Further evidence for bow hunting and its implications more than 60 000 years ago: results of a use-trace analysis of the bone point from Klasies River Main site, South Africa.

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Abstract

The bone point (SAM 42160) from >60 ka deposits at Klasies River Main Site, South Africa, is reassessed. We clarify the stratigraphic integrity of SAM 42160 and confirm its Middle Stone Age provenience. We find evidence that indicates the point was hafted and partially coated in an adhesive substance. Internal fractures are consistent with stresses occasioned by high-velocity, longitudinal impact. SAM 42160, like its roughly contemporaneous counterpart, farther north at Sibudu Cave, likely functioned as a hafted arrowhead. We highlight a growing body of evidence for bow hunting at this early period and explore what the implications of bow-and-arrow technology might reveal about the cognition of Middle Stone Age people who were able to conceive, construct and use it.

Keywords: arrowhead; bone point; bow hunting; traceology; cognition, palaeo-neurology; symbiotic technology
1. Introduction

Multiple lines of evidence have been mounting over the last decade to support bow hunting in South Africa before 60 ka. Use-wear, micro-residues, macro-fractures indicative of impact, and their distribution patterns have been cited as evidence that some stone tools were hafted and used as arrow tips or barbs at sites like Sibudu Cave and Umhlatuzana Rock Shelter in KwaZulu-Natal, South Africa (Fig. 1; e.g., Pargeter, 2007; Lombard and Pargeter, 2008; Wadley and Mohapi, 2008; Lombard and Phillipson, 2010; Lombard, 2011; de la Peña et al., 2018; but see Villa et al., 2012 for a counter argument), and experimental work continues to assess best-fit scenarios (e.g., Pargeter et al., 2016; Schoville et al., 2017; Pargeter et al., 2018). Bow hunting is further corroborated by the discovery of a bone point from a Howiesons Poort context at Sibudu Cave dating to 61.7±1.5 ka with macro- and micro-fractures that suggest it experienced longitudinal impact usually associated with such use (Backwell et al., 2008, 2018; Bradfield and Lombard, 2011). Similar bone artefacts are known from ethno-historical sources to have been used as arrowheads or link-shafts by southern African hunter-gatherers (e.g., Vinnicombe, 1971; Wiessner, 1983; Deacon, 1992; Bradfield, 2012), and are still used in this manner today (see Wadley et al., 2015).
At Sibudu Cave there is evidence of a local tradition of bone tool manufacture from at least 77 ka, where a variety of specialised tool forms have been recognised (d’Errico et al., 2012a). Bone points also occur during Middle Stone Age occupations at Bushman Rock Shelter (Plug, 1982), Peers Cave (d’Errico and Henshilwood, 2007), and Blombos Cave dating to between ~85 ka and ~73 ka (Henshilwood et al., 2001). In addition to these artefacts, bone points are directly associated with bow hunting 39 ka ago at Border Cave, South Africa (Beaumont, 1978), 36 ka ago at White Paintings Shelter, Botswana (Robbins et al., 2012), and 21 ka ago at Boomplaas Cave, South Africa (Deacon, 1984), most of which are thought to have been used as poisoned arrowheads (d’Errico et al., 2012; Robbins et al., 2012; Bradfield et al., 2015). By at least 15 ka bone tools were firmly embedded within culturally mediated technological strategies in parts of North Africa (Desmond et al., 2018), and were probably being used to hunt with the aid of poison by 13 ka in parts of East Africa (Langley et al., 2016a).
In 1968 John Wymer excavated the Howiesons Poort layers at Klasies River Main site (KRM) on the Tsitsikamma Coast in the Eastern Cape, South Africa (Fig. 1). Among the cultural artefacts recovered was a single bone point (SAM 42160), almost identical to the one later found at Sibudu; but at the time, a unique find. The KRM point came from a compressed layer in an undisturbed, laminated stratigraphic context, and was associated with many silcrete artefacts and distinctive trapezes, characteristic of the Howiesons Poort technocomplex (Singer and Wymer, 1982: 115-116; Wurz, 2013), for which most dated assemblages have ages of between ~66 ka and ~58 ka (see Lombard et al., 2012). Despite the presence of engraved bone artefacts from the same context at KRM, the remaining faunal assemblage reported by Singer and Wymer (1982) did not appear to have been deliberately fractured or otherwise modified for tool making. In most respects SAM 42160 resembles twentieth century ethno-historical arrowheads; a technology previously assumed not to predate the Later Stone Age, starting from ~40 ka in southern Africa.

Elsewhere, use-trace evidence suggests bone points were hafted as part of complex mechanisms at Matja Kuru 2, Timor Island, 35 ka ago (O'Connor et al., 2014), and bow hunting of arboreal fauna with bone-tipped arrows is also implicated at Niah Cave, Borneo, from Terminal Pleistocene deposits (e.g., Barton et al., 2009; Wedage et al., 2019). Currently the oldest purported bone arrow point from Eurasia dates to ~32 ka at Potočka Zijalka, Slovenia (Odar, 2011), while mechanically delivered projectile hunting in Europe has recently been pushed back to 40-45 ka (Sano et al., 2019).

