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The management of symbolic raw materials in the Late Upper Paleolithic of South-Western France: a shell ornaments perspective

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Abstract

Personal ornaments manufactured on marine and fossil shell are a significant element of Upper Palaeolithic symbolic material culture, and are often found at considerable distances from Pleistocene coastlines or relevant fossil deposits. Here, we report on a significant collection of shell objects (n=377) from the Upper Magdalenian site of Rochereil (Dordogne, France). Despite the location of the site at more than 200km from the Pleistocene coast, the majority of the shells recovered here are unmodified, suggesting that transport and accumulation of shell raw material was an important component in the production of symbolic technologies some 16 15,000 years ago. A detailed comparative and microscopic reanalysis of this assemblage explores which species were selected, examines technological and taphonomic modification of the material, and compares this collection with the use of similar shell ornaments in the wider Magdalenian world.

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Introduction

The land-use strategies and social networks of Paleolithic societies are often investigated through proxies such as lithic raw material transport, alongside the evaluation of stone toolkit maintenance and reduction rates at landscape scales (Kelly, 1995; Cowan, 1999; Jones et al., 2003; Andrefsky, 2009). Spatial variation in hunting and gathering strategies has also been investigated to explore the mobility and territories of past societies (Binford, 1980; Delagnes & Rendu, 2011; O'Shea et al., 2013). Complicating the issue, however, is the ethnographic observation that historic forager range sizes and interaction spheres often extend significantly beyond what is required for subsistence (Kroeber, 1922; Spencer & Gillen, 1927; Thomson, 1949; Goldschmidt, 1951; Sharp, 1952). In the archaeological record, personal ornaments are commonly used to explore these extensive networks of exchange and circulation, which appear to greatly exceed in scale the subsistence or economic requirements of forager societies (Taborin, 1993; Álvarez-Fernández, 2001; Eriksen, 2002; Whallon, 2006; Fullola et al., 2007; Rigaud, 2014; Rigaud & Gutiérrez-Zugasti, 2016). In addition to the identification of allochthonous raw material, information about where exactly past foragers procured, used, and discarded their personal ornaments allows us to explore different aspects of these complex systems of territorial organization, and the associated social behaviors (Rigaud et al., 2014).

The discovery of hundreds of marine shells ($n=377$) at the site of Rochereil, in Dordogne region of south-west France (Jude, 1960), presents an ideal opportunity for investigating this phenomenon. This shell accumulation, discovered in deposits attributed to the Upper Magdalenian, provides new data on raw material procurement and management strategies developed by Late Upper Palaeolithic hunter-gatherers. The presence of a very small number of modified shell beads, alongside several hundred unmodified shells which feature no evidence for use as elements of ornamentation, is unlike any known archaeological shell accumulation.

Here, we investigate the social and economic behavior responsible for such an accumulation, and suggest models for the economic, technological, and social organization of Upper Paleolithic societies in south-west France.

Archaeological context and objectives

The cave of Rochereil (Grand-Brassac, Dordogne) is part of a karstic system in the Coniacian limestone cliffs along the right bank of the Dronne River (Figure 1). The cave consists of one main gallery (12m long, 2-3m wide and 5.5m high) which forms a semicircular chamber. The cave is oriented to the south-east, and opens onto a 3.5m² terrace (Jude, 1960).

The site was discovered in 1906 (Ricard, 1906), and quarried in 1912 and 1921 to access the sediments inside the cave (Delluc & Delluc, 2005; Man-Estier & Paillet, 2013; Paillet & Man-Estier, 2014). From 1937-1947, the site was then excavated by P.-E. Jude and J. Cruveiller, who provide the first and only spatial records of material at the site (Jude & Cruveiller, 1938; Jude, 1960), as a number of subsequent clandestine excavations unfortunately erased any remaining archaeological deposits in the cave. Precise findspot information is unavailable, and records only attribute material to archaeological stratum (Jude 1960). While the sediment was not screened, the excavation seems to have been meticulous and comprehensive, as recent water-screening of the backdirt with a 4mm mesh has not resulted in the recovery of additional shell remains (P. Paillet, unpublished).

Jude and Cruveiller identified 4 discrete sedimentary layers during their decade-long sequence of excavations. Directly above bedrock, a 0.8m thick sterile layer (Layer I) was identified. Layer II, approximately 0.4m thick, overlies this sterile layer, and was subdivided into units IIa and IIb. The material recovered in this layer is attributed to the Upper Magdalenian, and is the subject of this paper. Layer III (1.8m thick) revealed several rich assemblages attributed to the Early Azilian, Final Azilian, and Laborian complexes. Due to the thickness of the layer, Jude subdivided Layer III into three subunits (IIIa, IIIb, IIIc), but reanalysis of the material indicates significant mixing of material between the sub-units (Langlais et al., 2014). Finally, Layer IV comprised a 2m thick layer of humic sediment devoid of archaeological material.

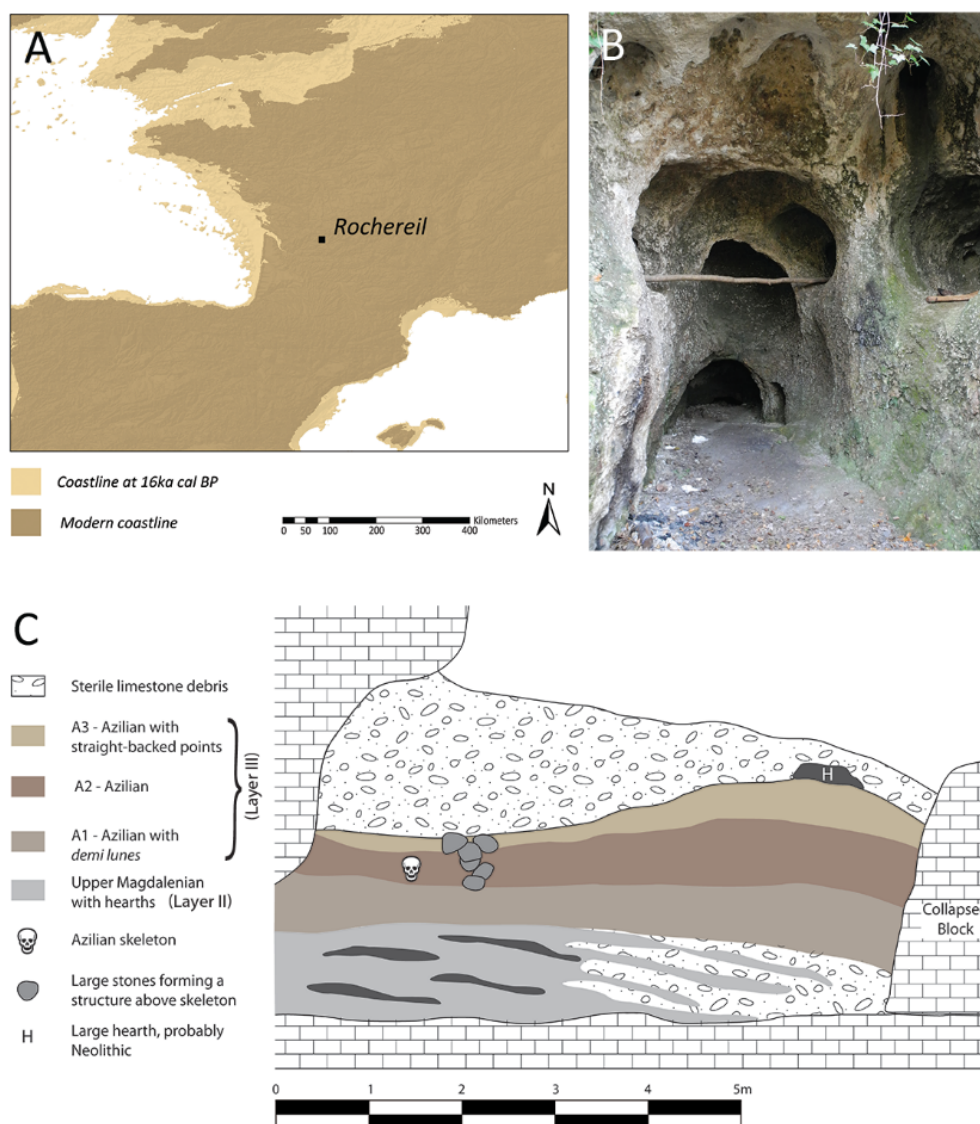


Figure 1: Location of the site of Rochereil (A); photograph of the cave entrance of Rochereil (B); stratigraphy of Rochereil redraw from Jude and Cruveiller 1938 (C).

This study focuses on recently reevaluated material recovered from Layer II (Man-Estier & Paillet, 2013; Paillet, 2014; Langlais et al., 2016). Archaeological material including stone and bone tools, faunal remains, and portable art is abundant in this layer. A number of personal ornaments comprising perforated fossil and marine shells, modified mammal teeth (2 bovid incisors and 4 reindeer incisors), and one short, conical pendant made from reindeer antler, have been identified (Jude, 1960; Taborin, 1992). In addition, several hundred marine shells, apparently unmodified, were also recovered from this layer. These shells have not been previously studied, with just a list of material published without evaluation of function (Taborin 1992). A number of reasons could explain the presence of unperforated shells within archaeological collections (Dupont, 2019), which we will explore below.

Our analysis will characterize the taxonomic diversity of the shell assemblage, examine shell modification and preservation, and identify the source of the material. We explore potential shell selection and collection strategies, contextualize the assemblage within wider Magdalenian shell selection patterns, and consider the motives of the Magdalenian groups in accumulating this assemblage.

Methods

Taxonomic identification

Taxonomic identification of the shells involved two steps: the characterization of general shape for class determination (e.g. Scaphopoda, Gasteropoda, Bivalvia), followed by examination of the shape and ornamentation of scaphopods and bivalves (Poppe & Goto, 1993), along with examination of the number of whorls, the form of the aperture, lip, ventral and dorsal sides, and ornamentation of gastropods to determine genus or species (Harasewych and Moretzsohn, 2010; Poppe and Goto, 1993). The nomenclature employed here adopts classifications available in Molluscabase (<https://www.molluscabase.org/>), the Paleobiology database (paleobiodb.org), and the "Biodiversity Heritage Library" for fossil species (<https://www.biodiversitylibrary.org/>). A review of the configuration and distribution of regional biotopes particular to each shell species and fossil outcrops of appropriate age revealed probable procurement location(s).

