Journal of Archaeological Science 42 (2014) 29–41

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Shell bead production in the Upper Paleolithic of Vale Boi (SW Portugal): an experimental perspective

Frederico Tátá, João Cascalheira, João Marreiros, Telmo Pereira, Nuno Bicho*

NAP, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

A R T I C L E I N F O

Article history:
Received 22 July 2013
Received in revised form
22 October 2013
Accepted 24 October 2013

Keywords:
Upper Paleolithic shell bead production
Experimental replication procedures
Southern Portugal

A B S T R A C T

In this paper, we focused on shell bead production during the Upper Paleolithic at the site of Vale Boi in Southwestern Portugal as a means of understanding social visual transmission. Vale Boi has a long sequence dated to between c. 32 and 7 ka cal BP with well-preserved bone and shell assemblages from early Gravettian to Neolithic times. The archaeological shell bead collection includes over 100 specimens from the Gravettian, Proto-Solutrean, Solutrean and Magdalenian layers from Vale Boi, including at least 5 species: *Littorina obtusata* or *Littorina fabalis*, *Trivia* sp., *Antalis* sp., *Mitrella scripta* and *Theodoxus fluviatilis*.

Experimental replication techniques included scratching, sawing, and hammering using lithic and bone implements on both internal and external sides of the shells. Experimental results indicate that there are a series of potential fabrication techniques for bead production, but there is a clear tendency in the archaeological record to use a single technique for each shell species. There also seems to be a focus on using a fast technique rather than a slower one, which seems to produce higher quality results.

Finally, we also address the topic of the impact of bead production techniques on the evolution of bead design technology through all Upper Paleolithic record in SW Portugal.

1. Introduction

Shell beads are one of the most common artifact types that are believed to convey complex symbolic communication (Álvarez Fernández and Jöris, 2008; Kuhn and Stiner, 2006; Kuhn and Stiner, 2007). Body decoration, including the use of shell beads, are clearly very important as visual statements regarding social information broadcasting elements such as group identity and affiliation (Kuhn and Stiner, 2007), among others. They are considered as one of the milestones of complex human behavioral (McBrearty and Brooks, 2000) and cognitive evolution, and are associated with the emergence of modern cognition (Álvarez Fernández and Jöris, 2008; Henshilwood and Marean, 2003; Klein, 2008; Marean, 2011).

Since they are fairly common in the Stone Age record they can easily be checked for their anthropogenic character (e.g., Francis, 1982; d'Errico et al., 2008; Steele and Alvaréz Fernández, 2012). The earliest examples are found in many parts of the Old World, from Blombos Cave (Henshilwood et al., 2004; d'Errico et al., 2005; Vanhaeren et al., 2013), Border Cave (Klein, 1989; d'Errico et al., 2012) and possibly Sibudu (d'Errico et al., 2008) in South Africa, Grotte des Pigeons, Rhafas, and Contrabandiers in Morocco (Bouzouggar et al., 2007; d'Errico et al., 2009; Steele and Alvaréz Fernández, 2012), Oued Djebbana (Vanhaeren et al., 2006) in Algeria, to Skhul (Vanhaeren et al., 2006) and Qafzeh (Bar-Yosef Mayer et al., 2009) in Israel, all in excess of 75 ka.

In Europe, the first evidence of the use of shell beads dates back to the early Upper Paleolithic, both in Central Europe (Anikovich et al., 2007) and eastern Mediterranean (Stiner et al., 2013). In Western Europe, the earliest shell beads were found in Chatelperronian and Aurignacian contexts dated to c. 40 ka ago (Álvarez Fernández and Jöris, 2008; Vanhaeren et al., 2013). The earliest evidence seems to be from Los Aviones Cave, where *Acanthocardia* shells might have been used as beads (but not produced as such) in the Middle Paleolithic of Eastern Spain, dated to c. 50 ka BP (Zilhão et al., 2010).

In Southern Iberia (Fig. 1), the earliest shell beads were found in the Gravettian horizons of Vale Boi (Bicho et al., 2004; Tátá, 2011), dated to c. 32 ka cal BP (Bicho et al., 2013a; Bicho et al., 2013b), corresponding to the earliest Upper Paleolithic in the region.

With few exceptions (d'Errico et al., 2009; Stiner et al., 2013; Vanhaeren and d'Errico, 2001), investigating shell bead production and technology as a means of social visual transmission was rarely studied. A range of physical properties (Stiner et al., 2013;

* Corresponding author.
E-mail addresses: nbicho@ualg.pt, nunofbicho@gmail.com (N. Bicho).

0305-4403/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2013.10.029

Fig. 1. Map of Portugal, with the location of Vale Boi and loci of collection of modern shells. 1. Amoeiras (*Trivia* sp.); 2. Sesimbra (*Trivia sp.*); 3. Guadiana (*Theoduxus fluviatilis*).

Kuhn and Stiner, 2007) including shell species (morphology), size, color, and the form of casting and suspension allow shell beads to represent elements of visual social information (Wiessner, 1997). Some of these properties were constrained by the natural environment and the frequency and availability of each shell type. Humans selected these from the available local resources, and less commonly from greater distances (Álvarez Fernández, 2001; Langley and Street, 2013; Whallon, 2006). Although shells themselves offer an incredible range of pleasing aesthetic characteristics, humans still manipulated and altered shells according to individual idiosyncratic and group aesthetic decisions and traditions (Wiessner, 1997), following very clear technological recipes for obtaining the final product. Experimental procedures for bead production have been carried out in various contexts and chronologies. For Old World Paleolithic and Mesolithic including Iberia, there is a range of important studies available that helped to characterize bead production technology and were used in this paper as basic information for the experimental work as well as for comparing the data (Francis, 1982; Taborin, 1993; Chauvière, 2002; Vanhaeren and D'Errico, 2002; Benghiat et al., 2009; Stiner et al., 2013; Vanhaeren et al., 2013).

In this paper, we focused on shell bead production at Vale Boi based on experimental replication procedures, following previous similar studies for Portugal (Francis, 1982; Chauvière, 2002; Vanhaeren and D'Errico, 2002; Stiner et al., 2013; Vanhaeren et al., 2013) and address the impact of bead production techniques on the evolution of visual design technology through an Upper Paleolithic record in Southern West Portugal.

2. Archaeological background of Vale Boi

2.1. The site of Vale Boi

Vale Boi (Fig. 2) is a very large site (>10,000 m^2) located 2.5 km from the modern coast in the eastern side of a limestone fluvial valley, whose small river runs through a canyon to a seasonal coastal lagoon. The access to the coast is easy either through the valley or crossing a short range of low hills. During human occupation, roughly 33 to 18 ka ago, sea level oscillated between 60 and 120 m below present sea level (Dias et al., 2000) from early Gravettian times to the peak of the LGM during the Solutrean. Nevertheless, the shore was never further away more than 15 km from the site during the Solutrean, while during the Gravettian and the Magdalenian, the shore was likely no more than 5 km away (Bicho et al., 2013b). Thus, access to marine resources in Vale Boi was easy, although varied across time.

The site has three main areas. There is a collapsed rockshelter near the cliff with a series of archaeological horizons: Early Gravettian and Proto-Solutrean followed by three well preserved Solutrean layers; after the Solutrean there was a shelter collapse, followed by a Magdalenian occupation (Bicho et al., 2013a; Bicho et al., 2013b).

The mid section of the site was on the slope and was used as a midden. The top of the deposits was badly preserved - some of the smaller materials were washed away and bone preservation was poor. After 25 cm below the surface, preservation improves, small artifacts (<1 cm) were very common and refitting within the same artificial spit and square unit is common for fauna, bone implements and shell (Bicho et al., 2012), clearly indicating that there was no relevant impact on the record by slope-related post-depositional events. The slope section has early and late Gravettian horizons, followed by Proto-Solutrean, Solutrean, and Magdalenian. At the bottom of the slope, there is a natural platform, designated Terrace, with a long sequence of human occupations, starting with Early Gravettian, Gravettian, Proto-Solutrean, Solutrean, Epipaleolithic, Mesolithic and Neolithic.

All sediments were screened carefully through a 2–3 mm fine mesh. Wet screening at the site was difficult because there was no water locally, therefore, in the first year, a series of samples were carried out and wet screened in the laboratory. The results were compared with those from dry screening, but no differences were observed between the two processes and we concluded that dry screening allowed an effective recovery of the artifacts and other organic materials such as small bones and shells. Samples were still collected for floatation to recover botanical residues. All materials larger than 2 cm were 3D plotted with total stations. Vertical control follows natural layers divided into 5 cm artificial spits. Screened materials were located according to the "bucket approach" (McPherron and Dibble, 2002). Most ornamental shells were recovered by hand during excavation, and only a few specimens were found in the screens.

2.2. Chronology

There are now 48 radiocarbon dates from Vale Boi, ranging from the very early Gravettian, some 32 ka cal BP to the early Neolithic (Table 1). Most dates are AMS results, and most bone samples were dated with the ultrafiltration technique (Higham et al., 2006). Bone samples in many cases had low collagen yield and the results should be considered as minimum dates. Different mineral fractions of the shell samples were dated to verify possible recrystallization processes. Charcoal samples were in some cases identified before dating. Still, in a few cases, the results were anomalous.

