ANTHROPOLOGY

Early Middle Stone Age personal ornaments from Bizmoune Cave, Essaouira, Morocco

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Ornaments such as beads are among the earliest signs of symbolic behavior among human ancestors. Their appearance signals important developments in both cognition and social relations. This paper describes and presents contextual information for 33 shell beads from Bizmoune Cave (southwest Morocco). Many of the beads come as deposits dating to ≥142 thousand years, making them the oldest shell beads yet recovered. They extend the dates for the first appearance of this behavior into the late Middle Pleistocene. The ages and ubiquity of beads in Middle Stone Age (MSA) sites in North Africa provide further evidence of the potential importance of these artifacts as signals of identity. The early and continued use of *Tritia gibbosula* and other material culture traits also suggest a remarkable degree of cultural continuity among early MSA *Homo sapiens* groups across North Africa.

INTRODUCTION

Symbolic artifacts and other behavioral indicators of hominin cognitive complexity appear quite early within Middle Stone Age (MSA) and Middle Paleolithic contexts in North Africa, South Africa, and southwest Asia. The most common and earliest material indicators of symbolic behavior are beads and other personal ornaments, frequently made from marine shells.

Some of the earliest evidence for use of marine shells in symbolic contexts comes from the eastern Mediterranean Levant. In Qafzeh Cave, layers dating to ca. 100 thousand years (ka) yielded *Glycymeris insubrica* shells with natural perforations (*1*). Clearer examples of shell beads were identified in Skhul Cave, on Mt. Carmel (*2*). The age of these artifacts could be between 100 and 135 ka (*3*). In South Africa, a large series of perforated *Nassarius kraussianus* shells from Blombos Cave (*4*) is dated to be between ca. 76 and 100 ka (*5*), while more varied assemblages of shell beads from the site of Sibudu date to somewhat later (*6*).

In North Africa, *Tritia gibbosula* shell beads occur in many MSA sites (*7–10*). A total of 33 perforated *T. gibbosula* shells have been recorded from a MSA/Aterian context at Grotte des Pigeons at Taforalt, with a most likely date of ~82.5 ka (*7*). Excavations at Contrebandiers Cave (*8*) identified a total of 151 shell beads in a context dated to ca. 115 ± 3 ka (*9*). At El Mnasra Cave, 234 *T. gibbosula* shells were collected from three MSA/Aterian layers (*10*). The age of this context was estimated to span the period ~107 to ~112 ka (*11*). At Ifri n'Ammar, in Eastern Morocco, single perforated specimens of *Tritia* and *Columbella rustica* were found in an MSA/Aterian context dated to 83 ka (*12*). Another single perforated *Tritia* shell was identified in Oued Djebbana, Algeria (*13*), although its age is poorly constrained (*14*).

Recent archeological excavations at Bizmoune Cave have documented the presence of perforated marine shells in MSA/Aterian contexts dating back to ≥142 ka. This extends the earliest date for this behavior into the late Middle Pleistocene.

RESULTS

Bizmoune Cave (31°39′96″ N, 9°34′09″ W) lies ~12 km from the present Atlantic coast of southwest Morocco (Fig. 1). The cave is situated at an elevation of ~171 m on the flanks of Jebel Lahdid. The cave formed in Upper Cretaceous limestone. It has a southeast-facing entrance and an open plan, measuring some 20 m deep by 6 m wide, with a vault between 2 and 4 m high. The site was found in 2004 during a survey of the Essaouira area and was subject to limited test excavations in 2007 and 2008 (*15*). Research beginning in 2014 expanded the excavation to an area of 30 m^2.

The stratigraphy of the site is based on lithostratigraphic and micromorphological descriptions supported by archeological data.