Morphological and morphometric analyses

Variation between natural populations and archaeological samples indicate the extent to which human choices were responsible for the accumulation. To pursue this question, morphometric variables (shell length and width, width of the spire and aperture) were recorded on the archaeological material, where post-depositional breakage permitted. Morphometric analysis was performed using the most frequently measured attributes for each species, and occasionally differed from species to species.

To explore size selection strategies, modern and fossil reference collections of scaphopods and two modern reference collections of gastropods, were compiled (Table 1). The shells were hand-collected from thanatocenoses (death assemblages) along the Atlantic coast. All shells visible to the naked eye were collected on the shore. The reference collections consist of 339 *Antalis vulgaris* collected in the Arcachon Basin (Vanhaeren & d'Errico, 2001; Vanhaeren, 2002), 244 fossil scaphopods, referred to *Dentalium* sp. from the Miocene outcrop of Saucats Geological reserve (Vanhaeren & d'Errico, 2001; Vanhaeren, 2002), and 70 *Tritia reticulata* and 101 *Ocenebra erinaceus* collected at Châtelailon and Moëze. Marine reference collections were made by 2 collectors, collected over 45 minutes on two beaches targeted for their relative proximity to Rochereil.

Table 1: Modern and fossil reference collections used for the analysis of the shells of Rochereil.

Species	Attribution	Location	Number	Reference
<i>Antalis vulgaris</i>	Modern	Arcachon	339	Vanhaeren 2002
<i>Dentalium</i> sp.	Miocene	Saucats	244	Vanhaeren 2002
<i>Tritia reticulata</i>	Modern	Boucholeur, Châtelailon	54	.
<i>Tritia reticulata</i>	Modern	Plage de plaisance, Moëze	16	.
<i>Ocenebra erinaceus</i>	Modern	Boucholeur, Châtelailon	67	.
<i>Ocenebra erinaceus</i>	Modern	Plage de plaisance, Moëze	34	.

Microscopic analysis

Shell surfaces exhibit microscopic modifications attesting to processes occurring either during the life of the mollusk or post-mortem. In cases of shells collected and/or modified by prehistoric groups, microscopic analyses provide information relevant to the environment in which shells were collected, as well as subsequent taphonomic and anthropogenic modifications (d'Errico et al., 2005; Dupont, 2006; Taborin, 1998; Vanhaeren et al., 2013). A Motic SMZ-168 microscope equipped with a Jenoptik ProgRes-CT3 digital camera was used to document surface modifications on each shell. Artefacts were examined at magnifications between 4x and 40x. The presence, location, and degree of natural modifications impeding microscopic analysis (calcite deposits, cracks) were recorded for each specimen, alongside the degree of preservation of the shell's original shape and ornamentation. Natural and anthropogenic modifications such as fractures, use-wear, modifications produced by suspension (e.g. perforations, residues, incisions)

were also systematically recorded on each part of the shells (apex, spire whorls, aperture, lip, umbo, ventral margin, dorsal and ventral sides).

Taphonomical and anthropic modifications were identified based on experimental and reference data available in the literature (d'Errico et al., 1993; Lescinsky et al., 2002; Dietl & Kelley, 2006; Rogalla et al., 2007; Benghiat et al., 2009; Avezuela Aristu et al., 2011; Peschaux, 2012; Gorzelak et al., 2013; Tátá et al., 2014; Rojas & Dietl, 2015; Kubicka et al., 2017; O'Hara, 2017).

Regional comparison

The Rochereil assemblage was referred to a database of Magdalenian ornaments from across Franco-Cantabria compiled from a combination of excavations reports, published literature (Taborin, 1993; Álvarez Fernández, 2006), and first-hand analyses of other collections (O'Hara, 2017). This georeferenced database records the presence of 87 different bead-types in over 200 discrete ornament-bearing layers from 85 sites across Franco-Cantabria. Where possible, archaeological layers were attributed to the Lower, Middle, Upper, or Final Magdalenian. Mapping of ornament distribution was performed using ESRI ArcGIS 10.4.1 and the ETOPO1 Global relief model (Amante & Eakins, 2009), with Late Pleistocene coastlines positioned at 90m below modern sea level (Lambeck et al., 2014; Lambeck and Chappel, 2001).

Results

Shell identification

377 shells belonging to at least 9 different species, including gastropods, bivalves and scaphopods, were identified in the material attributed to Layer II (Table 2, Figure 2, Figure 3). Eight Muricidae belonging to the species *Ocenebra erinaceus* were identified (Figure 2, n°3). These gastropod shells bear five to eight whorls, an oval aperture, and a well-developed siphonal canal equal to aperture length. Sutures are deep and sinuous. The species is attested along both Atlantic and Mediterranean shores in the Pleistocene.

217 Nassariidae are attributed to the species *Tritia reticulata* (formerly termed *Nassarius reticulatus*, *Nassa reticulata* or *Hinia reticulata*) (Figure 2, n°1). This gastropod shell is conical, featuring of axial ribs containing 7 to 9 whorls, and is also present along Atlantic and the Mediterranean coasts (Poppe and Goto, 1991).

Three other Nassariidae belong to the species *Tritia gibbosula* (previously *Arcularia gibbosula* or *Nassarius gibbosulus*). The shell of this taxon features five or six whorls with a large body whorl, flattened and widened at the sides. This species is currently extant solely along southern Mediterranean shores, but there are historic accounts of its presence on Southern French coasts (Granger, 1880). Paleontological data suggest that *Tritia gibbosula* is limited to warm waters, and so was not present along French coasts, either Atlantic or Mediterranean, during the Pleistocene (Moshkovitz, 1968). A fossil origin for these shells (Figure 2, n°4), presumably from Mediterranean Pliocene deposits, seems most likely (Taborin 1992), but its sporadic presence along the French Mediterranean coast during the Pleistocene cannot be excluded.

The scaphopods (n=217) generally present a smooth surface at the anterior end and weak longitudinal striations at the posterior end (Figure 2, n°2). Several scaphopod species with similar shape and surfaces were present along both the Mediterranean and Atlantic shores during the Pleistocene and can also be found in Miocene fossil deposits from the south-west of France (Cossmann and Peyrot, 1915 ; Poppe and Goto, 1993). Formerly in the generic genus *Dentalium*, most recent species from European shores are now attributed to the genus *Antalis*. The Rochereil specimens are most likely *Antalis vulgaris*, but may be also a mix of several species that we group under the generic name *Dentalium* sp.

One of the two valves of Glycymerididae presents an oval form but with a surface rounded and smoothed by post-depositional processes (Figure 3, n°11). The absence of anatomical features impedes identification of species. The other small valve presents a regular morphology, round in outline, convex, and slightly longer than it is wide (Figure 3, n°3), probably corresponding to *Glycymeris glycymeris* which is present along modern Atlantic and Mediterranean shores (Poppe and Goto, 1993).

Among the four valves belonging to the Cardiidae family, two valves are clearly fossil specimens (Figure 3, n°7, 8) and present anatomical features suggesting they do not belong to the same species. Fossil Cardiidae are present in the Miocene deposits of south-west France (Michel et al., 2012), but shells at Rochereil present a yellowish surface patina which differs markedly from the Miocene fossils (Cahuzac & Chaix, 1996; Parize et al., 2008), and also from other specimens in the archaeological collection, which are

characterized by a whiter coloration (Figure 3). The yellowish color echoes the natural coloration of the surrounding Coniacian limestone of the cave. Limestone weathering is a well-known phenomenon in Perigordian karstic contexts, with erosion of the surrounding rock a significant contributing agent to sediment formation in caves and rockshelters (Texier, 2006). With this in mind, close examination suggests a local origin from within the eroding limestone for these two shells. The two remaining Cardiidae specimens are convex, feature radial ribs, a crenulated edge, and the adductor scar and lateral tooth are still visible (Figure 3, n°9, 10). The morphology of these shells probably corresponds to the modern species *Cerastoderma edule*, present along both Atlantic and Mediterranean coasts (Poppe and Goto, 1993).

Table 2: Shell species identified in the Upper Magdalenian layer II of Rochereil.

Jude 1960	Taborin 1992	This study		
Species	Species	Species	N	Figure
•	<i>Arcularia gibbosula</i>	<i>Tritia gibbosula</i>	3	Fig.2 n°4
<i>Cardium edule</i>	<i>Cerastoderma edule</i>	<i>Cerastoderma edule</i> .	2	Fig.3 n°9, 10
•	•	Fossil Cardiidae	2	Fig.3 n°7, 8
•	<i>Dentalium</i> sp.	<i>Dentalium</i> sp.	138	Fig.3 n°2
<i>Pectunculus glycymeris</i>	<i>Glycymeris</i> sp.	<i>Glycymeris</i> sp.	2	Fig.2 n°3, 11
<i>Nassa reticulata</i>	<i>Hinia reticulata</i>	<i>Tritia reticulata</i>	217	Fig.2 n°1
•	<i>Mitra dufresnei</i>	•	•	
•	<i>Semicassis saburon</i>	•	•	
•	<i>Tritonalia erinacea</i>	<i>Ocenebra erinaceus</i>	8	Fig.2 n°3
•	<i>Turritella</i> sp.	•	•	
<i>Pecten maximus</i>	•	<i>Pecten maximus</i>	1	Fig.3 n°6
<i>Mytilus edulis</i>	•	<i>Mytilus</i> sp.	1	Fig.3 n°1
<i>Mytilus galloprovincialis</i>	•	<i>Mytilus</i> sp.	1	Fig.3 n°2
•	•	<i>Spondylus</i> sp.	1	Fig.3 n°4
•	•	<i>Bivalve indet.</i>	1	Fig.3 n°5