The early Gravettian is now well bracketed between 32 and 28.5 ka cal BP, and is characterized by the presence of small, bipointed double backed bladelet points (Bicho et al., 2013b; Marreiros and Bicho, 2013). It was found both at the Shelter (Layer D) and in the Terrace (Layers 6 and 5). The Gravettian phase, present in the Slope and Terrace areas (respectively, Layers 3 and 4) was securely dated between 28.5 and 26.5 ka cal BP and is marked by the presence of common microlithic backed retouched tools (Microgravette points and backed bladelets) (Bicho et al., 2013a). Proto-Solutrean materials present in the Terrace and Slope *loci*, are

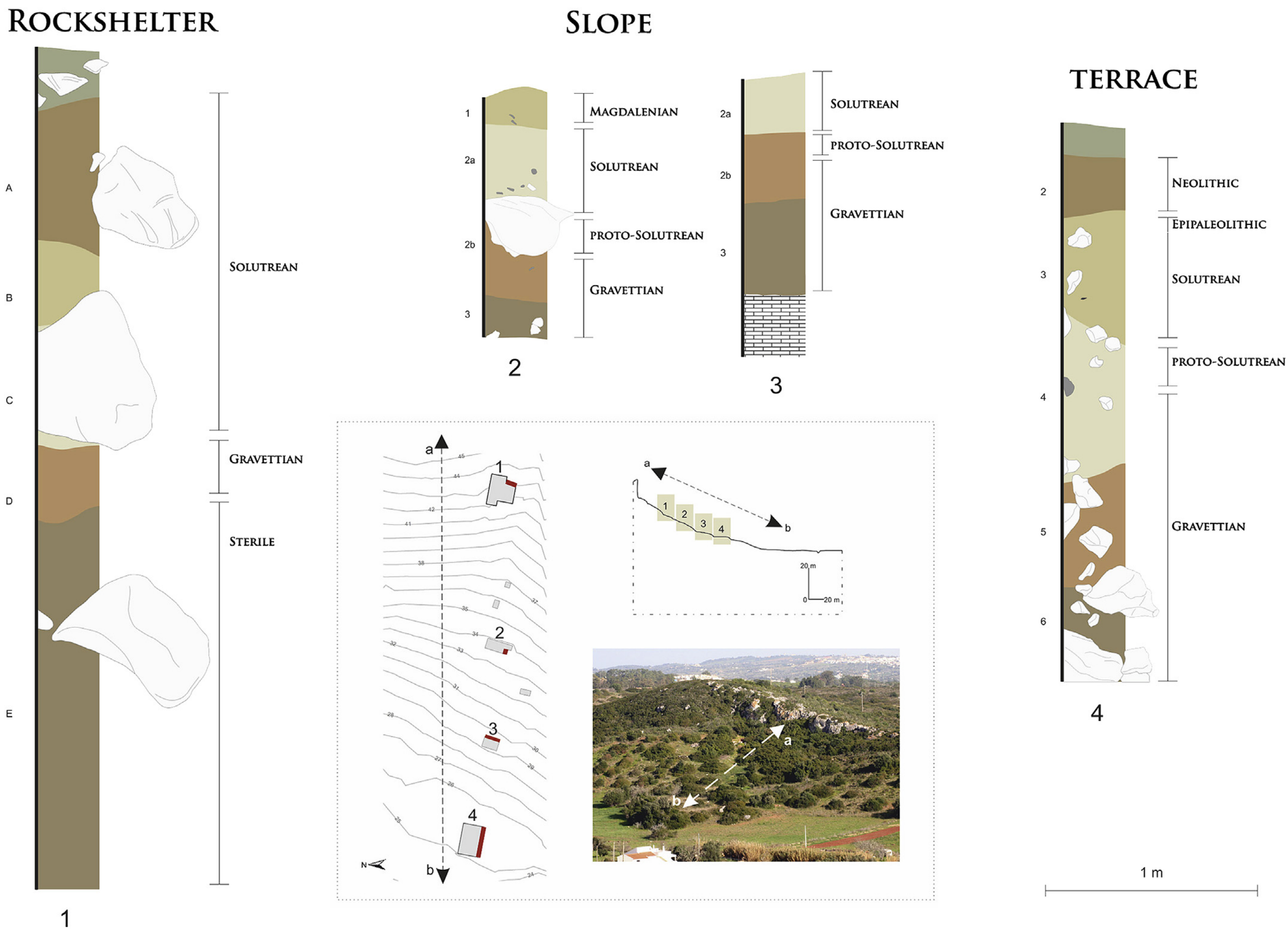

Fig. 2. General view of Vale Boi with the three loci sequences.

dated 26–24.5 ka cal BP (Bicho et al., 2013a; Cascalheira and Bicho, 2013). The lithic assemblages are characterized by the presence of the Vale Comprido point, typical from this period (Zilhão, 1997).

The Solutrean is better known in the Rockshelter (Cascalheira, 2009) but it is also found both in the Slope and Terrace areas. It is dated to between 24.5 and 20.5 ka cal BP. The lithic assemblages are typical of the Mediterranean Upper Solutrean and are characterized by a wide range of distinctive Solutrean points (Cascalheira et al., 2013).

2.3. Ornamental shells from Vale Boi

We have recovered, up to 2010, over 12,000 fragments or complete shells with a MNI of close to 1650 individuals in the Paleolithic horizons of Vale Boi (Manne and Bicho, 2011; Manne et al., 2012). The main edible species are limpets (*Patella* sp.), mussels (*Mytilus* sp.), and clams (*Ruditapes decussatus*), although there are about a dozen or more species at the site (Manne and Bicho, 2011). These are mostly present in the Gravettian layers of the *midden* in the Slope area. During the Solutrean they are not nearly as common (less than half of the NISP and MNI, and richness severely decrease too) and are only vestigial during the Magdalenian.

In this study, we followed Stiner's et al. (2013) definition of ornamental shells: separation between shells from edible species and those which were not used as food and can be transformed into a technological product. The focus of this paper includes two main phases of human manipulation for shell bead production: selection and transportation to the site and the transformation of the shell according to stylistic local standards.

There are a total of 113 ornamental specimens (Fig. 3; Table 2) comprising different species (Tátá, 2011): *Littorina obtusata* or *Littorina fabalis*, *Theodoxus fluviatilis*, *Trivia* sp., *Antalis* sp., *Mitrella scripta*. While the three first species were object of transformation through the manufacture of a perforation, the latter two do not present any evidence for anthropogenic modification. If they were used as beads, they were likely set or crimp on a fabric perhaps with the help of resin, since there is no evidence for perforation or suspension (Tátá, 2011). Still, in the case of the *Antalis*, in a total of 16 in Vale Boi, since it has a natural orifice, it could have been used without any artificial perforation but they do not present any signs of interior wear from suspension in a line or string, unlike other Paleolithic sites in Western Europe (e.g., Vanhaeren and d'Errico, 2001). They have, however, indication of sectioning to produce shorter beads.

The natural habitat of the *Antalis* is sandy and muddy bottoms of various depths below the intertidal zone. They are common in the Atlantic waters of Algarve whereas *Mitrella* has been recorded at about 40 m of depth (Macedo et al., 1999). It is not a very common species found on the shore. It is possible that, since shellfish gathering by Vale Boi population targeted mostly edible species found in rocky environments, the *Mitrella* may have been scattered on the shore while searching for *Antalis* and were collected due to its different and rare appearance.

Table 1
Radiocarbon dates from the site of Vale Boi.

