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Backdating systematic shell ornament making in Europe to 45,000 years ago

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This is the final peer-reviewed accepted manuscript of:

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**Backdating systematic shell ornament making in Europe to 45,000 years ago**

Archaeological and Anthropological Sciences

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29

## 30 **Backdating systematic shell ornament making in Europe to 45,000 years ago**

31

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44

## 45 **Abstract**

46 Personal ornaments are commonly linked to the emergence of symbolic behaviour. Although their  
47 presence in Africa dates back to the Middle Stone Age, evidence of ornament manufacturing in

48 Eurasia are sporadically observed in Middle Palaeolithic contexts, and until now large scale  
49 diffusion has been until now well documented only since the Upper Palaeolithic.

50 Nevertheless, little is known during the period between ca.50,000 and 40,000 years ago (ka), when  
51 modern humans colonized Eurasia replacing existing hominin populations such as the Neandertals,  
52 and a variety of so called “transitional” and/or early Upper Palaeolithic cultures emerged. Here we  
53 present shell ornaments from the Uluzzian site of Grotta del Cavallo in Italy, southern Europe. Our  
54 results show evidence of a local production of shell beads for ornamental purposes as well as a  
55 trend toward higher homogeneity in tusk bead shape and size over time. The temporal interval of  
56 the layers of interest (45-40 ka) makes Cavallo the earliest known shell ornament making context in  
57 Europe.

58 Key words: Uluzzian, Italy, Grotta del Cavallo, shell ornaments

59

## 60 **1.Introduction**

61

62 The use of personal ornaments in human history is a key issue to understand the evolutionary  
63 processes that led to modern humankind beyond a biological perspective. Over the past decades  
64 various hypotheses have been expressed on this topic, based on the different perspectives of  
65 anthropology, ethnography, sociology, and linguistics (White 1989; d’Errico et al. 2003a; McElreath  
66 et al. 2003; Abadia and Nowell 2015).

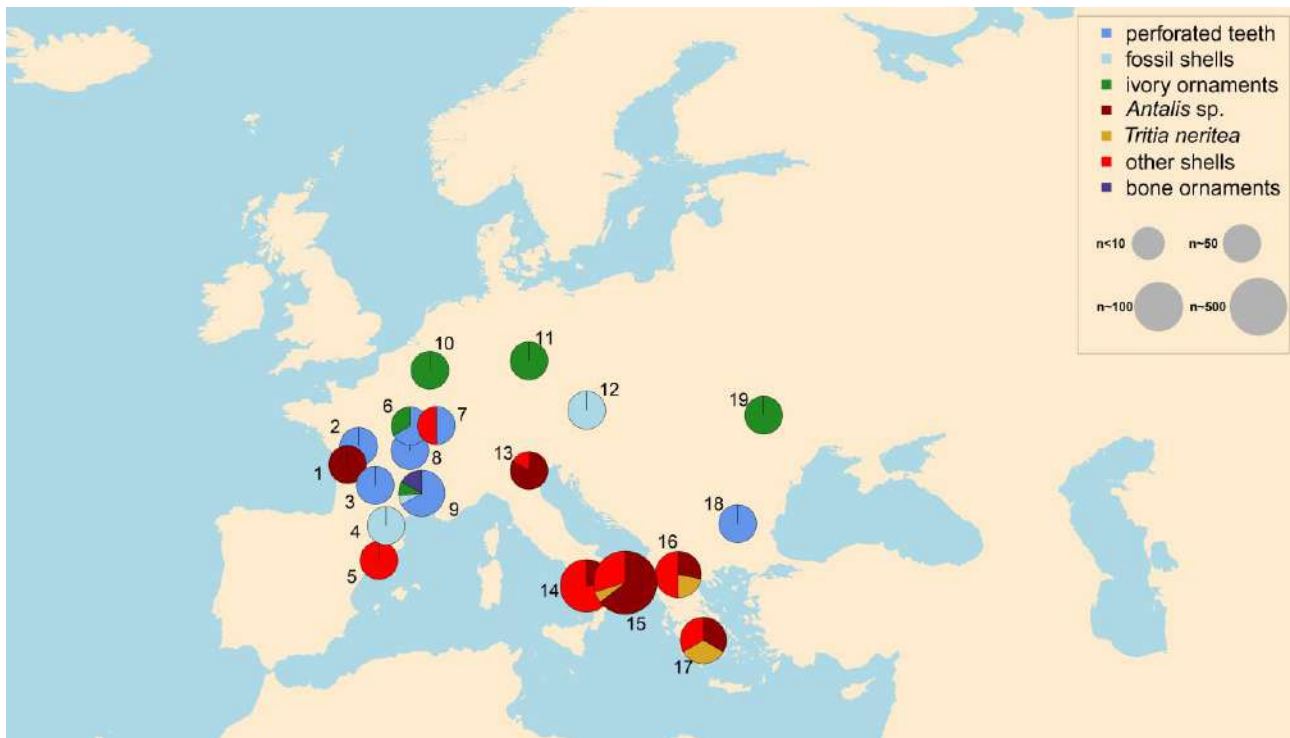
67 Personal adornments are interpreted as markers of population structure from a cultural/linguistic  
68 and social point of view since the beginning of the Upper Palaeolithic (Vanhaeren and d’Errico  
69 2006; Stiner et al. 2013), but they are also proof of an initial aesthetic perception (Leroi-Gourhan  
70 1964) and their presence is the best archaeological evidence of shared symbolic language linked to  
71 individual appearance (White 1989; d’Errico et al. 2003a). Unfortunately, the vast majority of  
72 deliberate body modifications (including tattoos, scarifications, ear piercing, lip and neck stretching

73 and other numerous kinds of alterations aimed to modify one's own physical appearance) are  
74 embedded in perishable materials and cannot be retrieved from Palaeolithic contexts. This makes  
75 high concentrations of non-functional elements – such as the one presented here - even more  
76 relevant and informative on the emergence of socially recognized symbolic expressions (which may  
77 or may not have involved other kinds of body alterations).

78 The earliest known evidence of ornaments is associated with Modern Humans (MHs), and dates  
79 back to 135-70 ka in Africa and in the Levant (Vanhaeren et al. 2006; d'Errico et al. 2009;  
80 Vanhaeren et al. 2013; d'Errico and Backwell 2016). In the latter region, evidence of personal  
81 ornaments is still consistently found in the period ranging from the Levantine Middle to Upper  
82 Palaeolithic (Bosch et al. 2019), while there is broad consensus on the fact that, in Europe, the  
83 systematic production of ornaments became a substantial component of material culture since the  
84 Protoaurignacian, an Upper Palaeolithic culture dated between 42-36 ka and confidently attributed  
85 to MH (Benazzi et al. 2015). There is no doubt, however, that during the Middle to Upper  
86 Palaeolithic transition (50-40 ka) ornaments were already becoming more common in the region.  
87 Such a trend documents a change in human social behavior compared to the scantier evidence of  
88 ornaments derived from animals and seashells attested in Middle Palaeolithic contexts attributed to  
89 Neandertals (Peresani et al. 2011; Peresani et al. 2013; Romandini et al. 2014; Radovčić et al. 2015;  
90 Hoffmann et al. 2018).

91 In this timeframe late Neandertals and the newly arrived modern human groups coexisted in  
92 Europe, and the archaeological record shows the emergence of new techno-complexes (the so-  
93 called transitional complexes) which exhibit a number of innovative features (such as formal bone  
94 tools manufacturing, the systematic use of ornaments and pigments, etc...) compared to late  
95 Mousterian assemblages (d'Errico et al. 2003a, 2003b; Zilhão 2006; Flas 2011; Boscato and  
96 Crezzini 2012; d'Errico and Banks 2013; Moroni et al. 2013 and 2018; Škardla, 2013; Hublin  
97 2015). Attribution of transitional industries to either Neandertals or modern humans is often  
98 difficult because of the scarcity of human fossils found in association with elements of the material

99 culture. Labelling these industries as “transitional” entails that they express admixed Middle and  
100 Upper Palaeolithic features and are the product of late Neandertal groups which interacted with  
101 modern humans or independently acquired modern behaviours (Hublin 2015).  
102 More recent research, however, questioned (Bar-Yosef 2007; Bar-Yosef and Bordes 2010; Benazzi  
103 et al. 2011; Moroni et al. 2013 and 2018; Gravina et al. 2018) the association of Neandertals with  
104 both Uluzzian (Zilhão et al. 2015, Villa et al. 2018) and Châtelperronian material cultures (Lévêque  
105 and Vandermeersch 1980; Hublin et al. 1996; Welker et al. 2016). In particular, the Uluzzian is now  
106 considered to be made by modern humans (Benazzi et al. 2011, Moroni et al. 2013 and 2018; Sano  
107 et al. 2019 but see contra Zilhao et al. 2015, Villa et al. 2018) on the basis of two deciduous teeth  
108 recovered at Grotta del Cavallo and attributed to *Homo sapiens*. Uluzzian assemblages display  
109 explicitly modern elements, such as the systematic presence of bone tools, colouring substances,  
110 ornaments, and a lithic technology that does not show any evidence of continuity with the  
111 Mousterian technological tradition (Ronchitelli et al. 2009; d’Errico et al. 2012; Peresani et al.  
112 2016; Moroni et al. 2018; Peresani et al. 2019a; Sano et al. 2019).  
113 Archaeological assemblages of continental Europe dated to the Middle to Upper Palaeolithic shift  
114 yielded sporadic evidence of ornaments and ornament manufacturing on animal bone and teeth  
115 (d’Errico et al. 1998; Zilhão 2007), with the exception of Châtelperronian contexts in France which  
116 also included a few seashells (Zilhão 2007) (Fig.1). On the other hand, personal ornaments  
117 uncovered in Uluzzian assemblages (~45-40 ka) of Mediterranean Europe only consist of seashells  
118 (Palma di Cesnola 1989; Fiocchi 1998; Stiner 2010). Findings of this kind are present and  
119 sometimes abundant at Klissoura (Greece; n=32), Grotta della Cala (southern Italy; n=30), and  
120 Riparo Broion (northern Italy; n=6). Grotta del Cavallo (southern Italy) stands absolutely out with  
121 531 seashells distributed across the entire Uluzzian sequence, dated between 45.5 - 39.9 ka  
122 (Benazzi et al. 2011; Douka et al. 2014; Moroni et al. 2018).



123

124 Fig. 1 Distribution of ornaments dated between ca. 45 and 39 ka across transitional contexts in  
 125 Europe (sites with debated cultural attribution are represented here, see “Discussion” section). Pie  
 126 radius is proportional to the total size of ornamental assemblages, while colors indicate the relative  
 127 proportion contributed by different classes of items. (1) Saint-Césaire, (2) Quinçay, (3) Roc de  
 128 Combe, (4) Caune de Belvis, (5) Cova Foradada, (6) Roche au Loup, (7) Grotte du Trilobite, (8)  
 129 Grotte des Fées, (9) Grotte du Renne, (10) Trou Magrite, (11) Ilsenhöle Ranis, (12) Willendorf II,  
 130 (13) Riparo Broion, (14) Grotta della Cala, (15) Grotta del Cavallo, (16) Klissoura Cave, (17)  
 131 Franchthi Cave, (18) Bacho Kiro, (19) Brynzeny I

132

133 Nonetheless, a systematic study of the Uluzzian shell assemblage was never undertaken. The  
 134 abundance of shell beads found at Grotta del Cavallo offers a privileged perspective for a  
 135 systematic reassessment of ornament making in this and other Uluzzian assemblages. The key  
 136 question is therefore to understand whether systematic manufacturing and personal use of shell  
 137 beads took place at the site, and therefore if Cavallo back dates to ~45 ka the beginning of one of  
 138 the most salient traits of Upper Palaeolithic Europe.

139 Here we present a thorough analysis of the entire sequence of shell assemblages found in the  
 140 Uluzzian layers at Grotta del Cavallo. At this site the Uluzzian can be followed from the archaic

(layer EIII) to the evolved-late phase (layer EII-I and D), sandwiched by the tephra Y-6 at  $45.5 \pm 1.0$  ka (Zanchetta et al. 2018) and Y-5 (Campanian Ignimbrite) at  $39.85 \pm 0.14$  ka (Giaccio et al. 2017; Zanchetta et al. 2018). All dates obtained from shells (5 *Antalis* sp. from EII-I, spit E-D, DII and DIIb, 1 *Lembulus pella* from DIIb - Benazzi et al. 2011) are consistent with the chronological frame established by the above mentioned tephra layers. Previous works maintained that the presence in the Uluzzian deposit of important post-depositional disturbances might undermine the association between Uluzzian assemblage and modern humans (Gioia 1990; Zilhão 2007; Zilhão et al. 2015). Nevertheless, more recent research has definitely confirmed the integrity of the archaeological deposit in which the teeth attributed to MHs were recovered and therefore the reliability of their association with the Uluzzian materials (Moroni et al. 2018; Zanchetta et al. 2018; see *Supplementary Information Appendix, Section I*). Here, we ascertain the presence of anthropogenic intervention on scaphopods (also known as tusk shells), gastropods, and bivalves as well as their use as personal ornaments through the combined use of quantitative analysis of morphology, experimental tests, use-wear, Sr isotopes, and micropalaeontological examination. Results, which are compared with the broader picture emerging from other Uluzzian contexts, show evidence of an increasing regularity in shape and size of the beads, as well as of their local production for ornamental purposes.