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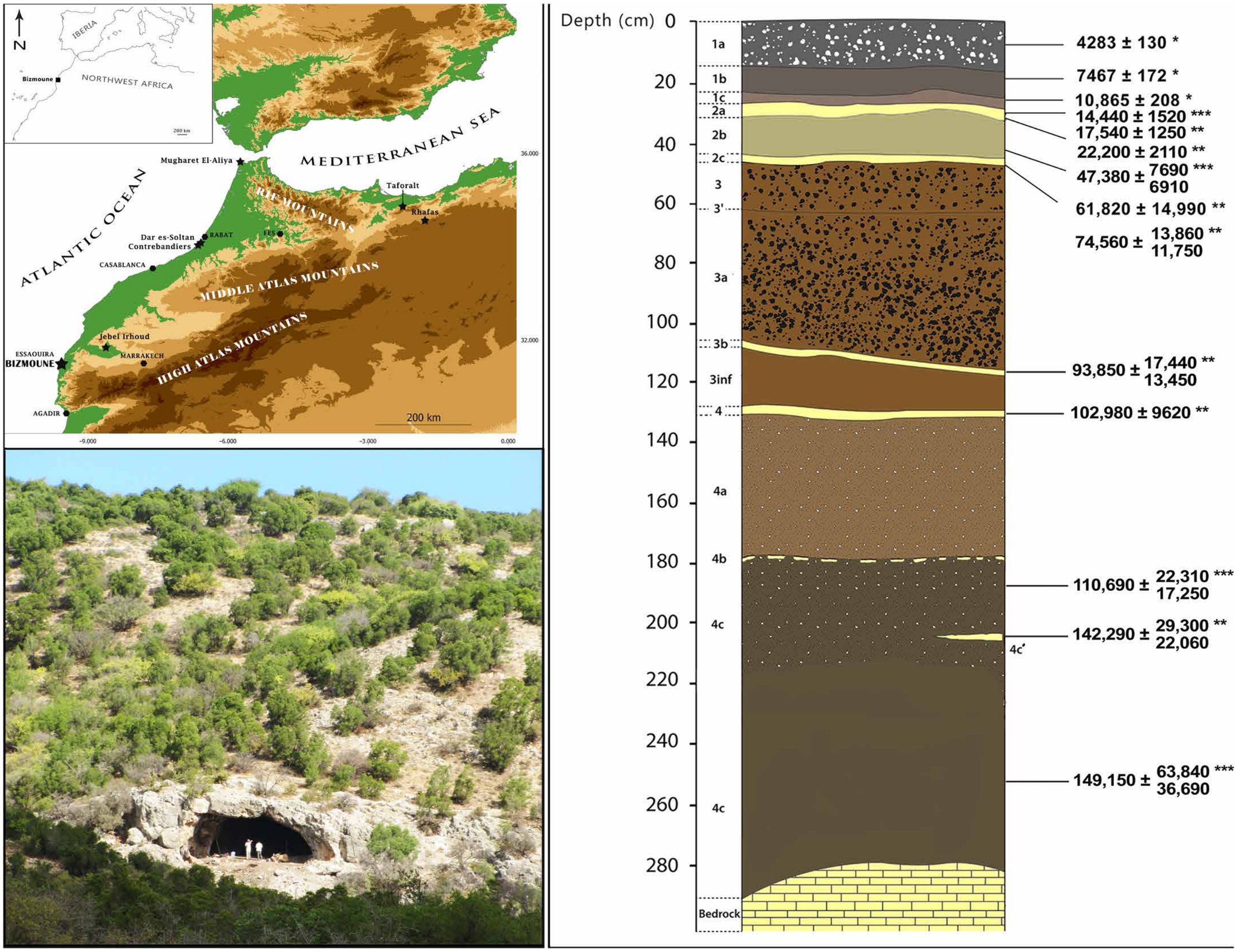

Fig. 1. Clockwise from upper left: Location of Bizmoune Cave, schematic stratigraphy with uranium-series dates (2-σ errors), photograph of cave from southwest. Depths are measured from the ground surface (*^{14}C, **U-series on speleothems, and ***U-series on animal teeth). Photo credit: A. Bouzouggar, INSAP, Morocco.

Layer 4c is the source of all but one of the shell ornaments. Layer 4c is ~50 to 100 cm thick; variation in thickness reflects both bedrock topography and erosion, especially near and outside the dripline. It is composed of dark gray silt (N 4/0) with abundant small fragments of ash and charcoal and variable quantities of angular limestone fragments. Together, the high density of artifacts, the scarcity of carnivore remains, and abundant evidence of burning indicate that the humans were the main agents of accumulation of archeological materials in the MSA layers (Supplementary Text).

Layer 4c is the richest of the MSA layers at Bizmoune in terms of stone artifacts and other products of human behavior. Analysis of abundant charcoal fragments (Fig. 2 and table S1) indicates open vegetation and subarid or semiarid conditions (*16*, *17*). The lithic technology displays a substantial Levallois component and systematic production of blades and bladelets (Supplementary Text). The assemblage contains typical MSA/Aterian artifact forms, including tanged tools (Fig. 3), rare bifacial foliates, side scrapers, end scrapers, and points or convergent scrapers.

