

The shell industry in Final Neolithic societies in Sardinia: characterizing the production and utilization of *Glycymeris* da Costa, 1778 valves

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ABSTRACT

Analyses of the Neolithic and Chalcolithic industry in hard animal material from the western Mediterranean include a rich corpus of studies focusing on osseous industries. However, studies relating to the shell industry mainly concentrate on the production of ornamental objects, and the overall background of this raw material for the production of utensils used for transformation activities is not yet well known. The technological analysis of the hard animal industry of Cuccuru S'Arriu (Cabras, Sardinia) discovered in Final Neolithic structures (4000-3500 BC) led to the identification of many sea shells collected for making artefacts, ornamental objects and utensils. This article focuses on the morpho-technological analysis of the *Glycymeris* da Costa, 1778 shells used as utensils, and the identification of artefact function. In particular, the experimental activities carried out for the analysis of use-wear traces are presented. These activities enhance our understanding of artefact functions (smoothers, scrapers or small containers). Finally, this study allows us to assess the important role of this industry in the production activities of Final Neolithic societies in Sardinia and reveals previously unknown data regarding the reconstruction of the ways of life of insular prehistoric societies. It is currently one of the few Neolithic samples in the western Mediterranean.

KEY WORDS

Shell industry,
use-wear traces,
Final Neolithic,
Cuccuru S'Arriu,
Sardinia.

RÉSUMÉ

L'industrie sur coquille dans les sociétés du Néolithique final en Sardaigne: caractérisation de la production et de l'utilisation des valves de Glycymeris da Costa, 1778.

L'analyse de l'industrie en matières dures animales du Néolithique et du Chalcolithique en Méditerranée occidentale repose sur un riche corpus d'études concernant les industries en matières osseuses. Cependant, les études relatives à l'industrie sur coquille sont le plus souvent centrées sur la production d'objets d'ornement. Le rôle que cette matière première a joué dans la production d'outils utilisés dans des activités de transformation n'est pas encore bien connu. L'analyse technologique de l'industrie en matières dures animales de Cuccuru S'Arriu (Cabras, Sardaigne) dans les structures du Néolithique final (4000-3500 av. J.-C.) a permis l'identification de nombreuses coquilles collectées dans le but de produire des objets de parure et des outils. Cet article se concentre sur l'analyse morpho-technologique de coquilles de *Glycymeris* da Costa, 1778 utilisées comme outils, qui a permis l'identification de la fonction des objets. Les activités expérimentales réalisées dans le cadre de l'analyse des traces d'utilisation ont permis de comprendre les fonctions de certains objets (lissoirs, grattoirs et petits conteneurs). Enfin, cette étude permet d'évaluer le rôle de cette industrie dans les activités de production des sociétés du Néolithique final en Sardaigne, révélant des informations inédites concernant la reconstruction des modes de vie des sociétés préhistoriques insulaires et représentant l'un des rares exemples pour le Néolithique de la Méditerranée occidentale.

MOTS CLÉS

Industrie sur coquille,
traces d'utilisation,
Néolithique final,
Cuccuru S'Arriu,
Sardaigne.

INTRODUCTION

For a long time, studies of industries in hard animal materials did not systematically define the role of the shell industry in techno-economical terms in the same way as for the osseous industry. This discrepancy is due to the fact that these studies traditionally reduce shell industry analysis, together with some artefacts in other raw materials, to the production of ornamental objects. The technical, aesthetical, social and cultural aspects of this production are considered separately in terms of aims and uses. However, the techno-economical systems of shell industries in prehistoric sites must also be taken into account, not only to understand the acquisition modes, techniques and methods used during transformation, but also to reconstruct the procurement and circulation of raw materials in the studied societies. In addition to this precious information, some shell artefacts provide important data for identifying the transformation of other materials, as they can be used for different purposes, as shown by ethnographic studies (Mansur & Clemente-Conte 2009; Attenbrow 2012; Cuenca-Solana *et al.* 2013) and archaeological evidence (Bernabò Brea 1946: tav. XXX, fig. 17 a-c; Vigie & Courtin 1986; Courtin & Vigie 1987; Vigie 1987, 1995; Gruet 1993; Taborin 2004; Choi & Driwantoro 2007; Lammers-Keijsers 2007; Pascual Benito 2008; Manca 2010, 2013, 2014; Van Gijn & Lammers-Keijsers 2010; Zilhão *et al.* 2010; Henshilwood *et al.* 2011; Serrand 2011; Serrand & Vigne 2011; Gutiérrez-Zugasti & Cuenca-Solana 2015). Besides their use as ornamental objects, shells have also been employed in the production of instruments which are often only recognizable through microscopic surface analysis.

In the past few decades, considerable progress has been made thanks to technical analysis and the analysis of use-wear traces on shells (Cristiani *et al.* 2005; Lucero & Donald 2005; Choi & Driwantoro 2007; Szabó *et al.* 2007; Szabó 2008;

Bonomo & Aguirre 2009; Mansur & Clemente-Conte 2009; Cuenca-Solana *et al.* 2010, 2014, 2015; Clemente-Conte & Cuenca-Solana 2011; Douka 2011; Tumung *et al.* 2012, 2015; Szabó & Koppel 2015). These studies have contributed to a more precise identification of the species used, the artefacts produced and the function and operation mode of finds, underlining the potentialities of a morpho-techno-functional approach.

Several studies carried out on the functional analysis of shells incorporated the experimental method for the establishment of a comparative reference collection.

Several species of Mediterranean bivalves were used for these experiments: *Mytilus galloprovincialis* (Lamarck, 1819), *Ostrea edulis* (Linnaeus, 1758), *Ruditapes decussatus* (Linnaeus, 1758), *Patella Vulgaxa* (Linnaeus, 1758) and *Pecten maximus* (Linnaeus, 1758) (Mansur & Clemente-Conte 2009; Cuenca-Solana *et al.* 2010, 2013, 2015; Tumung *et al.* 2015). Some experiments were carried out on the Glycymeridae *Glycymeris violacescens* (Lamarck, 1819) (Tumung *et al.* 2015), with a longitudinal movement in both directions to deflesh and dislocate, for a period of ten minutes.

However, studies adopting this approach to shell industries are not systematic, and current knowledge is thus inadequate for defining their role in prehistoric societies in the western Mediterranean. For the present analysis of the Final Neolithic shell industry (4000-3500 BC) from Cuccuru S'Arriu (Cabras, Oristano, Italy), the experimental method played a central role. The discovery of Glycymeridae valves with clear non-human modifications caused by abrasion on beaches or undertows (Bignon *et al.* 2008; Manca 2011, 2013) before they were transported to the site demonstrated the deliberate introduction of the remains to the site for non-food purposes. We then sought to confirm the anthropogenic action on these valves. This involved the observation of the remains from two distinct and complementary viewpoints. The technical

perspective aimed to identify the marks associated with the transformation of the raw material, while the use-wear perspective focused on identifying traces of use.

ARCHAEOLOGICAL CONTEXT

The site of Cuccuru S'Arriu is at a strategic location between the inland waters and external waters, on the south-western shores of Cabras pond on a fossil barrier beach, near the coastline overlooking the Gulf of Oristano (Sardinia, Italy). The site was discovered in the late 18th century by Zanardelli (Zanardelli 1899: 161; Santoni 1977) and later studied by Atzeni (Atzeni 1962: 192; 1975; 1978: 83), then excavated under the direction of V. Santoni during the 1970s and 1980s (Santoni 1989). The excavation comprised an area of about 3750 square meters, which only represents part of the archaeological complex.