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159

## 160 **2.Materials - The shell assemblage from Grotta del Cavallo**

161 The Uluzzian layers of Cavallo yielded 618 shell remains (531 NISP), mostly retrieved in the  
162 uppermost layers DII and DI. Among them, 285 can be assigned to 32 *taxa* (Table 1 and Fig. 2)  
163 while the majority is still undetermined due to their bad state of preservation. Among identified  
164 classes, scaphopods are the most represented and ubiquitous one across the entire sequence, while  
165 gastropods and bivalves are considerably less abundant and clustered in the upper layers DI and DII  
166 (n=124, of which 28 are pierced). The lowermost Uluzzian layer yielded, in addition to 67

167 scaphopods, 7 bivalves and 33 gastropods, one of which consists of a pierced *Tritia neritea*  
 168 (Fig.2b). Species richness increases over time and reaches its maximum in the uppermost layers  
 169 with 22 identified species encompassing both edible and not edible species. The most represented  
 170 species are *Tritia neritea*, *Lembulus pella* and *Glycymeris* sp.  
 171

<i>Taxa</i>	E III	EII-I	E-D	DII	DI	D (DI+DII)	<b>Total</b>
<i>Gasteropode</i> undet.	21	-	-	-	-	-	<b>21</b>
<i>Patella rustica</i> *	2	-	-	-	-	-	<b>2</b>
<i>Jujubinus striatus</i>	-	-	-	-	2	-	<b>2</b>
<i>Phorcus</i> sp.	-	-	-	-	1	-	<b>1</b>
<i>Phorcus turbinatus</i> *	-	-	-	1 (1)	-	-	<b>1 (1)</b>
<i>Homalopoma sanguineum</i>	-	-	-	2	8 (1)	1 (1)	<b>11 (2)</b>
<i>Bittium reticulatum</i>	1	-	-	-	-	-	<b>1</b>
<i>Cerithium</i> sp.	-	-	-	-	1	2	<b>3</b>
<i>Cerithium vulgatum</i> *	3	-	-	-	1	1	<b>5</b>
<i>Turritella</i> sp.	3	-	-	-	2	2	<b>7</b>
<i>Melaraphe neritoides</i>	1	-	-	-	-	-	<b>1</b>
<i>Trivia pulex</i>	-	-	-	-	1	-	<b>1</b>
<i>Naticarius hebraeus</i> *	1	1	-	-	-	-	<b>2</b>
<i>Euspira catena</i>	-	-	1	-	1	-	<b>2</b>
<i>Aporrhais pespelecani</i> *	-	-	-	1	-	-	<b>1</b>
<i>Tritia</i> sp.	-	-	-	-	-	1	<b>1</b>
<i>Tritia cuvierii/unifasciata</i>	-	-	-	-	2	-	<b>2</b>
<i>Tritia neritea</i>	1 (1)	-	-	5 (4)	22 (5)	4 (2)	<b>32 (12)</b>
<i>Tritia nitida</i>	-	-	-	1 (1)	-	-	<b>1 (1)</b>
<i>Columbella rustica</i> *	-	-	-	-	1	2 (1)	<b>3 (1)</b>
<b>Total gastropods</b>	<b>33 (1)</b>	<b>1</b>	<b>1</b>	<b>10 (6)</b>	<b>42 (6)</b>	<b>13 (4)</b>	<b>100 (17)</b>
<i>Lembulus pella</i>	-	-	-	-	10 (10)	-	<b>10 (10)</b>
<i>Mytilus galloprovincialis</i> *	-	-	-	-	27	-	<b>27</b>

<i>Glycymeris</i> sp.	1	-	-	2	13 (2)	1	<b>17 (2)</b>
<i>Glycymeris nummaria</i> *	-	-	-	-	-	1	<b>1</b>
<i>Pecten jacobaeus</i> *	-	-	-	-	1	-	<b>1</b>
<i>Spondylus gaederopus</i> *	-	-	1	-	-	-	<b>1</b>
<i>Acanthocardia</i> sp. *	6	-	-	-	1	-	<b>7</b>
<i>Callista chione</i> *	-	1	-	-	2	-	<b>3</b>
<i>Corbula gibba</i>	-	-	-	-	1	-	<b>1</b>
<b>Total bivalves</b>	<b>7</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>55 (12)</b>	<b>2</b>	<b>68 (12)</b>
<i>Antalis</i> sp.	10	11	13	63	72	77	<b>246</b>
<i>Antalis vulgaris</i>	32	1	2	23	15	6	<b>79</b>
<i>Antalis dentalis/inaequicostata</i>	25	6	2	1	-	3	<b>37</b>
<i>Fissidentalium rectum</i>	-	-	-	-	-	1	<b>1</b>
<b>Total scaphopods</b>	<b>67</b>	<b>18</b>	<b>17</b>	<b>87</b>	<b>87</b>	<b>87</b>	<b>363</b>
<b>Total NISP</b>	<b>107</b>	<b>20</b>	<b>19</b>	<b>99</b>	<b>184</b>	<b>102</b>	<b>531</b>
Undetermined	8	4	-	-	52	23	87
<b>Total NR</b>	<b>115</b>	<b>24</b>	<b>19</b>	<b>99</b>	<b>236</b>	<b>125</b>	<b>618</b>

172

173 Table 1 Malacological assemblage from Grotta del Cavallo. Edible species are marked with an  
174 asterisk. Numbers in brackets are for pierced specimens. The taxonomic analysis is based on the  
175 updated datasets available online on the World Register of Marine Species (WoRMS;  
176 [www.marinespecies.org](http://www.marinespecies.org)), also the number of rests (NR) and the number of identified specimens  
177 (NISP) have been used in order to define the right amount of the assemblage

178

179

180 Shells from layer EIII were mostly found in an area of about 4 square meters (squares E 13, F11,  
181 F12 and G 11) (94.1%) while only 5.9% comes from the 1963-66 excavation trench corresponding  
182 to an area of about 2.5-3 x 3.5 m (Moroni et al., 2018) (Table 2; see *SI Appendix, Section I* for  
183 details and Fig.S1).

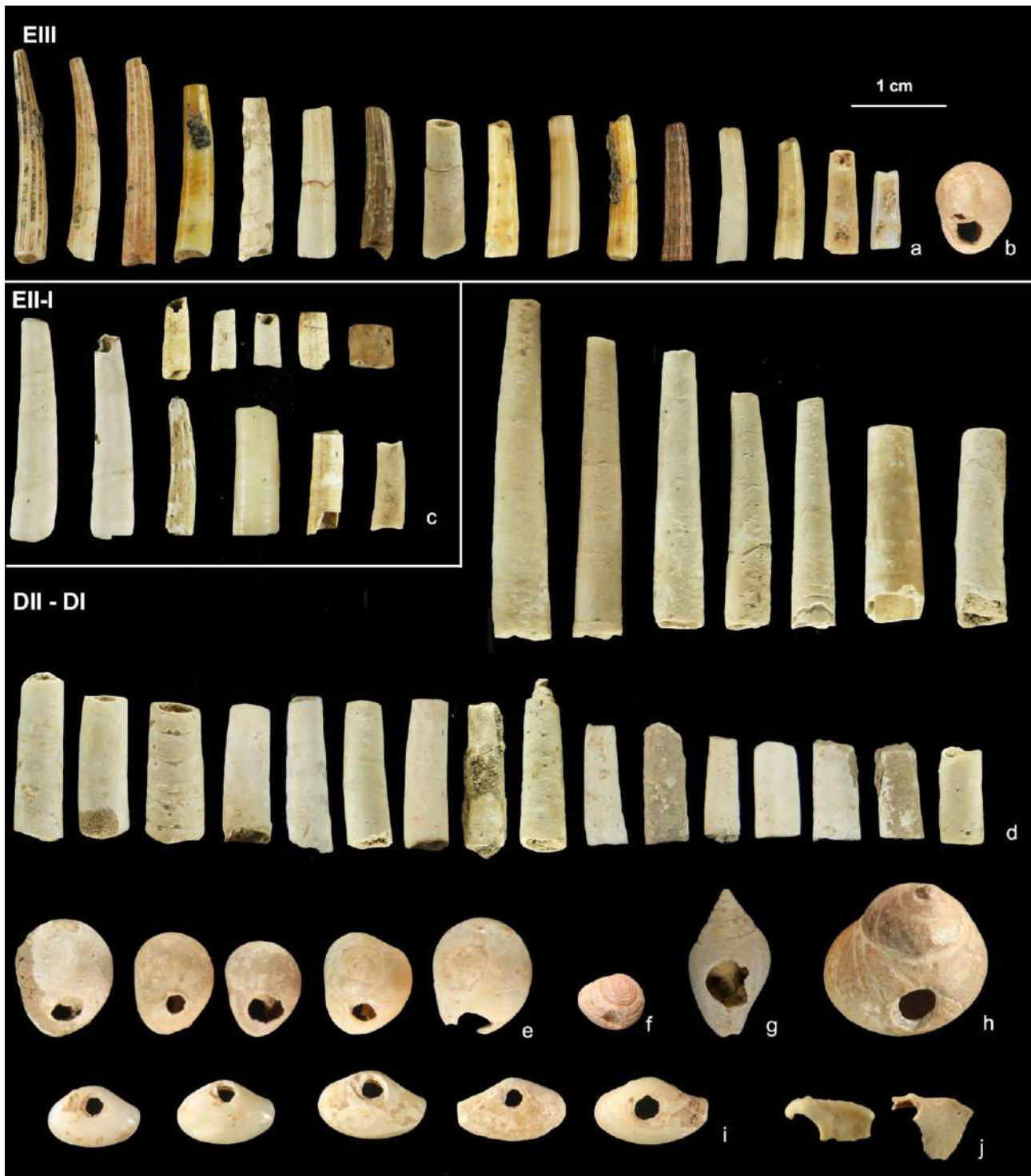
184 Shells from layer EII-I were retrieved in square H11 and in the 1963-1966 excavation trench (Table  
 185 2). Shells from layers DII and DI come almost exclusively from two square meters (H11 and H7 -  
 186 Fig. S1). Only very few specimens from both layers were found in the 1963-66 excavation trench  
 187 (Table 2).

188

	EIII	EII-I	E-D	DII	DI	D whole	<b>Total</b>
E-F-G8*; E-F9*; E-F10* (1963-66 excavation trench)	5 (4)	5 (5)	-	21 (17)	3	-	<b>34 (26)</b>
E13*	17 (1)	-	-	-	-	-	<b>17 (1)</b>
E11	2	-	-	-	-	-	<b>2</b>
F13*	-	-	-	-	-	-	-
F12*	12 (4)	-	-	-	-	-	<b>12 (4)</b>
F11*	18 (12)	-	-	-	-	-	<b>18 (12)</b>
G11*	59 (46)	-	-	-	-	-	<b>59 (46)</b>
G10*	-	-	-	-	-	-	-
G7	-	-	-	-	-	-	-
H11	-	17 (13)	17 (15)	78 (70)	233 (87)	102 (74)	<b>447 (259)</b>
H8*	-	-	-	-	-	-	-
H7*	2	2	2 (2)			23 (13)	<b>29 (15)</b>
<b>Total</b>	<b>115 (67)</b>	<b>24 (18)</b>	<b>19 (17)</b>	<b>99 (87)</b>	<b>236 (87)</b>	<b>125 (87)</b>	<b>618 (363)</b>

189

190 Table 2 Spatial distribution of the shells by layer. For the squares marked with an asterisk only the  
 191 portion occupied by undisturbed deposit has been considered (for further details see *SI Appendix*,  
 192 *Section I* and Fig.S1). Numbers in brackets are the scaphopods



193

194 Fig. 2 Selection of shells from Grotta del Cavallo. a *Antalis* sp. b *Tritia neritea*. c *Antalis* sp. d

195 *Antalis* sp. e *Tritia neritea*. f *Homalopoma sanguineum*. g *Columbella rustica*. h *Phorcus*

196 *turbinatus*. i *Lembulus pella*. j *Glycymeris* sp.

197

198

### 199    **3. Methods**

200    The present research mostly focuses on tusk shells due to their abundance across all layers. Their  
201    bad state of preservation, however, required the design of experimental and quantitative analyses to:  
202    a) understand whether these shells were collected from fossiliferous deposits rather than from  
203    thanatocoenoses (namely ‘gathered on the beach’); b) ascertain the presence and the effects of  
204    anthropogenic breakage and post-depositional processes; c) analyse non-macroscopic  
205    morphological change over time.

