An early bone tool industry from the Middle Stone Age at Blombos Cave, South Africa: implications for the origins of modern human behaviour, symbolism and language

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Twenty-eight bone tools were recovered *in situ* from ca. 70 ka year old Middle Stone Age levels at Blombos Cave between 1992 and 2000. These tools are securely provenienced and are the largest collection to come from a single African Middle Stone Age site. Detailed analyses show that tool production methods follow a sequence of deliberate technical choices starting with blank production, the use of various shaping methods and the final finishing of the artefact to produce "awls" and "projectile points". Tool production processes in the Middle Stone Age at Blombos Cave conform to generally accepted descriptions of "formal" techniques of bone tool manufacture. Comparisons with similar bone tools from the Later Stone Age at Blombos Cave, other Cape sites and ethnographic collections show that although shaping methods are different, the planning and execution of bone tool manufacture in the Middle Stone Age is consistent with that in the late Holocene.

The bone tool collection from Blombos Cave is remarkable because bone tools are rarely found in African Middle or Later Stone Age sites before ca. 25 ka. Scarcity of early bone tools is cited as one strand of evidence supporting models for nonmodern behaviour linked to a lack of modern technological or cognitive capacity before ca. 50 ka. Bone artefacts are a regular feature in European sites after ca. 40 ka, are closely associated with the arrival of anatomically modern humans and are a key behavioural marker of the Upper Palaeolithic "symbolic explosion" linked to the evolution of modern behaviour.

Taken together with recent finds from Klasies River, Katanda and other African Middle Stone Age sites the Blombos Cave evidence for formal bone working, deliberate engraving on ochre, production of finely made bifacial points and sophisticated subsistence strategies is turning the tide in favour of models positing behavioural modernity in Africa at a time far earlier than previously accepted.

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Introduction

By around the early 1990s there was a general assumption that African Middle Stone Age people, like their Middle Palaeolithic counterparts, did not make bone tools (Clarke, 1989; Thackeray, 1992), possibly because they did not have the mental capacity (e.g. Klein, 1989*b*; for a *contra* view see Mellars & Stringer, 1989). This assumption was largely based on the infrequency of formal bone tool finds from Middle Stone Age (MSA) contexts in Africa prior to 1990 (see Clark *et al.*, 1950; Clark, 1959; Wendorf & Schild, 1974; Marks, 1968; Beaumont *et al.*, 1978; Singer & Wymer, 1982; Mason, 1988) and because the dating and secure context of these few finds was open to question (e.g. Volman, 1984; Singer & Wymer, 1982; Klein, 1989*b*).

In Eurasia shaped bone tools are virtually unknown at sites pre-dating 40 ka but are fairly common in the region after this date (Hahn, 1988; Camps-Fabrer, 1988; Mellars, 1989*b*; Knecht, 1993; Hahn, 1995; Otte, 1995; Oliva, 1995; d'Errico *et al.*, 1998; Christensen, 1999; d'Errico & Laroulandie, 2000; Villa & d'Errico, 2001). It seemed, from the evidence, that bone tool technology occurred first in Eurasia and was only adopted or developed in Africa at a much later date. Bone tools only became a regular feature at African sites in the Later Stone Age (LSA) post ca. 25 ka (for a fuller discussion see McBrearty & Brooks, 2000).

The discovery in the early 1990s of barbed and unbarbed bone points at the Katanda sites in the Semliki Valley, D.R. Congo, dated at ca. 75 ka (Yellen *et al.*, 1995; Brooks *et al.*, 1995; McBrearty & Brooks, 2000; Feathers & Migliorini, 2001), generated considerable debate over their actual age (Ambrose, 1998) and provenience (Klein, 1999; see McBrearty & Brooks for a fuller discussion), but are the first major find to provide strong evidence for early bone working in Africa.

In this paper we present an analysis of the largest known MSA bone tool collection excavated from Blombos Cave (BBC), South Africa. In 1992 a single worked and polished bone point was recovered during preliminary excavation of the MSA levels dated at ca. 70 ka (Henshilwood *et al.*, 2001; and see below). Expanded excavations in 1997 produced 14 MSA bone tools (Henshilwood & Sealy, 1997), and between 1998–2000 13 more were recovered. All the BBC MSA bone tools show evidence of deliberate shaping to create tools of various sizes and forms; most are polished, either intentionally or from use-wear. The BBC bone tool collection clearly demonstrates that MSA people had the capacity to perceive bone as a raw material, understand its working properties and fashion it as required using a variety of techniques to produce shaped (formal) artefacts for diverse applications.

Modern human behaviour and bone tools

Current and past debate over the origins and development of bone tool technology are part of a far larger and equally heated debate—the origins of modern human behaviour. Genetic and fossil evidence strongly suggests anatomically modern humans, *Homo sapiens*, evolved in Africa at ca. 300–150 ka and by ca. 35–30 ka were effectively established in all areas of the Old World (Vigilant *et al.*, 1991; Templeton, 1992; Mellars, 1993; Stringer, 1993; Stoneking *et al.*, 1993; Deacon, 1993, 1998*b*; Foley, 1998; Zilhão & d'Errico, 1999; but for a *contra* view see Wolpoff *et al.*, 1984; Wolpoff, 1989, 1996). Correlating anatomical with behavioural modernity in Africa is more problematic. Due, in part, to the lack of reliable and/or dated archaeological evidence from most African Mid and Late Pleistocene sites, some researchers consider the Middle Palaeolithic (MP) to

Upper Palaeolithic (UP) transition in Eurasia the benchmark for constructing "modern" behavioural models (Klein, 1989*a*,*b*, 1994*b*, 1995; Mellars, 1989*a*,*b*, 1991, 1993, 1996; Ambrose & Lorenz, 1990; Ambrose, 1998). The tenets of these essentially eurocentric models is that early "modern" behaviour—the "behavioural revolution"—equates with *H. sapiens* and the MP–UP transition at ca. 40–30 ka and that the African equivalent is the MSA/LSA transition at ca. 50–40 ka (Ambrose, 1998; Klein, 1989*a*,*b*, 1992, 1995, 1999, 2000). Anatomically modern humans in Africa and West Asia during the MSA/MP are regarded by some researchers as behaviourally non-modern until the early LSA/UP at ca. 50–40 ka (Binford, 1984; Klein, 1989*a*,*b*, 1992, 1994*b*, 1995; Ambrose & Lorenz, 1990; Ambrose, 1998). Klein (1999, 2000) argues further that the shift to fully modern behaviour at ca. 50–40 ka is linked to an advantageous genetic mutation. The absence or presence of formal bone tools is frequently cited as a marker for assessing modern behaviour during the MP/UP transition (Mellars, 1989*a*,*b*, 1991, 1993) and the African MSA (Klein, 1989*a*,*b*, 1992, 1994*b*, 1995; Ambrose, 1998). Interestingly, Neanderthals are known to have manufactured bone tools in Eurasia during the late MP (d'Errico *et al.*, 1998).

In contrast to the above "linear", temporally restricted models, proponents of a "mosaic" approach suggest elements indicative of "modern" behaviour *are* present during the Mid to Late MSA in Africa but they are spatially and temporally disparate and cannot be equated with an UP derived "trait" list (Deacon, 1989, 1993, 1998*b*; Chase & Dibble, 1990; Foley & Lahr, 1997; Yellen, 1998; McBrearty & Brooks, 2000). Examples of innovative elements in the African MSA are the Howiesons Poort (HP) in southern Africa (Mellars, 1989*b*; Deacon, 1993, 1998*a*,*b*; Deacon & Wurz, 1996), the Lupemban in central Africa, the Bambatan in south-east Africa (Foley & Lahr, 1997), the Aterian in North Africa (Hublin, 1993; Hajraoui, 1994) and evidence from Namibian sites (Vogelsang, 1996). Adherents or near adherents to early African "modern" type behaviour models have diverse views on the role, or presence *vs.* absence, of bone tools in the MSA. Clark (1989) believes MSA people had the mental capacity for bone working but preferred wood as it is easier to work. Thackeray's (1992) observation is that bone was simply not an important source of raw material in the MSA. Whether important or not, McBrearty & Brooks (2000) argue that carving and polishing bone was not beyond the capabilities of the maker of a levallois flake or, in our opinion, a Still Bay bifacially worked stone point.

What is the evidence for bone technology in the African MSA or earlier? Shaft fragments recovered from Pliocene levels at Swartkrans, Sterkfontein and Driemolen (Brain & Shipman, 1993; Keyser *et al.*, 2000) show wear consistent with digging termite mounds (Backwell & d'Errico, 2001) but this is best described as *ad hoc* bone use. A bone point and utilized ivory pieces come from the Kabwe site (Clark *et al.*, 1950) but their age and association with faunal and hominid remains is questionable (McBrearty & Brooks, 2000). A bone point, purportedly from the lowest HP levels at Klasies River (KR) dated at ca. 65–70 ka (Miller *et al.*, 1999; Vogel, 2000) is described by Singer & Wymer (1982) as similar in colour to MSA bone from the same level. Notched bone pieces come from Apollo 11, Namibia (Volman, 1984) and KR (Singer & Wymer, 1982; Wurz, 2000). Four unpointed tools made on ribs are reported from the Aterian site, Grotte d'el Mnasra in Morocco (Hajraoui, 1994). At White Paintings Shelter, Botswana, a single bone point comes from transitional MSA/LSA deposits dated at ca. 38–50 ka (Robbins *et al.*, 1994; Kokis *et al.*, 1998; Robbins & Murphy, 1998). Barbed and unbarbed points were recovered from a series of three MSA sites in the Semliki Valley, D.R. Congo, Kt-2, Kt-9 and Kt-16 (Brooks *et al.*, 1995; Yellen *et al.*, 1995; Yellen, 1998). These tools come from secure stratigraphic horizons and at each site the MSA levels are overlain by fluvial and colluvial deposits, distinct paleosols, a massive ash capping and a Holocene soil. A minimum date of ca. 75 ka, obtained by a series of dating methods, is indicated for these tools (McBrearty & Brooks, 2000).

Taken together, the evidence to date indicates that the context within which bone tools have been recovered from African MSA sites remains a crucial issue, and that the firm assignation of bone tools to an MSA context, with the exception of the Katanda finds, is fairly limited.

In this paper the 28 bone tools recovered from secure stratigraphic context at BBC are described (Appendix, Table A1). This is the largest excavated collection of MSA bone tools and, given the large sample size, provides an opportunity for a detailed intra-site comparison of technical variability and methods used in their manufacture. In this paper, we also describe the seven bone tools excavated from the LSA levels at BBC between 1992–2000 (Appendix, Table A1) (Henshilwood, 1995). Comparison of the LSA and MSA tools provides a unique opportunity to look at variations in raw material selection, morphology and manufacturing techniques over time within the same site. Bone tools of known function (in this case "awls" or "projectile points") recovered from other LSA sites in the southern Cape and from ethnographic collections at the South African Museum provide a useful comparative aid in determining the likely functional use of the MSA tools from BBC. The possible intrusion of LSA tools within MSA levels at BBC has been raised (see Klein, 2000, 2001) and this important issue is addressed in this paper. Two bone tools from known provenience but mixed context (Layers: DUN–SAM AA 8975 and MOF–SAM AA 8982) are excluded from this study.

Context of the Blombos Cave bone tools

Site background

BBC is located 300 km east of Cape Town at 34°24.857′S, 21°13.371′E. The cave is 34·5 m above sea level and some 100 m from the Indian Ocean [Figure 1(a)]. The cave formed by wave cutting of the calcarenite cliff that lies above a basal layer of Table Mountain Sandstone of the Cape Supergroup. This basal layer is at least 4–6 m below the cave's surface deposits.

Deposits within the cave extend over about 50 m^2 with a further 18 m^2 of *in situ* deposit forward of the drip line [Figure 1(b)]. The BBC deposits were excavated over five field seasons between 1992–2000 and about 13 m^3 of MSA and 9·2 m^3 of LSA deposits have been recovered. The MSA deposit is capped by LSA occupations less than 2000 years old. The LSA layers have been allocated to three phases of occupation, named here BBC L1, BBC L2 and BBC L3 [Figure 2(b)]. Below the LSA occupation levels are sterile dune sands—BBC Hiatus—composed of geological rather than anthropogenic sediments. The MSA layers are stratified below these sterile sands [Figure 2(a), (b)].

In 2000 the excavated MSA layers were allocated to three phases, BBC M1, BBC M2 and BBC M3 [Figure 2(b)] based on content and stratigraphy (note: these MSA layers are named BBC 1, BBC 2 and BBC 3 in Henshilwood *et al.*, 2001). The top MSA phase, BBC M1, contains more than 400 bifacially worked lanceolate points, the *fossile directeurs* of the Still Bay Industry (Goodwin & van Riet Lowe, 1929). Two pieces of ochre, each deliberately engraved

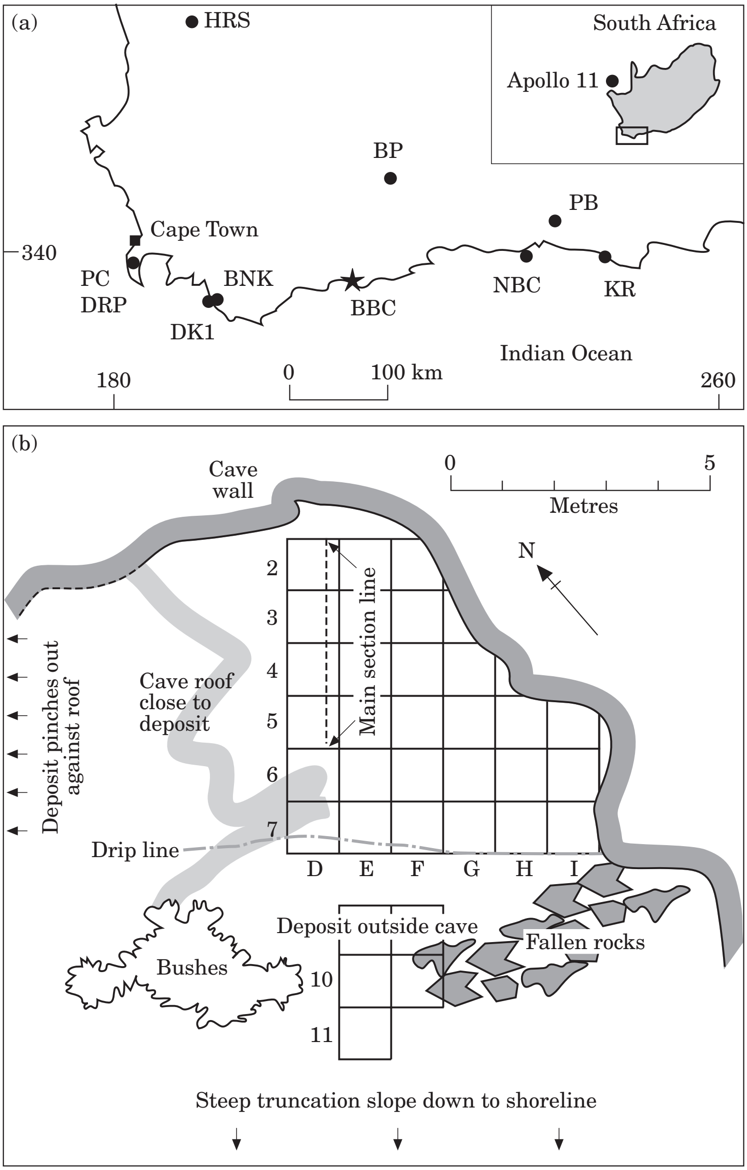


Figure 1. (a) Location of Blombos Cave and sites mentioned in the text. (b) Site of excavated area. (BBC=Blombos Cave, BNK=Byneskranskop, BP=Boomplaas, DK1=Die Kelders Cave 1, DRP=Dale Rose Parlour, HRS=Hollow Rock shelter, KR=Klasies River, NBC=Nelson Bay Cave, PB=Paardeberg, PC=Peers' Cave.)

with an abstract cross-hatched pattern (Henshilwood *et al.*, in prep.) and an engraved bone fragment (Henshilwood & Sealy, 1997; d'Errico *et al.*, 2001) were recovered from BBC M1. The BBC M2 phase contains most of the bone tools and BBC M3 is predominantly a dense shell midden although marine shells occur in relatively high quantities in all phases. More than 8000 pieces of ochre, mostly worked by

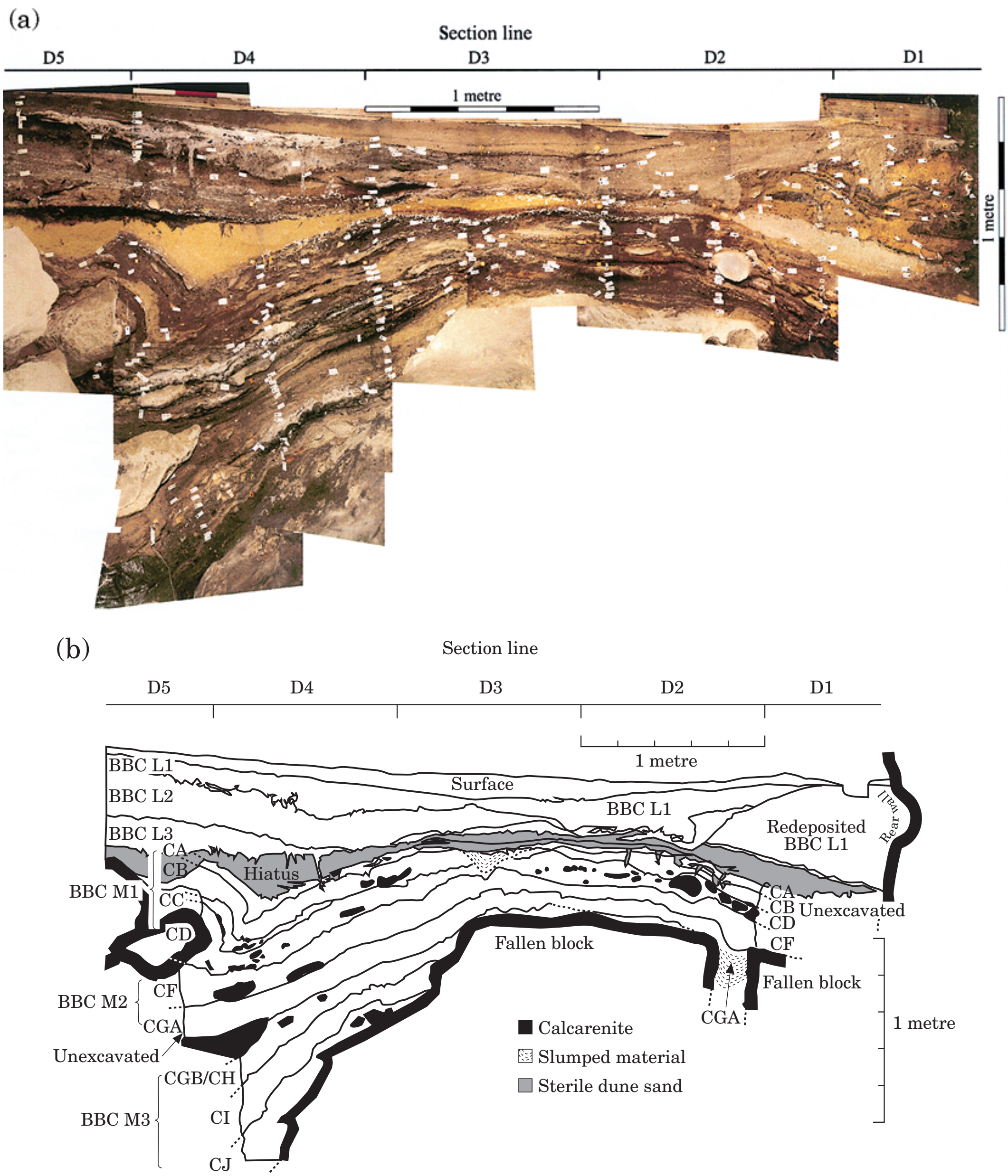


Figure 2. (a) Orthographic composite photograph of main section line; (b) stratigraphy showing sterile hiatus layer separating LSA and MSA levels.

scraping and grinding, occur throughout the sequence with the highest concentrations in BBC M3. Recovered faunal remains indicate the subsistence strategies of the BBC MSA people were wide ranging and included hunting large and small mammals, shellfishing, obtaining marine mammals perhaps by hunting and/or scavenging, and catching large fish and reptiles (Henshilwood *et al.*, 2001).

