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Material culture of the Sicilian Epigravettian: ornaments and tools from Trench M, San Teodoro Cave (Acquedolci, Messina)

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KEY WORDS
Upper Pleistocene,
Sicily,
ornaments,
Epigravettian,
red pigment,
San Teodoro Cave.

ABSTRACT
Renewed excavations at the significant Upper Pleistocene site of Grotta di San Teodoro in Acquedolci, Sicily, focused on a newly opened excavation area named Trench M. This is a sub-vertical cavity, which is approximately 1.80 metres deep and averages less than 80 cm in width, which revealed layers rich in Epigravettian artefacts, charcoal, faunal, and food remains. Three distinct deposits were identified during the excavation: a superficial layer (USM1) compromised/contamined, a middle layer (USM2) containing faunal remains and rare Bronze Age ceramics, and a deeper layer (USM3) resembling the Epigravettian layers already recovered in other areas of the cave. Discoveries from USM3 include distinctive artefacts such as perforated marine shells (several of which bear red pigment traces), a polished stone pendant, and other tools indicative of symbolic and hand-crafted/manufacturing activities. These remains highlight the sophisticated resource management and symbolic practices of the Epigravettian hunter-gatherer groups that occupied the site. This study provides valuable insights into the cultural dynamics and material culture of these ancient Sicilian Epigravettian communities.

MOTS CLÉS
Pléistocène supérieur,
Sicile,
ornements,
Épigravettien,
pigment rouge,
grotte de San Teodoro.

RÉSUMÉ
Culture matérielle de l'Épigravettien sicilien : ornements et outils provenant de la tranchée M, grotte de San Teodoro (Acquedolci, Messine).
Les fouilles renouvelées sur le site important du Pléistocène supérieur de la Grotta di San Teodoro à Acquedolci, en Sicile, se sont concentrées sur une zone de fouilles nouvellement ouverte, appelée Trench M. Il s'agit d'une cavité subverticale, d'environ 1,80 mètre de profondeur et d'une largeur moyenne inférieure à 80 cm, qui a révélé des couches riches en artefacts épigravettiens, en charbon de bois, en restes fauniques et alimentaires. Trois dépôts distincts ont été identifiés lors des fouilles : une couche superficielle (USM1) compromise/contaminée, une couche intermédiaire (USM2) contenant des restes fauniques et des céramiques rares de l'âge du bronze, et une couche plus profonde (USM3) ressemblant aux couches épigravettiennes déjà mises au jour dans d'autres zones de la grotte. Les découvertes provenant de l'USM3 comprennent des artefacts distinctifs tels que des coquillages marins perforés (dont plusieurs portent des traces de pigment rouge), un pendentif en pierre polie et d'autres outils indiquant des activités symboliques et artisanales/manufacturières. Ces vestiges mettent en évidence la gestion sophistiquée des ressources et les pratiques symboliques des groupes de chasseurs-cueilleurs épigravettiens qui occupaient le site. Cette étude fournit des informations précieuses sur la dynamique culturelle et la culture matérielle de ces anciennes communautés épigravettiennes siciliennes.

INTRODUCTION

The Grotta di San Teodoro, located in northern Sicily, in the province of Messina, is of considerable palaeontological and palaeoanthropological importance (Fig. 1). Extensive excavations have been carried out at the site since the 19th and 20th centuries (Anca 1860; Vaufrey 1928; Tricomi 1938; Maviglia 1941; Graziosi 1943, 1947; Graziosi & Maviglia 1947; Vigliardi 1968; Bonfiglio *et al.* 2001, 2003, 2008). New excavation campaigns began in 2018 during Vita's doctoral research and continued between 2021 and 2024, focusing on the Graziosi pit (Fig. 1C) and in other newly identified areas (Garilli *et al.* 2020a, b; Vita 2021; Forgia *et al.* 2025). Although numerous studies have explored the culture of Upper Palaeolithic European populations, including peninsular Italy, the scarcity of sites and materials in Sicily has hindered our understanding of the lifeways and cultural practices of the Epigravettian populations on the island (Leighton 1999). During the 2022 excavation campaign, an unexpected discovery was made in a lateral niche on the right wall near the entrance (Figs 1C; 2). Initially perceived as a simple recess, subsequent investigation revealed a deep, sub-vertical cavity extending to a depth of approximately 180 cm, with a variable width (averaging 80 cm), designated as Trench "M" (Fig. 1C, marked with a red spot). Due to its predominantly vertical orientation, excavating the sinkhole was challenging in places where it narrowed. Trench M yielded a substantial assemblage of intentional fractured bones, terrestrial gastropods, and flint and quartzite artefacts. In addition, among the most noteworthy remains in this study, there are personal ornaments, such as perforated marine shells and a stone pendant, as well as possible tools and implements. The recurrent selection of specific marine taxa across geographically dispersed sites suggests symbolic and cultural preferences, making Epigravettian shell ornaments a key proxy for understanding identity, interaction networks, and symbolic behaviour in southern Europe during the Late Glacial period. Other artefacts recovered from Trench M are currently under study and will be presented in future publications. Furthermore, the red pigment is being studied separately, as it requires specific chemical characterisation

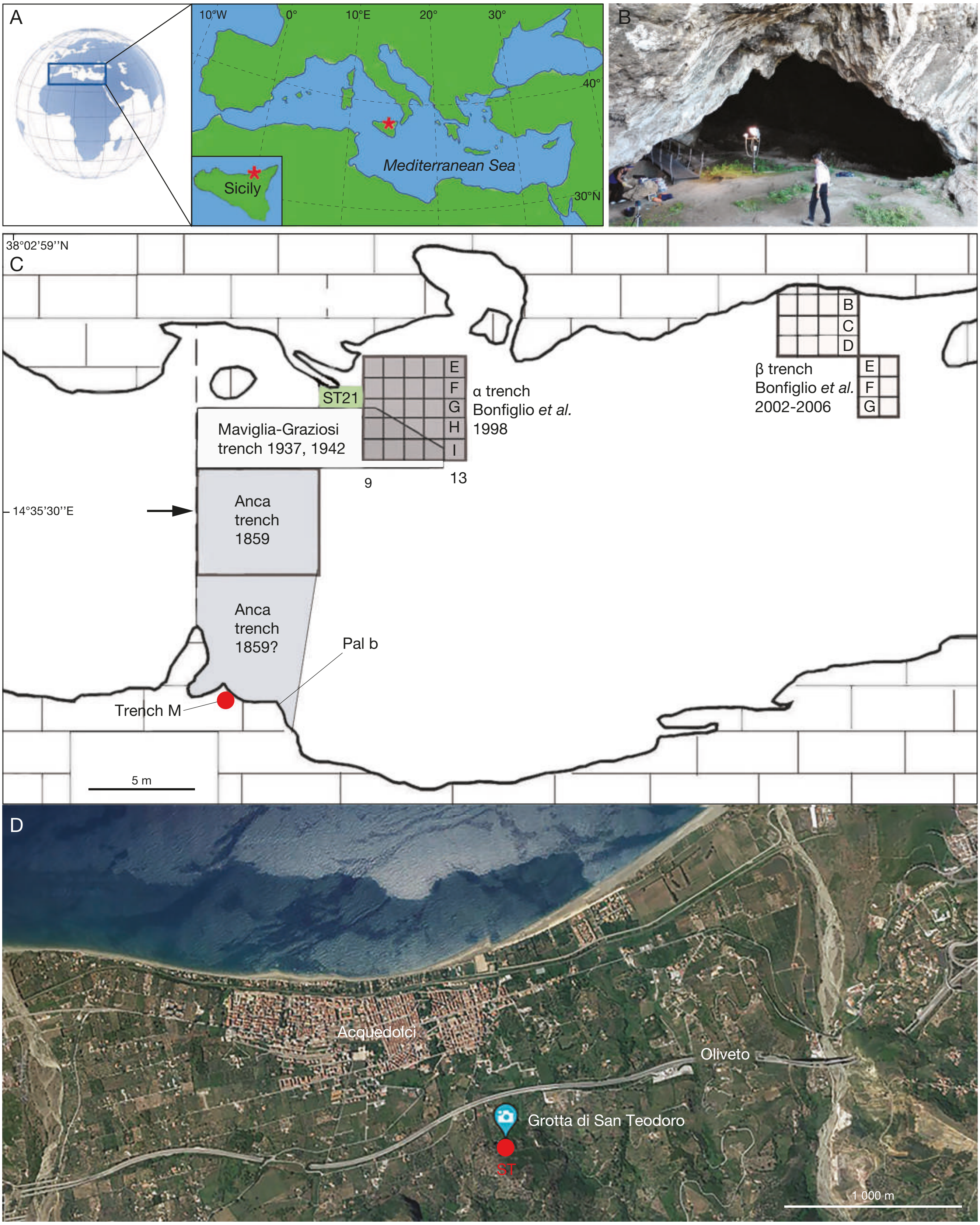

FIG. 1. — **A**, **D**, General location of the study sites; **B**, external view of the ST Cave; **C**, plan of the ST Cave (modified from Bonfiglio *et al.* 2001) showing the locations of the historical and recent excavations. The trench of the 2021 excavation is marked in **green**, and the Trench M in **red**. On the opposite side the position of Trench M here described, is marked in **red**, along with the indication of the breccia remnants Pal b (Garilli *et al.* 2020a); **D**, satellite image from Google Earth, modified, depicting the site, Grotta di San Teodoro site flagged in light blue.

and comparison with Sicilian ochres and other red pigments from the same period (Vita *et al.* 2024). Due to Sicily's insular condition during the Epigravettian, which resulted from a sea levels being approximately 120-90 metres lower than today (Lea *et al.* 2002; Antonioli *et al.* 2014), this study also aims to contribute to the understanding of whether, and to what extent, cultural interactions with the Italian Peninsula and with continental Europe occurred.

THE SITE

Background of the study site

The San Teodoro cave (ST) is located in northeastern Sicily, approximately 1 km from the village of Acquedolci (Messina) and around 1.2 km from the current coastline (Fig. 1D). During the Late Epigravettian occupation, about 15-17 kyr ago (Garilli *et al.* 2020a; Forgia *et al.* 2025), the sea level was approximately 120-90 m lower (Lea *et al.* 2002; Antonioli *et al.* 2014), meaning that the nearest coastline was around 6 km away from the study site. The cave is very large, consisting of a main chamber and a few smaller side chambers. The entrance aperture is about 5 m high and 15 m wide, with a maximum internal height of 20 m. Several excavations were carried out at the ST site from the late 1800s to the summer of 2024 (Anca 1860; Maviglia 1941; Graziosi 1943, 1947; Bonfiglio *et al.* 2001, 2008; Vita 2021, Vita *et al.* 2022a, 2024). Among the main trenches excavated, those of Anca (1860), Maviglia (1941) and Graziosi (1947) are no longer visible. The last excavation was carried out by our team/under the scientific direction of L.S. in the summer of 2025. The paleontological and radiometric analyses (Maviglia 1941; Graziosi 1943; Bonfiglio *et al.* 2001, 2008; Mannino *et al.* 2011; Garilli *et al.* 2020a; Vita 2021, Forgia *et al.* 2025) have provided insight into the stratigraphy and the chronology of the ST site (Appendix 1).