#### 207    **3.1 Micropalaeontological and isotope analysis**

208    The micropalaeontological content of several samples of sediment contained in the tusks from Grotta  
209    del Cavallo and in the Uluzzian layers of the cave was examined to establish if the shells were  
210    collected from nearby sedimentary outcrops or from beach deposits contemporaneous to the  
211    Uluzzian activity at the site. The material was examined through classic micropalaeontological  
212    techniques, which include the preparation of washed samples for the analysis of microfossils and of  
213    smear slides for calcareous nannofossils, as well as observation under a microscope (*SI appendix,*  
214    *Section II*).

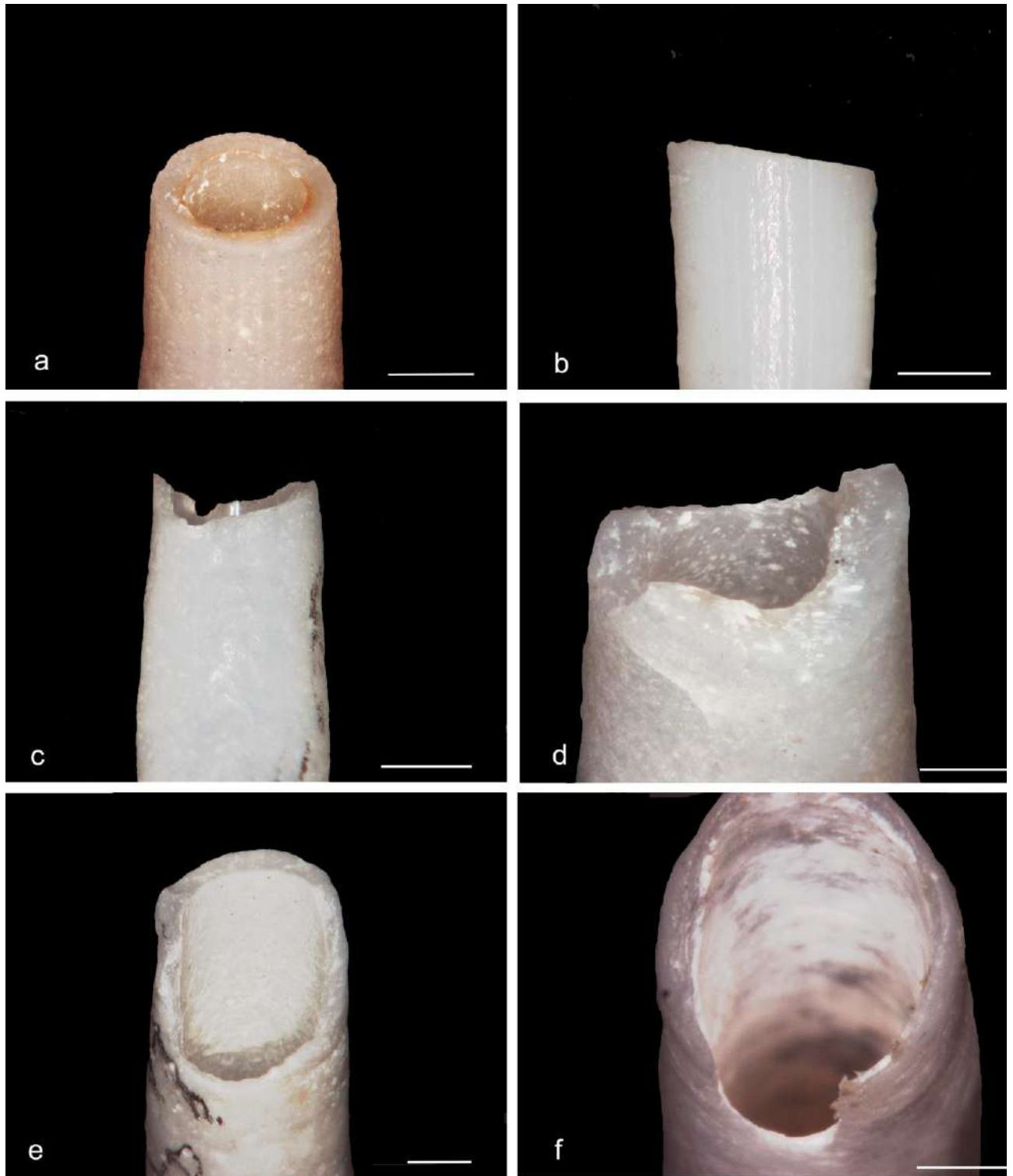
215    *In situ* trace element analysis was carried out by means of LA-ICP-MS on eight samples of tusk  
216    specimens from layers E and D of Grotta del Cavallo to test their diagenetic preservation, and  
217     $^{87}\text{Sr}/^{86}\text{Sr}$  ratio was analyzed by MC-ICP-MS to test the non-fossil origin of the archaeological  
218    samples (see Lugli et al. 2017) (*SI appendix, Section III*). Elemental and isotope analyses were  
219    conducted at the Centro Interdipartimentale Grandi Strumenti of the University of Modena and  
220    Reggio Emilia.

#### 222    **3.2 Morphological analysis**

223 All the archeological tusk shells were measured (length, maximum and minimum diameters) in  
224 accordance with normalized zoological parameters: the apex of the shell is anatomically dorsal, the  
225 large aperture is ventral and anterior, and the concave side is anatomically dorsal (Shimek and  
226 Steiner 1997).

227 The archeological and experimental tusk shells were classified according to the type of apical and  
228 basal fractures. Seven different types of fractures were described (Fig. 3 and Fig. S5):

- 229 a)Rectilinear: regular and straight fracture, perpendicular to the longest axis of the shell;
- 230 b)Oblique: regular and straight fracture, oblique to the longest axis of the shell;
- 231 c)Symmetric-irregular: uneven fracture forming a symmetric profile;
- 232 d)Asymmetric-irregular: uneven fracture;
- 233 e)Flute-mouth: uneven fracture taking the shape of a flute mouth;
- 234 f)Notch: fracture forming a notch;
- 235 g)Rectangular notch.

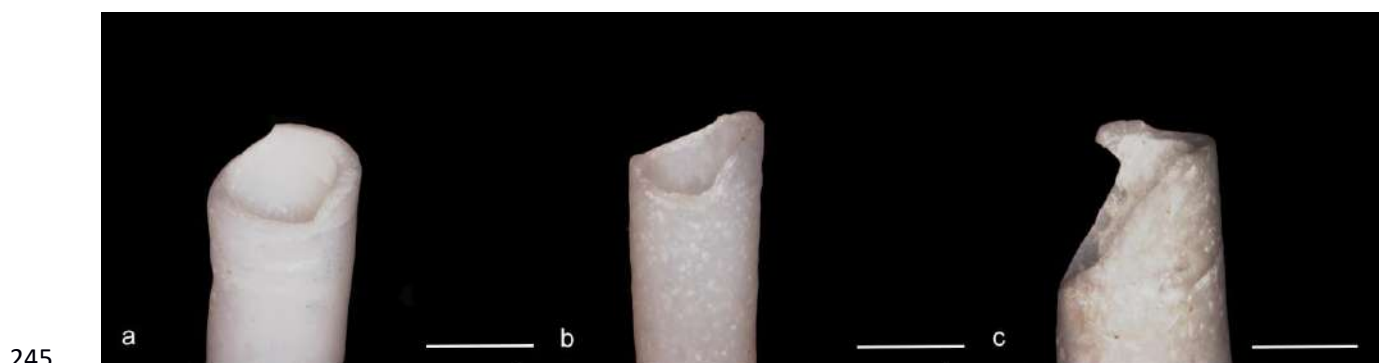


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237 Fig. 3 Type of fractures. Classification according to the type of fracture on the experimental  
 238 material: rectilinear (a), oblique (b), symmetric irregular (c), asymmetric irregular (d), flute-mouth  
 239 (e), and notch (f). The bar is 1 mm

240

241 The degree of the fracture's invasiveness and of the discontinuity of the fractured edge were also  
242 described. Rectilinear and oblique fractures, which usually have a straight edge, are degree 0.  
243 Jagged edges have a degree value included between 1 and 3, according to invasiveness of the  
244 alteration (Fig. 4).



246 Fig. 4 Fracture degrees. Flute-mouth fracture with degree 1 (a). Flute-mouth fracture with degree 2  
247 (b). Flute-mouth fracture with degree 3 (c). The bar is 2 mm

249 Specimens were classified according to their remnant portion (entire, apical, central and basal).  
250 Given the general bad preservation of the archaeological shells, this classification is not based on  
251 zoological parameters. We consider entire or nearly entire the specimens where all the  
252 morphological features can be recognized. The apical (or distal) elements are those in which the  
253 posterior end is recognizable. Central (or mesial) portions are usually considered those elements  
254 showing scarce difference between maximum and minimum diameter. In the basal (or proximal)  
255 elements the base is present.  
256 The possibility that a thread could go through the apical hole was considered as a critical  
257 discriminant factor. In this case, apical hole refers to the actual empty space within the shell, and  
258 may or may not coincide with the minimum diameter. A minimum threshold of 0.5 mm was  
259 established for this condition to be met, considering that sturdy horsehairs, the smallest suitable  
260 strings documented in ethnographic studies (Orchard 1929), present with diameters ranging from  
261 0.08 to 0.4 mm (Craveri 1931). Of course, other materials, such as vegetal fibers or sinews, cannot  
262 be excluded as potential strings for suspension.

### 263 3.3 Experimental tests

264 Experimental tests for shell beads production and post-depositional damage was carried out only for  
265 tusk shells, due to their relevance among the whole assemblage and to the difficulty in evaluating  
266 the origin of the fracturing on this kind of shell.

267 The experimental program involved the gathering of current specimens (mostly *Antalis vulgaris*) in  
268 the surroundings of Grotta del Cavallo, their breaking by bending, sawing, crushing (direct  
269 percussion) and trampling (for further details see *SI Appendix, Section IV*). The experimental shells  
270 were measured and classified according to the same parameters used for the archaeological ones,  
271 before and after each experimental test.

272 Possible technological attributes of gastropods and bivalves were instead evaluated by comparison  
273 with literature data and available reference collections (Taborin 1993; Benghiat et al. 2009; Stiner et  
274 al. 2013; Vanhaeren et al. 2013; Tátá et al. 2014).

275

### 276 3.4 Exploratory data analysis

277 Significant differences in unique variables such as length, minimum diameter, and maximum  
278 diameter across layers were assessed through non-parametric tests due to small sample size and to  
279 the presence of violations of the assumptions of parametric tests. More specifically, two-tailed  
280 Mann-Whitney U test for independent study design was performed when only two groups were  
281 compared, while Kruskal-Wallis test was used when more than two groups were to be compared  
282 against each other. Associations between pairs of categorical variables were explored on  
283 contingency tables via Correspondence Analysis using the function *ca* of the package *ca* (Nenadic  
284 and Greenacre 2007) and through Pearson's Chi-square test for independence. All analyses were run  
285 in R version 3.4.4 (R Core Team 2018).

286

### 287 3.5 Diversity and similarity

288 Intra-layer diversity was measured through Gini-Simpson index of diversity and its numbers  
289 equivalent (i.e. the exponential of Gini-Simpson index, following Jost 2006 and 2007 based on the  
290 relative frequency of proximal fracture types, distal fracture types, and remnant portions obtained  
291 for each layer. Results were obtained using respectively the functions H and d contained in the  
292 package vegetarian (with order of diversity  $q=2$ ; Charney and Record, 2012). Similarity between  
293 layers was measured through Morisita-Horn index of overlap using the function sim.table of the  
294 package vegetarian (with order of diversity  $q=2$ ). Clustering of layers was obtained using  
295 hierarchical clustering with Ward's clustering criterion (Murtagh and Legendre 2014), i.e.  
296 dissimilarities were squared before cluster updating. All analyses were run in R version 3.4.4.

297

### 298 **3.6 Taphonomic analysis**

299 The taphonomic study of the malacological assemblage was performed on the NISP and it focused  
300 on three main kinds of alterations: pre-depositional alterations (e.g. marine abrasion, predation by  
301 other molluscs and bioerosion); intentional/unintentional anthropogenic alterations (e.g. thermic  
302 alterations, ochre traces and human modifications due to consumption or ornamental purpose); and  
303 post-depositional transformations (e.g. fragmentations and decalcification).

304

### 305 **3.7 Use-wear analysis**

306 The shells were analyzed by means of a Hirox KH 7700 3D digital microscope (Arrighi and Borgia  
307 2009) using two different optics: a MX-G 5040Z zoom lens equipped with an AD-5040 Lows  
308 objective lens (20-50x) and a coaxial vertical lighting MXG-10C zoom lens and an OL-140II  
309 objective lens (140-560x). The analytical criteria (surface polishing, rounding, faceting) for the  
310 functional interpretation of the ornaments build upon previous analyses of prehistoric shells  
311 described in literature (e.g. Taborin 1993; Vanhaeren and d'Errico 2001; Bonnardin 2007).

