



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ARCHIVIO ISTITUZIONALE DELLA RICERCA

Alma Mater Studiorum Università di Bologna Archivio istituzionale della ricerca

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

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Simona Arrighi, E.B. (2020). Backdating systematic shell ornament making in Europe to 45,000 years ago. *ARCHAEOLOGICAL AND ANTHROPOLOGICAL SCIENCES*, 12, 1-22 [10.1007/s12520-019-00985-3].

Availability:

This version is available at: <https://hdl.handle.net/11585/724188> since: 2020-03-04

Published:

DOI: <http://doi.org/10.1007/s12520-019-00985-3>

Terms of use:

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>).
When citing, please refer to the published version.

(Article begins on next page)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

This is the final peer-reviewed accepted manuscript of:

Simona Arrighi, Eugenio Bortolini, Laura Tassoni, Andrea Benocci, Giuseppe Manganelli, Vincenzo Spagnolo, Luca Maria Foresi, Anna Maria Bambini, Federico Lugli, Federica Badino, Daniele Aureli, Francesco Boschini, Carla Figus, Giulia Marciani, Gregorio Oxilia, Sara Silvestrini, Anna Cipriani, Matteo Romandini, Marco Peresani, Annamaria Ronchitelli, Adriana Moroni, Stefano Benazzi

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

Archaeological and Anthropological Sciences

The final published version is available online at:

<https://doi.org/10.1007/s12520-019-00985-3>

Rights / License:

The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

24 Simona Arrighi^{a,b,c*}, Eugenio Bortolini^a, Laura Tassoni^d, Andrea Benocci^b, Giuseppe Manganelli^b,
25 Vincenzo Spagnolo^{b,c}, Luca Maria Foresi^b, Anna Maria Bambini^b, Federico Lugli^{a,e}, Federica
26 Badino^{a,f}, Daniele Aureli^{b,c,g}, Francesco Boschin^{b,c}, Carla Figus^a, Giulia Marciani^{a,b}, Gregorio
27 Oxilia^a, Sara Silvestrini^a, Anna Cipriani^{e,h}, Matteo Romandini^{a,d}, Marco Peresani^d, Annamaria
28 Ronchitelli^b & Adriana Moroni^{b,c,i}, Stefano Benazzi^{a,j}

29

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

31

32 ^aDipartimento di Beni Culturali, Università di Bologna, 48121 Ravenna, Italy, ^bDipartimento di
33 Scienze Fisiche della Terra e dell’Ambiente, Università di Siena, 53100 Siena, Italy ^c Centro Studi
34 sul Quaternario, 52037 Sansepolcro, Italy, ^d Dipartimento di Studi Umanistici, Università di Ferrara,
35 44100 Ferrara, Italy, ^e Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e
36 Reggio Emilia, 41125 Modena, ^f C.N.R. - Istituto per la Dinamica dei Processi Ambientali, 20126
37 Milano, Italy, ^g UMR 7041 ArScAn Equipe An-TET, Université Paris Ouest Nanterre La Défense,
38 F-92023 Nanterre, France, ^h Lamont-Doherty Earth Observatory, Columbia University, Palisades,
39 New York, 10964, USA, ⁱ Istituto Italiano di Paleontologia Umana, 03012 Anagni (FR), Italy, ^j
40 Department of Human Evolution Max Planck Institute for Evolutionary Anthropology, 04103
41 Leipzig, Germany.

42 *Corresponding author (e-mail: simona.arrighi@unibo.it)

43

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).

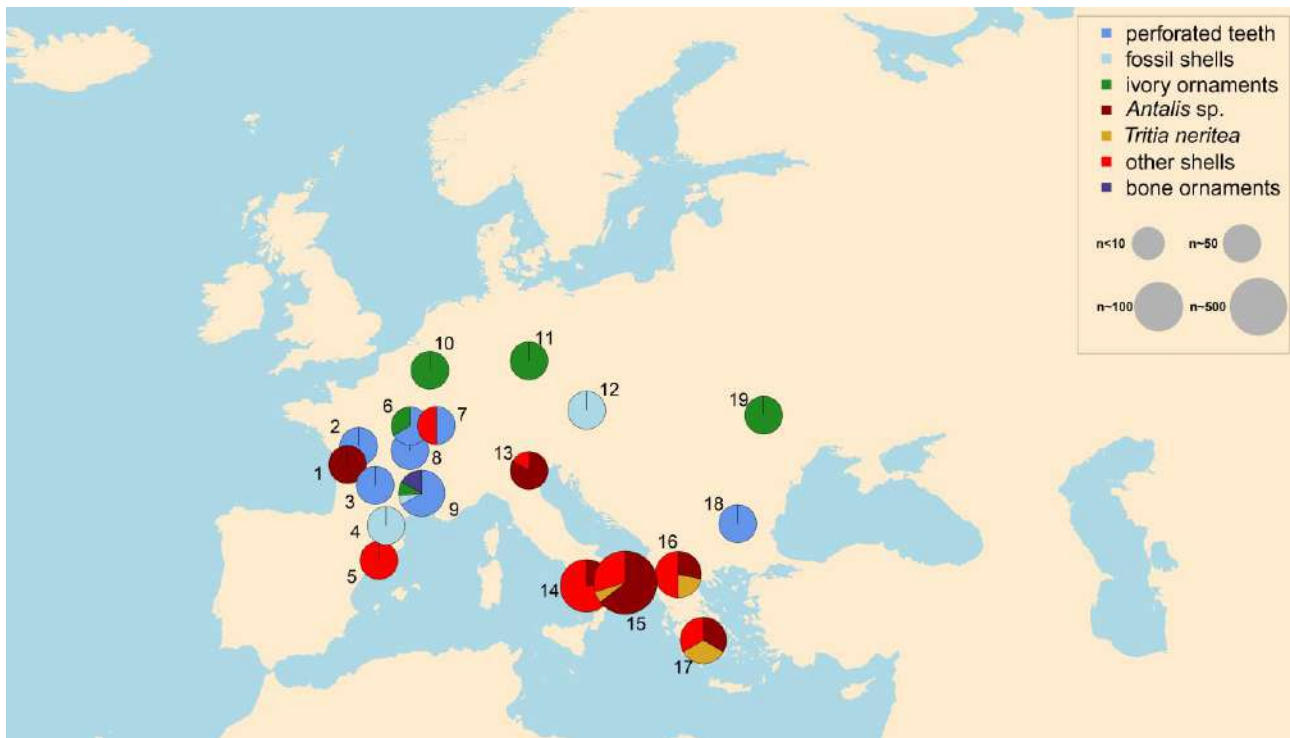
67 Personal adornments are interpreted as markers of population structure from a cultural/linguistic
68 and social point of view since the beginning of the Upper Palaeolithic (Vanhaeren and d’Errico
69 2006; Stiner et al. 2013), but they are also proof of an initial aesthetic perception (Leroi-Gourhan
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 scantly 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) Ilsehöle 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

141 (layer EIII) to the evolved-late phase (layer EII-I and D), sandwiched by the tephra Y-6 at 45.5 ± 1.0
142 ka (Zanchetta et al. 2018) and Y-5 (Campanian Ignimbrite) at 39.85 ± 0.14 ka (Giaccio et al. 2017;
143 Zanchetta et al. 2018). All dates obtained from shells (5 *Antalis* sp. from EII-I, spit E-D, DII and
144 DIIb, 1 *Lembulus pella* from DIIb - Benazzi et al. 2011) are consistent with the chronological frame
145 established by the above mentioned tephra layers. Previous works maintained that the presence in
146 the Uluzzian deposit of important post-depositional disturbances might undermine the association
147 between Uluzzian assemblage and modern humans (Gioia 1990; Zilhão 2007; Zilhão et al. 2015).
148 Nevertheless, more recent research has definitely confirmed the integrity of the archaeological
149 deposit in which the teeth attributed to MHs were recovered and therefore the reliability of their
150 association with the Uluzzian materials (Moroni et al. 2018; Zanchetta et al. 2018; see
151 *Supplementary Information Appendix, Section I*).

152 Here, we ascertain the presence of anthropogenic intervention on scaphopods (also known as tusk
153 shells), gastropods, and bivalves as well as their use as personal ornaments through the combined
154 use of quantitative analysis of morphology, experimental tests, use-wear, Sr isotopes, and
155 micropalaeontological examination. Results, which are compared with the broader picture emerging
156 from other Uluzzian contexts, show evidence of an increasing regularity in shape and size of the
157 beads, as well as of their local production for ornamental purposes.

158

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

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

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

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.

206

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.

