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Bone retouchers and end-scrapers side by side at Bushman Rock Shelter: Exploring a ca. 100,000-year-old technological imbrication in southern Africa

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ABSTRACT

A growing body of archaeological data points towards distinct cultural innovations during Marine Isotopic Stage (MIS) 5 in Africa. At Bushman Rock Shelter in South Africa, we described previously a large corpus of end-scrapers that constitute a technological novelty in the context of MIS 5 developments. Here, we describe 25 bones with impressions collected from the same deposits. Middle Stone Age layers at the site represent a succession of distinct technological phases, but the bones with impressions are strictly associated with one of them only, characterised by the presence of end-scrapers. Our refined optically stimulated luminescence and U-series chronology, presented here, dates securely this technological association to 103 ± 3 ka. Amongst the bones with impressions, there is a marked preference for the diaphyses of large ungulate long bones. Scraping marks linked to periosteum removal and evidence of fresh breakage indicate the use of bones while still fresh. Macro- and microscopic characteristics of the used areas confirm that the bones were used during percussive activities. The orientation of the bone surface modifications indicates repeated, similar technological gestures. We propose that these bones with impressions are bone retouchers that were fully integrated into the production of the end-scrapers and that they document a clear technological imbrication between the processing of animal resources and the manufacture and use of stone tools. We argue that the use of bones in lithic retouching or resharpening activities represents a critical step in the technological process that led to the exploitation of bone as a versatile raw material by hunter-gatherers.

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1. Integration of animal products within technical systems of African hunter-gatherers during Marine Isotopic Stage 5

Africa is home to a diverse and bountiful fauna with an evolutionary history which, from the Pliocene until today, cannot

be disentangled from that of our lineage. Throughout hominin evolution, our coexistence with animals in the same environments has shaped key aspects of our behaviour. Besides the obvious nutritional advantages of consuming bone marrow, meat, brain, or viscera, animals represent a wealth of products that can fulfill various functions as tools, accessories, and elements of personal ornamentation. In southern Africa, early hominins experimented as far back as the Early Pleistocene the use of bone fragments as

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digging tools to extract food such as insects and tubers (Backwell and d'Errico, 2001, 2009). With the development of our species in the region, the archaeological record reveals new ways of exploiting an array of animal products, from bones to ostrich eggs, feathers, skins, and tusks, for the production and hafting of new types of tools, flasks, and items of clothing (e.g., Vogelsang et al., 2010; d'Errico et al., 2012a; Texier et al., 2013; Val et al., 2016; Tomasso et al., 2020; Val et al., 2020). Ultimately, this leads to the incredible diversity in the use of animal products documented ethnographically in recent hunter-gatherers' technological, functional, and symbolical productions in southern Africa, in the form of beads, pendants, bone points, arrowheads and awls, leather pouches, and decorated tortoise shell and ostrich eggshell containers, to name but a few (e.g., Lee and DeVore, 1976; Marshall, 1976; Silberbauer, 1981; Wiessner, 1983; Backwell and d'Errico, 2021).

Notwithstanding possible issues of preservation inherent to the archaeological record, a turning point seems to take place during the Marine Isotopic Stage (MIS) 5—between 130 and 70,000 years—possibly at the continental scale. The archaeological record of MIS 5 stands out by the emergence of new behaviours typical of modern hunter-gatherer societies. It is associated with the development of regionally distinct technological traditions, which signal marked changes in the cultural evolution of humans. The dynamic research focus on this period yields strong evidence for its unique inventive and creative nature (e.g., Hallett et al., 2021; Porraz et al., 2021; Steele et al., 2019; Wadley, 2021; Mackay et al., 2022). In southern Africa, this period witnesses the experimentation by hunter-gatherers of innovative ways to exploit animal resources, in the hunting and gathering spheres, for domestic activities, in relationship to lithic productions, and as part of the symbolic realm (e.g., Texier et al., 2010, 2013; Wadley, 2010; Val et al., 2016, 2020; Rots et al., 2017; Val and Conard, 2025; Clark, 2019; Schmid et al., 2019; Niespolo et al., 2021; Porraz et al., 2021). We suggest that there is constant porosity between these different aspects and that while the most visible expression of such innovations is the production of personal ornaments and engravings, these are fully imbricated within a changing relationship with the animal world as a whole.

Bone, and in particular freshly fractured bone, with its specific mechanical properties that combine strength and elasticity (Lyman, 1994), constitutes a resource known to African hominins for more than 3 Myr. The extraction of marrow through direct percussion of bone is already documented in the African Late Pliocene record and likely predates the production of sharp-edged stone flakes to cut meat from animal carcasses (see Thompson et al., 2019 and references therein). Experimental data suggest that wood is as efficient as stone to break open long bones (e.g., Peretto et al., 1996; Vettese et al., 2023). Those percussive activities, whether involving wood or stone, represent a critical aspect of subsistence that likely formed part of the cultural repertoire of hominins, uninterruptedly from the Pliocene until the Holocene (e.g., Caruana, 2015). In southern Africa for instance, faunal assemblages accumulated by early *Homo sapiens* in rock shelters abound in animal bones fractured by humans to extract marrow (e.g., Thompson and Henshilwood, 2011; Reynard et al., 2016; Reynard, 2022). From the Late Pleistocene onwards, a new type of interaction emerges: bone (alongside other hard animal resources), now clearly identified as a raw material in itself, is modified using lithic implements to be manufactured into new types of tools, which enrich the paraphernalia of hunter-gatherers. The mental template involved when humans start shaping animal products, such as bones, into weapons that can then be used to kill

another animal has far-reaching implications regarding the evolution of our species' own perception of its place within the natural world (Otte, 2024).

In Africa, barbed and unbarbed bone harpoons retrieved from layers dated to at least 90 ka at Katanda on the Congo-Uganda border document early evidence for fishing (Yellen et al., 1995; and see Feathers and Migliorini, 2001 for a confirmation of the age of the specimens). In South Africa, bone points emerge in the archaeological record after 85 ka, perhaps indicating brief, local shifts in hunting practices (d'Errico and Henshilwood, 2007; d'Errico et al., 2012b; Backwell et al., 2018). Besides these isolated finds documenting innovative projectile technologies, at Sibhudu Cave, a large sample of modified bones and bone tools has been retrieved from excavations in the late MIS 5 and early MIS 4 deposits (ca. 80 to 60 ka). The size, diversity, and richness of this sample, unparalleled at any other site in southern Africa for that period, has incited the team working on the material to propose the existence and the persistence of a regional trend at Sibhudu Cave (d'Errico et al., 2012b, 2022). Bone tools from the pre-Still Bay, Still Bay, and Howiesons Poort layers include awls, notched pieces, smoothers, pins, *pièces esquillées*, pressure flakers, and bone wedges (Backwell et al., 2008; d'Errico et al., 2012b, 2022). This bone toolkit would have been used for a diverse set of processing, splitting, piercing, digging, or softening activities related to animal and plant materials, for instance debarking trees and digging in soft soil in the case of wedges (d'Errico et al., 2022).

If we consider the cultural material from Sibhudu Cave further, one category of bone tools is of special interest here: bone pressure flakers. These artefacts document a new form of interaction between organic and mineral elements within the technological systems of hunter-gatherers in the region: namely, the imbrication of bone as a raw material into the lithic *chaîne opératoire*. Three bone pressure flakers are documented by d'Errico et al. (2012b) from post-Howiesons Poort ($n = 1$) and Howiesons Poort ($n = 2$) layers; their shape and the microscopic use-wear traces observed on their tips are consistent with their use in shaping and/or retouching lithic implements carefully by pressure flaking. Within the framework of continued excavations in the deeper MIS 5 iLembian deposits at Sibhudu Cave, a multidisciplinary analysis of the manufacturing of serrated bifacial points identified a bone pressure flaker and several fragments of bone pressure flakers (therein referred to as 'bone compressors') (Rots et al., 2017). These worked bones were all collected from the stratigraphic unit (SU) Casper, which dates to >77 ka. The damage observed on these worked bones and their stratigraphic association with the serrated pieces indicate that they were likely used for pressure flaking during the manufacture of these lithic implements. In the same iLembian layers at Sibhudu Cave, one bone artefact was identified as a 'bone percussion tool' (Rots et al., 2017). This bone percussion tool is a small bone flake that preserves a fragment of quartzite flake still embedded inside one of the damaged areas, which confirms its use in the *chaîne opératoire* of the quartzite bifacial tools (Rots et al., 2017; Schmid, 2019).

In this context of integrating bone within the production of lithic tools during MIS 5 in southern Africa, it is interesting to note the rarity of bone retouchers, a type of artefact that is contrastingly well documented from a range of chronological and geographic contexts across Eurasia and the Levant from the Middle Pleistocene onwards. Retouchers include bone, tusk, and tooth blanks used to modify lithic implements, most commonly within the frame of percussive activities, in particular retouching or resharpening lithic artefacts (Patou-Mathis and Schwab, 2002). Retouchers are identified by the specific used areas produced by such percussive activities. These areas include, typically, a

localized concentration of pits and scores, whose orientation, anatomical position, as well as macro and microscopic characteristics differ from those produced by other bone-modifier agents such as carnivores (e.g., [Henri-Martin, 1907-1910](#); [Patou-Mathis and Schwab, 2002](#)). In Africa, despite the growing body of evidence for bone tool manufacture during the Middle Stone Age (MSA), as highlighted earlier (and see also [El Hajraoui, 1994](#); [El Hajraoui and Debénath, 2012](#); [Bouzouggar et al., 2018](#); [Hallett et al., 2021](#) for northern Africa; [Barham et al., 2002](#) for central Africa; and [Bradfield and Langley, 2026](#) for a comprehensive review at the continental scale), bone retouchers are extremely scarce. In fact, for the entire MSA and across the continent, their occurrence is documented at five sites only. In Morocco, at the Grotte des Pigeons in Taforalt, 20 retouchers retrieved from archaeological deposits dated from ~84.5 ka to 24 cal. BP are associated with Aterian and Late MSA technologies ([Turner et al., 2020, Fig. 1](#)). Still in Morocco, at the Grotte des Contrebandiers, a publication dedicated to the bone tool assemblage associated with the 120- to 90-ka-old MSA deposits mentions the presence of 13 bone retouchers, awaiting further analysis ([Hallett et al., 2021](#)).

Three bone retouchers have been described from the Aterian layers of El Harhoura 2 (Morocco) by [Campmas \(2012 and references therein\)](#). In southern Africa, besides the specimen from Sibhudu Cave mentioned earlier, there are two bone retouchers from MSA deposits at Blombos Cave dated from 78 to 72 ka and associated with the Still Bay technocomplex ([Henshilwood et al., 2001](#); [d'Errico and Henshilwood, 2007](#)).

In this paper, we present a sample of 25 bones with impressions from the MSA site of Bushman Rock Shelter, on the eastern fringe of the Highveld, in the southern African interior ([Fig. 1](#)). This represents a rare case of such modified bones known from an MSA context in Africa. The specimens we describe here were collected during renewed excavations at the site from deposits that have yielded abundant end-scrapers. Here, we describe the bones with impressions and propose a possible scenario whereby their presence at Bushman Rock Shelter is intimately intertwined with that of the end-scrapers. In an earlier publication ([Porráz et al., 2018](#)), we described these lithic end-scrapers in detail and we proposed an initial chronology for the archaeological deposits. Here, we update this chronology, based on new optically stimulated luminescence



Figure 1. A) Map of Africa showing the location of Bushman Rock Shelter (BRS) and Middle Stone Age sites across the continent where bone retouchers have been reported. B) Location of BRS in the Ohrigstad River Valley, on the edge of the Highveld (image: Google Earth, modified). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

(OSL) results, combined with U-series dating of biocarbonates from archaeological shells of the giant land snail *Lissachatina* sp.