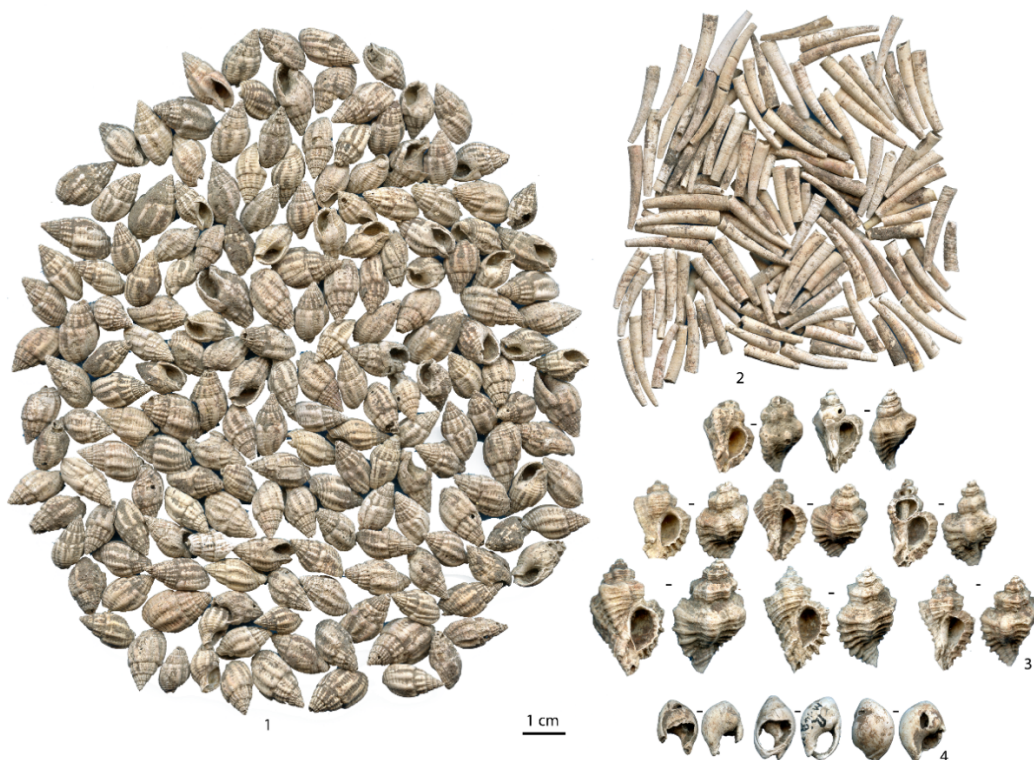


Figure 2: Gastropods and scaphopods recovered in the Upper Magdalenian from Rochereil. 1) *Tritia reticulata*, 2) *Dentalium* sp., 3) *Ocenebra erinaceus*, 4) *Tritia gibbosula*.

A large fragment of a bivalve presents significant exfoliation on the external surface. Fine radiating ridges, larger ribs, and intervening grooves are still visible on the limited preserved areas, suggesting the shell belongs to the taxon *Pecten maximus* (Figure 3, n°6). This species is exclusively present along Atlantic shores. A fragment of a fossil valve from a large species within the genus *Spondylus*, with fine radial ribs, squamate at the marginal side, is also present in the collection (Figure 3, n°4). The yellowish patina suggests an autochthonous origin similar to the two fossil *Cardiidae*. Two fragments of *Mytilus* sp. cannot be taxonomically attributed to species (Figure 3, n°1, 2). One further fragment of unidentified bivalve is also present (Figure 3, n°5), but comparison with previously published inventories show that 3 shell species are missing from the current collection (Table 2, Jude, 1960; Taborin, 1992). The long history of curation of the collection may explain discrepancies between previously published material and the material currently present in the collection. In summary, *Dentalium* sp. (n=138) and *Tritia reticulata* (n=217) are the most abundant taxa in the material, followed by *Ocenebra erinaceus* (n=8), *Cardiidae* indet. (n=4), *Tritia gibbosula* (n=3), *Glycymeris* sp. (n=2), *Mytilus* sp. (n=2), a single specimen of *Pecten maximus* and *Spondylus* sp. and one unidentified fragment of bivalve.



Figure 3: Bivalves recovered in the Upper Magdalenian from Rochereil. 1, 2) *Mytilus* sp., 3, 11) *Glycymeris* sp., 4) *Spondylus* sp., 5) indet., 6) *Pecten maximus*, 7-8) *Cardiidae* indet., 9-10) *Cerastoderma edule*.

Morphometric, technological and use-wear analyses

The fragments of the bivalves *Mytilus* sp., *Pecten maximus*, *Spondylus* sp. and the two fossil Cardiidae show no anthropogenic modification.

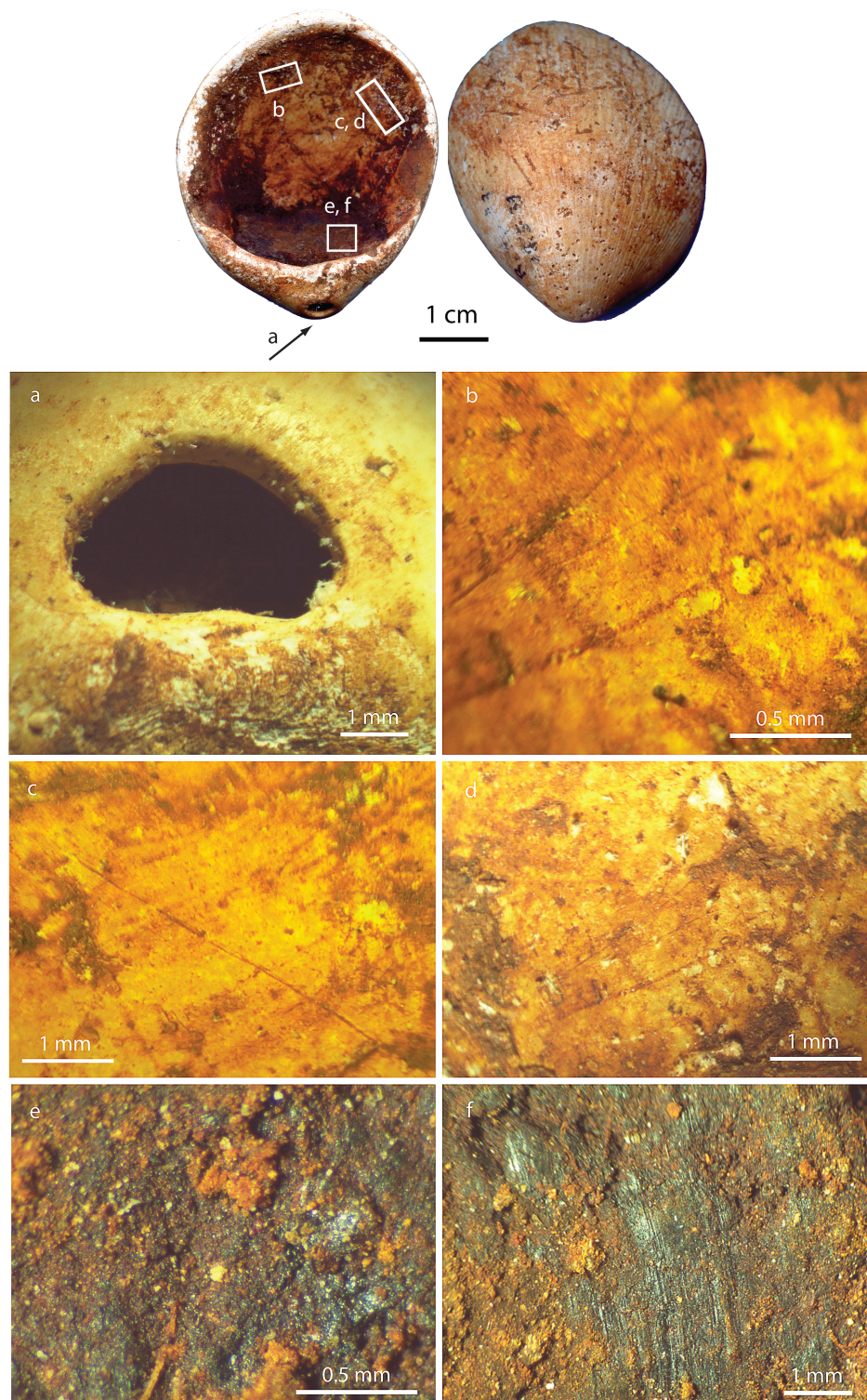


Figure 4: Natural perforation present on the umbo of a *Glycymeris* shell (a), striations on the ventral margin of the shells (b-d), close view of the red compound (e), and parallel striations present on the surface of the residue (f).

The two *Glycymeris* sp. shells feature a perforation at the umbo. The location and smoothed edges of the perforation correspond to natural modifications resulting from surf action (Rogalla et al., 2007; Cabral & Martins, 2016). Use-wear analysis reveals no evidence for the use of these natural perforations in suspension. The larger *Glycymeris* sp. is covered in a red residue, with a relatively plastic, centimeter-thick red compound firmly adhering to the interior of the shell, concentrated at the umbo (Figure 3). The residue comprises a heterogeneous texture composed of a combination of coarse, rounded, red and black grains, cemented in a dark red powder matrix. Microscopic analysis reveals that the ventral side of the shell bears multiple short, thin striations (Figure 4b-d). These striations run sub-parallel to the ventral margin of the shell, indicating they were produced by the repeated application of a sharp lithic point in circular gestures. The surface of the red residue also shows multiple thin parallel striations, indicating that the surface was scraped (Figure 4e,f).

A single *Cerastoderma edule* also shows anthropic modifications. A groove, located on the dorsal side near the umbo, was created through multiple parallel striations organized transversely to the maximum length of the shell. The thin “V” shaped profile of the striations and the regular edges indicate they were produced with a sharp point (Figure 5a, b). Just above the groove, a small, irregular perforation with obliquely rounded edges attests of the predation of this valve by a naticid or worm (Cabral et al. 2015, Rojas and Dietl, 2015).