Various Neolithic and Chalcolithic phases were identified at the site of Cuccuru S'Arriu, which correspond to distinct cultural contexts: the necropolis and habitat of the Middle Neolithic Bonu Ighinu (4800-4400 BC) and the habitat structures ("fondi di capanna" and refuse pits) of San Ciriaco (4400-4200/4000 BC), Ozieri I (4200-3700 BC) and Ozieri II or sub-Ozieri (3500-2900 BC) (Santoni 1982a: 70). Absolute dating indicates Middle Neolithic occupation phases (structure 422 (bone; AMS dates): AA-58900: cal. 2 sigma 4685-4437; AA-58901: cal. 2 sigma 4590-4340; AA-58902: cal. 2 sigma 4790-4500; AA-75644: cal. 2 sigma 4778-4494) (Bignon *et al.* 2008: 774; Sebis *et al.* 2012: 500). No comprehensive study of the abundant remains found at the site has yet been published. However, the study of the significant material remains, especially ceramics and the lithic industry, helped to identify and characterize other phases (Santoni 1989, 1991, 1992, 1999; Santoni *et al.* 1997).

This research focused on part of the habitat site, comprising burial structures with archaeological levels in Area C, which yielded remains chronologically attributed to Ozieri I. During a first phase of research, we selected the pieces potentially belonging to the shell industry from the (still unpublished) faunal remains. Most of the shell industry is represented by bivalves (81 specimens) and only occasionally by gastropods (5 specimens) (Table 1). The most common shell type in the corpus is the *Glycymeris* from the Ozieri I structures located in sector C (structures 126 bis, 129, 131, 132, 133 bis, 147, 164, 165, 172, 173, 173 ter, 175, 175 bis, 179) (Santoni 1982b, 1989). The chronological attribution to Ozieri I is based on a bibliographic overview, the consultation of the planimetric and excavation data and the precious support of Vincenzo Santoni.

MATERIALS AND METHODS

The studied corpus includes 65 *Glycymeridae* valves. Among them we identified 43 *Glycymeris glycymeris* (Linnaeus, 1758) and *Glycymeris pilosa* (Linnaeus, 1767) samples, 13 *Glycymeris* sp. specimens and nine *Glycymeris nummaria* (Linnaeus, 1758) specimens (Table 1).

TABLE 1. — Composition of the hard animal shell industry from the Ozieri I phase of Cuccuru S'Arriu site (C sector structures). Abbreviation: NR, number of remains.

Famille	Espèce	NR	%
Gastéropodes		5	5,81
Cerithiidae (Fleming, 1822)	<i>Cerithium cf. vulgatum</i> (Bruguière, 1792)	3	3,49
Muricidae (Rafinesque, 1815)	<i>Hexaplex trunculus</i> (Linnaeus, 1758)	1	1,16
Muricidae (Rafinesque, 1815)	<i>Stramonita haemastoma</i> (Linnaeus, 1767)	1	1,16
Bivalves		81	94,19
Glycymerididae (Dall, 1908 (1847))	<i>Glycymeris glycymeris/pilosa</i> (Linnaeus, 1758)	43	50,00
Glycymerididae (Dall, 1908 (1847))	<i>Glycymeris</i> sp.	13	15,12
Glycymerididae (Dall, 1908 (1847))	<i>Glycymeris nummaria</i> (Linnaeus, 1758)	9	10,47
Spondyliidae (Gray, 1826)	<i>Spondylus gaederopus</i> (Linnaeus, 1758)	8	9,30
Spondyliidae (Gray, 1826)	<i>Spondylus cf. crassicosta</i>	2	2,33
Ostreidae (Rafinesque, 1815)	<i>Ostrea edulis</i> (Linnaeus, 1758)	1	1,16
Cardiidae (Lamarck, 1809)	<i>Cerastoderma glaucum/edule</i>	1	1,16
Cardiidae (Lamarck, 1809)	<i>Acanthocardia tuberculata</i> (Linnaeus, 1758)	1	1,16
Veneridae (Rafinesque, 1815)	cf. <i>Venerupis decussata</i> (Linnaeus, 1758)	1	1,16
Bivalvia	Bivalvia	2	2,33
TOTAL		86	100,00

For the analysis of this collection we followed the experimental protocol, which consists in the transformation of various raw materials of animal, plant and mineral origin. The valves used in the experiments were collected dead on the beaches near the Cuccuru S'Arriu site (near the archaeological site of Tharros West and San Giovanni di Sinis) (Fig. 1) in order to study the macroscopic characteristics of the valves found at the Cuccuru S'Arriu site (see below, paragraph "Characterisation of the natural surfaces"). We recorded the microscopic characteristics of twelve of these shells before their modification through experimentation as a benchmark for distinguishing microtraces of natural origin from anthropogenic traces.

We then characterized the macro and microtraces present on the surfaces in order to identify their function (action) and functioning (mode of action). The description of micro use-wear traces is based on two different types of traces: micro-polish and striations (Plisson 1985; Peltier & Plisson 1986; Maigrot 1993, 2003; Christidou 1999; Legrand 2005; Mansur *et al.* 2014; Bradfield 2015; Evora 2015). The main micro-polish traces, and their characterization (location, position, organization, micro-topography, microrelief, texture, fabric, contouring, extension, and brightness), define the mode of use and the hardness of the worked material. In the same way, the characterization of striations (location, position, organization, orientation, frequency, continuity, morphology and dimensions) indicates the direction of movement during use.