312

## 313 **4. Results**

#### 314 4.1 Taphonomic processes

315 The shell assemblage from Grotta del Cavallo exhibits traces of decalcification (Table 3), in  
 316 particular in the case of tusk shells. Among the latter, some specimens exhibit partially exfoliated  
 317 surfaces that probably facilitated post-depositional fragmentation. Sea wash is also documented.  
 318 Only a few specimens are affected by alterations due to thermic effects, predator activity or  
 319 reducing conditions in soil.

320

Layers/ Spit	Classes	NISP	Sea washed	Boring sponge	Predators	Burned	Decalc.	Post-dep. cracks
E III	Gastr.	33	25	-	1	1	28	14
	Biv.	7	7	-	-	-	6	5
	Scap.	67	7	-	-	-	37	3
E II-I	Gastr.	1	-	-	-	-	1	1
	Biv.	1	1	-	-	-	1	-
	Scap.	18	-	-	-	-	17	2
E-D	Gastr.	1	1	-	-	-	1	-
	Biv.	1	1	-	-	-	1	1
	Scap.	17	-	-	1	-	16	-
D II	Gastr.	10	10	-	-	-	6	1
	Biv.	2	2	-	-	-	2	2
	Scap.	87	-	-	-	1?	79	3
DI	Gastr.	42	37	1	6	5	19	12
	Biv.	45	31	-	10	-	26	17
	Scap.	87	5	-	-	-	85	-
D whole	Gastr.	13	11	-	-	-	9	7

	Biv.	2	2	1	-	-	2	1
	Scap.	87	1	-	2	-	73	1
Total %	-	521	27.1%	0.4%	3.6%	1.2%	78.5%	13.4%
Total		521	141	2	20	7	409	70

321

322 Table 3 Taphonomy of the malacological assemblage from Grotta del Cavallo. Anthropic traces are  
323 not included in this table, as they are discussed in the following chapters

324

## 325 **4.2 Scaphopods**

### 326 4.2.1 Fossil and non-fossil origin of the archaeological specimens.

327 Since *Fissidentalium rectum* is an extinct species, this specimen was probably collected at a  
328 fossiliferous Pleistocene formation cropping in the Salento region (Largioli et al. 1969).

329 Both micropaleontological analyses (*SI Appendix, Section II*) carried out on the sediment preserved  
330 inside the tusks, and Sr isotopic analysis (*SI Appendix, Section III*), excluded a fossil origin of all  
331 the other *taxa*.

332

### 333 4.2.2 Experimental study

334 Manufacturing was experimentally tested on complete and almost complete specimens collected on  
335 the present-day beach in the surroundings of Grotta del Cavallo. Naturally broken specimens  
336 usually lack the apical portion. Fractures are frequently asymmetric-irregular (~60%) (see  
337 paragraph *Methods* and the *SI Appendix, Section IV* for description of the methodology applied).  
338 Rectilinear (~24%) and oblique (~8%) fractures are less frequent. Many elements have their natural  
339 basis preserved. The fracturing degree is predominantly 1 (~46%) and, to a lesser extent, 2 (~24%).  
340 Experimental manufacturing revealed an association (see *SI Appendix, Section V*) of rectilinear and  
341 oblique fractures with bending (~91%) and sawing (~46%), as well as an association between

342 irregular fractures and crushing (~60%). Unlike other actions, sawing can produce a tiny  
343 rectangular notch due to the pressure exerted on the starting point.

344 Notch fractures, which can be considered lesser developed flute-mouth fractures, cannot be clearly  
345 related to a specific bead making technique. These kinds of fractures rarely occur, although their  
346 frequency is a bit higher in crushing tests. Vanhaeren and d'Errico (2001) suggest that notch and  
347 flute-mouth fractures originate when a needle is used for stringing a thread into a shell. Comparable  
348 notch fractures, however, were obtained from our experimental trampling tests and from some  
349 explorative suspension tests when one tusk was inserted into the other, as also observed in other  
350 research (Álvarez Fernández 2006).

351 The occurrence of clear cut-marks on the shells is consistently associated with sawing. Bending is  
352 mostly related to fractures of degree 0 (85%) and to a lesser extent degree 1 (~14%), sawing almost  
353 exclusively to degree 0 (~46%) and 1 (~50%), whereas the effect of crushing is more variable,  
354 including degrees 1 (~36%), 2 (50%) and 3 (3%).

355 Experimental trampling did not produce substantial evidence of breakage, although it generally  
356 results in a more conspicuous presence of chipping at the base of the shell. Fractures associated  
357 with trampling are mostly asymmetric-irregular and to a lesser extent flute-mouth and notch usually  
358 with degree 2 or 3.

359

#### 360 4.2.3 Morphological and use-wear analysis

361 Scaphopods are the most recorded class in all the Uluzzian layers of Grotta del Cavallo. When  
362 identified at the species level, they are *Antalis dentalis/inaequicostata* and *Antalis vulgaris* (Table  
363 1). Noteworthy is the presence of a single fossil specimen, probable *Fissidentalium rectum* in the  
364 entire macro-layer D.

365 Central and apical portions are the most common ones in all the layers (*SI Appendix, Section VI*  
366 *Table S14*). In the uppermost layers (D), short apical portions are particularly abundant (32 out of  
367 261), usually truncated with rectilinear fractures at their base (Fig. 5). This evidence suggests the

368 systematic removal of the shell apical portions by flexing, in order to obtain segments with a  
 369 diameter as wide as possible to allow the passage of the string. For this reason, these short apical  
 370 fragments could be interpreted as waste products.



372 Fig. 5 Waste products. Small apical portions interpreted as waste products

374 Entire or almost entire specimens are considerably less frequent (*SI Appendix, Section VI Table*  
 375 *S14*). Among these, specimens preserving the apical portions (tot=91; nEIII=20, nEII-I= 5, nD=66)  
 376 are not suitable for suspension, since their apical holes are too narrow to be stringed.  
 377 Rectilinear fractures, followed by irregular asymmetric ones, are the dominant types in all layers  
 378 (Table 4, *SI Appendix, Section VI Table S15-16*). In layer EII-I there is a slight predominance of  
 379 flute-mouth fracture (~25 %) and rectilinear fracture (25%) compared to and asymmetric irregular  
 380 ones (~16%; *SI Appendix, Section VI Tables S15 and S16; Fig S4*). Rectangular notch fractures  
 381 related to sawing are attested on 1 specimen from layer EII-I and on 2 specimens respectively from  
 382 DII and D whole (*SI Appendix, Section VI Fig. S5*). None of these shells exhibit cut-marks.  
 383 Scratches comparable to those experimentally produced by cutting with a flint tool (*SI Appendix,*  
 384 *Section VI Fig. S5 and Fig 6*) are recorded only on one tusk (layer DII), which displays rectilinear  
 385 fractures at both ends and some sort of marks overlapping with the basal one.

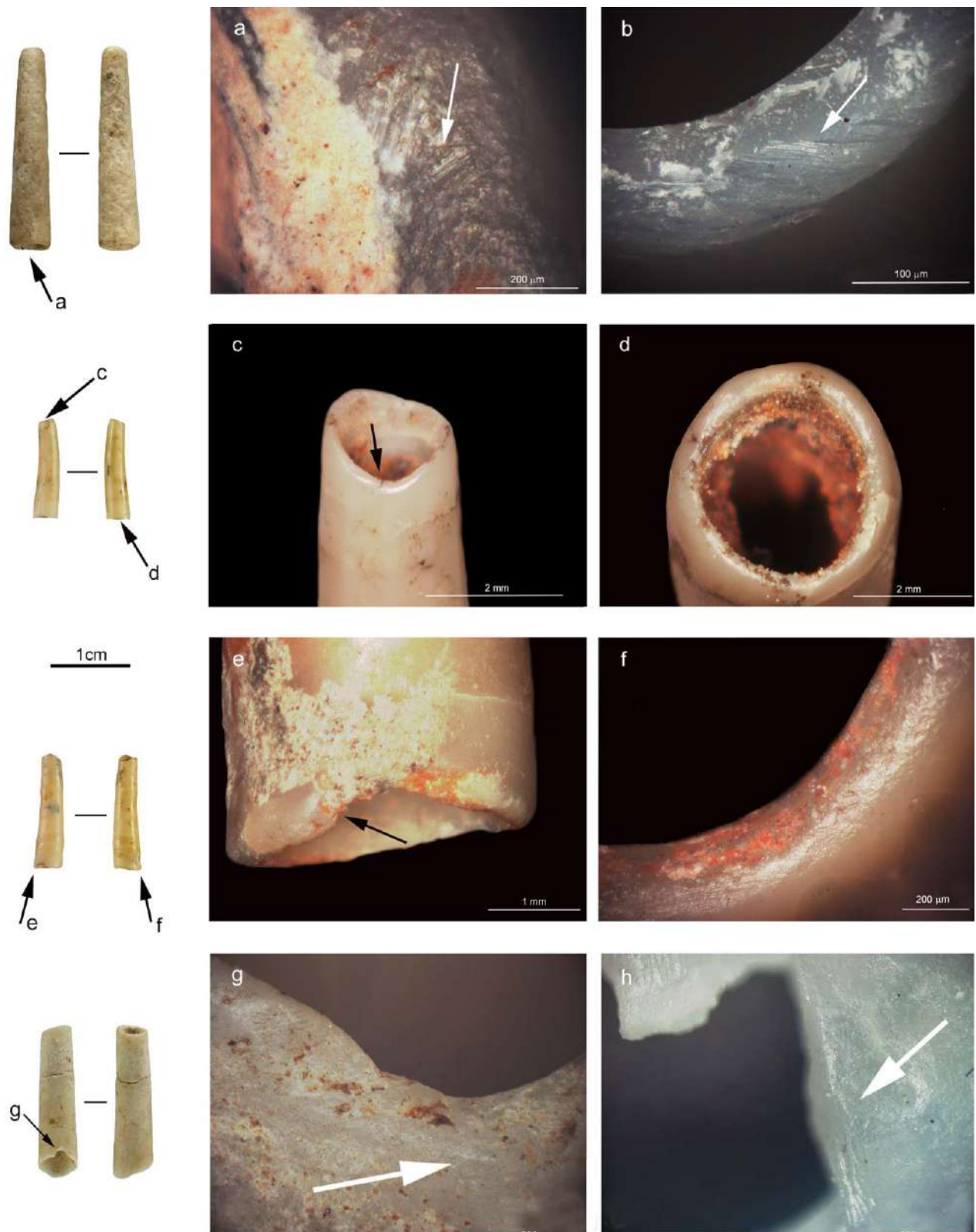
Layer/ Spit	Entire	Rectilinear	Oblique	Asymmetric- irregular	Symmetric- irregular	Flute- mouth	Notch	Rect. notch	Unid.
EIII	12.6% (17)	38.8 % (52)	6.7 % (9)	23.1% (31)	7.4% (10)	2.9% (4)	8.2% (11)	0% (0)	0% (0)

EII-I	8.3% (3)	25% (9)	5.5% (2)	16.6% (6)	8.3% (3)	25% (9)	8.3% (3)	2.7% (1)	0% (0)
E-D	5.8% (2)	32.3% (11)	5.8% (2)	23.5% (8)	0% (0)	11.7% (4)	17.6% (6)	0% (0)	2.6% (1)
DII	12.6% (22)	37.3% (65)	5.1% (9)	24.7% (43)	2.8% (5)	7.4% (13)	8% (14)	0,5% (1)	1.1% (2)
DI	13.7% (24)	40.8% (71)	4% (7)	29.8% (52)	1.1% (2)	5.7% (10)	2.8% (5)	0% (0)	1.7% (3)
D whole	10.9% (19)	43.1% (75)	2.8% (5)	28.7% (50)	2.2% (4)	8% (14)	2.8% (5)	0.5% (1)	0.5% (1)

387 Table 4 - Frequencies of the fractures identified on tusk shells by layer. Real data are reported in  
388 brackets

389

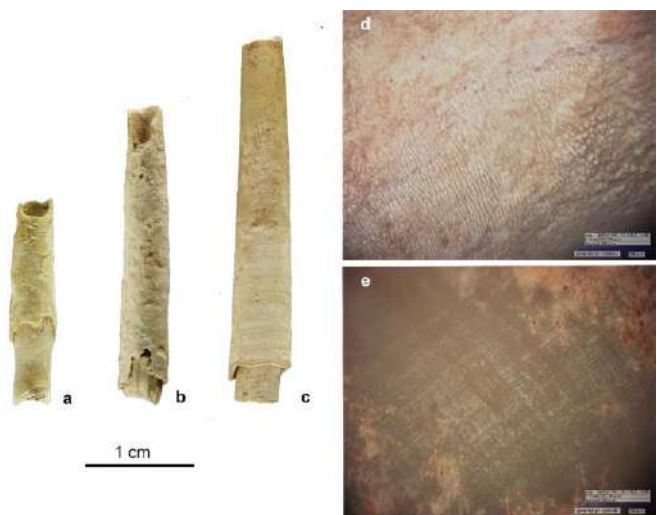
390 The majority of fractures exhibit degree 0 (50.8%), and frequency tends to decrease with increasing  
391 fracture degree (degree 1=22.8%; degree 2=19.8%; degree 3=6.0%) *SI Appendix, Section VI Tables*  
392 *S17 – S22*). A different trend is registered in layer EII-I, where degree 2 is the predominant one.