A total of 33 marine shell beads were recovered from Bizmoune between 2014 and 2018, all from layer 4c except one from layer 4a. Perforated *T. gibbosula* specimens occur throughout layer 4c but are most abundant in the deepest parts of the unit. Most of the shells have been found in the excavations closest to the center of the cave ($n = 27$), where the trench is deepest (Fig. 4). Many of the shell ornaments from Bizmoune are partially covered with calcite concretion (Fig. 5), making it difficult to examine all features and surfaces closely. All but one of the beads belong to the species *T. gibbosula*. The remaining specimen is a shell of *C. rustica*. The *T. gibbosula* shells of Bizmoune are large compared to other examples from North Africa and the Levant (fig. S4). The shells display mainly oval-shaped ($n = 22$) or circular ($n = 8$) perforations. Most perforations are partly natural, but many show traces of additional human modification such as chipping, possibly produced using a stone tool (Figs. 6 and 7 and table S2). The perforations and shell apertures frequently exhibit smoothed edges and polish (Fig. 6 and table S2). Polish and fine striations are very localized around the holes in the

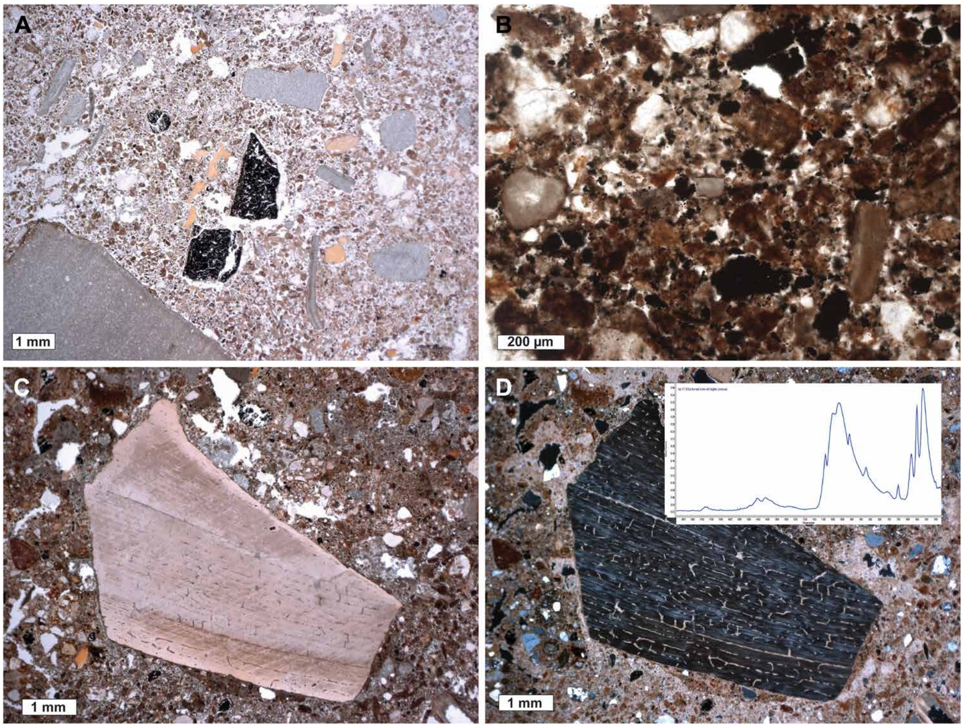

Fig. 2. Burned materials and other anthropogenic components are present throughout layer 4. (**A**) Large fragment of charcoal. (**B**) Micro-charcoal as one component of the sedimentary fine fraction. (**C**) Bone burned to greater than 700°C, as evidenced by Fourier transform infrared spectroscopy (FTIR) measurements. (**D**) Same view as (C), showing typical birefringence of the burned bone, cross-polarized light. Photo credit: S. Mentzer, Universität Tübingen, Germany.

Fig. 3. Five tanged artifacts from layer 4c at Bizmoune Cave. Photo credit: A. Bouzouggar, INSAP, Morocco.