Stratigraphy of San Teodoro Cave

The basal unit of the cave (the E-F layer, as defined by Graziosi (1947) corresponding to the B unit by Bonfiglio *et al.* (2001)) consists of sandy-muddy sediments bearing a characteristic Late Pleistocene mammalian fauna belonging to the San Teodoro-Pianetti Faunal Complex (Bonfiglio *et al.* 2001, 2008; Mangano & Bonfiglio 2005). An intercalated concretion in the lower part of this unit has been dated to 32 ± 4 kyr from a $^{230}Th/^{234}U$ analysis (Bonfiglio *et al.* 2008). The skeletal remains of six human individuals (ST1-4 and ST6-7) were found in the upper part of this unit, near the entrance to the cave (Maviglia 1941; Graziosi 1943, 1947). Some of these individuals were probably buried at the same time about 15 kyr ago (Mannino *et al.* 2011; Garilli *et al.* 2020a) and covered with a large and thick layer of ochre (Graziosi 1947; Garilli *et al.* 2020a). The gastropods *Patella* sp. and the bivalve *Cerastoderma glaucum* have been recovered in this layer (Maviglia 1941). A younger anthropic unit (the D-A layers of Graziosi (1947), corresponding to the A unit of Bonfiglio *et al.* (2001) and the PAL layers of Garilli *et al.* (2020a) is currently exposed near the cave entrance, on proximity of the left rock wall. This unit consists of locally consolidated, reddish-greyish sandy sediments that are rich in organic remains (mainly fragmented bones), locally abundant charcoal (Lona 1949) and many lithic artefacts attributed to the Epigravettian culture (Vigliardi 1968; Vita *et al.* 2022a; Forgia *et al.* 2025). During the 2019 excavation of the PAL, a shell of the littoral gastropod *Tritia incrassata* (synonym of *Nassarius incrassatus*) was recovered, representing the only marine element has been described in the 2019 excavation of the PAL (Garilli *et al.* 2020a). Today this unit is preserved in the consolidated breccia exposed along the cave walls (Fig. 1C).

The PAL Layer

Following the recent resumption of excavations, it was decided to further rename the original layers excavated by Graziosi (A-D) as PAL layer, to indicate this stratigraphic set characterised by high human activity. The PAL layer (Garilli *et al.* 2020a) at San Teodoro Cave represents a distinct phase of late Upper Palaeolithic activity, stratigraphically positioned above the red ochre burial level. Consisting of two main facies (PAL1 and PAL2), it contains a high amount of burnt and fragmented faunal remains, lithic artefacts (mainly quartzite), charcoal, and terrestrial gastropods. This layer indicates a shift in site use from funerary to domestic and subsistence-related activities, including intensive butchering, marrow extraction, and cooking, as evidenced by the numerous cut marks and traces of burning recovered on the bones. The PAL units were in fact progressively destroyed during human occupation of the site and during the archaeological excavations of the last century, remaining only present in some peripheral areas, on the wall. An AMS ^{14}C analysis performed on an aurochs tooth collected from the lower part of this unit yielded an age of 15 224-14 708 cal years BP (Garilli *et al.* 2020a), which corresponds to the late Epigravettian occupation. The beginning of Epigravettian attendance has recently been dated to 16 500 BP (Forgia *et al.* 2025).

The lithic industries of San Teodoro Cave

The assemblage is characterised by a dominance of small- to medium-sized tools, primarily end-scrapers, burins, and retouched flakes, which are often made on short, thick blanks (Vigliardi 1968). As by Vigliardi (1968) and Martini *et al.* (2007) have previously noted, the site is characterised by the prevalence of marginal, direct retouch, and a lack of formal microliths, although some semi-microlithic elements are present. Together with the typological parallels to other southern Italian contexts, these traits support attribution to the Epigravettian, particularly its evolved and final phases. The upper portion of Layer D (Appendix 1), displays a return to more macrolithic forms, which Vigliardi interprets as a functional rather than chronological shift. Among the lithic assemblage from Grotta di San Teodoro, Vigliardi reports the presence of several backed points, primarily made from flint. Though not numerous, these pieces stand out for their relatively regular shaping

Fig. 2. — External view of the niche containing Trench M, the PAL-e breccia, and the location of the PAL-b breccia (labelled in **light blue**). The **red line** connecting the lower levels of the two breccias represents the presumed ground level during the Epigravettian period. The **transparent yellow silhouette** depicts the section of Trench M.

and careful retouching along one edge, forming a steep, often abrupt back. Their modest dimensions are consistent with Epigravettian typologies, and they probably served as armature elements for composite projectiles. The use of flint, a finer-grained and more workable material than the predominant quartzite, allowed for more precise shaping and finer retouch. Backed pieces can be considered as further evidence of cultural affinities with the broader Epigravettian technocomplex, particularly given their resemblance to similar tools found at contemporaneous sites in southern Italy. Forgia *et al.* (2025) also report this diversification in the lithic assemblage from San Teodoro, noting the use of local raw materials (both quartz-arenite and high-quality chert), likely collected from nearby riverbeds or beaches. The presence of all phases of the quartz-arenite *chaîne opératoire*, along with most phases of the flint production sequence, confirms on-site knapping activities. Retouched tools are scarce but they suggest a high level of technical investment in finishing, with deep, invasive retouches and the probable use of pressure flaking and anvil percussion, as attested by end-scrapers with flat, parallel negatives.

TRENCH M

Stratigraphy

Trench M is a natural recess that has been filled by a progressive stochastic accumulation. It was presumably included and sealed by the expansion of the breccia that covered both sides of its entrance, and which is visible in limited portions of the margins and the surrounding area. As in other parts of the cave, the breccia layer has been removed by anthropic activity, but the interior of this natural recess has presumably not been further modified except in the uppermost layers. Despite the limited reliability of a stratigraphic approach in this sub-vertical hole, we can provide evidence to support the identification of three main phases and three distinct horizons, proceeding from the top to the bottom (Fig. 3).

USM1

Superficial layer with an average thickness of about 10 cm consisting of greyish silty sand containing ancient and modern pottery, plastics, glass, and bone fragments.

TABLE 1. — ^{14}C and $^{230}Th/^{234}U$ Dates for Stratigraphic Layers at San Teodoro Cave.

Laboratory Number	Sample	Material Dated	$^{230}Th/^{234}U$ Age	^{14}C Age (BP)	Calibrated Calendar Age (cal. BP)	Cultural attribution	Layer/References
ND	Subsample 1	Flowstone	32 000 ± 400 Ky	–	–	–	Layer B, sublayer βCl in the β trench/ Bonfiglio *et al.* (2008)
ND	ST1	Human bone collagen	–	–	14 750	Late Epigravettian	Layer E (burial)/ Incarbona *et al.* (2010)
ETH-34451	San Teodoro 1	Human bone collagen	–	12 580 ± 130	15 232-14 126 (95.4%)	Late Epigravettian	Layer E (burial)/ Mannino *et al.* (2011)
DSH-2749	–	Equid bone collagen	–	18 330 ± 400	1σ: 22 340-21 440 (68%) 2σ: 23 230-23 120 (1%) 23 000-20 910 (95%) 20 680-20 570 (0.9%)	–	Layer B, facies B1 in the β trench/ Antonioli *et al.* (2014)
DSH9270-GE	ST-01	Aurochs tooth collagen	–	12 624 ± 59	1σ: 15 146-14 878 (100%) 2σ: 15 224-14 708 (100%)	Late Epigravettian	Layer PAL/ Garilli *et al.* (2020a)
LTL22344	ST21-1	Charcoal	–	14 140-13 780	16 090-15 730	Epigravettian	Layer ST21/ Forgia *et al.* (2025)
LTL22345	ST21-2	Charcoal	–	14 340-13 970	16 290-15 920	Epigravettian	Layer ST21/ Forgia *et al.* (2025)
LTL22343	ST21-3	Charcoal	–	14 740-14 360	16 690-16 310	Epigravettian	Layer ST21/ Forgia *et al.* (2025)

USM2

Intermediate layer with an average thickness of about 20 cm. Dark grey silty sand containing an Epigravettian lithic industry, charcoals, a few fragments of broken bones (from wild and domestic animals, including *Cervus elaphus* and *Capra* sp.), pottery presumably from the Bronze Age and many fragments of terrestrial gastropods.

USM3

Deepest layer within the sub-vertical cavity. It is approximately 1.50 metres thick, but we have not reached the bottom as the cavity narrows and splits into two smaller chambers. It is a filling of a dark coloured silty sand due to the presence of abundant charcoal. Many complete shells of terrestrial gastropods are dispersed in the sediment, and accumulated in two areas. There are numerous intentionally fractured bones and two modified bones consisting in two perforated red deer femurs. Furthermore, Epigravettian lithic artefacts made of both quartzite and flint, numerous processing waste and yellow flint projectiles were also found. Moreover, marine shells (four perforated and two red pigment-stained), a stone pendant and a red pigment-stained pebble (probably a pestle). Sporadic human bone remains from one adult and one infant were also found (not included in this discussion).

AMS radiometric analysis

An AMS ^{14}C dating was performed to define the chronostratigraphy of the USM3 and USM2. Radiocarbon analysis was conducted at the Innova SCaRl laboratory (Naples, Italy) on two femur fragments (*Cervus elaphus* and *Sus scrofa*) from USM3. A further attempt was made at Beta Analytic (Miami, Florida, United States) on two deer bones: one astragalus from USM3 and another from USM2.

The stratigraphic layers, the associated material culture, and the radiocarbon dates in the different excavation sectors of the cave are presented in Table 1.

The reconstruction of the paleosol and the genesis of the filling of the sinkhole

In order to gain a deeper understanding of the significance of this cavity, we endeavoured/attempted to reconstruct the likely level of the cave floor during the Epigravettian period. Examining the remnants of ossiferous breccia scattered around the cave, referred to as PAL (Garilli *et al.* 2020a; Vita 2021) scattered around the cave led us to conclude that the current ground level does not align with the historical one (Fig. 2; Appendix 2). A substantial sediment thickness of the sediment, ranging from 1.40 to 2 m, appears to be missing. We speculate that this deposit removal occurred during the 1859 excavation of Anca (Anca 1860; Fig. 1A) particularly in the proximity of the M area. While precise data on the extent of sediment removal is lacking, the presence of suspended breccia indicates its formation on the sediment supporting PAL-b (Appendix 2B). Based on the PAL-b and PAL-e breccias, we reconstructed the likely ground level during the Epigravettian period corresponding to the opening (niche) in the right wall, designated as trench M (Fig. 2, red line). This suggests that the niche was initially at ground level and gradually filled with various materials, including bones, land snails, Epigravettian lithic artefacts, and charcoals. Notably, due to the narrow and steep course of this natural sinkhole, no evidence of trampling by humans or animals was observed. Consequently, numerous fragile objects that would otherwise been fragmented by trampling have been preserved in this deposit, including two strata of fragile marine shells such as *Columbella*.