393

394 Fig. 6 Traces of anthropogenic manipulation. Grotta del Cavallo. Layer DII—tusk shell with cut-  
 395 marks (a), this kind of marks is very similar to those obtained experimentally by cutting tusk shells  
 396 with a flint tool (b). Layer EIII—tusk shell with a notch fracture showing well rounded (c) and

397 polished edges (d). Layer EIII—tusk shell showing a notch fracture with flattened (e) and polished  
398 areas (f). Layer EIII—weak polishes inside a notch fracture (g) and weak polishes inside a notch  
399 fracture produced during suspension experiment with a leather string (h)  
400  
401 The retrieval of two shells inserted into each other is documented in three cases (layers EII-I, E-D,  
402 and DI). This eventuality can be due either to human intervention or taphonomic causes (Fig. 7).  
403 Intentional insertion of tusk shells into each other, especially for the making of necklaces, is well  
404 documented in both archaeological and ethnographic evidence (Ruppert and Bernet 2001;  
405 Dimitrijević 2014). Otherwise, this occurrence was also observed during the gathering of present-  
406 day tusks used for experimental tests, even if in the whole collected sample (1908 tusks) only one  
407 case of insertion was reported. Since the tusks retrieved in layer DI could be easily separated, the  
408 parts of the surface originally located inside the external tusk were analyzed. This portion appears  
409 considerably better preserved and presents some polished areas, while the exposed surface exhibits  
410 the usual altered appearance (Fig. 7).



411  
412  
413 Fig. 7 Tusk shells inserted one into another from Grotta del Cavallo. Tusk shells inserted one  
414 into another from layer EII-I (a), spit E-D (b), and layer DII (c), while the external surface of the  
415 tusks looks weathered (d), and the inner, protected trait shows its original aspect (e)

416 Consequently, the insertion can be considered intentional and not due to post-depositional  
417 processes. Unexpectedly, the same pattern was detectable on the surface of the external shell. In this  
418 case two scenarios can be envisaged:

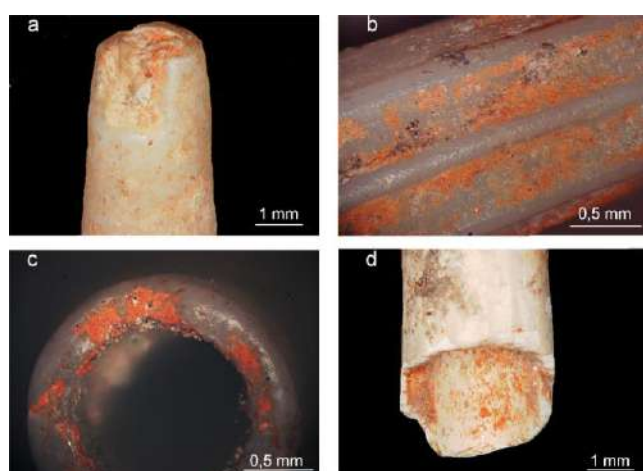
- 419 1. The external shell was in its turn inserted into another shell, which is now lost.
- 420 2. This differential surface preservation could be attributed to post-depositional phenomena acting  
421 with different intensity on the two shells (partial burial for some time?)

422 According to the first hypothesis, we can imagine an adornment object composed of several tusks,  
423 inserted into each other, as largely reported in archaeological and ethnographic contexts (Ruppert  
424 and Bernet 2001; Dimitrijević 2014).

425

426 A number of tusks (11) from layer EIII are coated with red pigment, usually on the whole outer and  
427 inner surfaces (Fig 8). Other items (14) preserve only a few residues of red coloring. They were all  
428 retrieved in two adjacent square meters of the excavation grid (*SI Appendix, Section VI* Fig. S1) and  
429 20 out of 25 ochered items are suitable for suspension, possibly suggesting that the shells were  
430 colored in an ornamental perspective.

431 Traces of red pigment were also recovered on a specimen from layer EII-I. The coloring substance  
432 is distributed inside the tusk and spreads longitudinally (Fig 8).



433

434 Fig. 8 Ochered shells from Grotta del Cavallo. Layer EIII—ocher associated to a notch fracture (a).  
435 Ocher and black residues on the external surface of a specimen (b). Ocher on the apical end of a

436 tusk. The edge is rounded and polished (c). Layer EII-I—ocher located inside the shell and  
437 longitudinally spread (d)  
438

439 Usually, scaphopods are not well-preserved due to decalcification. Only in layer EIII a good number  
440 (30) of tusks exhibits well-preserved surfaces. About half of them (18) show weak traces of  
441 polishing on the outer surface of one or both ends (Fig. 6), often clustered on a limited portion of  
442 the rim (Fig 6). Such traces appear more frequently in central (9) and apical (7) portions, and to a  
443 lesser extent in basal ones (1) and almost complete (1) shells. Polishing traces are associated with  
444 rectilinear, asymmetric, symmetric irregular, and notch fractures.

445 In the uppermost layers the state of preservation of tusks did not allow for a reliable evaluation of  
446 suspension traces. Nevertheless, when the pristine surface of the shell is preserved, slightly rounded  
447 edges on one or both extremities can be observed, although it is difficult to identify actual patterns  
448 and therefore to discriminate between usage (suspension) and post-depositional processes.  
449 Specimens displaying such traces are 3 in layer EII-I, 3 in split E-D, and 25 in unit D. It usually  
450 consists of central portions mainly associated with rectilinear or notch fractures.

451

#### 452 4.2.4 Analysis of variability over time

453 Quantitative analyses were run on a controlled subset (n=255) obtained excluding observations  
454 uncovered in the E-D split and shells generically attributed either to layer DI or DII. Records with  
455 missing information were also not considered (n=4). In this case, sampled shells are almost equally  
456 distributed across layers with the exception of EII-I (nEIII=67, nEII-I=17, nDII=87, nDI=84).

457 Results show that shell minimum and maximum diameter are significantly wider in *Antalis sp.* than  
458 in *Antalis vulgaris* and *Antalis dentalis/inaequicostata* (*SI Appendix, Section VII* Tables S23, S26  
459 and S27). At the same time, maximum diameter increases over time for all the examined portions  
460 including apical ones (*SI Appendix, Section VII* Fig. S6; Tables S30-32), and such an increase is  
461 mirrored by significant increase in the minimum diameter of medial pieces (*SI Appendix, Section*

462 VII Fig. S6; Table S33). Length of entire shells also increases over time (*SI Appendix, Section VII*  
 463 Tables S28 and S35, Fig. S6). However, no difference in length in any layers between likely  
 464 suspended apical pieces and pieces that are less likely to have been used in suspension was recorded  
 465 (*SI Appendix, Section VII Table S34*).

466 The distribution of both distal and proximal fracture types significantly differs across layers (Tables  
 467 S24-25 and S38-40). More in detail, rectilinear and irregular asymmetric fractures are the most  
 468 frequent types among proximal fractures, and their presence tends to increase over time (*SI*  
 469 *Appendix, Section VII Table S36*). Layer EII-I is associated with “notch”, “rectilinear cut”, and  
 470 “flute-mouth” fractures and is segregated from all other layers in multivariate analyses.

471 Correspondence Analysis also suggests a shift over time from irregular/symmetric and oblique  
 472 fractures to irregular/asymmetric and rectilinear fractures in both distal and proximal fractures.

473 The distribution of remnant portions and that of potentially suspended pieces does not significantly  
 474 differ from one layer to the other (*SI Appendix, Section VII Table S35 and Tables S38-39*). The  
 475 distribution of distal fractures is significantly associated with the possibility of being worn in  
 476 suspension in the whole of the stratigraphic sequence (*SI Appendix, Section VII Table S41-43*).

477 More specifically, rectilinear fractures are more frequent in potentially suspended pieces, while non-  
 478 suspended pieces exhibit no distal fractures in any layers with the exception of two instances of  
 479 rectilinear fracture in layer DI (*SI Appendix, Section VII Tables S44-46*). The relative proportion of  
 480 different fracture types visibly changes over time (*SI Appendix, Section VII Tables S47-53*).

481 Diversity in proximal and distal fracture types steadily decreases over time, while diversity in  
 482 remnant portion types tends to increase over time (*SI Appendix, Section VII Fig. 9*). Frequency  
 483 seriation (*SI Appendix, Section VII Fig. S8*) suggests the progressive emergence of irregular  
 484 asymmetric fractures become more abundant over time while irregular symmetric, notch, oblique,  
 485 and flute-mouth fractures decrease in both apex and base. Proximal portions and entire shells are the  
 486 least represented in the assemblage (*SI Appendix, Section VII Fig. S8*). It is interesting to note that,

for all traits, EII-I always exhibits an inverse tendency compared to that of previous and following layers.

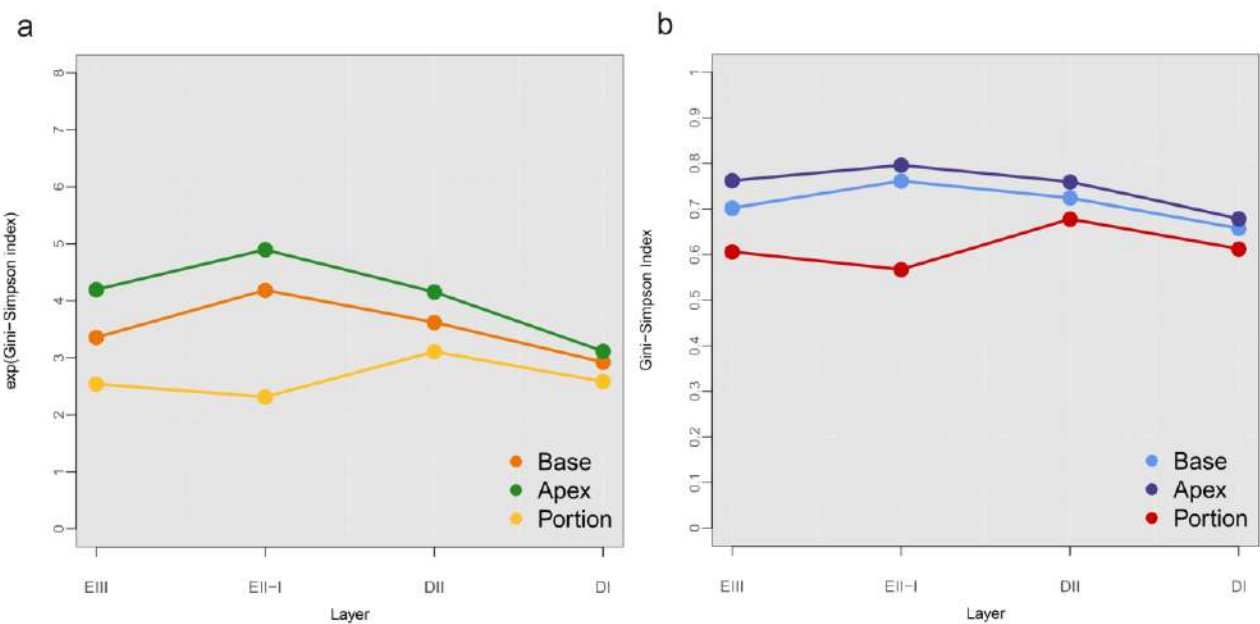


Fig. 9 Diversity over time graphs representing Gini–Simpson’s diversity index (a) and their equivalent numbers (b; following Jost 2006) across the sequence of examined layers at Grotta del Cavallo

When layers are clustered based on measures of pairwise similarity (*SI Appendix, Section VII Table S54; Fig. S9*) EII-I always emerges as the outlier.

### 4.3 Gastropods and bivalves

In the archaic Uluzzian layer EIII gastropods and bivalves are scarce (n=40) and affected by high fragmentation (87.5%) and decalcification (Table 3).