Area	Level	Phase	Lab.	Date	Material	Date cal BP[a]	Notes
Terrace	2	Early Neolithic	Wk-17030	6036 ± 39	Bone	6990–6785	
Terrace	2	Early Neolithic	OxA-13445	6042 ± 34	Bone	6982–6791	
Terrace	2	Early Neolithic	Wk-17842	6095 ± 40	Bone	7157–6807	
Terrace	2	Early Neolithic	Wk-13865	6018 ± 34	Bone	6950–6752	
Terrace	2	Mesolithic	TO-12197	7500 ± 90	Tooth, H. sapiens	8514–8056	
Shelter	Z1	Magdalenian	Wk-31088	15,660 ± 86	Tooth	19,250–18,606	
Slope	2	Solutrean	AA-63307	11,840 ± 280	Charcoal	14,821–13,131	
Slope	2	Solutrean	AA-63308	15,710 ± 320	Charcoal	19,548–18,115	
Terrace	3	Epipaleolithic	Wk-13685	8749 ± 58	Charcoal	10,116–9548	
Terrace	3	Epipaleolithic	Wk-24761	8886 ± 30	Charcoal	10,170–9906	
Terrace	3	Epipaleolithic	AA-63305	8825 ± 57	Charcoal	10,160–9683	
Terrace	3	Solutrean	AA-63310	8696 ± 54	Charcoal	[b]	
Terrace	3	Solutrean	Wk-36255	8664 ± 25	*Olea*	[b]	
Terrace	3	Solutrean	Wk-36256	8737 ± 25	*Olea*	[b]	
Shelter	B1	Solutrean	Wk-17840	20,340 ± 160	*Patella*	24,305–23,380	Calcite
Shelter	B6	Solutrean	Wk-24765	18,859 ± 90	Charcoal	23,233–22,191	
Shelter	C1	Solutrean	Wk-24763	19,533 ± 92	Charcoal	23,720–22,684	
Shelter	C4	Solutrean	Wk-26800	20,620 ± 160	Charcoal	25,045–24,196	
Shelter	D2	Solutrean	Wk-26802	20,570 ± 158	Charcoal	25,020–24,119	
Slope	2	Solutrean	Wk-12131	17,634 ± 110	Bone	21,405–20,518	
Slope	2	Solutrean	Wk-12130	18,410 ± 165	Bone	22,357–21,505	Minimum Age
Shelter	D4	Gravettian?	Wk-26803	21,859 ± 186	*Patella*	[b]	Calcite
Terrace	4	Gravettian	Wk-24762	24,769 ± 180	Charcoal	30,211–29,287	–
Terrace	4	Gravettian	Wk-31090	24,549 ± 165	Bone	29,825–28,608	Minimum age – small sample with low collagen yield
Terrace	4	Gravettian	Wk-32144	24,381 ± 258	*Patella*	29,307–27,981	Calcite
				23,613 ± 240	*Patella*	28,440–26,919	Aragonite
Slope	3	Gravettian	Wk-13686	22,470 ± 235	Bone	27844–26288	–
Slope	3	Gravettian	Wk-16414	23,995 ± 230	*Patella*	28,741–27,650	Calcite
Slope	3	Gravettian	Wk-12132	24,300 ± 205	Charcoal	29,522–28,539	–
Slope	3	Gravettian	Wk-17841	24,560 ± 570	*Patella*	30,211–27,743	Calcite
Terrace	5	Early Gravettian	Wk-31089	24,183 ± 161	Bone	[b]	Minimum age – small sample with low collagen yield
Terrace	5	Early Gravettian	OxA-25710	25,050 ± 100	*Patella*	29,565–28,636	Calcite
Terrace	5	Early Gravettian	Wk-30677	25,196 ± 103	*Patella*	29,906–28,620	Calcite
				22,235 ± 173		[b]	Aragonite
Terrace	5	Early Gravettian	Wk-32145	25,181 ± 293	*Pecten*	30,200–28,600	Minimum age – burnt sample
Terrace	5	Early Gravettian	Wk-30679	25,317 ± 99	*Patella*	30,141–29,246	Calcite
				25,390 ± 255		30,331–28,970	Aragonite
Terrace	5	Early Gravettian	Wk-26801	27,720 ± 370	Charcoal	[b]	–
Terrace	6	Early Gravettian	Wk-30678	25,579 ± 98	*Patella*	30,232–29,487	Calcite
Terrace	6	Early Gravettian	Wk-35713	25,930 ± 122	*Pecten*	30,482–29,599	–
Terrace	6	Early Gravettian	Wk-35714	25,964 ± 110	*Pecten*	30,570–29,585	–
Terrace	6	Early Gravettian	Wk-35712	26,026 ± 114	*Nassarius*	30,590–29,645	–
Terrace	6	Early Gravettian	Wk-30676	24,318 ± 90	*Patella*	[b]	Calcite
				26,353 ± 284		31,096–29,740	Aragonite
Terrace	6	Early Gravettian	Wk-32147	27,141 ± 365	*Acanthocardia*	31,502–30,474	Aragonite
Terrace	6	Early Gravettian	Wk-32146	28,321 ± 422	*Pecten*	33,070–31,240	Calcite
Terrace	6	Early Gravettian	Wk-35717	28,012 ± 192	*Arbutus*	32,875–31,566	–
Shelter	D4	Early Gravettian	Wk-31087	28,140 ± 195	*Littorina obtusata*	32,324–31,253	Aragonite

[a] Calibration with OxCal version 4.2 (Bronk Ramsey, 1995) with the IntCal09 curve (Reimer et al., 2009). Marine data (Delta-R 209 ± 102) from Reimer et al. (2009).
[b] Non-calibrated results due do inversion, contamination or recrystallization of samples.

The *Littorina* group (flat periwinkle), in a total of 81 specimens, was in the past considered as a single species, *Littorina littoralis*. The two species are very similar in shape, color, general morphology, and in their natural habitat. They are not that common today in the coastal Algarve where the site is located. In general, *L. obtusata* shells (no more than 18 mm long) are larger and thinner than *L. fabalis*. Yet, there is an important overlap between the two species in terms of size, due to a high level of geographic variability. A great variability also exists in terms of coloration of the shells: at least nine chromatic groups can be differentiated today (Dautzenberg and Fisher, 1914; Reid, 1996). Vanhaeren and D'Errico (2002) argued that some of these chromatic groups can be differentiated in terms of their mean size, but our own results (Tátá, 2011) do not confirm this pattern: from our collection of 315 specimen (Fig. 4), 80% of the citrina color morph variety specimens ($n = 70$) are larger than 13.9 mm in length, the maximum length in Vanhaeren and d'Errico's collection for that same morph color. The reticulata morph color presents specimens even larger, up to 16.6 mm in length, which are again larger than the stipulated limits reported by Vanhaeren and D'Errico's (2002).

Today, the two *Littorina* species can be found in the middle and lower intertidal zone in rocky settings, sometimes in estuarine environments, as well as on the shore as empty shells. At Vale Boi, there is one case of a non-perforated shell with a smaller shell inside, suggesting post-mortem collection. There is no other evidence to suspect that *Littorina* specimens were not collected as live animals in low tide periods while looking for edible shell species.

From 81 cases, there are 39 perforated specimens, 28 whole shells and 14 fragments. The latter are possibly the result of manufacturing accidents while perforation was attempted.

The six *Trivia* shells found in Vale Boi are Solutrean. These shells, known as cowrie (Graham, 1988:326), are very small (15.4 mm maximum length, Pelseneer, 1932) and lemon shaped with 20–30 small, transverse parallel ridges. The genus comprises two different

Fig. 3. Ornamental shells from Vale Boi. 1 – *Littorina obtusata* or *L. fabalis* from Gravettian, Proto-Solutrean and Solutrean layers (Slope area); 2 – *Trivia monacha* or *T. arctica* from Solutrean layers (Slope and Rock-Shelter); 3 – *Theodoxus fluviatilis* from Solutrean layers (Rock-Shelter); 4 – *Antalis* sp. from Solutrean layers (Rock-Shelter).

species, *Trivia monacha* and *T. arctica*. The only difference between the two shells is the presence of three dark dots on the top surface of *T. monacha*. These tend to fade out completely after death, and archaeologically the two species are undistinguishable. The natural habitat is from the intertidal zone down to circalittoral, but they can be easily found post-mortem on the sandy shores near rocky areas where they lived. The perforations found in the Vale Boi *Trivia* specimens are very regular and do not show any evidence of external wedging, due to the thinness of the shell as well as post-depositional erosion.

Table 2
Number of ornamental shells from Vale Boi.

	Early Gravettian	Late Gravettian	Proto-solutrean	Solutrean	Magdalenian	Total
Littorina						
Perforated	–	14	11	14	–	39
Whole	1	16	7	4	–	28
Fragments	–	9	2	3	–	14
Total	1	39	20	21	–	81
Theodoxus	2	–	–	7	–	9
Trivia	–	1	–	5	–	6
Dentalium	–	1	–	14	1	16
Mitrella scripta	–	–	–	1	–	1
Total	3	41	20	48	1	113
Number of species	2	3	1	5	1	

T. fluviatilis is a freshwater, small gastropod, with high chromatic variation, found in springs and rivers, such as the Vale Boi stream. Known as river nerite, it prefers waters with high levels of calcium such as limestone bedrock environments. It is also well adapted to high salinity in brackish waters near the Atlantic coast. In shallow waters, when present, they tend to be highly numerous and are easy to collect in great numbers. Here, they reached a maximum diameter of 10 mm (Nobre, 1941). The low numbers of archaeological specimens found in Vale Boi are mostly characterized by perforations with irregular edges, while the internal surface shows signs of flaking (internal wedging). There is a single exception, where the shell perforation is circular and the edges are very regular.