221

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;

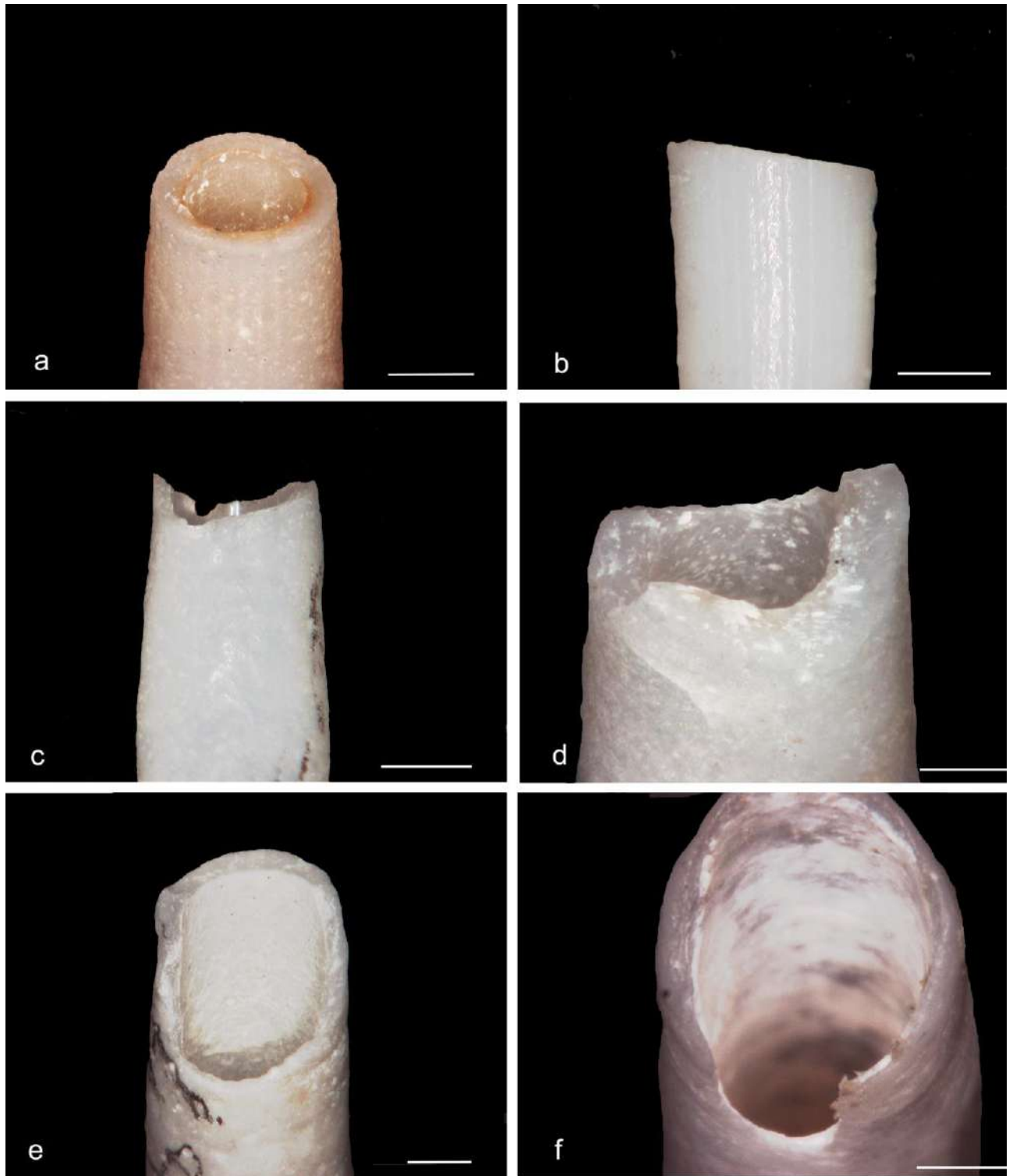
231 c)Symmetric-irregular: uneven fracture forming a symmetric profile;

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.

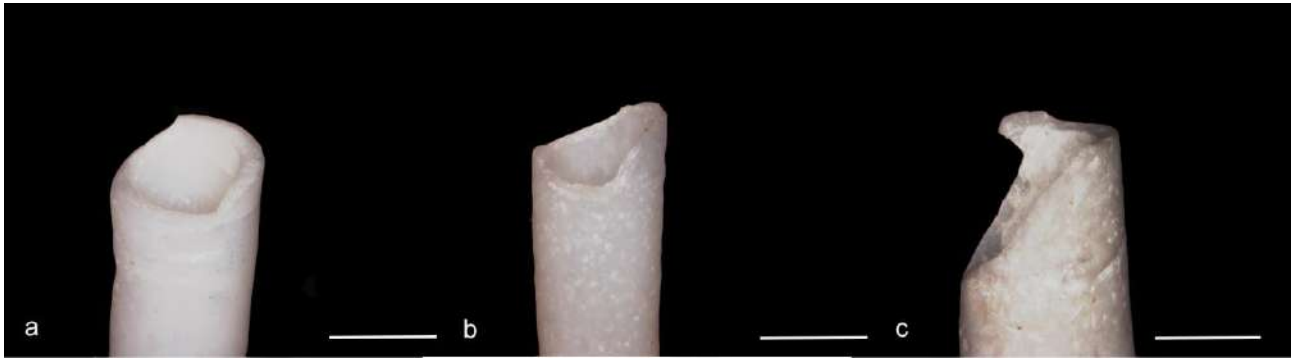


236

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).



245
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

248

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.



371
 372 Fig. 5 Waste products. Small apical portions interpreted as waste products

373
 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.