2. Archaeological context

2.1. Bushman Rock Shelter, Ohrigstad River Valley

Bushman Rock Shelter, in the district of Ohrigstad, Limpopo province, sits on the northeastern edge of the South African plateau at an altitude of ca. 950 m above sea level. In South Africa, the African inland plateau is known as the Highveld, and Bushman Rock Shelter is situated on its eastern ledge, referred to as the 'Great Escarpment,' a prominent topographic feature in the region. Bushman Rock Shelter opens to the south and directly overlooks a wide valley that hosts the confluence between the intermittent Molapong River and the perennial Ohrigstad River. Less than 30 km eastward of the shelter as the crow flies, the Ohrigstad River joins the Blyde River (Fig. 1). There, the Blyde River cuts through the rocks of the Great Escarpment across a spectacular canyon, which constitutes the ecological boundary between the Highveld and the Lowveld. Bushman Rock Shelter is the remnant of a vast dolomitic cave, once entirely sealed. Today, the sheltered area represents a surface of about 900 m² (52 m wide by 23 m deep), while the roof reaches a height of 14 m (Plug, 1978).

The preservation of archaeological deposits inside the rock shelter was first brought to the attention of R.J. Mason and J.J. Malan from the University of the Witwatersrand, who encouraged A.W. Louw to conduct the first excavation. In 1965, A.W. Louw excavated a trench against the wall at the back of the rock shelter to a depth of 8 feet—ca. 2.5 m (Louw, 1969). The documentation and material related to this excavation are, however, lost. The description of the faunal material is the only one to have survived since the analysis conducted on this material by C.K. (Bob) Brain constitutes, together with the analysis of the fauna from Pomongwe Cave in Zimbabwe, a fundamental chapter of his pioneering monograph on African cave taphonomy (Brain, 1981; see also Brain, 1969).

From 1967 to 1976, another excavation took place in the form of a yearly field school, under the leadership of Professor J. (Hannes) Eloff from the University of Pretoria. Eloff's work at the site exposed almost 8 m of archaeological deposits and revealed an archaeological sequence characterised by a high stratigraphic resolution and excellent organic preservation; bedrock was not reached. Eloff's excavation confirmed the initial identification by Louw of three major phases of occupation of the site, consistent with the MSA, the Later Stone Age (LSA), and the Iron Age (Eloff, 1969; Louw, 1969). With the notable exception of I. Plug's work (Plug, 1978, 1981, 1982; Badenhorst and Plug, 2012), very little was published, and some key aspects, such as the chronology of the MSA occupations, remained unclear. Moreover, one critical portion of the archaeological material, namely the large MSA faunal assemblage, could not be relocated (Porráz et al., 2018).

In 2014, we initiated a new project at Bushman Rock Shelter, with the intention to clarify the chronocultural sequence and site formation processes, as well as to conduct renewed analyses of the cultural and organic material from both Eloff's and our own excavation (Porráz et al., 2015). An additional objective of this field project was to collect a new faunal sample for the MSA layers. The material presented here comes exclusively from our own, ongoing excavation of the MSA deposits at the site.

2.2. Stratigraphic context

The deposits preserved inside Bushman Rock Shelter are consistent with three distinct phases in the history of human

occupation at the site (Porráz et al., 2015). The oldest deposits, which represent 5 m of sediments, are associated with MSA industries and date back to the MIS 5 (Porráz et al., 2018; Martin et al., 2022). In this study, we focus on the upper part of the MSA deposits (blocks E to H; Fig. 2), for which we provide a revised chronology (see below).

At Bushman Rock Shelter, we have adopted a system developed initially at sites on the West Coast of South Africa that uses two-syllable names following the alphabetical order, starting with A—for the uppermost deposits. Based on archaeological content and sedimentary features, we have subdivided the complete sequence into distinct stratigraphic blocks, each corresponding to a letter (Porráz et al., 2015). Inside each stratigraphic block, we have defined SUs, the names of which start with the letter of the block and follow the alphabetical order (e.g., from SU 'Gabi' to SU 'Gotlib' for the block G). The roof spall horizon coincides with our stratigraphic block E, at the contact between the LSA and the MSA deposits. Since 2015, we have excavated at the site following constraints related to the geometry of the deposits and the need to secure some of the profiles and steps inherited from previous excavations. We excavated the LSA and the MSA deposits in parallel.

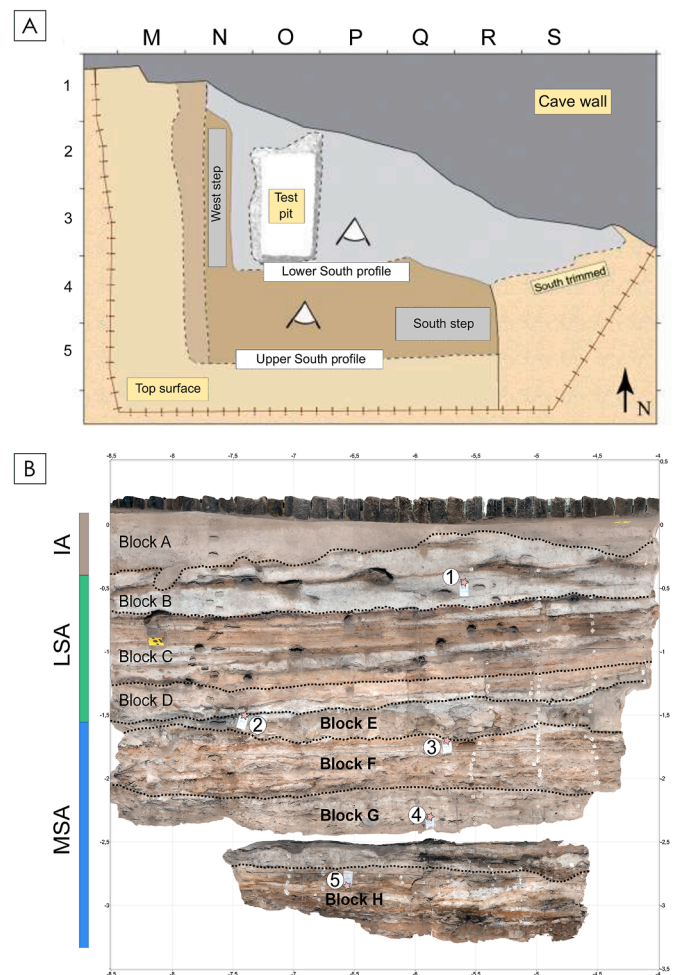


Figure 2. Bushman Rock Shelter. A) Different excavation areas and position of stratigraphic profiles (from Porráz et al., 2018). B) Photogrammetric model of the Upper South profile prior excavation in 2015 (model produced by Magnus Haaland), with the limits between stratigraphic blocks and the position of five samples for optically stimulated luminescence dating (BRS1 to BRS5). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

We have completed the excavation of blocks E, F, and G, and excavation of the block H is underway. Since the beginning of the project, we have focused primarily on the South profile. In 2015, however, we also excavated a somewhat unstable step along the eastern side of exposed deposits (referred to as the 'Eboulis'), as well as another one along the western profile (referred to as the 'West step'; Fig. 2). Stratigraphic units identified in both these steps could be correlated with those excavated on the South profile. They all belong to the stratigraphic block G. Thanks to his detailed field notes and the preservation of nails on the profile, we are able to correlate most of Eloff's archaeological layers with our SUs. The terminology of our chronocultural phases (e.g., 'Phase 28') follows the eponymous layers from Eloff's excavation (Porráz et al., 2018). Phase 28, which is of interest here, is consistent with our stratigraphic block G.

The lithic assemblages from Bushman Rock Shelter encompass a long archaeological sequence, which was recognized early on as a reference for the MSA regional expressions of the northeastern interior of South Africa (e.g., Mason, 1969; Sampson, 1974; Wadley, 2015). The MSA industry at the site remains unexplored, with the exception of the upper MSA occupations. The upper MSA of Bushman Rock Shelter is characterized by a selection of raw materials available locally, dominated by hornfels and quartz. We recognize three distinct technological phases, which are the phases 36, 28, and 21, consistent with our stratigraphic blocks H, G, and F, respectively. The oldest Phase 36 typifies the production of blades and flakes with a preference towards triangular morphologies (Douze et al., 2020); formal tools are rare. Phase 28 introduces a technological change from the phase 36 and shares technological similarities with the youngest phase 21. In Porráz et al. (2018), we grouped the phases 28 and 21 within the so-called Pietersburg technocomplex, but we subdivided it into a lower (phase 28) and an upper (phase 21) phase. Both phases 28 and 21 comprise the production of large blades and flakes, including a Levallois reduction strategy. The main difference between phase 28 and phase 21 is expressed within the formal tool assemblage. In particular, phase 28 is associated with the production of a technological novelty: end-scrapers. The systematic manufacture of end-scrapers, as it is documented at Bushman Rock Shelter, is thus far unique in the context of the southern Africa MSA. While the end-scrapers vary in shape and dimensions, several traits highlight some degree of homogeneity within their production and use (Porráz et al., 2018). There is a clear preference for blades and laminar flakes made from fine-grained materials, in particular fine-grained hornfels. Ninety-two percent of the sample of end-scrapers described in our 2018 publication ($n = 131$) are made on hornfels, while a few remaining specimens are made on fine quartzite. Most of the fronts show a regular convex shape, with an average length of 10.8 mm. The use-wear analysis documents similar scraping motions against different types of raw materials, including hard mineral and hard organic ones (e.g., stone, wood, and bone), as well as soft organic ones (e.g., dry hide) (Porráz et al., 2018). The presence of abundant lithic retouch and resharpening flakes demonstrates that end-scrapers were manufactured and resharpened on-site. In Porráz et al. (2018), we highlighted the intensive use, combined with routine resharpening and recycling of end-scrapers, as key factors to explain the high variability in both their dimensions and morphology. The regular occurrence of a lip on the butts of sharpening flakes implies that the force applied during percussion followed a tangential movement; this is indicative of the use of a soft hammer.

2.3. Preliminary chronology for the Middle Stone Age occupations at Bushman Rock Shelter

The MSA sediments and associated material from the blocks F and G at Bushman Rock Shelter have been dated using luminescence dating on sedimentary quartz and feldspar grains (OSL and infrared stimulated luminescence [IRSL]). In Porráz et al. (2018), we presented the results of the luminescence dating on two samples from the South profile, samples BRS3 and BRS4 from layers 21 and 28a of Eloff, respectively our SUs Fali/Falim and several SUs in the upper part of our block G (SUs Gandi to Gemma in the West step) (see Fig. 2 for the location of these samples on the South profile). Since our 2018 publication, we have reassessed the calibration of the beta source, which allows us to present revised ages here. These are complemented by new U-series (U/Th) ages on shells of the giant land snail *Lissachatina* sp. from the same deposits.

3. Materials and methods

3.1. Chronology

A revision of the calibration dose rate allows us to update the OSL and IRSL ages presented in Porráz et al. (2018). In order to translate the luminescence signal measured for an archaeological sample into a stored energy (equivalent dose, in Gy), this natural signal is compared to the one obtained after irradiation with a calibrated artificial beta source. The calibrated dose rate (i.e., the energy delivered per unit of time of irradiation, in Gy/s) is determined from the irradiated quartz powders provided with a certified known dose. Any error in this dose is reported directly on the calibrated dose rate, then on the equivalent dose, and ultimately on the proposed age. In 2019, we showed (Tribolo et al., 2019) that the calibration quartz provided by different laboratories led to, unexpectedly, up to 14% discrepancies between the measured beta source dose rates for the same irradiator. The situation was clarified recently since one of the calibration quartz providers identified the mistakes that had been made, leading to both underestimates and variability of the actual given dose (Autzen et al., 2022). We were then able to correct and refine the calibration of our own readers, as well as to re-evaluate the equivalent doses for the quartz and feldspar grains from Bushman Rock Shelter.

In addition to OSL and IRSL, two *Lissachatina* sp. shell fragments were analysed for U-series dating: BRS9A comes from SU Giro (MSA-phase 28), and the methodology and age have been presented in Martin et al. (2022). The same methodology was applied to BRS11, from SU Giro.

This technique, developed recently, is based entirely on the measurement of radioisotopes relevant to U-series dating (^{238}U , ^{235}U , ^{234}U , ^{232}Th , and ^{230}Th), mapped with a femtosecond ablation laser coupled with a high-resolution inductively coupled plasma mass spectrometer (FSLA-HR-ICPMS) [257 nm femtosecond laser: Lambda 3, Nexeya SA, Mérignac, France] (Supplementary Online Material [SOM]). The high spatial resolution (pixels of $30 \times 50 \mu\text{m}^2$) allows us to identify and discard areas that may have suffered from leaching and/or high detrital ^{232}Th incorporation. Several regions of interest, mainly based on $^{238}\text{U}/^{232}\text{Th}$ ratio, were defined, and isochrones based on $^{230}\text{Th}/^{232}\text{Th}$, $^{234}\text{U}/^{232}\text{Th}$, and $^{238}\text{U}/^{232}\text{Th}$ activity ratios were plotted, allowing us to take into account any remaining detrital Th incorporation (see SOM for more details).