The shells of *Littorina* sp., *Trivia* sp. and *T. fluviatilis* in Vale Boi were used for beads. With a single Solutrean exception of a *Littorina*,

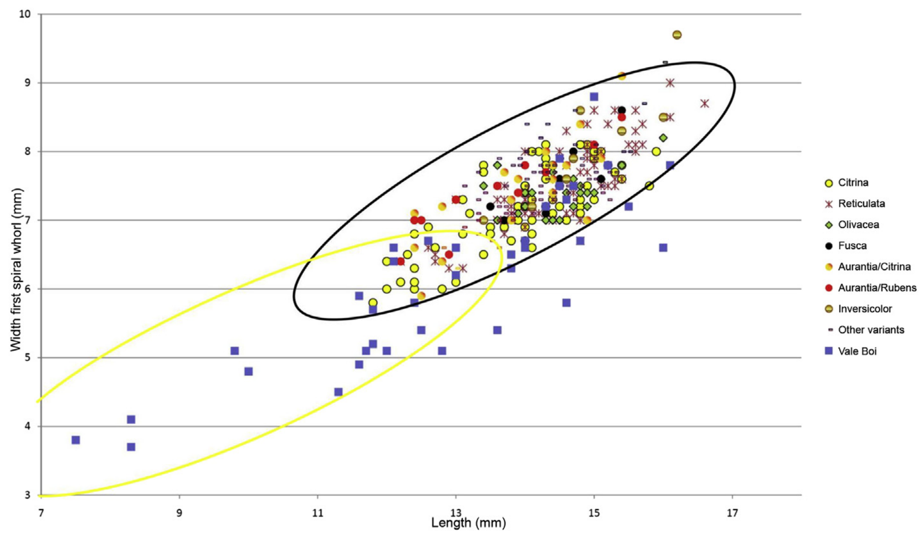

Fig. 4. Scattergram of modern *Littorina obtusata* from the Channel Islands (length vs. width), according to color morph, and the Vale Boi archaeological specimens. The confidence ellipses presented by Vanharen and D'Errico (2002:171) are also plotted, corresponding, from left to right, to citrina and fusca.

all others were perforated with a single hole, usually on the two last body whorls of the shell, where the shells are naturally thinner. The perforations on *Littorina* sp. and *T. fluviatilis* are marked by tendentiously irregular circular holes. The edges are frequently slightly jagged and interior wedging is present in all cases, but there is no loss of the internal nacreous surface. The size of the perforation diameter is highly variable, ranging from 2.1 up to 6.8 mm in the maximum axis and 1.6–4.4 mm in the minimum axis.

There seems to be differences in the occurrence, both in numbers of beads and in the number of species present in each phase. During the Early Gravettian, only 2 specimens made of *Theodoxus* were identified. There is another shell of *Littorina*, which is not perforated. It might have been used but was either set or crimped and not suspended.

With the Gravettian, the number of species and beads increased to 3 species (*Littorina* and rare *Trivia* and *Antalis*) and 41 specimens, respectively. Proto-Solutrean may present the same pattern as before, but since the sample is smaller, the only genus present is *Littorina*.

During the Solutrean, there was a change, with an increase in the number of both species (5) and specimens (48). *Antalis* and *Littorina* are the most common species found during the Solutrean. It seems that specimens were used as beads during this phase both for suspension and setting. During the Magdalenian, very low number of specimens were observed, which might be the result of taphonomy in the top part of the sequence.

The differences between phases in the number of species and frequency of specimens are likely the result of different cultural approaches for the use of ornamental beads, including that of social markers in adaptive processes to the new and changing ecological niches, resilience forces through impacting climatic events, or highly mobile human pressure (Bradtmöller et al., 2012; Stiner et al., 2013; Bicho et al., 2013b). However, other variables such as distance to shore, sampling and volume of excavation, and area function might also have had an impact.

3. Ornamental shell technology – experimental procedures and results

3.1. Samples and tools

Experimental manufacture of shell beads has been frequently tried in the recent past in both Paleolithic and Mesolithic contexts (Francis, 1982; Taborin, 1993; Benghiat et al., 2009; Stiner et al., 2013; Vanhaeren et al., 2013). Some of the techniques used in the present study were used in earlier studies. We felt, however, necessary to carry out a diverse set of trials to better understand the shell bead production as the way shell respond to the perforation techniques varies from species to species.

The experimental work started with the collection of shells of all the ornamental species, except for *Mitrella*, since it was not perforated. A total of 145 *T. fluviatilis* were collected (74 were alive) from the Guadiana river where they were present in abundance. A total of 34 *Trivia* shells were collected from Amoreiras (Santa Cruz) and Sesimbra beaches in central Portugal. A few *Antalis* specimens from previous collections from Estremadura beaches were also used in this study. The *L. obtusata* 311 specimens were acquired from the Channel Islands (United Kingdom), as they are fairly rare in southern and central Portugal.

A total of 16 lithic pointed implements were produced with hard hammer and a variety of local and non-local cherts (Fig. 5). These 16 perforators replicated artifacts that were found both in Vale Boi and other sites of the Portuguese Upper Paleolithic. Lithic implement morphologies varied to produce a wide range of perforating shapes.

A set of organic tools was also produced, made on red deer bone and antler. These were collected from animals killed in controlled specialized hunting parks in Alentejo, near Évora. These perforators (Fig. 5) were made with modern carpenter tools such as coping saw, different files and a woodworker's bench vice.

3.2. Selected specimens and experimental perforation techniques

A total of 113 shells were used in the experimental perforation (73 *Littorina*, 35 *Theodoxus* and 5 *Trivia* shells). In addition, a small set of *Antalis* was also used experimentally, by snapping and sawing. Since, we did not know what were the likely techniques used for the perforation of the archaeological specimens, we used an array of six different methods of shell perforation. This diversity of techniques was used to identify the technique(s) with morphological results similar to those from the archaeological specimens as well as to screen the most efficient techniques. The techniques included direct pressure, direct and indirect percussion, rotation, scratching and abrasion in a total of 32 individual technical combinations of movements, tools and shell species (Table 3; Fig. 6). The perforation of *Littorina* and *Theodoxus* was tried from both the

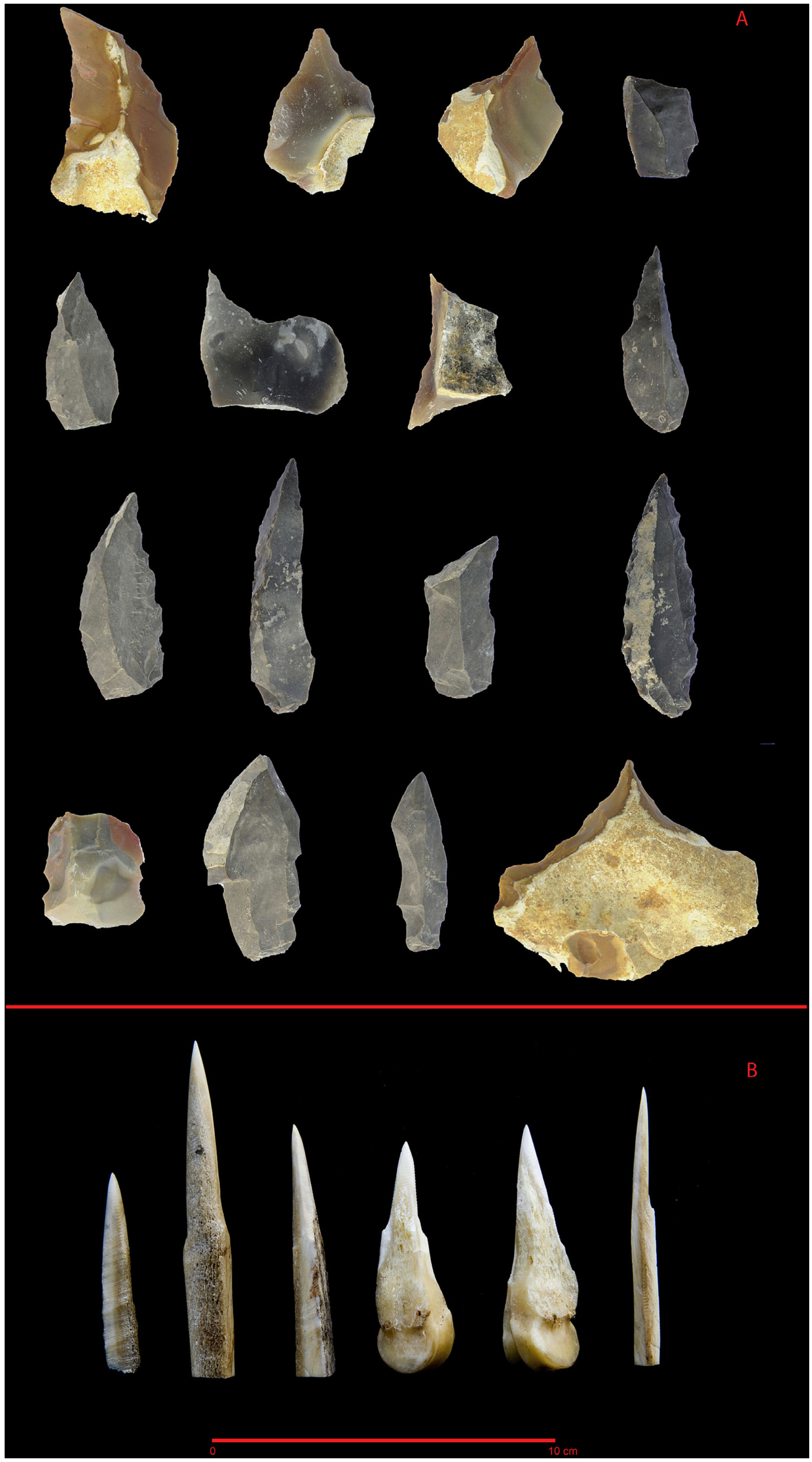

Fig. 5. Experimental implements. A – lithic; B – bone and antler.