Table 1 C^{14} dates for the LSA layers at BBC

Lab. No.	Sq	Layer	Phase	Material	Date (BP)
Pta-6184	E4	Coke	BBC L1	Charcoal	290 ± 20
Pta-6185	E4	MC IV	BBC L3	Charcoal	1840 ± 50
Pta-6246	E4	MC IV	BBC L3	Shell	1880 ± 50
Pta-6247	E4	MC IV	BBC L3	Shell	1940 ± 50
Pta-6175	E4	MC IV	BBC L3	Shell	2000 ± 40
CAMS-15870	E2	TOB	BBC M1	Charcoal	2100 ± 160
CAMS-15872	E2	SAN	BBC M1	Charcoal	2000 ± 160
CAMS-15871	E2	PIP	BBC M1	Charcoal	1950 ± 160
Pta-6557	E2	PIP	BBC M1	Shell	38,500 ± 1760
CAMS-15875	E2/3/4	PIP	BBC M1	Shell	35,670 ± 1510
CAMS-15876	E2/3/4	PIP	BBC M1	Shell	35,640 ± 1440
CAMS-15873	E4	CLR	BBC M2	Charcoal	1480 ± 150
CAMS-15877	E3	CCO/COF	BBC M1/2	Shell	32,660 ± 1310
CAMS-15874	E3	COF	BBC M1/2	Charcoal	39,200 ± 1680

The C^{14} half-life used is 5568 years. Ages are corrected for variations in isotope fractionation; 400 years has been subtracted from the uncalibrated shell dates to correct for the marine reservoir effect.

Descriptions of deposits

Both the MSA and LSA layers consist principally of sands interlayered with beds, lenses and stringers of marine shells, organic matter and ash. Ground waters rich in $CaCO_3$ percolate through the cave roof and walls creating an environment suited to the preservation of bone and shell, particularly near hearths and ash deposits. There is differential preservation in some areas within the MSA deposits, probably due to raised pH levels (humates) from decomposed plant materials and/or discarded animal remains. Bone and shell preservation in these areas is not as good.

Most of the MSA deposits are finely bedded to laminated with occasional thick, clast-supported shell lenses. Calcarenite rockfall is confined to large blocks at the base of the excavation and to smaller size blocks mostly near the cave entrance. The MSA deposits undulate considerably from the back to front of the cave due to subsidence that produces a "wrapping effect" over the rockfalls and occasional slump faults into gaps between rocks. The stratigraphy of the MSA levels consequently is complex with the draping or wrapping of sediments as the principle challenge for the excavators.

Culturally sterile bright yellow and occasional grey dune sands of Pleistocene and Holocene age (BBC Hiatus), covered the entire surface of the MSA before the LSA occupation [Figure 2(a), (b)]. The LSA deposits are not as deep as the MSA, tend to be more massively bedded and are undistorted. In addition, burned layers tend to be thicker and several appear to preserve their original hearth-like structures.

Dating

Charcoal and shell recovered from 30 cm deep MSA deposits in the area where the sterile BBC Hiatus phase is thinnest (square E2), was accelerator ^{14}C dated in 1994 (Table 1). The ca. 1·4 ka date arises from the submission of charcoal for dating from an LSA layer in square E4 (Cochlear—CLR or COC) that was mistaken, due to an acronym error, for an MSA layer (Cocoa—COC or CCO). The three charcoal samples that date to ca. 2·0 ka come from the topmost MSA phase BBC M1 (Layers TOB, SAN and PIP) in square E2

[Figures 1(b), 2(b)]. These ca. 2·0 ka determinations are statistically identical to the dating results from the lowermost LSA (Table 1) and to accelerator dates obtained from sheep in the basal LSA (Henshilwood, 1996). The dated charcoal from the MSA layers in square E2 clearly derives from the overlying LSA and the probable reasons for the contamination can be attributed, variously, to slumped burrows, digging stick holes or postholes. In this area the BBC Hiatus phase is particularly thin and provides a limited buffer to LSA intrusions.

Five dates on marine shell opercula (*Turbo sarmaticus*) range between ca. 32 and 39 ka BP. The dated shells derive from the same MSA layers as the younger charcoal, demonstrating that contamination was limited and that the young charcoal dates for the BBC MSA can be discounted. In radiocarbon terms, the MSA at BBC is of infinite age (Vogel, personal communication).

The MSA levels are being dated using luminescence techniques: single-grain laser luminescence (SGLL), single aliquot optically stimulated luminescence (OSL and IRSL), multiple aliquot OSL on sediments and also TL of burnt lithics and electron spin resonance (ESR) of teeth. This work is ongoing in Aberystwyth (U.K.), Gif-sur-Yvette (France) and Hamilton (Canada). Using a highly experimental TL subtraction method to overcome the problems of erroneous ages due to changes in surrounding radioactivity, Vogel *et al.* (1999) obtained a mean of individual ages of ca. $103 \pm 9{\cdot}8$ ka for the uppermost MSA level at BBC. This age is 10% higher than the mean of the ages for the TL and IRSL, but these ages are within the high uncertainty limit of the subtraction age. However, all these ages are likely to be overestimates since the sample came from an occupation layer that may have contained roof spall. For this reason, single grain OSL measurements are currently being applied to this and other sedimentary units at the site (Wintle, personal communication).

The location of bifacial points, markers of the Still Bay phase within the regional culture stratigraphic sequence, allows for the calculation of a minimum indirect date for the upper BBC M1 phase [Figure 2(b)]. Still Bay points are defined as "fully bifacially flaked, and lanceolate to narrowly elliptic in shape" (Henshilwood *et al.*, 2001) and are temporally and stratigraphically restricted within MSA sites in the Western Cape Province. At Peers' Cave (Peers, 1929:9), Still Bay points lie beneath the HP; at KR bifacial retouch is most common just below and within the lower part of the HP (Singer & Wymer, 1982; Wurz, 2000). Bifacial points also occur within and below the basal HP at Nelson Bay Cave (Volman, 1981) and in a HP-like assemblage at Paardeberg (Wurz, 2000). There is no evidence for bifacial points in MSA 3, the final phase post-dating the HP (Volman, 1984), at Peers Cave (Peers, 1929:5), Boomplaas (Deacon, personal communication), Die Kelders Cave 1 (Grine *et al.*, 1991; Thackeray, 2000), KR (Wurz, 2000) or Strathalan (Opperman, 1996).

The bulk of available evidence indicates that the Still Bay sub-stage lies immediately below the HP dated at about 65–70 ka (Miller *et al.*, 1999; Vogel, 2000). This date places the youngest MSA phase, BBC M1, within a late phase of oxygen isotope stage 4 or early 5a (Figure 3) (Henshilwood *et al.*, 2001).

Provenience of bone tools from BBC

The key issue here is whether any of the bone tools recorded in MSA layers could have derived from the LSA levels and *vice versa*. Given the rarity of bone tools in MSA contexts and the presence of LSA deposits in BBC, it is necessary to establish firmly the provenience of the MSA bone tools in this site (also see Klein, 2000, 2001). Five

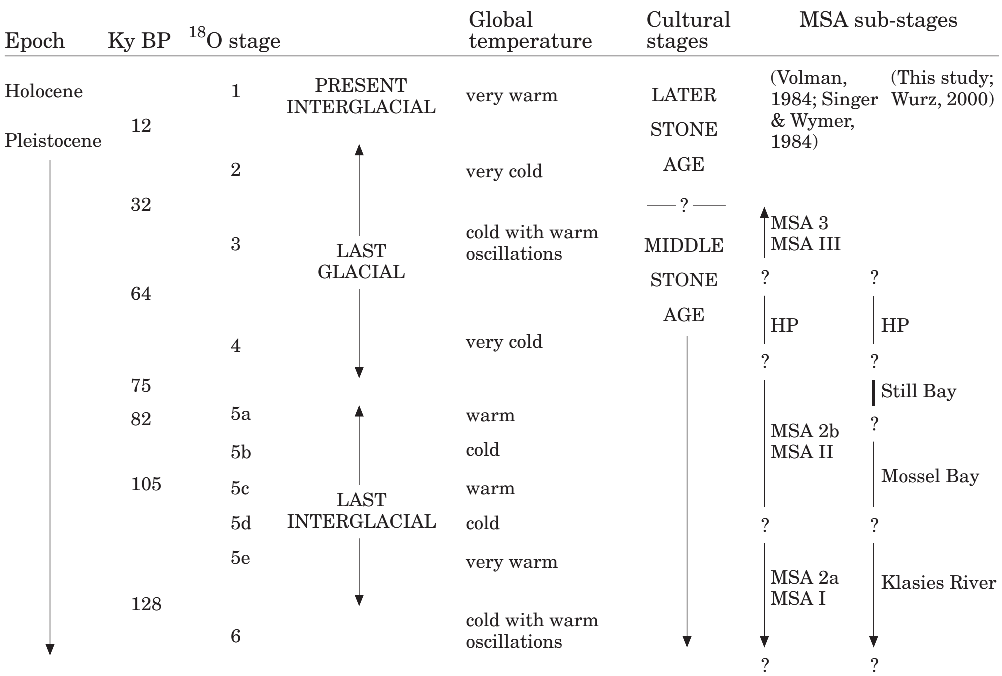


Figure 3. Culture stratigraphic location of the Still Bay sub-stage within the southern Cape MSA and probable association with oxygen isotope phases.

independent lines of evidence are presented below: stratigraphic integrity; the distribution of key finds; chemical testing; the stratigraphic distribution of the tools; the size of the LSA and MSA tools.

Stratigraphic integrity

Potential causes of an admixed assemblage at BBC are human and nonhuman digging during the historical or LSA periods; geological processes, such as sedimentary erosion and re-deposition, faulting and slumping; and cross-cutting of LSA and MSA levels during excavation. The evidence and implications of each are discussed below.

When excavations at BBC commenced in 1991 the cave entrance was almost totally sealed by dune sand—also ca. 20 cm of undisturbed aeolian sand overlay the surface of the LSA indicating no disturbance of the cave's contents since the final LSA occupation ca. 290 years ago. Sterile yellow dune sand, 10–60 cm thick, separates the LSA and MSA across >90% of the excavated area and provides visible evidence that the LSA occupation did not disturb the underlying MSA deposits, with the possible exception of squares E2/F2 and E3/F3 [Figure 1(b)]. Here the sterile dune layer is relatively thin (2–5 cm) [see section line D2/D3 in Figure 2(b)], probably due to clearing or the excavation of bedding hollows by LSA people, but even in this area there is no visual evidence that LSA people disturbed MSA deposits.

If large-scale burrows were dug through the base of the LSA they would be readily visible during excavation because of clear differences in colour between the introduced bright yellow sterile dune sand and surrounding dark grey to black layers. The few "burrow" features [Figure 2(b), section line D2] are vertical and too narrow and shallow to effectively allow items the size of LSA bone tools to mobilise through the dune sand into the MSA. Very uncommon, larger holes (<3 cm) might introduce some materials but on a very limited scale and depth.

No burrows penetrated the yellow dune sand and MSA levels in the excavated area along grid lines 4, 5 and 6 [Figure 1(b)] where the sand is particularly thick. There is evidence of a vertical burrow or possible posthole- or digging stick-like feature in square E2 that might be responsible for the contaminated ^{14}C dates. However, if elongated objects such as bone tools were to fall down such burrows, they would most likely lie in a vertical rather than horizontal position. All the MSA bone tools, when recovered, were oriented in the same plane as the natural bedding, generally horizontal or near horizontal. Intrusion of bone tools into the MSA by means of burrows can thus be excluded.

Over most of the excavated area draping and slumping of sediments affects only the MSA and not the LSA. The basal LSA sediments do not reflect the marked undulations of the MSA surface that underlies the sterile aeolian sand [Figure 2(a), (b)]. Compression and draping of the MSA opened up a 0·05–0·1 m gap between the rear cave wall and the MSA sediments in squares F2, F3, G3, G4 and H5 [Figure 1(b)]. Dune sand and LSA material percolated into this narrow band and contaminated the MSA. Material recovered from this area has been excluded from all BBC analyses (Henshilwood *et al.*, 2001).

Distortion within MSA layers was only observed and properly appreciated after the 1992 and 1997 field seasons. During these two seasons there was some cross-cutting of layers *within* the MSA but not between the LSA and MSA. After 1997, individual layers were systematically redefined according to basal markers and content and a new nomenclature was introduced. This strategy has been successful and provides confidence that MSA materials recovered from the 1998 and subsequent excavations are temporally and spatially secure within an MSA context.

Contextual distribution of key LSA and MSA finds

One method of testing for admixture is by ascertaining whether elements unique to the MSA or LSA are found out of context at BBC. Ostrich egg shell beads, absent from the MSA levels, are relatively common in the BBC LSA and 86 were recovered from squares E2/E3/E4 in 1992 (Henshilwood, 1995); 21 of these beads come from the lowermost LSA layers in BBC L3 that lie directly above the sterile dune layer where it is thinnest. Beads, given their small size, would be more susceptible to mixing than bone tools. No beads were recovered from the MSA levels in 1992. Between 1997–2000 a further 140 beads were excavated from LSA levels but again none were recovered from MSA levels. The only area in which beads were found at MSA depths is from an area of known mixed context against the cave wall in square G4 [see above and Figure 1(b)] and these deposits are excluded from analyses.

Fifty-four bifacial points were recovered from MSA levels in squares E2/E3/E4 and a total of more than 400 within the site. Bifacial points are most common in the uppermost MSA layers just below the BBC Hiatus yet no bifacial points have been found in any LSA layers. The confinement of beads and bifacial points to within their respective LSA and MSA levels is a strong argument against the mobility of bone tools across the LSA/MSA boundary.

The stratigraphic and spatial distribution of bone tools

Seven bone tools were recovered from the LSA levels. Three came from the lowermost LSA, BBC L3, two from the middle phase

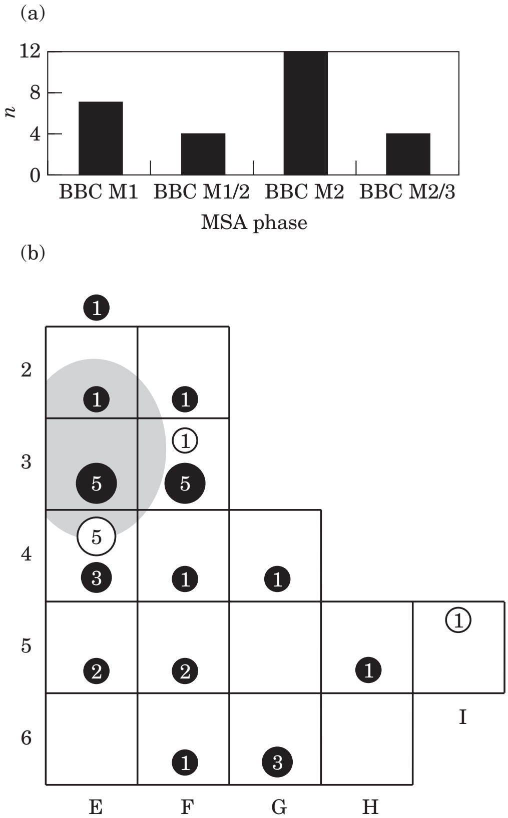


Figure 4. (a) Number of bone tools from each of the MSA phases. (BBC M1/2, 2/3 indicates the number of bone tools associated with the MSA but that cannot be allocated precisely to a BBC MSA phase); (b) spatial distribution of LSA (○) and MSA (●) bone tools. Grey shading indicates area where sterile BBC Hiatus layer is less than 10 cm thick. Over the rest of the excavated area the yellow dune sand is 10–60 cm thick. (Note: the bone tool "percussor" 8950 is excluded from this figure.)

BBC L2 and two from the upper phase BBC L1. Twenty-eight bone tools came from MSA levels. During the 1992/1997 seasons fifteen (54%) were recovered from 4·0 m^3 of excavated MSA material, and in 1998/1999/2000 13 (46%) came from a further 8·4 m^3 of MSA deposit. Fourteen (50%) of these bone tools can be securely placed within the BBC M2 phase and six (21%) within BBC M1 [Figure 4(a)].

Eight bone tools came from cross-cut MSA levels excavated in 1992/1997; five could derive from either BBC M1 or BBC M2 [BBC M1/2 see Figure 4(a)] and three, recorded in BBC M3, probably derive from the BBC M2 phase [BBC M2/3 see Figure 4(a)]. Excavations at BBC during the 1998–2000 seasons, when the stratigraphic separation of the MSA phases was clearly understood, shows that bone tools are most common in the middle MSA phase BBC M2. This provides further argument against the downward intrusion of bone tools from the MSA as most were recovered from the middle BBC MSA phase and not the upper, as would be expected if there was admixture from above.

Three further points can be argued against the likelihood of admixture. First, bone tools are considerably less common in the LSA levels (0·8 per m^3) compared to the MSA (2·3 m^3). Since no displacement between these two main horizons is observed amongst typical LSA and MSA finds (i.e., eggshell beads and bifacial points, respectively) an hypothesis for admixture would need to explain the selective displacement of the majority of purported "LSA" bone tools into MSA levels. The sum of evidence lends no credence to this argument. Second, spatial distribution of the LSA bone tools is restricted mainly to one square (E4) [Figure 4(b)] while those from the MSA levels are spatially widespread and particularly abundant in squares E3 and F3, where only one LSA bone tool is found [Figure 4(b)]. Third, many of the MSA bone tools were recovered from a 7 m^2 area where the MSA and LSA layers are distinctly separated by a 10–60 cm thick yellow sterile sand dune layer [Figure 4(b)]. Evidence of intrusion from the LSA layers above would be clearly visible but this was not the case.

Chemical testing

Two shaped and polished bone tools (8954 and 8947) from MSA levels and a random selection of eleven animal bones recovered from MSA and LSA levels in 1992/1997

Table 2 Mean length, width and cortical thickness of LSA and MSA bone tools

	Length (mm)			Width (mm)			Mean thickness (mm)		
	Mean	Std	*n*	Mean	Std	*n*	Mean	Std	*n*
LSA	61·4	9·4	6	8·2	4·8	6	2·0	0·7	6
MSA	76·1	31·7	22	10·2	4·4	22	3·0	0·9	22

were tested for relative percentages of carbon and nitrogen (C, N). Bone protein is known to degrade over time resulting in the loss of carbon and nitrogen, hence bones from the LSA and MSA levels will have considerably different concentrations of these two elements (Henshilwood & Sealy, 1997). One of these bone tools (8947) came from square E3, adjacent to E2, the source of the contaminated ^{14}C charcoal dates. The results show that both the bone tools tested have the same C/N ratios as the MSA bone and are unambiguously from the MSA levels (see Henshilwood & Sealy, 1997 for a fuller discussion).

Size of bone tools

The cortical thickness of the bone used for MSA tools is significantly thicker than those for the LSA, and MSA tools are generally longer and wider (for full discussion see below and Table 2). The larger size of the MSA tools is the reverse of what would be expected if their presence in the MSA deposits were the result of LSA tools being displaced into the MSA layers, as smaller items have a better chance of travelling down rodent burrows and other intrusions.

Analytical methodology

Given the ca. 70 ka age and large number of MSA bone tools from BBC a detailed analysis of the technology used to manufacture these tools is essential. A *chaîne opératoire* approach, traditionally applied to stone tool reduction sequences (Lemonnier, 1986; Schlanger, 1994), was chosen to analyse the BBC bone tools. This meant attempting to use available contextual information (zooarchaeology and taphonomy of the bone assemblage) and examining all recovered bones showing traces of manufacture or use (by-products, finished, unfinished, worn, re-shaped and broken tools). From this base a reconstruction of the sequence of actions was followed for each tool, starting with acquisition of the bone raw material, then the process of manufacture, subsequent tool use and ending with discard of the tool (for a similar approach see Hahn, 1986; Camps-Fabrer, 1999 and Averbouh, 2000). Bone type, body part, class size and species used to produce the tools were recorded and where possible each bone tool was assigned to skeletal element and age class (juvenile or adult). Identification was by way of comparison with faunal collections held at the South African Museum, Cape Town and the State University of New York at Stony Brook.

Each specimen was examined with a reflected light microscope in order to identify anthropogenic and natural traces. Identification of shaping techniques and use-wear on archaeological specimens is based on data obtained from experimental manufacture and use of similar bone tools (Newcomer, 1974; d'Errico *et al.*, 1982–1984, 2000; Christensen, 1999), on comparative analysis with European Upper Paleolithic worked bone (Villa & d'Errico, 2001) and an analysis of LSA bone tools from Nelson Bay Cave and Byneskranskop.