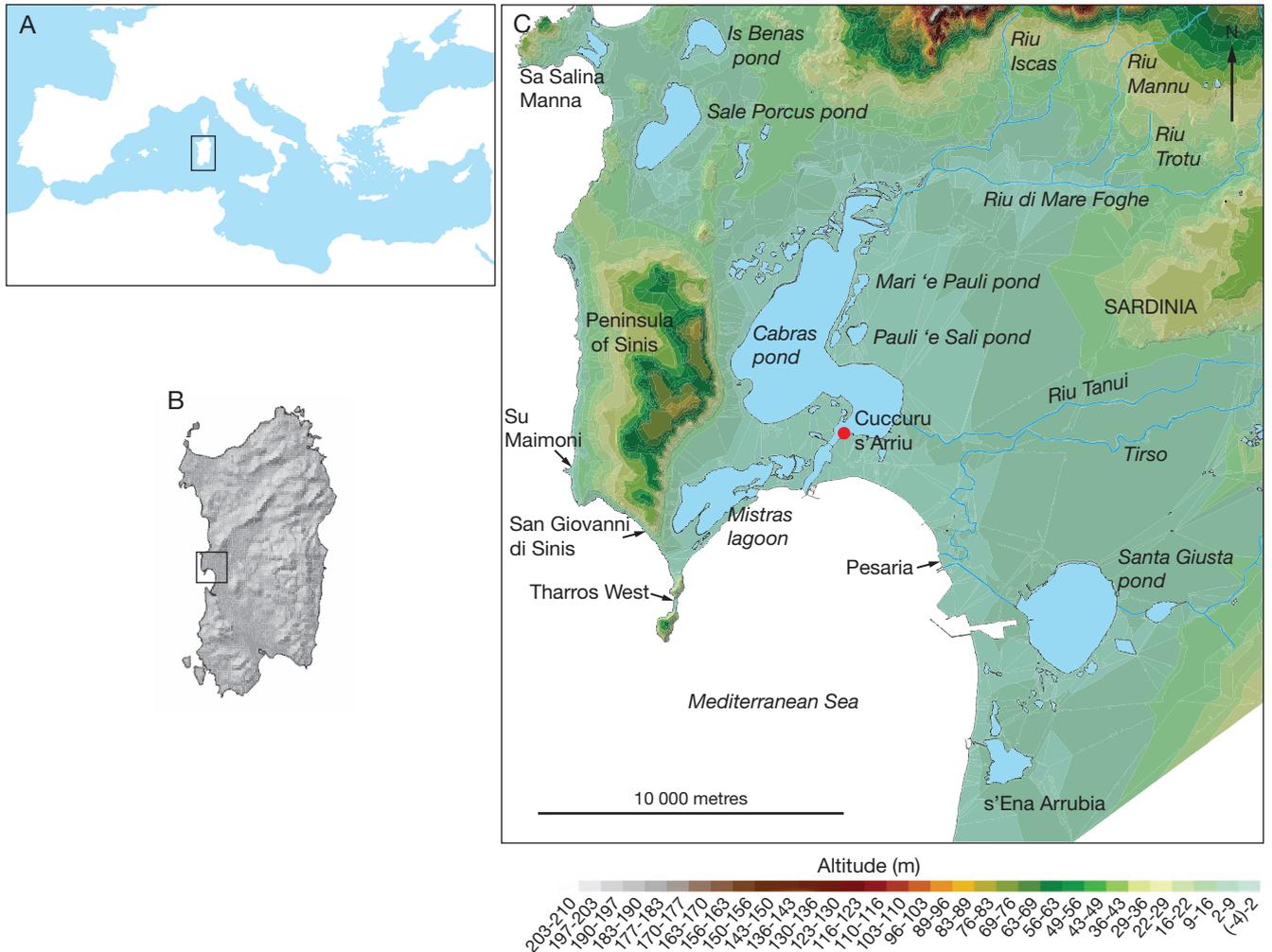


FIG. 1. — **A, B**, Geographical data; **C**, Location of the site of Cuccuru s'Arriu (red point) and indication of beaches near the site with *Glycymeris* valves (Tharros West, San Giovanni di Sinis, Su Maimoni and Pesaria).

All the experimental and archaeological shells were observed using an Olympus stereomicroscope ($\times 3.8$ - $\times 40$ magnification), and photographs of the macroscopic traces were taken with a Canon EOS 550D camera ($\times 5.7$ - $\times 80$ magnification). A Leica MDR metallographic microscope (lenses $\times 50$, $\times 100$, $\times 200$, $\times 500$) was used for higher magnifications with the Canon 550D camera. For greater depth of field, we systematically took several photos of the same area focusing the lens on a different part of the object for each shot. The Helicon Focus program was then used to blend all the sharp areas together and produce a completely sharp image. This procedure is often used by archaeologists (Plisson 1997: 378, 379), and was applied to our photomicrographs and photomacrographs whenever necessary.

All experimental and archaeological use-wear traces are visible and can be characterized at magnifications of $\times 100$ and $\times 200$, but the observation of bright surfaces is often difficult, and sometimes raises problems for identifying striations and evaluating the brightness of the polish. Better contrast facilitates the observation of the surfaces, and can be obtained with the use of differential interferential contrast (Plisson & Lompré 2008).

EXPERIMENTATIONS

The shell valves used for the experiments are Glycymeridae and were collected on the beaches near the site of Cuccuru s'Arriu (Fig. 2A), apart from four *Tapes decussatus* (Linnaeus, 1758) valves used for a long time (1 consecutive month) for smoothing and scraping clay. They were included in our experimental corpus on account of the long period of use.

The Glycymeridae valves bear clear traces of natural modifications, identical to those present on most of the archaeological remains. These modifications were described and characterized on the experimental valves before the experiments.

CHARACTERIZATION OF THE NATURAL SURFACES

The macroscopic observation of surfaces made it possible to confirm the natural modifications previously described by several authors (Driscoll & Weltin 1973; Parsons & Brett 1991) (Fig. 2B): rounded valve edges, the presence of a hole in the umbo with convex margins, impact traces evidenced by the absence of certain parts of the valve, rounded fractured edges, or by still visible fracture lines,

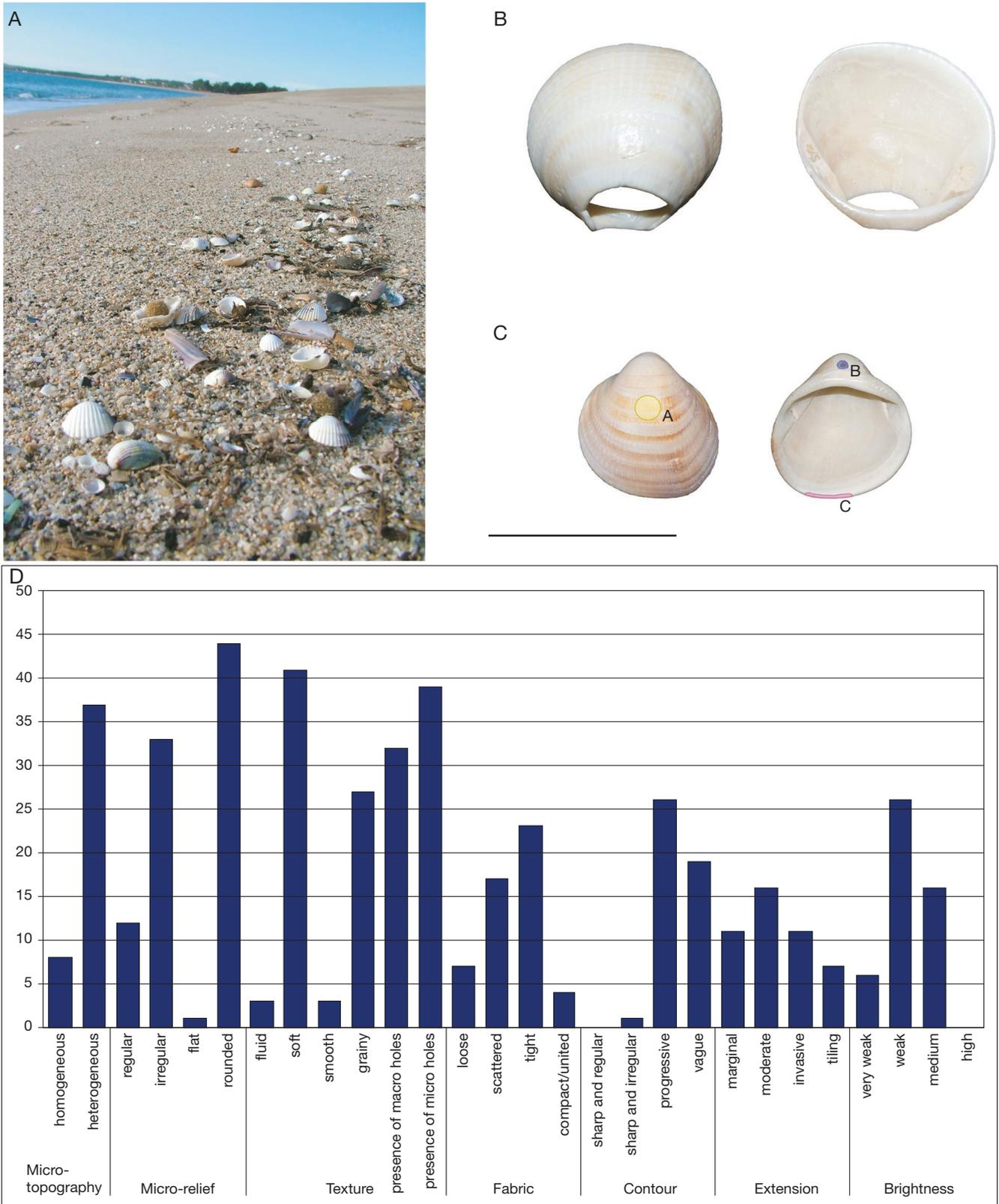


FIG. 2. — **A**, area of experimental shell collection; **B**, macroscopic evidence of non-human modifications on experimental *Glycymeris* valves; **C**, localization of points with abundant natural microtraces; **D**, frequency distribution of the characteristics of natural micro-polishes. Scale bar: 5 cm.

a glossy surface, and in certain cases the presence of an opaque white patina caused by the exposure of the valves to atmospheric conditions.