A full technological description of the bone artefacts from some South African Middle Stone Age sites, including SAM 42160, was published by d’Errico and Henshilwood (2007). They suggested that the KRM point was made from a long bone shaft of a medium-sized bovid, and that it was fashioned by scraping with a sharp retouched lithic edge. The reduction in width near the current proximal end suggested to them that the piece was originally pointed at both ends, but that one of the tips snapped off after deposition. They highlighted the morphological and technological similarities of SAM 42160 to that of twentieth century San hunter-gatherer arrow components, implying that the KRM artefact was similarly used. But, based on its morphological traits, they questioned its association with the Middle Stone Age (d’Errico and Henshilwood, 2007: 154-155).
If the Howiesons Poort context for SAM 42160 is accepted, it represents one of the oldest known examples of bone tool technology worldwide. Such an age would link it intimately with discussions on the emergence of behavioural complexity (see Galway-Witham et al., 2019 for a recent synthesis). Through their association with bow hunting, bone points also have the potential to inform on the evolution of complex of cognition (see discussion below).

We therefore revisit the context of SAM 42160 within the site’s sequence and why it is associated with the Howiesons Poort occupational layers, and not the Later Stone Age. We present new use-trace and computed tomographic evidence, indicating that SAM 42160 was hafted and used in a manner consistent with a modular arrow component, thus corroborating the functional interpretation proposed by d’Errico and Henshilwood (2007). Based on these outcomes, we provide an up-to-date discussion about what this may mean in terms of human cognition at KRM during its Howiesons Poort occupation.

2. The bone point in the context of Klasies River Main site

Klasies River Main site consists of Caves 1, 1A, 1B and 2, which are cut into a Table Mountain sandstone cliff facing the Indian Ocean. The vegetation in the immediate vicinity of KRM consists of a complex mosaic of densely interdigitated thicket, forest and coastal vegetation (Van Wijk et al., 2017), forming part of the greater Cape Floristic Region’s Fynbos biome (Mucina and Rutherford, 2006). Precipitation at KRM generally occurs throughout the year (Chase and Meadows, 2007) and the warm Agulhas Current from the south-east results in a relatively mild climate and sea surface temperatures (Carr et al., 2007).

KRM was inhabited during the Middle Stone Age, from approximately 120 ka to 48 ka, with the four cave recesses forming a single depository. The overhang of Cave 1A, contains more than 15 metres of steeply sloped midden deposits that formed between 100 ka and 48 ka. The 1.8 metres of Howiesons Poort deposits occur high on the slope. These layers were first excavated by John Wymer in 1968, in the ‘Initial Cutting’ and thereafter in several transects within the Top Cutting (Singer and Wymer, 1982: figure 6.1, page 88). Singer and Wymer (1982) identified 11 layers (layers 10-21) within the Howiesons Poort strata in Cave 1A.
bone point was reported to have come from layer 19 (Singer and Wymer, 1982: 115). In the
1980s Hilary Deacon excavated the Howiesons Poort in squares E50, H51 and J51 to the
south east of Wymer’s excavation (Deacon and Geleijnse, 1988). Singer and Wymer’s layer
19 corresponds broadly to the layers between YS6 in square H51 and CPx1 in square J51
(Fig. 2; Villa et al., 2010; Deacon excavation notes). Initially, Deacon (1989) suggested an age
centred around 70 ka for the technocomplex at KRM. Subsequent dating of the middle
Howiesons Poort layers at Cave 1 provided age ranges between ~70 ka and 60 ka. For
example, Vogel (2001) obtained an age of 65.6±5.3 ka based on uranium series for Layer 14
(Fig. 2), and Jacobs and colleagues reported three OSL determinations of respectively
63.4±2.6, 65.5±2.3 from Cave 2 and 64.1±2.6 from Cave 1A (Jacobs et al., 2008). The age for
Cave 1A, from square E50 layer CP18, equivalent to Singer and Wymer’s layer 14 (Fig. 2, see
also Fig. S13, sample ZKR6, Jacobs et al. 2008), has recently been revised to 63.2 ± 2.7
(Jacobs and Roberts, 2017). These ages are consonant with the interpretation that the
Howiesons Poort of southern Africa is generally associated with the penultimate glacial
maximum, Marine Isotope Stage (MIS) 4 (Wurz, 2002; Lombard et al., 2012; Langejans et al.,
2017).

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Figure 2. Stratigraphic context of the relevant excavation profiles showing the location of SAM 42160 in SW layer 19 relative to the dated SW layer 14 of the Howiesons Poort at KRM. Note that the CP and other stratigraphic units in E50 and H51 are not continuous, which, apart from the natural slope of the sediment deposit, accounts for the repetition of stratigraphic unit names at different levels. The grey polygons seen in the inset represent the location of Singer & Wymer’s original excavation transects, with the approximate location of SAM 42160 indicated by a star.