The localisation and extent of worked areas, the manufacturing technique used and their chronology were systematically recorded for each BBC piece. Also noted

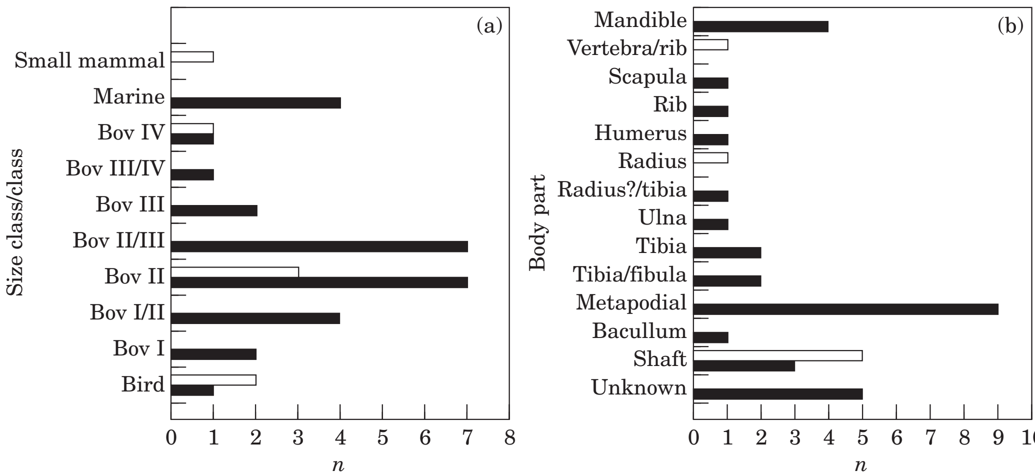


Figure 5. (a) Source of bone tool raw material by class and size class for the LSA and MSA (bov=bovid); (b) source of bone tool raw material by animal body part for the LSA and MSA levels: LSA (□), MSA (■).

were the presence, location and type of breakage, the occurrence of wear, burning, ochre staining, cut-marks and various types of post-depositional traces such as root etching. Morphometric data included measuring length, width and thickness of each tool, and width and thickness at 5, 10 and 30 mm from the tip (see Appendix, Tables A1 and A2). For comparative purposes the same variables were also recorded on ten ethnographic San Masarwa arrowhead bone points from the Kalahari desert, on 32 awls and projectile points from the LSA levels of Nelson Bay Cave (Inskeep, 1987), and 20 awls from the LSA levels of Byneskranskop (Schweitzer & Wilson, 1982). These collections are curated at the South African Museum, Cape Town.

Selected areas on some BBC MSA bone tools were replicated with Provil L impression material (Bayer, Germany). Positive casts, made in RBS resin (T2L Chimie, France), were observed with an SEM 840A Jeol. Transparent replicas obtained with the same replica technique were also observed and photographed in transmitted light with a Wild M3C stereomicroscope. Transmitted light microscopic images of experimental and archaeological surfaces were digitised using a CCD KP-M1E/K Hitachi camera mounted on the stereomicroscope and connected with a Toshiba Satellite Pro 430 CDT laptop equipped with a Snappy frame grabber.

Bone tool technology: Phase 1—raw material selection

None of the MSA tools preserved epiphyseal or metaphyseal surfaces, so assignment to age class was more subjectively dependent on features of the cortical bone. Juveniles often have thin, flaky, and/or porous cortical bone, and when this was evident the bone tool was assigned to the juvenile class. Figure 5(a) and (b) indicates the source of the bone raw material by body part, class/class size and age.

Bones of both adult and juvenile animals were selected for tool manufacture in the MSA, and only adult bone in the LSA but the result may be a function of the small size of the LSA sample. It is unclear at this stage if the frequencies of juvenile and adult bone reflect deliberate selection. Alternatively, these frequencies may represent the broader population characteristics of the sample of bone they were drawn from. This can only be further investigated when an analysis of the entire faunal assemblage, currently in progress, is completed.

It was not possible to identify the origin of bone used for each tool to taxon and skeletal element as many are made on bone fragments considerably modified by shaping and polishing. Also the vast majority are derived from shaft regions on long bones where articular areas are not preserved. However, in most cases family could be determined. Most tools in the MSA and LSA are made on bovid bone, perhaps not surprising as bovids dominate the mammalian fauna (Henshilwood *et al.*, 2001). Tool makers in the MSA selected long bones, especially metapodials but also mandibles, a single bacullum and a scapula. LSA tools are mostly made from bovid long bone shaft fragments. A few tools are on bone other than bovid including marine mammal bone, probably seal (MSA), bird (LSA and MSA) and small mammal, possibly hare (LSA). All these animals are present in the BBC faunal assemblage.

There appears to be a selection for bone from Size I and II bovids (see Brain, 1981 for bovid size class descriptions) in the MSA—however, this might represent the relative abundance of bone from this size class within the site (see Henshilwood *et al.*, 2001). Also, juvenile animals are allocated to a size class according to their size at the time they were killed. This will produce some skewing of results as, for example, a juvenile classed as size II or III could fit size class IV when adult.

Bone tool technology: Phase 2—manufacture

Blank production

As noted in Phase 1 above, the majority of the MSA tools are made on the shafts of either long bones or mandibles. In some cases, the approximate location of the tool blank on the bone could be confidently established, and where possible is illustrated here (Figures 6 and 7). Positional assignments allow for identification of favoured locations on bones that were exploited for blank manufacture. Given increased and sufficient sample sizes it is hoped that analyses of these positional data will provide future insights into the bone choice and blank manufacturing process of early bone tool technology. Bone tools are illustrated on skeletal elements selected from taxa likely to have been exploited, but these assignments cannot be verified. Drawings are not precisely to scale—that would require knowing the precise size of the exploited animal, which is not possible—so the locations and spans of the bone tools are approximations.

Fresh bone was selected for blanks in the MSA. Evidence for fresh bone use was determined by examining breakage morphology, in particular spiral fractures and cut marks typical of those made on fresh bone surfaces (8944, 8964 and 8968) [Figures 8(i) (f) and 9(j)]. In only one case (8942) [Figure 8(g)] a weathered bone was used as the surficial primary lamellae on the periosteal surface of the bone were lost prior to scraping, and existing root markings were removed during this process. All the LSA tools were made on fresh bone.

Descriptions of the source of the blank and, where possible, technique of blank manufacture follows. Specimen 8941 [Figures 6(a) and 9(b)] was manufactured from the right mandible of a size III or IV bovid, very likely an eland. The tool blank is derived from the horizontal ramus of the mandible. Long linear shaft fragments such as this are commonly produced during hammerstone percussion of the mandible for the purpose of marrow extraction, which is best accomplished by a series of blows below the tooth row, often detaching a long section of

Figure 6. Approximate location of bone tool blanks on skeletal elements: (a) specimen 8941 positioned on a right mandible of an eland, buccal (left) and lingual (right) views; (b) specimen 8948 positioned on a right ulna of a springbok, medial view; (c) specimen 8949 positioned on a left tibia of a springbok, lateral view; and (d) specimen 8950 positioned on a right metacarpal of an eland, posterior (left) and lateral (right) views. Skeletal elements not presented to scale.

ramus. The cortical bone in this location is thick, and when combined with the curve formed by the base of the ramus, would make a strong blank well suited to tool manufacture.

Specimen 8949 [Figures 6(c) and 8(m)] is a long thin shaft fragment from the postero-lateral aspect of a size I or II bovid tibia, very likely a springbok. Shaft fragments of this form are commonly produced during

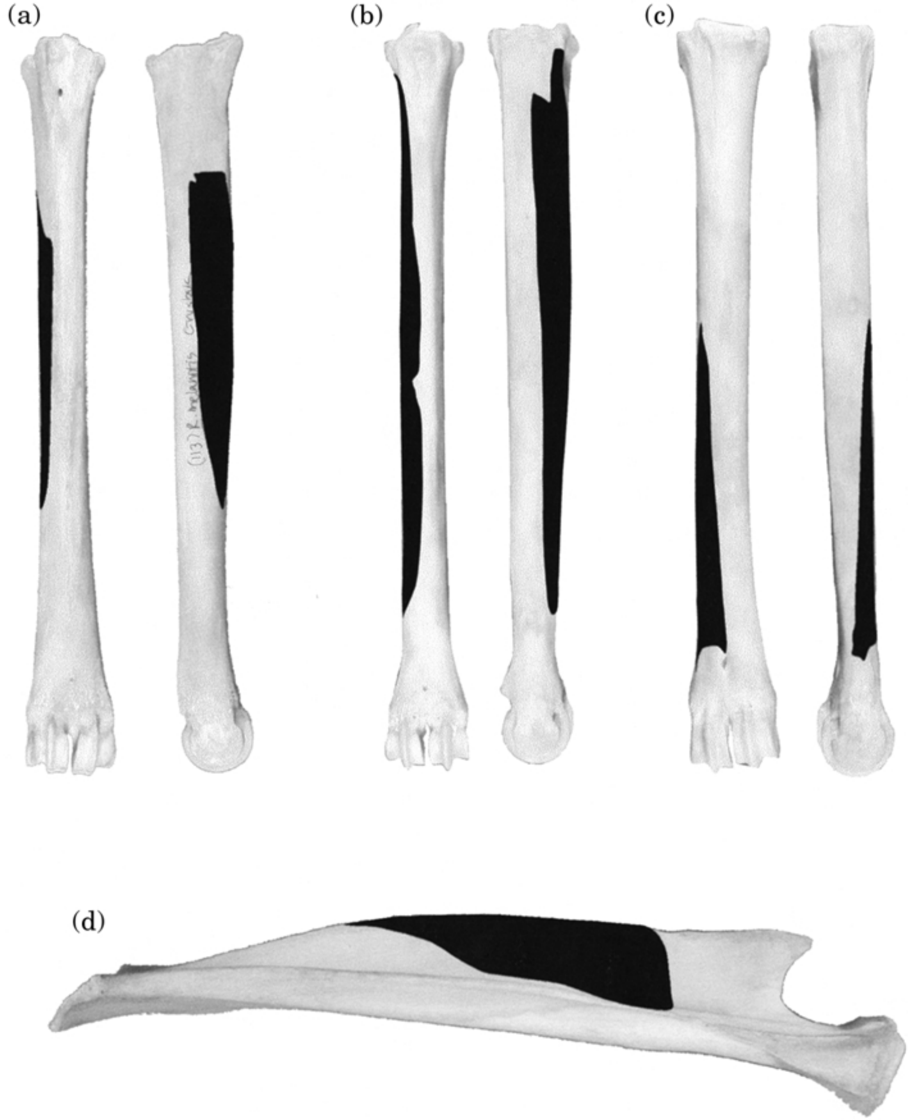


Figure 7. Approximate location of bone tool blanks on skeletal elements: (a) specimen 8953 positioned on a right metatarsal of a grysbok, posterior (left) and medial (right) views; (b) specimen 8964 positioned on a left metatarsal of a springok, posterior (left) and lateral (right) views; (c) specimen 8965 positioned on a right metacarpal of a springbok, anterior (left) and lateral (right) views; and (d) specimen 8966 positioned on a right scapula of a bontebok, lateral view. Skeletal elements not presented to scale.

hammerstone percussion of tibia for marrow extraction. Tibia and medapodial shaft fragments produced by hammerstone percussion are often long and gradually taper to a point, making them ideal candidates for the production of pointed tools. This may explain the abundance of metapodials in the sample that can be confidently placed on a skeletal element.

Four specimens from the tool set that can be positioned are from metapodials, and all are made on shafts that are typically

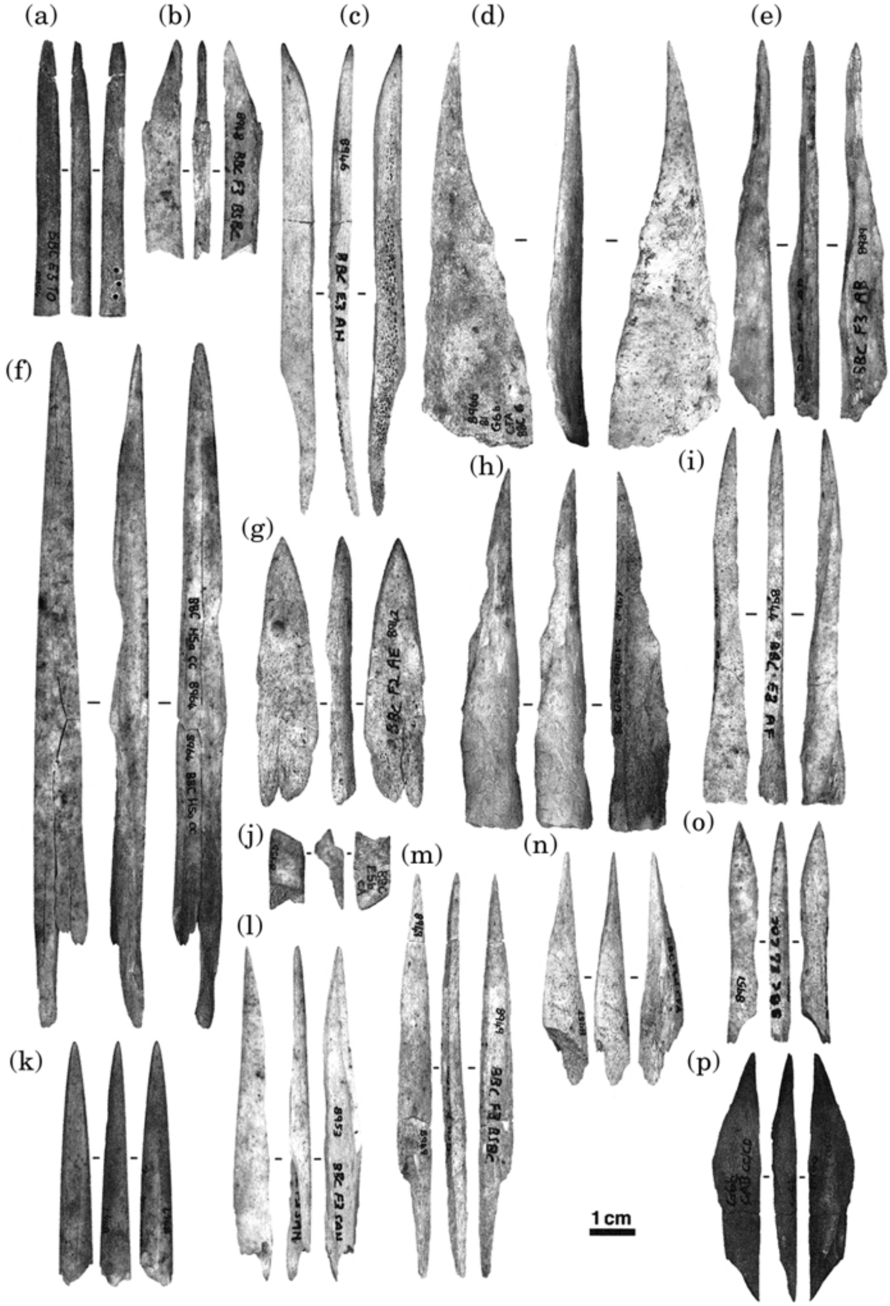


Figure 8. MSA bone tools [(a)=8954; (b)=8948; (c)=8946; (d)=8966; (e)=8939; (f)=8964; (g)=8942; (h)=8967; (i)=8944; (j)=8955; (k)=8947; (l)=8953; (m)=8949; (n)=8957; (o)=8951; (p)=8960].

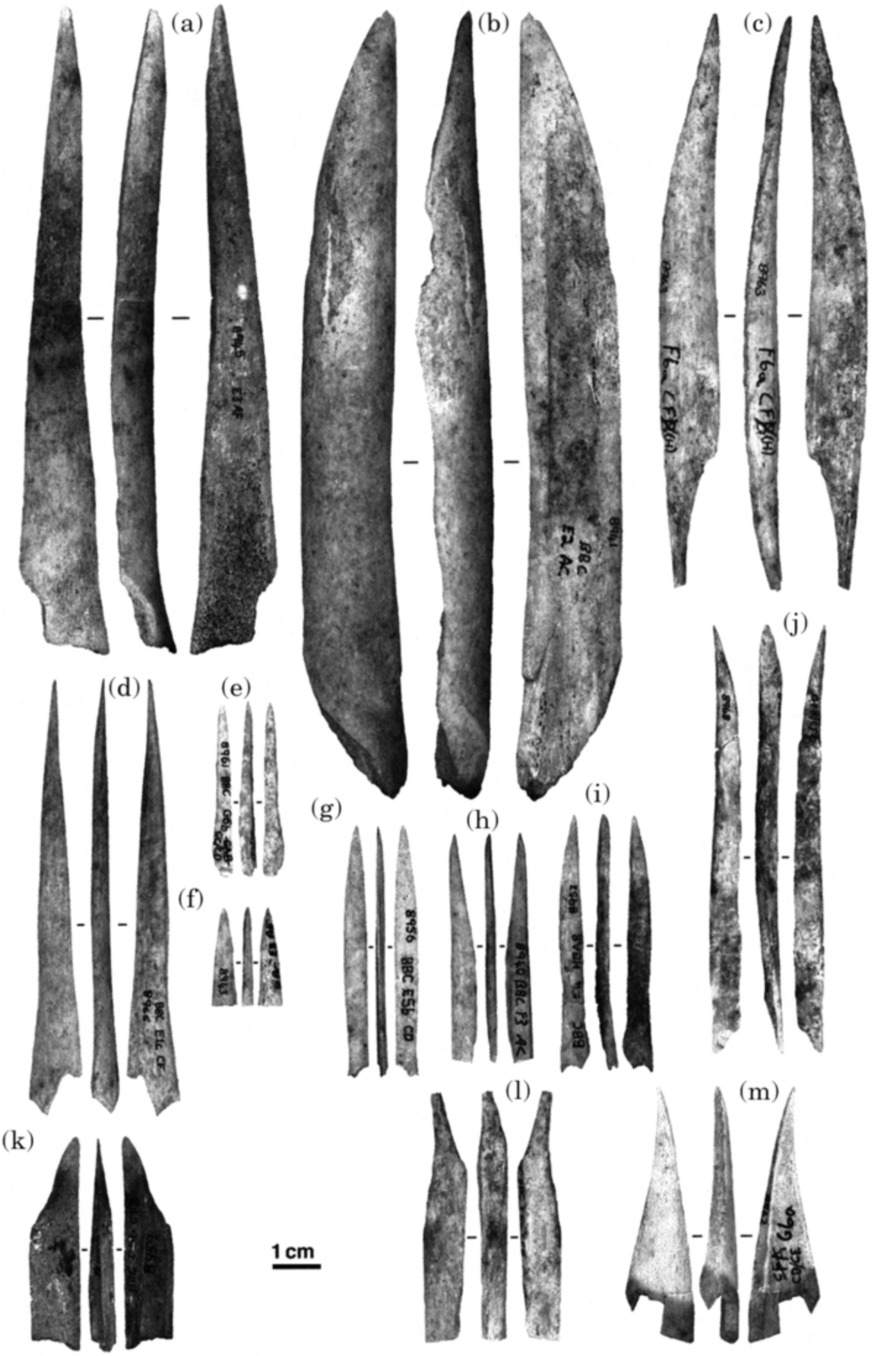


Figure 9. MSA bone tools [(a)=8945; (b)=8941; (c)=8963; (d)=8965; (e)=8961; (f)=8943; (g)=8956; (h)=8940; (i)=8952; (j)=8968; (k)=8959; (l)=8958; (m)=8962].