Although the whole surface was analysed, the photographic and descriptive record of the microtraces focused mainly on the zones that normally reveal the presence of human use-

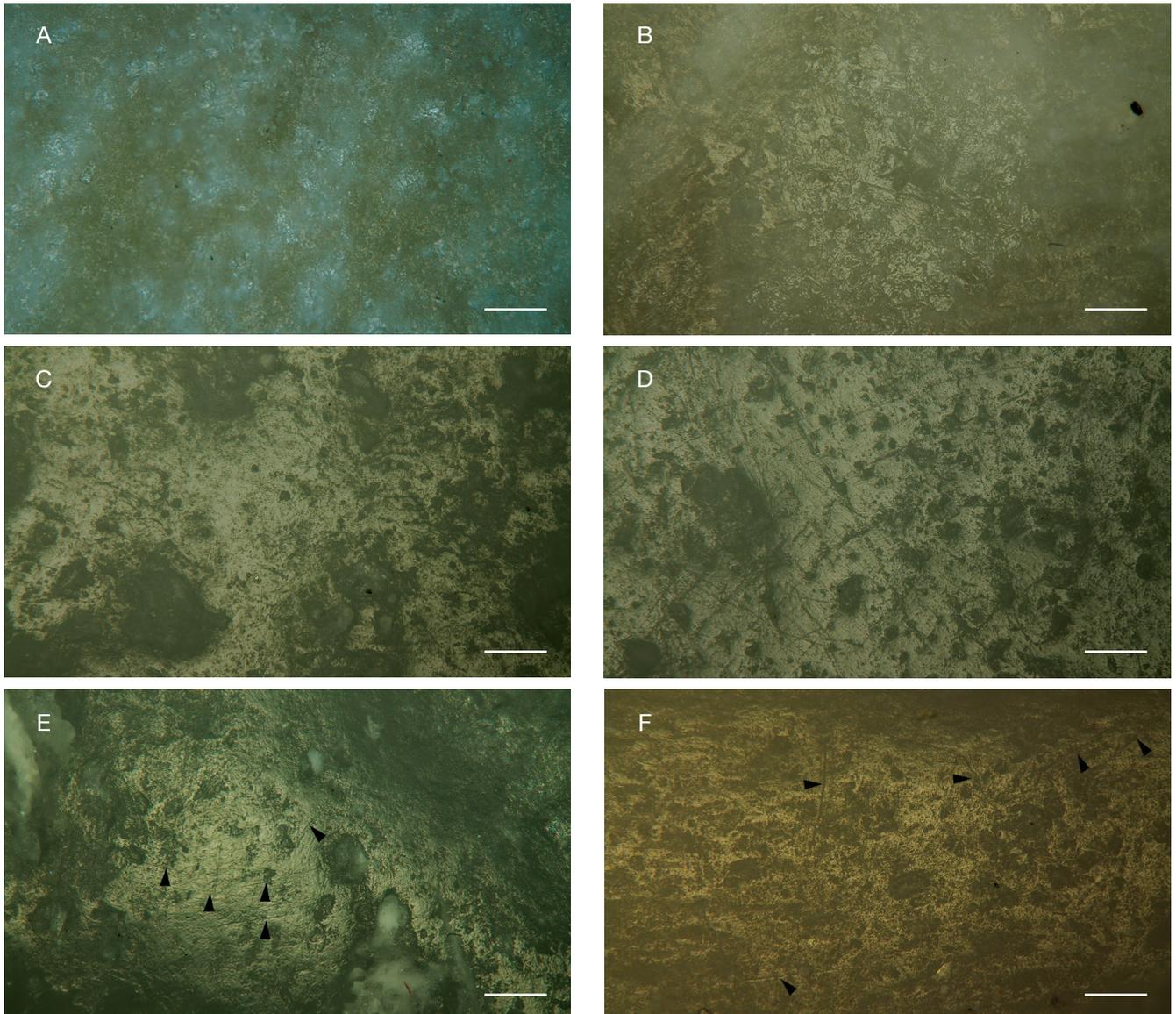


FIG. 3. — **A-D**, micro-polishes identified on the dorsal face of *Glycymeris* valves with different microtopography, texture, fabric and extension: **A**, absence of micro-polish; **B-D**, presence of micro-polish becoming gradually more marked; **E, F**, scratches identified on the dorsal face of valves. Scale bars: 100 μ m.

wear traces, like the umbo, for the suspension or binding of the valves, or like the edge and the ventral face, for the use of valves as tools (Fig. 2C). Out of the 12 observed valves, 50 zones were described and photographed and 45 microtraces were identified.

The majority of the microtraces of natural origin on the valves are micro-polishes. They are concentrated in the zones most exposed to the erosive action of the tide and the beach, like the edges, the umbo and the dorsal face. They are mainly micro-polishes with a heterogeneous micro-topography, irregular and rounded microrelief, distributed in a linear way compared to the examined zone, with a mainly tight but scattered fabric, a grainy texture with the frequent presence of macro and micro-holes. The contour is only seldom sharp; it often has a progressive

aspect and, in many cases, remains fuzzy. The brightness ranges from weak to medium and can be extremely variable (Figs 2D, 3A-D).

Unlike micro-polishes, scratches were not frequently observed: out of 45 zones with identified microtraces, we only recorded the presence of scratches in 15 cases. They are located mainly on the umbo (8 cases), on the dorsal face (6 cases) and only in one case on the edges.

The scratches are mainly narrow and superficial, of variable length, of low density and random orientation, although there are cases where they are dispersed obliquely in relation to the longitudinal axis of the valve. They are either organized, parallel or subparallel or intersecting each other, or distributed in a random way (Fig. 3E, F). Two characteristics can be taken into consideration for

TABLE 2. — Description of the experimental sample and experimental activities.

Number of valves	Activity	Direction of movement in relation to the active part of valve	Inclination of tool in relation to the worked surface	Surfaces of block in contact with worked material	Worked material
2	scraping	transverse bidirectional	oblique (45°) towards dorsal face / perpendicular (90°)	edge	goat skin
2	scraping (softening)	transverse bidirectional	oblique (135°- 45°)	edge	tanned and rigid sheepskin
1	scraping	transverse bidirectional	perpendicular (90°)	edge	tanned lambskin
2	scraping	transverse bidirectional	perpendicular (90°)	edge	tanned lambskin
2	scraping	transverse bidirectional	perpendicular (90°)	edge	tanned wild boar skin
2	scraping	transverse bidirectional	oblique (45°) towards dorsal face / perpendicular (90°)	edge	tanned wild boar skin
2	scraping	transverse bidirectional	grazing angle	edge	tanned sheep skin
2	scraping	transverse bidirectional	oblique (30°-70°)	edge	wood of boxwood
2	scraping	transverse bidirectional	oblique (30°-70°)	edge	bark of basswood
2	scraping	transverse bidirectional	perpendicular (90°)	edge	<i>Juncus acutus</i>
2	scraping	transverse bidirectional	perpendicular (90°)/oblique (100°)	edge / dorsal face	<i>Linum cf. usitatissimum</i>
2	scraping	transverse bidirectional	oblique (45°) towards dorsal face/ perpendicular (90°)	edge	paille
2	polishing	oblique	grazing angle	dorsal face	clay
1	smoothing	perpendicular	grazing angle	edge	clay
1	smoothing/ scraping	perpendicular	abrupt (80°)	edge	clay
4 (<i>Tapes decussatus</i>)	smoothing/ scraping	pluridirectional	grazing angle	dorsal face	clay
2	friction	rotating movement	perpendicular (90°); abrupt (80°); oblique (45°)	ventral face and edges	ochre+egg white +fingers
2	friction	rotating movement	perpendicular (90°); abrupt (80°); oblique (45°)	ventral face and edges	ochre+egg white + hairs of wild boar