Palaeoclimatic models suggest that this period in the southern Cape, where KRM is located, was likely cooler than the preceding MSA II phase (Thackeray, 1987; Simon et al., 2015; Langejans et al., 2017). Chase and colleagues argue that in the southern Cape MIS 4 was
probably a humid period due to westerly storm fronts and the effects of warmer Indian Ocean sea surface temperatures (Chase and Meadows, 2007; Chase, 2010; Carr et al., 2016). Micromammal indices also show an increase in moisture during the Howiesons Poort period at KRM (Avery, 1987). Given the links between glacial conditions and marine regression, shorelines were likely farther away from the site during the Howiesons Poort. However, the relative abundance of seal remains suggests that the shoreline may have fluctuated during this time (Van Pletzen-Vos et al., 2019). Jacobs and Roberts (2008) note that the Howiesons Poort included both a cooling and warming phase, which may account for the relatively close sea levels implied at times throughout this period. The dietary preference of some of the ungulate communities at KRM suggests that grassland habitats prevailed at certain times during the Howiesons Poort. The associated faunal assemblage is dominated by grazers such as equids (*Equus quagga*), wildebeest (*Connochaetes gnou*), and buffalo (*Syncerus caffer* and *S. antiquus*), particularly in the upper part of the Howiesons Poort (Klein, 1976; Van Pletzen-Vos et al., 2019). The earlier Howiesons Poort, where the bone point occurs, also includes *Raphicerus* and kudu (*Tragelaphus strepsiceros*) with eland (*Tragelaphus oryx*) present in the basal layers (SW layers 17-21), thus implying that the lower Howiesons Poort may have been bushier and more closed compared to the upper period. From layer 19, transect B2, which is below the dated Howiesons Poort layers mentioned above, Singer and Wymer (1982: 115, fig 8.1 no 5) found an “elegant, delicate ground bone point” from compressed, laminated layers, where “not the slightest sign of disturbance” was evident. They noted that the point was stained and in a similar condition to the other bone material from the Howiesons Poort context – i.e., different from the typical yellow, greasy bones found in several Later Stone Age middens (cf. Schweitzer and Wilson, 1978; Schweitzer, 1979). SAM 42160 is not the only worked bone artefact from the Howiesons Poort levels at the site. An incised bone artefact (SAM-AA 26733) from layer 20, Cave 1A, was found and its Middle Stone Age context is uncontested (Singer and Wymer, 1982; d’Errico and Henshilwood, 2007).
A taphonomic assessment of bone fragments from Layer YS6 in H51, to CPx1 in J51 generally shows a distinct colour difference between bone from the CP (Carbonized Parting) layers (CPx1 and CP8-12), and those from the YS (Yellow Sand) layers (YSx1, YS6 and YS7). Given its similarity to bone in the YS layers, we infer that the bone point most likely originates from a YS, rather than a CP layer. Most bone fragments in the CP layers exhibit sheen or a reflective surface usually linked to abrasion, polish or burning (Bromage, 1984; Nicholson, 1993). They are generally dark brown or black in colour and a significant proportion are grey or white. While manganese staining is evident on some fragments, the abundance of calcined bone suggests that most of the bones in these layers were burnt in hearths (Stiner et al., 2011). In contrast, bone in the YS layers are generally light brown or beige in colour and there is little evidence that these bones were modified by heat. While the edges of most YS bone fragments tend to be ‘rounded’ or smoothed, their surfaces are generally chalky and sheen is not common. This suggests that it is unlikely the polished surfaces of any worked bone in these layers was a result of natural abrasion.

Thus far, the preliminary results of the ongoing taphonomic analysis of the KRM faunal remains from the Howiesons Poort layers has identified several bone flakes with minimal use-wear, the characteristics and placement of which are dissimilar from natural abrasion and suggestive of ancient human handling (cf., Reynard, 2014; Reynard et al., 2016, in prep). Based on the above context, the notes by the excavators, the presence and condition of other worked bone in the Middle Stone Age of KRM and its Howiesons Poort layers, as well as the fact that the stone tool component of Cave 1 Layer 19 where the point was found is of bona fide Howiesons Poort character (Singer and Wymer 1982), we consider it to have been found in situ – similar to the Middle Stone Age bone points from Blombos Cave that were initially thought to be intrusive from the Later Stone Age (see discussion in Henshilwood et al., 2001). The undisturbed layer from which SAM 42160 was excavated is overlain by the dated layers, so that its age is at least older than 63.4±2.6 ka, the youngest estimate obtained for the Howiesons Poort at KRM by Jacobs and colleagues (2008).

3. New analysis of the SAM 42160 bone point

3.1 Methods
Reflected light microscopy and high-resolution computed tomography (CT) were used to analyse the bone point. We followed standard analytical protocols for each method (see Evora, 2015; Griffin et al., 2015; Backwell et al., 2018; Bradfield, 2015a, 2018a). Residues were analysed as far as possible in situ on the artefact surface and were not removed. The micro-wear and residue analysis were undertaken using an Olympus BX51M light microscope, mounted with a DP72 digital camera. The surface of the bone point was analysed at 10x to 500x magnification under fluorescent light using a combination of filters and polarising lenses. The interpretation of use-wear and residues was likewise based on the literature, comparative reference collections (e.g., Bradfield, 2014) and our own experience (e.g., Legrand and Sidéra, 2007; Lombard and Wadley, 2007; Langejans, 2011; Bradfield, 2015a, b; Antonites et al., 2016).