386

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

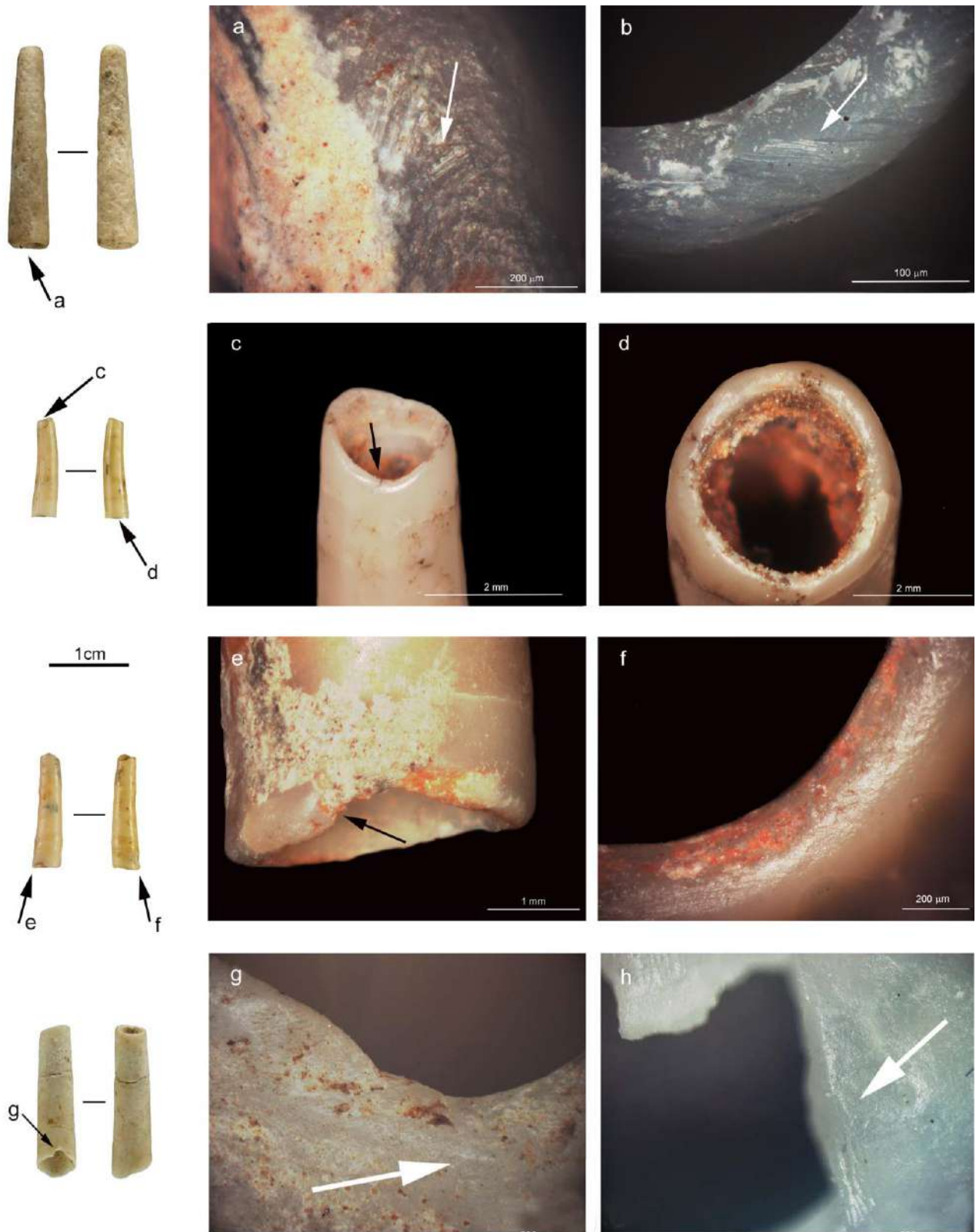
388 brackets

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

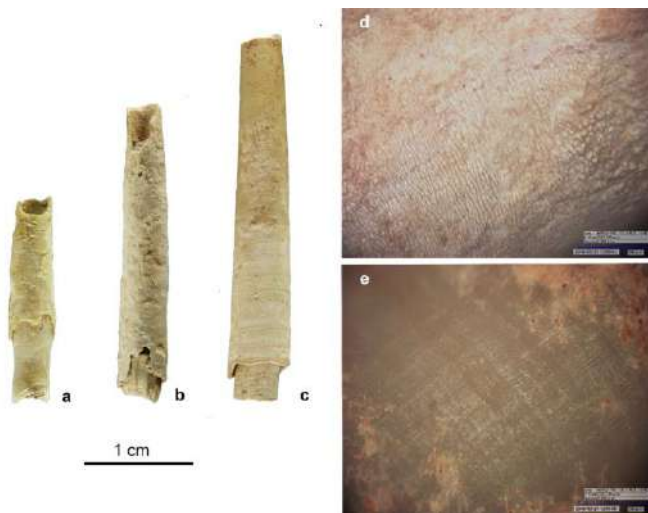
401 The retrieval of two shells inserted into each other is documented in three cases (layers EII-I, E-D,
402 and DI). This eventuality can be due either to human intervention or taphonomic causes (Fig. 7).

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.

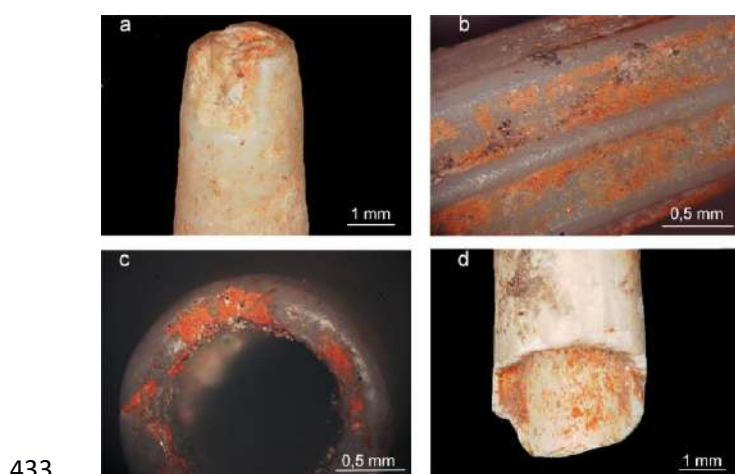
420 2. This differential surface preservation could be attributed to post-depositional phenomena acting
421 with different intensity on the two shells (partial burial for some time?)

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).



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.

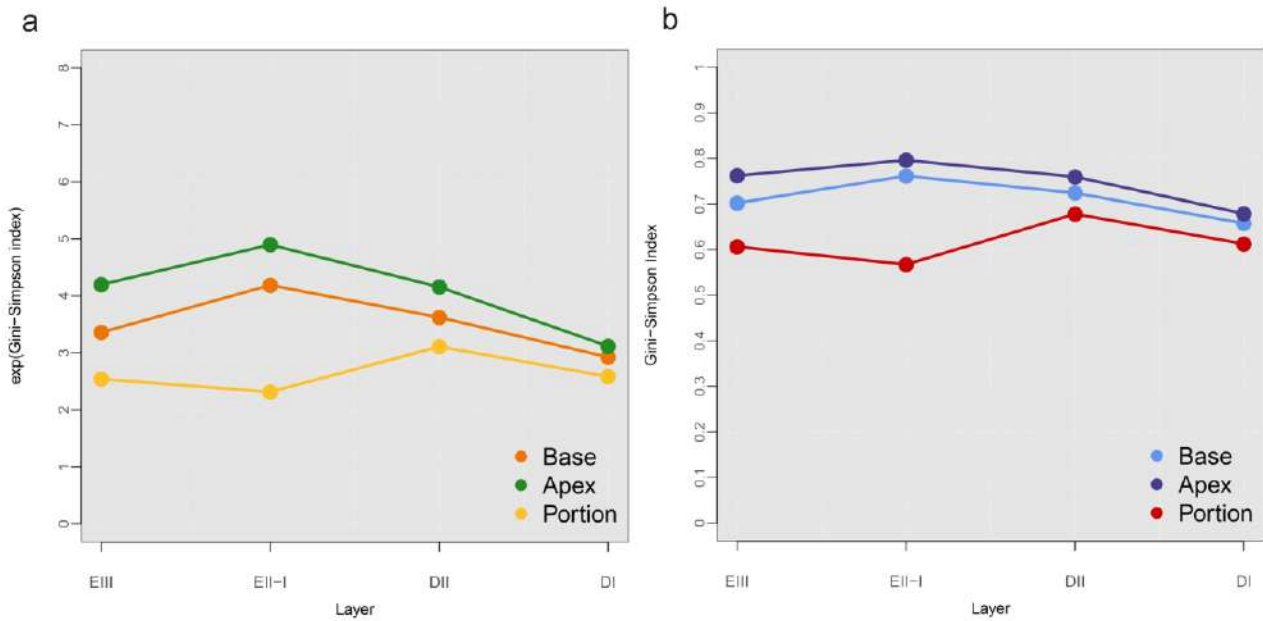
471 Correspondence Analysis also suggests a shift over time from irregular/symmetric and oblique
472 fractures to irregular/asymmetric and rectilinear fractures in both distal and proximal fractures.

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,

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



489

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

493

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

496

497 4.3 Gastropods and bivalves

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

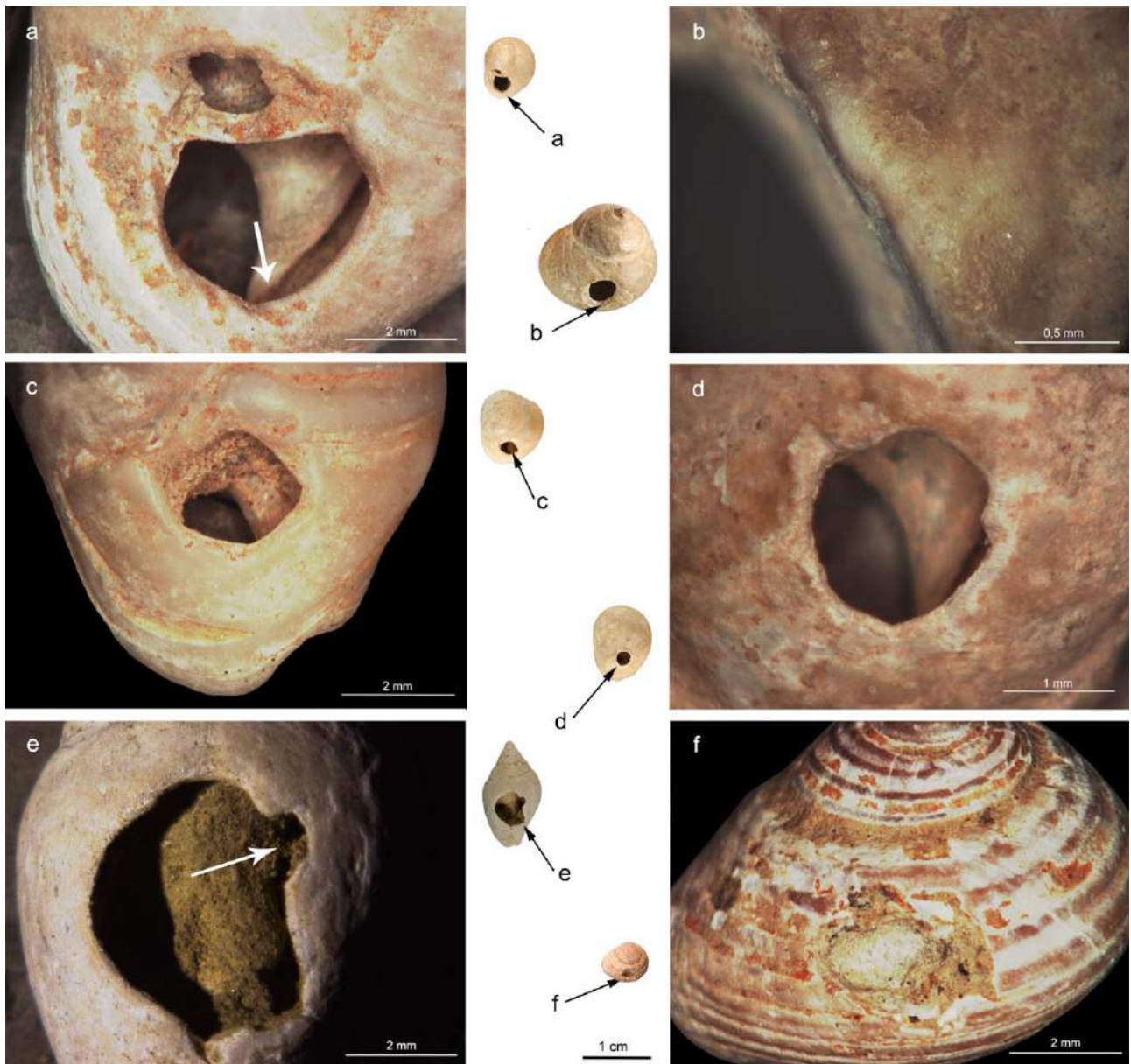
Layers/ Spit	Classes	NISP	Anthropogenic processes					
			ochre	tot_hole	broken	abr_crack	anthropic	anthropized
E III	Gastr.	33	-	2	-	-	1	-
	Biv.	7	-	-	-	-	-	-