3.2. Stratigraphic provenience of the bone retouchers

The comprehensive analysis of the faunal assemblage collected since the beginning of the excavation in 2015 is ongoing, and here

we present some general observations only. While bone preservation varies due to distinct modes of sediment accumulation, faunal remains are present throughout all stratigraphic blocks excavated. In blocks F and G, the fauna is abundant and generally well preserved, and most of the mammal remains that could be identified taxonomically are from layers in those blocks. In block H, the faunal material is less abundant and comprises a mix of fragile, small, and calcined bone fragments with unburnt compact elements (i.e., short bones and fragments of long bone diaphyses). The ongoing geoarchaeological appraisal of site formation processes should shed light on these differences in faunal preservation; field observations suggest the critical role played by combustion activities in the formation of the block H, including repeated discard of ashes and associated burnt material at the back of the shelter. The faunal spectrum in block G (number of analysed remains = 1882) is taxonomically diverse and includes mammals, reptiles, and gastropods. Ungulates dominate the assemblage, in particular medium to large bovids. Specific identification is impeded by the scarcity of dental specimens and the fragmentation of the material. Several complete carpals, tarsals, sesamoids, and phalanges (NISP = 25) are, however, assigned tentatively to the following bovid taxa: Klipspringer *Oreotragus oreotragus*, Nyala *Tragelaphus angasii*, Roan Antelope *Hippotragus equinus*, Greater Kudu *Tragelaphus strepsiceros*, Eland *Taurotragus oryx*, and African Buffalo *Syncerus africanus* (binomial name following [Dusseldorp and Reynard, 2022](#)). One lower deciduous tooth belongs to an equid *Equus* sp. and one lower molar belongs to the Warthog *Phacocoerus africanus*. Tortoises are abundant, overwhelmingly preserved in the form of carapace and plastron fragments. Most of them likely belong to the Leopard Tortoise *Stigmochelys pardalis*, although the presence of another species, possibly a hingeback tortoise (*Kinixys* sp.), is suspected. Bones of snakes, as well as small, medium, and large lizards *Varanus* sp. (including cut-marked ones) occur in the assemblage. Shell fragments of the Pinked-lipped Agate Snail cf. *Lissachatina immaculata* are abundant and often burnt. Most of the animal taxa identified were also present in the corresponding MSA deposits excavated by Eloff, as

previously identified by I. Plug ([Badenhorst and Plug, 2012](#)). In layers 22 to 30 of Eloff, she also identified the remains of alcelaphines, a family that we have not identified so far. There is only extremely limited evidence of worked bones from the MSA deposits at Bushman Rock Shelter. We did not identify any convincing worked specimen from our excavations. I. Plug mentions the presence of two possible bone tools, respectively from Eloff's level 25 (an oval bone fragment, with polish along the edge) and level 29ii (a bone scraper that 'mimics a stone side scraper'; [Badenhorst and Plug, 2012](#): 21). While we were not able to relocate this material, it is interesting to note that these two specimens were collected from the phase 28, the same phase associated with the bone retouchers.

During our analysis, we identified 25 bone fragments that show evidence of percussive activities and that we interpret as the remnants of bone retouchers. We did not identify any other technical modification (e.g., shaping, flaking, or polishing) on bone remains that could indicate the presence of a bone industry at the site. Although faunal remains are preserved in all SUs excavated, all but one of the bone retouchers come from deposits in phase 28 ([Fig. 3](#)). [Figures 3 and 4](#) illustrate the clear stratigraphic association between end-scrapers and the bone retouchers, all collected from the sediments of block G, with a single exception for specimen BRS-5586, a fragment collected from the uppermost unit of block H, SU Hannes. The sample of bone retouchers includes 22 specimens retrieved from the South profile, two from the West step, and one from the *Eboulis*. There is a particularly high concentration of bone retouchers ($n = 9$) within SU Gisel and associated features. Eighteen specimens were piece-plotted during the excavation; seven are small fragments that were identified during the analysis of the sieving refuse. One of them (specimen BRS-3060.10) refits with a plotted piece (specimen BRS-3183), and they are both from SU Gisel in two distinct but adjacent subsquares, N4b and N4a. These two specimens refit with another bone fragment from the same SU and were collected in a separate subsquare (M4b), which does not show surface modifications. One bone retoucher retrieved from the sorting fraction, specimen BRS-3556.7, refits

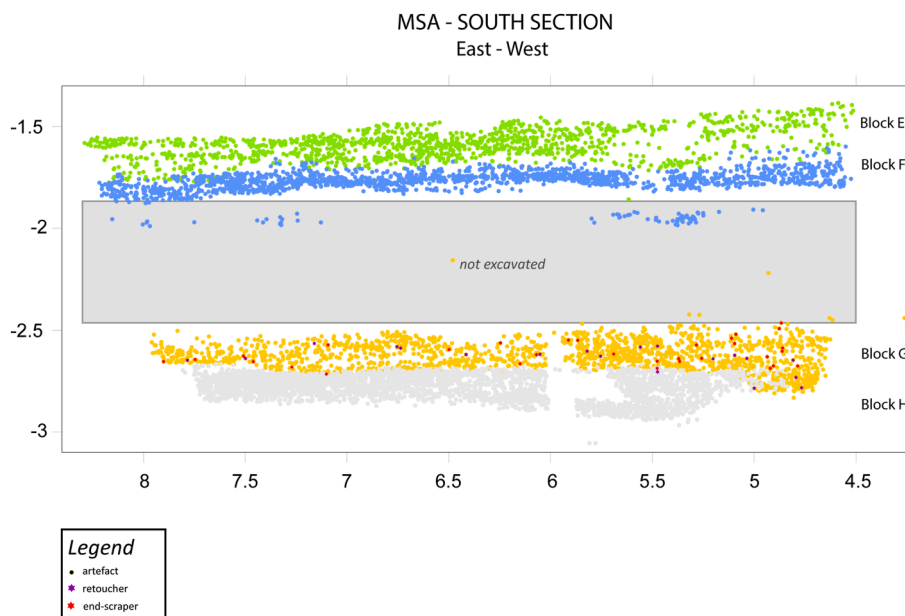


Figure 3. Vertical distribution of piece-plotted material across the MSA deposits (values in meters) excavated between 2016 and 2022 on the southern profile at Bushman Rock Shelter. Note the clear stratigraphic association between end-scrapers (red stars) and bone retouchers (purple stars), which were all exclusively collected from the block G. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

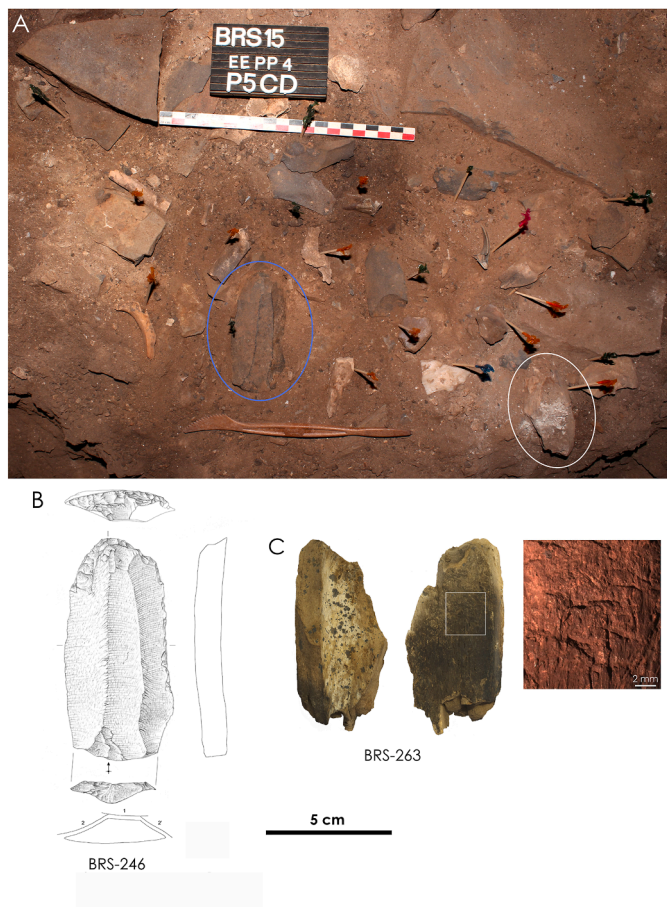


Figure 4. Field pictures illustrating one example of sedimentary association between end-scrapers and bone retouchers in the SUs of the phase 28, here from SU Eepp excavated in 2015. A) Picture taken during the excavation of SU Eepp in subsquares P5c and P5d. Note the proximity between the end-scraper BRS-246 (inside the blue circle) and the bone retoucher BRS-263 (inside the white circle, resting on the cortical surface). B) Drawing of the end-scraper BRS-246 by Michel Grenet. C) Bone specimen BRS-263, with a closer view on the area with modifications to the right. Note that the orientation of the bone specimen BRS-263 differs between A (distal part facing up) and C (distal part facing down). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

with a bone fragment from the same stratigraphic feature (Gisel lens within) and the same subsquare (M4c), which does not show surface modifications.

3.3. Analytical methods for the bone retouchers

In the field, the excavation proceeds by subsquare meters of 50 cm² and follows the natural stratigraphy of the deposits. We piece-plot systematically all objects equal to or larger than 2 cm. The sediments are sieved using 2-mm and 1-mm meshes. In the field and during the analysis of the fauna, several bone retouchers were recognised. This led to a thorough search throughout the entire collection. In this study, we therefore include the bones identified amongst the piece-plotted specimens, as well as those fragments identified during a careful examination, using a hand lens, of all the faunal material retrieved from the 2-mm sieving refuse. All MSA SUs ($n = 40$) excavated since the beginning of the project have been considered.

The taxonomic and anatomical attribution of the bone fragments was conducted using the extensive osteological collection

of modern southern Africa mammals housed at the Ditsong National Museum of Natural History in Pretoria, South Africa. For the bovid, equid, ungulate, and nonidentifiable mammal bones, we used the class sizes defined by Brain (1974) and adapted by Reynard et al. (2016). For the orientation of specimens, we follow the protocol recommended by Tartar (2009) and Mallye et al. (2012) for bone retouchers, where the position of the used area determines the apical part of the retoucher, regardless of the anatomy. We attempted initially to place the exact anatomical location of bone retouchers on templates of ungulate skeletons (e.g., Costamagno et al., 2018). This was, however, prevented by the degree of fragmentation of the specimens, which could not be located exactly on the skeletal portions besides general attribution (e.g., metacarpal anterior shaft fragment).

We performed a macro and microscopic observation of bone surface modifications, using the naked eye, a hand lens, a ZEISS Stemi 305 binocular microscope with magnifications up to $\times 40$, and an Olympus SZ61 Stereo Zoom microscope, with magnifications up to $45\times$ and mounted with a camera Olympus EP50, connected to software EPview. In order to evaluate how much of the cortical surface was visible—i.e., not obscured by manganese coating, intense root etching or concretions for instance—we used a scale system from 0 (cortical surface entirely obscured) to 5 (cortical surface entirely visible). When describing bone surface modifications, we paid particular attention to the presence of other anthropogenic damage (cut, scraping, and percussion marks). Trampling marks were recorded following criteria proposed by Domínguez-Rodrigo et al. (2009) and Reynard (2014). We described the degree of burning using the colour code established by Stiner et al. (1995). The proportion of spongy bone was recorded, using a 0- to 5-point system (0; 1 = 1–25%; 2 = 25–50%, 3 = 50–75%, 4 > 75%,

Table 1
Criteria observed during the macroscopic and microscopic analyses of the used areas on bone retouchers from Bushman Rock Shelter (after Tartar, 2009; Mallye et al., 2012; Costamagno et al., 2018).