MATERIAL AND METHODS

Faunal assemblage

During the sieving of the sediment contained in trench M, several bones were recovered, most of which showed signs of breaking and chipping.

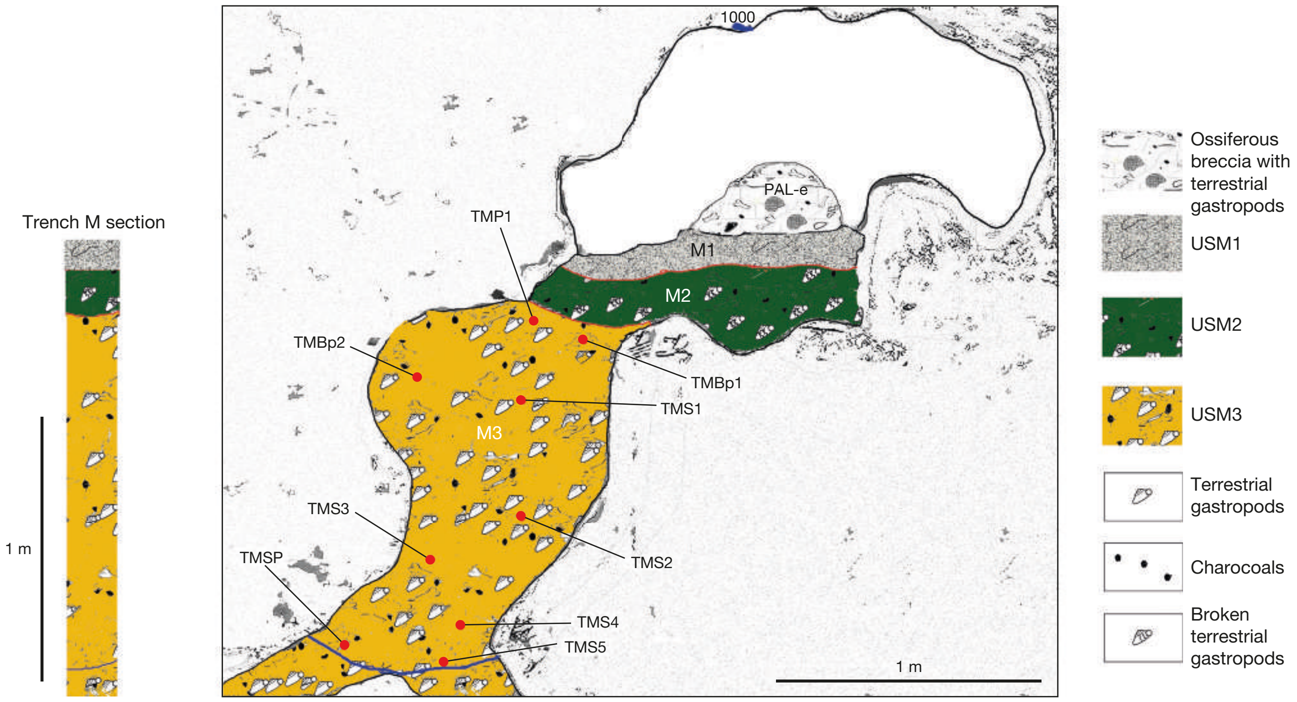

Fig. 3. — Section of Trench M showing the niche containing PAL-e and the stratigraphy with layers M1, M2 and M3. The **blue line** indicates the level reached by the excavation. The **red points** indicate the location of the finds of Table 2; 1 000 represents the reference quota. Abbreviations: **TMBp**, Trench M Bone perforated; **TMP**, Trench M Pestle; **TMS**, Trench M Shells; **TMSP**, Trench M Stone Pendant; **USM**, Unità Stratigrafica M.

These were mixed with terrestrial snails, charcoal, and Epigravettian lithic artefacts. Animal remains have been collected and identified through the reference osteological collections at the Laboratory of Anthropology of the University of Palermo (LabHomo) and in the Laboratory of Archaeozoology at the University of Ferrara. Specific manuals were also consulted (Pales & Lambert 1971; Schmid 1972; Pales & Garcia 1981; Cohen & Serjeantson 1996). The Number of Identified Specimens (NISP) was used for the preliminary quantitative analysis of the sample. This allowed to estimate the total number of the remains, including fragments (Grayson 1984). Taphonomic data were collected following among others Fernandez-Jalvo & Andrews 1996; Vettese *et al.* 2020. However, analysis is still ongoing.

Ornaments and small finds

As previously mentioned, Trench M has revealed itself to be very rich in lithic industry, bone objects and “jewels” of intentional artistic production.

The samples are summarised in Table 2.

Method

Reference articles for technology analysis and use-wear

As far as the drilling method is concerned and use-wear analysis, we compared the shape of the hole with the experimental data obtained by Harzhauser *et al.* 2007; Tátá *et al.* 2014; Cabral & Martins 2016; Cristiani *et al.* 2020; Hoareau *et al.* 2021a; and studies on archaeological samples by André & Bicho 2016; Cabral & Martins 2016; Rigaud & Gutiérrez-Zugasti 2016; Guzzo Falci *et al.* 2019; Bar-Yosef Mayer *et al.* 2020; Cristiani *et al.* 2021.

Table 2. — Materials under study taken from Trench M.

Sample	Material
TMS 001	*Columbella rustica*
TMS 002	*Columbella rustica*
TMS 003	*Anadara gibbosa*
TMS 004	*Naticarius* sp.
TMS 005	*Patella caerulea*
TMS 006	*Glycymeris glycymeris*
TMBp 001	*Cervus elaphus* femur
TMBp 002	*Cervus elaphus* head femur
TMSP 001	Stone pendant
TMP 001	Pebble (pestle)

Stereomicroscope analysis

In order to investigate the morphological characteristics of perforations on shell and bone artefacts, we employed a Hirox HRX-01 digital optical microscope. This high-resolution system is capable of both two- and three-dimensional imaging. The magnification of this Hyrox system provides a magnification ranges from 20× to 160×, allowing for detailed examination of microtopography and surface alterations without the need for coating or destructive preparation. Regarding illumination, observations were carried out using auxiliary lamps, which enabled the adjustment of the light’s position to highlight the area of interest. This provided a clearer view of the edge morphology, wear patterns, and potential manufacturing traces. This method was particularly

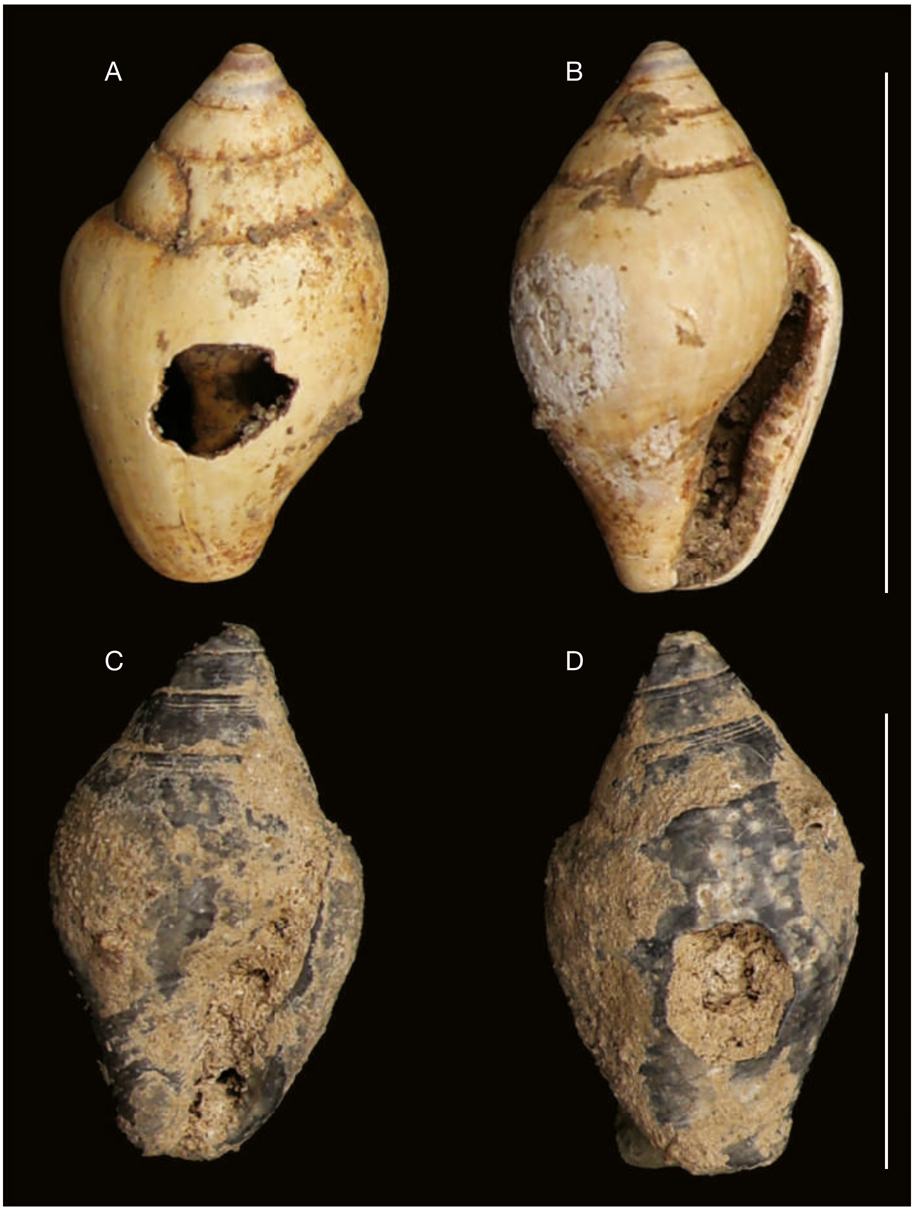

Fig. 4. — **A**, Dorsal view of *Columbella rustica* (Linnaeus, 1758) TMS1 shell with hole; **B**, apertural view of *Columbella rustica* TMS1 shell; **C,** apertural view of *Columbella rustica* TMS2 shell; **D**, dorsal view of *Columbella rustica* TMS2 shell with a hole. Scale bars: 1.5 cm.

effective in distinguishing between natural and anthropogenic perforations, as well as identifying traces of rotational or percussive techniques that may have been used in the manufacturing process. Selected specimens were further reconstructed in 3D to assess the depth and morphology of perforation traces, as well as any evidence of biogenic or anthropogenic modifications.

Abbreviations

PAL	Paleolithic anthropogenic layer;
USM	Unità Stratigrafica M;
ST	San Teodoro cave;
TMS	Trench M Shells;
TMBp	Trench M Bones perforated
TMSP	Trench M Stone Pendant
TMP	Trench M Pestle.

RESULTS

Technological analyses and use-wear analyses

We analysed a few objects which, based on the current literature and the use of stereomicroscope are interpreted as ornaments or tools.