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	-	-
Total %	-	158	3.1%	27.84%	3.7%	6.9%	8.2%	5.0%
Total	-	158	5	44	6	11	13	8

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 flacking 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.

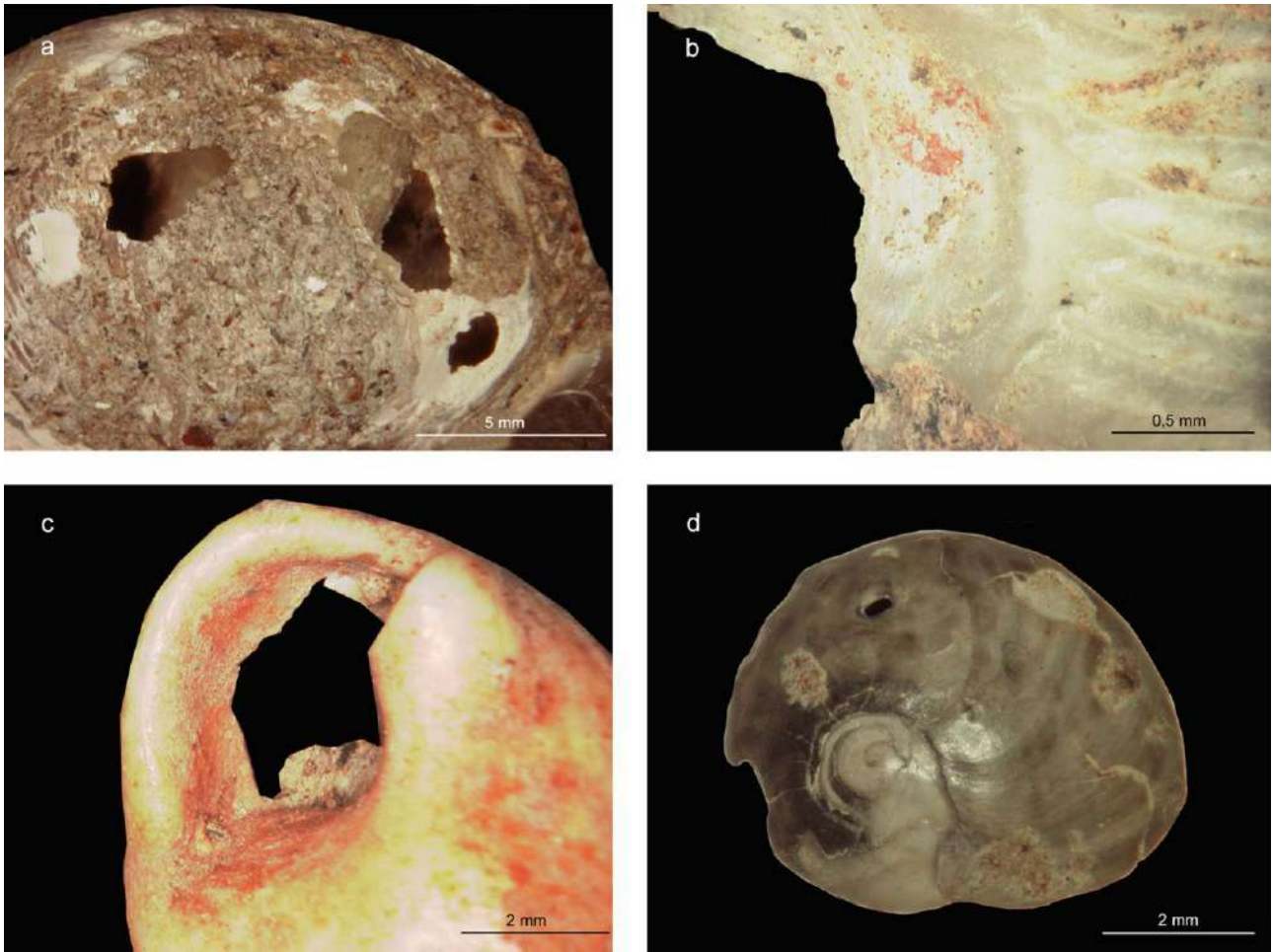


507

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

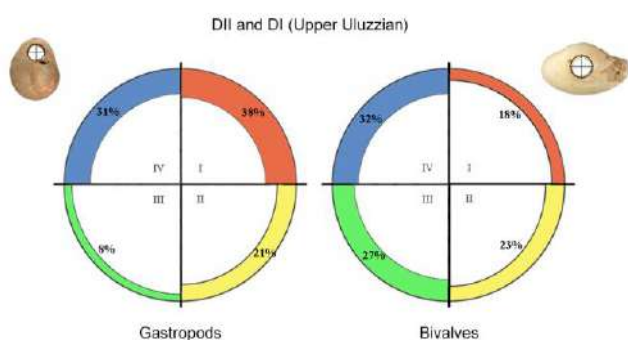
519 Fig. 11 Layer EII-I—postdepositional holes on a *Naticarius hebraeus* (a). Layer DI—traces of
 520 red pigment near the hole of a *Lembulus pella* (b). Layer DI—residues of red pigment located
 521 inside the hole of a *Tritia neritea* (c). Layer DI—heat cracks on a *Tritia neritea* (d)

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).