Criteria	Characteristics
Position of the used area	• Apical extremity • Right lateral edge • Left lateral edge • Centred • Covering
Used surface	• Convex • Concave • Plane • Planoconvex
Distribution of the damage	• Isolated • Scattered • Concentrated • Concentrated and superimposed
Pits	Present/absent
Pit aspect	• Triangular • Ovoid
Scores	Present/absent
Score aspect	• Rectilinear • Sinuous
Orientation of the scores	• Longitudinal • Transversal • Oblique
Depth of the stigmata	• Superficial • Intermediary • Deep
Nature of the used surface	• Pitted • Scaled • Hatched
Small bone flakes, chipping	Present/absent
Scraping marks	Present/absent

5 = 100%). We also noted the presence or absence of marks produced by nonhuman predators and scavengers, including mammalian carnivores, porcupines, and invertebrates, based on criteria traditionally utilized in taphonomic studies and examples from the fossil record (including but not limited to Maguire et al., 1980; Brain, 1981; Blumenschine et al., 1995; Backwell et al., 2012; Fernández-Jalvo and Andrews, 2016). We recorded the weathering stage for long bone fragments following Behrensmeier (1978). To distinguish between fresh and dry breakage for the specimens that were long bone fragments, we followed the criteria proposed by Villa and Mahieu (1991) related to the fracture outline, angle, texture, and shaft circumference. We used these criteria to attribute a breakage pattern (fresh, dry, or recent) to the apical and basal edges of the bone retouchers.

Using a digital calliper, we recorded the length and width of the specimens, their maximum thickness, the width and length of the used areas, and the cortical thickness of the used areas. As done by Costamagno et al. (2018) for specimens with dry/recent fracture, the length was considered the minimum length and those specimens were not considered when commenting on the size of the bone implements. We followed the methodology developed by Tartar (2009) and Mallye et al. (2012), with several additions proposed by Costamagno et al. (2018), and generally adopted by others for similar studies (e.g., Doyon et al., 2018; Turner et al., 2020) to describe areas affected by percussive activities on the bones (Table 1). Assigning the position of the used area could only be done for the most complete specimens. The distribution of the damage (e.g., isolated or concentrated and superimposed) helps in quantifying the intensity of use for the bone implements. We recorded the presence/absence of small bone flakes and chipping, which are related to the state of freshness of the bone when used as a retoucher (Mallye et al., 2012; Mozota Holgueras, 2012; Costamagno et al., 2018). We recorded whether scraping marks were present; when present, we recorded whether they occurred on the top of or underneath the used area (Costamagno et al., 2018). Periosteum removal prior to the use of bones as retouchers is documented archaeologically (e.g., Leonardi, 1979; Armand and Delagnes, 1998; Brugal, 2001; Blasco et al., 2013; Soulier, 2013; Daujeard et al., 2014; Van Kolfschoten et al., 2015; Abrams, 2018; Banda et al., 2019). Two nonmutually exclusive intentions could explain why the periosteum is scraped off the bone surface. Removing the periosteum facilitates breaking bones to access the marrow, a practice that is documented, for instance, amongst the Nunamiuts (Binford, 1978) and several reindeer-herding groups in Siberia (Costamagno and David, 2009), as well as archaeologically and experimentally (e.g., Vincent, 1993; Daujeard, 2008; Stewart, 2010; Thiébaud et al., 2018–2019). Some authors have also suggested that removing the periosteum might increase the efficiency of bones as retouchers (e.g., Vincent, 1993; Auguste, 2002; Tartar, 2009). We have recorded the orientation of the scores compared to the axis of the bone, as done in Costamagno et al. (2018), because this may provide indication of the type of activity conducted (e.g., retouching a blade, a bladelet or a flake, or shaping the front of an end-scraper; Schwab, 2002; Tartar, 2012; Abrams, 2018). A comprehensive database including descriptions of bone surface modifications and characteristics of the used areas is available publicly online at <https://doi.org/10.5281/zenodo.15205599>.

4. Results

4.1. Updated chronology for phase 28 at Bushman Rock Shelter

The revised OSL and IRSL ages are presented in Table 2. Quartz ages are based on single-grain single aliquot regenerative dose

(SAR) protocol and the Average Dose Model; feldspar ages are based on multigrain PIR290 protocols (see Porraz et al., 2018 for details). Note that the ratios between the revised and previous age estimates are not all identical because the measurements were performed on various devices that were calibrated with different batches of calibration quartz.

The discrepancy between the quartz and feldspar age estimates for BRS3 is reduced significantly, and both ages are statistically consistent with each other. This is, however, not the case for BRS4, for which the discrepancy between quartz and feldspar ages (only consistent at three sigma) remains unexplained.

The U-series ages are presented in Table 3. The shell ages are consistent at one sigma with the feldspar age of BRS4 and allow us to estimate the age of block G (phase 28), where the end-scrapers and the bone retouchers come from, at 103 ± 3 ka (calculated as $\bar{A} = \Sigma(A_i/\sigma_i^2)/\Sigma(1/\sigma_i^2)$ and $\sigma_{\bar{A}} = 1/\sqrt{\Sigma(1/\sigma_i^2)}$). A summary of existing OSL and new U-series ages for the MSA deposits at Bushman Rock Shelter is illustrated in Figure 5.

4.2. The bone retouchers from phase 28: blank selection

There is a clear over-representation of large ungulate long bone diaphysis fragments in the selection of blanks used during percussive activities. Only two specimens were identified as fragmentary flat bones, while the remaining 23 are long bone fragments (Table 4). Such long bones include in particular large (class III) bovid metapodials ($n = 8$) and other long bones unidentifiable to elements ($n = 3$). These specimens might belong to any of the species of large ungulates (bovids class size III and equids) present in the MSA faunal assemblage at Bushman Rock Shelter, namely the Greater Kudu, a zebra, the Roan Antelope, or perhaps alcelaphines (wildebeest/hartebeest). Most other specimens that could not be identified taxonomically and/or anatomically fall into a general category of large mammal or large ungulate ('bovid/equid III' or 'ungulate III') long bone diaphysis fragments (Table 4). The only large mammals identified from the MSA deposits at Bushman Rock Shelter are ungulates, and it is reasonable to expect that those specimens classified as 'mammal III' are likely fragments of ungulate bones. Only one bone retoucher is a fragment of a very large ungulate bone, namely a bovid class IV, which could represent the Eland *T. oryx* or the African Buffalo *S. africanus*. The 23 specimens that are long bone fragments show no or limited spongy bone (21 specimens have no spongy bone at all, and two have a code of 1, which is less than 25%). This is consistent with the selection of diaphysis fragments located in the middle part of the shaft, away from the spongier epiphyses.

We described the breakage pattern (fresh vs. dry) of 23 apical and 22 basal edges. (Two specimens are fragments of flat bones, and we did not attempt to characterize their breakage patterns; for the basal edge of specimen Godot BRS2254.1, the characteristics of the breakage were inconclusive.) The occurrence of fresh breakage (24 edges out of 45) confirms the clear anthropogenic origin of the ungulate remains in the deposits, and the systematic and intentional breakage of long bones. Dry breakage is also common and underlines the role played by combustion and several post-depositional processes, particularly trampling and sediment compaction. Trampling marks are noted on 13 specimens, in the form of randomly orientated, sinuous, microscopic grooves.

Eight bone retouchers preserve apical and basal edges characteristic of having been fractured while still fresh; these specimens are therefore considered complete (Fig. 6). The remaining 17 pieces are broken fragments of presumably once larger retouchers (Figs. 7 and 8). The length of complete retouchers ranges from 30.9 to 117.3 mm; the average length is 67 mm, but it is worth noting that five of the complete retouchers are <50 mm long (Table 4).

Table 2

Revised and previous age estimates for samples BRS3 and BRS4.

Sample	Phase	Eloff layer	Stratigraphic unit	Mineral	Previous age estimate		Revised age estimate	
BRS3	MSA-phase 21	21	Fali	Quartz	73	6	90	7
				Feldspar	91	10	98	11
BRS4	MSA-phase 28	28a	Gemma	Quartz	75	7	80	7
				Feldspar	97	10	106	11

Uncertainties (including statistic and systematic errors) are given at one sigma. The age estimates for BRS4 in phase 28, which has yielded the end-scrapers and the bone retouchers, are highlighted in bold.

The dimensions of the complete bone retouchers and the fragmentary ones are consistent with the general fragmentation of the faunal assemblage. [Figure 9](#) compares first the length of bone retouchers to the lengths of unmodified ungulate bone fragments from SU Gisel and second the length of bone retouchers to the lengths of unmodified ungulate bone fragments from the other SUs in block G. In SU Gisel, the 165 ungulate remains identified range from 1.2 to 74.3 mm in length, but 163 of them (>98%) are shorter than 45 mm.

With a few exceptions, the cortical thickness of the used areas is similar to the maximum thickness of the specimens ([Fig. 10](#)). This suggests that the thickest portions of bones were often selected as active parts. The cortical thickness of used areas of the bone retouchers ranges from 4.9 mm to 12.8 mm, and only to 10 mm when removing the specimen attributed to a very large ungulate. The average cortical thickness of used areas is 7 mm; when excluding the very large ungulate this average is 6.7 mm, with a median of 6.6 mm, which indicates a high degree of homogeneity in the blank selection.

Burning is visible on more than half of the specimens ([Table 5](#)); nine of them have been exposed to temperatures >600 °C and have reached the grey and/or white colours of complete calcination, and two of them are fully carbonized. The cortical surfaces of the calcined specimens are friable and crumbly, which complicates the description of several characteristics of the used areas (e.g., shape of the pits and scores). Seven specimens show a dark-brown colour that is distinct from the black colour associated with carbonization. We suggest that it indicates some degree of exposure to heat rather than sediment staining or other postdepositional processes affecting the bone colour.

4.3. Nonanthropogenic bone damage and association with other butchery marks

Within the sample of bone retouchers, there are no bone surface modifications related to the action of nonhuman predators and no evidence for porcupine or other rodent gnawing. We did not observe root etching, which corroborates modern data on the extremely stable conditions of humidity and temperature at

the back of the rock shelter (i.e., dry and with a yearly record of constant temperatures of 18 °C: [Porráz and Val, 2023](#)). Invertebrate damage was documented on four specimens in the form of boring; only on a single specimen, BRS-2353 in Giro, did invertebrate damage affect our ability to describe the anthropogenic modifications. There is no indication of weathering on any of the specimens. The main process that modified the cortical surfaces is exposure to heat, which makes them fragile and friable (see above). Notwithstanding, only five specimens preserved 50–75% of visible cortical surface, while all other specimens preserved more than 75%.

Seventeen bone retouchers also bear butchery marks, which confirms the anthropogenic origin of these remains, accumulated via human acquisition and processing of animal carcasses inside the rock shelter. The cut-marked specimens include four metapodial shaft fragments, with butchery marks mostly related to skinning, and seven specimens that are nonidentifiable long bone shaft fragments with cut-marks related to skinning and/or defleshing. Of particular interest, we observed on six bone implements the presence of longitudinal, parallel marks that are consistent with scraping and that we interpret as the result of removing the periosteum. These scraping marks, when they do overlap with the percussive impressions on the bones, are always located under the latter (for example, see [Fig. 11](#) and specimen Gisel LA BRS-2570.9 in [Fig. 8](#)) and therefore clearly consistent with an action that took place before the use of the bone fragment in a percussive activity.

We do not exclude that these scraping marks could result from a general preparation of the surface of long bones to facilitate their breakage for marrow extraction. It appears, however, that the scraping marks occur preferentially on the bone retouchers. While the comprehensive taphonomic analysis of the complete MSA faunal assemblage is ongoing, we have conducted a microscopic inspection of all faunal remains from the SU Gisel and associated features, and we did not observe any scraping marks other than those documented on the bone retouchers. We therefore propose that scraping the periosteum off was an intentional modification in anticipation of the use of bones as retouchers.

Table 3Results for the U-series analysis with FsLA-HR-ICPMS for two *Lissachatina* sp. shells samples from the MSA phase 28 at Bushman Rock Shelter.