Table 3
Summary of techniques used for experimental work in shells.

Technique	Tool	Species	Direction of perforation	Duration of action	Number of specimens	Successful trials
Direct percussion with the shell held by hand on a wood anvil;	Lithic	*Littorina sp.*	From the external surface	–	1	0
Direct pressure with rotating alternating movements, with short and multidirectional strokes, with the shell held by hand on a wood anvil;	Lithic	*Littorina sp.*	From the external surface	95–16 s	10	9
			From the internal surface	35 s	1	1
		Theodoxus sp.	From the external surface	11–15 s	2	2
			From the internal surface	–	1	0
		Trivia sp.	From the external surface	12 s	1	1
Linear or multilinear scratching with the shell held by hand on a wood anvil;	Lithic	*Littorina sp.*	From the external surface	22–26 s	2	1
		Theodoxus sp.	From the external surface	19 s	1	1
		Trivia sp.	From the external surface	25 s	1	1
Direct pressure with the shell held by hand on a wood or cork anvil;	Lithic	*Littorina sp.*	From the external surface	–	1	0
	Bone, antler		From the internal surface	Immediate	10	10
	Lithic	*Theodoxus sp.*	From the internal surface	Immediate	3	2
	Bone, antler		From the external surface	–	1	0
	Lithic		From the internal surface	Immediate	10	9
		Trivia sp.	From the external surface	Immediate	1	1
Indirect percussion, with the implement hit by a soft antler hammer – the shell is on a wood or cork anvil;	Lithic	*Littorina sp.*	From the internal surface	–	1	0
	Bone, antler			Immediate	40	34
	Lithic	*Theodoxus sp.*	From external surface	Immediate	2	2
	Bone, antler		From interior surface	Immediate	2	2
			From the external surface	Immediate	3	3
			From interior surface	Immediate	5	5
Direct abrasion of the shell against an abrasive rock	Rock	*Littorina sp.*	From the external surface	53 s	1	1
		Theodoxus sp.		42 s	1	1
		Trivia sp.		35 s	1	1
Snapping	Hand	*Antalis*	–	Immediate	3	3

internal and external surface of the shell with different methods. In the case of *Trivia*, the perforation was only tried from the outside due to the very tight natural aperture of the shell, with no space available for a perforator. Whenever necessary, the shell was held manually on a wood or cork anvil. The anvil simultaneously allowed the perforator to cross the shell and stop before crushing the shell.

3.3. Results

The perforations obtained by the experimental trials resulted in a set of well-defined patterns for the morphology and cross-section of the perforated hole (Fig. 7).

Littorina shells were the most robust, larger, thicker and, thus, hardest of the various species in this experiment (Fig. 8). Many techniques used in the study resulted in accidental broken specimens and even the techniques with more controlled strength and movements there was some extent of fracturing reported. It seems that the resistance to the pressure was variable within the shells with the same dimensions within this species (Fletcher, 1995; Reimchen, 1982). The result showed that a well succeeded perforation does not depend exclusively on the quality of the technique and strength used in the perforation.

The better results for *Littorina* (Fig. 9) were obtained by the following three techniques:

a) Rotation with lithic implements on the exterior surface (Francis, 1982) – this technique offers an excellent control for pressure strength as well as the movement, with a very low accidental breakage (only 10%) and a fairly rapid result (16–95 s each perforation). The negative aspect is the rapid wear of the lithic bit. The hole is highly patterned (Table 4), very circular with a regular contour and frequent external wedging, with a section type D (Fig. 7).
b) Internal indirect percussion with bone or antler perforator with a cork anvil: This is the fastest technique, since there is a single controlled movement. Still, the perforation frequently took place in the second or third try. There is, however, a strong negative aspect due to the difficulty in controlling the impact force – that of accidental fracture of the shell (45% of the trial times in the first 20 shells, success rate rose to 85% in the second batch of 20 shells). The holes are mostly circular with irregular contours and section type A with no internal scaling. There seems to be no difference between bone and antler bits, heat treated or not.
c) Internal direct pressure with bone or antler perforator on cork anvil: This is the technique with a better success rate. All 10 specimens were successful with no accidental fractures. The negative point was that the hole was less patterned in terms of morphology than with other techniques. The circular shaped holes present a similar morphology to indirect percussion, with irregular contours and sections type A with no internal scaling.

Fig. 6. Detailed photographs of the main (most efficient) perforating techniques. A – internal pressure with organic implement; B – internal indirect percussion with organic implement; C – external pressure and rotation with lithic implement.

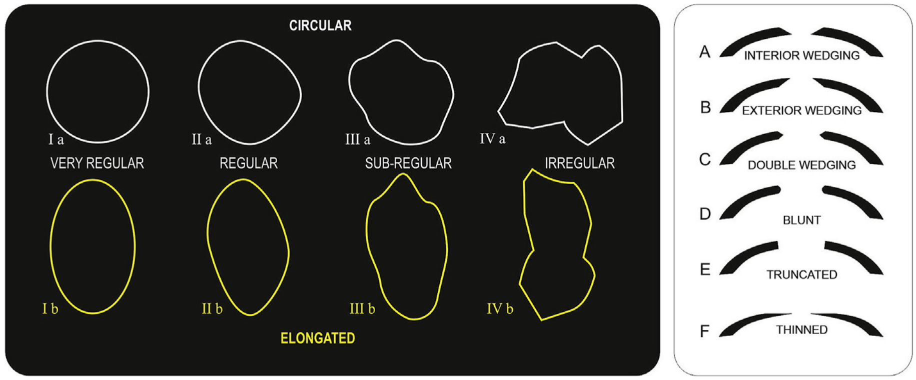

Fig. 7. Morphology (left) and cross-section (right) of experimental perforations.

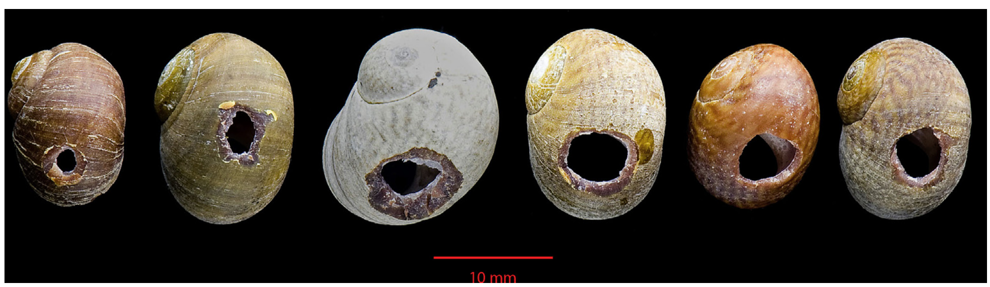

Fig. 8. Examples of experimental shell beads perforated using bone or antler implements by internal pressure: *Littorina obtusata*.

The other techniques also produced perfect exemplars, but the success rate was clearly much lower, there was a heavier wear of the implement used for the perforation and, finally, it was more time consuming.

The morphology of *Trivia* shells prevents internal perforation due to the very small and tight opening (Fig. 9). In addition, due to shell shape and size, no indirect percussion was attempted because it was very difficult to hold the shell in the correct position due to the sliding of the bit over the shell. Nevertheless, the experimental techniques of rotation, direct percussion and scratching showed that perforation is fairly easy as long as it is made with a lithic implement. The more economic shape for the lithic bit is the direct percussion, while the technique that makes the holes most perfect, is rotation. The shell ridges help to increase the precision of the hole location.

Theodoxus shells were the easiest to perforate, because they are very thin and their natural aperture gives easy access to the interior surface (Fig. 10). Thus, the number of techniques successful for perforating this species was higher than with the other species. Nevertheless, the better perforation techniques were exactly the same as those used for *Littorina*, but with a higher success rate. It is very difficult to separate the various techniques in terms of hole morphology and section, but they still tend to be identical to those seen in the *Littorina*. The hole created by rotation presents the most regular contours, while those made by pressure and indirect percussion were more irregular. It was therefore, difficult to control the size of the perforation with pressure and indirect percussion techniques.

Experiments with *Antalis* were only supplementary since they followed the detailed work of Vanhaeren and D'Errico (2001). The few trials confirmed the results obtained by these authors for the Magdalenian materials from La Madeleine.