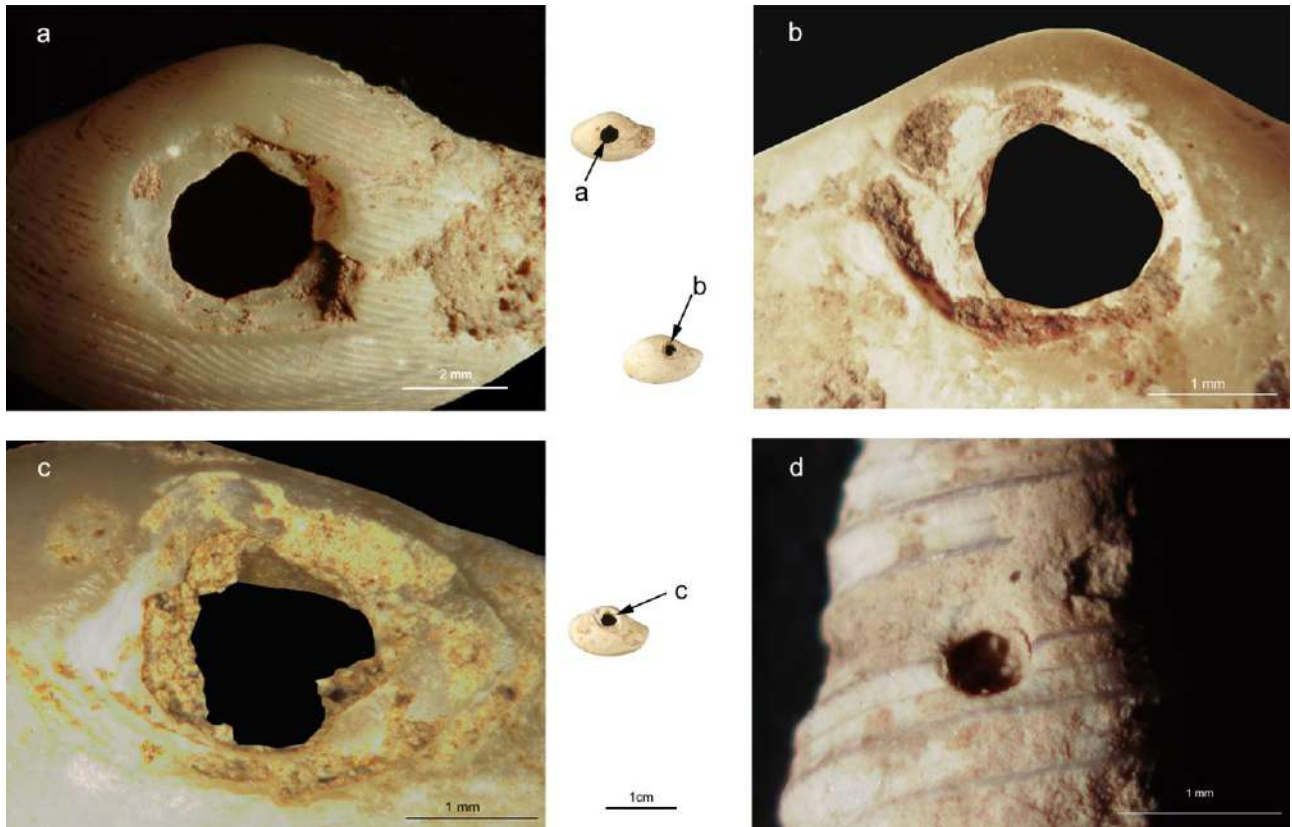
541

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 Féés, 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
768 supplementary information files.

769 **Acknowledgements**

770 **Acknowledgements:** We thank the Soprintendenza Archeologia, Belle Arti e Paesaggio per le
771 Province di Brindisi, Lecce e Taranto for supporting our research in Apulia over the years. We

772 express gratitude to prof. Palma di Cesnola and prof. Paolo Gambassini for giving permission to
773 study the Uluzzian materials from their excavations at Grotta del Cavallo.
774 We are grateful to Luigi Romani for his help in taxonomic classification of scaphopods, to Lavinia
775 Corbo who contributed to measuring specimens, and to Stefano Ricci who made photographic
776 documentation of the shells from Grotta del Cavallo. We also acknowledge all the students who
777 helped us in experimental tests (Francesco Antonini, Giulia Cappelletti, Margherita Gramigni,
778 Simone Marzocca and Irene Mazza). A special thanks to Sem Scaramucci for his contribution in
779 collecting tusks in Salento and for his precious advice. We are also grateful to the two anonymous
780 reviewers for their careful reading of the manuscript and constructive comments. This project has
781 received funding from the European Research Council (ERC) under the European Union's Horizon
782 2020 research and innovation program (grant agreement No 724046 – SUCCESS - [http://www.erc-](http://www.erc-success.eu)
783 [success.eu](http://www.erc-success.eu)).

784 **Author contributions:** S.A., E.B., S.B and A.M. designed research; S.A. performed morphological
785 and use-wear analysis. E.B. carried out statistical analysis. L.T carried out taphonomic and
786 technological analysis. A.B., G.M., and L.T. made the taxonomic classification of the shells. A.M.B
787 and L.M.F. carried out micropaleontological studies and F.L. and A.C. realized isotope analysis.
788 Experimental tests were performed by S.A., D.A., F. Bo, C.F., G.M., G.O. and S.S. Paleoclimate
789 and paleoecological conditions were described by F.Ba. V.S. collected present day tusk shells and
790 reconstructed the palaeo-geographic conditions of the Uluzzian coastline. A.M., M.P., M.R. and
791 A.R. provided archaeological data and contributed to the revision of the manuscript. S.A., E.B., A.
792 M., A.B., V.S., L.M.F., A.M.B., M.R., F.L., F.Ba., L. T and S.B. wrote the paper with inputs from all
793 co-authors.

794 **Competing Interests:** The authors declare no competing interests.

795

796 **References**

797 Abadia OM, Nowell A (2015) Palaeolithic Personal Ornaments: Historical Development and
798 Epistemological Challenges. *J Archaeol Method Th* 22: 952-979. [https://doi.org/10.1007/s10816-](https://doi.org/10.1007/s10816-014-9213-z)
799 014-9213-z

800

801 Álvarez Fernández E (2006) Los objetos de adorno-colgantes del Paleolítico superior y del
802 Mesolítico en la cornisa cantábrica y en el valle del Ebro: una visión europea. Unpublished PhD
803 thesis, Universidad de Salamanca

804

805 Arrighi S, Borgia V (2009) Surface Modifications of Flint Tools and Their Functional Meaning.
806 *Mater Manuf Process* 24: 922-927. <https://doi.org/10.1080/10426910902987150>

807

808 Bar-Yosef Mayer D (2008) Dentalium Shells Used by Hunter-Gatherers and Pastoralists in the
809 Levant. *Archaeofauna* 17:103-110

810

811 Bar-Yosef Mayer D (2019) Upper Paleolithic Explorers: The Geographic Sources of Shell Beads
812 in Early Upper Paleolithic Assemblages in Israel. *PaleoAnthropology* 105–115.
813 doi:10.4207/PA.2019.ART126

814

815 Bar-Yosef Mayer D E, Vandermeersch B, Bar-Yosef O (2009) Shells and ochre in Middle
816 Paleolithic Qafzeh Cave, Israel: indications for modern behavior. *J Hum Evol* 56 (3):307–314.
817 doi:10.1016/j.jhevol.2008.10.005

818

819 Bar-Yosef O (2007) The archaeological framework of the Upper Paleolithic revolution. *Diogenes*
820 54(2): 3–18

821

822 Bar-Yosef O, Bordes JG (2010) Who were the makers of the Châtelperronian culture? *J Hum Evol*

823 59(5): 586–93. <https://doi.org/10.1016/j.jhevol.2010.06.009>
824
825 Benazzi S, Douka K, Fornai C, Bauer CC, Kullmer O, Svoboda J, Pap I, Mallegni F, Bayle P,
826 Coquerelle M, Condemi S, Ronchitelli A, Harvati K, Weber GW (2011) Early dispersal of modern
827 humans in Europe and implications for Neanderthal behaviour. *Nature* 479: 525-528.
828 <https://doi.org/10.1038/nature10617>
829
830 Benazzi S, Slon V, Talamo S, Negrino F, Peresani M, Bailey SE, Sawyer S, Panetta D, Vicino G,
831 Starnini E, Mannino MA, Salvadori PA, Meyer M, Pääbo S, Hublin JJ (2015) The Makers of the
832 Protoaurignacian and Implications for Neandertal Extinction. *Science* 348: 793-6
833
834 Benghiat S, Komso D, Miracle PT (2009) An experimental analysis of perforated shells from the
835 site of Sebrn Abri, Istria, Croatia. In: McCartan S, Schulting R, Warren G, Woodman P (eds)
836 *Mesolithic Horizons*. Oxbow books, Oxford, pp 730-736
837
838 Bonnardin S (2007) From traces to function of ornaments: some Neolithic examples. In: Longo L,
839 Skakun N (eds) “Prehistoric Technology” 40 Years Later. BAR Int. Ser. 1783, Archaeopress,
840 Oxford, pp 297-308
841
842 Bordes F, Labrot J (1967) La stratigraphie du gisement de Roc de Combe (Lot) et ses implications.
843 *Bull Soc Préhist Fr* LXIV (1): 15–28
844
845 Boscato P, Crezzini J (2012) Middle-Upper Palaeolithic transition in Southern Italy: Uluzzian
846 macromammals from Grotta del Cavallo (Apulia). *Quat Int* 252: 90–98.
847 <https://doi.org/10.1016/j.quaint.2011.03.028>
848