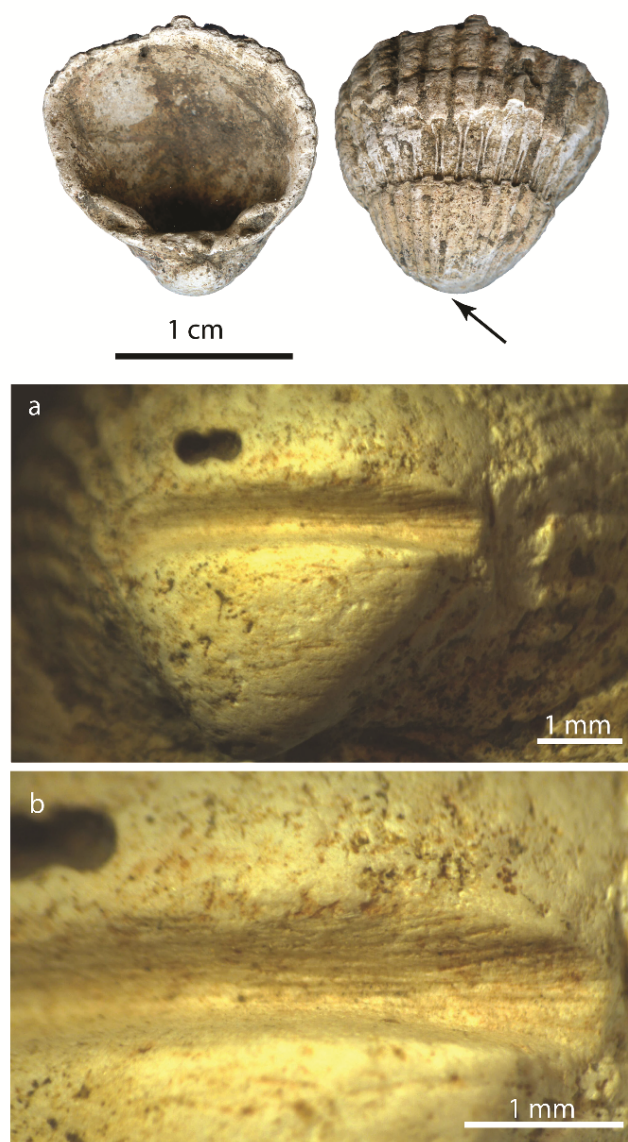


Figure 5: Transversal groove made with a lithic tool observed on the umbo of the *Cerastoderma edule* from Rochereil (a, b). The perforation has a natural origin.

Two of the three *Tritia gibbosula* show breakage on the dorsal side, close to the aperture (Figure 2). The surface alterations present on the shell, visible in the intense exfoliation of the surface, preclude identification of its origin. Another shell presents a perforation on the ventral side (Figure 2, Figure 6), with the maximum length of the oval perforation (4.16 mm) oriented along the longitudinal axis of the shell. Microscopic analysis identifies multiple short striations, positioned around the perforation, but transverse to its edge (Figure 6a-c). None of these incisions present any side-striations along their inner surface. Reference data indicate that similar striations can be produced by applying a pointed tool in a single movement along the surface of the shell (Joordens et al., 2014). The perforation itself truncates the transverse striations, indicating that the surface was grooved before being perforated. The perforation is oval and its maximum diameter oriented toward the extremities of the striations. The edge of the perforation is irregular and presents micro-removals all around. Experimental reproduction of anthropic perforations indicate that direct pressure and indirect percussion produce similar fractures (d’Errico et al., 1993; Tátá et al., 2014). The presence of two different categories of modification indicates that the perforation was created by grooving the ventral side of the shell using a sharp pointed tool, followed by percussion or pressure. Similar perforation techniques have been documented in other contexts (Peschaux, 2012). A set of short, thin parallel striations is also visible on the left side of the aperture, when facing the ventral side of the shell, apex upward. The striations are oriented perpendicular to the longitudinal axis of the shell. This modification is associated with the intense smoothing and polishing of the surface of the shell (Figure 6d, e). Use-wear present on the ventral side indicates the shell was attached with the ventral side in contact with a slightly abrasive surface.

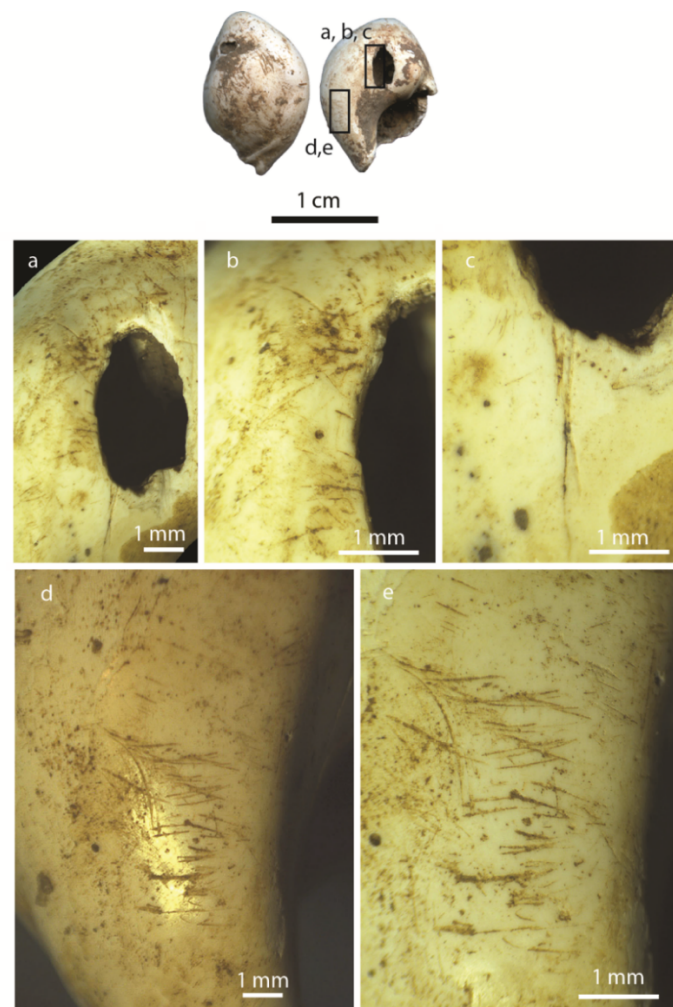


Figure 6: Short striations present around the perforation of the *Tritia gibbosula* (a-c) and use-wear on the ventral side close to the aperture (d, e).

One specimen of *Ocenebra erinaceus* presents a small (3.2 mm) perforation located on the ventral side of the fourth whorl (Figure 2). The location, conical shape, and smooth edges of the perforation suggests natural perforation due to predation (Dietl & Kelley, 2006; Gorzelak et al., 2013; Rojas & Dietl, 2015). Another specimen presents a large perforation on the ventral side of each of the three first whorls (Figure 2). Such alteration is frequently documented on gastropods modified by surf action (Gorzelak et al., 2013). No other modification is observed on the shells.

Morphometric analysis of these shells reveals that the specimens from Rochereil differ significantly from the modern reference collections (Mann-Whitney U test $p < 0.01$). The smallest specimens present in modern collections fall outside the range of variability of the shells from Rochereil, and four of the shells from Rochereil are larger than the largest shells from the reference collections (Figure 7).

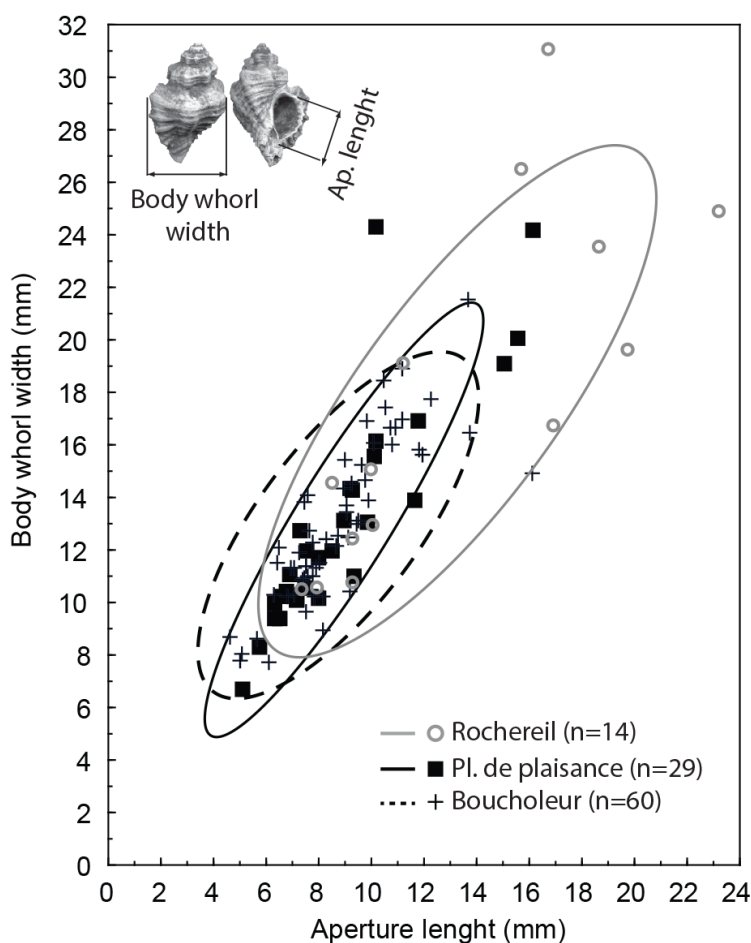


Figure 7: Scatterplot plot the aperture length and body whorl width registered on the modern reference collections of *Ocenebra erinacea* and the specimens from Rochereil attributed to the Upper Magdalenian.