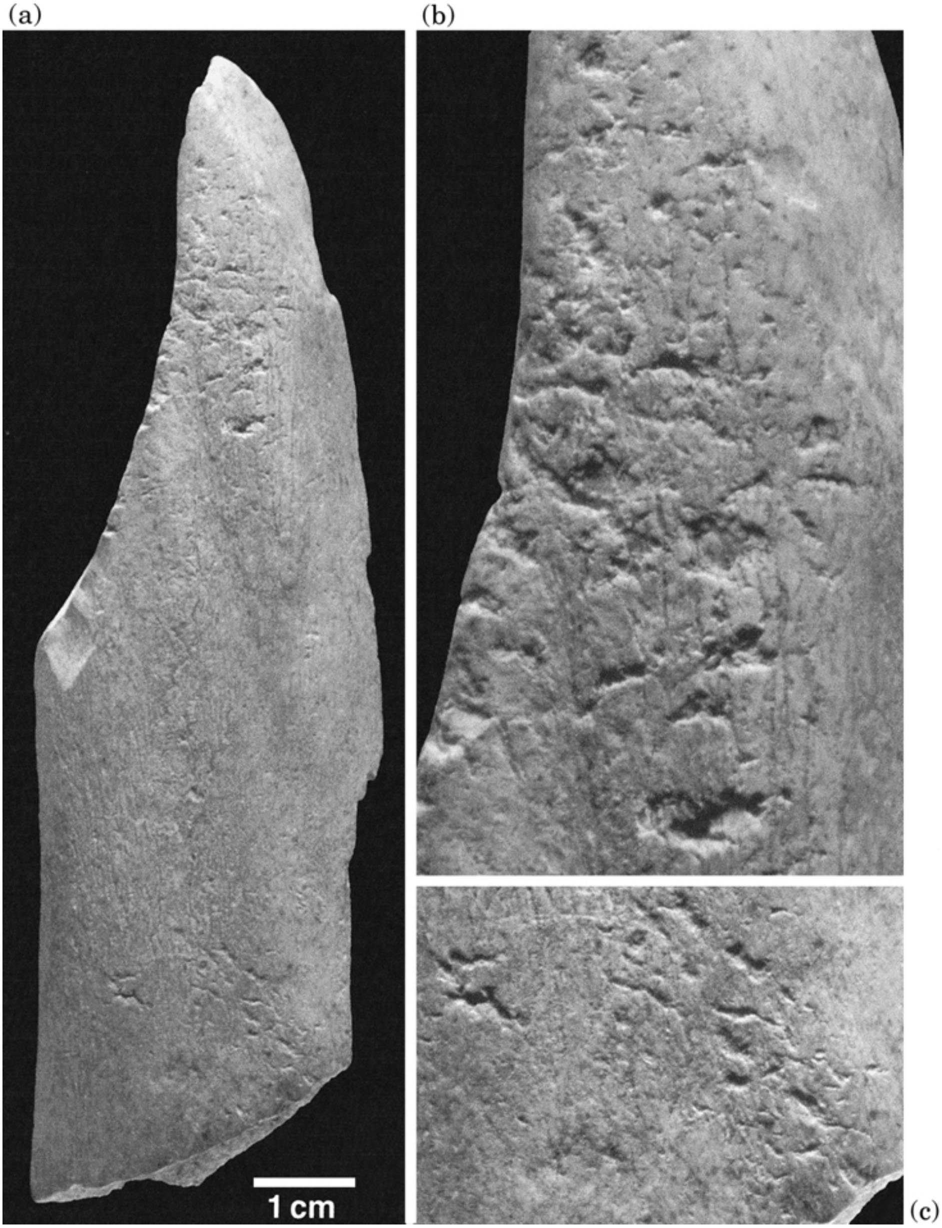


Figure 10. (a) Bovid metapodial shaft fragment used to retouch lithic artefacts (8950); (b), (c) close up views of two areas showing elongated impact scars resulting from knapping.

produced during hammerstone percussion of metapodials. Specimen 8950 [Figures 6(d) and 10] is a large fragment shaft derived from the metacarpal of a size IV bovid, almost certainly an eland. The tool blank covers nearly the entirety of the posterior distal shaft and curves up into the middle shaft, forming a stout end that was polished to a blunt point. Hammerstone percussion of large bovid metapodials is often best accomplished by a series of blows to the lateral or medial aspects of the metapodials, splitting the metapodials apart. This often produces large shaft fragments that cover the anterior or posterior aspects, as does this tool. Specimens 8953 [Figures 7(a) and 8(l)] and 8964 [Figures 7(b) and 8(f)] are both metatarsals of size I (probably grysbok) and size II or III bovids, respectively. Both tool blanks are taken from the intersection of the posterior aspect and the lateral or medial aspects. The angle formed at this juncture provides a thick cortical line that runs the length of the tool, and likely provides strength and rigidity. Specimen 8965 [Figures 7(c) and 9(d)] is taken from the anterior aspect of the metacarpal of a size II juvenile bovid, and this location together with the juvenile nature of the bone produces a much more fragile tool than with the previously discussed set.

Two specimens of the tool set that can be positioned diverge from the general pattern by being made on nonmedullary cavity bone. Specimen 8948 [Figures 6(b) and 8(b)] was manufactured from the middle shaft portion of a size II bovid ulna, very likely a springbok. The distal end of the tool is broken nearly transversely, while the proximal and worked end of the tool has been polished to a point that partially makes use of the natural posterior border of the ulna shaft. The ulna bone in this area is completely cortical and thus very strong. The ulna was unfused to the radius at the time the tool was manufactured. Specimen 8966 [Figures 7(d) and 8(d)] was manufactured from the scapular spine of a juvenile size II or III bovid. The spine appears to have been snapped off, and then worked to a point employing the natural margin of the spine as one edge of the tool. The result is a thin and fragile tool.

The positional data show several patterns. Most of this bone tool set are derived from cortical areas of bones with medullary cavities, and most of these fall within the range of shaft fragments produced during marrow processing. Most of these are derived from metapodials and tibia, both of which tend to break into long, gradually tapering shafts when broken by hammerstone percussion. This part of the blank manufacture process can be explained as simply using shafts broken by marrow processing. However, several 8941 [Figures 6(a) and 9(b)], 8948 [Figures 6(b) and 8(b)], 8950 [Figures 6(d) and 10], 8953 [Figures 7(a) and 8(l)], and 8964 [Figures 7(b) and 8(f)] were chosen from locations where the geometry and cortical thickness combine to form stout shafts well suited to resisting strain. This suggests that the blanks come from well-known and expedient processes (marrow processing) while the choice of shaft fragments to use was targeted. These conclusions are preliminary given the small size of the sample.

Blank manufacturing techniques

An attempt was made to ascertain whether a systematic technique was used to produce blanks, and/or if already fragmented bone, perhaps a by-product of marrow extraction, was used for the MSA and LSA. The majority of worked ends of the MSA tools are long gradually tapering breaks typical of fragments produced from bovid long bones fragmented for marrow extraction. Two pieces 8964 [Figure 8(f)] and 8941 [Figure 11(a)] show negative flake scars (i.e., notches, see Capaldo & Blumenschine, 1994) indicating percussion. In one case opposite sides of a mandible were percussed to split it and produce an elongated fragment [Figure 11(a)]. Some fragments of Class 5 in Table 3 retain evidence of notches made to split long bone shafts and create a blank, but in some cases notches, 8939 [Figure 8(e)] and 8951 [Figure 8(o)], were made after the blank was produced. Hammerstone percussion marks (Blumenschine *et al.*, 1996), typically abundant on hammerstone-broken long bone shafts, were rare. In many

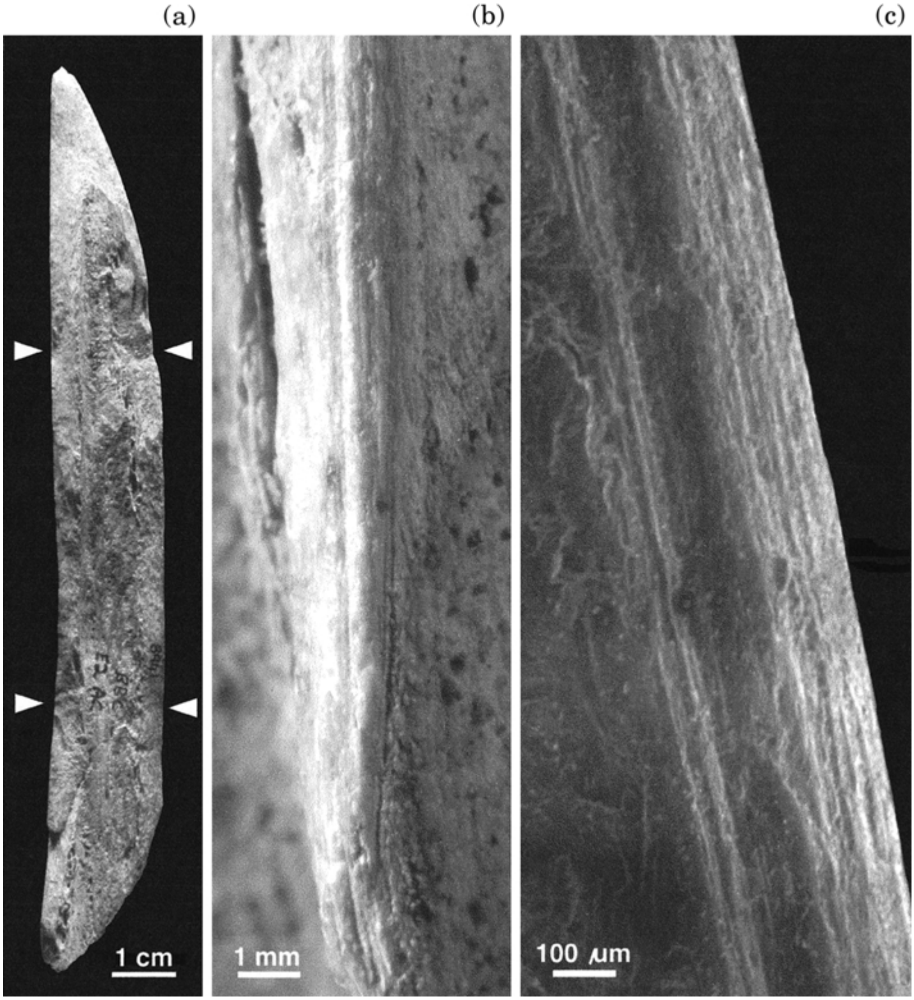


Figure 11. (a) Elongated mandibular fragment (8941) produced by percussion (arrows) on opposite sides of the mandible; (b), (c) scraping marks at the top right margin of fragment (8941) produced by irregular lithic edge [(b) is an SEM photo].

cases subsequent scraping and polishing of blanks probably removed evidence of blank preparation in the form of percussion marks and notches. Class 6 blanks (Table 3), mostly unbroken, are much smaller than those for other classes and derive mainly from shaft fragments of small bovids and a bird.

A detailed taphonomic analysis of the entire BBC MSA faunal assemblage, including all long bone shafts, has commenced using methods described in Marean (1998) and Marean & Kim (1998). This will help determine whether shafts processed strictly for marrow access fragmented differently to shafts ultimately used to produce bone tools. However, this study may be inconclusive due to the heavy modification of the bone tool shafts by polishing and grinding that obscures much of the evidence for blank preparation, and because of the small sample of bone tools.

Size of bone tool blanks

The MSA bone tools are longer and wider than the LSA bone tools, but not significantly (Mann–Whitney U-test, $P>0{\cdot}05$). Visually, MSA tools seemed to be derived from larger bones, and to test this observation the cortical thickness as preserved by each bone tool was measured. Several measurements were made for each bone tool from areas where the cortical bone was not reduced by working, and then a mean cortical thickness was calculated for each specimen. The results (Table 2) show that the MSA bone tools are, as a whole, derived from bones that are significantly thicker than those used to make the LSA bone tools (Mann–Whitney U-test, $P<0{\cdot}01$, $U=56$). This suggests that the bone blanks being chosen for working by MSA people were thicker, and thus likely from larger animals.

Fragmentation

As noted above, most of the tools are made on long bone shafts and many of the worked ends have a morphology typical of that produced when long bones are broken by hammerstone percussion. However, there does seem to be a bias toward long gradually tapering breaks, and these are often produced on tibia and metapodials of bovids during hammerstone percussion. In contrast, opposite these worked ends there is a tendency for the bone tool to have a break that cuts sharply across the longitudinal axis of the bone, and the angle formed by the cortical surface and broken surface is often nearly a right angle [Figures 8(b), (h), (e), (i) and 9(a) (d), (k), (l)]. The intention here was to determine whether this pattern differed from what would be expected from breakage resulting from hammerstone percussion. Villa & Mahieu (1991) have described an approach to classifying long bone breakage morphology that is useful and widely applicable. This approach attempts to measure the amount of green bone (fresh bone) *vs.* dry bone (degreased bone) breakage by describing the shape of a break across the longitudinal axis of a long bone with a set of simple morphological categories. In blind tests between students at SUNY, Stony Brook, it was found that these classifications can be very effectively replicated between researchers (>85% correspondence).

Villa & Mahieu (1991; also Johnson, 1985) argue that transverse and right-angle breaks tend to occur when a bone was broken in a dry state, while curved and oblique (obtuse and acute) breaks occur when bones were broken while fresh and greasy. They used this procedure to assess the amount of dry bone breakage, resulting from trampling and sediment compaction, in several archaeological assemblages. Marean *et al.* (2000) calibrated these frequencies with a controlled study of modern processes of bone breakage. Green bone breakage is primarily the result of hammerstone breakage by hominids (hominid only), carnivore breakage (carnivore only), and the former followed by the latter (hominid to carnivore). These three processes were experimentally replicated, and the breakage frequencies for each process are provided in Table 4 compared to the BBC sample. The BBC sample excludes all breaks that displayed fresh surfaces, and includes only tools derived from shafts or mandibles.

The experimental data show that the agent (humans *vs.* carnivores) and the type of loading [dynamic (hammerstone) *vs.* static (carnivore), as in Johnson, 1985], has little impact on the frequency of breakage types. Thus the frequency of breakage types is a function of dry *vs.* green bone breakage. Interestingly, the BBC unworked end right-angle and transverse break frequencies are much higher than the experimental samples (Table 4), and fall outside bootstrapped 95% confidence limits (see Marean *et al.*, 2000). Clearly, the frequencies of right and transverse breaks cannot be accounted for only by green bone breakage, and this means

Table 3 Classes of bone tool blanks

MSA Class of blank	SAM-AA No.
1. Complete bone that is naturally pointed, e.g. bacullum	8954, 8948
2. Fragments created by breaking and shaping bones naturally pointed by contact with other bone surfaces, e.g. ulna, scapula	8946, 8966
3. Long bone fragments exploiting natural ridges for shaping purposes.	8964, 8939
4. Weathered long bone fragment.	8942
5. Fragments from long bone shafts and mandibles.	8967, 8944, 8953, 8949, 8947, 8955, 8963, 8951, 8957, 8960, 8968, 8941, 8962, 8958, 8959
6. Thin, short, points derived from breakage of small shaft fragments, mostly Class size I bovids or bird bone.	8961, 8940, 8952, 8943, 8956
LSA Class of blank	**SAM-AA No.**
7. Fragments from long bone shafts (bovid and small mammal)	8977, 8980, 8981, 8974
8. Thin, short points (bird bone)	8976, 8979
9. Fragment created by breaking and shaping (vertebra or rib)	8978

Table 4 The frequency of right angle and transverse outline breaks on the unworked end of the BBC bone tools compared to experimental samples of broken fresh long bone shafts

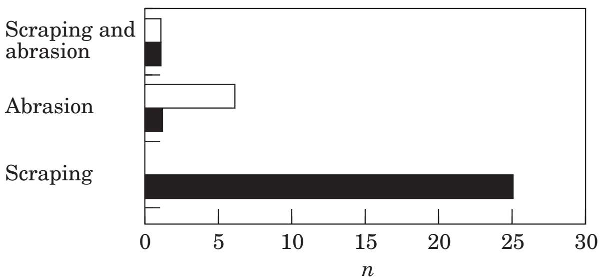
	Sample size	Right angles	% Right	Sample size	Transverse outlines	% Transverse
BBC						
LSA	7	3	42·9	7	4	57·1
MSA	24	8	33·3	24	7	29·2
Experimental						
Carnivore	622	22	3·5	623	36	5·8
Hammerstone to Carnivore	1167	46	3·9	1174	48	4·1
Hammerstone	588	27	4·6	589	30	5·1

one of three things: (1) either the ends were intentionally snapped to produce a blunt morphology, (2) the ends broke in use and due to the hafting or holding configuration tended to snap directly across the longitudinal axis, or (3) the high frequency of dry bone breaks resulted from post-depositional breakage.

None of the worked areas of the bone show these dry bone breaks, and the likelihood of post-depositional breakage occurring on one of two ends should be random. Thus it is unlikely that the high frequencies of right-angle transverse breaks across the unworked end result from post-depositional breakage. At this point we are unable to resolve whether these breaks result from a technological process that regularly included snapping the end to produce a blunt tool butt, or breakage during use. Breakage of

Table 5 Shaping techniques used to manufacture bone tools in the MSA and LSA

MSA Shaping technique	SAM-AA No.
1. Scraping with lithic edge	8939, 8940, 8941, 8942, 8943, 8944, 8946, 8947, 8948, 8949, 8951, 8952, 8953, 8954, 8955, 8957, 8958, 8960, 8963, 8964, 8965, 8966, 8967, 8968
2. Shaping by flake removal	8939, 8948, 8951
3. Abrasion against fixed surface	8945, 8946
4a. Shaping and polishing by small particle abrasion (probably fine-grained sand)	8947, 8955, 8964
4b. Shaping by polishing after shaping by scraping	8947
LSA Shaping technique	**SAM-AA No.**
7. Partial scraping with lithic edge	8980
8. Abrasion against fixed surface	8976, 8977, 8978, 8979, 8980, 8981



	Scraping	Abrasion	Scraping and abrasion
□ LSA		6	1
■ MSA	25	1	1

Figure 12. Numbers of MSA and LSA bone tools shaped by scraping, abrasion or the scraping and abrasion techniques.

five of the LSA tools at the butt end occurred post-depositionally, the other two are all recent. In some cases it is difficult to establish whether a tool was originally longer, and then broke during use or was deliberately broken during manufacture.

Shaping techniques

Techniques used to further modify a bone blank into a tool are described below and demonstrate that substantially different techniques were employed in the MSA and LSA.

Four shaping techniques are used in the MSA (Table 5, Figure 12). The first and most commonly used technique (96%) is scraping the bone blank with a stone tool [Figures 11(b), (c), 13(a), (b) and 14(a), (b)]. This involves applying a sharp lithic edge to the bone using an irregular stroking motion and with minimal contact at each stroke. Tool edges were generally irregular as demonstrated by the deep scraping marks and small area of contact with the bone surface. The second technique is shaping by flake removal [8951, 8948 and 8939 (Figure 8)]. Here, small flakes of bone are removed by percussion, probably with a pointed stone hammer thereby thinning the fragment. The

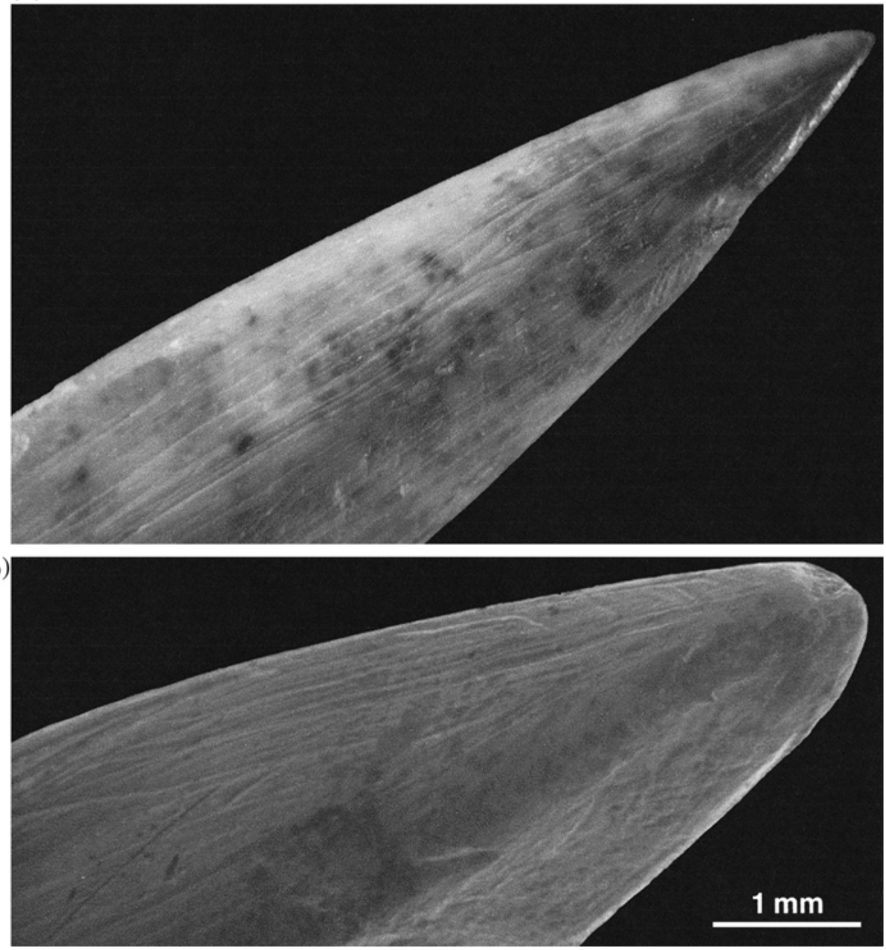
(a)
(b)


Figure 13. (a) Point of awl (8951) showing shaping by scraping with a handheld lithic edge; (b) close up view of point showing flake removal from use and subsequent wear.

third method, rarely used, involves holding the tool and abrading it against a fine-grained surface, possibly silcrete or calcrete. Examples are: 8945 [Figure 9(a)], partially abraded on the only worked facet; 8946 [Figure 14(c)], partially abraded on one facet. The fourth method is shaping by polishing. There are three examples of tools with highly polished surfaces (8947, 8955 and 8964) and these are characterised at microscopic scale by fine, individual, curved striations [Figure 14(d)]. This type of polish was probably produced by rubbing the tool against the hand or soft leather (d'Errico, 1993).