Number of valves	Activity	State of raw material	Time of working/ minutes		Observations / figures
2	scraping	wet	5	15	The working of wet skin is not illustrated in the paper due to the inefficacy of this technical action.
2	scraping (softening)	dry	5	15	Figs 4A; 4B
1	scraping	dry	15		Figs 4C; 4D; 4E; 4F
2	scraping	dry	5	15	Figs 4C; 4D; 4E; 4F
2	scraping	dry	5	15	These use-wear traces are similar to those obtained with tanned lambskin.
2	scraping	re-wet	5	15	/
2	scraping	dry + ochre	5	15	Figs 5A; 5B; 5C; 5D
2	scraping	dry	5	15	Figs 5E; 5F
2	scraping	wet	5	15	Figs 5G; 5H
2	scraping	worked 2 weeks after the collecting	5	15	Figs 6A; 6B; 6C; 6D
2	scraping	dry	5	15	Figs 6E; 6F; 6G; 6H
2	scraping	dry	5	15	These use-wear traces are similar to those obtained with flax.
2	polishing	wet	5	15	(clay with addition of calcareous inclusions – ≥ 1 mm) Fig. 7A, B
1	smoothing	wet	15		/
1	smoothing/ scraping	wet	15		(clay with addition of calcareous inclusions – ≤ 1 mm) Fig. 7C; 7D
4 (<i>Tapes decussatus</i>)	smoothing/ scraping	wet	1 month		Figs 7E-G
2	friction	wet	30	60	(granulometry of grains: $3 < x < 1$ mm) Figs 8A, B
2	friction	wet	30	60	This experimentation is not illustrated in the paper as it left no use-wear traces

a comparison between the microtraces of natural origin and those of anthropogenic origin: the low density and shallow depth of the scratches. These characteristics are present in almost all the cases and the only exceptions are strictly related to location of use-wear traces: the presence of dense scratches and variable depths were only identified on the dorsal face.

MICROSCOPIC CHARACTERIZATION OF EXPERIMENTAL USE-WEAR TRACES

The activities carried out in the experiments with the valves were based on ethno-archaeological examples, in keeping with evidence of the potential activities at the archaeological site (Leroi-Gourhan 1945), indicating the potentially worked materials and methods of use. The experimental tests related to

production activities (35 valves) (Table 2). In order to estimate the time necessary for the formation of surface modifications, we carried out experiments with durations of 5 minutes and 15 minutes. The latter duration results in the formation of a more marked polish with well-developed scratches, which we will describe below.

Animal matter, skin in a dry state

Softening skin to the very fine hypodermis does not require very much work. Once dry, the skin can be cleaned of possible residues and softened at the same time (Beyries 2008: 23). This activity is usually conducted with a pebble, but due to the robustness and the morphology of the edges of Glycymeridae valves, we tested the effectiveness of these shells. Pieces of dry lambskin were placed on a wooden anvil and scraped with a bidirectional transverse movement. The contact angle between the edge of the valve and the skin was almost perpendicular. The micro-polish on the edge after 15 minutes is flat, with a regular micro-topography and a flat microrelief, compact fabric and a smooth texture. The contour is progressive, the brightness is remarkable and the extension is invasive (Fig. 4A, B). The scratches are long, and of variable width and depth. They are dense and parallel to each other.

Before being used, skin can be treated in order to thin it, to regularize any possible asperities and to make it more supple. It can also be coloured by scraping associated with colouring substances. In order to reproduce these operations, the dry sheepskin was scraped, on the one hand without the addition of abrasive substances, and on the other, by adding ochre. The skin was placed on a wooden anvil. The movement of the valve was transverse and bidirectional. The edge of the valves were at an oblique angle (45° and 135°) for scraping without ochre (Fig. 4C, D), whereas for colouring the skin with ochre the dorsal face of the valves was used at a very slight angle (Fig. 5A, B).

The traces obtained by scraping without abrasive substances are micro-polishes and scratches.

The micro-topography on the edge is homogeneous with a regular rounded microrelief. It appears a dense fabric and a smooth and soft texture. The contour is sharp and irregular, it is invasive and very bright (Fig. 4E, F). The irregular contour of the polished surface follows the direction of the movement: small extensions stem out from the “body” of the polish with a perpendicular orientation in relation to the edge of the shell. The scratches are short, fine and not very deep, dense and parallel to each other.

The traces produced by scraping the skin with ochre as a colouring substance are more marked.

The micro-polish developed on the dorsal face is localized in a semicircular linear zone. The micro-topography is homogeneous and the microrelief is irregular with a tight fabric and a grainy texture. The contour is regular, of medium brightness and polish extension is relatively invasive (Fig. 5C, D). The surface is characterized by macro-holes with irregular contours. The scratches are long, of variable depth and width, dense and subparallel. We also distinguish curved scratches.

Plant matter, wood

The use of shell valves for working wood is attested in several populations (Cuenca-Solana *et al.* 2011: 84). We tested scraping (on boxwood) and hulling basswood fibres. The edge of the valves was used in a transverse direction, at an angle oscillating between 70° and 30°.

Scraping wood for 15 minutes resulted in the formation of polish and scratches (Fig. 5E, F). The polish is localized along the edge and extends slightly onto the lower face. The micro-topography is homogeneous and the microrelief is regular and rounded, with a tightened fabric and a soft flat texture. It is of marginal extension and with a progressive contour, with macro-holes and micro-holes. The brightness is marked in the central part and moderate towards the periphery of the polish. Scratches accompany the whole extension of the polish; they are dense, short and discontinuous, fine and superficial.

The traces related to scraping the interior of the basswood bark are slightly different from those previously described (Fig. 5G, H). The polish is localized along the edge and extends slightly onto the lower face. The micro-topography is heterogeneous and the microrelief is irregular and rounded, with marginal extension, a progressive contour, a joined fabric and smooth texture, and macro-holes and micro-holes. The brightness is marked. Scratches accompany the whole extension of the polish; they are of medium density and are short and discontinuous, fine and superficial.

Plant matter, rushes

This material (*Juncus acutus* L.) was probably used by the population of Cuccuru s'Arriu. Rushes are very abundant in marshy environments and can be used for clothes, cords and baskets. The separation of the stems is traditionally carried out with knives or awls, but scraping can easily be carried out with shell valves. Once the edge of the valve is inserted in the cut end of the stem, simple pressure and a longitudinal movement make it possible to divide it over its entire length. This operation also eliminates the internal woody part (Fig. 6A, B).

We observe the formation of use-wear traces on the edge with an extension limited to several millimetres. The micro-topography is homogeneous and the microrelief is regular and rounded, with a tightened fabric and a soft grainy texture, with macro-holes. The contour is progressive, the brightness is strong and the extension is marginal (Fig. 6C, D). The scratches are loose, short, fine and continuous, parallel to each other and oriented transversely in relation to the cutting edge. Their density changes when the shells are used for a longer duration.