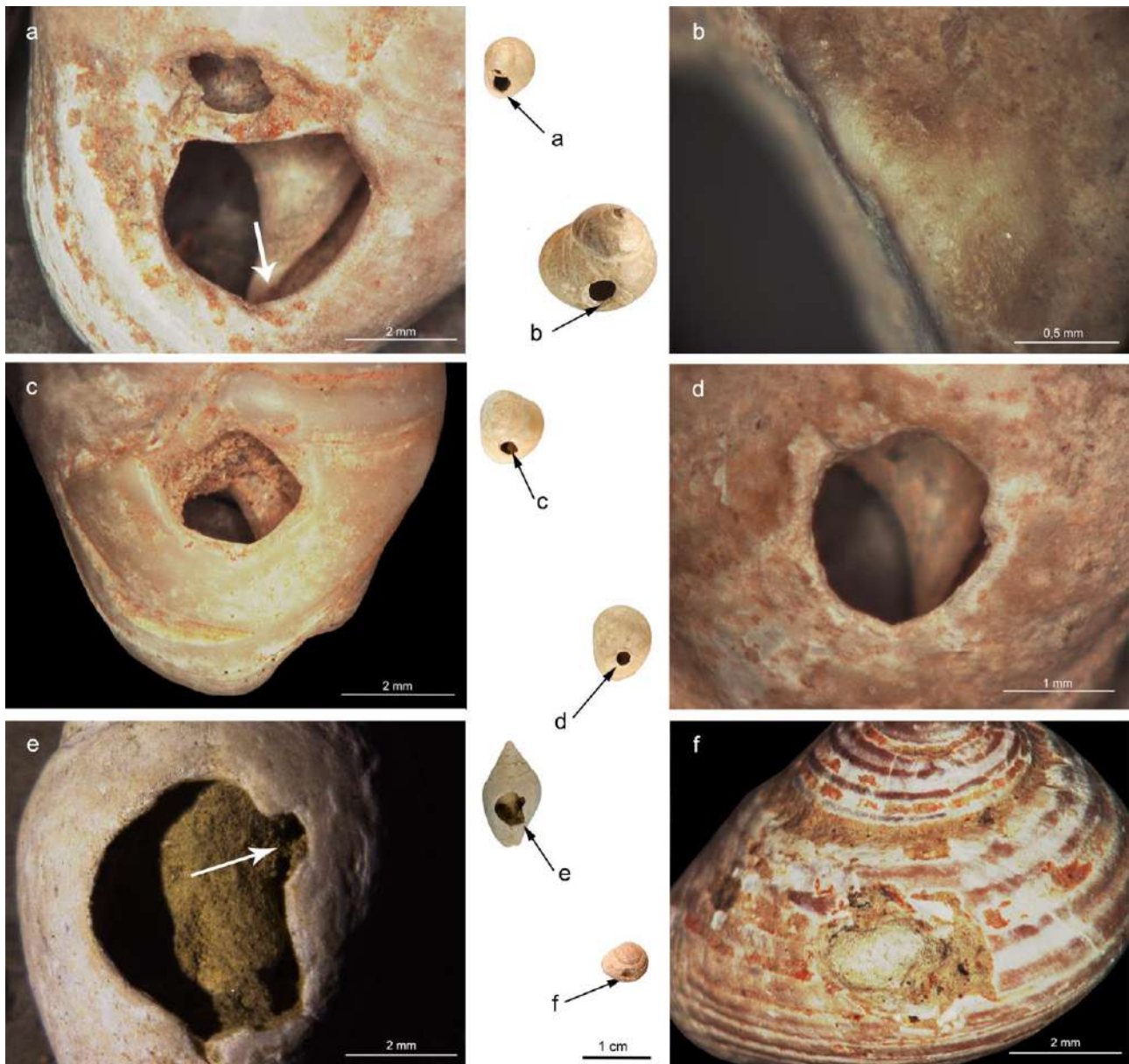
Layers/ Spit	Classes	NISP	Anthropogenic processes					
			ochre	tot_hole	broken	abr_crack	anthropic	anthropized
E III	Gastr.	33	-	2	-	-	1	-
	Biv.	7	-	-	-	-	-	-

E II-I	Gastr.	1	-	1	-	1	-	-
	Biv.	1	-	-	-	-	-	-
E-D	Gastr.	1	-	-	-	-	-	-
	Biv.	1	-	-	-	-	-	-
D II	Gastr.	10	1	6	-	-	6	-
	Biv.	2	-	-	-	-	-	-
DI	Gastr.	42	2	17	1	6	5	-
	Biv.	45	1	12	2	2	-	8
D whole	Gastr.	13	1	5	3	1	1	-
	Biv.	2	-	1	-	1	-	-
<b>Total %</b>	-	<b>158</b>	<b>3.1%</b>	<b>27.84%</b>	<b>3.7%</b>	<b>6.9%</b>	<b>8.2%</b>	<b>5.0%</b>
<b>Total</b>	-	<b>158</b>	<b>5</b>	<b>44</b>	<b>6</b>	<b>11</b>	<b>13</b>	<b>8</b>

500

501 Table 5 Anthropogenic traces on the bivalve and gastropod assemblage by layer

502 Among all uncovered specimens the most outstanding one consists of a complete pierced specimen  
503 of *Tritia neritea* (Table 5 and Fig. 10a). The cross-section exhibits traces of flaking on the outside  
504 surface (defined “interior wedging” by Tátá et al. 2014) that are consistent with perforation from  
505 the inside of the shell. A notch found on the edge of the shell (Fig. 10a) and the rounded rims of the  
506 pierced hole are compatible with repeater contact with a rope used to thread the bead.

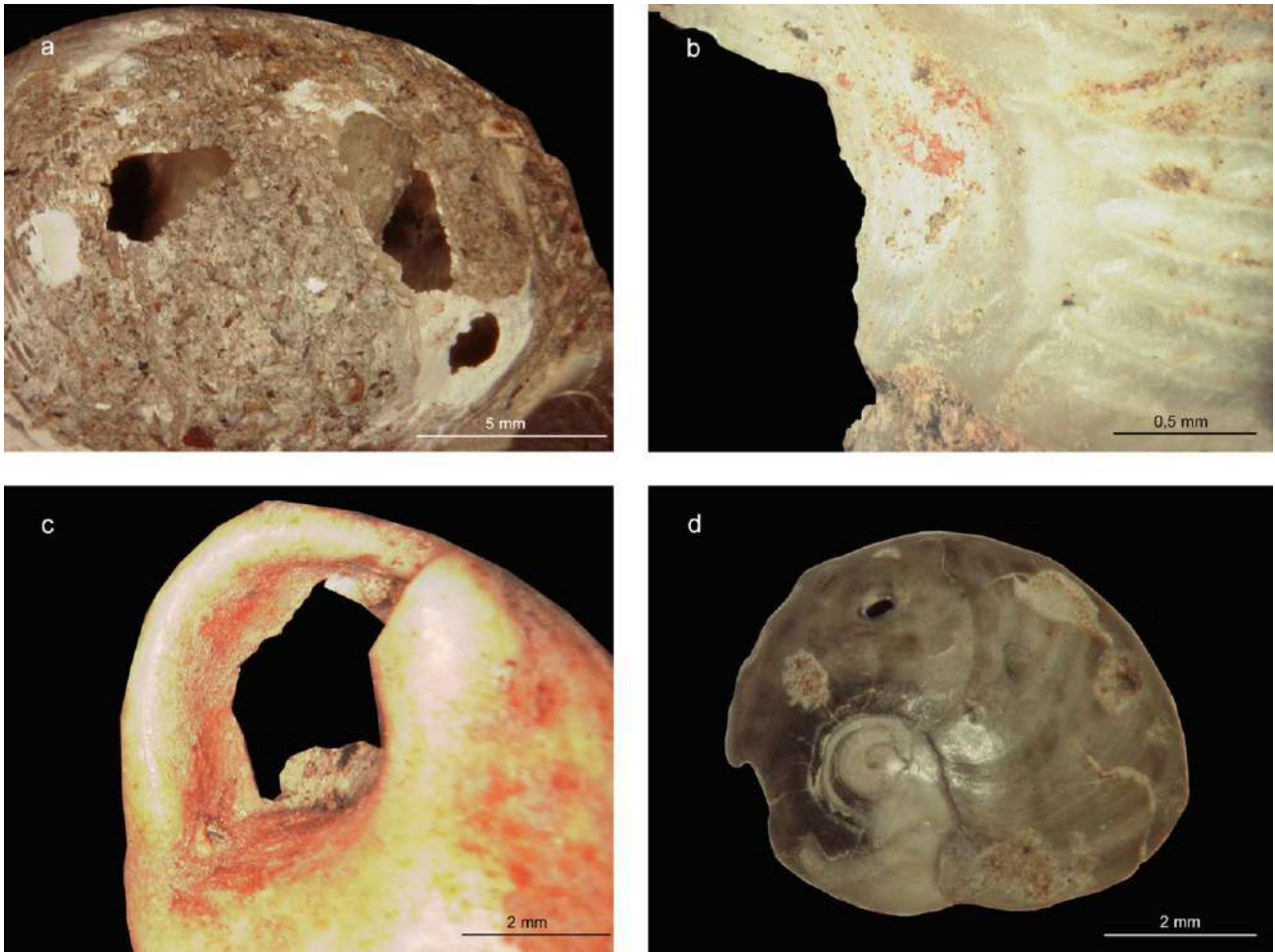


507

508 Fig. 10 Technological traces on gastropods from Cavallo. Layer EIII— perforated *Tritia neritea*  
 509 showing a notch consistent with suspension (a). Layer DII—close-up of use-wear on the edge of the  
 510 hole on a perforated *Phorcus turbinatus* (b). Layer DII—rounded edges on perforated specimens of  
 511 *Tritia neritea* (c, d). Layer DI—perforation on a *Columbella rustica*, showing a notch and rounded  
 512 edge (e). Layer DI— subcircular hole on a *Homalopoma sanguineum* (f)

513

514 A decalcified fragment of *Callista chione*, a *Naticarius hebraeus* covered with concretions and two  
 515 unidentified fragments are the only shells found in layer EII-I. The three holes identified on the  
 516 specimen of *N. hebraeus* present with irregular contours and potential recent breakage of the edges,  
 517 all of which point to post-depositional processes (Fig. 11a).



518

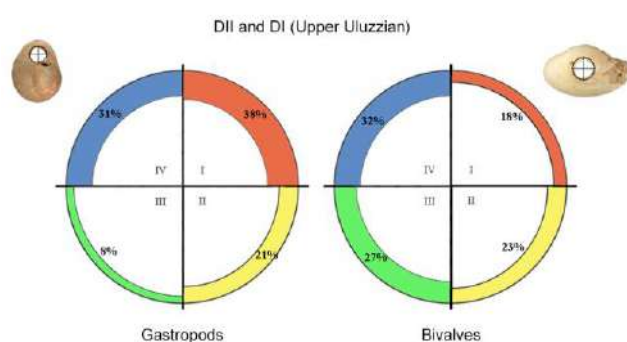
519 Fig. 11 Layer EII-I—postdepositional holes on a *Naticarius hebraeus* (a). Layer DI—traces of  
 520 red pigment near the hole of a *Lembulus pella* (b). Layer DI—residues of red pigment located  
 521 inside the hole of a *Tritia neritea* (c). Layer DI—heat cracks on a *Tritia neritea* (d)

522

523 Only two identified specimens have been retrieved in the transitional split E-D: a fragment of  
 524 *Spondylus gaederopus* and a small shell of *Euspira catena*. These remains no longer show the  
 525 periostracum and their sculptural features due to decalcification.

526 Layers DII and I (Upper Uluzzian) stand out for the large number of gastropods and bivalves. In  
 527 particular *Tritia neritea* (n=31) and *Homalopoma sanguineum* (n=11) are the most abundant species  
 528 in the assemblage. The taphonomic study (Table 3) identified traces of beach weathering on 90% of  
 529 gastropods and traces of predation by other carnivores on ~9% of them. These results suggest that

530 the vast majority of gastropods were collected dead from beach shores, and they were not taken to  
 531 the cave to be consumed as food. The most represented species such as *T. neritea*, *H. sanguineum*,  
 532 *C. rustica* and *Ph. turbinatus* present with regular sub-circular holes located near the shell aperture.  
 533 Notches were detected on hole rims, and edges were abraded probably due to use-wear (Fig.10 b-f).  
 534 The majority of notches are located in the IV (31%) and I (38%) quarters (Fig.12), and are  
 535 consistent with the use of *T. neritea* as suspended ornaments.



536

537

538 Fig. 12 Graphic representation of the location of notches on edges of pierced shell found at Grotta  
 539 del Cavallo during the Upper Uluzzian (DII-DI) Ochre was found inside three specimens (Fig. 11b  
 540 and c), and five gastropods show heat cracks on their external surface (Fig 11d).