Two shaping techniques were used in the LSA (Figures 15 and 16, Table 5). The preferred technique for complete shaping (86%) and partial shaping (14%) of tools in the LSA is by abrasion [Figure 16(a)–(c)]. This involves moving the blank almost perpendicularly over a coarse, fixed surface, probably quartzite, producing parallel fusiform grooves. The width of these grooves and the absence of individual thin striations indicates that no loose sand or

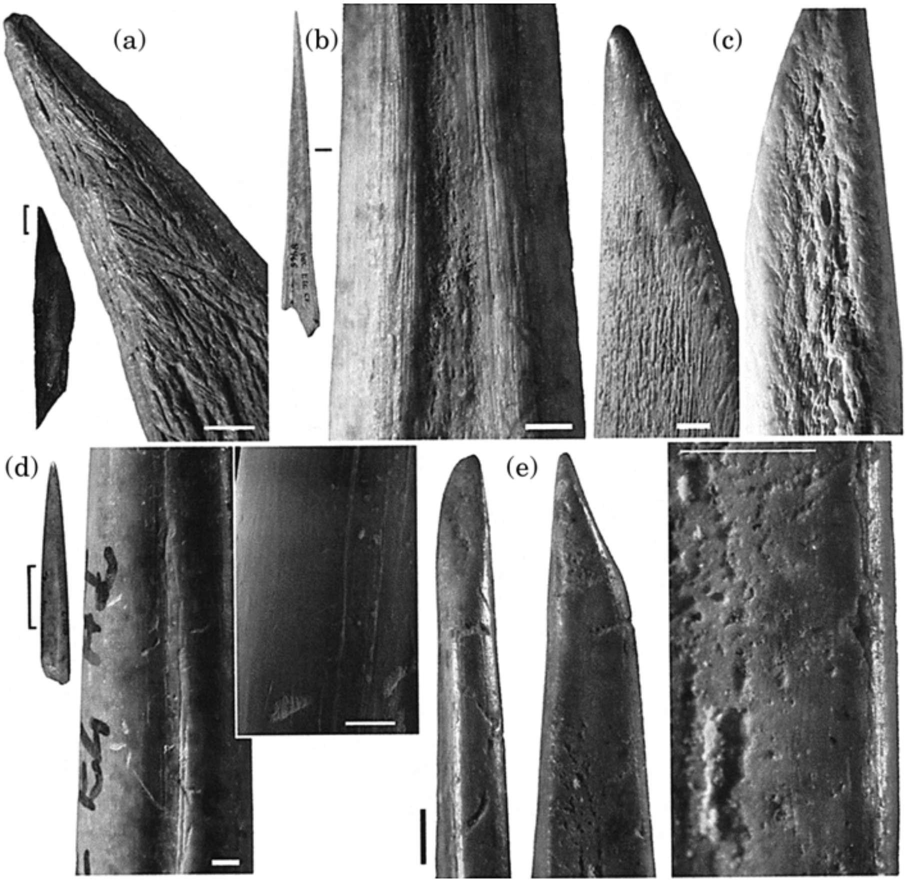


Figure 14. (a) Tip of awl (8960) shaped by scraping with irregular lithic edge; (b) scraping made on medullary surface of an awl (8965) to smooth ridges created by breakage; (c) awl tip (8946) showing evidence of burning and oblique grinding; (d) projectile point (8947) with residual traces of scraping on concave medullary surface. The remainder of the surface is highly polished. SEM micrograph shows polished area covered by individual striations; (e) broken awl tip (8940) with evidence of polishing resulting from re-use after breakage. Within the broken area the patina is distinct from the surrounding polish. Longitudinal thin striations on the tool edge are due to use-wear.

other abrasive particles were present or produced during the grinding process. The two LSA tools made on bird bone, 8976, 8979 [Figure 15(f), (g)], were produced by the same technique using the same motion but the striations are thinner indicating use of a finer grained grinding surface.

There is one marginal example (8980) of shaping by scraping with a stone tool in the LSA where, of the three facets worked, two were both scraped and abraded and one abraded [Figure 16(f)]. An unusual tool made in the LSA on a juvenile bovid tibia is 8974 [Figure 15(c)]. A series of notches with a screw-like morphology were deliberately cut near the point, possibly with a lithic edge. The tool was then used, resulting in some of the notches near the tip becoming dulled from polish while those further from the tip remained sharp.

The degree of tool modification by shaping was gauged from the number of shaped facets, the length of shaping marks on each facet (Figure 17, Table 6) and any other

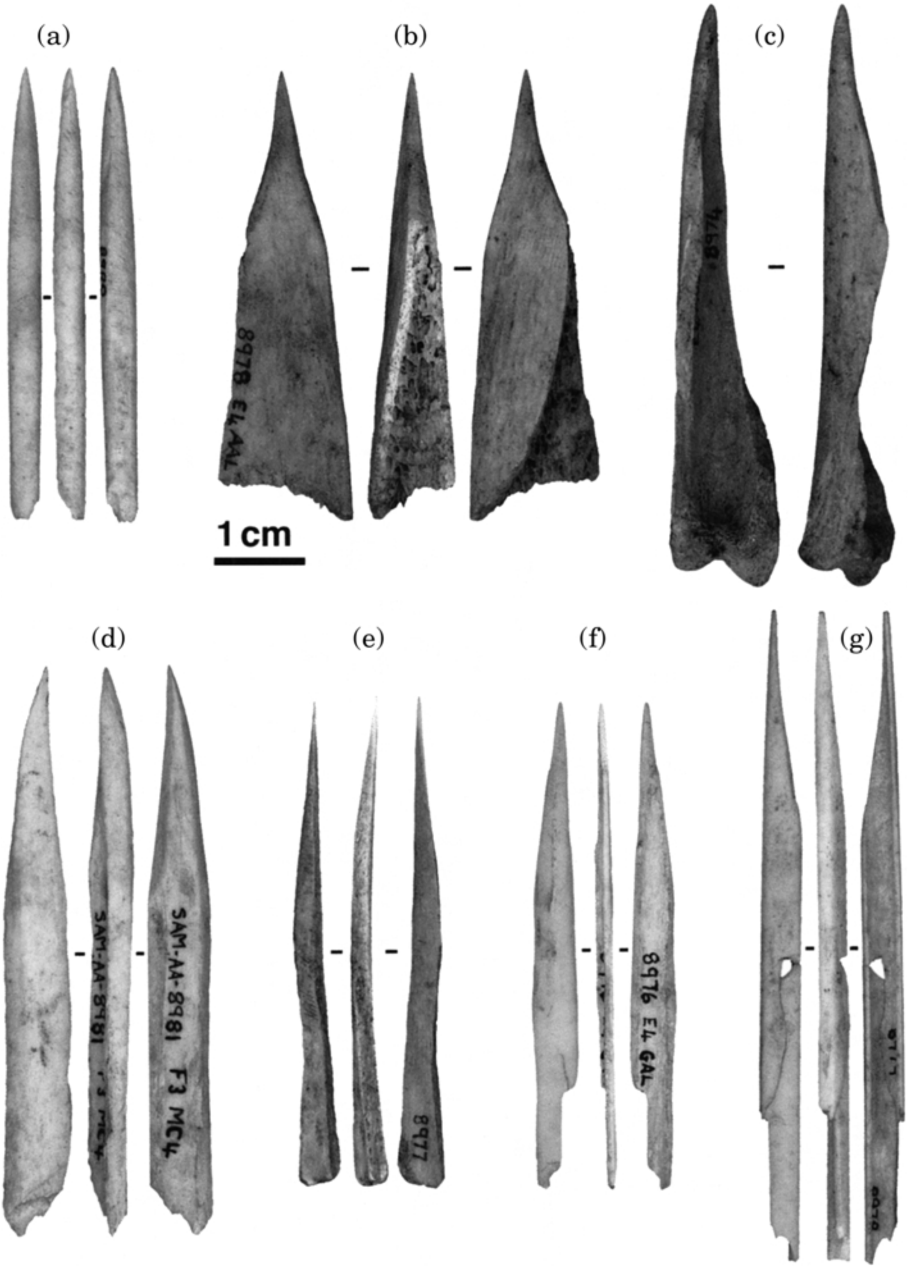


Figure 15. LSA bone tools (a) 8980; (b) 8978; (c) 8974; (d) 8981; (e) 8977; (f) 8976; (g) 8979.

deliberate markings on the tool. The maximum number of facets shaped for any tool was four, described here (with the tool held periosteal surface up and pointed end away from the viewer) as left, periosteal, right and medullary. The length of shaping marks are measured on each facet from the tip of the pointed end towards the butt (Figure 17).

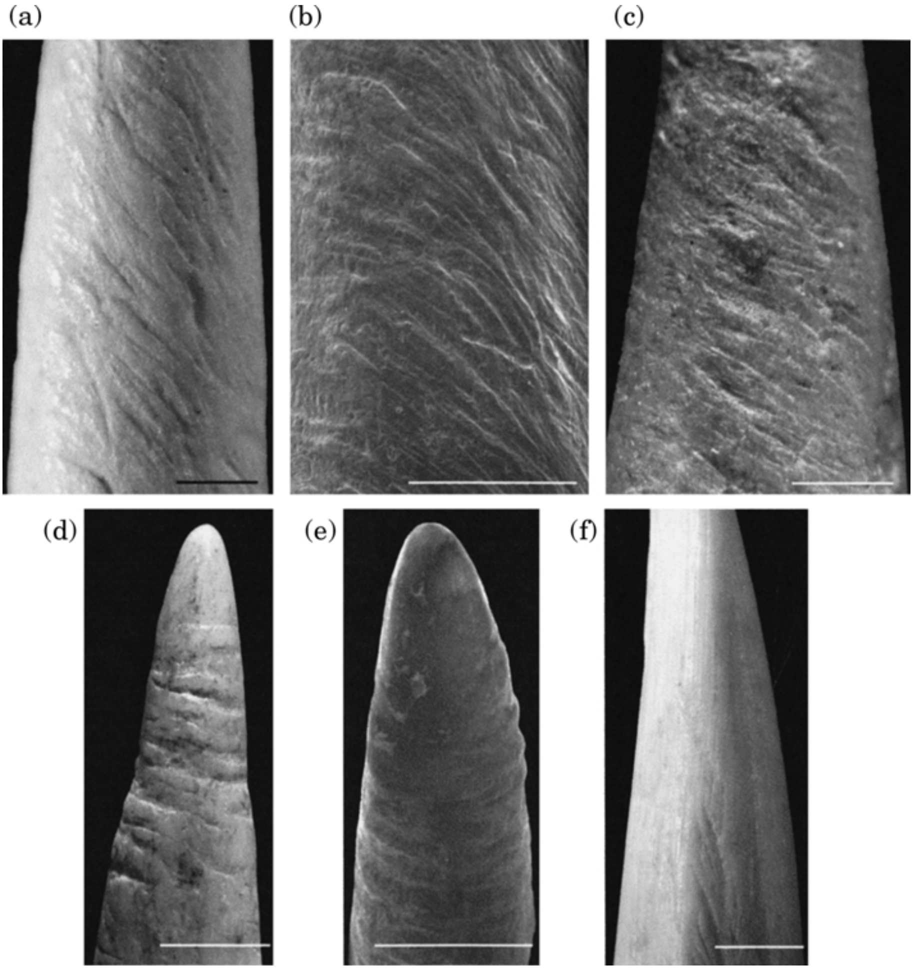


Figure 16. (a), (b), (c) Fusiform sub-parallel striations produced by oblique grinding on a coarse fixed surface [(a), (b)=8980; (c)=8978]; (d), (e) tip of awl showing corkscrew like grooves produced during shaping by a cutting edge and subsequently smoothed by use-wear; (f) awl shaped by scraping with a lithic edge.

The mean length of shaping marks (either by scraping or abrasion) for any number of facets is similar for the LSA (27·5 mm; S.D.=18) and MSA tools (28·7 mm; S.D.=18). Minimum and maximum shaping lengths range from 9–59 mm (LSA) and 4–85 mm (MSA).

Other tool modifications

Deliberate markings are defined as cuts or incisions not produced during the shaping process or by handling, use-wear or post-depositional factors, such as root etching. Three short parallel cuts near the butt on 8964 were made with an unretouched lithic edge. They are not butchery cut marks as they occur on the surface of a fracture and were made after polishing was completed [Figure 18(a)].

There are three sets of oblique lines at the midshaft position on 8954; two sets consist of five lines and one of six [Figure 18(b),

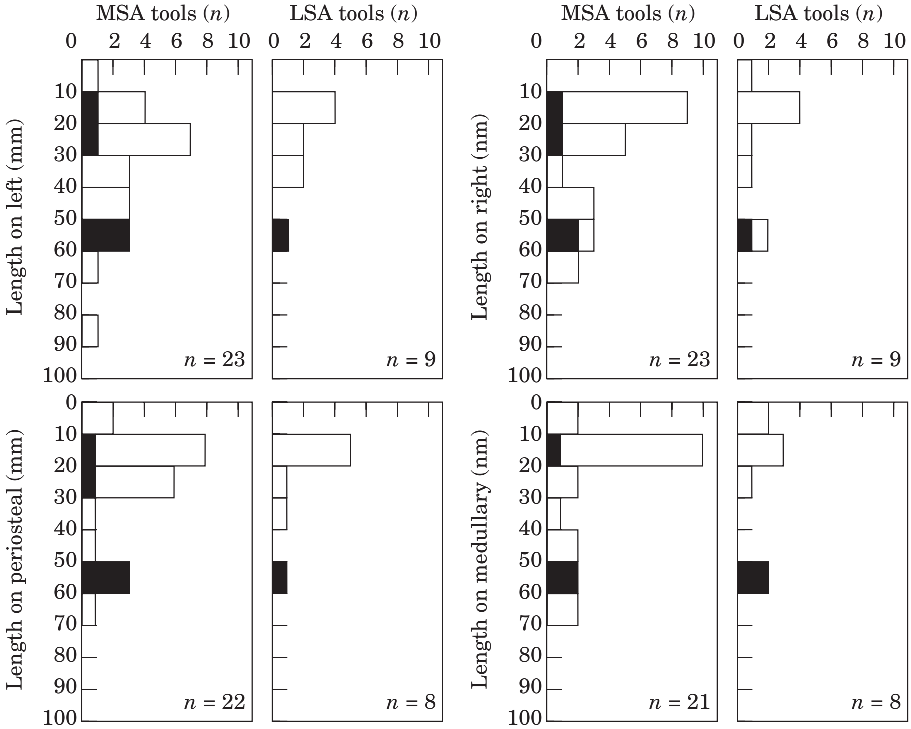


Figure 17. Length of shaped surfaces on each of four facets on LSA and MSA bone tools. White bars indicate the lengths of shaped areas that are not truncated by a break; black bars are lengths truncated by a break.

Table 6 Principal technological differences between MSA and LSA bone tools

MSA No. of shaped facets	SAM-AA No.
1	8944, 8945
2	8963
3	8941, 8946, 8949, 8952, 8959, 8966, 8967, 8968
4	8939, 8940, 8942, 8943, 8947, 8948, 8951, 8954, 8955, 8956, 8957, 8958, 8960, 8964, 8965
LSA No. of shaped facets	**SAM-AA No.**
3	8978, 8980
4	8974, 8976, 8977, 8979, 8981

(c)]. These lines were engraved after shaping and have no obvious functional purpose.

Cutting a series of lines near the butt prior to binding assists in preventing the point from slipping (Allain & Rigaud, 1986;

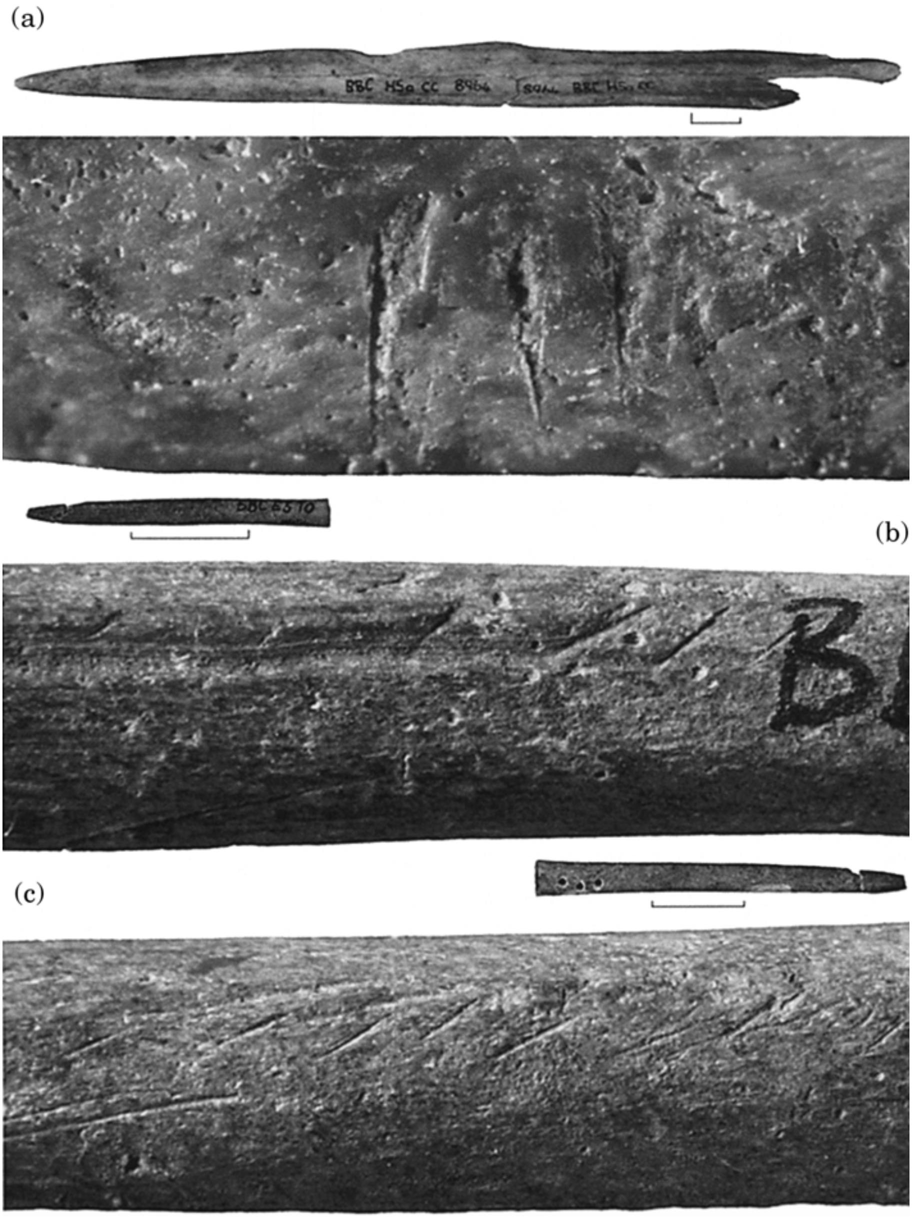


Figure 18. (a) Parallel marks made by a cutting edge on surface of tool near butt on 8964; (b), (c) sets of oblique marks on two aspects of tool 8954.

Weniger, 1992) but in the latter case the lines are at the midshaft position and are very shallow. They are unlikely to be decorative, as is the case for many UP tools (Julien, 1982; Corchon, 1986; Clottes, 1990), as they are barely visible to the naked eye. It is possible they were cut by the maker to facilitate tool grip or to identify ownership, as is common among Khoisan hunter-gatherers (Wiessner, 1983; Deacon

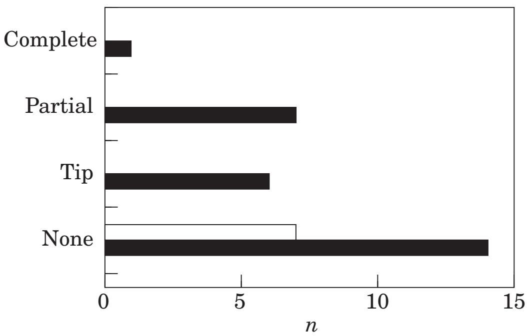


Figure 19. Incidence of burning on LSA (□) and MSA (■) bone tools.

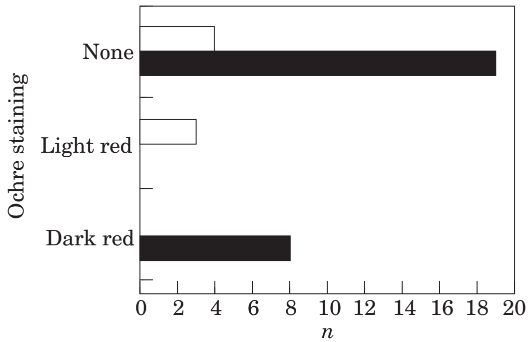


Figure 20. Incidence of ochre staining on LSA (□) and MSA (■) bone tools.