4. Discussion

The archaeological specimens from Vale Boi present a fairly tight pattern of technological choices for the production of perforated shell beads. Except for a single case of *Littorina* with two holes (one cannot unequivocally be attributed to human production), all shell beads presented a single hole (Fig. 11). Independently from the chronology, most *Littorina* and *Theodoxus* beads presented perforations consistent with the experimental results of internal direct pressure with bone or antler implements. There are two exceptions, one *Littorina* dated to the Gravettian that seems to have been perforated by external pressure; and one Solutrean *Theodoxus* perforated with a lithic bit with external rotation. This is congruent with the experimental results in this study, proven to be the fastest and with fewer accidental fractures. This technique is used almost in every single case independently of the chronology. The location

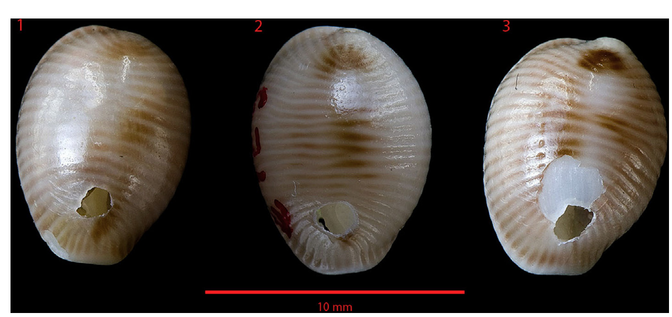

Fig. 9. Examples of experimental shell beads: *Trivia monacha*, perforated with lithic implements, by scratching (1), pressure and rotation (2), and direct pressure (3), all in the external surface of the shell.

Table 4
Morphological characteristics of the main experimental perforations and techniques.

Technique	Species	Morphological characteristics of the perforation
External direct percussion	*Littorina obtusata*	Circular holes, with irregular contours, sometimes angular edges, with internal wedging. No or little external flaking of the nacreous surface.
External direct pressure with rotation	*Littorina obtusata* *Theodoxus fluviatilis* *Trivia monacha*	Circular holes with regular contours; external wedge is present and in the case of *Littorina* there are some with blunting of the edges.
Internal direct pressure with rotation	*Littorina obtusata* *Theodoxus fluviatilis*	Circular holes with regular contours; internal wedge is present.
External scratching	*Littorina obtusata* *Theodoxus fluviatilis* *Trivia monacha*	Oval to circular holes with irregular contours. Some external wedging is present
External direct pressure	*Littorina obtusata* *Theodoxus fluviatilis* *Trivia monacha*	Circular holes, with irregular contours, sometimes angular edges, with internal wedging. No external flaking of the nacreous surface.
Internal direct pressure	*Littorina obtusata* *Theodoxus fluviatilis*	Circular holes, with irregular contours, sometimes angular edges, with external wedging. No internal flaking of the nacreous surface.
Internal indirect percussion	*Littorina obtusata* *Theodoxus fluviatilis*	Circular holes, with irregular contours, sometimes angular edges, with external wedging. No internal flaking of the nacreous surface.
Direct abrasion	*Littorina obtusata* *Theodoxus fluviatilis* *Trivia monacha*	Oval to circular holes with irregular contours. Some external wedging is present together with the thinning of the shell. Diameter of perforation is variable.

of the *Littorina* perforation, near the lip and rarely in more interior areas, seems to be related with the fact that such regions are thinner and less resistant.

All archaeological perforated *Trivia* were consistent with the results of external perforation by rotation using a lithic bit. For *Trivia*, the technological recipe was different from that used for the other two species, most likely due to general morphology, size of the aperture and thickness of this species. Nevertheless, it follows the same logic of a single technique used across time and, apparently, across space since there are similar examples in Lapa do Suão (Ferreira and Roche, 1980).

As mentioned above, *Antalis* and *Mitrella* do not show any signs of anthropogenic alteration – we did not recognized any evidences of thread, which if occurred, would be expected to become evident since the aperture is quite narrow (always less than 1 mm). They were likely to be set on the fabric rather than used as a pendant and thus, their use was different from that of *Trivia, Littorina* and *Theodoxus*. The presence of non-perforated *Littorina* might indicate similar applications, although it likely represents raw material for bead production.

Previous studies including experimental work have been carried out in central Portugal for the sites of Lagar Velho rockshelter (Gravettian and Solutrean), Anecrial (Solutrean) and Caldeirão caves (Gravettian, Solutrean and Magdalenian) (Chauvière, 2002; Vanhaeren and D'Errico, 2002), but unfortunately, these studies did not present numeric data on their trial experiments and they focused mostly on the *Littorina*.

However, in the case of *Littorina,* their results were similar to ours both for experimental and archaeological specimens: the tendency seems to use internal punching of the body whorl through the shell aperture with a pointed tool (Chauvière, 2002; Vanharen and D'Errico, 2002); the holes tend to be circular to oval, sometimes slightly irregular. In case of the Gravettian Lagar Velho specimens associated with the human burial, there seems to be a blunting of the perforation (Vanharen and D'Errico, 2002), marking a clear different style from that found in Vale Boi. The diameter of the hole also presents a similar pattern as seen in the collections from central Portugal, ranging from 2.1 up to 6.8 mm in the maximum axis and 1.6–4.4 mm in the minimum axis. There was no chronological pattern as that observed by Vanharen and

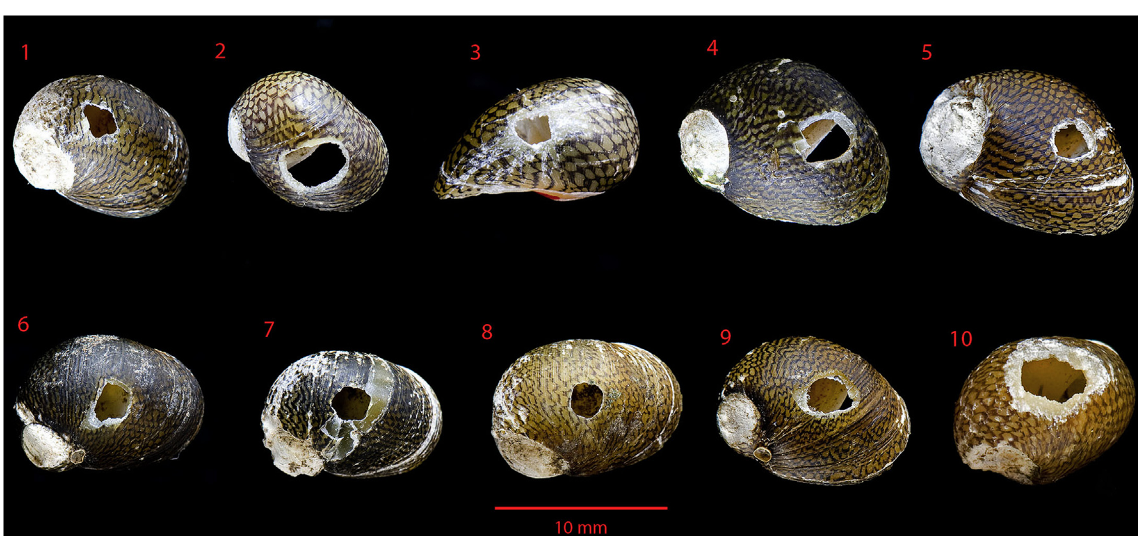

Fig. 10. Examples of experimental shell beads: *Theodoxus fluviatilis*. Indirect external percussion with lithic implement (1); indirect internal percussion with lithic implement (2); external scratching with lithic implement (3); direct internal pressure with lithic implement (4); external pressure and rotation with lithic implement (5); direct internal pressure with antler implement in the interior (6); indirect external percussion with antler implement (7); direct external pressure with antler implement (8); indirect internal percussion with antler implement (9); external abrasion with lithic implement (10).

Fig. 11. Details of archeological perforations. Top row: *Littorina* sp. from the Solutrean layers in the Slope (left) and the Rockshelter (right); Middle row: *Theodoxus fluviatilis* from the Solutrean Rock-shelter layers; Lower row: *Trivia* sp. from Solutrean layers in the Slope.

D'Errico (2002). Another apparent difference between Vale Boi and the other sites is the distance between the perforation and the shell lip: in the case of the Vale Boi specimens there seems to be a much lower variation than that found in the central Portugal sites.

From an information technology perspective (Stiner et al., 2013), it seems that species diversity changed diachronically: the Solutrean phase is marked by the widest range, followed by the Late Gravettian; Magdalenian whereas Proto-Solutrean show very low species richness. This pattern however does not fit with the number of perforated specimens. Due to the sample size and number of variables, we used Principal Component Analysis to confirm association and differences among phases. The results (Fig. 12) indicate that there was no association observed among different chronological phases of the Vale Boi Upper Paleolithic. There is one except between the Gravettian and the Proto-Solutrean assemblages where there is evidence for proximity and it is *Littorina* that is responsible for the correlation between these two phases (Table 5). Early Gravettian, Solutrean and Magdalenian are clearly independent from each other. This pattern was confirmed by Pearson Correlation (with significant results at .01 – two tailed) where there is a high positive direct correlation between the Gravettian and the Proto-Solutrean, with low or negative correlations among the other Upper Paleolithic phases.

