

# The Taphonomy of the Final Middle Stone Age Fauna from Sibudu Cave, South Africa

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**ABSTRACT** This study applies a taphonomic analysis to the final Middle Stone Age faunal assemblage from Sibudu Cave, South Africa, by assessing bone surface modifications, breakage patterns and skeletal element abundances. Cut marks, percussion marks, severe fragmentation and the high frequency of burned bone combine to demonstrate that human behaviour was the principal agent in the assemblage's formation. These results are consistent with previous research on earlier occupations of Sibudu during the Middle Stone Age. Moreover, this assemblage is proposed to reflect regular site maintenance and cleaning. This conclusion is consistent with previous research that demonstrates systematic site maintenance during the Middle Stone Age at Sibudu and emphasises this behaviour as being a consistent activity for Middle Stone Age foragers. Copyright © 2013 John Wiley & Sons, Ltd.

*Key words:* burned bone; Middle Stone Age; Sibudu Cave; taphonomy; zooarchaeology

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## Introduction

There has been much previous research on the Middle Stone Age (MSA) faunal assemblages from Sibudu Cave, South Africa (Plug, 2004; Cain, 2005, 2006; Wells, 2006; Clark & Plug, 2008; Wadley *et al.*, 2008; Clark & Ligouis, 2010; Clark, 2011). However, the majority of these studies have focused on the earlier MSA occupations, with relatively little research being conducted on the more recent final MSA (fMSA) occupation (Plug, 2004; Wadley *et al.*, 2008). The fMSA faunal studies have provided a sound understanding of the faunal species present and the environment during this occupation at Sibudu. However, this research has not specifically examined the taphonomic factors that influenced the assemblage's formation.

This study focused on identifying the agents involved in the formation of the fMSA faunal assemblage through undertaking a thorough taphonomic analysis. In this manner, both anthropogenic and non-anthropogenic behaviours and their respective contributions to the formation of the fMSA faunal assemblage were identified. This approach also examined whether regular site

maintenance and cleaning, a feature of earlier MSA occupations at Sibudu (Cain, 2006; Goldberg *et al.*, 2009; Clark & Ligouis, 2010), was also being practised during the fMSA.

## Background

Sibudu Cave is located roughly 40 km north of the city of Durban in KwaZulu-Natal, South Africa. The site is approximately 15 km inland from the Indian Ocean and overlooks the Tongati River (Figure 1). From 1998 to 2011, the site was excavated by Dr Lyn Wadley, with the artefacts and faunal remains from the fMSA occupation being recovered between 1998 and 2002. Sibudu is excavated in 1 m by 1 m units following the natural stratigraphy at the site. From 1998 until 2002, all of the sediment was screened using 2-mm sieves, and from 2003 onwards, the sediment was further screened with 1-mm sieves (Wadley & Jacobs, 2006). Sibudu has a long and detailed archaeological sequence, with Iron Age occupations in the upper layers being immediately followed by MSA occupations. The MSA occupations at Sibudu include the fMSA at ~38,000 years ago (kya), followed by a late MSA at ~48 kya, a post-Howieson's Poort (HP) at ~58 kya, HP from 64 to 62 kya, Still Bay at ~70 kya, pre-Still Bay at ~77 kya and earlier deposits that have not yet been dated (Jacobs *et al.*, 2008a, 2008b).

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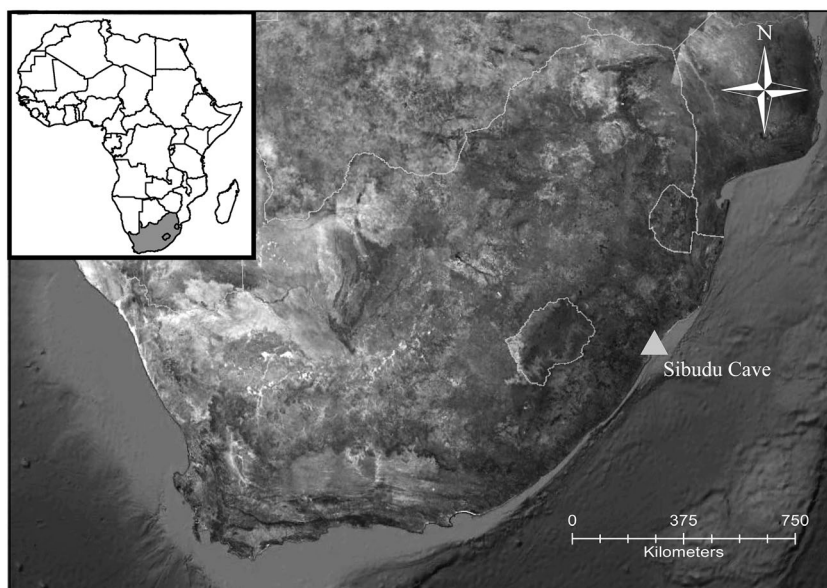