Table 7 Number of shaped facets for MSA and LSA bone tools

Category	MSA	LSA
1. Shaping	Scraping, flake removal, fine abrasion, polishing	Abrasion by grinding against fixed coarse surface
2. Other tool modifications	Oblique engraving, deliberate burning, ochre incorporation in polish	Notches with screw-like morphology, surface ochre deposited post-depositionally
3. Taphonomic differences	Tools medium to dark brown in colour, most with heavy patina	Tools light in colour with minimal or no patina

& Deacon, 1999). None of the LSA tools has these oblique engravings.

Fourteen of the MSA bone tools show evidence of burning (Figure 19): one is completely burnt, seven are partially burnt and six (8942, 8944, 8946, 8951, 8954 and 8960) are burnt at the tip, [e.g., Figure 14(c)]. Complete and partial burning may have occurred post-depositionally and was not intentional. However, tip burning was probably deliberate and done to harden the tip after it was shaped by scraping. None of the LSA tools show evidence of burning.

Some tools are ochre stained, either during manufacture and/or use or post-depositionally (Figure 20). Three of the LSA tools have traces of light red ochre powder and eight of the MSA tools are stained with a dark red ochre. In the case of the MSA tools the ochre is incorporated in the polish suggesting it was transferred to the tool during use, perhaps from the user's hand or an ochre stained hide. Experimental piercing of ochred hides by one of the authors (d'Errico *et al.*, 2000) demonstrates that the ochre pigment permanently stains the bone awls used in this activity. Light red ochre is visible only on the surface of the LSA tools, not in the polish, and may have been transferred post-depositionally and not during use.

Summary of key differences between MSA and LSA bone tools

First, MSA people chose blanks that were bigger and thicker, probably from larger animals (Table 7). Second, MSA people held the bone blank and, with a lithic flake held in the other hand, they scraped or whittled the bone to roughly the required shape. Finer shaping was achieved by repeatedly passing the tool through, or by rubbing with, fine-grained sediment. In some cases tools were further modified by deliberate burning, perhaps to harden the bone, and by the addition of oblique engraving, the purpose of which is unknown. MSA tools were polished probably both by shaping and through use-wear and often ochre was incorporated in the polish during these processes. Post-depositional taphonomic processes have resulted in MSA tools becoming coloured medium- to dark-brown and most are heavily patinated.

Bone tools from the LSA levels are shaped primarily by coarse abrasion. Bone blanks were hand-held and abraded across a fixed coarse surface, such as a quartzite or calcrete boulder. After a facet is shaped by grinding the piece is turned, another facet ground and so on until the required shape is achieved. There is scant evidence that the LSA tools were further shaped by fine finishing techniques, as evidenced on MSA tools, such as polishing or fine grinding or by use-wear and suggests the use life of an LSA tool at BBC was minimal. Specks of light red ochre, visible on the surface of some LSA tools, are probably the result of post-depositional adherence and not due to shaping or use. There is some evidence of use-wear and one tool was used in a screw-like motion, possibly when drilling into a coarse material, leaving a series of deeply etched notches. The light colour of LSA tools is similar to that of the fresh-looking LSA bone, suggesting minimal post-depositional staining or other taphonomic alteration.

Bone tool technology: Phase 3—application and use-wear

Possible functions for excavated bone tools can be derived by comparison with ethnographic examples, from tool morphology and comparative analysis of experimental and archaeological use-wear. LSA tools in southern Africa are well described (Deacon, 1984; Deacon & Deacon, 1999) and, apart from one, the BBC LSA tools fit the ‘‘awl’’ category; 8980 [Figure 15(a)] is probably a projectile point. It is a less easy task to allocate the MSA tools to a functional category as comparisons with LSA and ethnographically described tools may not hold into such deep time. All the MSA tools are pointed at one end indicating they were probably made for a piercing action (apart from 8950). Almost all (89%) of the MSA tools, with the exception of 8941, 8945, 8964 are broken at the butt end. Some of the MSA tools are morphologically robust (e.g., 8947, 8955, 8964, 8954) while others are delicate and even at the time of manufacture were fairly fragile [e.g., Figures 8(d), (e), (l) and 9(d), (g), (h)].

All the MSA tools show traces of extensive use. Original scraping marks are often smoothed by use-wear that produces a polish, particularly up to 10 mm from the point [Figure 14(e)]; tool points are mostly worn from use. Striations are also produced on tools from use, for example, elongated striae on the medullary facet and short, perpendicular bands near the point on 8940 [Figure 14(e)] are from use-wear. On many tools striated bands are visible near the tip due to rotation of the piece when in use.

Morphology and use-wear patterns suggest most MSA bone tools (85%) were used to perforate fairly soft material such as well-worked hides, possibly during the manufacture of clothing and/or carrying bags, and were probably used in an ‘‘awl-like’’ action.

Three MSA tools [8954, 8947 and 8964 (Figure 8(a), (k), (f)] are visually similar to bone projectile points from various archaeological (e.g., Nelson Bay—Inskeep, 1987; Byneskranskop—Schweitzer & Wilson, 1982) and ethnographic (Kalahari Masarwa San) collections housed at the South African Museum, Cape Town.

Ethnographic and LSA projectile points are symmetrical both at the tip and in overall shape. They are worked on the entire

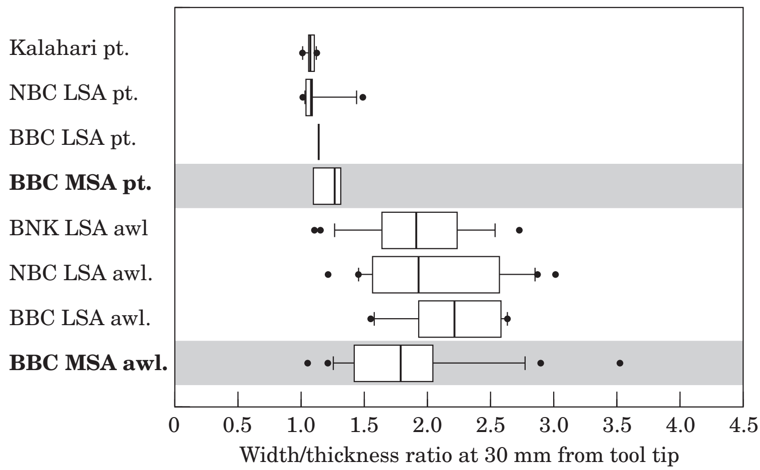


Figure 21. Width to thickness ratio at 30 mm from tool tip measured on points from ethnographic and archaeological contexts and awls from archaeological contexts.

surface, and tend strongly toward a circular cross-section. In contrast, awls are often asymmetrical in shape, may be incompletely worked, and mostly have an elliptical cross-section. BBC bone tools that we interpret as "awls" conform with their LSA counterparts (see Inskeep, 1987; Schweitzer & Wilson, 1982) (Figure 21). Most "awls" and projectile points are rounded at the extreme tip, often from use-wear, hence measurements of ellipticity or circularity to distinguish awls from projectile points need to be taken further up the shaft. To determine whether there was justification for describing these three MSA BBC tools as "projectile points" rather than awls, the width to thickness ratio was measured at 30 mm from the tool tip and the results compared with those from measurements taken at the same position on ethnographic and LSA projectile points, as well as LSA awls. The results (Figure 21) indicate that the three MSA tools (8954, 8947 and 8964) are most similar to the known LSA and ethnographic points suggesting they were probably manufactured for use as projectile points.

As a further test to try and determine the classification of an "awl" *vs.* a "point" all the MSA tools were rated according to five factors: (1) tip symmetry, (2) overall symmetry, (3) number of shaped facets, (4) width to thickness ratio at 30 mm and (5) the maximum width to thickness ratio. These factors, in our opinion, are appropriate measures of morphological differences between the two tool types. The rationale for selecting these variables is that to be ideally effective a fairly small (based on the probable overall length of the BBC tools) bone projectile point needs to be symmetrical along most of its length and rounded rather than flat for greater strength. Overall symmetry and sphericity is most likely to have been achieved by shaping all sides of a tool (measured as number of shaped faces or facets). Width to thickness ratio is a measure of sphericity or circularity, but as most tools are broken it was measured at the maximum diameter (for width and thickness) and at 30 mm from the point. Again, roundness of the tool near the tip alone is not an effective measure as most "awl-like" tools fit this description. "Overall symmetry" is by visual assessment—a projectile point needs to be fairly straight to maximise its aerodynamic properties and consequent force of penetration. All

Table 8 Ranking of MSA tools according to tip symmetry, overall symmetry, number of shaped faces, width to thickness ratio at 30 mm and maximum width to thickness ratios

SAM-AA No.	Tip symmetry	Overall symmetry	No. shaped faces	Width:thickness ratio at 30 mm	Max width:thickness ratio
*8954	1	1	4	1	1·4
*8947	1	1	4	1·3	1·1
*8964	1	1	4	1·3	2·5
8951	1	0	4	1·3	1·7
8944	1	0	1	1·4	2·8
8939	1	0	4	1·4	3·1
8945	1	0	1	1·5	4·1
8957	0	0	4	1·3	2·1
8967	0	0	3	1·4	2·8
8958	0	0	4	1·5	1·5

Tools marked * best fit our criteria for "projectile points".

tools were scored by this method and the ten tools that ranked highest are listed in Table 8.

The results from this test again show that the three artefacts most probably manufactured as points are 8954, 8947 and 8964 [Figure 8(a), (k), (f)] and the others are probably "awls". The most common failure to qualify as a projectile point was because of asymmetry. One of the bone "projectile" points 8954, shows evidence of hafting (Henshilwood & Sealy, 1997) and it is likely that the other points were also hafted. A fragment from the shaft of a highly polished tool, 8955 [Figure 8(j)], is very similar to 8947, and may have been part of a projectile point. An additional observation is that the three possible projectile points are shaped by polishing, while this is not the case for any of the tools interpreted as "awls". This may indicate a special technique was applied in the final stages of manufacture of projectile points. It is unlikely this final polish was applied as a practical shaping technique but rather it may have imbued the artefact with a symbolic value, particularly if it was associated with hunting (see Wiessner, 1983).

The most probable functions of LSA and MSA bone tools are listed in Table 9.

Table 9 Allocation of MSA and LSA tools to most probable function

MSA Possible tool function	SAM-AA No.
"Awl"	8939, 8940, 8941, 8942, 8943, 8944, 8945, 8946, 8948, 8949, 8951, 8952, 8953, 8956, 8957, 8958, 8959, 8960, 8963, 8965, 8966, 8967, 8968
"Point"	8947, 8954, 8964, (8955?)
LSA Possible tool function	**SAM-AA No.**
"Awl"	8974, 8976, 8977, 8978, 8979, 8981
"Point"	8980

Bone tool technology: Phase 4—resharpening and discard

MSA bone tools at BBC were extensively used after manufacture, in many cases re-used even after tip breakage, suggesting that tools were curated at the site. Eleven of the MSA tools have ancient tip breakage, five were re-used after the point broke, one was resharpened and five were not re-used. Thirteen tips are unbroken and of these

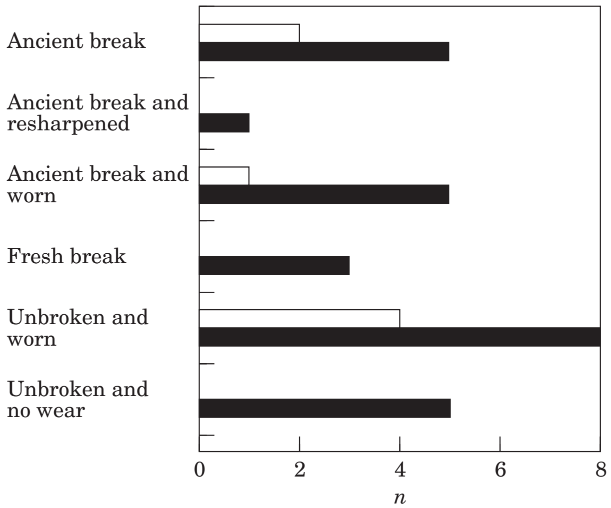


Figure 22. Incidence of point breakage and re-use after breakage for LSA (□) and MSA (■) bone tools.

eight are worn and five have no indication of use-wear. Fresh breaks on three MSA tools occurred during or post-excavation. One LSA tool was re-used after the point broke, two were not re-used after breakage; the four tools with unbroken tips show signs of use-wear (Figure 22).

Discard probably occurred when the tool broke nearer the midpoint, rather than the tip, making the tool too small to hold for further use. Projectile points were probably discarded when they broke in the haft. However, if used for hunting, breakage of the pointed ends is most likely to have occurred away from the cave; this may partially account for the few MSA bone points recovered. It is, of course, possible that some were returned to the cave within the carcass of the hunted animal, as has been shown to be the case for some Solutrean points at Combe Sauniére, France by Geneste & Plisson (1989). The broken portion of a hafted projectile point may have been removed and discarded in the cave before a new point was fitted to a shaft. If this was the case then the in progress identification of modified MSA bone should result in the recovery of butt ends from broken points.

Summary and discussion

The issue as to whether the BBC MSA bone tools could have derived from the LSA levels has been resolved. Based on their stratigraphic integrity, the distribution of key LSA/MSA finds, chemical testing of MSA tools, the stratigraphic distribution of the tools themselves, and on visible manufacturing and other differences when compared to the LSA tools, it is unambiguous that all the bone tools recovered from the MSA levels are correctly assigned to the Middle Stone Age.

The raw material for the LSA and MSA bone tools was probably acquired from animals brought to the site. Supporting evidence is that all the blanks come from taxa, size classes, body part and age classes present at the site (Henshilwood *et al.*, 2001) and almost all the tools were made on fresh bone. Clearly, some fauna was viewed not only as food by MSA people but also as a source of raw material for tool production. In the MSA and LSA most blanks were obtained by percussion of long bone and tools were then manufactured to the required shape. It seems unlikely that all the bone tools were brought to the cave from elsewhere, particularly as they could be manufactured quickly from easily available raw material, but also because some of them, such as the awls with very thin points, are relatively fragile and easily broken during transport.

The term "formal" is frequently used (e.g., Deacon, 1998*b*; Klein, 1989*a*,*b*; Klein, 1995; Milo, 1998) to distinguish the bone tools of modern and nonmodern humans. If the Blombos bone tools are to be labelled "formal" then the generally accepted archaeological understanding of the terms "informal" and "formal" as applied to bone tools needs to be defined. Informal bone tools are described by Johnson *et al.* (2000:468) as fracture based utilitarian tools with little or no modification of the fractured edge and where the fracture surface is the tool bit. The classification of a bone as an informal tool is dependent on the presence of use-wear as clearly not all fractured bones are tools. Johnson *et al.* (2000) describe formal tools as products of cultural manipulation subject to quite complex manufacturing processes. The cutting, carving, polishing or otherwise shaping of bone, ivory and antler into "pieces that were probably projectile points, awls, punches, needles and so forth" is Klein's (2000:520) definition of formal tools. The production of the BBC bone tools results from a sequence of deliberate technical choices starting with blank selection up to the final shaping of the finished artefact. MSA tools are shaped using at least one, or multiple techniques (Table 5). Although the methods of shaping are different, the planning and execution of bone tool manufacture in the MSA at BBC is consistent with that carried out by the LSA inhabitants. All the MSA bone tools were manufactured according to the processes defined as "formal manufacturing techniques" by Johnson *et al.* (2000) and Klein (2000). The bone tools recovered from the LSA and MSA levels at BBC can unequivocally be classified, using accepted archaeological nomenclature, as "formal" bone tools.

Systematic polish, striations, tip wear, probable breakage during use and re-sharpening of broken points show that MSA bone tools were extensively used and probably indicates specialised activities. Suggested uses for bone tools includes leather or hide working, processing of plant materials and for hafting as projectile points. Taken together, the above evidence argues strongly that bone tools were an integral part of the toolkit of MSA people in the upper two phases at BBC.

Despite the BBC, Katanda and other evidence for the presence of some bone tools in the MSA the questions remains—if, as contended in this paper, MSA people had the mental capacity and the raw material—as to why so few bone tools are found in the African MSA. One explanation is that MSA people infrequently chose to work bone. Chase & Dibble (1990) argue that local conditions, needs and environments will drive the technologies that appear in different areas and at different times (see also Deacon, 1989*a*,*b*, 1998). African hardwoods, well suited to the manufacture of tools such as awls and points, may have been a preferred raw material as wood is easier to work than bone (cf. Clark, 1989). Wood is seldom preserved in MSA sites so we have no knowledge of the likely extent of a wood based industry. One can also argue that MSA bone tools in Africa are rare as they may have served specific, time limited functions within small populations that were relatively isolated (see Yellen, 1998), a very different demographic picture to that of the UP in Europe. At Katanda the points were probably used for fishing (Yellen, 1998). Overall, bone tool use in Africa may have been the exception rather than the rule.

In addition, there are a number of practical factors that, at this stage, mitigate against the recovery of large numbers of MSA bone tools. There is a lack of well excavated sites in Africa for the period ca. 100–40 ka ago (for further comment see Clark, 1989, 1993; Klein, 1989*b*; Mellars, 1989*b*; Thackeray, 1992; Hublin, 1993; Larsson, 1996; Foley & Lahr, 1997; Vogelsang, 1996), because many were excavated using outdated techniques and before modern dating methods were available, rendering the evidence from many sites unreliable (e.g., Sampson, 1972; Volman, 1984; Vogelsang, 1996; Larsson, 1996). Demographic modelling indicates low population densities in parts of Africa, particularly in the south, at about 60–30 ka ago (Klein, 1989*b*) and consequently relatively fewer sites for this time period. Taphonomic factors in some cases mitigate against bone preservation at MSA sites, particularly those in a quartzitic environment. Bone is not preserved at a number of known sites in the Western Cape Province that contain, like BBC, large assemblages of Still Bay bifacial points, for example Hollow Rock Shelter (Evans, 1993), Dale Rose Parlour (Schirmer, 1975) and Paardeberg (Wurz, 2000). At Peers Cave, located on the Cape Peninsula, bone is poorly preserved in parts of the MSA and most recovered was discarded at the site (Yates, unpublished data).

The discard of all or some excavated bone and the use of large diameter sieves at MSA excavations in the Western Cape, particularly during the first half of the last century, but also later, is well-known. Several researchers have pointed out that long bone shaft fragments were discarded during the Singer and Wymer excavations at KR (Turner, 1989; Marean, 1998; Marean & Kim, 1998; Bartram & Marean, 1999). Since the vast majority of bone tools at BBC are made on long bone shafts, it is very likely that similar tools may have been missed or discarded during the KR excavations. Finally, dating the African MSA, a period mostly beyond the limits of radiocarbon is also particularly problematic (e.g., Deacon, 1989; Hublin, 1993; Ambrose, 1998).

Various explanations arguing for bone tool absence or presence in the MSA/MP is also a symptom of a lack of consensus on the evolutionary significance of bone tool technology. In fact, no analogue exists to establish why humans began to produce bone tools or what the incidence (or consequence) of bone tool manufacture and use was in prehistoric societies. Consequently we do not know whether bone tool technology represents one attribute of cultural modernity or that it results from punctuated cultural adaptations that have little evolutionary significance. This should be borne in mind when general explanations are proposed for bone tool use in antiquity. Current models on the role of bone technology in human evolution have their base in the association of formal or elaborate bone artefacts and the UP in Europe. This association provides a *post hoc* accommodative argument that is used to "establish" that bone technology is allied with cultural modernity, anatomically modern humans and a package of other eurocentrically derived modern cultural behaviours. What is observed in one region, in this case Europe, does not necessarily constitute a general paradigm however. Laminar technologies, long considered a clear sign of a qualitative shift in human cognitive evolution have now lost this role after the discovery of many scattered instances of Middle Palaeolithic blade industries across Eurasia (Bar-Yosef & Kuhn, 1999). This may now well be the case for bone technology. If this issue is to be correctly addressed then the answer must be sought in the empirical evidence.