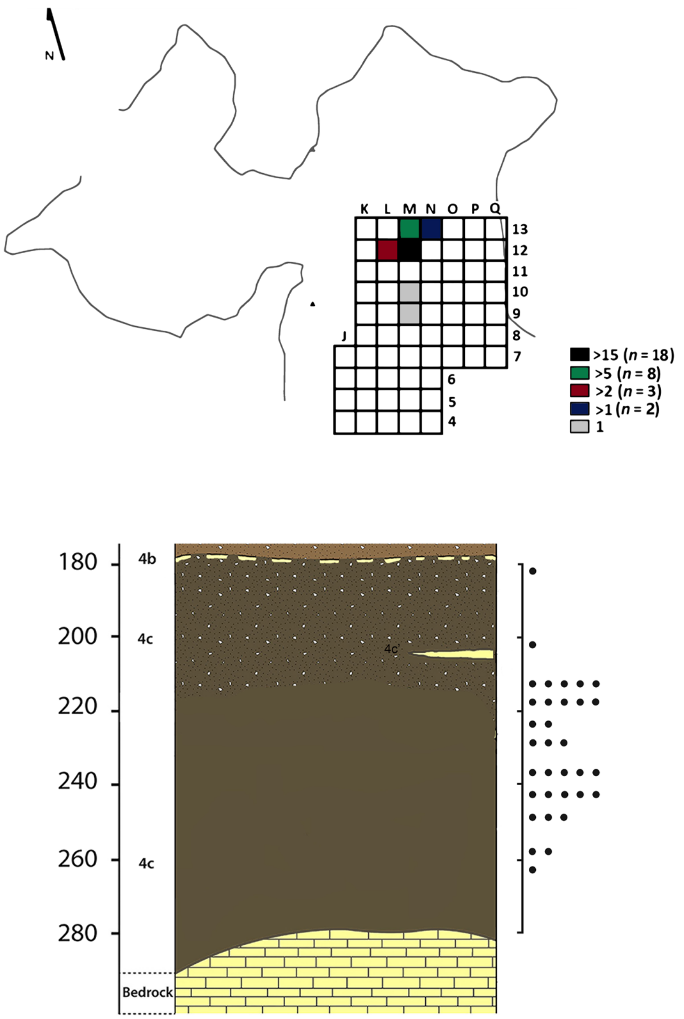

Fig. 4. Distributions of shell beads in Bizmoune Cave. (**Top**) Map showing locations of ornament shells recovered between 2014 and 2018. (**Bottom**) Graphic showing depths of shell beads projected against the lower part of strata log from Fig. 1, illustrating vertical relationship between shell beads and speleothem dated to ~142 ka.

shells. Seventy-five percent of the shells show polish and striations in the apertures, but only 21% show similar modification of the apex, suggesting that these traces were caused by use rather than postdepositional factors (table S2). Traces of red pigment occur on some shells (Fig. 6), and small red pigment blocks as well as ochre residues were identified on some stone tools and pebbles from layer 4c. Evidence points to the *Tritia* shells having been moved to the site by hominins for use as ornaments. Bizmoune is situated ~12 km from the modern coastline, and based on sea level estimates, we calculate that it was ~50 to ~30 km away from the sea when layer 4c was deposited.

Our current understanding of the chronology of the MSA deposits at Bizmoune is based mainly on uranium-series dating (Fig. 1, Table 1, and tables S3 and S4). In many areas of the cave, flowstones provide datable material, also serving as effective barriers to most upward or downward movement of archeological materials (Supplementary Text). Uranium-series dates on speleothems provide a coherent and well-ordered chronology of the main core of the MSA sequence, bracketing it between ~62 and ≥142 ka (Fig 1, Table 1, and tables S3 and S4). Divergent ages from the same carbonate units (2a and 2c) probably represent multiple episodes of crust formation that could not be easily separated in the field. Optically stimulated luminescence (OSL) dates show stark inconsistencies. They are coherent with uranium-series dates through layer 3, but OSL dates from layer 4c are uniformly younger than U/Th dates (Table 1 and tables S5 and S6) and no older than OSL dates from overlying layers. The explanation for this inconsistency is a topic for future research. However, recorded environmental dose rates in the lower part of the sequence are much higher than in the upper levels, a phenomenon observed at other Moroccan sites such as Rhafas (*18*). One preliminary hypothesis is that radiogenic materials accumulated in the layers immediately above the bedrock sometime after deposition, resulting in increases in dose rates over time and consequent underestimation of luminescence ages.

The U/Th dating results from layer 4c at Bizmoune Cave extend the earliest date for production and use of personal ornaments to at least the later part of marine isotope stage 6. A broadly distributed flowstone at the top of layer 4 provides a minimum age for the top of layers 4 to 4c of ~103 ka (Table 1 and tables S3 and S5). An isolated speleothem (4c′) that formed within layer 4c close to the current cave mouth dates to ~142 ka (Table 1, Fig. 1, and table S4). Similar to other speleothems from Bizmoune, this sample is micritic rather than sparitic. However, the portion sampled is dense, shows no sign of recrystallization, and does not contain fragments of older carbonate, indicating that the sample age is reliable (Fig. 8 and Supplementary Text). Most shell beads from layer 4c were recovered from absolute depths greater than this speleothem (Fig. 4). Most of the shells recovered to date come from several meters farther back in the cave. Both bedrock and sedimentary units dip in elevation toward the front of the cave. The dip of the layers and the depths of the finds indicate that a large part of the bead sample comes from a position stratigraphically beneath that of the dated speleothem. Although much less reliable than dates on flowstone carbonates, a U/Th age estimate on an ungulate tooth from deeper within layer 4c suggests an age of ~149 ka (Table 1 and table S4).