Sample	BRS49		BRS411	
Analysed sample mass (mg)	1.95		0.30	
U content range (ng/g)	10–30		10	
Total number of detected 230Th ions	776		1662	
²³⁰ Th/ ²³² Th isotopic ratio	2–290		2–60	
Detrital corrected 230Th/234U	0.63	±0.03	0.67	±0.02
Detrital corrected 234U/238U	1.68	±0.02	1.74	±0.02
Corrected age (ka)	100	6	109	+9/–8

We provide 95% confidence intervals.

FsLA-HR-ICPMS = femtosecond ablation laser coupled with a high-resolution inductively coupled plasma mass spectrometer.

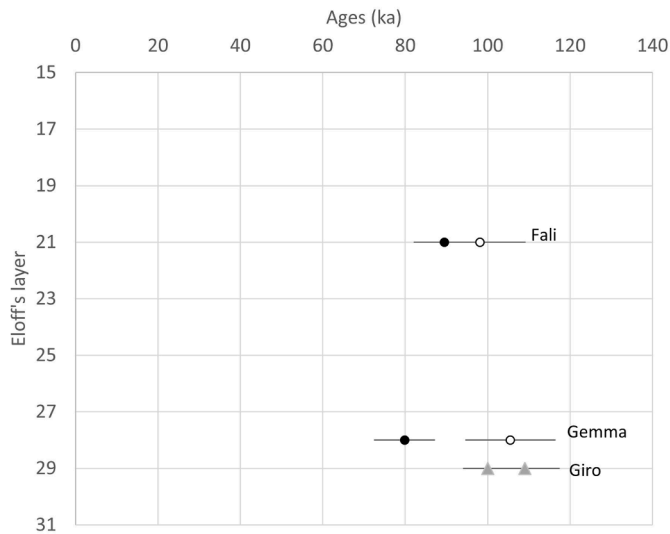


Figure 5. Summary of the available ages for the MSA deposits at Bushman Rock Shelter. Black dots: OSL quartz ages; white dots: IRSF feldspar ages; and grey triangles: U-series shells ages. Note that the error bars are at one sigma for the OSL/IRSL ages but at two for the U-series ages.

4.4. Location and morphological characteristics of the used areas

Because fragmentation has affected most of the specimens, it was not always possible to provide accurate dimensions of the used areas. Out of the 30 used areas identified and described below, 20 are considered fragmentary and only the remaining 10 are preserved completely. By fragmentary, we mean the used areas with, for instance, scores that are clearly interrupted in their

trajectory along a broken edge (for example, see specimen Gisel BRS-2836 in Fig. 7). These bone implements could have broken during their use or due to postdepositional processes. The fragmentary nature of the specimens also means that in six instances it was not possible to localize the used area on the bone (apical, centred, left/right lateral edge, or covering), and in nine we could only propose a tentative centred position. Two used areas are on the apical part of the bone retouchers, four are centred, three are covering, and six are on the lateral edge (three on the right edge and three on the left).

On most of the specimens, only one area shows traces of use. Several bone retouchers refitted with unmodified bone fragments, but there was no refitting between two bone retouchers or fragments thereof. This confirms that most bone retouchers were used on one area only. There are two exceptions to this general pattern: specimen Gisel BRS-2836 (Fig. 7) has three distinct used areas, and specimen Go BRS-1868 has two (Fig. 6).

The majority of the bone retouchers bears modifications that are clustered within small areas, while seven specimens have used areas that are more extensive, as illustrated in Figure 12. The used areas have a maximum length of 58.9 mm and a minimum length of 8.1 mm (average: 22.5 mm; median: 20.7 mm); a maximum width of 26.4 mm and a minimum width of 5.4 mm (average: 11.01 mm; median: 9.4 mm).

Most used areas are transverse ($n = 20$), oblique ($n = 4$), or both ('transverse-oblique', $n = 4$), and only specimen Godot BRS-1868 has one used area with scores that are longitudinal to the axis of the bone. All used areas are on plane ($n = 14$) or planoconvex ($n = 15$) surfaces, which indicates a clear preference for these types of blank morphologies. One specimen, Given BRS-4383, was used on a convex surface. On most specimens, the modifications are concentrated ($n = 16$) or concentrated and superposed ($n = 10$). A single specimen, Gandi BRS-164 (Fig. 7), has isolated modifications, while three have dispersed pits and/or scores. Many

Table 4

Stratigraphic provenience, class size, element, dimensions, and breakage patterns of the bone retouchers from Bushman Rock Shelter.

Number	SU	Class size	Element	Length (mm)	Width (mm)	Cortical thickness (mm)	Max. thickness (mm)	Fracture	
								Edge 1	Edge 2
Bone retouchers									
263	Eepp	Bovid IV	Long bone diaphysis	78	34.3	12.8	17.1	F	D
94	Eepp	Bovid III	Metapodial diaphysis	50	13.5	10	11.3	D	D
164	Gandi	Mammal III	Femur/humerus diaphysis	29	16.4	7.2	7.9	D	D
235	Gatting	Mammal III	Long bone diaphysis	31	Indet.	6.9	8.3	D	D
2353	Giro	Bovid III	Metapodial diaphysis	117.3	21.2	6.9	7.2	F	F
2570.9	Gisel LA	Mammal II/III	Indeterminate flat bone	15.9	12.2	N/A	N/A	N/A	N/A
2570.10	Gisel LA	Bovid/Equid III	Long bone diaphysis	49.2	13.5	6.5	6.5	F	F
3556.7	Gisel LW	Bovid III	Long bone diaphysis	31.6	11.9	6.3	6.3	D	D
2822	Gisel	Bovid III	Metapodial diaphysis	72.6	22.9	7.7	12	F	F
2836	Gisel	Bovid/Equid III	Long bone diaphysis	74.3	18.8	7.5	7.8	F	D
3060.10*	Gisel	Bovid II/III	Long bone diaphysis	27	6.1	6.1	6.7	D	D
3183*	Gisel	Bovid III	Metacarpal diaphysis	42.1	25.4	6.1	6.1	F	F
3418	Gisel	Bovid III	Tibia diaphysis	38.6	26.6	5.7	7.5	F	D
4345a	Given	Bovid III	Metatarsal diaphysis	91.4	24.3	6	6.1	D/F	F
4308	Given	Bovid III	Femur diaphysis	71.2	19.7	6.1	9.7	D	F
4383	Given	Mammal III	Femur/humerus diaphysis	44.2	31.1	6	8.6	F	F
8321	Given pit	Bovid/Equid III	Metapodial diaphysis	44.3	23.1	5.5	6.8	D	D
8494	Given pit	Bovid III	Metacarpal diaphysis	30.9	10.2	8.8	9.9	F	F
4253.2	Given	Mammal II/III	Indeterminate flat bone	26.6	11.5	N/A	N/A	N/A	N/A
1868	Go	Bovid III	Metacarpal diaphysis	88.1	16.2	6.7	7.7	F	Indet.
1524.1	Go	Ungulate II/III	Long bone diaphysis	29.2	19.6	6.8	8	D	D
1864c	Go	Mammal II/III	Long bone diaphysis	37	15.8	5.8	5.8	D	D
2552a	Godot	Bovid/Equid III	Long bone diaphysis	67	20.4	4.9	5.4	D	D
2254.1	Godot	Mammal II/III	Long bone diaphysis	25.3	10.3	6.9	6.9	Indet.	D
5586	Hannes	Bovid III	Metapodial diaphysis	56.4	13.6	6.3	8.4	F	D

Cortical thickness is recorded at the used area; maximum (max.) thickness is consistent with the maximum thickness of specimens, including the cortex and spongy fraction when present. LA = lens above; LW = lens within; F = fresh; D = dry. The specimens with an asterisk refit and represent a single bone.



Figure 6. Complete bone retouchers from the MSA SUs Given, Giro, Gisel, and Go at Bushman Rock Shelter. The black squares outline selected used areas that are enlarged next to the specimens; they do not outline the full extent of used areas. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

of the used areas ($n = 17$) are characterized by a combination of pits and scores, while in six cases we observed scores only, and in seven cases pits only. The morphology of the pits is ovoid in 13 cases, triangular in nine cases, and undefined in two cases. Scores are rectilinear in 10 cases, sinuous in 5 cases, and undefined in two cases. Table 6 is an extract from the database (available at <https://doi.org/10.5281/zenodo.15205599>) that combines information on those three criteria: morphology of the pits (ovoid or triangular), scores (rectilinear or sinuous), and used area (scaled, hatched, or pitted).

During the microscopic analysis of bone surface modifications, we were confronted with some difficulties while recording several of the morphological criteria. In particular, the morphology of the pits, scores, and used areas was often difficult to characterise even

with a microscope. These criteria, when considered in combination, were precisely the ones identified by Mallye et al. (2012) to distinguish successfully retouchers used in contact with quartzite from those in contact with flint, in both experimental and archaeological contexts. The authors proposed that flint implements produced, in general, triangular pits, rectilinear scores with smooth interior surfaces, and hatched areas (in the case of superimposed traces), while quartzite implements produced pits that were mostly ovoid, sinuous scores with rough interior surfaces, and pitted areas (in the case of superimposed traces) (Mallye et al., 2012). At Bushman Rock Shelter, while most of the triangular pits are associated with rectilinear scores, they are consistent with pitted areas (as opposed to the hatched areas typical of flint retouching). Ovoid pits are associated with rectilinear and sinuous



Figure 7. Fragmentary bone retouchers from the MSA SUs Eepp, Gandi, Gisel, Given, Godot, and Hannes at Bushman Rock Shelter. The black squares outline selected used areas that are enlarged next to the specimens; they do not outline the full extent of used areas. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

scores and show various scaled, pitted, and hatched used areas, with no apparent pattern. In other words, the morphology of the used areas described at Bushman Rock Shelter differs both from the typical flint-induced and quartzite-induced modifications described in Mallye et al. (2012). There is no systematic combination of criteria; rather, a range of combinations with no predominance for any of them is documented across the sample of bone retouchers (Table 7).

5. Discussion

The bone retouchers from Bushman Rock Shelter, securely dated to MIS 5 at 103 ± 3 ka, offer an interesting insight into the

integration of bone as a raw material by hunter-gatherers into their daily technical practices. At the site, the bone retouchers occur strictly in association with the end-scrapers and vice versa. The MSA bone retouchers from Bushman Rock Shelter were selected amongst available butchery waste, and the selection was clearly guided by a preference for specific types of blanks in terms of shape, thickness, and, presumably, weight. The specimens demonstrate a marked preference for plane or planoconvex surfaces on elongated and straight fragments of similar cortical thickness, such as shaft portions of metapodials, tibiae, or femora. The fragmentation degree of the bone retouchers hinders our ability to recognize a possible preference for a specific size. Notwithstanding, all retouchers were deliberately made on