Plant matter, flax

We used the edge of the valves to crush the woody part to prepare the flax for obtaining fibres. This activity is traditionally carried out by hammering fibres on a flat stone or by placing the dry flax between two planks of wood (Médard 2006: 41). We positioned the flax stems (*linum* cf. *usitatissimum*) on a wooden anvil and crushed them with a bidirectional movement of the valve. The edge of the valve was used at a perpendicular (90°) and more open

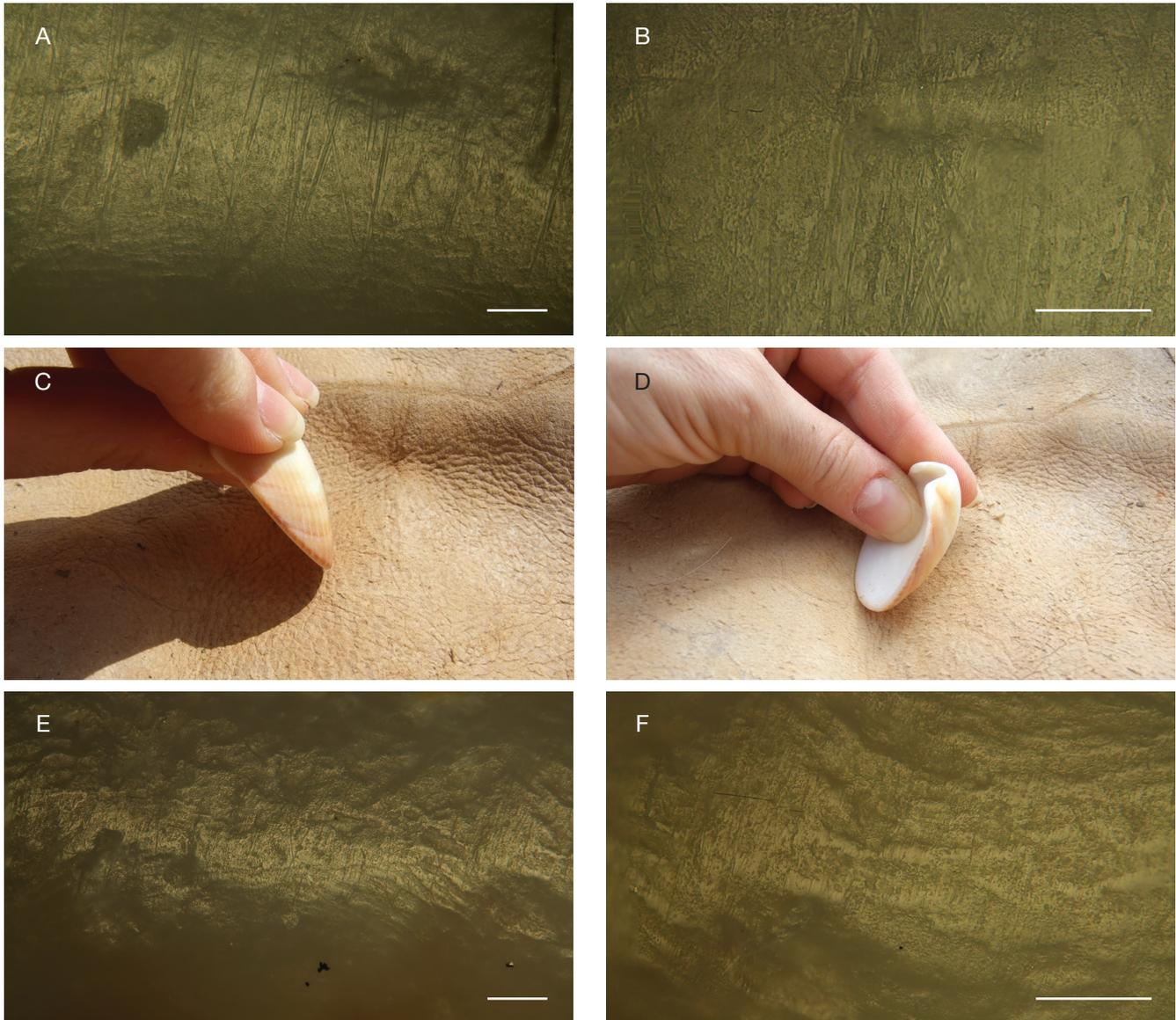


FIG. 4. — **A, B**, experimental shell surface used to process dry hide (softening; 15 minutes); **C, D**, working conditions (C, 45° inclination; D, 135° inclination); **E, F**, experimental shell surface used to process dry hide (scraping). Scale bars: 100 μ m.

(100°) angle (Fig. 6E). The active part, with a convex section and non-cutting edge, enabled us to crush the woody parts of a modest amount of flax without damaging the fibres (Fig. 6F).

The polish that developed after 15 minutes maintains a homogeneous micro-topography and a regular rounded microrelief with a tightened or compact fabric (Fig. 6G, H). The texture is soft and flat. The macro- and micro-holes become more marked and numerous. The striations are located on the upper (dorsal) edge, indicating an open active angle. The striations are dense, long, thin and continuous and parallel to each other.

Mineral matter, clay

Various ethnographic examples confirm the use of shell valves to smooth ceramics. This use has been documented in the Canary Islands (Rodríguez & Navarro 1999) and in

several African populations (Dupont 2003; Cuenca-Solana *et al.* 2011).

The use of the dorsal face held at an acute angle makes it possible to obtain a polish with a compact fabric (Fig. 7A, B).

The valve fragment used to smooth wet clay during the assembly phase presents very few microtraces (Fig. 7C, D). The micro-polish only affects the most marked parts of the structural composition of the valve.

The traces on the valves used for approximately one month present different macro-characteristics depending on their localization on the valve. The micro-topography on the dorsal face is homogeneous with a regular flat microrelief and has a compact fabric and a smooth texture. It is characterized by a progressive contour, strong brightness and is relatively invasive (Fig. 7E). The scratches are long, fine and not very deep, dense and parallel to each other.