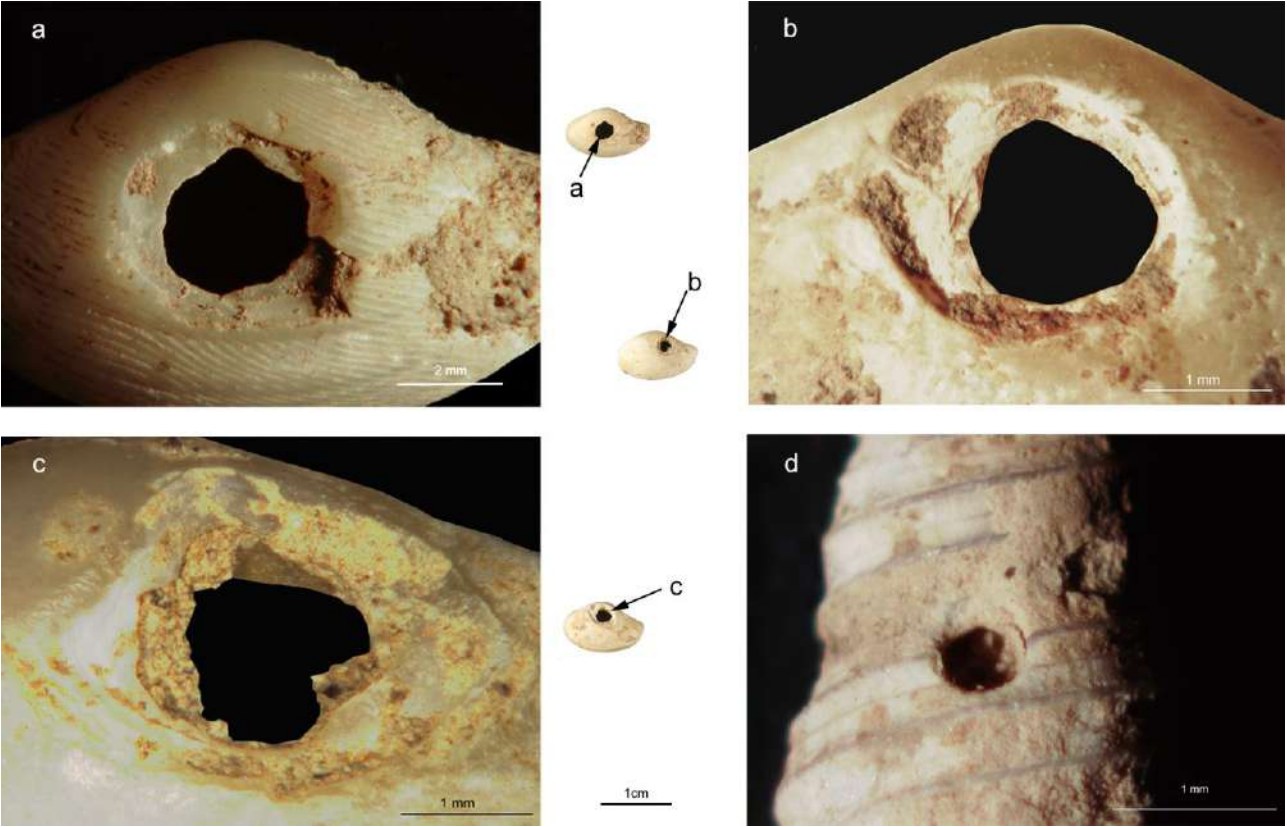
541

542 Bivalves mostly consist of *Mytilis galloprovincialis*, *Glycymeris* sp., and *Lembulus pella*. The first  
 543 species is represented by fragments and hinges. Two broken hinges of *Glycymeris* sp. exhibit partial  
 544 holes on the umbos although fragmentation makes it impossible to discriminate between anthropic  
 545 and natural taphonomic processes. Specimens of *L. pella* consist instead of entire valves.

546 Taphonomic analysis based on all fragments and the small amount of complete specimens support  
 547 the conclusion that almost 70% of bivalve remains were abraded by sea waves on the shore.

548 Furthermore, all valves of *L. pella* show perfectly round and bevelled holes, both signs of drilling  
 549 by mollusc predators. Nevertheless, notches and irregular flaking are once again visible on the  
 550 edges of drilled holes (Fig. 13a-c), both of which are consistent with use-wear (Fig. 13b-c). These  
 551 traces, however, are not coherent with drilling perforation operated by other molluscs (Fig.13d).

552 The notches are located near the umbo (quarter IV, 32%) and on the edge above it (quarter III, 27%)  
 553 (Fig.12). We therefore suggest that these naturally pierced shells were deliberately chosen to be  
 554 used as beads by humans. In addition, some red dusty substance (possibly ochre) was found on the  
 555 external surface of one of the valves (Fig.11d).



556  
 557 Fig. 13 Layer DI—*L. pella* with a round drilled hole showing a notch in quarter IV (a). Layer DI—  
 558 *L. pella* with drilled holes showing notches in quarter IV and irregular flaking (b, c). Layer EIII—  
 559 hole due to predation on a *Turritella* sp. (d)

560

## 561 5. Discussion

562 The ornamental shell assemblage of Grotta del Cavallo is mostly characterised by a large amount of  
 563 scaphopods which are present across the entire archaeological sequence and abound in the  
 564 uppermost layers, where gastropods and bivalves are also recorded. Among gastropods *Tritia*  
 565 *neritea* is the most frequently recorded species, while *Lembulus pella* dominants among bivalves.

566

### 567 5.1 Bead making at Grotta del Cavallo

568 As far as tusk shells are concerned, the results of our multidisciplinary study point to an  
569 anthropogenic action both in terms of their collection and manufacture. As attested by directly  
570 dating results (Benazzi et al. 2011), and micropaleontological and Sr isotope analyses, the  
571 archaeological specimens presented here are not fossil shells deriving from sedimentary outcrops  
572 located in site surroundings, but rather consist of shells collected from beach shores at the same  
573 time as the Uluzzian occupation of Grotta del Cavallo. The distance between Grotta del Cavallo and  
574 the coastline was then about 12 km, enough to exclude any possible natural origin for the  
575 occurrence of tusk shells inside the cave (*Appendix, Section VIII* and Fig S10).

576 These molluscs live in the sandy seabed below the intertidal zone, down to relatively great depths  
577 (*Appendix, Section IX*). Therefore, they were most likely collected by the Uluzzian groups on the  
578 beaches of shores that today are submerged. The collection of scaphopods by prehistoric people for  
579 feeding purposes is generally rejected, considering their small size and their very low nutritional  
580 value (Bar-Yosef Mayer 2008).

581 Data resulting from our experimental and statistical tests support a human origin also for  
582 manufacture, and experimental results reveal a possible association between scaphopod portioning  
583 and type of fracture. Nevertheless, we agree with Vanhaeren and d’Errico (2001) and Taborin  
584 (1993) that no specific fracture can be univocally associated with anthropogenic action. Although  
585 intentionality cannot be definitely proven for any rectilinear fracture uncovered in archaeological  
586 assemblages, this kind of fracture is abundant in the dataset from Grotta del Cavallo, while it is  
587 considerably rarer among experimental samples generated through trampling or in shells collected  
588 on the present-day beaches, as already pointed out by previous research (Vanhaeren and d’Errico  
589 2001). The only traces that surely correlate with human intervention are sawing cut-marks. In the  
590 assemblage of Cavallo cut-marks were identified only on one specimen from layer D because of the  
591 general bad state of preservation of all shells. In both layers E and D at Cavallo, however, a  
592 particular notch-shaped fracture is documented, which, based on our experimental results and on  
593 data from the literature (Vanhaeren and d’Errico 2001), can still be related to sawing. The other

594 types of fractures (in particular asymmetric and symmetric irregular fractures) are less diagnostic  
595 because they can be also produced by trampling and other post-depositional processes. Notch and  
596 flute-mouth fractures can also occur during suspension, due to the contact among beads (Álvarez  
597 Fernández, 2006). In this light, the presence of red coloring substances on the shells exhibiting  
598 flute-mouth and notch fractures becomes more informative. These characteristics are reminiscent of  
599 the ochred shell from Riparo Broion, also displaying a notch fracture (*Appendix, Section X, Fig.*  
600 *S12*).

601 Results also support change over time in the most represented distal and proximal fracture types.  
602 Irregular asymmetric and rectilinear fractures increase their presence over time and become the  
603 most represented ones. In earlier phases, notch, oblique, and irregular symmetric fractures are more  
604 frequent. Diversity is generally high in the whole of the sequence (especially in distal fractures).  
605 Nevertheless, a tendency towards higher homogeneity of fracture types can be ascertained over time  
606 (lowest diversity in DI), with a preference for rectilinear ones. This evidence may be also due to a  
607 change in manufacturing techniques (i.e. percussion technique in earliest and bending in recent  
608 phases respectively) or to different post-depositional processes. Dimensional analysis shows a  
609 generalised increase in complete shell size and maximum diameter of all portions over time. This  
610 could be due to a change in catchment preference guided by a selective pressure for bigger shells; or  
611 it could relate to change in environmental conditions, despite data are still scarce to support this  
612 hypothesis. Relations between some environmental factors and morphological variations (e.g. body  
613 size) are known for the most common benthic molluscs in the Mediterranean (e.g. Mamouridis et al.  
614 2011; Peharda et al. 2017), but currently are not available for *Antalis* specimens.

615 Despite the increase in the size of entire shells over time, length of distal pieces does not change  
616 and may reflect a choice aimed to obtain homogeneous beads. Although the level of regularity  
617 exhibited by the Magdalenian *parure* of La Madeleine in France (Vanhaeren and d'Errico 2001) is  
618 never reached. In the assemblage found at Cavallo there are also entire tusks that are suitable for  
619 suspension, suggesting that this use might have involved beads of different size. The type of tusk

620 remnant portions tends to become more diverse over time. Only layer EII-I exhibits a different  
621 distribution, displaying a predominance of medial portions consistently associated with a large  
622 variety of fracture types (in both apex and base).

623 Furthermore, the presence of short apical portions in unit D often associated with rectilinear  
624 fractures at the base of the apical portion, could suggest a manufacturing process *in situ*. They seem  
625 to illustrate the systematic breakage of the apexes by bending to obtain beads easily and quickly.  
626

627 As far as gastropods and bivalves are concerned, 13.2% of the total NISP exhibits traces of  
628 anthropic manipulation for ornamental purposes. Nevertheless, shell collection for dietary purpose  
629 can be confidently excluded for most gastropods and bivalves, because of their small size and  
630 because they were collected dead on beaches, as suggested by taphonomic analysis (Stiner 1999;  
631 Vanhaeren and d'Errico 2006; Colonese et al. 2011; Stiner et al. 2013; Stiner 2014; Bosch et al.  
632 2015).

633 *Tritia neritea* is the most frequent species among gastropods (37.5% of which exhibits signs of  
634 perforation) followed by *Homalopoma sanguineum* (18.2% of which is perforated).

635 Pierced specimens show a high degree of s regularity in perforation techniques. Holes are  
636 consistently located near the shell aperture, anthropogenic-flaking is always found on the outer  
637 surface of the shell, and use-wear abrasion is consistently found on the lips near the aperture. These  
638 data are consistent with those observed in our experimental collection, even though further tests are  
639 required to better understand the exact method of perforation.

640 Bivalves seem to be less frequently chosen as adornment objects, evidence of which can be only  
641 found in the latest Uluzzian phase (layer DI). This might be due to the great incidence of alimentary  
642 species among bivalves, such as *Mytilus galloprovincialis*, *Glycymeris nummaria* and *Callista*  
643 *chione*. Anthropogenic traces can be detected on the 10 remains attributed to *Lembulus pella*, even  
644 if no intentional perforation can be identified. All specimens present with circular holes with

645 bevelled edges that can be attributed to predator gastropods. At the same time, the best preserved  
646 shells also exhibit notches located near the umbo that are consistent with deliberate suspension.  
647 The opportunistic use of natural holes is commonly documented in archaeological contexts (Bar-  
648 Yosef Mayer et al. 2009; Cabral and Martins 2016).

649

650 All the above mentioned results support human involvement in collection, transportation, and  
651 modification (the latter for a part of the assemblage) of the shells uncovered at Grotta del Cavallo. If  
652 pierced specimens and intentionally broken or used tusks can be confidently associated with an  
653 ornamental role, unmodified shells can be interpreted as raw materials waiting to be used in bead  
654 production. Since natural accumulation of shells can be excluded, the occurrence of unpierced  
655 items which are not suitable for consumption, tusk shells which are not suitable for suspension, and  
656 waste products suggests that a systematic manufacturing process was taking place at the site.  
657 Considering the clustered distribution of shells illustrated above, the presence of an adornment  
658 manufacturing area could be proposed for the most recent phase (layer DI). This area was likely  
659 located in square H11 and, to a lesser extent, in square H7, where shells have been retrieved. In the  
660 oldest layers, shells were found in a different area of the cave. Here the retrieval of tusk distal  
661 portions not suitable for suspension is also documented, and is also possible to hypothesize  
662 breakage *in situ*, even if with lower levels of intensity and dimensional homogeneity.

663

## 664 **5.2 Bead making in the Uluzzian**

665 When looking at the other main Uluzzian sites found in Italy and Greece (e.g., Grotta della Cala,  
666 Grotta di Castelcivita, Klissoura Cave, Riparo Broion), we observe a uniform scenario (except for  
667 Castelcivita) exclusively characterized by shell ornaments, among which tusk shells are usually  
668 prevalent (Fiocchi 1998; Stiner 2010; Peresani et al. 2019a). Such a composition of ornamental  
669 assemblages testifies to the existence of a shared and widespread tradition across the Mediterranean.  
670 Clearly recurrent features and marked similarity between sites imply either common ancestry or

671 cumulative mechanisms of cultural transmission and diffusion, processes that are commonly  
 672 accepted for the Protoaurignacian (Vanhaeren and d'Errico 2006; Stiner et al. 2013). At Riparo  
 673 Broion (Northern Italy), where the Uluzzian layers (SU 1f and 1g) have been recently dated to 44.4  
 674 – 42.8 ka cal BP, a few finished shell beads have been retrieved (*Appendix, Section X, Fig. S12-13*).  
 675 These consist of five scaphopods (4 *Antalis vulgaris* and 1 *Antalis dentalis/inaequicostata*) and a  
 676 pierced gastropod (*Teodoxus fluvialis*; Peresani et al. 2019a). All tusk beads show clear signs of  
 677 anthropogenic manipulation, documented by the occurrence of cut-marks on a specimen and well-  
 678 developed suspension wear-traces on the whole of the sample (Peresani et al. 2019a). These beads  
 679 are notably constrained in their size range, when compared with those from Cavallo. Noteworthy is  
 680 the presence of notch fractures that can be related to suspension (*Appendix, Section X, Fig. S13*). In  
 681 addition, the gastropod shows traces of intentional perforation and suspension (Peresani et al.  
 682 2019a). The distance of Riparo Broion from possible fossil outcrops and/or the coast suggests that  
 683 the shells were brought to the site as finished products.