Figure 1. Map of Sibudu.

The earlier MSA deposits at Sibudu have made significant contributions to our understanding of MSA hunter-gatherers, particularly in the use of ochre as a compound adhesive (Wadley *et al.*, 2009; Wadley, 2010a, 2010b), plant matter being used as bedding (Wadley *et al.*, 2011) and the use of trapping and snaring techniques for exploiting small mammals (Clark & Plug, 2008; Wadley, 2010c). These findings have all contributed to the behavioural modernity debate, through furthering the argument for modern cognition being present during the MSA.

The fMSA layers at Sibudu are also of importance, as they immediately precede the Middle to Later Stone Age transition, the causes of which are generally poorly understood because of its temporally and geographically staggered nature (Mitchell, 2008). These layers [Co, Bu, LBMOD, MC (a hearth feature), Es and Mou] are only present in the eastern part of the excavation in units C2, D2, D3, E2 and E3 (Figure 2) and have been dated using optically stimulated luminescence (OSL) to ~38 kya.

## Materials and methods

### *Previous research and materials*

The faunal assemblage from the fMSA layers at Sibudu was initially studied by Dr Ina Plug (Plug, 2004), who analysed a selection of the faunal remains that had been recovered at that time, including those from the Iron Age and earlier MSA layers. However, Plug's research

focused on the identification of taxa and not the taphonomy; therefore, it did not include the non-identifiable fraction of the assemblage. Plug's study also took place before OSL dates were available. The OSL dates demonstrated that the initial combination of fauna from various strata was incorrect, with Plug's initial fMSA totals containing data from older layers (Jacobs *et al.*, 2008a, 2008b). However, there was no

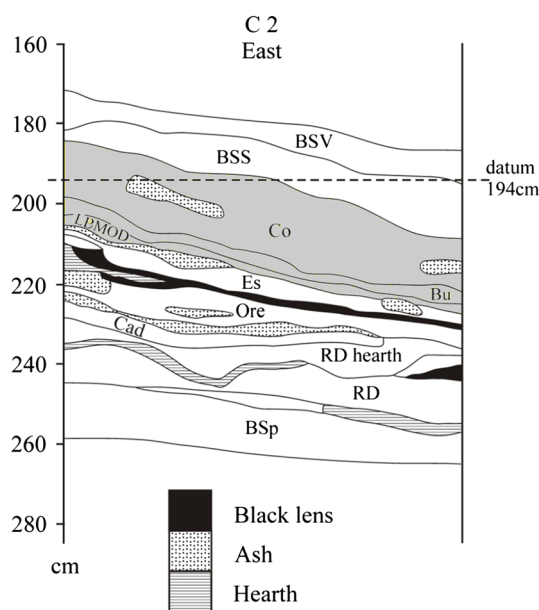


Figure 2. Eastern wall profile showing part of the stratigraphy from Sibudu. The final Middle Stone Age layers are in grey. Image used with permission from Dr Lyn Wadley.

physical mixing of the layers, and the data were subsequently re-organised by Wadley *et al.* (2008) into the fMSA and late MSA occupations.

The faunal data, in combination with OSL dates and the plant remains, have all contributed to demonstrate that the fMSA at Sibudu is linked to a warmer, wetter and more wooded environment than the late MSA and HP occupations. However, this environment was more arid and contained more savannah plant taxa than are present in the region's current coastal forest environment, (Allott, 2004; Sievers, 2006; Jacobs *et al.*, 2008a, 2008b; Wadley *et al.*, 2008; Bruch *et al.*, 2012).