DISCUSSION

On the basis of analogies with extant and historically documented societies, Paleolithic ornaments such as beads and pendants were a means of communicating aspects of identity (*19*, *20*). The appearance and proliferation of these objects have been widely interpreted as evidence for expanding social networks and complexity of social interactions during the Pleistocene (*20*, *21*). *T. gibbosula* was the dominant ornamental taxon across the entirety of North Africa, and arguably into the Levant, for tens of thousands of years. This taxon may have originally been used because it was common, although other species of marine mollusk could have been and were used as beads (*22*). However, once a particular form becomes common in a system of communication, there is strong pressure to conform (*23*).

Much discussion of the evolution of complex behavior and cognition among *Homo sapiens* has been focused on precocious developments in South Africa and adjoining countries. Emerging evidence from North Africa tells a somewhat different story. Now, the earliest fossils attributed to *H. sapiens* come from Jebel Irhoud in western Morocco (*24*). Material traces of complex or novel behaviors,

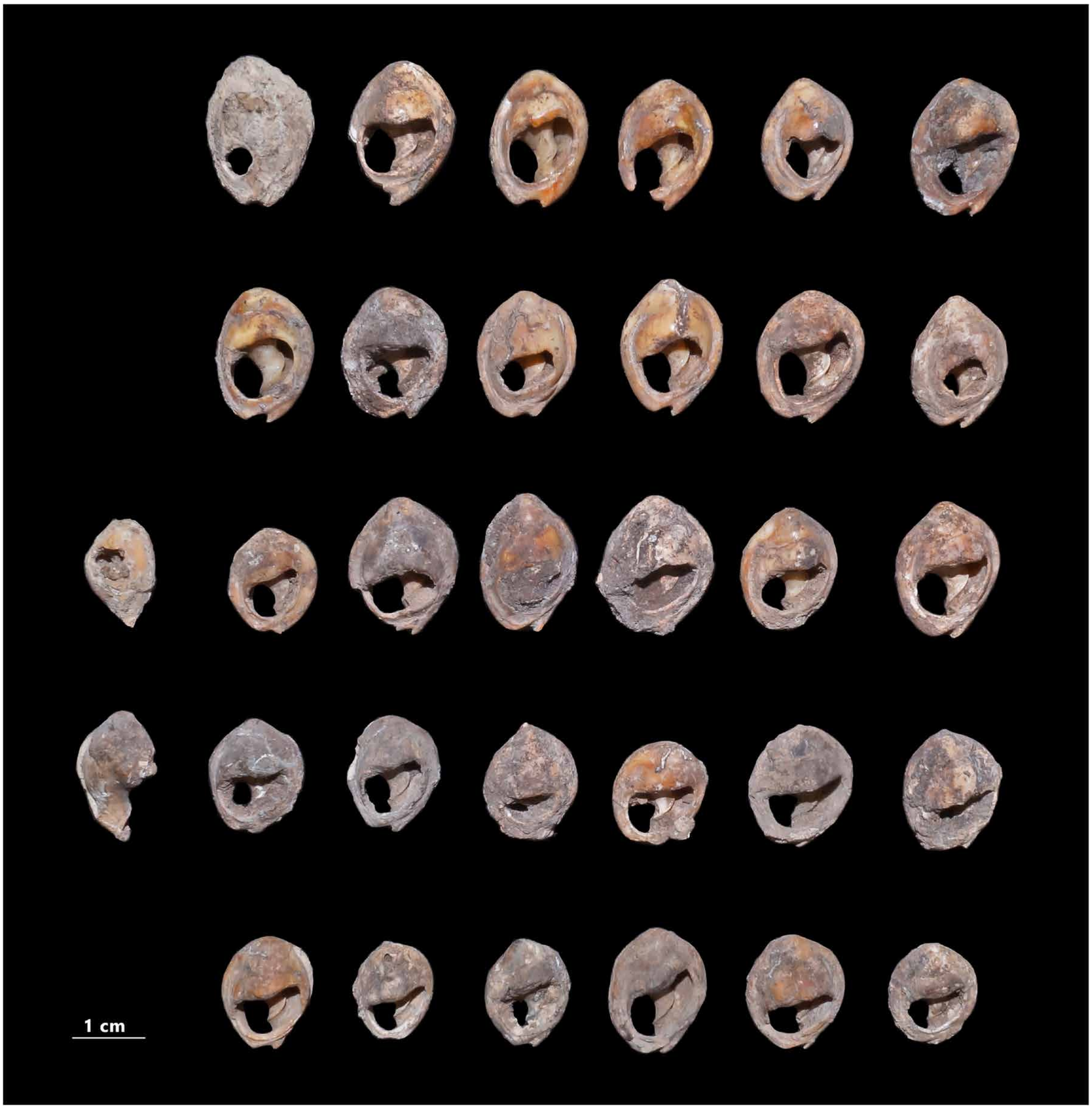

Fig. 5. *T. gibbosula* and *C. rustica* shells from layer 4c. Photo credit: A. Bouzouggar, INSAP, Morocco.

such as carved and polished bone tools (*25*) and beads also appear quite early in the North African record. The MSA cultural record in South Africa shows multiple cycles of change in material culture. In contrast, the archeological record of the MSA in western North Africa is notably stable, demonstrating marked continuity in material culture. The set of traits that define the Aterian—including tanged and bifacial tools, small Levallois cores, and *Tritia* beads—persisted with some modification from >140 ka to as late as ca. 60 ka. This observation is consistent with recent proposals that the cultural and biological evolution of *H. sapiens* in Africa occurred as a mosaic of local developments (*26*).

MATERIALS AND METHODS

