosse, and Raphaele Guibert. 2005. "The use of bone as fuel during the Paleolithic, experimental study of bone combustible properties," in *The Zooarchaeology of Milk and Fats*, *(Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham 2002)*. Edited by J. P. Mulville and A. K. Outram, pp.

50-59. Oxford: Oxbow Books.

Thomas, D. S. G., and P. A. Shaw. 2002. Late Quaternary environmental change in central southern Africa: new data, synthesis, issues and prospects. *Quaternary Science Reviews* 21:783-797.

Ugan, Andrew. 2005. Climate, bone density, and resource depression: what is driving variation in large and small game in Fremont archaeofaunas? *Journal of Anthropological Archaeology* 24.

Valladas, H., L. Wadley, N. Mercier, L. Froget, C. Tribolo, J.L. Reyss, and J.L. Joron. 2005. Thermoluminescence dating on burnt lithics from Middle Stone Age layers at Rose Cottage Cave. *South African Journal of Science* 101:169-174.

Vanhaeren, M., F. d'Errico, C. Stringer, S. L. James, J. A. Todd, and H. K. Mienis. 2006. Middle Paleolithic shell beads in Israel and Algeria. *Science* 312:1785-1788.

Villa, Paola, Jean-Cristophe Castel, Cedric Beauval, Valerie Bourdillat, and Paul Goldberg. 2004. Human and carnivore sites in the European Middle and Upper Paleolithic: Similarities and differences in bone modification and fragmentation. *Revue de Paleobiologie, Geneve* 23:705-730.

Villa, Paola, Anne Delagnes, and Lyn Wadley. 2005. A late Middle Stone Age artifact assemblage from Sibudu (KwaZulu-Natal): comparisons with the European Middle Paleolithic. *Journal of Archaeological Science* 32:399-422.

Villa, Paola, and M. Lenoir. 2006. Hunting weapons of the Middle Stone Age and the Middle Palaeolithic: spear points from Sibudu, Rose Cottage and Bouheben. *Southern African Humanities* 18:89-122.

Villa, Paola, and Eric Mahieu. 1991. Breakage patterns of human long bones. *Journal of Human Evolution* 21:27-48.

von den Driesch, Angela. 1976. *A Guide to the Measurement of Animal Bones from Archaeological Sites*. *Peabody Museum Bulletin 1*. USA: Peabody Museum Press, Harvard University.

Wadley, Lyn. 2001. What is cultural modernity? A general view and a South African perspective from Rose Cottage Cave. *Cambridge Archaeological Journal* 11:201-221.

—. 2004. Vegetation changes between 61500 and 26000 years ago: the evidence from seeds in Sibudu Cave, KwaZulu-Natal. *South African Journal of Science* 100:167-173.

—. 2005a. A typological student of the final Middle Stone Age stone tools from Sibudu Cave, KwaZulu-Natal. *South African Archaeological Bulletin* 60:51-63.

—. 2005b. Putting ochre to the test: replication studies of adhesives that may have been used for hafting tools in the Middle Stone Age. *Journal of Human Evolution* 49:587-601.

—. 2006. Partners in grime: results of multi-disciplinary archaeology at Sibudu Cave. *Southern African Humanities* 18:315-341.

—. 2007. Announcing a Still Bay industry at Sibudu Cave, South Africa. *Journal of Human Evolution* 52:681-689.

—. 2008. The Howieson's Poort Industry of Sibudu Cave. *South African Archaeological Society Goodwin Series* 10:122-132.

Wadley, Lyn, and Zenobia Jacobs. 2004. Sibudu Cave, KwaZulu-Natal: Background to the excavations of Middle Stone Age and Iron Age occupations. *South African*

Journal of Science 100:145-151.

—. 2006. Sibudu Cave: background to the excavations, stratigraphy and dating. *Southern African Humanities* 18:1-26.

Wadley, Lyn, and Moleboheng Mohapi. 2008. A segment is not a monolith: evidence from the Howiesons Poort of Sibudu, South Africa. *Journal of Archaeological Science* 35:2594-2605.

Wadley, Lyn, Ina Plug, and Jamie L. Clark. 2008. "The contribution of Sibudu's fauna to an understanding of KwaZulu-Natal Environments at ~60, ~50 and ~37ka," in *Animals and People: Archaeozoological Papers in Honour of Ina Plug*, *British Archaeological Series (BAR)*. Edited by S. Badenhorst, P. Mitchell, and J. C. Driver, pp. 34-45. Oxford: Archaeopress.

Wadley, Lyn, Bonny Williamson, and Marlize Lombard. 2004. Ochre in hafting in Middle Stone Age southern Africa: a practical role. *Antiquity* 78:661-675.

Watts, Ian. 2002. Ochre in the Middle Stone Age of southern Africa: Ritualized display or hide preservative? *South African Archaeological Bulletin* 57:1-14.

Wells, Colleen R. 2006. A sample integrity analysis of faunal remains from the RSp layer at Sibudu Cave. *Southern African Humanities* 18:261-277.

White, Randall. 1982. Rethinking the Middle/Upper Paleolithic Transition. *Current Anthropology* 23:169-192.

Wiessner, Pauline. 1983. Style and social information in Kalahari San projectile points. *American Antiquity* 48:253-276.

Williamson, B.S. 2004. Middle Stone Age tool function from residue analysis at Sibudu Cave. *South African Journal of Science* 100:174-178.

Wurz, Sarah. 1997. The Howiesons Poort at Klasies River: from artefacts to cognition. unpublished Masters thesis, University of Stellenbosch.

Wurz, Sarah, and Marlize Lombard. 2007. 70,00o-year-old geometric backed tools from the Howiesons Poort at Klasies River, South Africa: were they used for hunting? *Southern African Humanities* 19:1-16.

Yellen, J.E., A.S. Brooks, E. Cornelissen, M.J. Melhman, and K. Steward. 1995. A Middle Stone Age worked bone industry from Katanda, Upper Semiliki Valley, Zaire. *Science* 268:553-556.

Yeshurun, Reuven, Nimrod Marom, and Guy Bar-Oz. 2007. Differential fragmentation of different ungulate body-size: a comparison of gazelle and fallow deer bone fragmentation in Levantine prehistoric assemblages. *Journal of Taphonomy* 5:137-148.

Zilhão, João. 2007. The emergence of ornaments and art: an archaeological perspective on the origins of "behavioral modernity". *Journal of Archaeological Research* 15:1-54.

Zilhão, João, and Francesco d'Errico. 2003. "The chronology of the Aurignacian and Transitional technocomplexes: Where do we stand?," in *The Chronology of the Aurignacian and of the Transitional Technocomplexes: Dating, Stratigraphy and Cultural Implications*, vol. 33, *Trabalhos de Arqueologia*. Edited by J. Zilhão and F. d'Errico, pp. 313-349. Lisbon: Instituto Portugues de Arqueologia.