The high-resolution computed tomography was carried out on a Nikon Metrology XTH 225/320 LC dual source industrial CT system housed in the Microfocus X-ray Computed Tomography Facility in the Evolutionary Studies Institute at the University of the Witwatersrand. The bone point was scanned in eight overlapping acquisitions at 70kV and 120μA energy settings using 3142 projections and 6μm voxel size. All raw data were reconstructed in CT Pro 3D software and the multiple volumes stitched together and analysed on VG Studio Max 2.3 software. Interpretations of fatigue fractures and histology are based on existing literature, summarised elsewhere (see Bradfield 2015a, 2018a; Bradfield et al., 2016).

Initial non-destructive analyses were performed to provide a rough characterisation of the black residue, pending permission to conduct destructive sampling for Liquid Chromatography – Mass Spectrometry (LC-MS). Raman spectra were acquired with a WITec alpha300R Confocal Laser Raman Microscope using a 532 nm strength laser. XRF analysis was conducted with a handheld Vanta machine, with a fixed aluminium filter and silicon PIN detector. This device has a 2-watt X-ray tube with 35 kV tungsten anode excitation source.

3.2 Results
The SAM 42160 bone point is slenderer than other Middle Stone Age bone points from southern Africa, plotting closer to arrowheads from the Iron Age and historic periods than to bone points from older contexts (Fig. 3). As mentioned previously (d’Errico and Henshilwood, 2007), the bone point was fashioned by scraping with a lithic edge. There is no sign of abrasive grinding, which is a common finishing technique on Later Stone Age bone points, although its absence should not be taken as an indicator of age (Bradfield, 2014, 2015c).

Fig. 3. Scatter plot showing SAM 42160 relative to other similar MSA bone points and a random sample of bone points from Early Later Stone Age, Robberg, Iron Age and ethnological contexts. Sites not mentioned in the key from which bone points are represented include: Boomplaas shelter, Sehonghong, White Paintings Shelter, Nelson Bay Cave, Kwagandaganda, Mapungubwe and the Fourie and Pitt Rivers Museum collections of historical material.

A hard, black residue is spattered over the surface of the bone point, but concentrated in a band near the proximal end (Fig. 4). This substance has a circumferential distribution and adheres firmly to the surface of the bone. Surprisingly, neither d’Errico and Henshilwood (2007) nor Singer and Wymer (1982) remarked on the presence of this residue. Immediately
below the concentrated band of residue the bone appears slightly discoloured, a feature consistent with bone that has been covered for an extended period with a plant-based substance, such as when hafted (see Bradfield, 2015b, 2018b). Under high magnification the heterogenous consistency of this residue is clear, with many inclusions visible (Fig. 4E, H). No chemical characterisation of this residue is attempted here, but is planned for the future. Thus far, we have not been granted permission for such destructive analysis. The entire surface of the bone point is covered in contaminant residues, probably flecks of skin, which fluoresce brightly under ultraviolet light (Fig. 4A-B). These flecks are more abundant overlaying the black residue, perhaps indicating that the latter substance has greater static properties. This kind of contamination occurs easily when artefacts are handled without latex gloves (Bradfield, 2016a), as is the case in the long curatorial history of SAM 42160. Clumps of starch grains are also present immediately overlaying the hard, black residue over most of the point’s length (Fig. 4C). Based on the shape and size of starch grains at least two plant species are represented (see Torrence et al., 2004; Piperno, 2006). In some instances, it is unclear whether the starch forms part of the black substance, but in other instances it clearly overlays the black material.