## *Methods*

This research focused on analysing the taphonomy of the fMSA faunal assemblage and therefore combined a re-analysis of the materials studied by Plug and an analysis of the previously unstudied fauna. Following Clark's (Clark & Plug, 2008, Clark & Ligouis, 2010; 2009; 2011) approach to analysing the earlier layers of Sibudu's fauna, the previously unstudied fauna was initially divided into identifiable and non-identifiable specimens. The non-identifiable fraction was further divided into >2- and <2-cm categories, and all specimens were examined for bone surface modifications.

The identifiable fraction of the total fMSA assemblage was then quantified into the number of identifiable specimens (NISP), the minimum number of elements (MNE) and the minimum number of individuals (MNI). To be considered identifiable, the specimen needed to be identified to element and at least ungulate size category, which was adapted from Brain (1981). MNEs were estimated using the comprehensive method and included consideration of long bone shaft fragments (Marean *et al.*, 2004; Barba & Dominguez-Rodrigo, 2005; Yravedra & Dominguez-Rodrigo, 2009). The comprehensive method takes into account age, sex and size and generates more accurate MNE estimates (de Ruiter, 2004; Lyman, 2008).

The MNI was estimated independently for each stratum, as the diligent excavation techniques employed by Wadley and her team, and the absence of re-fits between layers, merit that each stratum be considered an independent depositional event. Estimates were made for each discrete taxonomic category using a comprehensive assessment of the MNE estimate for that category. In order to increase the sample size, MNIs were then constructed for size classes, with all of the materials from a size class being compared to ensure that no overlap occurred. Materials that bordered between size classes, such as Size Class 1/2,

were not considered for this study as these categories are too vague for analysis.

Elsewhere, the use of MNEs and MNIs for analysing faunal assemblages has been strongly contested, as they provide minimum estimates only, are derived measures and are argued to correlate with NISP (Plug & Plug, 1990; Lyman, 2008). Instead, the use of NISP and/or quantifiable skeletal parts (QSP) has been advocated (Plug & Plug, 1990; Clark & Plug, 2008; Lyman, 2008). QSP is a ratio measure derived from NISP, where identifiable skeletal parts are normalised with regard to skeletal complexity (the number of discrete elements present in a complete skeleton for that taxon), and it is used to address issues with NISP, such as interdependence, differential preservation and animals with different numbers of bones (de Ruiter, 2004, 269). However, it is important to note that MNE and MNI provide different information than NISP, giving estimates of the number of elements and individuals in an assemblage and not the number of specimens for an element or individual.

This difference is important, especially in extremely comminuted assemblages, such as Sibudu, as both different species and different elements have been experimentally shown to produce different fragmentation patterns, which biases the element and species NISP counts (Pickering & Egeland, 2006). Highly fragmentary assemblages have also been shown to bias QSP estimates, which renders QSP inappropriate for assessing taphonomy (de Ruiter, 2004; Dominguez-Rodrigo, 2012). Furthermore, as demonstrated by Bartram (1993, 208) and Dominguez-Rodrigo (2012), the correlation between NISP and MNI decreases with highly fragmentary assemblages. For these reasons, MNE and MNI, as well as NISP, were used to assess the taphonomy of the fMSA.

In addition, the standardised minimum animal unit measure (%MAU, Binford, 1978) was used to assess variation in skeletal element abundances. %MAU was calculated and tested against element utility (using Metcalfe and Jones', 1988, Food Utility Index) and bone density (using the BMD<sub>2</sub> measurements of Lam *et al.*, 1999, for adult *Connochaetes taurinus*) to assess both human and taphonomic actions that may have contributed to the assemblage formation (Marean *et al.*, 2004; Lam & Pearson, 2005; Dominguez-Rodrigo *et al.*, 2007; Collins & Willoughby, 2010). The data were divided into ungulate Size Classes 1, 2 and 3+ to increase the sample size (Collins & Willoughby, 2010; Clark, 2011).

Several measures were used to assess the influence of the taphonomic agents that affected the faunal

assemblage. Bone surface modifications, including cut marks, percussion marks, trampling marks, tooth marks and diagenetic marks, were observed using a  $\times 16$  hand lens and strong, indirect light. A  $\times 40$  binocular microscope was used for marks that were more difficult to identify. Marks were identified using the criteria outlined by Binford (1981), Behrensmeyer *et al.* (1986), Blumenschine (1995), Blumenschine *et al.* (1996), Bunn (1982) and Dominguez-Rodrigo *et al.* (2009).