Of the 217 *Tritia reticulata* shells, 24 are perforated (Figure 8A). Perforations are mainly observed on the dorsal side of the last whorl, but several small perforations are also observed on the ventral side, and sometimes close to the apex on either the ventral or dorsal side. Post-depositional alterations and recent exfoliation present on many of the perforations precludes identifying their origin, and so taphonomic processes cannot be completely excluded (Gorzelak et al., 2013), but two specimens bear clear anthropic modifications in the form of sub-parallel longitudinal striations located at either extremity of the oval perforation (Figure 8A, t, w, Figure 8B, d-h).

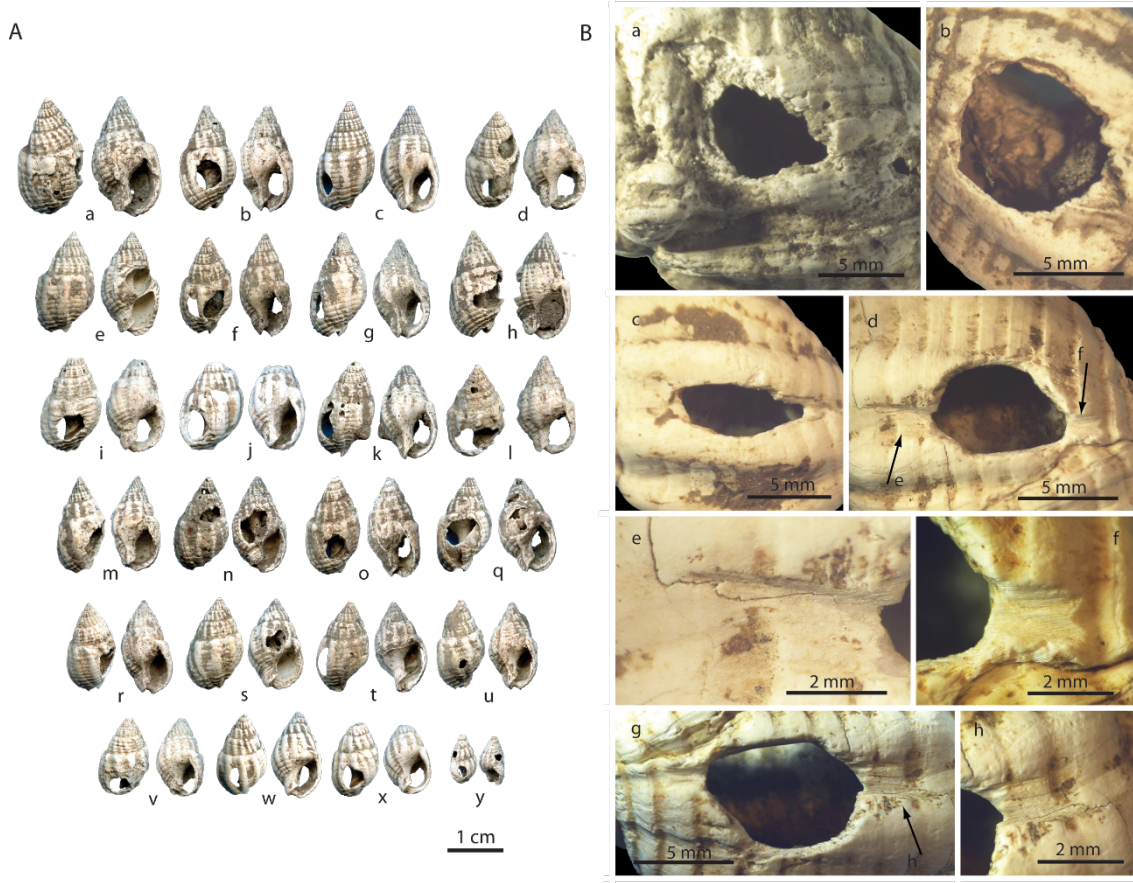


Figure 8: A) perforated *Tritia reticulata*, B) macrophotos of the perforations: probable anthropogenic dorsal perforations on the last spire whorl (a, b), dorsal anthropogenic perforations with longitudinal striations made by scraping the last spire whorl (c-h).

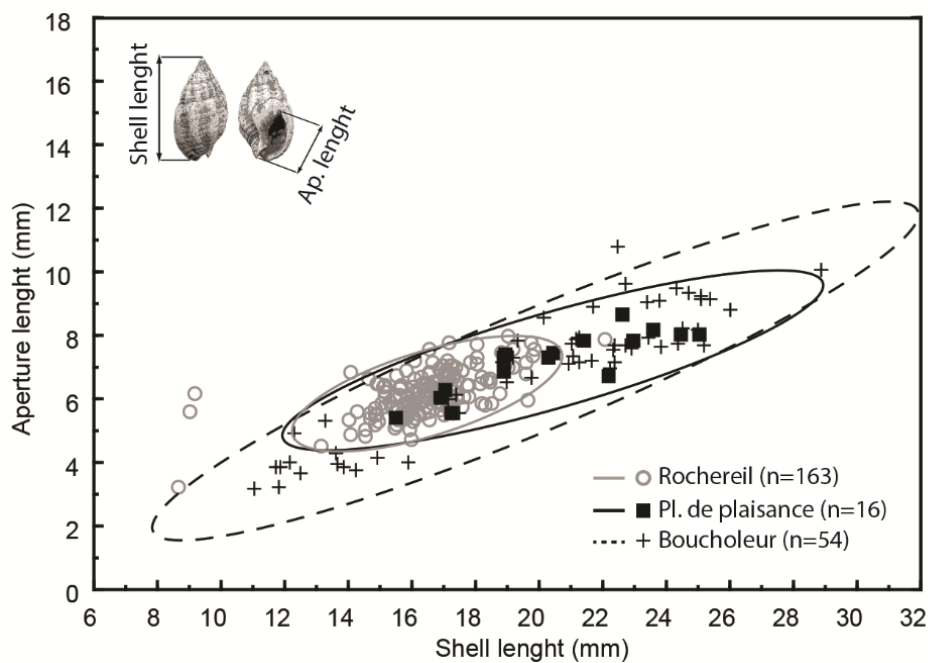


Figure 9: Scatterplot of the length and aperture length registered on the *Tritia reticulata* from the modern reference collections and the specimens from Rochereil attributed to the Upper Magdalenian.

These perforations are located on the dorsal side of the last whorl, very close to the aperture; other perforations located in the same place with a similar shape may have been crafted using the same technique, but post depositional alteration of the surface of the objects has erased any technical traces of the perforation process (Figure 8A, c, f, g, Figure 8B, c). As with the *O. erinaceus*, the measurements recorded on the *T. reticulata* shells from Rochereil differ significantly from those of the modern reference collections (Mann-Whitney U test $p < 0.01$). The archaeological shells fall mainly within the range of variability of the modern reference collections (Figure 9), but the largest shells in the reference collections do not correspond to the Rochereil material. The size of the two specimens perforated by scraping, however, falls within the range of variability of the unmodified shells from Rochereil.

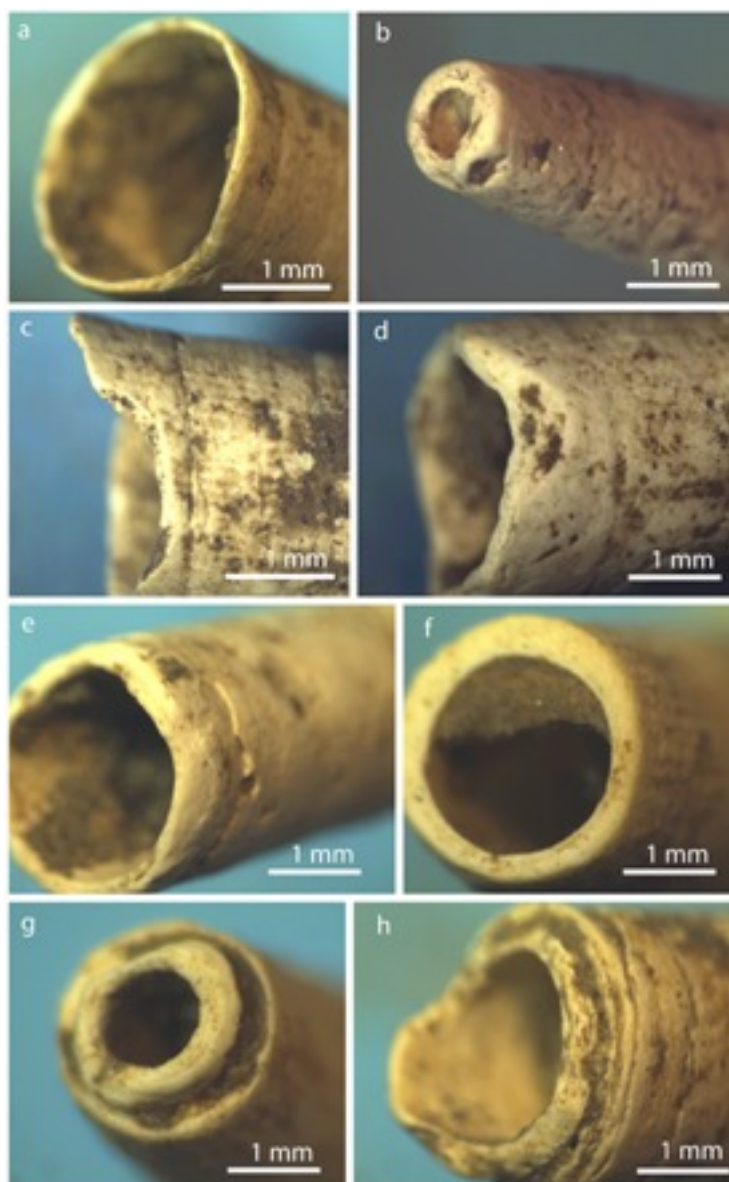
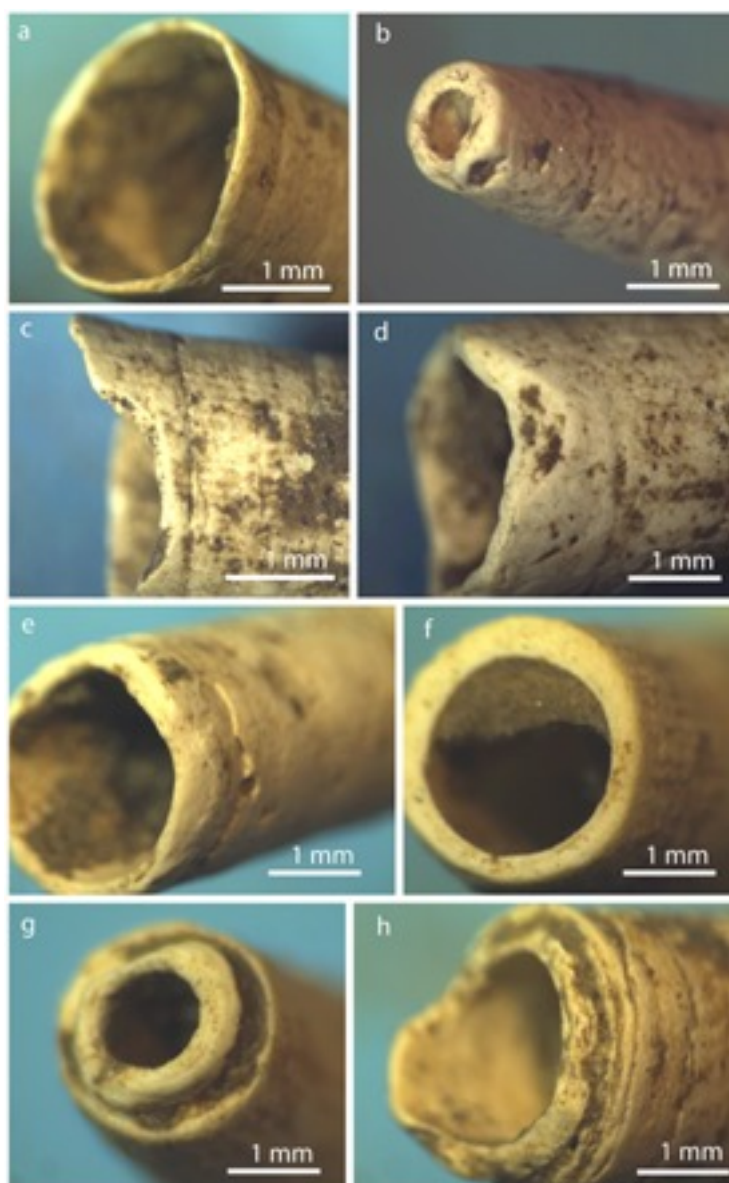