Consistent with previous observations, very little use-wear is present on the bone point. Use-wear is, however, present overlaying the black residue in places where the latter is still well represented. Together with the heterogenous consistency of the residue, this indicates that the bone point was used after the black substance was applied. Two distinct polish and striation characteristics occur. Towards the proximal section the striations are long, deep and consistent with contact against a hard, woody material (Fig. 4G; St-Pierre, 2007; Van Gijn, 2007; Bradfield, 2015a). Towards the apical end the use-wear overlying the black substance becomes more rounded and polished, with shorter, finer striations consistent with contact against a soft, malleable material, like skin (Fig. 4F; Buc and Loponte, 2007; Buc, 2011; Bradfield, 2015a). That this use-wear is present only overlying the black residue and not directly on the bone surface indicates it did not arise from curatorial handling. Faint striations do occur on the bone itself, but these are confined to the darkened area at the base of the point (Fig. 4D). These circumferential striations run perpendicular to the axis of the bone point and are consistent with contact against a soft plant-like material (Becker,
Fig. 4. Use-wear and residue indicators identified on the KRM bone point (SAM 42160). A-B) contaminant flecks fluorescing under ultra-violet light; C) concentration of starch granules seen under cross-polarised light; D) concentration of faint perpendicular striations at base of piece; E) hard, black residue seen under normal light and blue penetrating light; F) minimal polish and wear confined to high point topography characteristic of the medial and apical sections of the bone point; G) use-wear overlying hard, black residue; H) showing heterogeneous consistency of hard, black residue.
The results of the high-resolution CT scan are presented in Fig. 5. Five two-dimensional thin sections taken along the length of the bone point are illustrated. Micro-cracks occur abundantly in the apical region and exhibit the typical tri-directional formation indicative of desiccation (Fig. 5A; Backwell et al., 2018). Internal separation of the bone lamellae is also evident, particularly in the apical half of the bone point and likewise indicates desiccation (Fig. 5A-C). A set of two, partially overlapping, unidirectional micro-cracks run from near the base of the piece to about three-quarters of the way up. These micro-cracks are consistent with stress-related damage occasioned by bending forces seen in bone arrowheads (Fig. 5B, C, E; Bradfield, 2013; Bradfield et al., 2016; Backwell et al., 2018). These micro-cracks appear to propagate from the lower extremity towards the tip, congruous with the placement of macro-fracture damage on hafted projectiles (Guthrie, 1983; Bradfield and Lombard, 2011). The extent and nature of the micro-cracks may be seen in the supplemental video file (Supplemental material).

The bone histology comprises a thin outer band of plexiform tissue (visible in Fig. 5B) with the rest of the bone matrix exhibiting a primary reticular formation. No secondary osteons are present. Although histological identification at this resolution is not conclusive, the tissue structure appears most similar to perissodactyla bone (Enlow, 1966; Francillon-Vieillot et al., 1990; Martiniaková et al., 2007). Perissodactyla bone was also used to make tools during the Howiesons Poort and older periods at Sibudu Cave in KwaZulu-Natal (Bradfield, 2018a).

The CT scans provide confirmatory data on the hard, black residue coating the bone point. Figure 5D shows that the residue has a higher density than the bone itself, similar to mineralised deposits. Unlike mineralisation, however, this substance clearly sits on the surface of the bone and has not infiltrated into the bone tissue (cf. Backwell et al., 2018: figure 6). This, together with the circumferential placement, the overlaying use-wear and heterogenous consistency of the residue, supports our interpretation that it was purposefully applied to the bone and did not accumulate incidentally after burial.
Fig. 5. High resolution computed tomographs showing two-dimensional cross-sections through the SAM 42160 at various stages. A) showing tri-directional desiccative microcracks; B-C) parallel and overlapping microcracks, also showing plexiform structure at the periosteal region and reticular canals in the medial and endosteal regions; D) high density substance adhering to the surface of the bone; E) parallel microcracks possibly occasioned by bending strain.
The Raman results clearly indicate the heterogenous nature of the residue, with peaks indicative of mineral and organic ingredients (Fig. 6). The haematite on the surface is of interest given the importance of ochre during the Middle Stone Age and the frequency with which people would have handled it (e.g., Henshilwood et al., 2011; Wadley 2012; Hodgkiss 2013). Whilst its presence here could result from ochre in the deposit or from transfer from the hands of one of the hunters, there is clear evidence for the use of ochre in adhesive recipes during the Howiesons Poort of South Africa, and it was applied to the surfaces of mastic objects to facilitate handling during Holocene (Lombard, 2007). In the spectra taken at 1nm depth there is evidence of a sugar ring and methylene (CH$_2$), pointing to the presence of organic molecules in the black substance. Peaks indicative of manganese oxide, however, dominate the same spectra. These Raman results suggest that the presence of manganese may be more complex than simple mineral accretion or absorption, as is the case with the Sibudu bone arrowhead (see Backwell et al., 2008).

These results highlight the complex nature of the black residue. Given the wide variety of ingredients, including rock minerals, known to have been used in hafting recipes and arrow poisons (Lombard 2007; Bradfield et al., 2015; Wadley et al., 2015; Chaboo et al., 2019), it is possible that manganese, or something containing manganese, was introduced into the residue by human action. Such an interpretation is corroborated by evidence of use subsequent to the application of the residue in the form of overlaying micro-striations. If the black residue was a post-depositional taphonomic phenomenon, one would not expect to see superimposed use-traces (see Lombard 2005 and Wadley & Lombard 2007 on distribution patterns of related use-traces on archaeological tools). Additional XRF results reveal manganese atoms in higher concentrations on the ‘clean’ bone surface, away from the black residue, than in the black residue itself. Manganese traces on the tool are thus not limited to the black residue only, indicating the mineral was probably introduced incidentally. The composition of the black residue itself can only be resolved with detailed LC-MS studies, which falls outside of the scope of this study, but will be conducted pending permission for destructive analysis.
Fig. 6. Raman spectra obtained of the black residue. The upper two spectra were obtained from the surface and the lower three were obtained at a 1nm depth. The slight florescence of the surface spectra is expected given the curatorial history of SAM 42160.
4. Discussion