TMS1

Columbella rustica (TMS1; Fig. 4A, B) has a pseudo-circular hole with an irregular outline. Cristiani *et al.* (2020) achieved this result and found that such a morphology can be obtained by striking the shell with a flint tool. This specimen (Fig. 5A) features a large, irregularly shaped perforation with extensively smoothed and rounded edges, indicative of prolonged mechanical wear. The degree of polish and the absence of sharp

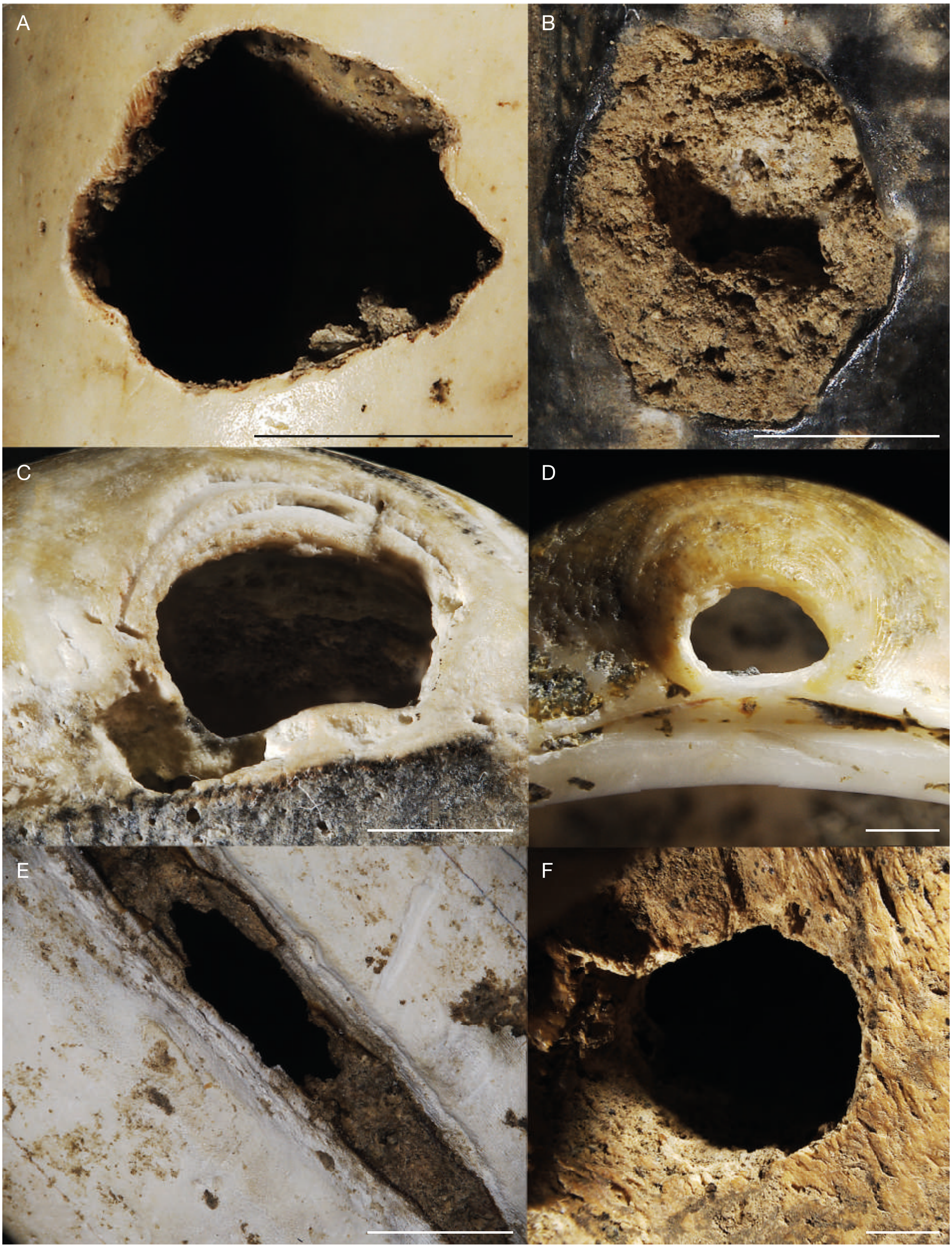

FIG. 5. — **A**, **B**, *Columbella rustica* (Linnaeus, 1758): **A**, the hole displays an irregular perforation with extensive edge rounding and internal polish, indicative of prolonged suspension use; **B**, the hole exhibits a circular perforation partially filled with sediment. The shell also presents surface encrustations and signs of corrosion, likely resulting from bacterial activity; **C**, *Anadara gibbosa* (Reeve, 1844). The hole has an oval shape with asymmetric wear and directional polishing, consistent with cord passage; **D**, *Glycymeris* sp. A well-defined hole with smooth, polished edges, suggesting use as a pendant or sewn ornament; **E**, *Naticarius* sp. The shell shows an elongated perforation with heavy edge abrasion and sediment accumulation, indicating prolonged use and post-depositional burial; **F**, close-up of the perforation on a red deer bone. The asymmetrical outline of the hole, along with radial striations and concentric micro-fractures (particularly visible in the upper left), suggests a manually executed rotary abrasion technique. The incision appears deeper on one side, consistent with unidirectional drilling. Scale bars: 2.000 mm.

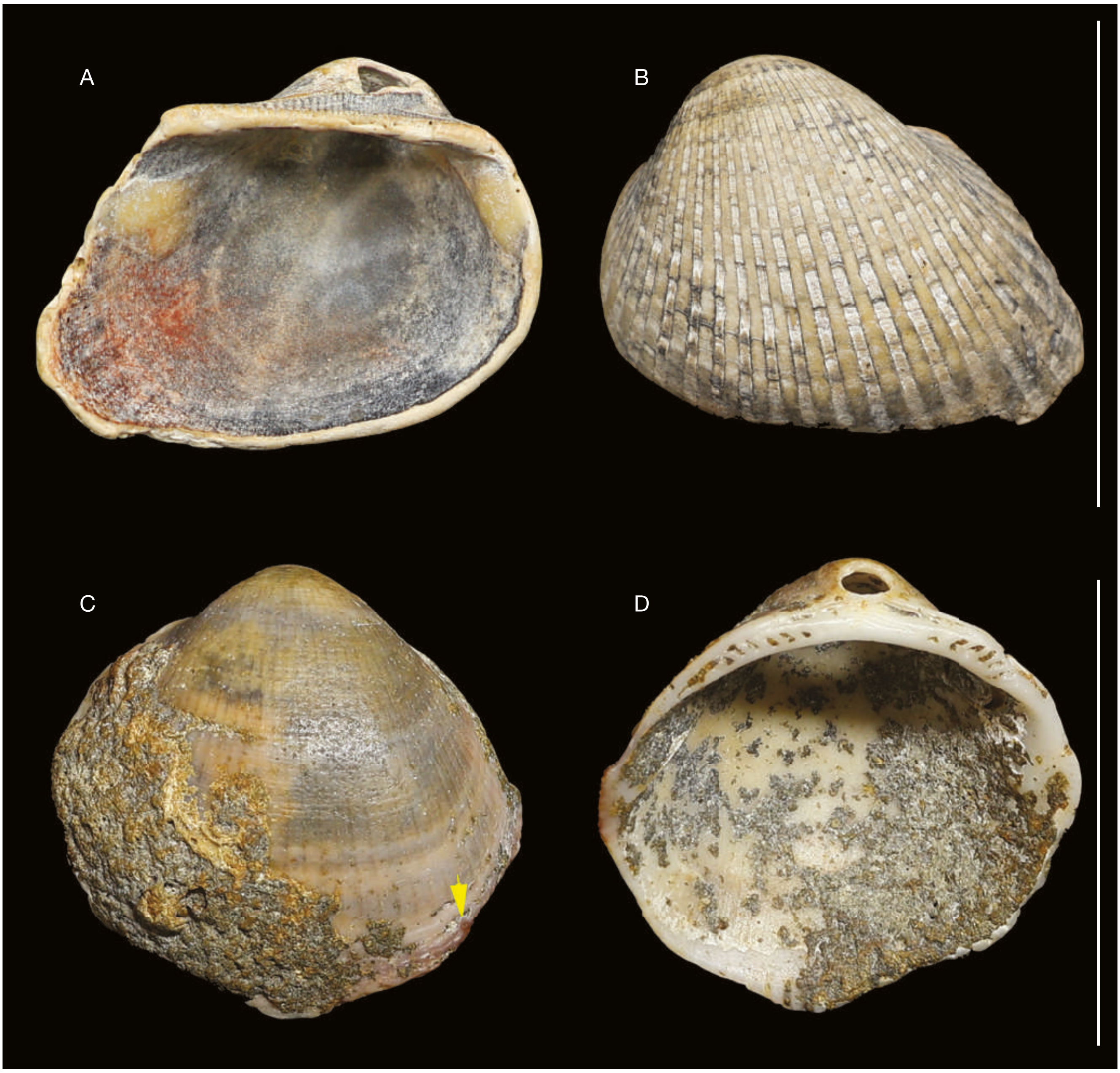

Fig. 6. — **A**, **B**, ventral, and dorsal view of *Anadara gibbosa* (Reeve, 1844). In the lower left part of the ventral view, red pigment stains are visible; **C**, **D**, ventral, and dorsal view of *Glycymeris* sp., a small trace of red pigment remains on the lower right part of the dorsal surface (**yellow arrow**). Scale bars: A, B, 3 cm; C, D, 4 cm.

fractures suggest repeated contact with a flexible element, such as a cord or fibre, which was likely used for suspension. The morphology and wear pattern are consistent with the object being used as a personal ornament, possibly as a pendant.

TMS2

Columbella rustica (TMS2) has a hole on the dorsal side, (Fig. 4C, D), and features a fairly regular, circular hole (Fig. 5B). Experimental data from Cristiani *et al.* (2020) show that this hole morphology can be produced by striking the shell with a pebble. Hoareau *et al.* (2021a) achieved a similar result through abrasion on rough stone. The only way to distinguish between these two techniques is to look for traces of abrasion near the hole. However, due to the presence of abundant sediments on the inside of the shell, the evidence of the wear is more difficult to detect. The polishing observed on some edges of the hole could be caused by a thin thread or string.

TMS3

Anadara gibbosa (TMS3) has a subcircular hole with abrasion marks located near the perforation (see Fig. 6A). In the case of TMS3, a subcircular perforation is located near the umbo. The drilling method probably involved a combination of abrasion and light percussion. The oval-shaped hole shows significant asymmetric wear, particularly on the upper margin (Fig. 5C). The inner edges are rounded and show

Fig. 7. — **A**, Dorsal and ventral view of *Patella caerulea* Linnaeus, 1758, with visible red pigment stains inside the shell (**blue arrows**); **B**, dorsal view of *Naticarius* sp. displaying a visible cut; **C**, detail of the cut. Scale bars: A, B, 3 cm; C, 1.5 cm.

localised polishing, which is strongly indicative of friction caused by the repeated movement of a suspending cord. The directionality of the wear supports the interpretation of its use as a hanging ornament.