684 Moving to southern Italy, several mollusks (n=78) were found in the Uluzzian layers of Grotta della  
 685 Cala. These specimens belong to 25 different *taxa* (classes Gasteropoda, Bivalvia, Scaphopoda;  
 686 Fiocchi 1998). Among them there are six pierced gastropods (*H. sanguineum* and *T. pellucida*), two  
 687 perforated bivalves (*Glycimeris nummaria*) and 24 scaphopods. At a preliminary analysis, tusk  
 688 shells show rounded edges and seem to be all finished beads with probable suspension traces.

689 Klissoura Cave I (Peloponnesus, Greece) yielded 11 tusk shells and several gastropods, especially  
 690 *Tritia neritea* (n=7), and a few bivalves. The predominance of tusks and *Tritia neritea* draws an  
 691 interesting parallel with the uppermost layers of Grotta del Cavallo, especially considering the  
 692 temporal overlap between the two contexts (Douka et al. 2014).

693 The cave site of Castelcivita, located at the foot of the Alburni massif (southern Italy), stands out  
 694 from this framework as it yielded, so far, only two fragmentary shells (bivalves) (Gambassini 1997).  
 695 However, investigations at this site are still ongoing and the ornamental record might be enriched  
 696 by further items.

697 It is worth noting the marked resemblance between Uluzzian contexts and the Preaurignacian levels  
698 of Franchthi Cave (Peloponnesus, Greece) sealed by CI tephra (Farrand 2000; Fitzsimmons et al.  
699 2013). Here a number of shells has been retrieved, but their poor state of preservation did not allow  
700 researchers to ascertain their use or the presence of perforation (Perlès 2019). The assemblage at  
701 Frachthi Cave mostly consists of inedible tusk shells and *Tritia neritea*, like in the case of Klissoura  
702 and Grotta del Cavallo DII-DI, both of which are used for ornament making in the following phases  
703 (Perlès 2019).

704 When ornaments of all Uluzzian contexts are considered at once a general trend over time can be  
705 identified in assemblage composition. The earliest phases (Cavallo layers EIII and EII-I, Broion)  
706 are characterized by scaphopods and rare pierced gastropods, whilst later phases (Cavallo layers DII  
707 and DI, Klissoura, Cala and maybe also Franchthi) show an increase in richness of species used for  
708 ornament production but still with a higher percentage of tusk shells, followed by gastropods  
709 (especially *Tritia neritea*). Among them *H. sanguineum* is marginally represented. In contrast,  
710 subsequent Upper Palaeolithic contexts display a marked preference for this species, which was  
711 consistently included in personal ornamental assemblages and exchanged over long distance across  
712 the Europe (Alvarez-Fernández 2006; Vanhaeren and d'Errico 2006; Peresani et al. 2019b). As far as  
713 bivalves are concerned, they seem to be considered less relevant until the latest Uluzzian phases.

714 Ornament assemblage size in Uluzzian sites is also relevant, when compared with the coeval  
715 Châtelperronian, the only European techno-complex to have yielded conspicuous ornamental  
716 assemblages, composed of bone and ivory pendants as well as very sporadic shells (Zilhão 2007).  
717 Their size, however, is considerably smaller than that of the Uluzzian assemblages. The bulk of the  
718 Châtelperronian ornaments are from Grotte du Renne (n=35, d'Errico et al. 1998), where uncertain  
719 integrity of the stratigraphic sequence made it difficult to accurately reconstruct the cultural  
720 provenance of some items (White 2002; Higham et al. 2010; but see *contra* Caron et al. 2011;  
721 Hublin et al. 2012).

722 The other Châtelperronian sites yielded only a few ornaments (Zilhão 2007), but many of these  
723 deposits, such as Grotte des Fées, Roc de Combe and Trou Magrite, suffered from the intrusion of  
724 Aurignacian materials (Bordes and Labrot 1967; Rigaud 2001; Moreau 2003; Mellars et al. 2007;  
725 Zilhão et al. 2007). The occurrence of several tusk shells at Saint-Césaire is certainly of great  
726 interest (d'Errico et al. 1998), but, regretfully, no further information is available on this material.  
727 The other European transitional techno-complexes are characterized by sporadic findings  
728 (Kozłowski 1982; Hülle 1977; Zilhão 2007) which do not seem to support a pivotal role of  
729 nonperishable personal ornaments in the local material cultures.

730 Also worthy of note is the complete lack of tusks in the Initial Upper Palaeolithic (Emiran)  
731 assemblages of the Levant, where gastropods and bivalves are the only species used for ornamental  
732 purposes. To date, the most ancient tusk beads of this region are from layer E-E2 (ca 42. ka cal BP;  
733 Kuhn et al. 2009) of Üçağızlı Cave (Turkey; Stiner et al. 2002; Campbell 2017), containing an early  
734 Ahmarian assemblage (Stiner et al. 2013). In this area other scaphopods have been recovered at  
735 Manot Cave and Kebara, inside contexts with mixed Ahmarian and Aurignacian materials. The  
736 presence of such shells is currently interpreted as the result of influence by groups bearing  
737 European Aurignacian cultural elements (Bar Yosef-Mayer 2019). This evidence confirms the  
738 differences existing between Uluzzian and IUP contexts and is consistent with the lack of Uluzzian-  
739 like techno-complexes in the Near East (Moroni et al. 2013).

740 In ethnographic instances ornaments connote and, in some cases, identify the human groups who  
741 produce and wear them, thanks to the social, symbolic, cognitive and artistic values they embody.  
742 In this perspective adornment objects (including but not limited to shell beads) are elements of  
743 visual communication. For these reasons their widespread presence in the Uluzzian suggests a high  
744 degree of cohesion within and possibly between human groups. What the use of ornaments exactly  
745 symbolized in the Uluzzian mental template is difficult to say, even if we can hypothesize that  
746 these objects played a key role in defining and communicating the identity of the individual and/or  
747 the group to which the individual belonged - thus suggesting, in some way, the occurrence of a

748 shared symbolic background. The systematic production and use of ornaments, in addition to other  
749 characteristics, markedly differentiate the Uluzzian from the Mousterian, as the occurrence of  
750 ornaments in the Middle Palaeolithic remains sporadic, despite some recent discoveries and  
751 researchers' increased interest for this debated issue (Zilhão et al. 2009; Peresani et al. 2011;  
752 Peresani et al. 2013; Romandini et al. 2014).

753

## 754 **6. Conclusion**

755 The widespread occurrence of shell beads in Uluzzian contexts supports the emergence of a well-  
756 established technology of bead making in Mediterranean Europe early as 45 ka, well before the  
757 onset of Aurignacian ornament productions across Europe. Uluzzian groups in Italy and Greece  
758 shared the same ornament traditions, and Grotta del Cavallo is the archaeological context that best  
759 explains this phenomenon. The Uluzzian sequence at this site yielded the most conspicuous amount  
760 of shell beads ever found in European transitional contexts. Analysing change over time in this  
761 assemblage allow us to document the presence of finished products and unfinished by-products,  
762 attesting to an increasing seek for dimensional regularity and serial production, as well as to the  
763 evidence for systematic ornament use. These features indicate that the Uluzzian bead making is  
764 fully comparable with the ornament productions typical of the Upper Palaeolithic, and push back  
765 the date for the beginning of systematic ornament use and manufacture in Europe to 45 ka

## 766 **Data availability**

767 Authors can confirm that all data and source codes for analyses are currently included as  
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787 and L.M.F. carried out micropaleontological studies and F.L. and A.C. realized isotope analysis.  
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795

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## List of captions

**Fig. 1** Distribution of ornaments dated between ca. 45-39 ka across transitional contexts in Europe (sites with debated cultural attribution are represented here, see Discussion chapter). Pie radius is proportional to the total size of ornamental assemblages, while colours indicate the relative

1177 proportion contributed by different classes of items. 1) Saint-Césaire, 2) Quinçay, 3) Roc de Combe,  
1178 4) Caune de Belvis, 5) Cova Foradada, 6) Roche au Loup, 7) Grotte du Trilobite, 8) Grotte des Fées,  
1179 9) Grotte du Renne, 10) Trou Magrite, 11) Ilsehöle Ranis, 12) Willendorf II, 13) Riparo Broion,  
1180 14) Grotta della Cala, 15) Grotta del Cavallo, 16) Klissoura Cave, 17) Franchthi Cave, 18) Bacho  
1181 Kiro, 19) Brynzeny I

1182

1183 **Fig. 2** Selection of shells from Grotta del Cavallo. a) *Antalis* sp. b) *Tritia neritea*. c) *Antalis* sp. d)  
1184 *Antalis* sp. e) *Tritia neritea*. f) *Homalopoma sanguineum*. g) *Columbella rustica*. h) *Phorcus*  
1185 *turbinatus*. i) *Lembulus pella*. j) *Glycymeris* sp.

1186

1187 **Fig. 3** Type of fractures. Classification according to the type of fracture on the experimental  
1188 material: rectilinear (a); oblique (b); symmetric irregular (c); asymmetric irregular (d); flute-mouth  
1189 (e); notch (f). The bar is 1 mm

1190

1191 **Fig 4** Fracture degrees. Flute-mouth fracture with degree 1(a); flute-mouth fracture with degree 2  
1192 (b); flute-mouth fracture with degree 3 (c). The bar is 2 mm

1193

1194 **Fig 5** Waste products. Small apical portions interpreted as waste products

1195

1196 **Fig.6** Traces of anthropogenic manipulation. Grotta del Cavallo. Layer DII – Tusk shell with cut  
1197 marks (a) this kind of marks are very similar to those obtained experimentally by cutting tusk shells  
1198 with a flint tool (b); Layer EIII - Tusk shell with a notch fracture showing well rounded (c) and  
1199 polished edges (d); Layer EIII- Tusk shell showing a notch fracture with flattened (e) and polished

1200 areas (f); Layer EIII. Polishes inside a notch fracture (g); polishes inside a notch fracture produced  
1201 during suspension experiment with a leather string (h)

1202

1203 **Fig.7** Tusk shells inserted one into another from Grotta del Cavallo. Tusk shells inserted one into  
1204 another from layer EII-I (a), split E-D (b) and layer DII (c). While the external surface of the tusks  
1205 looks weathered (d), the inner, protected trait shows its original aspect (e)

1206

1207 **Fig.8** Ochred shells from Grotta del Cavallo. Layer EIII- Ochre associated to a notch fracture (a).  
1208 Ochre and black residues on the external surface of a specimen (b). Ochre on the apical end of a  
1209 tusk. The edge is rounded and polished (c). Layer EII-I- Ochre located inside the shell and  
1210 longitudinally spread (d)

1211

1212 **Fig. 9** Diversity over time Graphs representing Gini-Simpson's Diversity index (a) and their  
1213 Numbers equivalent (b; following Jost 2006) across the sequence of examined layers at Grotta del  
1214 Cavallo

1215

1216 **Fig. 10** Technological traces on gastropods from Cavallo. Layer EIII – Perforated *Tritia neritea*  
1217 showing a notch consistent with suspension (a). Layer DII – Close-up of use-wear on the edge of  
1218 the hole on a perforated *Phorcus turbinatus* (b). Layer DII - Rounded edges on perforated  
1219 specimens of *Tritia neritea* (c-d). Layer DI - Perforation on a *Columbella rustica*, showing a notch  
1220 and rounded edge (e). Layer DI - Sub-circular hole on a *Homalopoma sanguineum* (f)

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1222 **Fig 11** Layer EII-I - Post-depositional holes on a *Naticarius hebraeus* (a). Layer DI -Traces of red  
1223 pigment near the hole of a *Lembulus pella* (b). Layer DI - Residues of red pigment located inside  
1224 the hole of a *Tritia neritea* (c). Layer DI - Heat cracks on a *Tritia neritea* (d)

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1226 **Fig.12** Graphic representation of notches location on edges of pierced shell found at Grotta del  
1227 Cavallo during the Upper Uluzzian (DII-DI)

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1229 **Fig 13** Layer DI - *L. pella* with a round drilled hole showing a notch in quarter IV (a). Layer DI - *L.*  
1230 *pella* with drilled holes showing notches in quarter IV and irregular flaking (b-c). Layer EIII - Hole  
1231 due to predation on a *Turritella* sp. (d)

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