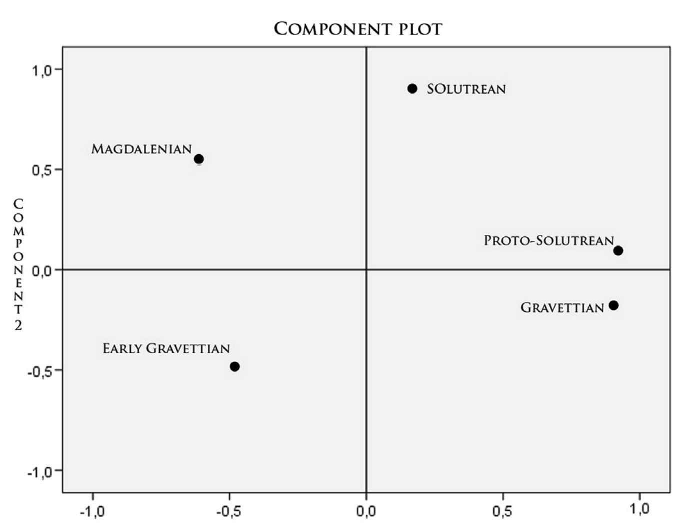

Fig. 12. Principal Component Analysis plot based on data from Table 2.

Table 5
Correlation results using the data from Table 2 (Number of specimens by species and cultural phases).

	Zscore (early Gravettian)	Zscore (Gravettian)	Zscore (Proto-Solutrean)	Zscore (Solutrean)	Zscore (Magdalenian)
Zscore (Early Gravettian)					
Pearson correlation	1	−.247	−.243	−.345	.205
Sig. (2-tailed)		.593	.599	.449	.659
N	7	7	7	7	7
Zscore (Gravettian)					
Pearson correlation	−.247	1	.896	−.031	−.439
Sig. (2-tailed)	.593		.006	.947	.325
N	7	7	7	7	7
Zscore (Proto-Solutrean)					
Pearson correlation	−.243	.896	1	.307	−.395
Sig. (2-tailed)	.599	.006		.503	.380
N	7	7	7	7	7
Zscore (Solutrean)					
Pearson correlation	−.345	−.031	.307	1	.304
Sig. (2-tailed)	.449	.947	.503		.507
N	7	7	7	7	7
Zscore (Magdalenian)					
Pearson correlation	.205	−.439	−.395	.304	1
Sig. (2-tailed)	.659	.325	.380	.507	
N	7	7	7	7	7

Correlation is significant at the .01 level (2-tailed).

5. Conclusions

It is likely that the differences in the frequency and diversity of ornamental items found in Vale Boi reflect a cultural reason, since they do not mimic the availability of the species present in the region, neither have they followed a chronological pattern of straight evolution. The previously thought cultural and chronological importance of color morphs of *Littorina*, both in central Portugal (Vanhaeren and D'Errico, 2002) and in Vale Boi (Bicho et al., 2004) are now doubtful since our *Littorina* modern collection shows a much wider variation than the Vanharen and d'Érrico's study (2002).

Based on both analyses of archaeological and experimental specimens, and although there is a clear oscillation in the differential species importance across time, bead transformation technique remains steady across time, apparently from Early Gravettian some 32 ka ago to Magdalenian times in southern Portugal. This is a different scenario of that found in central Portugal (Vanhaeren and D'Errico, 2002). Thus, in Vale Boi one can argue for the presence of a cultural resilience (Redman and Kinzig, 2003) based on the constant presence of bead perforating techniques. The maintenance of techniques also implies the preservation of a local or regional technological information tradition, suggesting that the human groups that returned to Vale Boi represented a valid social set of technological traditions across time, as suggested elsewhere (Bicho, 2009; Bicho et al., 2004; Marreiros and Bicho, 2013; Cascalheira et al., 2013).

Acknowledgments

We would like to thank to Esmeralda Gomes, Ana Barão, Rui Luís, Inês Espadinha, João Regala and Nuno Rodrigues for helping with the collection of live specimens and shells for the experimental work. Guilherme Castela (Faculty of Economics, Universidade do Algarve) helped with the statistical procedures.

We also thank to 3 anonymous reviewers for their comments that helped to improve the paper.

The work in Vale Boi has been funded by Fundação para a Ciência e Tecnologia, National Geographic Society, Archaeological Institute of America, and Wenner Gren Foundation.

References

Álvarez Fernández, E., 2001. L'axe Rhin-Rhône au paléolithique supérieur récent: l'exemple des mollusques utilisés comme objets de parure. L'Anthropologie 105, 547–564.
Álvarez Fernández, E., Jöris, O., 2008. Personal ornaments in the early Upper Paleolithic of Western Eurasia: and evaluation of the record. Eurasian Prehist. 5 (2), 31–44.
Anikovich, M., Sinitsyn, A., Hoffecker, J., Holliday, V., Popov, V., Lisitsyn, S., Forman, S., Levkovskaya, G., Pospelova, G., KuźMina, I., Burovan, D., Goldberg, P., MacPhail, R., Giaccio, B., Praslov, N., 2007. Early Upper Paleolithic in Eastern Europe and implications for the dispersal of modern humans. Science 315, 223–225.
Bar-Yosef Mayer, D., Vandermeersch, B., Bar-Yosef, O., 2009. Shells and ochre in Middle Paleolithic Qafzeh cave, Israel: indications for modern behaviour. J. Hum. Evol. 56, 307–314.
Benghiat, S., Komso, D., Miracle, P.T., 2009. An experimental analysis of perforated shells from the site of Sebrn Abri, Istria, Croatia. In: McCartan, S., Schulting, R., Warren, G., Woodman, P. (Eds.), Mesolithic Horizons. Oxbow books, Oxford, pp. 730–736.
Bicho, N., 2009. Fashion and glamour: weaponry and beads as territorial markers in Southern Iberia. In: Djindjian, F., Kozlowski, J.K., Bicho, N. (Eds.), Le concept de territoires dans le Paléolithique supérieur européen, Proceedings of the XV Congress of UISPP. BAR, pp. 243–252.
Bicho, N., Stiner, M., Lindly, J., 2004. In: Spiritualité, La, Otte, M. (Eds.), Shell Ornaments, Bone Tools and Long Distance Connections in the Upper Paleolithic of Southern Portugal. ERAUL, Liege, pp. 71–80.
Bicho, N., Cascalheira, J., Marreiros, J., 2012. On the (l)edge: the case of Vale Boi rockshelter (Algarve, Southern Portugal). In: Bergsvik, K., Skeates, R. (Eds.), Caves in Context. The Economical, Social, and Ritual Importance of Caves and Rockshelters. Oxbow Books, pp. 65–81.
Bicho, N., Haws, J., Marreiros, J., 2013a. Desde el Mondego al Guadiana: la ocupación Gravetiense de la fachada atlántica portuguesa. In: Pensando el Gravetiense: Pensando el Gravetiense: nuevos datos para la Región Cantábrica. Museo de Altamira, Santilla del Mar, pp. 55–79.
Bicho, N., Manne, T., Marreiros, J., Cascalheira, J., Pereira, T., Tátá, F., Évora, M., Gonçalves, C., Infantini, L., 2013b. The ecodynamics of the first modern humans in Southwestern Iberia: the case of Vale Boi, Portugal. Quat. Int. (in press).
Bouzouggar, A., Barton, N., Vanhaeren, M., d'Errico, F., Collcutt, S., Higham, T., Hodge, E., Parfitt, S., Rhodes, E., Schwenninger, J.-L., Stringer, C., Turner, E., Ward, S., Moutmir, A., Stambouli, A., 2007. 82,000-year-old shell beads from North Africa and implications for the origins of modern human behaviour. PNAS 104, 9964–9969.
Bradtmöller, M., Pastoors, A., Weninger, B., Weniger, G.-C., 2012. The repeated replacement model: rapid climate change and population dynamics in Late Pleistocene Europe. Quaternary International 247 (9), 38–49.
Bronk Ramsey, C., 1995. Radiocarbon calibration and analysis of stratigraphy. Radiocarbon 37 (1), 425–430.
Cascalheira, J., 2009. Tecnologia Lítica Solutrense do Abrigo de Vale Boi. Unpublished M.A. thesis. Universidade do Algarve, Faro.
Cascalheira, J., Bicho, N., 2013. Hunter–gatherer ecodynamics and the impact of the Heinrich event 2 in Central and Southern Portugal. Quat. Int. (in press).

Cascalheira, J., Bicho, N., Marreiros, J., Pereira, T., Évora, M., Cortés, M., Gibaja, J., Manne, T., Regala, F., Gonçalves, C., Monteiro, P., 2013. Vale Boi and the Solutrean in southwestern Iberia. In: Proceedings of the Congreso Internacional El Solutrense. Centenario de las excavationes en Cueva Ambrosio (in press).

Chauvière, F., 2002. Industries et aprures sur matières dures animales du Paléolitique supérieur de la grotte de Caldeirão (Tomar, Portugal). Rev. Port. Arqueol. 5 (1), 5–28.