TMS4

Naticarius sp. (TMS4) appears to bear engravings and sawing marks (Fig. 7B). The shell has thin incisions (Fig. 7B), which were likely caused by repeatedly sliding a flint blade back and forth, as well as a narrow, elongated slit (Fig. 7C), which is consistent with sawing, and is comparable to figure 4b in Hoareau *et al.* (2021a). The elongated perforation on this shell is bordered by highly abraded and polished surfaces, indicating intense and possibly directional use-wear (Fig. 5E). The irregular outline and the presence of residual sediment suggest that the object had been used extensively before burial. The morphology and polish distribution could be consistent with a sewn ornament or a shell incorporated into a flexible structure, such as a garment. The incisions above the hole that seem to form a pattern are most likely recent. Due to the difficulty of excavating such a small cavity, the shell may have been damaged during extraction.

Fig. 8. — Frontal view of the two faces and lateral view of the broken stone pendant, showing numerous traces of polishing on the profile face. Scale bar: 3 cm.

TMS5
Patella caerulea (TMS5) bears traces of red pigment on its inner surface (Fig. 7A).

TMS6
Glycymeris sp. (TMS6, Fig. 6C, D) has an almost perfectly circular hole in the umbo. It was most likely bored naturally by a mollusc predator and the shell was introduced into the cave already perforated. Cabral & Martins (2016) observed that numerous specimens of *Glycymeris glycymeris*, often display natural perforations near the umbo on Portuguese beaches. It has been suggested that Palaeolithic populations may have collected already-perforated specimens. This specimen shows a neatly formed perforation with clearly polished inner margins (Fig. 5D). The even, smooth surface around the hole points to extensive contact with a cord or thread, that was likely used to string the item. The intensity of the wear and the regularity of the polish suggest sustained use, possibly as part of a necklace or composite ornament. Traces of red pigment are also present.

TMSP1 stone pendant
A stone pendant shows evidence of smoothing, particularly along its profile (Fig. 8). This effect is partly due to the characteristics of the raw material: the two larger surfaces are naturally pseudo-smooth owing to the rock's foliated structure, while the lateral sides required additional abrasion to achieve a comparable finish. As the stone is fine-grained, shiny, and foliated, it is likely a phyllite (on the base of GV personal professional expertise). Confirming this would require thin section analysis; however, given the uniqueness and rarity of the object, no further destructive analyses were undertaken.

TMP1 pestle
A pebble bears red pigment residues (Fig. 9A) on its well-rounded, smooth end. It also displays striations that suggest it was used as a grinding tool (Fig. 9B-D, blue arrows).

TMBp1
A bone perforation on the distal epiphysis (Appendix 3A, B) of a red deer femur does not appear to be of an anatomical nature, because as it exhibits asymmetry along the edge and an irregular diameter that does not conform to the typical morphological characteristics of the bone structure (Fig. 5F). The presence of radial striations and concentric micro-fractures visible around the hole (particularly in the upper left area) and the depth of the incision (which appears larger on one side) could suggest a manual perforation method. The area surrounding the hole shows slight polish and rounding, potentially due to contact wear or prolonged handling.

TMBp2
The perforated femur head features a non-perfectly circular aperture (Appendix 3C, D). The margins of the hole are smoothed and show concentric micro-fractures, which are compatible with bidirectional or alternating drilling. This would be necessary to create a central aperture in such a dense anatomical area. Surface polish is visible around the hole, especially in Appendix 3D, along with slight flattening of the edges. This may indicate wear from suspension or repeated contact with other materials.

Faunal assemblages
The faunal assemblage recorded in Trench M shows strong similarities to the PAL layer in the previously studied relict sectors (Garilli *et al.* 2020a), particularly regarding to the prevalence of large ungulates such as *Cervus elaphus* and *Sus scrofa*. Actually, a substantial proportion of the material, consists of unidentified large ungulate bones, indicating a high degree of fragmentation. This fragmentation is not random but rather the result of intentional human processing, most likely linked to marrow extraction, as evidenced by numerous percussion marks and fresh fracture patterns in the PAL layer. Furthermore, the presence of burnt bones in the assemblage suggests that combustion was a systematic activity during food processing, either through roasting or waste disposal in hearths. The high level of fragmentation, coupled with the scarcity of complete elements and the abundance of cortical bone splinters, points to intensive butchering practices, consistent with a subsistence-oriented occupation. This pattern reinforces the interpretation of these contexts (PAL and M) as reflecting functional domestic activities, with a strong focus on optimising the nutritional yield from large game. In contrast, the bird bones from Trench M show no evidence of human modification or burning, suggesting that they may

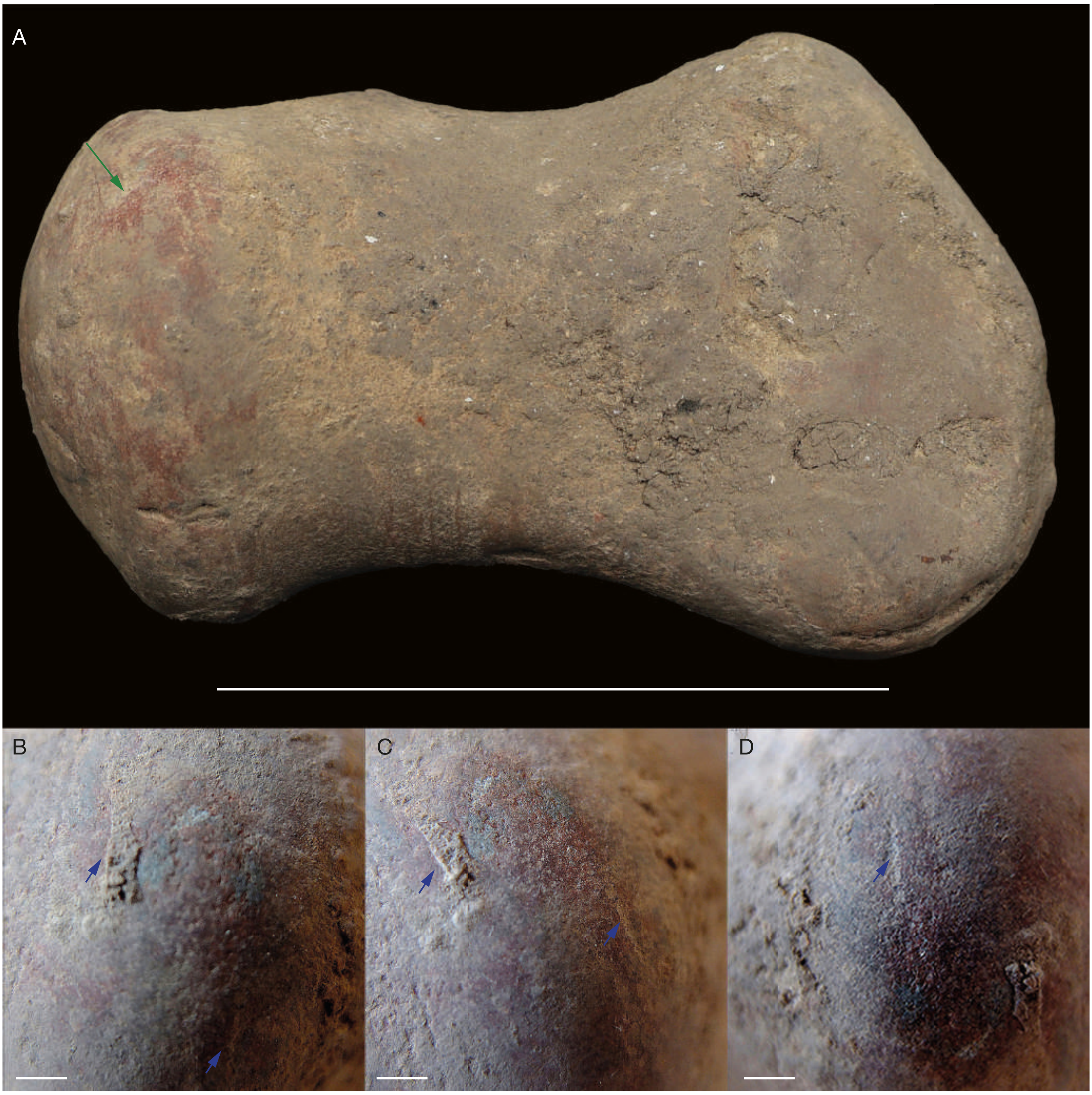

Fig. 9. — **A**. Eight-shaped pebble, with the left side rounded and smooth, displaying traces of red pigment (**green arrow**); **B**, **C**, **D**, details of traces of red pigment and pebble use as striation (**blue arrows**). Scale bars: A, 8 cm; B-D, 8 mm.

have accumulated through raptor activity (Rufà & Laroulandie 2021). Amphibians such as toads may enter caves naturally, as they favour cool and humid environments (Lanza *et al.* 2007). However, we cannot exclude the possibility that these taxa were actively collected for nutritional or other purposes. It is interesting that the specimens of red fox, are more numerous than in other areas of the cave. Presumably, the sediments in Trench M preserved their fragile bones better. The specimens of *Vulpes vulpes* deserves further analysis, as this animal was shaping a synanthropic niche in the Late Epigravettian, and it could not have been an exception in ST.

As regards the faunal composition, the number of remains and their relative percentages are shown in Table 3.

The lithic industries of USM3

The lithic assemblage from USM3 at Grotta di San Teodoro comprises approximately 70% quartzite and 30% flint artefacts. The quartzite component (Appendix 4) comprises coarser, less finely worked artefacts, such as cores, flakes, and tools shaped on flakes or fragments. These are generally more roughly made, suggesting a less formalised production sequence compared to the flint tools. The flint artefacts (Appendix 5)

TABLE 3. — Composition of the faunal remains found in USM3.

Taxa	NR	Percentage of bones
Mammalia		
Vulpes vulpes	9	1.30%
Large indeterminate ungulates	189	27.23%
Sus scrofa	121	17.44%
Cervus elaphus	248	35.73%
Equus hydruntinus	1	0.14%
Aves		
Columba palumbus	5	0.72%
Turdus sp.	1	0.14%
Amphibia		
Bufo sp.	2	0.29%
Gastropoda		
Patella caerulea patellidae	1	0.14%
Columbella rustica	2	0.29%
Cornu aspersum	107	15.42%
Naticarius sp.	1	0.14%
Bivalvia		
Anadara gibbosa	1	0.14%
Glycymeris sp.	2	0.14%
Mytilus galloprovincialis	2	0.29%
Venus sp.	3	0.43%
Total fauna	694	

include cores, blades, bladelets, points, and flakes of varying sizes. Several specimens show a refined débitage technique, aiming at the production of elongated blanks for composite tools. Among the flint implements, backed bladelets (both straight and curved) are present and indicate a microlithic tradition consistent with the Final Epigravettian, as described by Martini *et al.* (2007). The occurrence of microburins further supports this association, as they are typically by-products of microlith fabrication. Several tools (Appendix 5), such as the thick end-scraper (specimen 1) and retouched flakes and blades (e.g. specimens 4, 8, 11), correspond to general Upper Palaeolithic tool types (Clark 1969). Regular blades without standardised retouch (e.g. specimen 7) may represent blanks or early-stage tools, a feature documented in Epigravettian *chaînes opératoires* (Martini *et al.* 2007). Notably, geometric microliths are absent from the assemblage, while the abundance of quartzite artefacts (Appendix 4) recalls the macrolithic component observed in Layer D by Vigliardi (1968). Although Martini *et al.* (2007) do not use the term "macrolithism", they note the persistent use of large tools alongside microliths in several Sicilian contexts. This reflects a diversification in tool production strategies, rather than a strict adherence to microlithic norms. Specimens 2, 5, and 6 in Appendix 5 are typical backed bladelets, characteristic of the Late Epigravettian in Sicily.