849 Bosch MD, Buck L, Strauss A (2019) Location, location, location: Investigating Perforation
850 Locations in *Tritia gibbosula* Shells at Ksar ‘Akil (Lebanon) Using Micro-CT Data.
851 *PaleoAnthropology* 52-63. <https://doi.org/10.4207/PA.2019.ART123>
852
853 Cabral JP, Martins JMS (2016) Archaeological *Glycymeris glycymeris* shells perforated at the
854 umbo: Natural or man-made holes? *J Archaeol Sci Rep* 10: 474–482.
855 <https://doi.org/10.1016/j.jasrep.2016.11.008>
856
857 Campbell G (2017) The Reproduction of Small Prehistoric Tusk Shell Beads. In: Bar-Yosef Mayer
858 D, Bonsall C, Choyke AM (eds) *Not Just for Show: The Archaeology of Beads, Beadwork and*
859 *Personal Ornaments*, Oxbow Books, pp 168-224
860
861 Caron F, d’Errico F, Del Moral P, Santos F., Zilhão J (2011) The reality of Neandertal symbolic
862 behavior at the Grotte du Renne, Arcy-sur-Cure, France. *PLoS One* 6(6): e21545.
863 <https://doi.org/10.1371/journal.pone.0021545>
864
865 Charney N., Record S (2012) *vegetarian: Jost Diversity Measures for Community Data*. R package
866 version 1.2. <https://CRAN.R-project.org/package=vegetarian>
867
868 Colonese A C, Mannino M A, Bar-Yosef Mayer D E, Fa DA, Finlayson JC, Lubell D, Stiner MC
869 (2011) Marine mollusc exploitation in Mediterranean prehistory: An overview. *Quat Int* 239 (1–2):
870 86–103. doi:10.1016/j.quaint.2010.09.001
871
872 Craveri M (1931) Crine. In: *Enciclopedia Italiana*, Istituto Enciclopedia Italiana, Roma
873

874 d'Errico F, Zilhão J, Julien M, Baffier D, Pelegrin J (1998) Neanderthal Acculturation in Western
875 Europe? A Critical Review of the Evidence and Its Interpretation. *Curr Anthropol* 39: 1–44
876

877 d'Errico F, Henshilwood C, Lawson G, Vanhaeren M, Tillier AM, Soressi M, Bresson F, Maureille
878 B, Nowell A, Lakarra J, Backwell L, Julien M (2003a) Archaeological evidence for the emergence
879 of language, symbolism, and music: an alternative multidisciplinary perspective. *J World Prehist*
880 17: 1-70
881

882 d'Errico F, Julien M, Liolios D, Vanhaeren M, Baffier D (2003b) Many awls in our argument.
883 Bone tool manufacture and use in the Châtelperronian and Aurignacian levels of the Grotte du
884 Renne at Arcy-sur-Cure. In: Zilhão J, d'Errico F (Eds) *The Chronology of the Aurignacian and of*
885 *the Transitional Technocomplexes. Dating, Stratigraphies, Cultural Implications. Proceedings of*
886 *Symposium 6.1 of the XIV Congress of the UISPP, Trabalhos de Arqueologia, vol. 33. Instituto*
887 *Português de Arqueologia, Lisboa, pp 247-271*
888

889 d'Errico F, Vanhaeren M, Barton N, Bouzougar A, Mienis H, Richter D, Hublin JJ, McPherron
890 SP, Lozouet P (2009) Additional evidence on the use of personal ornaments in the Middle
891 Palaeolithic of North Africa. *Proc Natl Acad Sci* 106: 16501-16056.
892 <https://doi.org/10.1073/pnas.0903532106>
893

894 d'Errico F, Borgia V, Ronchitelli A (2012) Uluzzian bone technology and its implications for the
895 origin of behavioural modernity. *Quat Int* 259: 59–71 <https://doi.org/10.1016/j.quaint.2011.03.039>
896

897 d'Errico F, Banks WE (2013) Identifying Mechanisms behind Middle Paleolithic and Middle
898 Stone Age Cultural Trajectories. *Curr Anthropol* 54 (8):371-387. <https://doi.org/10.1086/673388>
899

900 d'Errico F, Backwell L (2016). Earliest evidence of personal ornaments associated with burial: the
901 *Conus* shells from Border Cave. *J Hum Evol* 93: 91–108
902

903 Dimitrijević V (2014) The provenance and use of fossil scaphopod shells at the Late
904 Neolithic/Eneolithic site Vinča – Belo Brdo, Serbia. In: Szabó K, Dupont C, Dimitrijević V,
905 Gómez Gastélum L, Serrand N (eds) *Archaeomalacology: Shells in the Archaeological Record*
906 *BAR International Series 2666*, Archaeopress, Oxford, pp 33-41
907

908 Douka K, Higham, TF, Wood R, Boscato P, Gambassini P, Karkanas P, Peresani M, Ronchitelli A
909 (2014) On the chronology of the Uluzzian. *J Hum Evol* 68: 1-13.
910 <https://doi.org/10.1016/j.jhevol.2013.12.007>
911

912 Farrand WR (2000) *Depositional History of Franchthi Cave, Sediments, Stratigraphy and*
913 *Chronology. With a Report on the Background of the Franchthi project by T.W. Jacobsen.*
914 *Excavations at Franchthi Cave, Greece, fasc. 12*, Indiana University Press, Bloomington &
915 Indianapolis
916

917 Fiocchi C (1998) *Contributo alla conoscenza del comportamento simbolico di Homo sapiens*
918 *sapiens. Le conchiglie marine nei siti del Paleolitico superiore europeo: strategie di*
919 *approvvigionamento, reti di scambio, utilizzo.* Unpublished PhD thesis Scienze Antropologiche,
920 Consorzio Universitario di Bologna, Ferrara, Parma
921

922 Fitzsimmons KE., Hambach U, Veres D, Iovita R (2013) The Campanian Ignimbrite eruption: new
923 data on volcanic ash dispersal and its potential impact on human evolution. *PLoS One* 8(6):
924 e65839. <https://doi.org/10.1371/journal.pone.0065839>
925

926 Flas D (2011) The Middle to Upper Paleolithic transition in Northern Europe: the Lincombian-
927 Ranisian-Jerzmanowician and the issue of acculturation of the last Neanderthals. *World Archaeol.*
928 43: 605-627

929

930 Gambassini P (1997) Le industrie paleolitiche di Castelcivita. In: Gambassini P (ed) *Il Paleolitico*
931 *di Castelcivita culture e ambiente*, Electa, Napoli, pp 75-145

932

933 Giaccio B, Hajdas I, Isaia R, Deino A, Nomade S (2017) High-precision ^{14}C and $^{40}\text{Ar}/^{39}\text{Ar}$
934 dating of the Campanian Ignimbrite (Y-5) reconciles the time-scales of climatic-cultural processes
935 at 40 ka. *Sci Rep* 7: 45940

936

937 Gioia P (1990) An aspect of the transition between Middle and Upper Paleolithic in Italy: the
938 Uluzzian. In: Farizy C (ed) *Paléolithique moyen récent et Paléolithique supérieur ancien en*
939 *Europe Ruptures et transitions: examen critique des documents archéologiques*, APRAIF,
940 Nemours, pp 241–250

941

942 Gravina B, Bachellerie F, Caux S, Discamps E, Faivre JP, Galland A, Michel A, Teyssandier N,
943 Bordes JJ (2018) No Reliable Evidence for a Neanderthal-Châtelperronian Association at La
944 Roche-à-Pierrot, Saint-Césaire. *Sci Rep* 8: 15134. <https://doi.org/10.1038/s41598-018-33084-9>

945

946 Higham T, Jacobi R, Julien M, David F, Basell L, Wood R, Davies W, Ramsey CB (2010)
947 Chronology of the Grotte du Renne (France) and implications for the context of ornaments and
948 human remains within the Châtelperronian. *Proc Natl Acad Sci* 107(47): 20234-9. <https://doi.org/10.1073/pnas.1007963107>