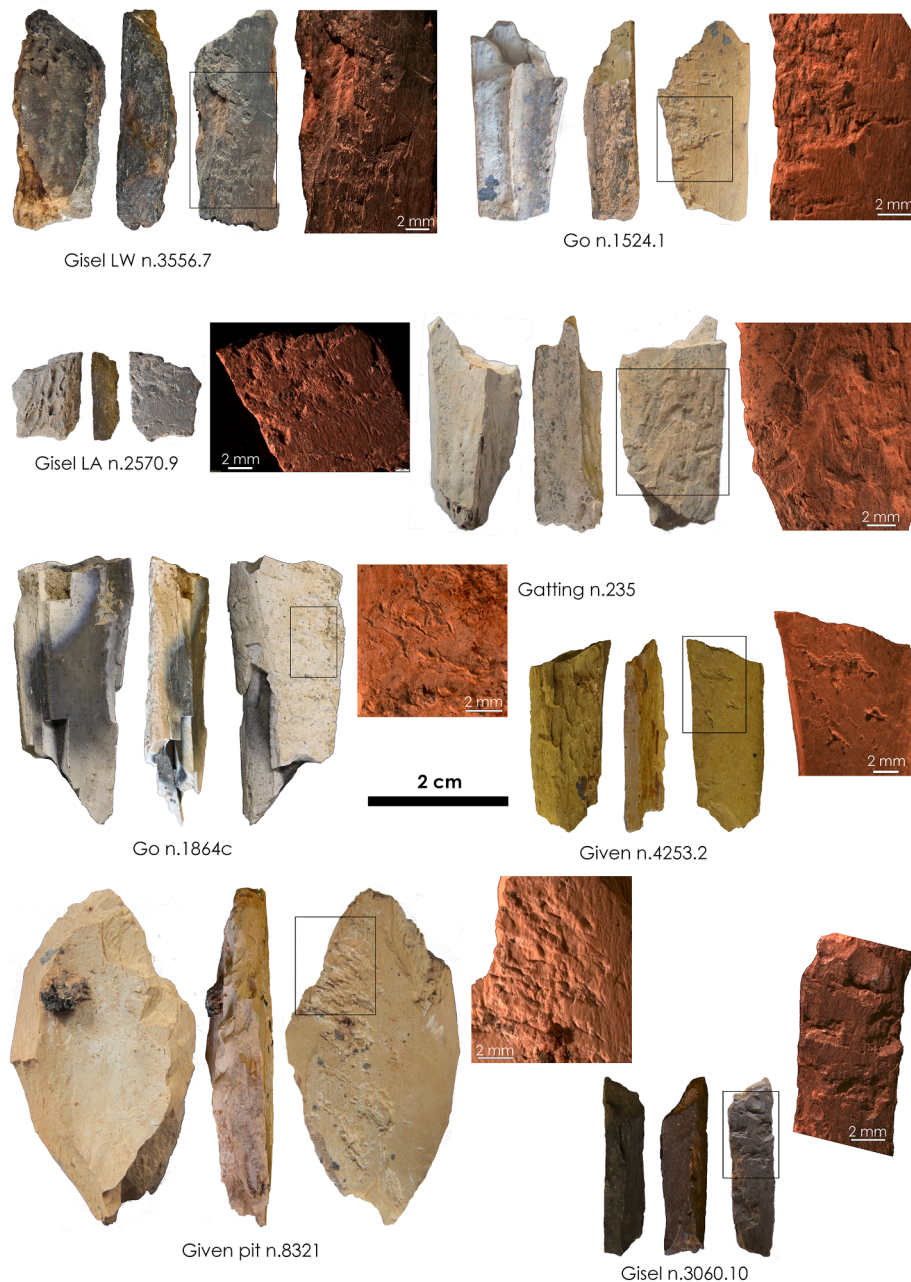


Figure 8. Fragmentary bone retouchers from the MSA SUs Gatting, Gisel, Given, and Go at Bushman Rock Shelter. The squares outline selected used areas that are enlarged next to the specimens; they do not outline the full extent of used areas. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

fragments of large ungulate carcasses, which may include greater kudus, wildebeests, hartebeests, roan antelopes, or zebras.

The bone retouchers from Bushman Rock Shelter show marks that are consistent with the use of fresh long bone shaft fragments for percussive activities on the edges of lithic implements. Several specimens bear additional scraping marks that we interpret as evidence for periosteum removal prior to their use as retouchers. Several studies have underlined surface preparation of bone retouchers by thoroughly scraping the periosteum, in order to improve their grip and efficiency during percussive activities (e.g., Vincent, 1993; Brugal, 2001; Auguste, 2002; Tartar, 2009). A clean bone surface, scraped of meat, tendons, and periosteum, offers a better contact between the dense and elastic cortical surface of the bone and the lithic implement.

The exclusive stratigraphic association between the bone retouchers and the end-scrapers at Bushman Rock Shelter supports the hypothesis of a technological imbrication between both types of tools (Fig. 13). In the archaeological context of Bushman Rock Shelter, we propose that bone retouchers might have been used in retouching/shaping or resharpener the active edge of end-scrapers, while end-scrapers themselves might have been used, at times, to scrape off the periosteum on the surface of the bone retouchers. This hypothesis is supported by the use-wear analysis conducted on the end-scrapers (Porráz et al., 2018), which identified the systematic use of end-scrapers in transverse (i.e., scraping) motions. While contacts with different hard and soft mineral and organic materials (e.g., stone, bone, dry hide, and wood) are documented, the use-wear traces all indicate similar,

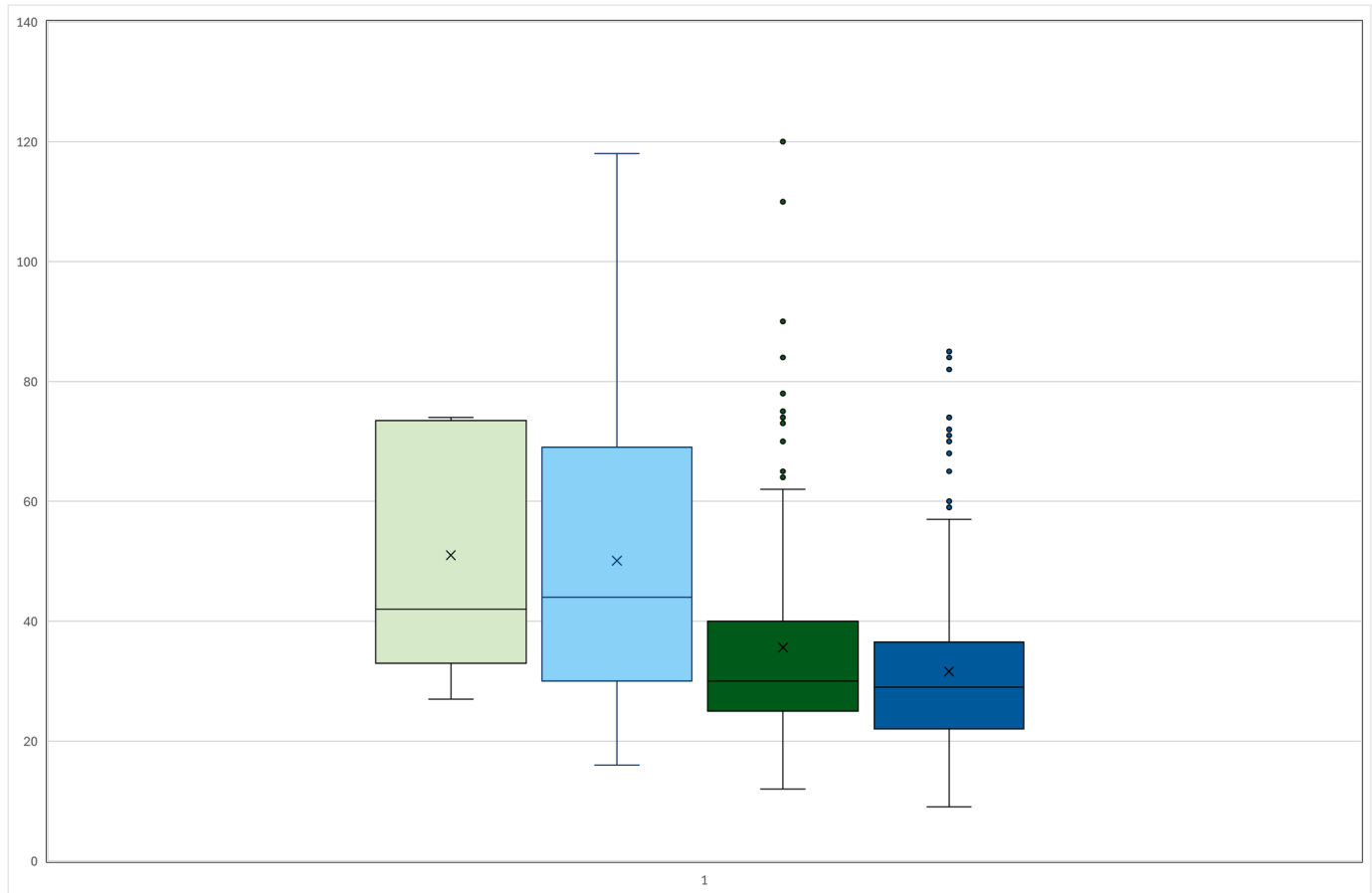


Figure 9. Distribution of the bone retouchers from SU Gisel (light green; $n = 5$), the bone retouchers from the other stratigraphic units (light blue; $n = 21$), unmodified ungulate bones and bone fragments from SU Gisel (dark green; $n = 165$), and unmodified ungulate bones and bone fragments from the other stratigraphic units (dark blue; $n = 313$), according to their length in mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

longitudinal motions in all cases, most likely consistent with scraping activities. Four end-scrapers preserve use-wear traces consistent with scraping hard material, such as bone. The initial manufacture of end-scrapers was evidently not driven by the need to scrape off the periosteum, and it is best understood within a broader development of scraping activities at large—likely related to the processing of various animal, plant, and mineral resources. We do suggest, however, that the co-occurrence of end-scrapers and bone retouchers would have represented a technical context prone to the emergence of new technological gestures, such as the use of the front of an end-scraper to remove the periosteum from a fresh bone. We refer to such interactions between bone and lithic implements as a case of technological imbrication between these two types of raw materials.

As mentioned earlier, we have collected abundant lithic retouching and resharpening flakes during our excavation in the deposits from the block G; these support the hypothesis of in situ manufacturing and resharpening of end-scrapers. The end-scrapers from Bushman Rock Shelter show a high degree of use, and they were regularly resharpened and recycled. With a single exception, the pits and scores related to percussive activities on the bone retouchers are always orientated obliquely and/or transversely to the long axis of the bone. This documents the repetition of similar technological motions, with the bone retouchers characterised by a basal, prehensile part, and used tangentially against a lithic implement. Variations in the intensity and/or duration of use of the retouchers could explain the

differences observed in the extent of the used areas, and in the variable abundance of modifications (pits and scores). Some blanks might have been used only once, while others might have been used either for longer or for several, distinct shaping/resharpening events.

Besides end-scrapers, which clearly dominate numerically the corpus of retouched tools, side-scrapers, convergent scrapers, notches, and denticulates tools were collected from the block G (Porraz et al., 2018). We would like to underline once more that end-scrapers from southern African MSA contexts are first documented during MIS 5, at Bushman Rock Shelter at 103 ± 3 ka. Circular end-scrapers are documented from the 72–75 ka Still Bay units at Blombos Cave in South Africa (Soriano et al., 2015). Typologically similar but manufactured differently and perhaps functionally distinct, the so-called basal end-scrapers from Apollo 11, Namibia, are associated with the ~71 ka MSA 2 units (Vogelsang et al., 2010); similar tools have been documented at two other Namibian sites, namely Pockenbank and Aar 1 (Vogelsang, 1998; Schmidt et al., 2023). Unlike end-scrapers, side-scrapers, convergent scrapers, notches, and denticulates constitute tool categories that are typical of the MSA across southern Africa (e.g., Lombard et al., 2012; Mackay et al., 2014; Wurz, 2024). End-scrapers are typically associated with much later, Holocene contexts in southern Africa, as well as with the Upper Palaeolithic toolkit. They constitute a distinctive innovation within the context of MIS 5 technological developments in Africa. Even though we cannot exclude the hypothesis that bone