RADIOCARBON DATING

No results were obtained from the bones from USM3. Attempts to use radiocarbon dating on the femur and astragalus samples from USM3 failed due to the absence of collagen. This outcome is likely attributable to extensive post-depositional diagenesis, particularly microbial degradation processes. Anaerobic bacteria such as Clostridium perfringens are known to play a significant role in the breakdown of bone collagen through the secretion of collagenolytic enzymes, as demonstrated in both experimental and archaeological contexts (MacLennan *et al.* 1953; Collins *et al.* 2002; Jans *et al.* 2004). The enzymatic activity of bacterial collagenase leads to the fragmentation of collagen fibrils, thus compromising the structural and chemical integrity of the bone matrix (MacLennan *et al.* 1953). Furthermore, the archaeological context in which the bones were found, characterised by a confined sedimentary space, high organic content, and evidence of burning may have further promoted additional microbial activity and collagen loss. The following dating was obtained for a deer astragalus from USM2 (at the top of the trench): Conventional Radiocarbon Age 4660 +/- 30 BP (Appendix 6).

DISCUSSION

FAUNAL ASSEMBLAGES, BONE, PESTLE AND STONE ORNAMENTS

The opening of a new trench near the western wall of the cave in 2021, in correspondence with a natural sinkhole, enabled interesting cultural evidence to be collected, over a two-year excavation campaign, of interesting cultural evidence. This evidence includes modified marine gastropods and bivalves, red pigment, a stone pendant, perforated bones, and zooarchaeological evidence deriving from human occupation and food processing activity. Regarding the faunal composition, the stratigraphic unit under study (USM3) does not differ significantly from the assemblages recovered in the opposite part of the cave (Garilli *et al.* 2020a). In Trench M, Bos remains were not identified, though it cannot be excluded that they are present within the relevant percentage of unidentified bone fragments. Notably, it differs from the faunal assemblage described in the PAL layer on the opposite side of the cave (Garilli *et al.* 2020a) due to the large number of terrestrial gastropods. In in two levels these form an assemblage of intact specimens (Appendix 7). Small and fragile bones such as those of birds and amphibians, may be better preserved here due to the absence of trampling pressure. USM3 shows a faunal content and lithic industry that closely resemble that of the PAL layer of the eastern side of the cave (Garilli *et al.* 2020a; Vita 2021), Consequently, it can be inferred that the unit contains materials that are chronologically comparable to those dated in the anthropological PAL layer. Although no radiocarbon dates are available for USM3 due to the absence of preserved collagen, Trench M is situated within a narrow vertical sinkhole, a geomorphological setting that likely contributed to poor sediment oxygenation. Such low-oxygen conditions would have favoured the proliferation of anaerobic microorganisms and intensified collagen degradation. These remains align with broader patterns observed in taphonomic analysis, which highlight the importance of both environmental and biological factors in collagen preservation. These issues constrain the chronological interpretation and reinforce the need to rely primarily on material culture for cultural attribution. The cultural attribution of this unit can be reliably inferred from the technological and typological characteristics of the lithic assemblage. The lithic industry is dominated by both quartzite and flint artefacts, the latter showing a clear laminar and microlithic component. The presence of backed bladelets (including curved and straight-backed points), microburins, and regular elongated blanks (Appendix 5) are diagnostic features of the Epigravettian tradition, and are widely attested in the Late and Final Epigravettian horizons of southern Italy and Sicily (Martini *et al.* 2007). In the Palaeolithic period, personal ornaments held symbolic significance, representing cultural identity, social hierarchy, and communication within and beyond the group (Maudet 2002). However, it was during the Upper Palaeolithic that *Homo sapiens* began to make extensive use of ornaments. Evidence of this can be found in numerous studies (Álvarez Fernández 2006; Vanhaeren & d'Errico 2006; Zilhão *et al.* 2010; Borić & Cristiani 2019; Arrighi *et al.* 2019; Cârciumaru *et al.* 2019; Perlès 2019; Shunkov *et al.* 2020; Tejero *et al.* 2021; Velliky *et al.* 2021; Rigaud *et al.* 2022; Borić *et al.* 2023; Gazzo *et al.* 2025). These artefacts, which were crafted from materials such as shells, ivory, stone, bones, and perforated teeth, contributed to the cultural repertoire of Palaeolithic communities (Kuhn *et al.* 2001; Baker *et al.* 2024 with references therein). The use of perforated bones in the Upper Palaeolithic has been documented for use as buttons on clothing (Ambrose 2001; Gilligan 2010; Cârciumaru *et al.* 2019) as well as for use as beads (Shunkov *et al.* 2020). The pierced red deer femur head TMBp1 (see Appendix 3C, D) suggests a potential use as either a point or a percussion instrument. This pierced femur head may be a bead or button. The drilling technique indicates that the hole in TMBp2 was created by a skilled hand, and the shape and internal surface of the hole suggest that a pointed tool was used in a rotating motion. The intended purpose of the pierced TMBp2 red deer femur bones cannot be determined (Appendix 3A-D). The stone pendant TMSP1, a key find from Trench M, underwent painstaking work; in addition to the surfaces being smoothed, the corners were rounded off. This object is a new specimen in the Sicilian archaeological context, and its shape likely held precise significance. The raw material is probably phyllite; this lithotype is quite common in the area and is found in the epimetamorphytes of Longi-Taormina (Giunta & Carbone 2013). Stone pendants have been found at several Palaeolithic sites (Rigaud *et al.* 2014; Cârciumaru 2022; Baker *et al.* 2024; Cârciumaru *et al.* 2024) and were made from different types of rocks with various petrographic characteristics and colours. This adds to the growing body of evidence for the symbolic role of such objects. Groundstone tools used for grinding ochre have been recovered in some Palaeolithic sites, especially in burials (Clark & Brown 2001; Dubreuil & Grosman 2009; Granato 2011; Cristiani *et al.* 2012; Richter *et al.* 2019). In the Oriente Cave on the island of Favignana, a pebble bearing traces of ochre was found in an Epigravettian burial (Mannino 2002; Vita *et al.* 2022b, 2024). The pebble (TMP1), which was used as a pestle, may have been sourced/collected from the terraces above the cave, where the raw material for the lithic artefacts was obtained (Vita *et al.* 2022a). In addition to presenting traces of ochre (Fig. 9A) on its rounded part, traces of streaks due to grinding can be seen (Fig. 9B-D).

The shell ornamentes

The symbolic use of marine shells for personal adornment is a long-standing tradition in human prehistory. Early examples can be traced back to Neanderthals in the Middle Palaeolithic, as evidenced by the modified shells from Cueva de los Aviones site, dating back approximately 115 ka BP (Hoffmann *et al.* 2018). Although molluscs were also consumed as food at Middle Palaeolithic sites in the Middle East and Europe (Bar-Yosef 2005), their intentional selection, modification, and use as body ornaments only became widespread with anatomically modern humans. Within this framework, the Epigravettian tradition on the Italian Peninsula is one of the most significant regional traditions in the use of marine shells as ornaments, with frequent selection of *Tritia incrassata, T. reticulata, T. gibbosula, Columbella rustica, Mitrella scripta, Antalis* sp., and *Glycymeris* sp. (Hoareau *et al.* 2021a, with references therein). The proportions of these species vary from site to site, with other species being rarer (Bar-Yosef 2005). In Sicily, examples of Palaeolithic ornaments include perforated shells found in Burial A of Grotta d'Oriente on the island of Favignana (Mannino 2002), including eight shells of Lurida lurida and two shells of Ostrea sp. In Grotta d'Oriente, burial C also contains some perforated shells in an Epigravettian layer, including one engraved shell of *Columbella rustica*, one shell of *Cerithium* sp., and one of *Tritia incrassata* syn. *Nassarius incrassatus* (Cilli *et al.* 2012). In the Capraia and Incisioni caves, on Mount Pellegrino in Palermo, many shells of *Columbella rustica* (some od which are perforated) have been found in probable Epigravettian levels (Reese 2016). In the burial ST1 of San Teodoro Cave, twelve perforated deer canines were found, presumed to have been part of a necklace among the funerary grave goods (Graziosi 1947). In Trench M, several marine shells (e.g. *Columbella, Naticarius, Glycymeris, Anadara*) had been clearly selected for ornamentation, as indicated by intentional perforation and the presence of red pigment in some specimens (see Results). The variety of perforation techniques observed suggests both technical expertise and individual choices. Notably, the *Glycimeris* specimen may have been naturally perforated, a practice attested in other Upper Palaeolithic contexts where shells with naturally occurring holes have been reused. Although its use as a container cannot be excluded, the presence of pigment suggests a symbolic or decorative role (Fig. 6C, D, yellow arrow). A fragment of *Glycymeris* sp. (Appendix 8) may represent a similar object, although its broken state prevents a definitive interpretation. The use-wear traces observed on the ornaments from Trench M provide compelling evidence of their actual use and cultural significance within the Epigravettian community. These traces, including edge rounding, localised polish, and striations, suggest that the objects were actively worn, manipulated, and integrated into daily or symbolic

Table 4. — Epigravettian sites with personal ornaments and detailed descriptions of associated mollusc species and other materials used during this period.