4.1. Our results in context

The dimensional dissimilarity of SAM 42160 to other Middle Stone Age bone points lead d’Errico and Henshilwood (2007: 160) to suppose that the bone point may have infiltrated into the Howiesons Poort layers from younger sediments. However, as discussed above, Singer and Wymer (1982:115) carefully considered this hypothesis and rejected it, as the bone point was found in an undisturbed context. Moreover, no LSA deposits occur in Cave 1A, only within Cave 1, much lower down in the sequence. We find no reason to doubt the integrity of the original context. Although SAM 42160 is slightly thinner than bone points of comparable age, e.g., Sibudu Cave and Peers Cave, all of these Middle Stone Age pieces overlap dimensionally with Later Stone Age, Iron Age and twentieth century arrowheads, suggesting that the small size differences are not meaningful (Fig. 3).
Bone points are not always associated with bow hunting. Use-trace evidence from twelve southern African sites indicates that during the Holocene, bone points – morphologically identical to arrowheads – were used, usually hand-held, additionally for wood-working, basketry and hide processing (Bradfield, 2015b, 2016a). The use-wear evidence for these activities, though, is distinctive, and notably absent on both the Sibudu and KRM bone points. Unlike these domestic tasks, hunting does not typically impart diagnostic polishes or micro-striations to bone weapons that would allow one to directly infer function (cf. Stone, 2013; Bradfield, 2012, 2015a, b). In the case of the Klasies River bone point, longitudinal striations, however, overlay the softer black residue, which would be consistent with any longitudinal action – including arrow use.

Isolated techniques are inadequate to make robust interpretations for a hunting function (Lombard, 2005; Rots and Plisson, 2014; Rots et al., 2016), and confidently identifying arrows or components thereof in the Stone Age record, and distinguishing them from other forms of projectile technology, is difficult. At present, the best approach is to record full suites of use-traces, including hafting traces and stress fractures that form during high-velocity impact (Bradfield, 2016b; Iovita and Sano, 2016). For this reason, we used a combined approach that looked at use-wear, in situ micro-residues and internal stress cracks during our study of the KRM bone point.

Despite the weak development of use-wear over much of SAM 42160 the distribution and orientation of micro-striations suggest the proximal 9 mm of the artefact was hafted, probably in a reed shaft. The darker discolouration of this section, a common feature on ethno-historic arrowheads, lends credence to this interpretation (Fig. 8). Socketing a bone arrowhead into a reed or hollow wooden shaft was the preferred method of hafting employed by southern African hunters in historic times (Sparrman, 1977), but was also used in other parts of the world perhaps as early as 32 ka (Odar, 2011).

The black residue, which coats SAM 42160, appears concentrated in a circumferential band close to the proximal end of the bone and immediately above the discoloured section. This substance may have been used as a mastic to secure the bone in the reed shaft, or it may be a poison that was applied to the bone after it was hafted. It may, of course, have served both purposes (see Wadley et al., 2015). Micro-morphologically, this substance is similar to
poisons used on twentieth century arrows and poison applicators (Fig. 8A), and to adhesives found on quartz arrow tips or barbs from the Howiesons Poort at Sibudu Cave (Lombard, 2007; Lombard and Phillipson, 2010; Lombard, 2011), and for adhesives molecularly identified on Howiesons Poort artefacts from Diepkloof in the Western Cape (Charrié-Duhaut et al., 2013).

The results of our preliminary Raman and XRF analyses reveal that the black substance is of a heterogenous nature, containing mineral and organic compounds. Although rich in manganese, the presence of this element does not seem to be the result only of normal post-depositional mineral absorption. There is no infiltration into the bone as can be seen in the case of the Sibudu bone point (see Francillon-Vieillot et al., 1990; Backwell et al., 2018); there is evidence for organic molecules in the residue; and use-wear clearly overlies the residue. More detailed organic chemistry of the residue is required to identify all the ingredients. The current distribution pattern of the black residue on the artefact is consistent with poison applications on bone arrowheads during the last few centuries in southern Africa (Fig. 8b), and it is probable that the residue was initially applied to the entire exposed surface of SAM 42160 but has flacked off with time.

Fig. 8. Bone tools from Holocene contexts showing the same use-traces present on SAM 42160. A) black tar-like poison on a poison applicator (MM-40-69-2607) from the Fourie collection, Museum Africa; B) nineteenth century poisoned arrowhead (ET 6593) from the Kalahari showing typical distribution of poison over the point and the natural limit where the bone is inserted into the reed link-shaft; and C) proximal discolouration on hafted bone arrow component from Mapungubwe.
Two varieties of starch granules were recorded over the black residue. Poisons and mastics are known to have incorporated numerous ingredients, some of which are rich in polysaccharides (Bradfield et al., 2015; Wadley et al., 2015; Chaboo et al., 2019), which could account for the starch granules (also see Rots et al., 2017 for possible starch-rich poison on a Sibudu artefact older than 77ka), and may reflect the sugar ring observed during Raman spectroscopy of the residue. However, given that most of the contaminant residues also occur on or in the vicinity of the black substance, a parsimonious interpretation would be that the starch granules too are contaminants from the soil. The black substance appears to have static properties that attract and adhere other residues.