Figure 10: Morphology of the extremities of the *Dentalium* from Rochereil: a) anterior intact extremity, b) posterior intact extremity, c) Lip fracture, d) irregular fracture, e) rounded end, f) straight fracture, g) posterior step fracture, h) anterior step fracture (according the classification established by Vanhaeren and d'Errico 2001).

Microscopic analysis of the 138 *Dentalium* sp. showed that 59% of the scaphopods featured an intact anterior extremity, and 29% an intact posterior extremity. Extremities that are not intact present various morphologies, including lip fractures, rounded ends, irregular fractures, straight fractures and step fractures (following the classification of Vanhaeren and d'Errico 2001, These perforations are located on the dorsal side of the last whorl, very close to the aperture; other perforations located in the same place with a similar shape may have been crafted using the same technique, but post depositional alteration of the surface of the objects has erased any technical traces of the perforation process (Figure 8A, c, f, g, Figure 8B, c). As with the *O. erinaceus*, the measurements recorded on the *T. reticulata* shells from Rochereil differ significantly from those of the modern reference collections (Mann-Whitney U test $p < 0.01$). The archaeological shells fall mainly within the range of variability of the modern reference collections (Figure 9), but the largest shells in the reference collections do not correspond to the Rochereil material. The size of the two specimens perforated by scraping, however, falls within the range of variability of the unmodified shells from Rochereil.



, Figure 10), corresponding to natural fractures observed on modern and fossil reference collections (Vanhaeren & d'Errico, 2001; Vanhaeren, 2002).

Table 3: Extremity morphologies observed on the *Dentalium* sp. from Rochereil.

Morphology	Extremity	
	% Proximal	% Distal
Intact	59.12	29.19
Round end	6.57	13.14
“Step” fracture	4.38	10.22
Straight fracture	24.09	6.57
Lip fracture	1.46	17.52
Irregular fracture	3.65	22.63

Dentalium from modern and fossil reference collections present a conical, slightly curved shape, with the shell length 7 to 12 times the maximum diameter. By comparison, the length of the scaphopods from Rochereil is, on average, 5 times greater than their maximum diameter meaning the scaphopods from Rochereil are shorter than those from the reference collections (Table 4).

Table 4: Measurements recorded on the *Dentalium* sp. From Rochereil.

	N	Mean	Minimum	Maximum	Std.Dev
Max. Diam.	137	3.49	1.99	4.24	0.31
Min. Diam.	137	1.80	0.80	3.58	0.40
Length	137	19.18	10.34	26.62	3.00

The *Dentalium* shells from Rochereil generally fall within the range of variability of the modern reference collection, although the smaller *Dentalium* shells present in the modern and fossil reference collection are not observed within the Rochereil collection (Figure 11). Moreover, the larger and longer scaphopods from Rochereil fall outside the size range observed in the fossil reference collection.

Regional comparison

The two shell types recovered in the greatest number from Rochereil, *Tritia reticulata* and *Dentalium* sp., were plotted alongside other examples of the same and similar shells recovered from throughout the Magdalenian, to provide a spatial context to their use as ornaments. *Tritia reticulata* has been identified at 42 separate Magdalenian sites, whereas shells of either *Dentalium* sp. Or of the closely related genus *Antalis* have been recovered from at least 76 sites (Figure 12). Both ornament types are quite common throughout the Franco-Cantabrian Magdalenian, their frequency remaining relatively consistent from the Lower Magdalenian through to the Upper and Final Magdalenian.

The use of *Tritia gibbosula* shells for personal ornamentation has a long history in Palaeolithic personal ornamentation (Soler Mayor, 1990; Bar-Yosef Mayer, 2015; Borić & Cristiani, 2019; Soler Mayor et al., 2019), but is unknown in the Lower and Middle Magdalenian. Its use as an ornament is attested in the Upper Magdalenian, but appears to be a phenomenon limited to northern Aquitaine and the Quercy (Taborin, 1993; O’Hara, 2017) where this bead type is found at six sites (Figure 13).

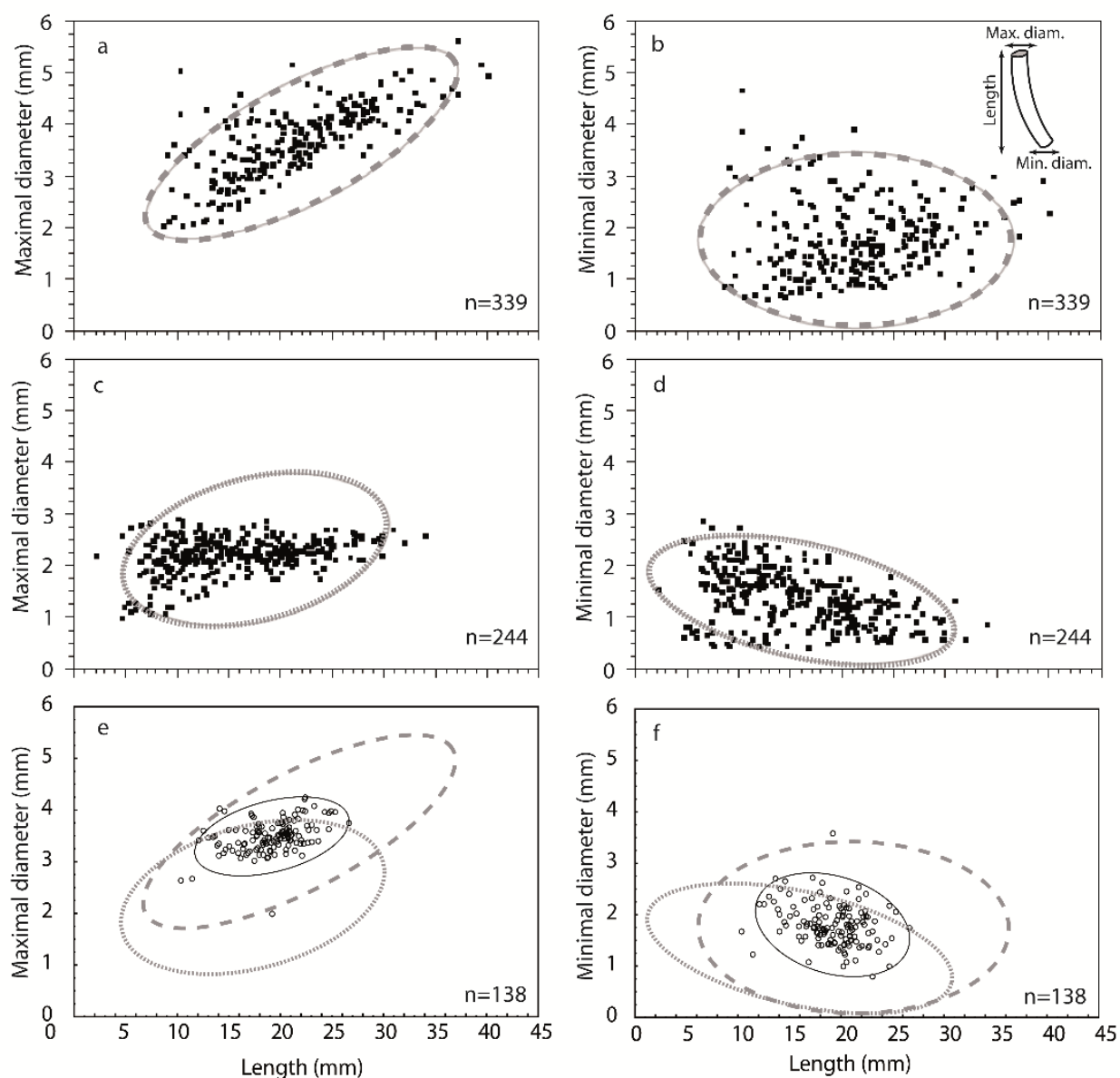


Figure 11: Scatterplot of the length and both maximal and minimal diameters of the *Dentalium* sp. From, the modern reference collection (a, b), fossil reference collection (c, d) and (e, f), comparison between the confidence ellipse (black) of the archaeological *Dentalium* sp. And those from modern and fossil (dotted lines) shells (confidence ellipses= 95%).