Bone surface modifications were only evaluated on specimens that demonstrated moderate-to-poor or better bone surface preservation. Surface preservation was assessed using a qualitative scale, with specimens displaying good preservation having surfaces that are completely intact. Moderately preserved specimens were only mildly damaged and have the majority (>50%) of their surface intact. Moderately-to-poorly preserved specimens demonstrated substantial damage to the majority (>50%) of the surface, but not to the extent that cut mark and percussion mark microstriations were obscured. Poorly preserved specimens had very little of the bone surface intact, and microstriations were undetectable.

Cain (2006, 255) has argued that Villa & Mahieu's (1991) criteria are not applicable to the Sibudu assemblage because of its extremely burnt and fragmentary nature. However, it is argued here that bone breakage patterns retain heuristic value for interpreting the context in which the bones were broken (fresh vs dry). In this regard, bone fragments were assessed using four of the five criteria discussed by Villa & Mahieu (1991): fracture angle, fracture outline, shaft circumference and shaft fragmentation to differentiate between green and dry fractures. Fracture edge, considered unhelpful by Villa and Mahieu, was disregarded for this study, following Stewart (2011).

Burned bone was assessed using Clark & Ligouis' (2010, 2651) criteria, in order to be consistent with the other research conducted on the Sibudu fauna. These criteria consist of four categories that are identified on the basis of colour: unburned, lightly burned (<50% carbonised), moderately burned (>50% carbonised) and heavily burned (>50% calcined). Experimental research has demonstrated that thermally treated bone exhibits predictable colour changes based on heat and length of exposure. Lower temperatures and shorter exposures will result in carbonising the bone and turning it black. Higher temperatures and longer exposures will cause the bone to become calcined, which turns it blue-white and gives it a chalky texture (Shipman *et al.*, 1984; Nicholson, 1993; Lyman, 1994).

Fracture and fragmentation patterning was further assessed using a fragmentation index and by considering limb shaft circumference ratio. The fragmentation index was calculated by dividing the total number of specimens by the total weight of the specimens and can be used to inform on the general amount of fragmentation in the assemblage, with higher values indicating higher amounts of fragmentation (Dewar & Stewart, 2012).

Limb shaft circumference ratios are calculated by comparing the number of Type 1 shaft fragments, which have less than half of the original circumference, against the combined number of Type 2 (more than half) and Type 3 (complete) shaft fragments (Bunn, 1982; Dominguez-Rodrigo *et al.*, 2007:25). Bunn (1982) found this ratio to vary from 0.44 to 0.10, with carnivore-impacted assemblages grouping at the high end of this range. Marean *et al.* (2004) also noted that when limb shaft fragments are considered for analysis, heavily fragmented assemblages and those that are not biased by excavator selection will be dominated by Type 1 shaft fragments.

Clark & Ligouis (2010) have discussed the presence of oxide staining throughout the earlier MSA faunal assemblages. These stains are blackish in colour and may be confused with carbonisation but are distinguished by their metallic sheen and circular shape.

## Results

### *Identification and quantification*

The initial analysis of the fMSA fauna generated an NISP of 331 (Plug, 2004; Wadley *et al.*, 2008). This study was able to increase the total NISP to 1424 (Tables 1 and 2), although the bulk of these specimens is limb shaft fragments that were identified to ungulate size class only.

An insignificant relationship was identified for all size classes when %MAU was compared against element utility (Food Utility Index). However, a significant relationship was found between %MAU and element density for Size 3+ ungulates (Spearman's  $\rho = 0.639$ ,  $p < 0.05$ ) and a suggestive relationship between %MAU and element density for Size 2 ungulates (Spearman's  $\rho = 0.606$ ,  $p = 0.06$ ) (Supplementary Tables 1–3). These results indicate that density-mediated attrition played a role in the formation of the Size Class 2 and 3+ faunal assemblages and offer an explanation for why high-survival elements are more frequent in these assemblages.