Site	Region/Country	Type of ornament	Shell species	Chronology	References
Grotta di San Teodoro	Sicily, Italy	Red deer canines, perforated shells	*Nassarius incrassatus*	*c.* 15 ka BP	Graziosi 1947; Garilli *et al.* 2020a; present study
Grotta d'Oriente	Sicily, Italy	Perforated and pigmented shells	*Columbella rustica*, *Cerithium* sp., *Tritia incrassata*, *Luria lurida*	*c.* 14.2 ka cal BP	Mannino 2002; Cilli *et al.* 2012
Capraia / Incisioni	Sicily, Italy (Mt. Pellegrino)	Perforated shells	*Columbella rustica*	Late Epigravettian	Reese 2016
Riparo Mochi	Liguria, Italy	Shell perforations, stone pendants	*Tritia gibbosula*, *Antalis* sp., *Glycymeris* sp.	*c.* 17-14 ka BP	Stiner 1999; Hoareau *et al.* 2021b
Vela Spila	Croatia	Ornaments with perforations and pigment	*Tritia* spp., *Columbella* spp., *Cerithium* sp.	18-13 ka cal BP	Borić & Cristiani 2019
Badanj	Bosnia-Herzegovina	Perforated and pigmented shells	*Tritia* spp., *Mitrella scripta*, *Antalis* sp.	Epigravettian	Borić *et al.* 2023
Paglicci Cave	Apulia, Italy	Perforated marine shells	*Tritia reticulata*, *Mitrella scripta*	*c.* 17-14 ka BP	Arrighi *et al.* 2019
Grotta delle Veneri	Marche, Italy	Funerary ornamentation	*Antalis* sp., *Glycymeris* sp.	*c.* 14-13 ka BP	Rigaud *et al.* 2014

practices rather than merely produced. Several shells exhibit well-developed smoothing and rounding around their perforations, suggesting extended contact with a flexible material, such as sinew or fibre. This wear pattern is consistent with suspension, likely as pendants or as elements sewn into composite ornaments. In some cases, the polish is distributed asymmetrically, wich implies that directional movement was caused by repeated friction during use. Such traces can provide insight into how these objects interacted with the human body and with other components of personal adornment. Notably, the *Anadara gibbosa* specimen shows polish and abrasion concentrated near the umbo, with directional wear consistent with a suspension that allowed the object to swing freely. This supports the hypothesis that it functioned as a mobile ornament. The *Naticarius* sp. specimen presents a more complex wear pattern, comprising surface polish, abrasion, and micro-striations along its aperture. These traces suggest repeated manipulation, potentially in association with a sewn or tied context. The orientation and localisation of the polish hint at specific modes of attachment and use, reinforcing the idea that ornamentation was dynamic rather than static. In addition, red pigment residues were observed on some of the mollusc shells, either within or around the perforations. Although sparse, these traces are significant as they may point to intentional colouring practices. The presence of ochre, which is commonly associated with symbolic or ritual activities in Palaeolithic contexts, further supports the interpretation of these objects as culturally significant. It is plausible that ochre was applied as part of body decoration or ornament preparation, suggesting that these shells were used not only fo adornment but also for broader symbolic puposes. These remains contribute to our growing understanding of symbolic behaviour in Late Epigravettian Sicily, showing that ornaments were markers of aesthetic expression as well as embodied cultural objects that were part of daily routines and social interactions, and potentially life-cycles. Their wear tells the story of continued use, movement, and contact. The red pigment preserved inside *Patella caerulea*, as was also observed in *Patella ferruginea* from an Epigravettian burial in Favignana (Mannino 2002), could indicate use as a container or applicator for pigment. Regarding their provenance, the molluscs were probably collected from the nearest available shoreline. During the Epigravettian period, at the beginning of the last deglaciation, the seabed was shallow, at around -90 m (Lea *et al.* 2002). Therefore, the nearest shore would have been approximately six kilometres away from the study site (Garilli *et al.* 2020a).

A comparison between the materials used for ornaments at various Italian Epigravettian sites is reported in Table 4.

CONCLUSION

The evidence recovered from USM3 of Trench M, along together with its contextual analysis, highlights some differences from the population believed to have preceded it (Garilli *et al.* 2020b), who were responsible for the burials. Significantly, the ecofacts of Trench M contained an abundance of red deer; however, no perforated deer teeth were found, despite their generally better preservation compared to marine shells. In contrast, burials yielded no perforated shells but instead contained perforated deer canines (Graziosi 1943). This may suggest that perforated canines were used exclusively used for burials and, therefore, absent from Trench M. The selection of *Columbella rustica*, *Naticarius* sp., *Glycymeris* sp. and a specimen of *Anadara gibbosa* (morphologically similar to *Cerastoderma* shells) together with the stone pendant, reflects affinities with European Epigravettian and Gravettian cultures. The perforation techniques employed are consistent with those observed at numerous continental Upper Palaeolithic sites. These observations suggest that these populations were not culturally isolated from the mainland. Taken together, these observations support the notion that the populations at San Teodoro were not culturally isolated for an extended period. On the contrary, they appear to have maintained or reintroduced cultural and technological traits of continental origin, as indicated by the absence of distinctly local or insular features in the artefact assemblage. This interpretation is consistent with genetic analyses that confirmed that these populations were not genetically distinct from the broader Mediterranean European population (Catalano *et al.* 2020).

Author contributions

GV, UTH & LS: conceptualization and writing of the manuscript; analysis of the materials. GV, UTH & AR: comparative analysis of the bone remains. GV, NC & MPV: excavation of the Trench M. GV, UTH & AR: microscopic analysis of the faunal remains and use-wear. GV & MAV: archaeometric analysis. LS: fund raising.

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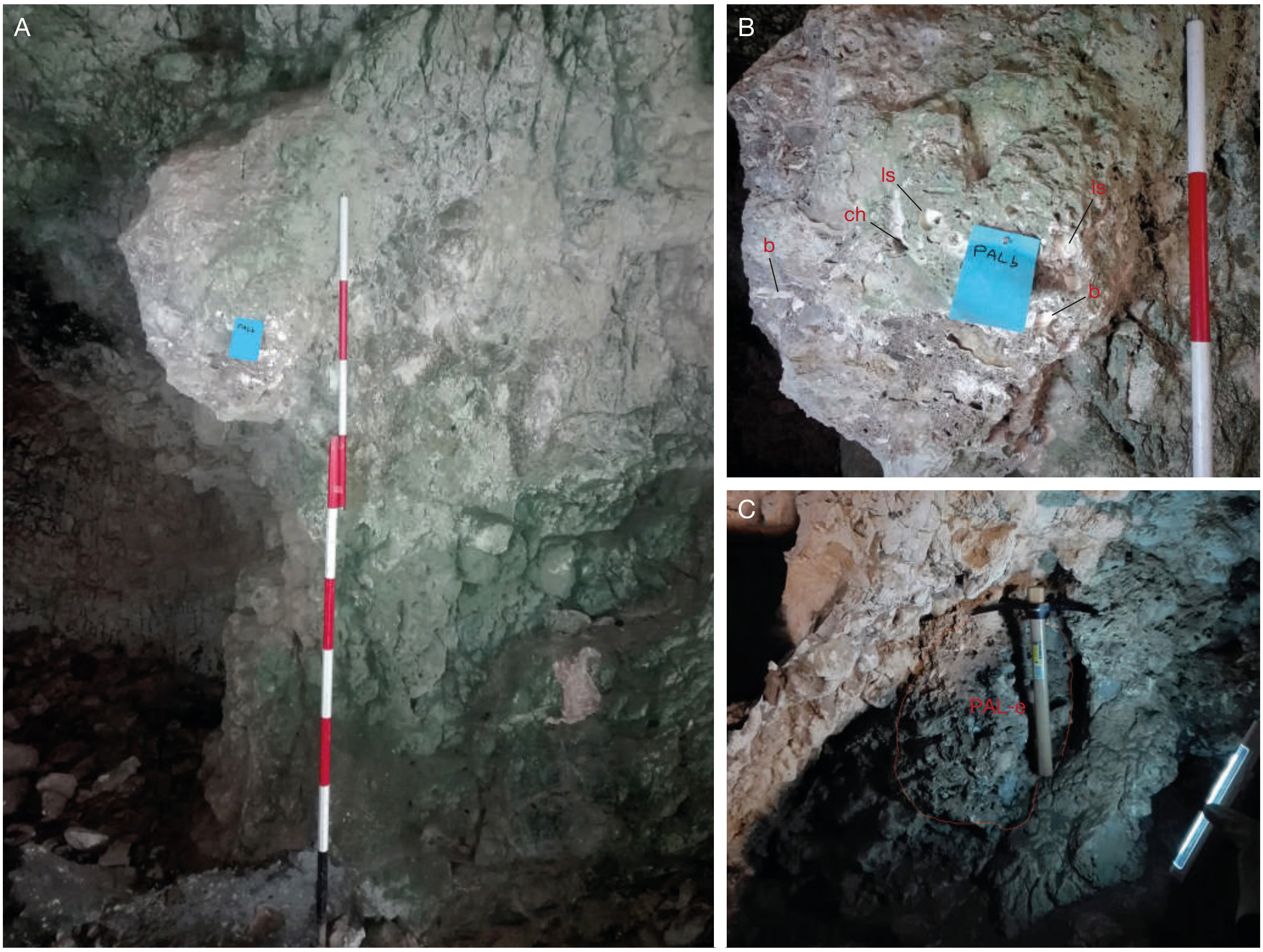
APPENDICES

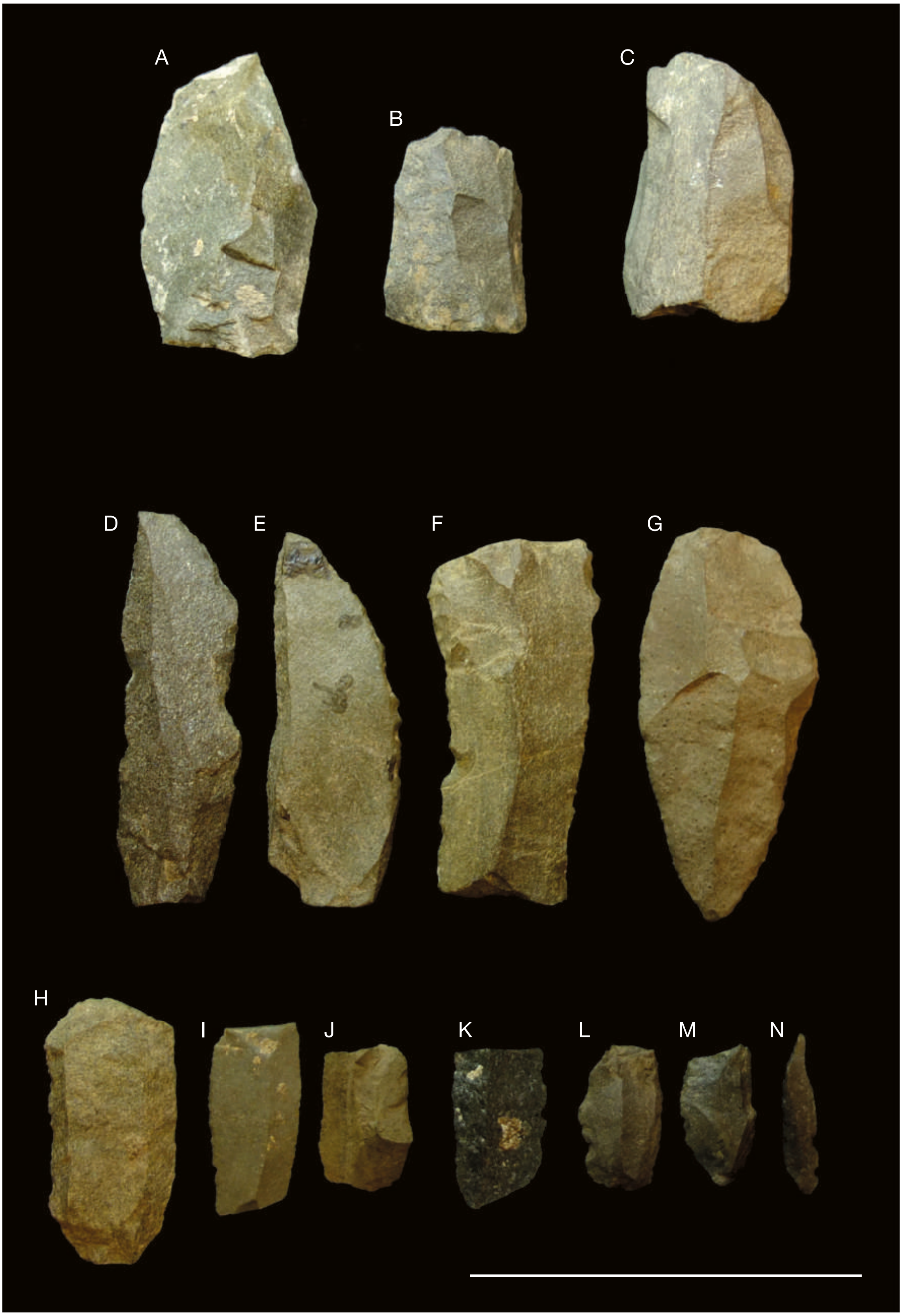
Appendix 1. — Section of the San Teodoro Cave deposit (from Figure 1 of Graziosi 1947, modified), showing stratigraphy and the position of four inhumed individuals found. Stratigraphy is as follows: **F**, **E**, Late Pleistocene layer with Upper Pleistocene mammal fauna, coprolites, and late Epigravettian human burials; **D**-**A**, anthropogenic layers with faunal remains, charcoals, and lithic artefacts (the PAL layer of Garilli *et al.* 2020a); **β**, ochre layer. Note that in the cave, layer A no longer exists as well as most of the upper part of the C, B layers.