Cerastoderma sp. and *Glycymeris* sp. shell ornaments are ubiquitous throughout the Upper Palaeolithic of south-west of Europe (e.g. Taborin 1993, O'Hara 2017), but never in large quantities. On the other hand, *Ocenebra* is rarely encountered in Magdalenian contexts; examples are reported from the Creswellian (cf. Upper Magdalenian) layers at Gough's Cave (Donovan, 1955), but it does not seem to have been a significant element in Magdalenian symbolic culture.

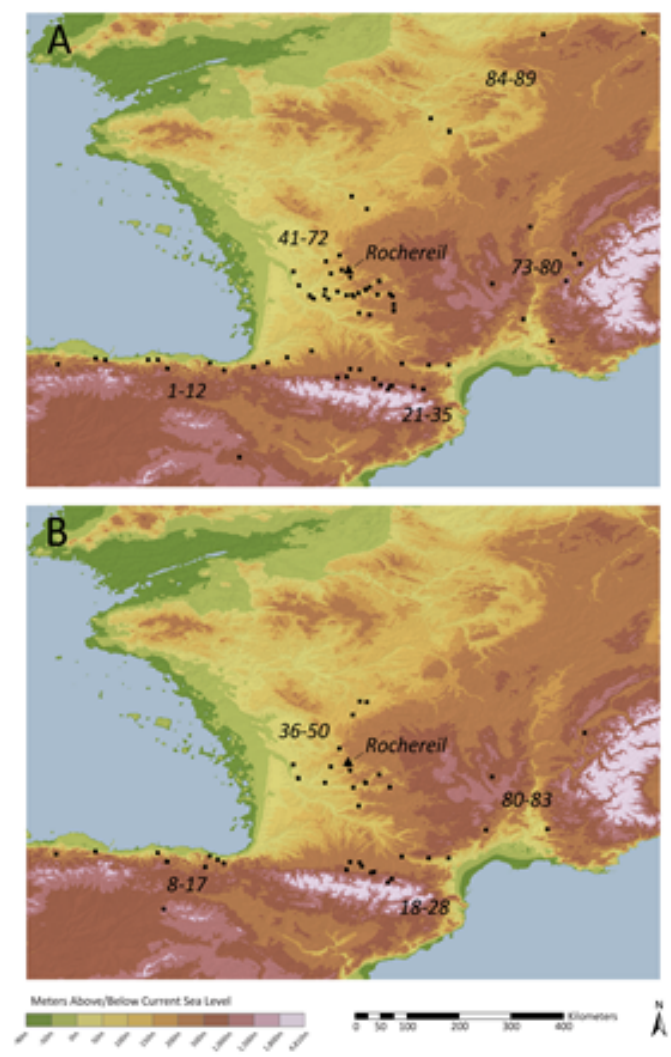


Figure 12: Distribution of *Dentalium* sp. (A) and *Tritia reticulata* (B) at Lower, Middle and Upper Magdalenian archaeological deposits across Western Europe. Map created using ETOPO1 digital relief model (Amante and Eakins 2009) and ESRI ArcMap 10.4.1. Sea levels estimated at -90m for approximately 16ka cal BP (Lambeck and Chappel 2001; Lambeck et al. 2014).

Site key : 1 : Las Caldas ; 2 : Cueto de la Mina ; 3 : El Juyo ; 4 : Pena del Diablo ; 5 : Berroberrria ; 6 : Isturitz ; 7 : Vidon ; 8 : Tito Bustillo ; 9 : La Garma A ; 10 : El Miron ; 11 : Lumentxa ; 12 : Erralla ; 13 : Cueva Oscura de Ania ; 14 : El Horno ; 15 : Chaves ; 16 : Bolinkoba ; 17 : Urtiaga ; 18 : La Tourasse ; 19 : Montfort ; 20 : Rhodes II ; 21 : Gourdan ; 22 : Grotte des Harpons ; 23 : Mas d'Azil ; 24 : Enlene ; 25 : La Vache ; 26 : Canecaude ; 27 : Gazel ; 28 : Tournal ; 29 : Lortet ; 30 : Massat ; 31 : Bedheilac ; 32 : Belvis ; 33 : Grotte de l'œil ; 34 : Petite Grotte de Bize ; 35 : Aurensan ; 36 : Le Souci ; 37 : Laugerie Basse ; 38 : Les Fadets ; 39 : La Marche ; 40 : Angles sur l'Anglin ; 41 : Roc de Marcamps ; 42 : Le Pla card ; 43 : Badegoule ; 44 : Chancelade ; 45 : Cap Blanc ; 46 : Crabaillat ; 47 : Lachaud ; 48 : Combe Cul lier ; 49 : Casse gros ; 50 : Abri Fritsch ; 51 : La Pique ; 52 : La Chaire a Calvin ; 53 : Grand Moulin de Lugasson ; 54 : Faustin ; 55 : Le Morin ; 56 : Gare de Couze ; 57 : Jamblancs ; 58 : Lestruque ; 59 : Abri Reverdit ; 60 : Le Flageole t II ; 61 : Les Marseilles ; 62 : Jolivet ; 63 : Pech de la Boissi ère ; 64 : Abri Murat ; 65 : Bruniquel-Lafaye ; 66 : Le Courbet ; 67 : Petit Cloup Barrat ; 68 : Gare de Conduche ; 69 : Abri de la Bergerie ; 70 : St Remy sur Creuse ; 71 : Les Fees ; 72 : La Madeleine ; 73 : Colombier ; 74 : Abri Soubeyras ; 75 : La Passagère ; 76 : Jean Pierre ; 77 : St Thibaud de Couz ; 78 : Grotte des Romains ; 79 : Solutre ; 80 : Rond du Barry ; 81 : La Roque ; 82 : Chinchon ; 83 : Douattes ; 84 : Goyet ; 85 : Gonnorsdorf ; 86 : Andernach ; 87 : Ville St Jacques ; 88 : Pincent ; 89 : Etiolles.

Discussion

Origin of the material

The two fossil specimens of Cardiidae and the *Spondylus* Sp. recovered from the Upper Magdalenian occupation of Rochereil present a patina on the surface that suggests a local origin in the surrounding karstic limestone. The absence of anthropic modification on these shells suggests they were naturally deposited in the cave sediment, and not intentionally introduced by Magdalenian occupants. Most of the other shell species present at the site were available along Atlantic and/or the Mediterranean shores during the Pleistocene (Taborin, 1993). Rochereil is currently 130km from the coast; during the site's occupation some 16-15,000 years ago, however, sea-levels were 90m lower than the today (Lambeck & Chappel, 2001; Lambeck et al., 2002; Galparsoro et al., 2010), leaving the site approximately 200km from the Atlantic shore and 350km from the Mediterranean coast. Given post-depositional alterations have erased many diagnostic features, it is not clear whether the scaphopods or *Tritia gibbosula* are coastal or fossil in origin. A possible origin in Miocene deposits can be proposed for the *Dentalium*; fossil specimens very similar in shape and size are documented in the Miocene crags (Aquitainian and Burdigalian stratotypes) located in the Aquitaine Basin (Cossmann and Peyrot, 1915), less than 90km from the site, but an Atlantic origin cannot be excluded. The closest known source of fossils of *Tritia gibbosula* is the Pliocene fossil outcrops in the Aude and Hérault, 300km to the south-east (Taborin, 1993).

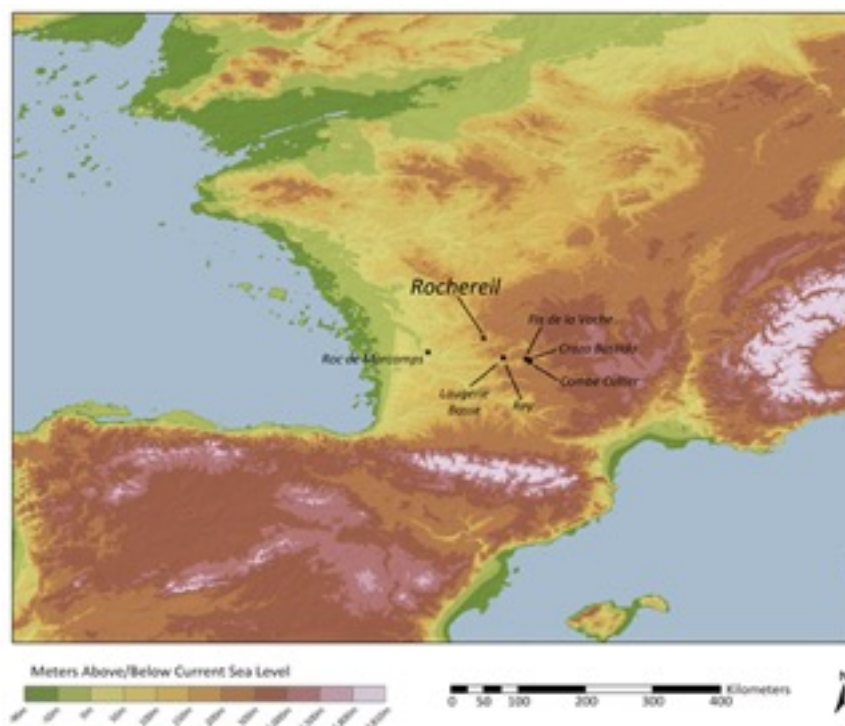


Figure 13: Distribution of shells of *Tritia gibbosula* in Magdalenian archaeological deposits across Western Europe. Map created using ETOPO1 digital relief model (Amante and Eakins 2009) and ESRI ArcMap 10.4.1. Sea levels estimated at -90m for approximately 16ka cal BP (Lambeck and Chappel 2001; Lambeck et al. 2014).