Table 1. Species list with ungulate size class and abundance measured using number of identifiable specimens (NISP) and minimum number of individuals (MNI)

Species	Common name	Size category	NISP	MNI
<i>Cephalophus natalensis</i>	Red duiker	1	1	1
cf. <i>Oreotragus oreotragus</i>	Klipspringer	1	1	1
<i>Raphicerus campestris</i>	Steenbok	1	2	2
<i>Philantomba monticola</i>	Blue duiker	1	12	5
Caprid		2	1	1
<i>Redunca</i> cf. <i>arundinum</i>	Southern reedbuck	2	1	1
Suid		2	1	1
<i>Phacochoerus africanus/aethiopicus</i>	Warthog	2	3	2
Alcephaline		3	4	1
<i>Equus</i> sp.		3	2	1
<i>Kobus ellipsiprymnus</i>	Waterbuck	3	1	1
<i>Equus (burchelli) quagga</i>	Plains zebra	3	60	4
<i>Megalotragus priscus</i>	Giant hartebeest	4	12	1
<i>Tragelaphus oryx</i>	Eland	4	7	1
<i>Syncerus caffer</i>	African buffalo	4	9	2
<i>Loxodonta africana</i>	African savannah elephant	5	1	1
<i>Hippopotamus amphibius</i>	Hippopotamus	5	30	1
Hippo/rhino		5	2	1
Bird		Large	4	1
Carnivore		Large	1	1
Carnivore		Medium	2	1
Bird		Medium-large	1	1
Bird		Small	2	1
Carnivore		Small	1	1
<i>Felis silvestris</i>	African wild cat		1	1
<i>Hyaena brunnea</i>	Brown hyena		2	1
Lagomorph			5	1
<i>Lepus saxatilis</i>	Scrub hare		1	1
<i>Redunca</i> sp.			1	1
cf. <i>Tyto alba</i>	Barn owl		2	1
<i>Papio hamadryas</i>	Chacma baboon		12	2
<i>Procavia capensis</i>	Rock hyrax		10	6
Undetermined ungulate		1	94	12
Undetermined ungulate		2	212	8
Undetermined ungulate		3	537	13
Undetermined ungulate		4	114	5
Undetermined ungulate		1–2	65	3
Undetermined ungulate		2–3	61	2
Undetermined ungulate		3–4	146	3
Total			1424	94

## Taphonomic results

Five hundred thirty specimens displayed bone surface modifications, with trampling marks being the most frequent (Figure 3). Only 50 cut marks and 71 percussion marks were observed, with cut marks being found predominantly on unidentifiable fragments (25 cut marks), limb shaft fragments (10 cut marks) and rib shaft fragments (six cut marks). However, it is important to note that there were many instances where bone surface modifications were indeterminate but demonstrated some characteristics of either cut or percussion marks. These specimens were all substantially burned (a score of  $\geq 2$ ) and had poor bone surface preservation. It is hypothesised that burning has deformed some cut and percussion marks so that they

no longer meet the diagnostic criteria required for their identification.

Thirty-four specimens displayed multiple marks produced by more than one agent. In every case, cut marks or percussion marks preceded marks made by other agents (Figure 4). The timing of the human-affected marks, coupled with the large lithic assemblage (Wadley, 2005) and scarcity of carnivore remains, identifies human agency as the primary accumulator of this faunal assemblage (Stiner, 1994).

Oxide staining and carbonate formation affected a significant amount of the assemblage (Table 3). In both cases, specimens with poor bone surface preservation were the most affected, and there is a highly significant association between poorer bone surface preservation and the presence of carbonate and oxide staining

Table 2. Number of identifiable specimens for selected elements from Size Classes 1 to 3

Element	Number of identifiable specimens		
	Size Class 1	Size Class 2	Size Class 3
Carpal	1	1	4
Cranium	0	6	11
Femur	5	11	3
Humerus	4	9	12
Mandible	1	1	0
Metacarpal	0	1	2
Metapodial	4	8	19
Metatarsal	1	2	3
Pelvis	2	5	6
Phalanges	8	9	11
Radius	10	2	2
Rib	25	68	162
Scapula	0	1	0
Sesamoid	0	1	20
Tibia	4	1	2
Ulna	0	1	2
Vertebra	3	12	39
Limb shaft fragment	28	54	262

( $\chi^2 = 1282.3$ ,  $p < 0.00$ , for carbonate formation and  $\chi^2 = 1406.2$ ,  $p < 0.00$ , for oxide staining).