Excavation methods at Bizmoune Cave follow common protocols for Paleolithic cave sites. All objects >15 to 20 mm in maximum dimension found during excavations—along with samples for geological, dating, and paleoenvironmental samples—are given unique numbers, and their locations were recorded in three dimensions within the cave. Most sediments from the excavation are dry-sieved through 4- and 2-mm mesh: Locations of sieved samples are also recorded in three dimensions. Systematically selected 5-liter samples of sediment are set aside for water sieving to recover macrofaunal and macrobotanical remains in the lab. Photogrammetric models of the cave and excavation trench are made yearly to situate geological and archeological findings.

The main aim of the geoarcheological studies of Bizmoune Cave is to reconstruct the formation processes of the archeological site, including the formation history of the cave chambers, mode of deposition, erosion and redeposition of sediment within the site, the meaning of stratigraphic divisions identified during excavation, and the integrity of any anthropogenic features (e.g., hearths) and

Fig. 6. Photographs of shell beads from layer 4c. (**1A and B and 2A**) Polish. Scale bars, 1 mm (1 and 2); 500 μm (1, A and B, and 2A). (**3A and 4A**) Possible modifications from the inner surface. Scale bars, 1 mm (3 and 4); 500 μm (3A and 4A). (**5A&B and 6A**) Red ochre residue. Scale bars, 1 mm (5 and 6); 500 μm (5A and 6A); 250 μm (5B). Photo credit: A. Bouzouggar, INSAP, Morocco.

other anthropogenic materials (e.g., bone or shell). Key methods include soil micromorphology, Fourier transform infrared spectroscopy (FTIR) on loose sediment and thin sections (μ-FTIR), and micro–x-ray fluoresence (μ-XRF) elemental mapping of thin sections and blocks.

Sediment and bedrock samples were collected from both the eastern and western chambers of the cave (Supplementary Text), as well as from modern soils outside of the cave. As excavations have not been conducted in the western chamber, sampling was limited to an eroded scarp of recent sediment that entered the cave via the western entrance. In 2014, 2016, and 2017, sediment samples were collected from active excavation areas and profiles in the eastern chamber. Oriented blocks were collected and processed into micromorphological thin sections. The blocks were dried and indurated