949

950

951 Hoffmann DL, Angelucci DE, Villaverde V, Zapata J, Zilhão J (2018) Symbolic use of marine
952 shells and mineral pigments by Iberian Neandertals 115,000 years ago. *Sci Adv* 4(2).
953 [https://doi.org / 10.1126/sciadv.aar5255](https://doi.org/10.1126/sciadv.aar5255)
954
955 Hublin JJ (2015) The modern human colonization of western Eurasia: when and
956 where? *Quat Sci Rev* 118: 194-210. <http://dx.doi.org/10.1016/j.quascirev.2014.08.011>
957
958 Hublin JJ, Spoor F, Braun M, Zonneveld F, Condemi S (1996) A late Neanderthal associated with
959 Upper Palaeolithic artefacts. *Nature* 381: 224–226. <https://doi.org/10.1038/381224a0>
960
961 Hublin JJ, Talamo S, Julien M, David F, Connet N, Bodu P, Vandermeersch B, Richards MP
962 (2012) Radiocarbon dates from the Grotte du Renne and Saint-Césaire support a Neandertal origin
963 for the Châtelperronian, *Proc Natl Acad Sci* 109(46): 18743-18748;
964 <https://doi.org/10.1073/pnas.1212924109>
965
966 Hülle W M (1977) Die Ilsenhöhle unter Burg Ranis/Thüringen. Eine paläolitische Jägerstation.
967 Gustav Fischer, Stuttgart
968
969 Jost L (2006) Entropy and diversity. *Oikos* 113(2): 363-375. [https://doi.org/10.1111/j.2006.0030-](https://doi.org/10.1111/j.2006.0030-1299.14714.x)
970 [1299.14714.x](https://doi.org/10.1111/j.2006.0030-1299.14714.x)
971
972 Jost L (2007) Partitioning diversity into independent alpha and beta components. *Ecology* 88(10):
973 2427-2439. <https://doi.org/10.1890/06-1736.1>
974
975 Kozłowski J (ed) (1982) Excavation in the Bacho Kiro Cave (Bulgaria): Final Report. Polish
976 Scientific Publishers, Warsaw

977 Kuhn SL, Stiner MC, Güleç E, Özer I, Yılmaz H, Baykara I, Açıkkol A., Goldberg P, Martínez
978 Molina K, Ünay E, Suata-Alpaslan F (2009) The early Upper Paleolithic occupations at Üçağızlı
979 Cave (Hatay, Turkey). *J Hum Evol* 56: 87-113. <https://doi.org/10.1016/j.jhevol.2008.07.014>
980
981 Largioli T, Martinis B, Mozzi G, Nardin M, Rossi D, Ungaro S (1969) Gallipoli. Note illustrative
982 della Carta Geologica d'Italia. Poligrafica e Cartevalori, Ercolano (Napoli)
983
984 Lévêque F, Vandermeersch B (1980) Les découvertes de restes humains dans un horizon
985 castelperronien de Saint-Césaire (Charente-Maritime). *Bull. de la Soc. Préhist. de Française* 77 :
986 187–189
987
988 Leroi-Gourhan A (1964) *Le geste et la parole* (Vol 2). Albin Michel, Paris
989
990 Lugli F, Cipriani A, Peretto C, Mazzucchelli M, Brunelli D (2017) In situ high spatial resolution
991 $^{87}\text{Sr}/^{86}\text{Sr}$ ratio determination of two Middle Pleistocene (ca 580 ka) *Stephanorhinus*
992 *hundsheimensis* teeth by LA–MC–ICP–MS. *Int J Mass Spectrom* 412: 38-48.
993 <https://doi.org/10.1016/j.ijms.2016.12.012>
994
995 Mamouridis V, Cartes JE, Parra S, Fanelli E, Salinas JS (2011) A temporal analysis on the
996 dynamics of deep-sea macrofauna: influence of environmental variability off Catalonia coasts
997 (western Mediterranean). *Deep Sea Res Part 1 Oceanogr Res Pap* 58 (4): 323-337
998
999 McElreath R, Boyd R, Richerson PJ (2003) Shared norms and the evolution of ethnic markers.
1000 *Curr Anthropol* 44: 122-129. <http://dx.doi.org/10.1086/345689>
1001

1002 Mellars P, Gravina B, Bronk-Ramsey C (2007) Confirmation of Neanderthal/Modern Human
1003 interstratification at the Châtelperronian type-site. *Proc Natl Acad Sci* 104: 3657–3662.
1004 <https://doi.org/10.1073/pnas.0608053104>
1005
1006 Moreau L (2003) Les éléments de parure au Paléolithique supérieur en Belgique. *L'Anthropologie*
1007 107: 603–614
1008
1009 Moroni A, Boscato P, Ronchitelli A (2013) What roots for the Uluzzian? Modern behaviour in
1010 Central-Southern Italy and hypotheses on AMH dispersal routes. *Quat Int* 316: 27-44.
1011 <http://dx.doi.org/10.1016/j.quaint.2012.10.051>
1012
1013 Moroni A, Ronchitelli A, Arrighi S, Aureli D, Bailey SE, Boscato P, Boschini F, Capecchi G,
1014 Crezzini J, Douka K, Marciani G, Panetta D, Ranaldo F, Ricci S, Scaramucci S, Spagnolo V,
1015 Benazzi S, Gambassini P (2018) Grotta del Cavallo (Apulia – Southern Italy). The Uluzzian in the
1016 mirror. *J Anthropol Sci* 96: 1-36. <http://dx.doi.org/10.4436/jass.96004>
1017
1018 Murtagh F, Legendre P (2014) Ward's hierarchical agglomerative clustering method: which
1019 algorithms implement Ward's criterion? *J Classif* 31. [http://dx.doi.org/10.1007/s00357-014-](http://dx.doi.org/10.1007/s00357-014-9161-z)
1020 [9161-z](http://dx.doi.org/10.1007/s00357-014-9161-z)
1021
1022 Nenadic O, Greenacre M (2007) Correspondence Analysis in R, with two- and three-dimensional
1023 graphics: The ca package. *J Stat Softw* 20 (3): 1-13. <http://dx.doi.org/10.18637/jss.v020.i03>
1024
1025 Orchard WC (1929) *Beads and beadwork of the American Indians*. Salzwasser-verlag Gmbh,
1026 Paderborn
1027

1028 Palma di Cesnola A (1965) Notizie preliminari sulla terza campagna di scavi nella Grotta del
1029 Cavallo (Lecce). Riv Sci Preistoriche 20: 291-302
1030
1031 Palma di Cesnola A (1966) Gli scavi nella Grotta del Cavallo (Lecce) durante il 1966. Riv. Sci.
1032 Preistoriche 21: 289-301
1033
1034 Palma di Cesnola A (1989) L'Uluzzien: Faciès italien du leptolithique archaïque. L'Anthropologie
1035 93 (4): 783–812
1036
1037 Peharda M, Thébault J, Markulin K, Schöne BR, Janeković I, Chauvaud L (2017) Contrasting
1038 shell growth strategies in two Mediterranean bivalves revealed by oxygen-isotope ratio
1039 geochemistry: The case of *Pecten jacobaeus* and *Glycymeris pilosa*. Chem Geol.
1040 <http://dx.doi.org/10.1016/j.chemgeo.2017.09.029>
1041
1042 Peresani M, Fiore I, Gala M, Romandini M, Tagliacozzo A (2011) Late Neandertals and the
1043 intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky
1044 B.P., Italy. Proc Natl Acad Sci 108 (10): 3888-3893. <https://doi.org/10.1073/pnas.1016212108>
1045
1046 Peresani M, Vanhaeren M, Quaggiotto E, Queffelec A, d'Errico F (2013) An ochered fossil marine
1047 shell from the Mousterian of Fumane Cave, Italy. PLoS One 8 (7): e68572. [http://dx.doi.org](http://dx.doi.org/10.1371/journal.pone.0068572)
1048 [/10.1371/journal.pone.0068572](http://dx.doi.org/10.1371/journal.pone.0068572)
1049
1050 Peresani M, Cristiani E, Romandini M, 2016 The Uluzzian technology of Grotta di Fumane and its
1051 implication for reconstructing cultural dynamics in the Middle-Upper Palaeolithic transition of
1052 Western Eurasia. J Hum Evol 91: 36-56. <https://doi.org/10.1016/j.jhevol.2015.10.012>
1053

1054

1055 Peresani M, Bertola S, Del Piano D, Benazzi S, Romandini M (2019a) The Uluzzian in the North
1056 of Italy. Insights around the new evidence at Riparo Broion Rockshelter. *Archaeol Anthropol Sci*.
1057 [http:// doi.org/10.1007/s12520-018-0770-z](http://doi.org/10.1007/s12520-018-0770-z)

1058

1059 Peresani M, Forte M, Quaggiotto E, Colonese AC, Romandini M, Cilli C, Giacobini G (2019b)
1060 Marine shell exploitation during the Aurignacian at Fumane Cave. *PaleoAnthropology* 64-81.
1061 [doi:10.4207/PA.2019.ART124](https://doi.org/10.4207/PA.2019.ART124)

1062

1063 Perlès C (2019) Cultural Implications of Uniformity in Ornament Assemblages: Paleolithic and
1064 Mesolithic Ornaments From Franchthi Cave, Greece. *PaleoAnthropology* 196-207.
1065 [doi:10.4207/PA.2019.ART131](https://doi.org/10.4207/PA.2019.ART131)