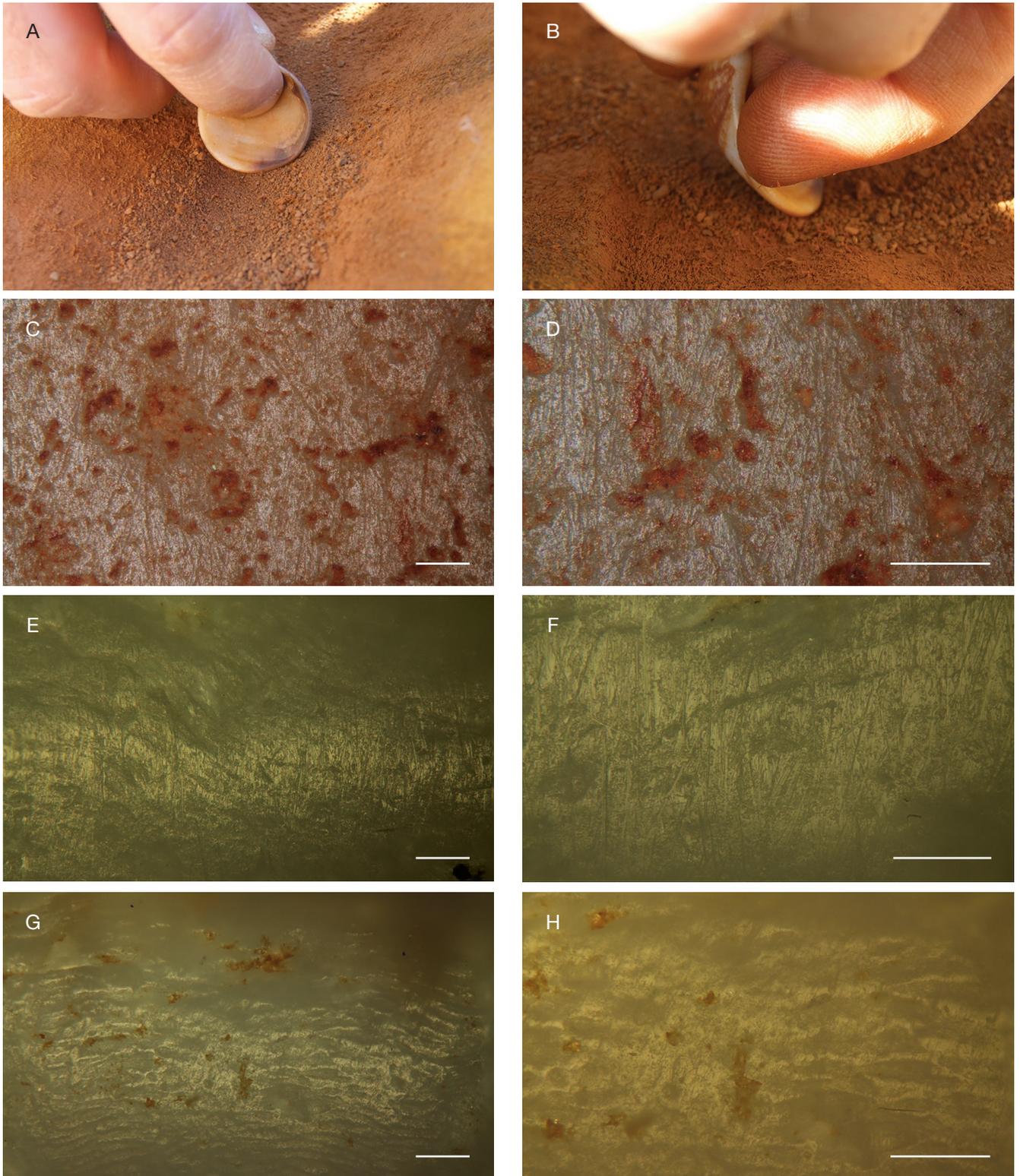


FIG. 5. — **A, B**, working conditions (**A**, 45° inclination; **B**, 135° inclination); **C, D**, experimental shell surface used to process dry hide (scraping with the use of ochre; 15 minutes); **E, F**, experimental shell surface used to process boxwood (scraping; 15 minutes); **G, H**, experimental shell surface used to process basswood (scraping; 15 minutes). Scale bars: 100 μ m.

On the dorsal face near the edges (Fig. 7F), the microtopography is homogeneous with a regular rounded microrelief and with a scattered fabric and soft texture. The contour

is progressive with medium brightness, and it is relatively invasive. The scratches have the same characteristics as those previously described. The cutting edge of the higher edge of



FIG. 6. — **A**, working mode; **B**, results obtained; **C**, **D**, experimental shell surface used to process rushes (separation of the stems; 15 minutes); **E**, working conditions; **F**, results obtained; **G**, **H**, experimental shell surface used to process flax (crushing; 15 minutes). Scale bars: 100 μ m.

the valves was used to scrape the clay (Fig. 7G). The recorded traces consist of a discontinuously distributed micro-polish on the higher edge, sometimes associated with scratches. It is rounded with a compact fabric and a smooth texture. The

contour is irregular, with medium brightness and relatively invasive extension. Scratches are not present on the whole edge, and their density is scattered and dense. They are long, fine and continuous, and parallel or subparallel to each other.

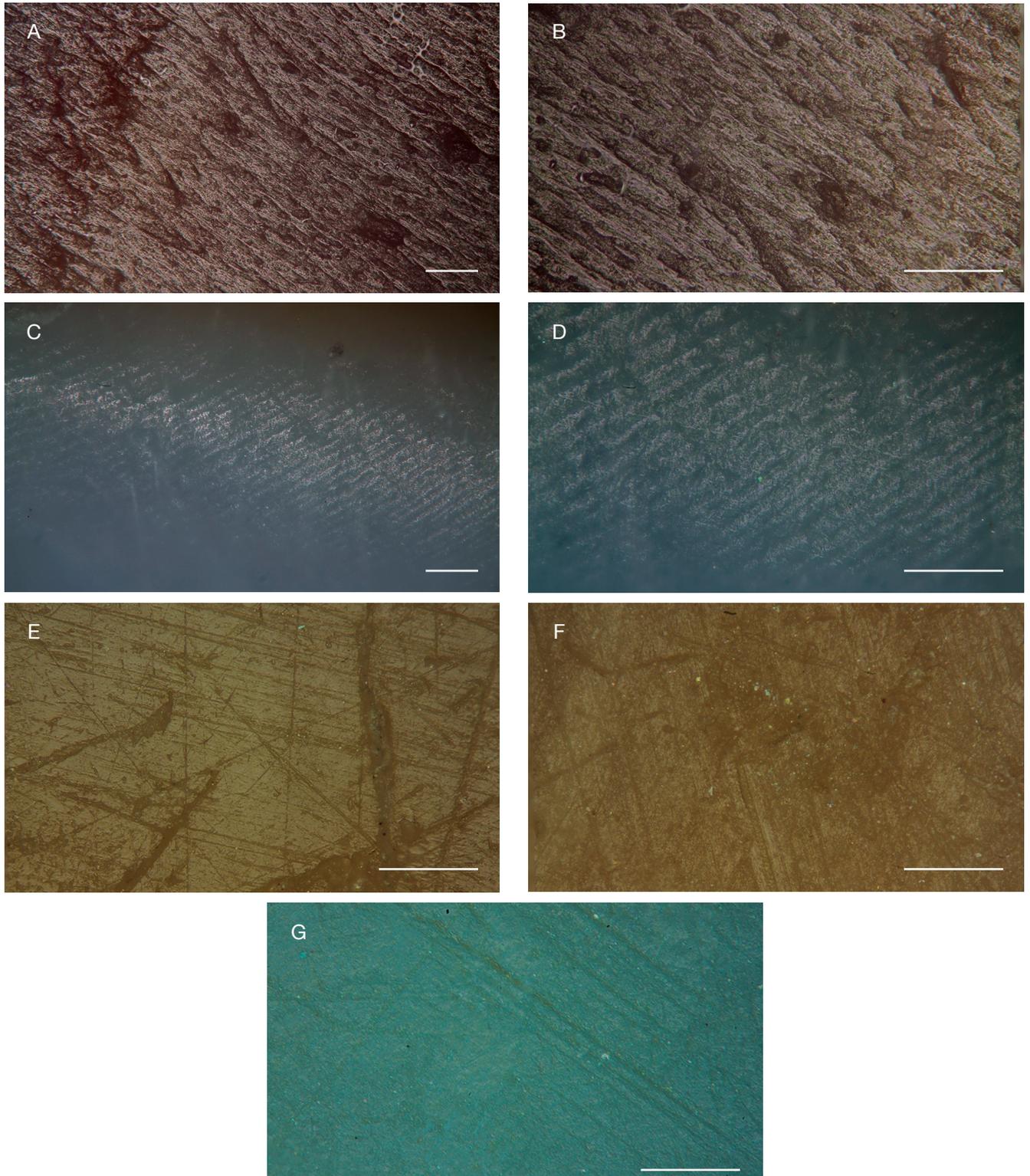


FIG. 7. — **A, B**, experimental shell surface used to process clay with the dorsal face of valves (smoothing; 15 minutes); **C, D**, experimental shell surface used to process clay with the edge of valves (smoothing; 15 minutes); **E-G**, experimental shell surface used to process clay with the dorsal face of valves (smoothing; 1 month). Scale bars: 100 μ m.