Cain (2005, 2006) and Clark (2009, 153–154) have discussed how the earlier Sibudu faunal assemblages are heavily burned, resulting in a significant amount of dry breaks, with bone being repeatedly exposed to post-depositional attrition. In this manner, the presence of green or fresh breaks is likely to be transformed during subsequent attrition events, which include burning and trampling, into dry breaks. The fMSA also demonstrates a high frequency (~94%) of dry breaks, indicating that much of the fragmentation took place when the bone was dry and likely during repeated exposures to fire (Supplementary Table 4).

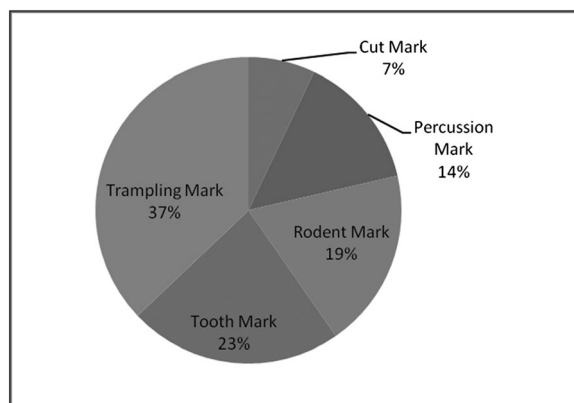


Figure 3. Distribution of bone surface modifications.



Figure 4. Burnt limb shaft fragment with cut mark overlain with a tooth mark.

Limb shaft circumferences were recorded for all limb shaft specimens. The ratio between Type 1 and combined Type 2 and 3 circumferences for the fMSA is 0.10, indicating a very high proportion of Type 1 (<50% complete) specimens. This result is at the bottom of the values discussed by Bunn (1982) (Supplementary Table 5) and furthers the argument for human agency in the assemblage's formation. Moreover, this result demonstrates the high degree of fragmentation in the assemblage and that the collection is not biased by excavator selection (Marean *et al.*, 2004).

The fMSA fauna is extremely comminuted, with the total weight of the <2-cm unidentifiable portion being 12.15 kg out of a total sample weight of 15.26 kg. Following Clark & Plug (2008), the total number of <2-cm unidentifiable specimens was only counted in one quadrant of each unit; therefore, only 2.01 kg of the 12.15 kg of <2-cm unidentifiable bone was quantified. This count generated 10,582 specimens, or 74.3% of the entire studied faunal sample.

The fragmentation index for the fMSA was 5.27 bone specimens per gramme, which is generally higher

Table 3. Amount of the studied faunal assemblage that was affected by carbonate formation and oxide staining

Preservation	Carbonate formation		Oxide stained	
	Count	Per cent	Count	Per cent
Good	4	0.13	15	0.50
Moderate	446	0.35	850	0.67
Moderate-poor	300	0.39	493	0.65
Poor	1045	0.41	1347	0.53
Total	1795	0.39	2705	0.59

Table 4. A comparison of the percentages of unidentifiable specimens <2 cm in the different occupations at Sibudu Cave, with data from Clark (2009) and Cain (2006)

Occupation	Unidentifiable specimens <2 cm (%)
Final Middle Stone Age	74.3
Late Middle Stone Age	~75.0
Post-Howieson's Poort 1	88.9
Post-Howieson's Poort 2	93.6
Howieson's Poort	95.1

than that recorded for post-HP 1 (2.65 specimens/gramme), post-HP 2 (2.88 specimens/gramme) and HP (4.02 specimens/gramme) occupations at Sibudu (Clark & Ligouis, 2010, 2659). The amount of fragmentation in fMSA is slightly less than that seen in some of the earlier layers of Sibudu but is on par with that exhibited by late MSA occupation, which immediately precedes the fMSA (Cain, 2006, 2009) (Table 4). These differences may be the result of the relative ages of the deposits, with the fMSA assemblage having had less time to be exposed to post-depositional attrition.