The location of the site at more than 200km from the shores and Pliocene fossil outcrops indicate that most of the shells accumulated at Rochereil have an allochthonous origin. The presence of one species extant exclusively in the Atlantic (*Pecten maximus*), and one species exclusively present in the Mediterranean (*Tritia gibbosula*), indicates the exploitation of two different catchment areas. Stone raw materials identified at Rochereil are mainly local in origin (Duchadeau-Kervazo, 1986). This pattern echoes a general trend observed in the Aquitaine Basin during the Upper Magdalenian: most of the lithic raw materials are locally acquired, with a small amount of exogenous raw materials coming from the Poitou, Charente and Massif Central, areas located at the North-West and East of the Aquitaine Basin (Langlais & Laroulandie, 2014; Langlais, Laroulandie, et al., 2014; Gourc et al., 2016; Langlais et al., 2016). Some flint types originating in the Charente are occasionally found in southern sites, but Mediterranean lithic raw materials are never found in more northern regions (Langlais et al., 2016). Differences between lithic and shell catchment areas suggest that the shells and the stone raw materials were acquired through two different acquisition networks. In the ethnographic record, objects found at considerable distances from source often attest to non-utilitarian mobility, or to exchange (Binford, 1978; Hayden, 1981). This long-distance transport of resources across the landscape may be motivated by social and ideological concerns, often partially motivated by the gathering of information from neighboring groups (Speth et al., 2013; Newlander, 2017). While distance from source cannot be directly correlated with likelihood of indirect acquisition or exchange (Hughes, 2011), in the case of Rochereil, the existence of two geographically distinct networks of acquisition, one for stone and another for shell procurement, suggests that the group indirectly acquired, at least partially, one of the two resources.

Function of the shells

The location of the site at a considerable distance from either coast indicates that the mollusks were not collected live for consumption. The accumulation of a red compound in one valve of *Glycymeris*, along with the evidence on the interior of the shell for the scraping or mixing of that compound with a lithic point, suggests that this specimen was used as an ochre container. No trace of this red compound was

found on the rest of the shell collection, and we suggest this *Glycymeris* specimen be considered functionally distinct from the rest of the assemblage; the composition of this red compound of the subject of ongoing analysis. The manufacture of a hole for suspension identified on one *Cerastoderma edule*, one *Tritia gibbosula* and two *Tritia reticulata*, on the other hand, suggest their use as personal ornaments. Use-wear identified on the perforated *Tritia gibbosula* suggests that the shell was introduced to the site having already been transformed into a bead, and may have been accidentally lost. Technological analysis does not identify anthropogenic modification on the scaphopods, however, or on the *Ocenebra erinaceus*.

Morphometric analysis indicates that the *Ocenebra erinaceus* from Rochereil are significantly larger than those in the modern reference collections. Morphometric analysis also indicates that the smaller *Dentalium* sp. present in the modern and fossil reference collections are not observed within the Rochereil collection. Furthermore, morphometric analysis shows that the large shells naturally present in modern reference collections are outside the size range of the *Tritia reticulata* from Rochereil.

Two factors, environmental conditions and human selection, may be responsible for the size differences observed between the archaeological material and the reference collections. The study of archaeological shell middens show that shell size tends to decrease with increased sea surface temperatures during the Pleistocene (Gutiérrez-Zugasti, 2011; Álvarez-Fernández, 2011). Visible during interstadial phases, this phenomenon becomes more pronounced at the beginning of the Holocene (Gutiérrez-Zugasti, 2011; Álvarez-Fernández, 2011). Local intertidal environments and sea temperature variations can also influence the intra-species size variability (Fisher et al., 2009; Avaca et al., 2013). The relatively large size of the Pleistocene *Ocenebra erinaceus* at Rochereil fits the climatic hypothesis, and therefore preferential selection is not necessarily evidenced. On the other hand, the significantly smaller size of the archaeological *Tritia reticulata* when compared to the modern examples does not correspond to the climatic hypothesis. The absence of larger specimens may be explained by intra-species variability between discrete populations. An alternative suggestion is that the archaeological *Tritia reticulata* were deliberately sorted before their introduction to the site, and larger shells excluded from the assemblage.

The size of the *Dentalium* sp. from Rochereil falls within the range of variability of the modern and Miocene reference collections, but the smallest scaphopods present in the two reference collections are absent from the archaeological assemblage. Absence of the smaller scaphopods again suggests that the shells were sorted before they were brought to the site, and that larger individuals were preferentially selected.

We propose that the most parsimonious explanation for the presence of unmodified shells is that the objects were collected with the intention of being transformed into ornaments, but were deposited before modification. While shells of *Ocenebra* are not well-represented in Magdalenian contexts, modified shells of *T. reticulata* and *Antalis* are well-known elements of Magdalenian cultures of personal ornamentation. Two hypotheses may explain their presence at Rochereil: 1) the shells represent an accumulation of raw material stored for subsequent transformation and use or 2), the shells were considered inappropriate for the manufacture of personal ornaments and were abandoned in the cave. We reject the second hypothesis due to the presence of modified *Tritia reticulata* within the same size range as the unmodified specimens, indicating the unmodified shells accumulated at the site were of an appropriate size for perforation as beads.

The shell accumulation hypothesis is further supported by the exclusion of the smaller scaphopods, which may correspond to the requirement for *Dentalium* sp. with a wide enough circumference for embroidery with a bone needle (Vanhaeren and d'Errico, 2001).

Regional synthesis

The shell material at Rochereil is a mixture of *taxa* widely used throughout the Magdalenian (*Cerastoderma* sp., *Glycymeris* sp., *Mytilus* sp.) and other types restricted to the region surrounding the site (*O. erinaceus*, *T. gibbosula*). The presence of *Tritia gibbosula* at Rochereil is noteworthy, as it is chronologically and geographically restricted to a small number of Upper Magdalenian sites in northern Aquitaine and the Quercy (Figure 13), raising the possibility of a local ornament tradition within a regionally discrete population. Conversely, the two *taxa* which dominate this assemblage, *Dentalium* sp. and *Tritia reticulata*, are both well-represented throughout the Magdalenian (O'Hara, 2017). Shells of either *Dentalium* sp. or the closely related genus *Antalis* (the two being often conflated) were identified at 76 Magdalenian occupations, at least 40 of which may be attributed to the Upper Magdalenian. Whether of

fossil or marine origin, no other purpose besides ornamentation is known for these objects. Shells of *Tritia reticulata* are also commonly used as personal ornaments, and are attested at 42 separate Magdalenian sites, 15 of which could be restricted to Upper Magdalenian occupations. The presence of the same shell types at so many sites, frequently several hundred kilometers from their source, suggests a complex array of relationships interlinking procurement and exchange as objects travel across the landscape. These individual episodes of exchange, involving not just collaboration but also the shared symbolic valorization of specific shell materials, are integral to the wider social economies that constitute the Magdalenian as a cultural complex.

Rochereil appears typically consistent in the ornament types favored, featuring a shell assemblage that is at once diverse, but also highly coherent with shell assemblages recovered from other Magdalenian sites in Aquitaine and to a lesser extent the Pyrenees and Vasco-Cantabria (e.g. Ladier & Welté, 1993; Taborin, 1993, 2007; Ladier et al., 1994; Alix, 2003; Álvarez Fernández, 2006). What makes the Rochereil assemblage particularly noteworthy is the sheer number of unmodified specimens, which suggests the existence of an accumulation phase in the procurement chain, with the perforation and modification of the objects occurring at a later point in the sequence. The presence of similar bead types at contemporaneous sites in the same region suggests that Rochereil belongs to a network of interactions involved in the diffusion and sharing of common styles and symbols within the Upper Magdalenian communities of the region.

Conclusions

The technological, morphometric and use-wear analysis of the shells from Rochereil identify for the first time a location dedicated to shell material accumulation during the Upper Magdalenian of the Aquitaine basin. The accumulation at Rochereil of raw materials of both fossil and marine origin implies a degree of scheduling in the gradual collection of the shells before modification. Accumulation sites such as this must therefore be integrated into our understanding of the “structured poses” of the aggregation/dispersion cycle by which we often imagine Magdalenian annual mobility strategies (Conkey et al., 1980; Rivero, 2014).

While the manufacture, modification and configuration of personal ornaments in the Paleolithic have each received valuable scholarly attention (e.g. White, 1997; Vanhaeren et al., 2013; d’Errico et al., 2015), shell procurement has not. We must begin to consider the nature of Magdalenian procurement strategies of unmodified shells from either fossil or marine contexts (Rigaud et al. 2019, 2021). Embedded procurement is commonly invoked when referring to resources available within a group’s foraging range (Binford, 1980). The evidence from Rochereil suggests diversion from regular foraging activities and related mobility in order to deposit or retrieve accumulated raw materials, or perhaps the incorporation of such activity as embedded within regular foraging patterns. When reconstructing the procurement of exotic raw materials, scholars frequently compare systems of direct procurement with those of inter-group or down-the-line exchange (e.g. Wiessner, 1982, 1997; Whallon, 2006; Hart et al., 2017; Newlander, 2017). The evidence from Rochereil complicates this dichotomy and suggests that exotic materials can be accumulated over an extended period of time and subsequently transformed, used, or exchanged as opportunities to do so arise. In this sense, the *chaîne opératoire* of ornament production is a segmented process of decision making which begins long before the actual physical modification of the object.

The accumulation of a large amount of allochthonous raw materials indicates the occupants of Rochereil were integrated within regional interaction spheres with groups sharing the same aesthetic standards. The large-scale dispersal of similar materials attests to the mobility of the occupants of Rochereil, and their contacts with other communities. The exchanges and potential gifting of personal ornaments likely contributed to a powerful social strategy to maintain cultural cohesiveness between communities, and stimulated flexibility and reciprocity between groups.

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Data, scripts and codes availability

Data are available online: <https://osf.io/mt87f>

Conflict of interest disclosure

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