The high-resolution CT scans reveal internal stress fractures that result from bending forces as well as fractures resulting from desiccation. Although not conclusive evidence, the parallel, grouped micro-cracks in the proximal half on SAM 42160 are consistent with bending forces that occur during longitudinal impact (Cotterell and Kamminga, 1992; Bradfield and Lombard, 2011; Bradfield et al., 2016).

Arrows, of course, are not the only type of projectile weapon that would experience longitudinal impact. The impact velocity of a modern commercial javelin is comparable to the impact velocity of an arrow shot from a traditional San hunting bow (cf. Hitchcock and Bleed, 1997; Milks et al., 2019), and we ought to expect similar fatigue stresses and fractures in javelin tips as we do in arrowheads. To date there have been no published studies providing reliable use-trace criteria with which to distinguish hand thrown javelins from arrows. There is, however, circumstantial evidence why we discount the possibility that SAM 42160 was anything other than an arrowhead.

1. The distribution of hafting traces only 9 mm from the proximal end of the bone indicates that the bone was not hafted in a manner conducive to withstand repeated use as a javelin (see Cotterell & Kaminga 1992; Knecht 1997).

2. The morphological and traceological characteristics of SAM 42160 is similar to thousands of Holocene and ethno-historic examples of bone arrowheads found throughout southern Africa.
3. There is a total absence of ethno-historically recorded bone-tipped javelins used in southern Africa. When these weapons are at play they are either single-component sharpened wooden or metal-tipped implements.

These points caution against an inferential leap ascribing SAM 42160 to anything other than an arrowhead – unless clear evidence can be provided to the contrary.

Considered together, the morphology, use-wear, residue, and micro-fracture evidence, as well as the absence of evidence of possible alternative uses, support a scenario in which SAM 42160 was hafted, coated in an adhesive (and possibly poisonous) substance, and used as part of an impact weapon such as an arrowhead, in a similar manner as the Sibudu bone point is thought to have been used and as twentieth century bone points were used by local hunter-gatherers.

4.2. Bow hunting in the southern Cape before 60 000 years ago

Thus far, evidence for bow hunting technology preceding 60 ka has only been reported from the KwaZulu-Natal region of South Africa (Backwell et al., 2008; Lombard and Phillipson, 2010). During the Howiesons Poort occupation at both Sibudu Cave and KRM backed stone geometrics were found that were hafted in innovative arrangements and used as weapon components (Villa et al., 2010), most likely as arrow tips, arrowhead insets or barbs (Lombard, 2011; de la Peña et al., 2018). Similar techno-behaviour is hinted at by 71 ka at Pinnacle Point 5-6 along the southern coast of South Africa, based on the presence of Howiesons Poort-like artefacts (Brown et al., 2012; McBrearty, 2012). However, the Pinnacle Point interpretation is speculative as no functional studies were conducted. The oldest supported evidence for bow hunting in the broader Cape region of South Africa during the early Howiesons Poort is therefore the KRM bone point.

Bow hunting has several advantages over other hunting strategies. An arrow travels along a straighter trajectory than a javelin, which has a large parabolic arc, thus increasing the accuracy of the hunter (Cotterell & Kaminga, 1992; Knecht, 1997; Hughes, 1998). This is particularly advantageous in closed, thicketed vegetation. The environment during the early Howiesons Poort in the southern Cape was cooler and probably wetter than today. The area
around KRM was characterised by a mixed environment, with closed, bushy vegetation (Klein, 1976; Van-Pletzen-Vos et al., 2019), a situation similar to Sibudu Cave, 15 km from the east coast farther north (Clark, 2013, 2017). Bone-tipped arrowheads were used during the Late Pleistocene in southeast Asia to hunt arboreal fauna in densely thicketed vegetation (Rabet and Piper, 2012). Another advantage of bow hunting is that a hunter may carry many arrows in a quiver, thus allowing for a higher success rate and mitigating against potential misses. The possible addition of backed stone geometrics to bone arrowheads (cf. Clark, 1959; Lombard and Parsons, 2008), would have added stabilising weight to the arrow and increased its lethality (Ellis, 1997).

Our results do not, however, automatically imply the persistence of bow-and-arrow technology for more than 60 ka on the southern African landscape (see Kuhn, 2006; Lombard and Parsons, 2010; Parsons and Lombard 2011; Lombard, 2016), nor does it imply cultural continuity (see Mitchell, 2012; Pargeter et al., 2016). It does, however, suggest that bow hunting was practised not only in KwaZulu-Natal during the Howiesons Poort, but also along the southern shores of South Africa.