### The effect of burning

Burning was a major taphonomic factor, with only 400 specimens of the total 14,245 (less than 3%) studied being unburned and the majority being carbonised and/or calcined (Figure 5). Heavily burned bone has been linked with increased fragmentation, as the bone's physical structure changes, making it more susceptible to breakage (Nicholson, 1993;

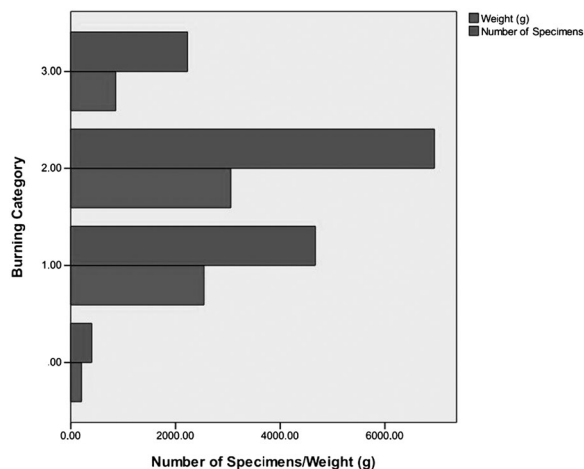


Figure 5. The amount of the faunal assemblage that has been burned in number of specimens and by weight.

Stiner *et al.*, 1995; Costamagno *et al.*, 2005). Of this sample, 72.5% was both <2 cm and burned. Clark & Ligouis (2010) have noted the relationship between burning and fragmentation for Sibudu's HP and post-HP occupations, with each assemblage having over 60% of the <2-cm fraction being moderately or heavily burned.

The MC layer is described by Wadley & Jacobs (2006) as a hearth feature and was therefore also analysed independently to allow for comparison with the other fMSA layers. MC displays differences in burning intensity (Table 5), with a significantly greater number of heavily burned (>50% calcined) bone specimens ( $\chi^2 = 670.01$ ,  $p < 0.000$ ).

Burning has also been previously linked to bone surface preservation, with more intense burning resulting in poorer preservation (Nicholson, 1993; Stiner *et al.*, 1995; Clark & Ligouis, 2010). The fMSA assemblage demonstrated a significant association ( $\chi^2 = 217.5$ ,  $p < 0.00$ ) between burning and poor surface preservation, with more heavily burned specimens exhibiting poorer preservation. This result demonstrates that burning was an important taphonomic factor in the faunal assemblage's formation.

## Discussion

### Taphonomic influences

The taphonomic analysis of the fMSA fauna reinforces an anthropogenic origin for this assemblage. This conclusion is warranted by the amount of fragmentation, intense burning, the presence and timing of cut marks and percussion marks and the large quantity of lithics (Wadley, 2005). Although tooth marks and gnawing marks are present, they are secondary to the initial human behaviours. Previous research on the fMSA and earlier layers from Sibudu has also determined an anthropogenic origin for their faunal assemblages (Plug, 2004; Cain, 2005, 2006; Clark & Plug, 2008; Goldberg *et al.*, 2009).

Burning is the most significant taphonomic factor that affected the fMSA faunal assemblage's formation. The high degree of burning is significantly associated with the large amount of fragmentation and the generally poor nature of bone surface preservation. Density-mediated attrition associated with Size Class 2 and 3+ animals may also be related to the large amount of burning. As discussed earlier, burning bone makes it more susceptible to fragmentation, which renders less dense elements more susceptible to being eliminated from the faunal assemblage. The high

Table 5. Quantification of burning for all layers except MC and the MC hearth layer

Burning category	Total (excluding MC)				Total (MC only)		
	Weight (g)	Count	%Weight	%Count	Weight (g)	Count	%Weight
0	164.9	286	3.41	3.12	38.7	114	2.12
1	2151.5	3429	44.53	37.39	392.4	1242	21.45
2	2104.0	4428	43.55	48.28	951.1	2517	51.98
3	410.9	1028	8.50	11.21	447.4	1201	24.45
Total	4831.3	9171	100.00	100.00	1829.6	5074	100.00

frequency of burning and heavy fragmentation can also be attributed to the small portion of the assemblage that was identifiable, as the destruction of the bone eliminates the landmarks and features that are necessary for an identification of the element and taxon (Lyman, 2008; Stewart, 2011).

Costamagno *et al.* (2005) have provided detailed experimental results describing the physical characteristics of bone used as fuel for fires. Their findings demonstrate that when bone is used for fuel, the majority of the faunal remains were calcined (52.4–98.6%, average of 76.7%). The fMSA fauna does not demonstrate comparable numbers of calcined bones, with only ~15% of the assemblage and ~24% of the hearth feature, MC, being calcined. Furthermore, the fMSA occupation occurred during a relatively wooded period (Jacobs *et al.*, 2008a; Wadley *et al.*, 2008) where firewood would have been easily available, furthering an argument against bone being used as fuel for fires.