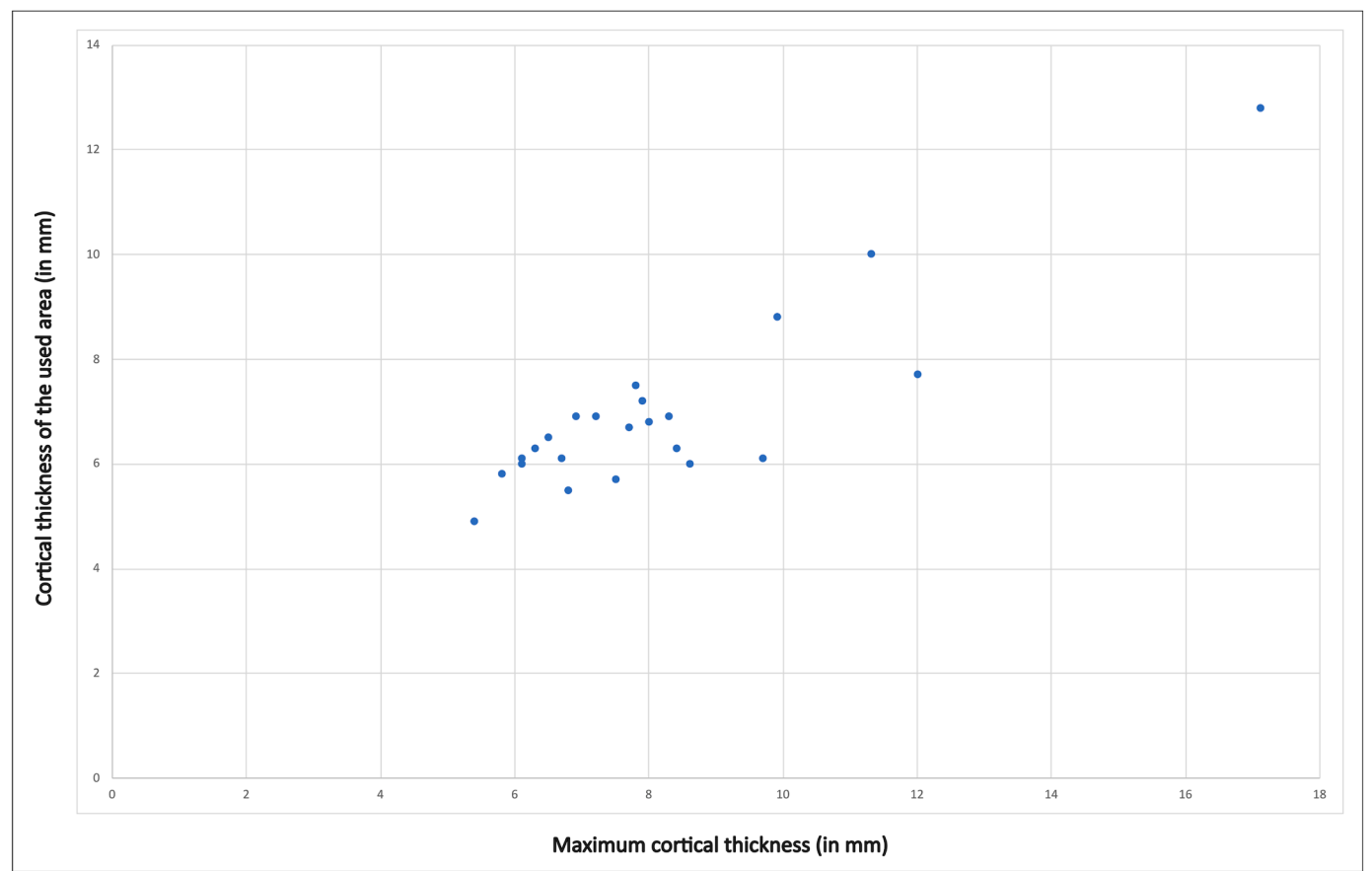


Figure 10. Correlation between the cortical thickness of the used areas and the maximum cortical thickness of the blanks selected to be used as bone retouchers. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

Table 5
Burning stage for the bone retouchers from Bushman Rock Shelter, per SU or stratigraphic feature.

Stratigraphic unit	No burning	Slightly burnt	Dark brown	Black	White/Grey
Epp	–	2	–	–	–
Gandi	–	–	–	–	1
Gatting	–	–	–	–	1
Giro	–	–	1	–	–
Gisel LA	–	1	–	–	1
Gisel LW	–	–	–	1	–
Gisel	–	–	4	1	–
Given	1	1	–	–	2
Given pit	–	1	1	–	–
Go	–	–	–	–	3
Godot	1	–	–	–	1
Hannes	–	–	1	–	–
Total	2	5	7	2	9

LA = lens above; LW = lens within; SU = stratigraphic unit.

retouchers were occasionally used to shape other tool types as well, the strict stratigraphic co-occurrence of both the retouchers and the end-scrapers indicates that the conditions of their emergence in the technological record of Bushman Rock Shelter are strongly inter-related.

Such a technological imbrication between a specific knapping implement on the one hand and a specific tool shape on the other is documented in other contexts. Hence, and although retouchers are documented in various chronocultural contexts, the archaeological record of Eurasia and the Levant seems to highlight their particular abundance in association with specific lithic tool types:

the Quina scrapers and demi-Quina scrapers of the Acheuleo-Yabrudian (e.g., [Blasco et al., 2013](#); [Rosell et al., 2018](#)) and of the Quina Mousterian technocomplexes (e.g., [Henri-Martin, 1907-1910](#); [Chase, 1990](#); [Chase et al., 1994](#); [Brugal, 2001](#); [Mozota Holgueras, 2009, 2012](#); [Niven et al., 2012](#); [Castel et al., 2017](#); [Costamagno et al., 2018](#); [Ready and Morin, 2019](#); [Martellota et al., 2021](#)), as well as, to a lesser degree, Mousterian Discoid scrapers and other retouched tools ([Martellota et al., 2020](#)), and end-scrapers produced during the Early Aurignacian ([Tartar, 2012](#)) and the Magdalenian ([Rigaud, 1977, 2007](#); [Schwab, 2009](#)). Clear patterns of use have been observed in these various contexts, as

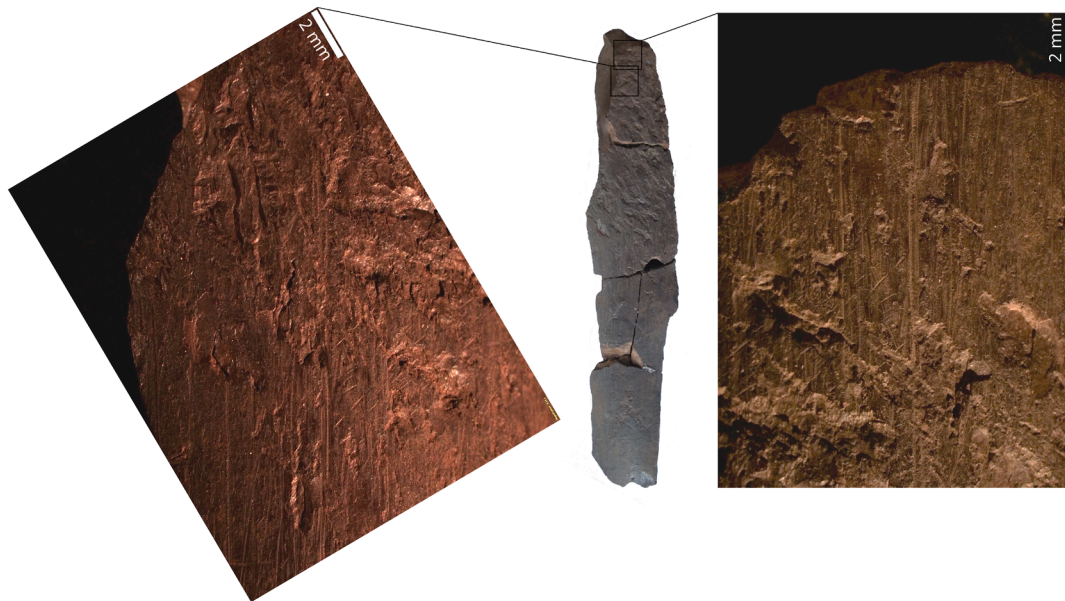


Figure 11. Scraping marks likely resulting from periosteum removal, and located under the used area on specimen Giro BRS-2353. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

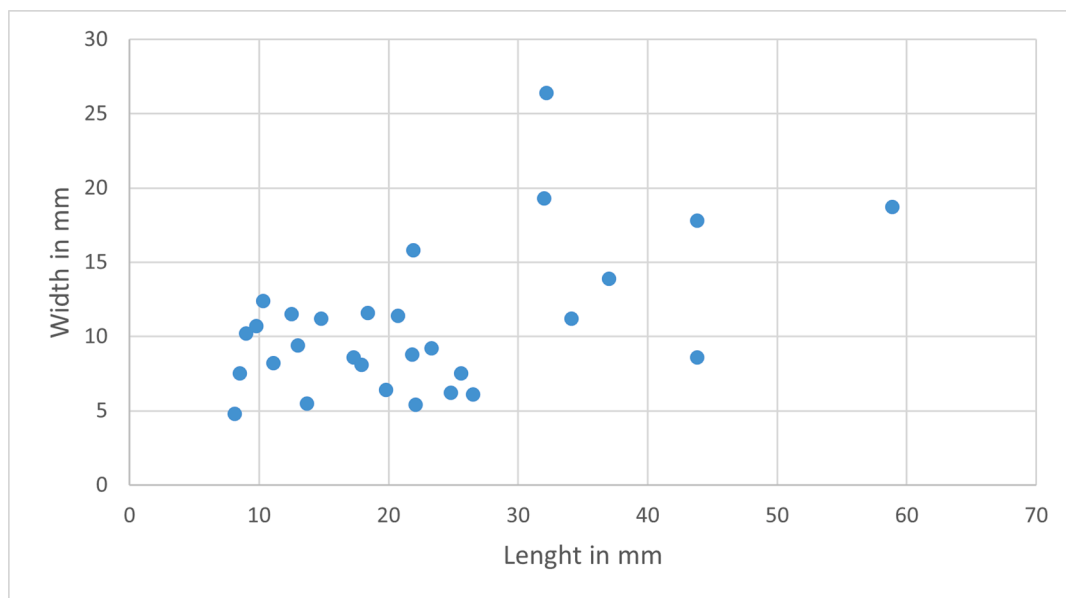


Figure 12. Dimensions (length and width) of the used areas on the bone retouchers from Bushman Rock Shelter; two distinct clusters may be observed, perhaps suggesting different types and/or different degrees in the intensity and/or length of use of the bone retouchers. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

well as differences in the way marks are orientated on the bones, which suggests some variability in gestures and technological intentions.

During the Lower and Middle Palaeolithic, besides the chronostratigraphic association noted between Quina scrapers and demi-Quina scrapers on the one hand and bone retouchers on the other, these implements often seem to co-occur in contexts where there is evidence for abundant and sometimes intensive on-site resharpening and recycling of the lithic tools. At the Mousterian site of Les Pradelles in France for instance, close to 500 bone retouchers were collected alongside abundant retouched lithic tools, including numerous Quina and demi-Quina scrapers (Costamagno

et al., 2018). The analysis of the lithic assemblage indicates regular on-site (re)sharpening and recycling of the scrapers (Bourguignon, 1997, 2001), which, together with their abundance, points towards a direct technological relationship between these lithic tools and the retouchers. At Qesem Cave, a series of retouchers dated to >300–420 ka is also interpreted in the framework of on-site resharpening of Quina and demi-Quina scrapers of the Acheuleo-Yabrudian occupation layers (Blasco et al., 2013; Rosell et al., 2018).

The series of bone retouchers from Bushman Rock Shelter constitutes a rare sample of well-contextualised specimens of such implements in Africa. Besides those, 20 bone retouchers were retrieved from Taforalt Cave (Grotte des Pigeons) in Morocco. Most

Table 6
Morphology of pits, scores, and used areas on the bone retouchers from Bushman Rock Shelter.

Specimen n.	Pits		Scores		Used area
	P/A	Morphology	P/A	Morphology	
Gandi 164	P	Ovoid	P	Rectilinear	Scaled
Gisel 2836	P	Ovoid	A	N/A	Pitted
Gisel 3183	P	Ovoid	A	N/A	Pitted
Go 1864c	P	Ovoid	P	Rectilinear	Scaled + pitted
Go 1524.1	P	Ovoid	P	Rectilinear + sinuous	Hatched
Godot 2552a	P	Ovoid	P	Rectilinear + sinuous	Hatched
Gisel 3060.10	P	Ovoid	P	N/A	Pitted
Gisel 2570.10	P	Ovoid	P	Sinuous	Hatched + scaled
Given 4345a	P	Ovoid	P	Rectilinear	Hatched
Given 4308	P	Ovoid	P	Rectilinear + sinuous	Pitted
Hannes 5586	P	Ovoid	P	N/A	Scaled
Godot 2254.1	P	Ovoid	P	N/A	Scaled + pitted
Given 8494	P	Ovoid	P	Sinuous	Pitted
Gatting 235	P	Triangular	P	Sinuous	Pitted
Gisel 3556.7	P	Triangular	P	Rectilinear	Scaled + pitted
Go 1868	P	Triangular	P	Rectilinear	Pitted
Gisel 2570.9	P	Triangular	P	Rectilinear	Pitted
Given 4253.2	P	Triangular	A	N/A	Pitted
Given 4383	P	Triangular	A	N/A	Scaled + pitted
Eepp 94	P	Triangular	P	Rectilinear	Hatched
Giro 2353	P	Triangular	P	Sinuous	Pitted
Gisel 2822	P	Ovoid + triangular	P	Rectilinear	Scaled + pitted
Gisel 3418	P	Ovoid + triangular	P	Sinuous	Pitted
Eepp 263	A	N/A	P	Sinuous	Hatched
Gisel 2836	A	N/A	P	Rectilinear	Hatched
Gisel 2836	A	N/A	P	Rectilinear	Hatched
Go 1868	A	N/A	P	Rectilinear	Hatched
Given 8321	A	N/A	P	Rectilinear	Hatched

Table 7
Frequencies of various associations of characteristics for the used areas on the bone retouchers from Bushman Rock Shelter (morphology of the pits, scores, and used areas).