4.3. Inferences about human cognition at Klasies River Main Site during the Howiesons Poort based on evidence for bow hunting

The Howiesons Poort was a period in the Middle Stone Age of southern Africa which saw a florescence of innovations and the technological manifestation of enhanced cognition (Henshilwood and Dubreuil, 2011; McCall and Thomas, 2012; Wadley, 2015). From at least 100 ka people in southern Africa were also combining multiple ingredients to form coloured pastes, possibly for decoration or skin protection (Henshilwood et al., 2011; Rifkin et al., 2015); and by 70 ka they were making glues and other compound adhesives using multiple ingredients combined in a series of complicated steps (Wadley et al., 2009, 2015; Wadley, 2010b). These glues were then used, among other things, to haft small stone segments in varying arrangements, probably as insets for hunting weapons (Lombard, 2007, 2011; Lombard and Pargeter, 2008). For their part, the insets facilitated easier maintenance of weapons and allowed for greater flexibility in how a weapon could be used (see Bousman, 1993; Pargeter, 2007).
The presence of these technical elements in the southern African Middle Stone Age is seen to represent cognitive complexity that includes notions of abstract thought, analogical reasoning, multitasking and cognitive fluidity (see Wadley, 2015).

Bow hunting has been discussed as the adoption of symbiotic or complementary technical systems (e.g., Haidle & Lombard, 2012; Haidle, et al. 2015), which is a manifestation of human cognitive flexibility (Lombard, 2016, 2019). For example, it involves episodic foresight (e.g., Williams et al., 2014; Coolidge et al., 2016) and causal network reasoning, indicating minds that are able to apply abstract engineering concepts across different knowledge domains (e.g., Lombard & Gärdénfors 2017). An even more complex form of reasoning about a ‘force’ that operates for an extended period of time and over long distances (often out of sight of the hunter), is the use of poison (Gärdenfors & Lombard 2018; also see Wadley 2010a on the use of snares). Once wounded with a poisoned arrow an animal may be tracked for many hours or even days before finally killed and harvested (see Marshall-Thomas, 2006). Poison is not a physical force; rather it functions chemically, adding yet another domain-specific causal node set to that of bow hunting when it is used.

Direct evidence of poisoned arrows dates to 13 ka in East Africa (Langley et al., 2016b), but may be considerably older at 24 ka at Border Cave, South Africa (d’Errico et al., 2012b). Beyond that, the evidence is equivocal. Hunting poisons and complex hafting adhesives could only be made by individuals possessing a basic understanding of 1) the physical and pharmacological properties of each ingredient, 2) the appropriate methods of preparation that would enhance the desired properties and not denature the toxicity or adhesive properties, and 3) the exact sequence and quantities in which ingredients must be added to achieve a successful adhesive or poison recipe (Wadley et al., 2015). Similar to bow hunting, the application of compound adhesives or poisons to hunting weapons requires a level of foresight, anticipation, planning, analogical thought and multi-tasking (e.g., Bradfield et al., 2015; Wadley et al., 2015; Wooding et al., 2017; Chaboo et al., 2019) – which is similar to the ways in which we think today.

KRM is the sub-Saharan site with the most prolific assemblage of *H. sapiens* remains spanning the last 100 ka (see Dusseldorp et al., 2013; Grine et al., 2017). Its archaeological record also sparked the first discussions raising the probability that complex human
behaviour and cognition were represented in sub-Saharan Africa long before its appearance in Europe (e.g., Deacon, 1989, 1992, 1995, 2001; Wurz, 1999; Deacon and Wurz, 2005). Subsequently, the revolution in dating methods and the excavation of other long-sequence Middle Stone Age sites, such as Sibudu Cave and Blombos Cave, have demonstrated the development of complex cognition for humans well before the suggested 50-45 ka date (e.g., Klein 2019). These discussions are best summarized in papers, amongst others, by Henshilwood (2012), Lombard (2012), McCall and Thomas (2012), and Wadley (2015), and is further supported by the provenience and use-trace evidence of SAM 42160 presented here.

5. Conclusion

We have presented here use-trace evidence that supports the interpretation of a bone point from KRM as a hafted arrowhead. Furthermore, we hope to have dispelled any doubt as to the provenience of SAM 42160 and its attribution to the Howiesons Poort technocomplex. SAM 42160 is part of a growing number of bone and stone artefacts found in Middle Stone Age contexts that are being recognised as arrow armature components. Our findings indicate that SAM 42160 was certainly hafted, maybe poisoned, and used in a manner that is not technologically dissimilar to bone points from more recent contexts. This implies a symbiotic technology that recurred several times with minimal modification throughout the last ~70 ka in southern Africa (see Högberg & Lombard 2020 on socio-technical dynamics of introduction, acceptance and destabilisation). Symbiotic technologies, such as the bow and arrow, tell us something about human cognition and its development (Lombard and Haidle, 2012; Lombard, 2019). Thus far, evidence to support bow hunting before 60 ka period has come from only a few sites, mainly in KwaZulu-Natal. The bone point from KRM extends this geographical distribution farther south and shows that bow hunting was a widely adopted technological innovation in southern Africa during this period.

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