Using evidence, such as the MSA bone tools from BBC, to argue for early "modern" or "nonmodern" type behaviour in Africa depends on how it is applied to the constructs of the various models. If presence or absence of some or all traits is a gauge for behaviour being modern, nonmodern or pre-modern (e.g., Klein, 1989*a*,*b*, 1995, 1999, 2000; Clark, 1989; Mellars, 1989*b*; Ambrose, 1998; for a fuller discussion see McBrearty & Brooks, 2000) then the BBC bone tool evidence removes "formal bone working" from this trait list. Bone tools are, however, only one element of a range of techniques used at BBC during the MSA to produce practical and/or symbolic artefacts indicative of a complex technological society. Other techniques used at BBC include: sophisticated working of lithic raw materials especially silcrete, quartzite and quartz to produce bifacial, lanceolate points, not unlike those of the UP Solutrean, and finely made circular- and end-lithic scrapers (Henshilwood & Sealy, 1997; Henshilwood *et al.*, 2001); extensive shaping of ochre, including the production of "pencil" and "crayon" forms, for application as a colourant (Henshilwood *et al.*, 2001); deliberate engraving on bone (Henshilwood & Sealy, 1997; d'Errico *et al.*, 2001); and the deliberate engraving of geometric designs on ochre (Henshilwood *et al.*, 2001; Henshilwood *et al.*, in prep.). Wide ranging and sophisticated subsistence strategies practised at BBC include catching large fish (Henshilwood & Sealy, 1997; Henshilwood *et al.*, 2001) and the procurement of a wide range of fauna, including shellfish (Henshilwood *et al.*, 2001), and further support the argument for advanced behaviour.

Material culture suggestive of symbolic behaviour is the only archaeological evidence of the use of modern syntactic language (Aiello, 1998). Some of the artefacts mentioned above (e.g., engraved ochre and bone) carry symbolic representations, others (e.g., utilised ochre) were probably used for symbolic purposes that are not directly evident. In either event these BBC artefacts reflect symbolic behaviour, the meaning of which was shared through the use of modern syntactic language. Bone tools from BBC may also reflect symbolic behaviour. The techniques used to manufacture objects in many societies are more often a reflection of their symbolic rather than utilitarian function. The careful deliberate polishing of the BBC MSA bone artefacts that we interpret as projectile points has no apparent functional reason and, rather, seems a technique used to give a distinctive appearance and/or an "added value" to this category of artefacts. In contemporary hunter-gatherer societies a consequence of the symbolic value of hunting weapons is that they are produced and handled solely by men (e.g., Lee, 1984). The differences in the manufacturing techniques between BBC MSA projectile points, probably used for hunting, and awls used domestically, may well reflect the different symbolic functions of these activities. These differences must have been linguistically transmitted.

In 1989, Clark suggested

> A resurgence of fieldwork—of survey and excavation—leading to increased input of information from the sites themselves could be the basis for more meaningfully specific rather than general modelling, and, in due course, could be the main source of information on social and economic patterning in the MP/MSA, and on the events and processes that brought about the appearance and rapid dispersal of modern humans (Clark, 1989:583).

Recent findings from the Howiesons Poort levels at KR (Deacon & Wurz, 1996; Wurz, 2000), the Katanda excavations (Brooks *et al.*, 1995; Yellen *et al.*, 1995; Yellen, 1996, 1998) and new insights into the Aterian and Lupemban traditions are important steps in the process of plotting the advance of modern human behaviour across Africa.

Clark's vision is still far from being met but the certain presence of a formal bone tool industry, advanced technologies including deliberate engraving and sophisticated subsistence strategies in the ca. 70 ka MSA levels at BBC add another dimension to efforts aimed at meaningfully and specifically modelling the origins of modern behaviour in Africa.

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References

Aiello, L. C. (1998). The foundation of human language. In (N. G. Jablonski & L. Aiello, Eds) *The Origin and Diversification of Language*, pp. 21–34. San Francisco: California Academy of Science.

Allain, J. & Rigaud, A. (1986). Décor et fonction. Quelques examples tirés du Magdalénien. *L'Anthropologie* **90,** 713–738.

Ambrose, S. H. (1998). Chronology of the Later Stone Age and food production in East Africa. *J. Archaeol. Sci.* **25,** 377–392.

Ambrose, S. H. & Lorenz, K. G. (1990). Social and ecological models for the Middle Stone Age in southern Africa. In (P. Mellars, Ed.) *The Emergence of Modern Humans*, pp. 3–33. New York: Cornell University Press.

Averbouh, A. (2000). Technologie de la matière osseuse travaillée et implications palethnologiques. PhD Dissertation, Universite' de Paris 1.

Backwell, L. R. & d'Errico, F. (2001). Termite gathering by Swartkrans early hominids. *Proc. Natn. Acad. Sci.* **98,** 1358–1363.

Bartram, L. E. & Marean, C. W. (1999). Explaining the "Klasies Pattern": Kua ethnoarchaeology, the Die Kelders Middle Stone Age archaeofauna, long bone fragmentation, and carnivore ravaging. *J. Archaeol. Sci.* **26,** 9–29.

Bar-Yosef, O. & Kuhn, S. L. (1999). The big deal about blades: laminar technologies and human evolution. *Am. Anthrop.* **101,** 322–338.

Beaumont, P. B., de Villiers, H. & Vogel, J. C. (1978). Modern man in sub-saharan African prior to 49 000 years BP: a review and evaluation with particular reference to Border Cave. *S. Afr. J. Sci.* **74,** 409–419.

Binford, L. (1984). *The Faunal Remains from Klasies River Mouth*. New York: Academic Press.

Blumenschine, R. J., Marean, C. W. & Capaldo, S. D. (1996). Blind tests on inter-analyst correspondence and accuracy in the identification of cut marks, percussion marks, and carnivore tooth marks on bone surfaces. *J. Archaeol. Sci.* **23,** 493–507.

Brain, C. K. (1981). *The Hunters or the Hunted? An introduction to African cave taphonomy*. Chicago: Chicago University Press.

Brain, C. K. & Shipman, P. (1993). The Swartkrans bone tools. In (C. K. Brain, Ed.) *Swartkrans. A Cave's Chronicle of Early Man*, pp. 195–215. Pretoria: Transvaal Museum Monograph 8.

Brooks, A. S., Helgren, D. M., Cramer, J. S., Franklin, A., Hornyak, W., Keating, J. M., Klein, R. G., Rink, W. J., Schwarcz, H., Leith Smith, J. N., Stewart, K., Todd, N. E., Verniers, J. & Yellen, J. E. (1995). Dating and context of three Middle Stone Age sites with bone points in the Upper Semliki Valley, Zaire. *Science* **268,** 548–553.

Camps-Fabrer, H. (1988). *Fiches Typologiques de l'Industrie Osseuse Préhistorique. Cahier I. Sagaies*. Aix-en-Provence: Université de Provence.

Camps-Fabrer, H. (Ed.) (1999). *Préhistoire d'Os*. Aix-en-Provence: Université de Provence.

Capaldo, S. D. & Blumenschine, R. J. (1994). A quantitative diagnosis of notches made by hammerstone percussion and carnivore gnawing on bovid long bones. *Am. Antiq.* **59,** 724–748.

Chase, P. G. & Dibble, H. L. (1990). On the emergence of modern humans. *Curr. Anthrop.* **31,** 58–59.

Christensen, M. (1999). *Technologie de l'Ivoire au Paléolithique Supérieur*. Oxford: BAR International Series 751.

Clark, J. D. (1959). Further excavations at Broken Hill, Northern Rhodesia. *J. R. Anthrop. Inst.* **89,** 201–231.

Clark, J. D. (1989). The origins and spread of modern humans: a broad perspective on the African evidence. In (P. Mellars & C. Stringer, Eds) *The Human*

Revolution, pp. 566–588. Edinburgh: Edinburgh University Press.

Clark, J. D. (1993). African and Asian perspectives on the origins of modern humans. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 132–147. Princeton: Princeton University Press.

Clark, J. D., Oakley, K. P., Wells, L. H. & McClelland, J. A. C. (1950). New studies on Rhodesian man. *J. R. Anthrop. Inst.* **77,** 7–32.

Clottes, J. (1990). *L'art des Objets au Paléolithique*. Paris: Ministère de la Culture.

Corchon, R. S. (1986). *El Arte Mueble Paleolitico Cantabrico: Contexto y Analisis Interna*. Madrid: Ministerio de Cultura.

Deacon, H. J. (1989). Late Pleistocene palaeoecology and archaeology in the southern Cape, South Africa. In (P. Mellars & C. Stringer, Eds) *The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans*, pp. 347–564. Edinburgh: Edinburgh University Press.

Deacon, H. J. (1993). Southern Africa and modern human origins. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 104–117. Princeton: Princeton University Press.

Deacon, H. J. (1998*a*). Elandsfontein and Klasies River Revisited. In (N. Ashton, F. Healy & P. Pettitt, Eds) *Stone Age Archaeology: Essays in honour of John Wymer*. Oxbow Monograph 102, Lithic Studies Society Occasional Paper 6, pp. 23–28.

Deacon, H. J. (1998*b*). Modern human emergence: an African archaeological perspective. *Dual Congress Proceedings, Colloquim 17, The archaeology of modern human origins*. Sun City, South Africa.

Deacon, H. J. & Wurz, S. (1996). Klasies River main site, cave 2: a Howiesons Poort occurrence. In (G. Pwiti & R. Soper, Eds) *Aspects of African Archaeology: Papers from the 10th Congress of the Pan African Association for Prehistory and Related Studies*, pp. 213–218. Harare: University of Zimbabwe Publications.

Deacon, H. J. & Deacon, J. (1999). *Human Beginnings in South Africa: Uncovering the Secrets of the Stone Age*. Cape Town: David Philip.

Deacon, J. (1984). Later Stone Age people and their descendants in southern Africa. In (R. G. Klein, Ed.) *Southern African Prehistory and Palaeoenvironments*, pp. 221–328. Rotterdam: A. A. Balkema.

d'Errico, F. (1993). La vie sociale de l'art mobilier paléolithique. Manipulation, transport, suspension des objets en os, bois de cervidés, ivoire. *Oxford J. Archaeol.* **12,** 145–174.

d'Errico, F. & Laroulandie, V. (2000). Bone technology at the Middle-Upper paleolithic transition. The case of the worked bones from Buran-Kaya III level C (Crimea, Ukraine). In (J. Orschiedt & G. C. Weiniger, Eds) *Neanderthals and Modern Humans: Discussing the Transition: Central and Eastern Europe from 50,000–30,000 B.P.*, pp. 227–239. Mettmann: Neanderthal Museum.

d'Errico, F., Giacobini, G. & Peuch, P.-F. (1982/1984). Varnish replicas. A new method for studying worked bone surfaces. *OSSA, Int. J. Skel. Res.* **9/10,** 29–51.

d'Errico, F., Zilhão, J., Julien, M., Baffier, D. & Pélegrin, J. (1998). Neanderthal acculturation in Western Europe? A critical review of the evidence and its interpretation. *Curr. Anthrop.* **39,** 1–44.

d'Errico, F., Baffier, D. & Julien, M. (2000). Technologie et fonction des poinçons en os des couches châtelperroniennes de la Grotte du Renne à Arcy-sur-Cure. *XXVeme Congrès de la Société Préhistorique Française, Approches fonctionnelles en Prehistoire*, Nanterre, 24–26 Novembre.

d'Errico, F., Henshilwood, C. S. & Nilssen, P. (2001). An engraved bone fragment from ca. 70 ka year old Middle Stone Age levels at Blombos Cave, South Africa: implications for the origin of symbolism and language. *Antiquity* **75,** 309–318.

Evans, U. (1993). Hollow Rock Shelter (Sevilla 48): lithic analysis, a small but significant contribution to future MSA studies. BA (Hons) thesis, University of Cape Town.

Feathers, J. K. & Migliorini, E. (2001). Luminescence dating at Katanda—a reassessment. *Quatern. Sci. Rev.* **20,** 961–966.

Foley, R. (1998). The context of human genetic evolution. *Genome Res.* **8,** 339–347.

Foley, R. & Lahr, M. M. (1997). Mode 3 technologies and the evolution of modern humans. *Cambridge Archaeol. J.* **7,** 3–36.

Geneste, J. M. & Plisson, H. (1989). Analyse technologique des pointes à cran solutréennes du Placard (Charente), du Fourneau di diable, du Pech de la Boissiere et de Combe Sauniere (Dordogne). *Paléo* **1,** 65–107.

Goodwin, A. J. H. & van Riet Lowe, C. (1929). The Stone Age cultures of South Africa. *Ann. S. Afr. Mus.* **27,** 95–145.

Grine, F. E., Klein, R. G. & Volman, T. P. (1991). Dating, archaeology and human fossils from the Middle Stone Age layers of Die Kelders Cave 1, South Africa. *J. hum. Evol.* **21,** 363–395.

Hahn, J. (1986). *Kraft und Aggression. Die Botschaft der Eiszietkunst im Aurignacien Süddeutchlands*. Tübingen: Verlag Archaeologica Venatoria, 7.

Hahn, J. (1988). *Die Geissenklösterle-Höhle im Achtal bei Blauberen I*. Stuttgart: Konrad Theiss Verlag.

Hahn, J. (1995). Les ivoires en Allemagne: débitage, façonnage et utilisation au Paléolithique supérieur. In (J. Hahn, M. Menu, Y. Taborin, Ph. Walter & F. Widemann, Eds) *Le Travail et l'Usage de l'Ivoire au Paléolithique Supérieur*, Actes Table Ronde de Ravello, pp. 115–135. Roma: Istituto Poligrafico dello Stato.

Hajraoui, M. A. (1994). L'industrie osseuse atérienne de la Grotte d'el Mnasra. *Préhist. Anthrop. Méd.* **3,** 91–94.

Henshilwood, C. S. (1995). Holocene archaeology of the coastal Garcia State Forest, Southern Cape, South Africa. Ph.D. Dissertation, University of Cambridge.

Henshilwood, C. S. (1996). A revised chronology for the arrival of pastoralism in southernmost Africa: new evidence of sheep at ca. 2000 b.p. from Blombos Cave, South Africa. *Antiquity* **70,** 945–949.

Henshilwood, C. S. & Sealy, J. C. (1997). Bone artefacts from the Middle Stone Age at Blombos Cave, southern Cape, South Africa. *Curr. Anthrop.* **38,** 890–895.

Henshilwood, C. S., Sealy, J., Yates, R., Cruz-Uribe, K., Goldberg, P., Grine, F. E., Klein, R. G., Poggenpoel, C., van Niekerk, K. & Watts, I. (2001). Blombos Cave, southern Cape, South Africa: Preliminary report on the 1992–1999 excavations of the Middle Stone Age levels. *J. Archaeol. Sci.* **28,** 421–448.

Henshilwood, C. S., d'Errico, F., Jacobs, Z., Mercier, N., Sealy, J., Tribolo, C., Valladas, H., Watts, I. & Yates, R. (n.d.). Geometric engravings on ochre from ca. 70 kyr Middle Stone Age levels at Blombos Cave, South Africa (in prep.).

Hublin, J. J. (1993). Recent human evolution in northwest Africa. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 118–131. Princeton: Princeton University Press.

Inskeep, R. R. (1987). *Nelson Bay Cave, Cape Province, South Africa: The Holocene levels*. International Series 357. Oxford: British Archaeological Reports.

Johnson, E. (1985). Current developments in bone technology. In (M. B. Schiffer, Ed.) *Advances in Archaeological Method and Theory*, pp. 157–235. New York: Academic Press.

Johnson, E., Politis, G. & Gutierrez, M. (2000). Early Holocene bone technology at the La Olla 1 site, Atlantic coast of the Argentine Pampas. *J. Archaeol. Sci.* **27,** 463–477.

Julien, M. (1982). *Les Harpons Magdaléniens*. Paris: CNRS.

Keyser, A., Menter, C. G., Moggi-Cecchi, J., Pickering, T. R. & Berger, L. R. (2000). Drimolen: A new hominid-bearing site in Gauteng, South Africa. *S. Afr. J. Sci.* **96,** 193–197.

Klein, R. G. (1989*a*). Biological and behavioural perspectives on modern human origins in southern Africa. In (P. Mellars & C. Stringer, Eds) *The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans*, pp. 529–546. Edinburgh: Edinburgh University Press.

Klein, R. G. (1989*b*). *The Human Career*. Chicago: Chicago University Press.

Klein, R. G. (1992). The archeology of modern human origins. *Evolut. Anthrop.* **1,** 5–14.

Klein, R. G. (1994*a*). Southern Africa before the Iron Age. In (R. S. Corrucini & R. L. Ciochon, Eds) *Integrative Paths to the Past: Paleoanthropological Advances in honour of F. Clark Howell*, pp. 471–519. Englewood Cliffs, NJ: Prentice-Hall.

Klein, R. G. (1994*b*). The problems of modern human origins. In (M. Nitecki & D. Nitecki, Eds) *Origins of Anatomically Modern Humans*, pp. 3–17. New York: Plenum Press.

Klein, R. G. (1995). Anatomy, behavior, and modern human origins. *J. World Prehist.* **9,** 167–198.

Klein, R. G. (1999). *The Human Career*. 2nd edn. Chicago: Chicago University Press.

Klein, R. G. (2000). Archaeology and the evolution of human behaviour. *Evol. Anthrop.* **9,** 17–36.

Klein, R. G. (2001). Southern Africa and modern human origins. *J. Anthrop. Res.* **57,** 1–16.

Knecht, H. (1993). Splits and wedges: the techniques and technology of Early Aurignacian antler working. In (H. Knecht, A. Pike-Tay & R. White, Eds) *Before Lascaux*, pp. 137–162. Boca Raton: CRC Press.

Kokis, J. E., Hare, P. E. & Brooks, A. S. (1998). Stratigraphic analysis of White Paintings Shelter, Botswana, using isolleucine epimerization in ratite eggshell. *Amino Acids* **15,** 280–281.

Larsson, L. (1996). The Middle Stone Age of Zimbabwe. Some aspects of former research and future aims. In (G. Pwiti & R. Soper, Eds) *Aspects of African Archaeology: Papers from the 10th Congress of the Pan African Association for Prehistory and Related Studies*, pp. 201–206. Harare: University of Zimbabwe Publications.

Lee, R. B. (1984). *The Dobe !Kung*. New York: Holt, Rinehart & Winston.

Lemonnier, P. (1986). The study of material culture today: towards an anthropology of technical systems. *J. Anthropol. Archaeol.* **5,** 147–186.

Marean, C. W. (1998). A critique of the evidence for scavenging by Neanderthals and early modern humans: new data from Kobeh Cave (Zagros Mountains, Iran) and Die Kelders Cave 1 Layer 10 (South Africa). *J. hum. Evol.* **35,** 111–136.

Marean, C. W. & Kim, S. Y. (1998). Mousterian faunal remains from Kobeh cave (Zagros Mountains, Iran): behavioral implications for Neanderthals and early modern humans. *Curr. Anthrop.* **39,** 79–114.

Marean, C. W., Abe, Y. A., Frey, C. J. & Randall, R. (2000). Zooarchaeological and taphonomic analysis of the Die Kelders Cave 1 Layers 10 and 11 Middle Stone Age larger mammal fauna. *J. hum. Evol.* **38,** 197–233.

Marks, A. E. (1968). The Mousterian industries of Nubia. In (F. Wendorf, Ed.) *The Prehistory of Nubia, Vol. 1*, pp. 194–314. Dallas: Southern Methodist University Press.

Mason, R. J. (1988). Cave of Hearths, Makapansgat, Transvaal. *Occasional Papers, Archaeological Research Unit, University of the Witswatersrand* **21,** 1–711.

McBrearty, S. & Brooks, L. (2000). The revolution that wasn't: a new interpretation of the origin of modern human behaviour. *J. hum. Evol.* **38,** 453–563.

Mellars, P. (1989*a*). Technological changes across the Middle–Upper Paleolithic Transition: Economic, Social and Cognitive Perspectives. In (P. Mellars & C. Stringer, Eds) *The Human Revolution*, pp. 338–365. Edinburgh: Edinburgh University Press.

Mellars, P. (1989*b*). Major issues in the emergence of modern humans. *Curr. Anthrop.* **30,** 349–385.

Mellars, P. (1991). Cognitive changes and the emergence of modern humans in Europe. *Cambridge Archaeol. J.* **1,** 63–76.

Mellars, P. (1993). Modern human origins in Europe. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 196–216. Princeton: Princeton University Press.

Mellars, P. (1996). Symbolism, language and the Neanderthal mind. In (P. Mellars & K. Gibson, Eds) *Modelling the Early Human Mind*, pp. 15–32. Cambridge: McDonald Institute for Archaeological Research.

Mellars, P. & Stringer, C. (1989). Introduction. In (P. Mellars & C. Stringer, Eds) *The Human Revolution*, pp. 1–14. Edinburgh: Edinburgh University Press.

Miller, G. H., Beaumont, P. B., Deacon, H. J., Brooks, A. S., Hare, P. E. & Jull, A. J. T. (1999). Earliest modern humans in southern Africa dated by isoleucine epimerization in ostrich eggshell. *Quatern. Sci. Rev.* **18,** 1537–1548.

Milo, R. G. (1998). Evidence for hominid predation at Klasies River Mouth, South Africa, and its implications for the behavior of early modern humans. *J. Anthrop. Sci.* **25,** 99–133.