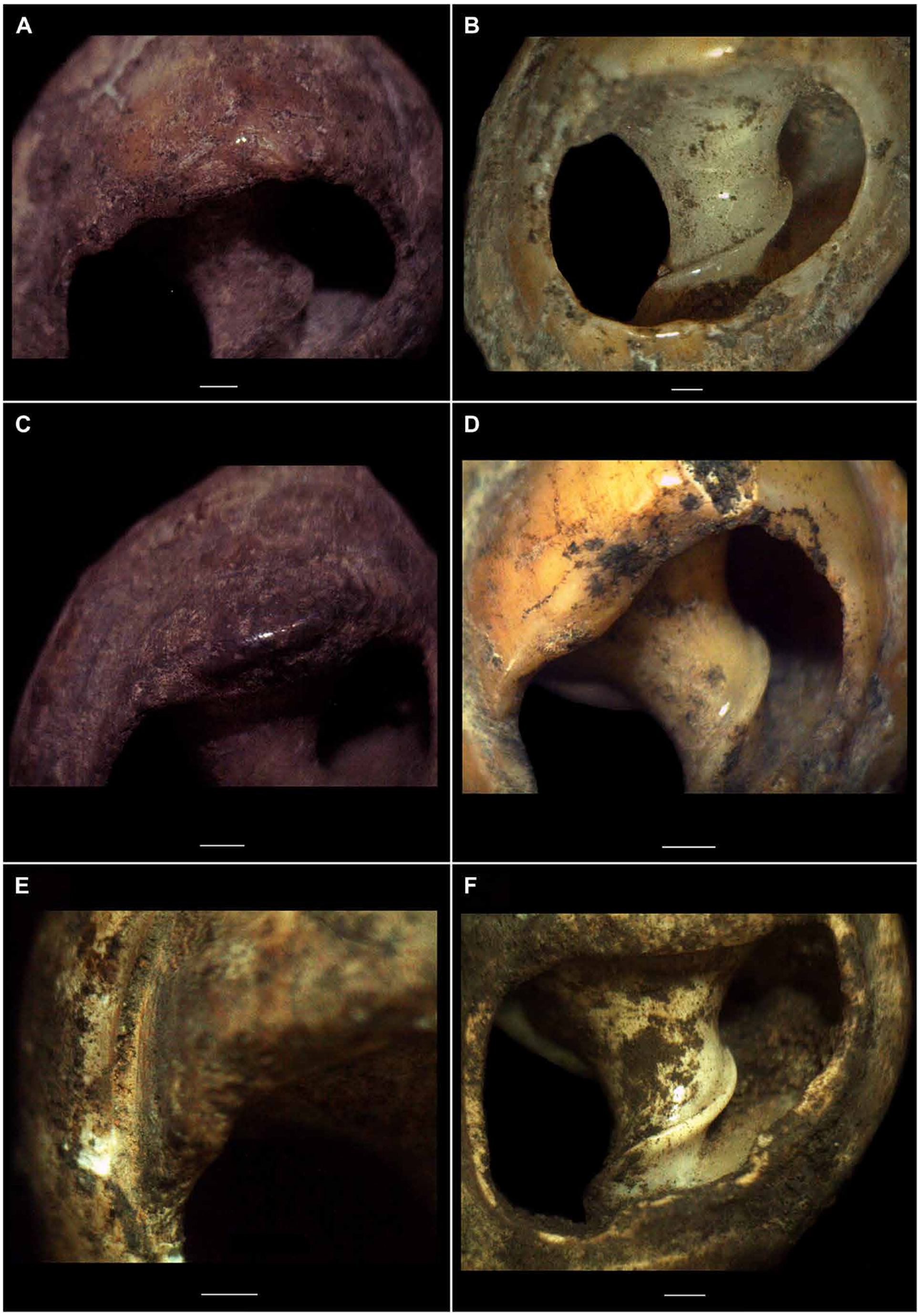

Fig. 7. Close-up photographs of apertures of shell ornaments. (**A** to **C**) Polish on the perforations. (**D** to **F**) Possible chipping from inside the shells. Scale bars, 1 mm. Photo credit: A. Bouzouggar, INSAP, Morocco.

with polyester resin at the University of Tübingen. The hardened blocks were then sliced with a diamond blade rock saw to expose oriented stratigraphic sequences, and areas were selected for processing into 6 cm by 9 cm petrographic thin sections. The thin sections were scanned at high resolution (4000 dots per inch) under plane- and cross-polarized light using a Nikon Super Coolscan slide scanner following protocols outlined by Haaland *et al.* (*27*). The samples were also studied at magnification using petrographic microscopes equipped with plane-polarized light, cross-polarized light, and oblique incident light. Some of the important features were photographed. Elemental mapping of thin sections was conducted using a Bruker M4 Tornado micro–x-ray fluorescence instrument.

Loose sediment samples were analyzed for mineral composition using a Fourier transform infrared spectrometer (Agilent Technologies)

Table 1. Summary of uranium-series and OSL results from Bizmoune Cave by layer (2-σ error).