Appendix 2. — **A**, Current height of the breccia PAL-b concerning the present walking surface; **B**, detail of the PAL-b breccia showing fractured/broken bones (**b**), land snails (**ls**) and charcoals (**ch**); **C**, Breccia PAL-e inside the niche.



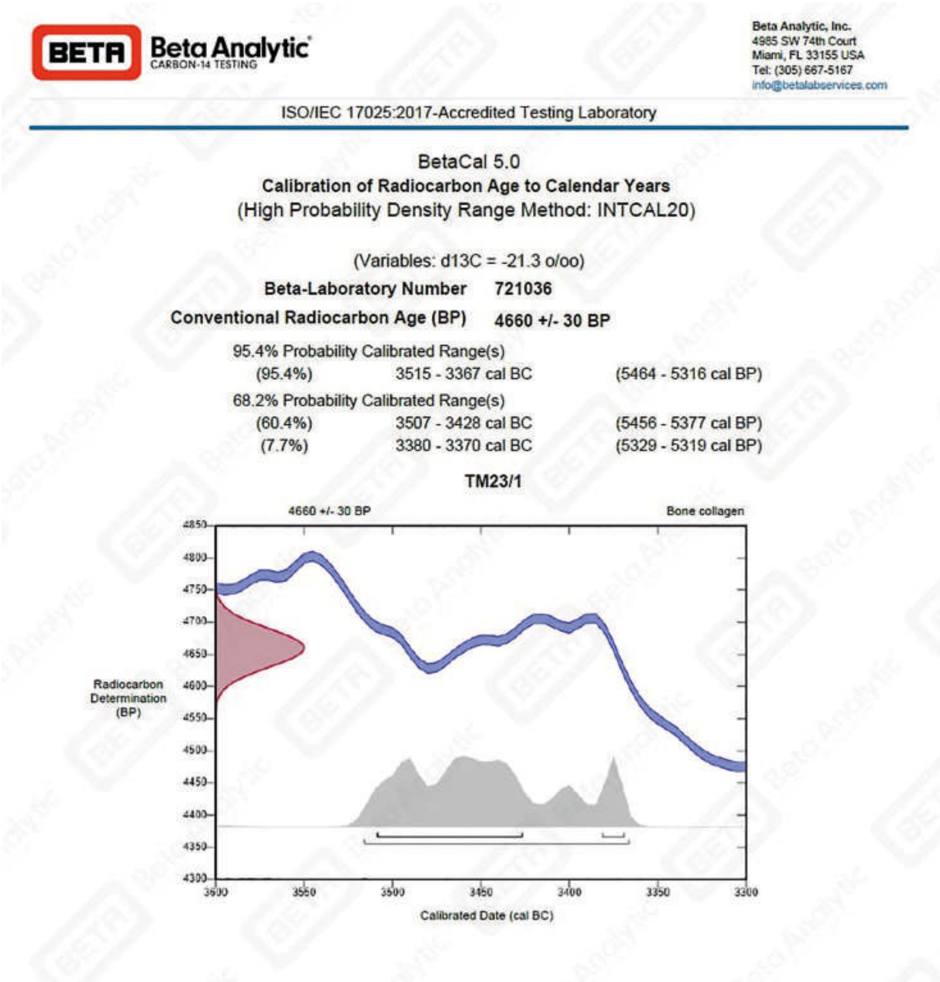
Appendix 3. — **A**, **B**, Perforated distal femur of red deer: **A**, anterior view; **B**, posterior view; **C**, **D**, perforated femur head of red deer: **C**, inferior view; **D**, superior view. Scale bars: A, B, 8 cm; C, D, 4 cm.

Appendix 4. — Selection of quartzite artefacts from USM3: **A**-**C**, cores or chunky flakes with knapping marks; **D**, a long flake with a potentially retouched edge. Could be a rough tool or a simple implement; **E**, flake with a curved profile and retouched edge. It could be a scraper or a bit of a more complex tool; **F**, thick, long flake with a straight worked edge. This could be a scraper or another type of tool made on a thick flake; **G**, slightly triangular flake with retouched edges. This could be a rough-out for a point or a fragment of a pointy tool; **H**, **I**, possibly small cores or tools on thick flakes with some edge work; **J**-**N**, small flakes or fragments. Some (such **K** and **M**) may show more obvious retouching. **N** is very tiny. Scale bar: 10 cm.



Appendix 5. — Selection of flint artefacts from USM3: **A**, thick end-scraper on flake; **B**, backed bladelet with pointed tip, curved back, likely a microlith; **C**, a thin, elongated bladelet of yellowish flint. One edge is relatively straight and sharp, while the other shows signs of irregular retouch or use; **D**, thick flake with abrupt retouch, likely a simple tool, not standardised; **E**, backed point with elongated triangular section, semi-abrupt straight back; **F**, backed point with curved dorsal edge, microlithic armature; **G**, a long, thin blade of reddish-brown flint. The lateral edges are relatively parallel and sharp, with minimal retouch. This is a regular blade; **H**, a shorter, thicker blade of brownish flint. One lateral edge shows signs of irregular retouch or possible use-wear; **I**, backed bladelet with well-defined dorsal back, broken at base; **J**, a short, thick piece of yellowish-white flint with some irregular flaking and possible crushing at one end. It might be a thick, retouched flake or a scraper fragment; **K**, retouched flake with simple marginal retouch on one edge; **L**, elongated, lamellar form. The edge exhibits a series of small notches or indentations, possibly intentional concave retouch; **M**, retouched pointed flake with natural convergence accentuated by retouch. May have functioned as a perforator; **N**, microlithic segment with trapezoidal shape with a retouched lower edge. Typical of the final Epigravettian industry, as part of composite hunting armatures; **O**, microburin, typical of microlith production; **P**, microburin, typical of microlith production. Scale bar: 10 cm.

APPENDIX 6. — 14C dating of a deer astragalus from layer M2 of Trench M.


Beta Analytic CARBON-14 TESTING

Beta Analytic, Inc.
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ISO/IEC 17025:2017-Accredited Testing Laboratory

BetaCal 5.0
Calibration of Radiocarbon Age to Calendar Years
(High Probability Density Range Method: INTCAL20)

(Variables: d13C = -21.3 o/oo)
Beta-Laboratory Number 721036
Conventional Radiocarbon Age (BP) 4660 +/- 30 BP

95.4% Probability Calibrated Range(s)

(95.4%)	3515 - 3367 cal BC	(5464 - 5316 cal BP)

68.2% Probability Calibrated Range(s)

(60.4%)	3507 - 3428 cal BC	(5456 - 5377 cal BP)
(7.7%)	3380 - 3370 cal BC	(5329 - 5319 cal BP)

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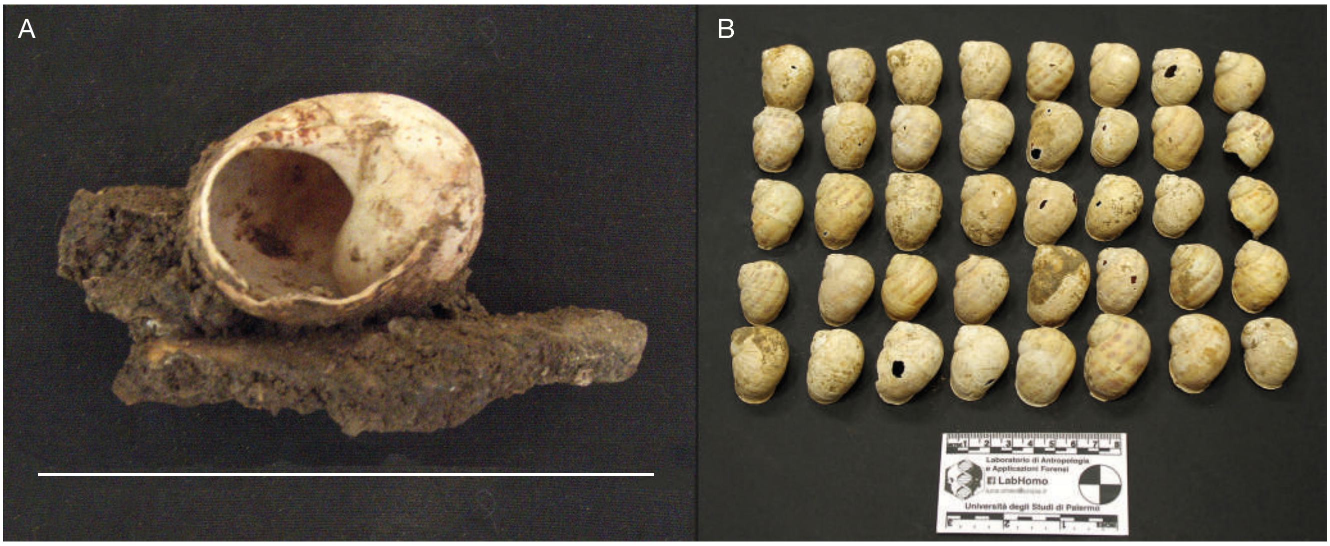
APPENDIX 7. — Land snails found in the Trench M: **A**, continental gastropod *Cornu aspersum* (O.F.Müller, 1774) found in a breccia, associated with remains of chipped bones, charcoal fragments, and lithic artefact waste; **B**, accumulations of terrestrial gastropods *Cornu aspersum* within Trench M. Scale bar: 8 cm.



Appendix 8. — Fragment of *Glycymeris* sp. valve found in trench M. Scale bar: 5 cm.