Newcomer, M. (1974). Study and replication of bone tools from Ksar Aquil (Lebanon). *World Archaeol.* **6,** 138–153.

Oliva, M. (1995). L'usage de l'ivoire au Paléolithique en Tchéchoslovakie. In (J. Hahn, M. Menu, Y. Taborin, Ph. Walter & F. Widemann, Eds) *Le Travail et l'Usage de l'Ivoire au Paléolithique Supérieur*, pp. 189–198. Actes Table Ronde de Ravello 1992. Rome: Istituto Poligrafico dello Stato.

Opperman, H. (1996). Strathalan Cave B, north-eastern Cape Province, South Africa: evidence for human behaviour 29 000–26 000 years ago. *Quatern. Int.* **33,** 45–53.

Otte, M. (1995). L'ivoire paléolithique au Nord-Ouest européen. In (J. Hahn, M. Menu, Y. Taborin, Ph. Walter & F. Widemann, Eds) *Le Travail et l'Usage de l'Ivoire au Paléolithique Supérieur*, pp. 103–113. Actes Table Ronde de Ravello 1992. Rome: Istituto Poligrafico dello Stato.

Peers, B. (1929). Preliminary report on the archaeology of the Fish Hoek—Noord Hoek valley. Unpublished Manuscript, South African Museum.

Robbins, L. H. & Murphy, M. L. (1998). The early Late Stone Age and evidence of modern human behaviour. *J. hum. Evol.* **34,** 144–150.

Robbins, L. H., Murphy, M. L., Stewart, K. M., Campbell, A. C. & Brook, G. A. (1994). Barbed bone points, paleoenvironments and the antiquity of fish exploitation in the Kalahari Desert, Botswana. *J. Field Archaeol.* **21,** 257–264.

Sampson, G. C. (1972). *The Stone Age Industries of the Orange River Scheme and South Africa*. Memoir No. 6. Bloemfontein: National Museum.

Schirmer, G. R. (1975). An analysis of lithic material from Dale Rose Parlour, Trappies Kop, Kalk Bay, Cape Peninsula. Unpublished Archaeology Additional Report, University of Cape Town.

Schlanger, N. (1994). Mindful technology: unleashing the chaîne opératoire for an archeology of mind. In (C. Renfrew & E. B. Zubrow, Eds) *The Ancient Mind: Elements of cognitive archaeology*, pp. 143–151. Cambridge: Cambridge University Press.

Schweitzer, F. R. & Wilson, M. L. (1982). Byneskranskop 1, a late Quaternary living site in the southern Cape Province, South Africa. *Ann. S. Afr. Mus.* **88,** 1–203.

Singer, R. & Wymer, J. (1982). *The Middle Stone Age at Klasies River Mouth in South Africa*. Chicago: Chicago University Press.

Stoneking, M., Sherry, S. T., Redd, A. J. & Vigilant, L. (1993). New approaches to dating suggest a recent age for the human mtDNA ancestor. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 84–103. Princeton: Princeton University Press.

Stringer, C. B. (1993). Reconstructing recent human evolution. In (M. J. Aitken, C. B. Stringer & P. A. Mellars, Eds) *The Origins of Modern Humans and the Impact of Chronometric Dating*, pp. 179–195. Princeton: Princeton University Press.

Templeton, A. R. (1992). Human origins and analysis of mitochondrial DNA sequences. *Science* **255,** 737.

Thackeray, A. I. (1992). The Middle Stone Age south of the Limpopo River. *J. World Prehist.* **6,** 385–440.

Thackeray, A. I. (2000). Middle Stone Age artefacts from the 1993 and 1995 excavations of Die Kelders Cave 1, South Africa. *J. hum. Evol.* **38,** 147–168.

Turner, A. (1989). Sample selection, schlepp effects and scavenging: the implications of partial recovery for interpretations of the terrestrial mammal assemblage from Klasies River Mouth. *J. Archaeol. Sci.* **16,** 1–11.

Vigilant, L., Stoneking, M., Harpending, H. C., Hawkes, K. & Wilson, A. C. (1991). African populations and the evolution of human mitochondrial DNA. *Science* **253,** 1503–1507.

Villa, P. & d'Errico, F. (2001). Bone and ivory points in the Lower and Middle Paleolithic of Europe. *J. hum. Evol.* **41,** 69–112.

Villa, P. & Mahieu, E. (1991). Breakage patterns of human long bones. *J. hum. Evol.* **21,** 27–48.

Vogel, J. C. (2000). Radiometric dates for the Middle Stone Age in South Africa. In (P. V. T. Tobias, M. A. Raath, J. Moggi-Cecchi & G. A. Doyle, Eds) *Humanity—from African Naissance to coming Millennia*. Florence: University of Florence Press.

Vogel, J. C., Wintle, A. G. & Woodborne, S. M. (1999). Luminescence dating of coastal sands: overcoming changes in environmental dose rate. *J. Archaeol. Sci.* **26,** 729–734.

Vogelsang, R. (1996). The Middle Stone Age in south-western Namibia. In (G. Pwiti & R. Soper, Eds) *Aspects of African Archaeology: Papers from the 10th Congress of the Pan African Association for Prehistory and Related Studies*, pp. 207–211. Harare: University of Zimbabwe Publications.

Volman, T. P. (1981). The Middle Stone Age of the southern Cape. Unpublished Ph.D. Dissertation, University of Chicago.

Volman, T. P. (1984). Early prehistory of southern Africa. In (R. G. Klein, Ed.) *Southern African Prehistory and Palaeoenvironments*, pp. 169–220. Rotterdam: A. A. Balkema.

Wendorf, F. & Schild, R. (1974). *A Middle Stone Age Sequence From the Central Rift Valley, Ethiopia*. Warsaw: Institute of the History of Material Culture, Polish Academy of Sciences.

Weniger, G. C. (1992). Function and form: an ethnoarcheological analysis of barbed points from northern hunter-gatherers. In *Ethnoarchéologie: Justification, problèmes, limites. XII Rencontres internationales d'archéologie et d'histoire d'Antibes*, pp. 257–268. Juin-les-Pins: APDCA.

Wiessner, P. (1983). Style and social information in Kalahari San projectile points. *Am. Antiq.* **48,** 253–276.

Wolpoff, M. H. (1989). Multiregional evolution: the fossil alternative to Eden. In (P. Mellars & C. Stringer, Eds) *The Human Revolution*, pp. 62–108. Edinburgh: Edinburgh University Press.

Wolpoff, M. H. (1996). Interpretations of multiregional evolution. *Science* **274,** 704–706.

Wolpoff, M. H., Wu, X. Z. & Thorne, A. G. (1984). Modern Homo sapiens origins: a general theory of hominid evolution involving the fossil evidence from East Asia. In (F. H. Smith & F. Spencer, Eds) *The Origin of Modern Humans: A world survey of the fossil evidence*, pp. 411–483. New York: Alan R. Liss.

Wurz, S. (2000). The Middle Stone Age at Klasies River, South Africa. Ph.D. Dissertation, University of Stellenbosch.

Yellen, J. E. (1996). Behavioural and taphonomic patterning at Katanda 9: A Middle Stone Age site, Kivu Province, Zaire. *J. Archaeol. Sci.* **23,** 915–932.

Yellen, J. E. (1998). Barbed bone points: tradition and continuity in Saharan and sub-Saharan Africa. *Afr. Archaeol. Rev.* **15,** 173–198.

Yellen, J. E., Brooks, A. S., Cornelissen, E., Mehlman, M. J. & Stewart, K. (1995). A Middle Stone Age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Science* **268,** 553–556.

Zilhão, J. & d'Errico, F. (1999). The chronology and taphonomy of the earliest Aurignacian and its implications for the understanding of Neandertal extinction. *J. World Prehist.* **13,** 1–68.

Appendix A1

MSA season	SAM-AA No.	Tool type	Square	Dug as	Correlation	Phase	Body part	Source	Size class	Age	Bone type
1997	8939	"Awl"	F3	AB	CF&CG	BBC M2	Metatarsal	Bovid	I/II	Adult	c
1997	8940	"Awl"	F3	AC	CF&CG	BBC M2	Metapodial	Bovid ?	I ?	Juvenile?	c
1997	8941	"Awl"	E2	AC	CF&CG	BBC M2	Mandible	Bovid	III/IV	Adult	c
1997	8942	"Awl"	F2	AE	CF&CG	BBC M2	Shaft	Bovid	II	Juvenile	c
1997	8943	"Awl"	E3	AF	CG-CI	BBC M2/3	Rib	Bovid	III	Adult	cs
1997	8944	"Awl"	E3	AF	CG-CI	BBC M2/3	Not examined	Not examined	Not examined	Not examined	c
1997	8945	"Awl"	E3	AF	CG-CI	BBC M2/3	Radius?/tibia?	Bovid	II	Adult	cs
1997	8946	"Awl"	E3	AH	CG	BBC M2/3	Tibia?/fibula?	Marine mammal	n.a.	Unknown	cs
1997	8947	"Point"	E4	AI	CC-CF	BBC M1/2	Metapodial	Bovid	II/III	Adult	c
1997	8948	"Awl"	F3	BSBCOF	CD-CF	BBC M1/2	Ulna	Bovid	II	Adult	c
1997	8949	"Awl"	F3	BSBCOF	CD-CF	BBC M1/2	Tibia	Bovid	II	Juvenile	c
1997	8950	Percussor	F3	CAR	CD-CF	BBC M1/2	Metacarpal?	Bovid	IV	Adult	
1997	8951	"Awl"	E4	COCOA	CB-CF	BBC M1/2	Long bone shaft	Bovid	I/II	Adult	c
1997	8952	"Awl"	E4	HbAB	CF&CG	BBC M2	Mandible?/shaft?	Bovid	I/II	Juvenile	c
1997	8953	"Awl"	F3	SAN	CC-CD	BBC M1	Metatarsal	Bovid	I	Adult	c
1992	8954	"Point"	E3	TOB	CB-CD	BBC M1	Bacullum	Marine mammal?	n.a.	Unknown	cs
1998	8955	"Point?"	E5b	CA	CA	BBC M1	Metapodial	Bovid	III	Adult	c
1998	8956	"Awl"	E5b	CD	CD	BBC M1	Unknown	Bird	n.a.	Unknown	c
1998	8957	"Awl"	F4d	CFA	CFA	BBC M2	Long bone shaft	Bovid	II/III	Adult	cs
1998	8958	"Awl"	F5a	CFB	CFB	BBC M2	Tibia	Marine mammal?	n.a.	Unknown	c
1998	8959	"Awl"	F5b	CFB	CFB	BBC M2	Unknown	Bovid	Unknown	Juvenile	c
1999	8960	"Awl"	G6b	CAB	CC/CD	BBC M1	Mandible?	Bovid	II/III	Juvenile	cs
1999	8963	"Awl"	F6a	CF(H)	CFB	BBC M2	Mandible?	Bovid	II/III	Juvenile	cs
2000	8964	"Point"	H5a	NC	CC	BBC M1	Metatarsal	Bovid	II/III	Adult	c
2000	8965	"Awl"	Elc	CF	CF	BBC M2	Metapodial	Bovid	II	Juvenile	c
2000	8966	"Awl"	G6b	CFA	CD/CE	BBC M1	Scapula	Bovid	II/III	Juvenile	c
2000	8967	"Awl"	G4c	CFB/CFC	CFB/CFC	BBC M2	Humerus?	Bovid	II	Juvenile	c
2000	8968	"Awl"	G6a	CFB/CFC	CFB/CFC	BBC M2	Metapodial?	Bovid	II/III	Adult	c

Appendix A1 ***Continued***

LSA season	SAM no.	Tool type	Square	Dug as	Phase	Body part	Class	Size class	Age	Bone type
1992	8974	"Awl"	E4	MC3	BBC L4	Tibia	Bovid	I	Adult	cs
1992	8976	"Awl"	E4	GAL	BBC L2	Shaft	Bird/small mammal	Unknown	n.a./unknown	c
1992	8977	"Awl"	E4	COK	BBC L1	Shaft	Bovid	Unknown	Adult	c
1992	8978	"Awl"	E4	AAL	BBC L2	Rib/vertebra	Bovid	IV	Adult	c
1992	8979	"Awl"	E4	HIS	BBC L1	Radius	Bird	n.a.	Unknown	cs
1999	8980	"Point"	15	KAR 2	BBC L4	Shaft	Bovid	II	Adult	c
1998	8981	"Awl"	F3	MC4	BBC L5	Shaft	Bovid	II	Adult	c

c=compact; s=spongy.

Appendix A2

		Tool dimensions							
Season excavated	SAM-AA No.	Max width-mm	Thick compact bone-mm	Width 5 mm	Thick 5 mm	Width 10 mm	Thick 10 mm	Width 30 mm	Thick 30 mm
MSA									
1992	8954	6·4	4·6	3·6	2·7	4·4	3·8	4·9	4·7
1997	8939	10·6	3·4	3·3	2·6	3·6	2·9	5	3·5
1997	8940	5·6	2·4	2·2	1·5	2·9	1·6	5·5	2·4
1997	8941	21·1	8·7	5·6	3·2	8	4·1	15·2	8·2
1997	8942	14·1	4·1	5·2	3·3	7·7	3·9	12·7	4·4
1997	8943	5·5	2·5	2·8	1·7	3·9	2·1	—	—
1997	8945	19·9	4·86	3·5	3·5	4·4	4·2	8·2	5·5
1997	8946	7·7	4·7	3·1	2·7	5·1	3·2	6·7	4·2
1997	8947	7·6	6·7	3	2·5	4·1	3·6	6·8	5·4
1997	8948	8·8	4·6	3·6	2·3	5·4	2·1	8·1	4
1997	8949	7·9	3·2	2	1·6	3·3	1·9	6·3	3·1
1997	8951	6·8	3·9	3·5	2·5	5·5	3·6	5·3	4·2
1997	8952	6·8	2·3	2·5	2·2	3·9	2·5	5	2·8
1997	8953	9	3	2·8	1·9	4·1	2·6	7·2	3·6
1997	8950	—	—	—	—	—	—	—	—
1997	8944	10·7	3·8	2·4	2·4	3·8	3·2	5·2	3·7
1998	8955	8·1	6·7	—	—	—	—	—	—
1998	8956	5·2	2·1	2·7	1·5	3·7	1·8	5·2	1·9
1998	8957	9·9	4·7	2·5	2·1	3·8	2·7	8·3	6·4
1998	8958	9·5	6·2	—	—	—	—	8·8	5·8
1998	8959	10·7	5	4·4	—	5·6	—	10·7	5·3
1999	8960	11·1	4·1	2·7	2·5	4·6	3·2	10·6	5·3
1999	8963	12·9	4·7	2·9	2	4·4	2·5	8·7	3·6
2000	8964	12·5	5·1	3·2	2·5	4·8	3·2	7·7	5·8
2000	8965	10·9	3·1	1·5	1·3	2·2	1·8	5·1	3
2000	8966	24·8	1·1	2·6	2·3	3·8	2·4	8·8	2·5
2000	8967	13·4	4·8	2·4	2·9	3·7	3·8	6·1	4·5
2000	8968	7·1	—	3·8	1·6	5	2·8	4·8	5
LSA									
1992	8974	12·9	2·8	2·7	2·6	3·9	3	9·3	4·1
1992	8976	12·6	4·4	5·4	3·4	7·6	4·8	11·9	6·2
1992	8977	5·4	1·3	1·9	1·2	2·9	1·3	5	1·9
1992	8978	5·4	2·6	1	1	1·6	1·6	4	2·6
1992	8979	15·8	1·8	2·5	1·7	4·2	2·3	11·7	5·4
1998	8981	4·1	3·7	2·3	2·3	3·2	3·1	4·3	3·8
1999	8980	5	0·9	1·3	0·9	2	1·2	4·9	1·9

Appendix A2 ***Continued***

Season excavated	SAM-AA No.	Shaping: Left shaping	Left mm	Peri shaping	Peri mm	Right shaping	Right mm	Medu shaping	Medu mm	No. shaped faces
MSA										
1992	8954	p	34	p	42	p	42	p	47	4
1997	8939	p	31	p	26	p	12	p	26	4
1997	8940	p	15	p	11	p	11	p	15	4
1997	8941	p	42	p	15	p	67	n	—	3
1997	8942	p	14	p	20	p	14	p	19	4
1997	8943	c	21	c	21	c	21	p	12	4
1997	8945	n	—	n.a.	—	n	—	pa	—	1
1997	8946	n	—	p	7	p	37	pa	36	3
1997	8947	c	54	c	54	c	54	c	54	4
1997	8948	p	22	p	14	p	15	p	6	4
1997	8949	p	21	p	22	p	12	n	—	3
1997	8951	c	50	c	50	c	44	c	48	4
1997	8952	n	—	p	10	p	28	p	11	3
1997	8953	p	22	p	4	p	23	p	17	4
1997	8950		—		—		—		—	
1997	8944	p	5	n	—	n	—	n	—	1
1998	8955	c	18	c	18	c	18	c	18	4
1998	8956	c	53	c	53	c	53	c	53	4
1998	8957	p	30	p	24	p	13	p	20	4
1998	8958	p	40	p	15	p	20	p	12	4
1998	8959	p	22	n	—	p	13	p	14	3
1999	8960	p	19	p	14	p	14	p	11	4
1999	8963	p	—	n	—	p	—	n	—	2
2000	8964	pa/p	86	p	30	p	61	p	60	4
2000	8965	p	62	p	65	p	57	p	62	4
2000	8966	p	43	n	—	p	46	p	7	3
2000	8967	p	22	p	17	n	—	p	14	3
2000	8968	p	22	p	25	p	23	n.a.	—	3
LSA										
1992	8974	pa	17	pa	16	pa	16	pa	11	4
1992	8976	pa	11	pa	10	pa	13	pa	13	4
1992	8977	pa	27	pa	16	pa	22	pa	10	4
1992	8978	pa	33	n		pa	9	pa	57·9	3
1992	8979	pa	19	pa	12	pa	19	pa	9	4
1998	8981	ca	54	ca	53·5	ca	53·5	ca	53·5	4
1999	8980	pa/p	33	pa	28	pa/p	59	n	—	3

n=none; p=partial scraping; c=complete scraping; pa=partial abrasion; ca=complete abrasion.

Appendix A2 ***Continued***

Season excavated	SAM-AA No.	Other								
		Wear	Point breakage	Butt breakage	Cut-marks	Root etchings	Notches	Burnt	Ochre colour	Tip symm.
MSA										
1992	8954	1	a	a	n	n	n	t	dr	s
1997	8939	1	n	a	n	n	1	n	dr	s
1997	8940	1	aw	f	n	y	n	n	n	s
1997	8941	1	a	a	y	y	4	p	dr	cr
1997	8942	1	—	—	—	y	n	t	n	s
1997	8943	1	—	f	n	n	n	n	n	s
1997	8945	1	f	n	—	y	n	p	n	s
1997	8946	1	n	a	n	n	1	t	n	cl
1997	8947	1	—	a	n	n	n	n	dr	s
1997	8948	1	n	a	n	n	2	n	n	cl
1997	8949	1	aw	a	n	n	n	—	n	s
1997	8951	1	aw	a	n	n	1	t	n	s
1997	8952	1	n	a	n	n	n	p	dr	cr
1997	8953	1	n	a	n	n	n	n	n	s
1997	8950	—	—	—	—	—	—	—	n	—
1997	8944	1	aw	a	y	n	n	t	n	s
1998	8955	1	a	a	n	n	n	n	dr	s
1998	8956	1	—	a	n	y	n	n	n	s
1998	8957	1	n	a	n	n	n	n	n	cr
1998	8958	1	f	f	n	n	n	p	n	cl
1998	8959	—	a	a	n	n	n	c	n	cr
1999	8960	1	f	a	n	n	—	c +	n	cr
1999	8963	1	aw	f+a	n	n	n	n	n	cr
2000	8964	1	a	—	y	n	1	p	dr	s
2000	8965	1	aw	a	n	n	n	n	n	s
2000	8966	1	—	a	n	n	2	n	dr	cr
2000	8967	1	n	a	n	n	n	p	n	cr
2000	8968	1	n	a	y	n	1	p	n	cl
LSA										
1992	8974	1	n	n	y	n	n	n	lr	cr
1992	8976	1	n	f	n	n	n	n	lr	s
1992	8977	1	n	a	n	n	n	n	n	s
1992	8978	1	a	abrasion	y	n	n	n	n	s
1992	8979	1	n	a	n	n	n	n	lr	s
1998	8981	1	aw	a	n	n	n	n	n	s
1999	8980	1	a	f	n	n	n	n	n	cl

n=none; y=yes; f=fresh; a=ancient; aw=ancient worn; t=tip; p=partial; c=complete; dr=dark red; lr=light red; s=symmetrical; cl=canted left; cr=canted right.