The quantity of burned bone, as well as its location in a rock shelter, strongly argues against the burning occurring during a natural forest fire. The hearth feature, the large amount of lithic debitage and the large amount of burned bone all argue for human agency in fire production and bone burning. This conclusion agrees with those from previous research that has proposed human agency for bone burning in the earlier layers at Sibudu (Cain, 2005, 2006; Clark & Ligouis, 2010).

### *Implications for human behaviour*

Recent studies have demonstrated that plant bedding was used in Sibudu's earlier layers and that the bedding was disposed in the hearth fires during regular site maintenance and cleaning (Sievers, 2006; Goldberg *et al.*, 2009; Wadley *et al.*, 2011; Miller & Sievers, 2012). Cain (2005, 2006) has strongly argued that bone was systematically discarded into hearths during site maintenance and cleaning for

the HP and post-HP levels and that these hearths were swept out, resulting in ash dumps and the distribution of heavily burned bone throughout the layers, a position that has been supported by Clark & Ligouis (2010) and Goldberg *et al.* (2009). Sibudu's earlier MSA assemblages strongly resemble the fMSA assemblage, with large amounts of heavily fragmented and carbonised bone. The faunal assemblage from the fMSA is therefore argued to also demonstrate regular site maintenance and cleaning, with bones being repeatedly discarded into hearths, which were then swept out, distributing the bone across the living surfaces.

This conclusion is further merited when comparing the assemblage with the criteria used by Bosch *et al.* (2012) to examine the causes for the burned bone within a Gravettian faunal assemblage. The authors constructed and tested eight hypotheses: natural fire on a non-human bone accumulation, natural fire shortly after butchery, bone used as fuel, bone marrow procurement, bone grease manufacture, roasting, ivory procurement and waste removal (Bosch *et al.*, 2012, Table 4). Their assemblage most closely fitted the criteria for waste removal, which are similar proportions of bone types in burned and unburned bones, *in situ* burning, human impact on fire, other human activity, butchery marks, fuel other than bones and varying burning stages present. These criteria are all met by the fMSA assemblage from Sibudu, which further strengthens the argument for the assemblage demonstrating waste removal and site maintenance.

What is not seen in the fMSA, but is seen in other layers, is evidence for plant bedding, such as carbonised seeds. A discussion of whether the fMSA foragers at Sibudu were using plant material for bedding is beyond the scope of this paper, but it should be noted that the fine fraction of sediment only started to be systematically examined for seeds and other plant materials after the fMSA had been excavated (Wadley & Jacobs, 2006).



## Conclusion

The taphonomy of the fMSA faunal assemblage was analysed by observing bone surface modifications, fracture patterns, fragmentation, burning and skeletal element profiles. These measures have reinforced an anthropogenic origin for the fMSA fauna. Heavy fragmentation and burning of the faunal assemblage is argued to demonstrate regular site maintenance and cleaning, related to the sweeping out of hearths. This conclusion mirrors those for the post-HP and HP layers at Sibudu and suggests that site maintenance and cleaning were behaviours that developed much earlier in the MSA and were a consistent part of the MSA foraging lifeway (Cain, 2005, 2006; Goldberg *et al.*, 2009; Clark & Ligouis, 2010). The behavioural continuity demonstrated at Sibudu raises questions of whether this is a unique case or if other MSA sites were occupied in a similar manner and whether this pattern reflects long-term cultural continuity in some of aspects of the MSA foraging lifeway.

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## Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

**Table S1.** Data used for comparing Size 1 skeletal element abundances with Food Utility Indices (FUI, Metcalfe and Jones, 1988) and Volume Density (VD, Lam et al., 1999).

**Table S2.** Data used for comparing Size 2 skeletal element abundances with Food Utility Indices (FUI, Metcalfe and Jones, 1988) and Volume Density (VD, Lam et al., 1999).

**Table S3.** Data used for comparing Size 3+ skeletal element abundances with Food Utility Indices (FUI, Metcalfe and Jones, 1988) and Volume Density (VD, Lam et al., 1999).

**Table S4.** Data for breakage types that were observed from the fMSA faunal assemblage.

**Table S5.** Limb shaft circumference data for the fMSA faunal assemblage.