1066

1067 Radovčić D, Sršen AO, Radovčić J, Frayer DW (2015) Evidence for Neandertal Jewelry:
1068 Modified White-Tailed Eagle Claws at Krapina. *PLoSOne* 10 (3): e0119802.
1069 <https://doi.org/10.1371/journal.pone.0119802>

1070

1071 R Core Team (2018) R: A language and environment for statistical computing. R Foundation for
1072 Statistical Computing, Vienna, Austria URL <https://www.R-project.org/>

1073

1074 Romandini M, Peresani M, Laroulandie V, Metz L, Pastoors A, Vaquero M, Slimak L (2014)
1075 Convergent Evidence of Eagle Talons Used by Late Neanderthals in Europe: A Further Assessment
1076 on Symbolism. *PlosOne* 9 (7): e101278. <https://doi.org/10.1371/journal.pone.0101278>

1077

1078 Ronchitelli A, Boscato P, Gambassini P (2009) Gli ultimi Neandertaliani in Italia: aspetti culturali.
1079 In: Facchini F, Belcastro G (eds) *La Storia di Neandertal. Biologia e Comportamento*. Jaka Book,
1080 Bologna, pp 257–288
1081
1082 Rigaud JP (2001) A propos de la contemporanéité du Castelperronien et de l’Aurignacien dans le
1083 nord-est de l’Aquitaine: une révision des données et ses implications. In: Zilhão J, Aubry T,
1084 Carvalho A (eds) *Les premières hommes modernes de la Péninsule Ibérique. Actes du Colloque de*
1085 *la Commission VIII de l’UISPP, Instituto Português de Arqueologia, Lisboa, pp 61-68*
1086
1087 Ruppert J, Bernet JW (2001) *Our Voices: Native Stories of Alaska and the Yukon*. University of
1088 Toronto Press, Toronto
1089
1090 Sano K, Arrighi S, Stani C, Aureli D, Boschini F, Fiore I, Spagnolo V, Ricci S, Crezzini J, Boscato
1091 P, Gala M, Tagliacozzo A, Birarda G, Vaccari L, Ronchitelli A, Moroni A, Benazzi S (2019) The
1092 earliest evidence for mechanically delivered projectile weapons in Europe, *Nat Ecol Evol* 3:140-
1093 1414.
1094
1095 Shimek R, Steiner G (1997) Chapter 6. Microscopic anatomy of invertebrates. Volume 6B:
1096 *Mollusca II*, Wiley-Liss, Inc
1097
1098 Škardla P (2013) The Bohunician in Moravia and Adjoining Regions. *Archaeology, Ethnology*
1099 *and Anthropology of Eurasia* 41 (3): 2-18- <https://doi.org/10.1016/j.aear.2014.03.002>
1100
1101

1102 Stiner MC (1999) Palaeolithic mollusc exploitation at Riparo Mochi (Balzi Rossi, Italy): Food and
1103 ornaments from the Aurignacian through Epigravettian. *Antiquity* 73: 735–754.
1104 <https://doi.org/10.1017/S0003598X00065492>
1105
1106 Stiner MC (2010) Shell ornaments from the Upper Paleolithic through Mesolithic layers of
1107 Klissoura Cave 1 by Prosymna (Peloponnese, Greece). *Eurasian Prehistory* 7 (2): 287–308
1108
1109 Stiner MC (2014) Finding a Common Bandwidth: Causes of Convergence and Diversity in
1110 Paleolithic Beads. *Biol Theory* 9(1): 51–64. doi:10.1007/s13752-013-0157-4
1111
1112 Stiner MC, Pehlevan C, Sağır M Özer I (2002) Zooarchaeological studies at Üçağızlı Cave:
1113 Preliminary results on Paleolithic subsistence and shell ornaments. *Araştırma Sonuçları Toplantısı*
1114 17: 29-36
1115
1116 Stiner MC, Kuhn SL, Güleç E (2013) Early Upper Paleolithic shell beads at Üçağızlı Cave I
1117 (Turkey): Technology and the socioeconomic context of ornament life-histories. *J Hum Evol*
1118 64(5) : 380–398. doi:10.1016/j.jhevol.2013.01.008
1119
1120 Taborin Y (1993) *La parure en coquillage au Paléolithique*. CNRS Éditions, Paris
1121
1122 Tátá F, Cascalheira J, Marreiros J, Pereira T, Bicho N (2014) Shell bead production in the Upper
1123 Paleolithic of Vale Boi (SW Portugal): An experimental perspective. *J Archaeol Sci* 42(1): 29–41.
1124 doi:10.1016/j.jas.2013.10.029
1125
1126 Vanhaeren M, d’Errico F (2001) *La parure de l’enfant de La Madeleine (fouilles Peyrony)*. Un
1127 nouveau regard sur l’enfance au Paléolithique supérieur. *Paléo* 13 : 201-240

1128

1129

1130 Vanhaeren M, d'Errico F (2006) Aurignacian ethno-linguistic geography of Europe revealed by
1131 personal ornaments. *J Archaeol Sci* 33(8): 1105–1128. doi:10.1016/j.jas.2005.11.017

1132

1133 Vanhaeren M d'Errico F, Stringer C, James SL, Todd JA, Mienis HK (2006) Middle Palaeolithic
1134 shell beads in Israel and Algeria. *Science* 312: 1785-1787. <https://doi.org/10.1126/science.1128139>

1135

1136 Vanhaeren M, d'Errico F, van Niekerk KL, Henshilwood CS, Erasmus RM (2013) Thinking
1137 strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave,
1138 South Africa. *J Hum Evol* 64: 500-517

1139

1140 Villa P, Pollarolo L, Conforti J, Marra F, Biagioni C, Degano I, Lucejko JJ, Tozzi C, Pennacchioni
1141 M, Zanchetta G, Nicosia C, Martini M, Sibilgia E, Panzeri L (2018). From Neandertals to modern
1142 humans: New data on the Uluzzian. *PLoS One* 13: e0196786. doi:10.1371/journal.pone.0196786

1143

1144 Welker F, Hajdinjak M, Talamo S, Jaouen K, Dannemann M, David F, Julien M, Meyer M, Kelso J,
1145 Barnes I, Brace S, Kamminga P, Fischer R, Kessler BM, Stewart JR, Pääbo S, Collins MJ, Hublin JJ
1146 (2016) Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian
1147 at the Grotte du Renne. *Proc Natl Acad Sci* 113(40): 11162–11167.

1148 <https://doi.org/10.1073/pnas.1605834113>

1149

1150 White R (1989) Visual thinking in the Ice Age. *Sci Am* 261(1): 92–99

1151

- 1152 White R (2002) Observations technologiques sur les objets de parure. In Schmider B (ed)
1153 L'Aurignacien de la Grotte du Renne. Les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure,
1154 (Yonne), XXXIVe Supplément à Gallia Préhistoire, CNRS, Paris, pp 257-266
1155
- 1156 Zanchetta G, Giaccio B, Bini M, Sarti L (2018) Tephrostratigraphy of Grotta del Cavallo,
1157 Southern Italy: Insights on the chronology of Middle to Upper Palaeolithic transition in the
1158 Mediterranean. *Quat Sci Rev* 182: 65-77. <https://doi.org/10.1016/j.quascirev.2017.12.014>
1159
- 1160 Zilhão J, 2006 Neandertals and moderns mixed, and it matters. *Evol Anthropol* 15: 183-195.
1161 <https://doi.org/10.1002/evan.20110>
1162
- 1163 Zilhão J (2007) The emergence of Ornaments and Art: An Archaeological Perspective on the
1164 Origins of "Behavioral Modernity". *J Archaeol Res* 15: 1-54
1165
- 1166 Zilhão J, d'Errico F, Bordes JG, Lenoble A, Texier JP, Rigaud JP (2007) Grotte des Fées
1167 (Châtelperron, Allier) ou une interstratification "Châtelperronien-Aurignacien" illusoire. *Histoire*
1168 *des fouilles, stratigraphie et datations. Paléo* 19: 391-432
1169
- 1170 Zilhão J, Banks WE, d'Errico F, Gioia P (2015) Analysis of Site Formation and Assemblage
1171 Integrity Does Not Support Attribution of the Uluzzian to Modern Humans at Grotta del Cavallo.
1172 *PLoS One* 10: e0131181

1173 **List of captions**

1174 **Fig. 1** Distribution of ornaments dated between ca. 45-39 ka across transitional contexts in Europe
1175 (sites with debated cultural attribution are represented here, see Discussion chapter). Pie radius is
1176 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)

1221

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)

1225

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)

1228

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)

1232