	U-series speleothem		U-series tooth		OSL	Max Planck	OSL	Sheffield
Layer	Central age	Uncertainty	Central age	Uncertainty	Central age	Uncertainty	Central age	Uncertainty
2a	17,540	±1250	14,440	+1540/−1500				
	22,200	±2110						
2b			47,380	+7690/−6910				
2c	74,560	+13,860/−11,750						
	61,820	±14,990						
3					74,600	±10,400	75,000	±11,400
					75,300	±9000		
					69,400	±11,000		
					69,400	±8600		
					71,300	±10,200		
					68,200	±8400		
3b	93,850	+17,440/−13,450						
3 inf							95,000	±16,000
4a	102,980	±9620					82,700	±13,800
							83,900	±13,800
4b			110,690	+22,310/−17,250				
4c′	142,290	+29,300/−22,060						
4c			149,150	+63,840/−36,690	57,800	±7200	109,000	±18,000
					61,400	±7400	77,100	±12,800
							66,400	±10,800
							74,600	±12,800
							54,300	±9400

equipped with a diamond crystal attenuated total reflectance accessory (PIKE Technologies). The mineral components of the sediment were identified by comparing peak positions and intensities in the spectra to those of references. A few sediment samples were also processed into KBr pellets and analyzed in transmission mode. This processing strategy was aimed at confirmation of mineral identifications using reference spectral libraries [e.g., (*28*)].

The study of the shell beads followed the methodology developed for other MSA sites in Morocco (*29*). Shells covered with carbonate crusts were partly cleaned, but cleaning was limited so as to minimize damage while exposing as much of the modified parts of the shell as possible. Length, width, and parietal shield thickness were measured for nonfragmented specimens (fig. S4). Many vertebrate faunal remains are also coated with carbonate crusts. The crusts are removed using dilute acetic acid and low-impact mechanical means.

A preliminary use-wear analysis was conducted on a sample of stone tools from layer 4c. The collection includes tanged tools, side scrapers, end scrapers, and MSA/Aterian blades and bladelets. Artifacts were examined under a Nikon Eclipse LV100ND microscope. Most of analyzed specimens exhibit postdepositional damage, including randomly oriented linear features, sediment polish, light gloss, and white patina. As a consequence, use-wear analysis was limited to examination under a stereomicroscope for most artifacts.

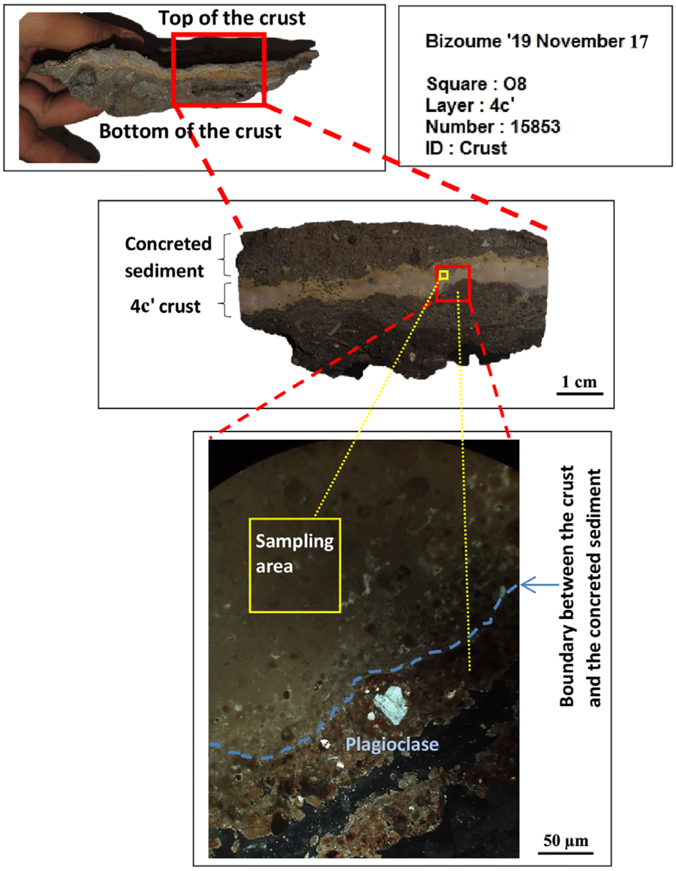

Fig. 8. Photograph and thin section of sample of speleothem from layer 4c′ dated to 142,290 years ago. Red box marks area sampled for dating. The area sampled is separate from the part of the flowstone containing detrital material (see Supplementary Text). Photo credit: A. Bouzouggar, INSAP, Morocco.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at https://science.org/doi/10.1126/sciadv.abi8620

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