		Scores			
Pits		Sinuous	Rectilinear	Sinuous/Rectilinear	
Ovoid		2	3	3	
Triangular		2	4	0	
Ovoid/Triangular		1	1	0	
		Used area			
Pits		Scaled	Pitted	Hatched	Scale/Pitted
Ovoid		2	5	3	2
Triangular		0	5	1	2
Ovoid/Triangular		0	1	0	0
		Used area			
Scores		Scaled	Pitted	Hatched	Scale/Pitted
Sinuous		0	4	1	0
Rectilinear		1	2	6	3
Sinuous/Rectilinear		0	1	2	0

Maximum values are highlighted in green, minimal values in gray.

of these retouchers are from Late MSA layers (ca. 30 ka ago), which have yielded abundant and heavily worked side-scrapers (Turner et al., 2020). Hallett et al. (2021) mention the presence of 13 retouchers from Contrebandiers Cave in Morocco; these were retrieved across several Maghrebian Mousterian and Aterian units, dated from ~120 to 90 ka. The two retouchers described from Blombos Cave in South Africa were collected from SUs associated with the Still Bay technocomplex (Henshilwood et al., 2001; d'Errico and Henshilwood, 2007). There, besides the emblematic Still Bay points, the toolkit also includes end-scrapers on thin flakes, as well as circular scrapers and side-scrapers (Soriano et al., 2015). Three

bone retouchers were found in the final MSA layers at Holley Shelter in KwaZulu-Natal (Bader et al., 2024). In those layers, dated to 35 ka, the lithic assemblage is dominated by splintered pieces and comprises unifacial points, Ndwedwe tools, retouched blades, and flakes. The presence of retouch and shaping flakes in the lithic assemblage indicates that retouching and (re)shaping took place inside the rock shelter. Finally, at Bushman Rock Shelter, the recent excavation and reappraisal of the legacy collections from the LSA layers have identified the presence of bone retouchers in layers associated with the macroscrapers characteristic of the Oakhurst technocomplex (Porraz et al., 2015; Feyfant, 2024).

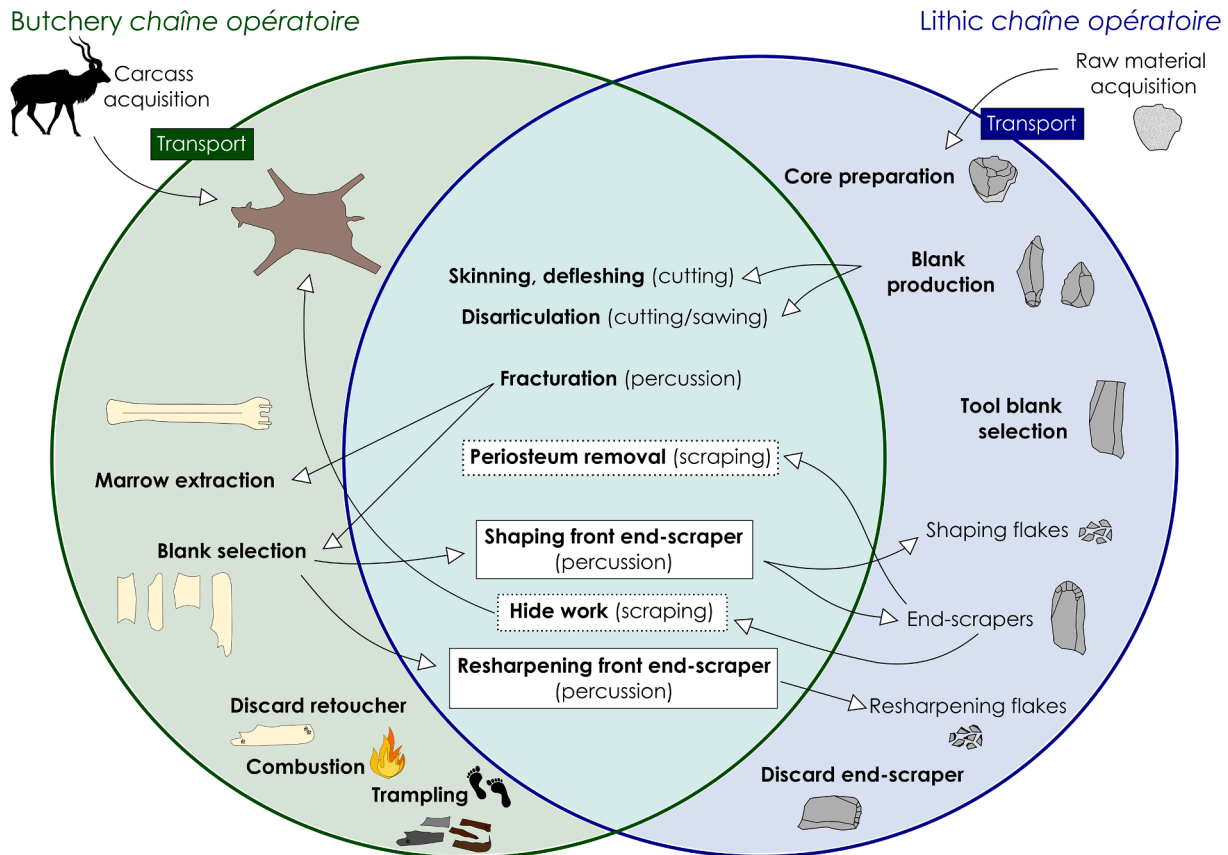


Figure 13. The technological imbrication of the *chaîne opératoire* for the bone retouchers within the production of end-scrapers, from the 103 ± 3 -ka MSA deposits at Bushman Rock Shelter. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

The co-occurrence of bone retouchers and end-scrapers at Bushman Rock Shelter provides an additional example, for an African Pleistocene context, of an imbricated technological relationship between two distinct tool types and raw materials. Knappers took advantage of the specific properties of bone, in particular its combined strength and elasticity, in order to improve their controlled shaping of the lithic edges intended to be used. The technological novelties documented at Bushman Rock Shelter add to the documented technical and symbolic innovations that flourished with MSA societies from MIS 5 onwards. The case study from Bushman Rock Shelter illustrates a significant degree of plasticity in the knappers' practices: they integrated faunal waste within their technical process by selecting specimens appropriate to their specific needs. This clearly shows that knappers were aware of the mechanical properties unique to bone and that they were able to transfer their empirical knowledge to new needs, such as in the case of the production of a novel tool type. Our case study is also a good reminder that any change observed in lithic technology should always only be regarded as the visible tip of a much deeper and complex remodelling of technical practices. Any stone tool is, indeed, part of a much broader technological system that includes various raw materials, imbricated within a synergetic design, which implies transferable knowledge. The emergence of end-scrapers at Bushman Rock Shelter at 103 ± 3 ka demonstrates the intimate intertwining between mineral and organic materials; it further illustrates that southern African MSA populations occasionally started to integrate bone within their technical repertoire as far back as MIS 5.

Apart from these isolated examples, bone retouchers are extremely scarce throughout the Stone Age in Africa. Retouchers might of course have been overlooked in African contexts, and a thorough taphonomic reassessment of faunal assemblages may prove successful in identifying larger samples of such artefacts. The current data suggest, however, that bone retouchers developed preferentially in the context of specific technical associations, where bone provided specific technical benefits. Such benefits may be dictated by technical properties, in comparison with other organic retouchers such as wooden ones, and/or by economical behaviours (e.g., recycling of food waste for supply). In both cases, bone retouchers require a modification in the way humans interacted with resource properties and the animal realm at large. We suspect that the use of bone blanks in percussive activities requires a specific combination of conditions to emerge. Such conditions include an intimate knowledge of the mechanical properties of bone as a raw material, a cultural and social context prone to the experimentation of new practices, and the pre-existence or coexistence of a technological need for the use of bone within a specific lithic *chaîne opératoire*. Here, we argue that the first condition has been unequivocally fulfilled for the last 3 Myr and constitutes a characteristic of African early hominins and modern humans engaging regularly with processing of animal carcasses. We further suggest that the second condition is consistent with the dynamic context of MIS 5, which can be described as a phase of cultural burgeoning and technological experimentation and innovation. Finally, we propose that the third condition was met at Bushman Rock Shelter, with the emergence in the technological repertoire of the inhabitants at the site of a new type of lithic tools, namely end-scrapers.

6. Conclusion

In 2018, we described a large sample of end-scrapers from the MSA deposits of Bushman Rock Shelter in South Africa. These artefacts constitute a technological novelty in the toolkit developed by MSA hunter-gatherers during MIS 5. Such artefacts are extremely discreet elsewhere in the region and almost absent during older and younger phases of the MSA, while they represent an emblematic tool type of the Eurasian Upper Palaeolithic. In this paper, we clarify the chronology of the occurrence of this tool type by providing revised OSL ages, as well as additional ages obtained from U-series dating of *Lissachatina* sp. shells. These new OSL and U-series dates, presented here, confirm the initial results proposed by Martin et al. (2022): the chronology of the MSA phase 28 at Bushman Rock Shelter is now securely anchored at 103 ± 3 ka years. With this critical aspect of the MSA sequence at the site clarified, it is possible to position more precisely the innovative technologies observed during phase 28 within the general frame of MIS 5 cultural trajectories in Africa. Such innovative technologies include in particular the emergence of end-scrapers, together with that of bone retouchers.

In this paper, we explore the association between those bone retouchers, described here, and end-scrapers at Bushman Rock Shelter. The bone retouchers were likely used to shape and/or resharpen the active fronts of the end-scrapers, which in turn may have been used, in part, to prepare the bone retouchers by scraping the periosteum, alongside a range of other scraping interactions with other hard and soft materials. These distinct raw materials—bone and fine-grained hornfels—were intimately intertwined within a *chaîne opératoire* orientated towards the creation of a new tool-type specialised in a specific working motion, namely scraping.

Bones utilised in retouching, shaping, and/or resharpening activities are extremely rare in Late Pleistocene contexts in Africa, and the specimens from Bushman Rock Shelter represent one of the few samples of such implements described thus far. The bone retouchers were selected amongst long bones of medium to large ungulates, with a clear preference for plane and planoconvex bone surfaces. Identifying the technical benefits of this bone retoucher/lithic synergy will require the establishment of a dedicated experimental protocol using long bones of African antelopes and the fine-grained hornfels documented at Bushman Rock Shelter or a similar raw material. In particular, the experiments might help addressing the question of the apparent scarcity of retouchers in Africa compared to Eurasian and Levantine contexts.

The bone retouchers and end-scrapers from Bushman Rock Shelter form a new and specific technical combination in the context of the MSA. It provides additional evidence of the innovative behaviours and practices that were in place from MIS 5 onward in southern Africa. The bone retoucher/end-scraper toolkit broadens our understanding of adaptive and innovative processes at work, and it illustrates the remodelling capacities of MIS 5 people, who opted for bone as their preferred raw material to shape and/or reshape sharp, convex edges on lithic artefacts. This plasticity consisted in proposing solutions as part of different technical repertoires and experiments. The capacity to transfer and extrapolate knowledge from one context to another may have sustained creativity and innovation. The bone retouchers, from casual items of food waste to opportunistic artefacts, were part of an arborescent system that involved constant synergistic reconfiguration. This imbrication also documents the way human societies during MIS 5 perceived their natural environment and combined empirical knowledge to propose new technical solutions.

Declaration of competing interest

The authors declare no conflict of interest.

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Supplementary Online Material

Supplementary Online Material related to this article can be found at <https://doi.org/10.1016/j.jhevol.2026.103845>.

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