Dautzenberg, P., Fisher, H., 1914. Étude sur *Littorina obtusata* et ses variations. J. Conchyol. 62, 87–130.

Dias, J., Boski, T., Rodrigues, A., Magalhães, F., 2000. Coast line evolution in Portugal since the Last Glacial Maximum until present – a synthesis. Mar. Geol. 170, 177–186.

d'Errico, F., Backwell, L., Villa, P., Degano, I., Lucejko, J., Bamford, M., Higham, T., Colombini, M.-P., Beaumont, P., 2012. Early evidence of San material culture represented by organic artifacts from Vorder Cave, South Africa. PNAS 109, 13214–13219.

d'Errico, F., Henshilwood, C., Vanhaeren, M., van Niekerke, K., 2005. Nassarius kraussianus shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age. J. Hum. Evol. 48, 3–24.

d'Errico, F., Vanhaeren, M., Wadley, L., 2008. Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. J. Archaeol Sci. 35, 2675–2685.

d'Errico, F., Vanhaeren, M., Barton, N., Bouzouggar, A., Mienis, H., Richter, D., Hublin, J.-J., McPherron, S., Lozouet, P., 2009. Additional evidence on the use of personal ornaments in the Middle Paleolithic of North Africa. PNAS 106, 16051–16056.

Ferreira, O., Roche, J., 1980. Os elementos de adorno do Paleolítico Superior de Portugal. Arqueologia 2, 7–11.

Fletcher, C., 1995. Microgeographical variation in the shell strength in the flat perinwinkles *Littorina obtusata* and *Littorina mariae*. Hydrobiologia 309 (1–3), 73–87.

Francis, P., 1982. Experiments with early techniques for making whole shells into beads. Curr. Anthropol. 23 (6), 713–714.

Graham, A., 1988. Mollucs: Prosobranch and Pyramidellid Gastropods. The Linnean Society of London. E.J. Bull, Leiden.

Henshilwood, C., Marean, C., 2003. The origin of modern human behaviour: a review and critique of models and test implications, models and test implications. Curr. Anthropol. 44, 627–651.

Henshilwood, C.S., d'Errico, F., Vanhaeren, M., van Niekerk, K., Jacobs, Z., 2004. Middle Stone Age shell beads from South Africa. Science 304, 403.

Higham, T., Jacobi, R., Bronk Ramsey, C., 2006. AMS radiocarbon dating of ancient bone using ultrafiltration. Radiocarbon 48 (2), 179–195.

Klein, R., 1989. Biological and behavioural perspectives on modern human origins in southern Africa. In: Mellars, P., Stringer, C. (Eds.), The Human Revolution. Edinburgh University Press, Edinburgh, pp. 529–546.

Klein, R., 2008. Out of Africa and the evolution of human behavior. Evol. Anthropol. 17, 267–281.

Kuhn, S.L., Stiner, M.C., 2006. Les Parures au Paléolithique. Enjeux congnities, démographiques et identitaires. Diogene 214, 47–58. Numéro Spécial: Naissance de la Pensée Symbolique et du Langage.

Kuhn, S., Stiner, M., 2007. Body ornamentation as information technology: towards and understanding of the significance of early beads. In: Mellars, P., Boyle, K., Bar-Yosef, O., Stringer, C. (Eds.), Rethinking the Human Revolution: New Behavioural and Biological Perspectives on the Origin and Dispersal of Modern Humans. McDonald Institute Monographs, Cambridge University, Cambridge, pp. 45–54.

Langley, M., Street, M., 2013. Long range inlandecoastal networks during the Late Magdalenian: evidence for individual acquisition of marine resources at Andernach-Martinsberg, German, Central Rhineland. J. Hum. Evol. 64, 457–465.

Macedo, M.C., Macedo, M.I., Borges, J., 1999. Conchas Marinhas de Portugal. Verbo, Lisboa.

Manne, T., Bicho, N., 2011. Prying new meaning from limpet harvesting at Vale Boi during the Upper Paleolithic. In: Bicho, N., Haws, J., Davis, L. (Eds.), Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement. Springer, New York, pp. 273–290.

Manne, T., Bicho, N.F., Marreiros, J., Cascalheira, J., Évora, M., 2012. Intensive subsistence practices at Vale Boi, an Upper Paleolithic site in southwestern Portugal. Quat. Int. 264, 83–99.

Marean, C., 2011. Coastal South Africa and the co-evolution of the modern human lineage and coastal adaptations. In: Bicho, Nuno, Haws, Jonathan, A., Davis, Loren, G. (Eds.), Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement. Springer, New York, pp. 421–440.

Marreiros, J., Bicho, N., 2013. Lithic technology variability and human ecodynamics during the Early Gravettian of Southern Iberian Peninsula. Quat. Int. (in press).

McBrearty, S., Brooks, A., 2000. The revolution that wasn't: a new interpretation of the origin of modern human behaviour. J. Hum. Evol. 39, 453–563.

McPherron, S., Dibble, H., 2002. Using Computers in Archaeology. A Practical Guide. McGraw-Hill Mayfield, Boston.

Nobre, A., 1941. Fauna Malacológica de Portugal II – Moluscos terrestres e fluviais. Memórias e Estudos do Museu Zoológico da Universidade de Coimbra.

Pelseneer, P., 1932. La métamorphose préadulte des Cypraeidae. Bull Biol. Fr Belg. LXVI (2), 149–163.

Redman, C., Kinzig, A., 2003. Resilience of past landscapes: resilience theory, society, and the longue durée. Conserv. Ecol. 7 (1), 14.

Reid, D., 1996. Systematics and Evolution of Littorina. Ray Society, London.

Reimchen, T., 1982. Shell size divergence in *Littorina mariae* and *L. obtusata* and predation by crabs. Can. J. Zool. 60, 687–694.

Reimer, P., Baillie, M., Bard, E., Bayliss, A., Beck, J., Blackwell, P., Bronk Ramsey, C., Buck, C., Burr, G., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kaiser, K., Kromer, B., McCormac, F., Manning, S., Reimer, R., Richards, D., Southon, J., Talamo, S., Turney, C., van der Plicht, J., Weyhenmeyer, C., 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. Radiocarbon 51 (4), 1111–11150.

Steele, T., Alvaréz Fernández, E., 2012. Restes de molluesques marins (Chapitre XXX). In: El Hajraoui, M.A., Nespoulet, R., Debénath, A., Dibble, H. (Eds.), Préhistoire de la Région de Rabat-Témara, vol. III. INSAP, Rabat, pp. 223–227. VESAM.

Stiner, M., Kuhn, S., Güleç, E., 2013. Early Upper Paleolithic shell beads at Üçagızlı cave I (Turkey): technology and the socioeconomic context of ornament life-histories. J. Hum. Evol. 64, 380–398.

Taborin, Y., 1993. La parure en coquillage au paléolithique. CNRS Editions, Paris.

Tátá, F., 2011. Os adornos do Paleolítico Superior de Vale Boi (Vila do Bispo – Algarve). Unpublished M.A. thesis. Universidade do Algarve, Faro.

Vanhaeren, M., d'Errico, F., 2001. La parure de l"enfant de La Madeleine (foilles Peyrony). Un nouveau regard sur l"enfance au Paléolithique supérieur. Paléo 13, 201–237. Les Eyzies.

Vanhaeren, M., D'Errico, F., 2002. The body ornaments associated with the burial. In: Zilhão, J., Trinkaus, E. (Eds.), Portrait of the Artist as a Child. The Gravettian Human Skeleton from the Abrigo do Lagar Velho and its Archaeological Context. IPA, Lisboa, pp. 154–186.

Vanhaeren, M., d'Errico, F., Stringer, C., James, S.L., Todd, J., Mienis, H.K., 2006. Middle Palaeolithic shell beads in Israel and Algeria. Science 312, 1785–1788.

Vanhaeren, M., d'Errico, F., van Niekerk, K., Henshilwood, C., Erasmus, R., 2013. Thinking strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. J. Hum. Evol. (in press).

Whallon, R., 2006. Social networks and information: non-"utilitarian" mobility among hunter-gatherers. J. Anth Arch. 25 (2), 259–270.

Wiessner, P., 1997. Seeking guidelines through an evolutionary approach: style revisisted among the !Kung San (Ju/'hoansi) of the 1990's. In: Barton, C., Clark, G. (Eds.), Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation. American Anthropological Association, Washington, pp. 157–176.

Zilhão, J., 1997. O Paleolítico Superior da Estremadura portuguesa, 2 vols. Colibri, Lisbon.

Zilhão, J., Angelucci, D., Badal-García, E., d'Errico, F., Daniel, F., Dayet, L., Douka, K., Higham, T., Martínez-Sánchez, M., Montes-Bernárdez, R., Murcia-Mascarós, S., Pérez-Sirvent, C., Roldán-García, C., Vanhaeren, M., Villaverde, V., Wood, R., Zapata, J., 2010. Symbolic use of marine shells and mineral pigments by Iberian Neandertals. PNAS 107, 1023–1028.