Mineral matter, ochre

The experimentation involved the use of valves as containers for mixing crushed ochre with a sticky substance, to prepare the mixture for use.

The emulsion was manufactured with egg white, respecting the results of the analyses conducted on the pigments present in the Domus de Janas, a set of Neolithic tombs in Sardinia (Cariati *et al.* 1981; Rampazzi *et al.* 2002). Two experiments

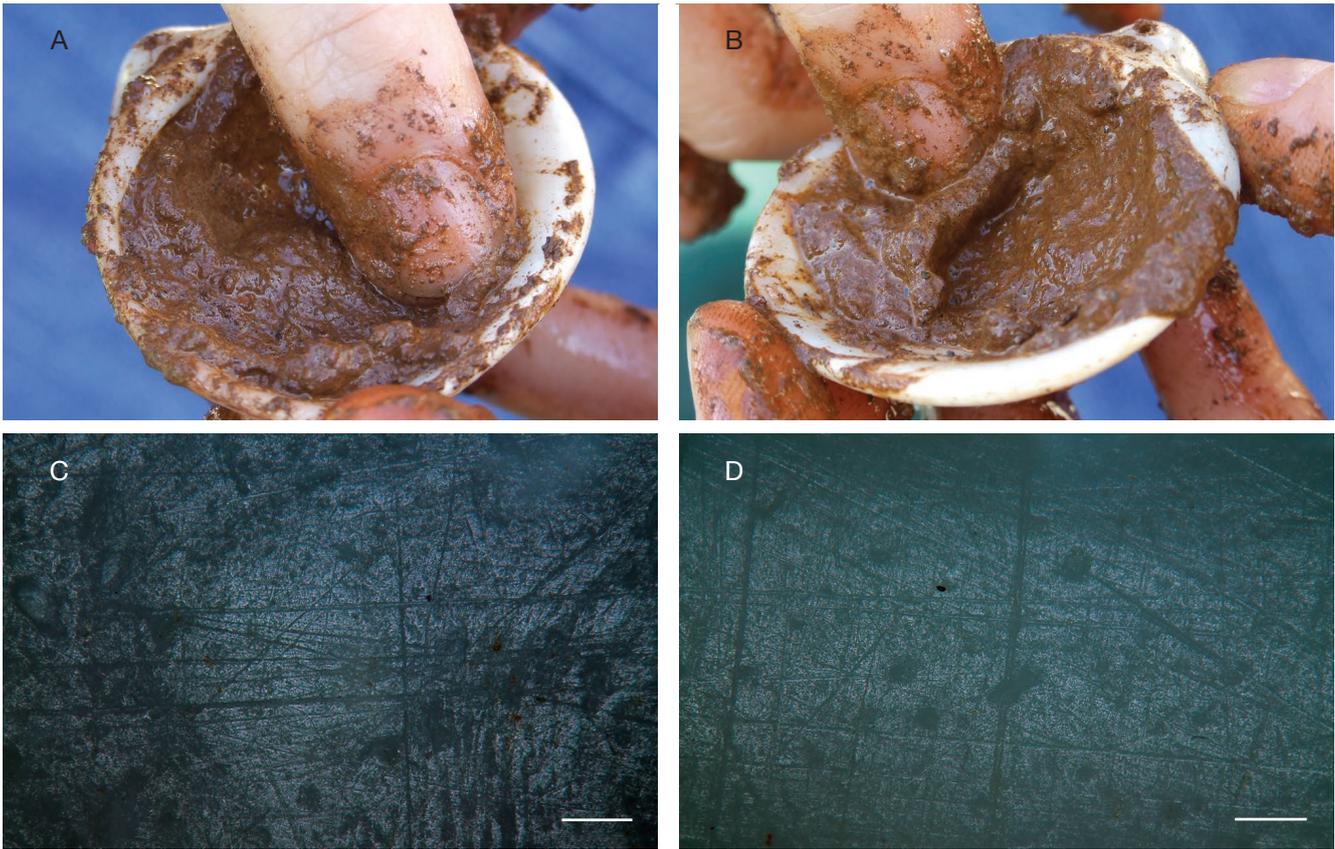


FIG. 8. — **A, B**, use of shells as containers (mixing the crushed ochre with a sticky substance; 1 hour); **C, D**, experimental shell surface. Scale bars: 100 μ m.

were carried out in which ochre was mixed and applied with the fingers (Fig. 8A, B).

The valves present well developed microtraces. The micro-polish is characterized by medium brightness and a vague contour. Its micro-topography is homogeneous and its microrelief is regular and smooth, with a soft texture. After half an hour of activity, the fabric is loose with a progressive contour. The scratches are long, broad and deep. The bottom is smooth and, in certain cases, it presents micro-scratches. More prolonged activity, for one hour, results in the formation of a tighter micro-polish on an area of the hinge where we can distinguish much denser and deeper scratches with random orientation and organization (Fig. 8C). Scratches are almost absent from the edges and polish is not developed (Fig. 8D).

RESULTS: ANALYSIS OF THE ARCHAEOLOGICAL FINDS

STATE OF CONSERVATION OF THE ARCHAEOLOGICAL FINDS

The overall state of conservation of the shell pieces from Cucuru is Arriu is average. The presence of concretions, mostly on the ventral and the dorsal face, can limit the observation of the pieces. However, these alterations usually only occupy limited portions of the surface and they are occasionally located on the umbo or on the hinge, more rarely on the edges. In

most cases, the dorsal surface only bears small concreted areas while the ventral side is affected by more compact concretions. The observation of the zones without concretions was often sufficient for identifying traces of use.

FUNCTIONAL ANALYSIS

The macroscopic and microscopic analysis of the *Glycymeris* shells found in the Ozieri structures (or Ozieri I) (65 valves) resulted in the identification of use-related traces on 18.46% of the remains (12 valves) (Table 3). In addition, we observed 20 valves with suspension use-wear traces pointing to their use as ornamental objects (Fig. 9).

This proportion may seem surprising as, a priori, all the valves were brought to the site to be used. However, it is essential to take into account the poor state of conservation of the remains and the absence of specific studies on the characterization of the post-depositional traces on the shells. These factors limit the study and call for extreme caution with the interpretation of the analysis.

The valves present traces of use on part of the dorsal face (3 valves) and on the edge (7 valves). On these same valves, it was seldom possible to identify valves presenting traces of use related to transformation and traces of suspension on the umbo (2 valves).

The three valves with traces of use on the dorsal or ventral face present wear related to contact with a mineral matter (Figs 10-12). For two of them, the use-wear traces are com-

TABLE 3. — Numerical and percentage distribution of the number of remains (NR) from Ozieri I of Cuccuru s'Arriu (Cabras, Italy), assigned to different types of use-wear traces (ornamental objects and instruments) and localization of the use-wear on the valves.

Species	Absence of use-wear traces (NR)	Absence of use-wear traces (%)	Use-wear traces localized on the dorsal or ventral face (NR)	Use-wear traces localized on the edge (NR)	Use-wear traces of suspension and of utilisation as instrument (NR)	Use-wear traces of suspension (NR)
<i>Glycymeris glycymeris/pilosa</i> (Linnaeus, 1758)	43	48,84	1	7	1	13
<i>Glycymeris</i> sp.	13	53,85	2	–	–	4
<i>Glycymeris nummaria</i> (Linnaeus, 1758)	9	55,56	–	–	1	3
Total	65	52,75	3	7	2	20

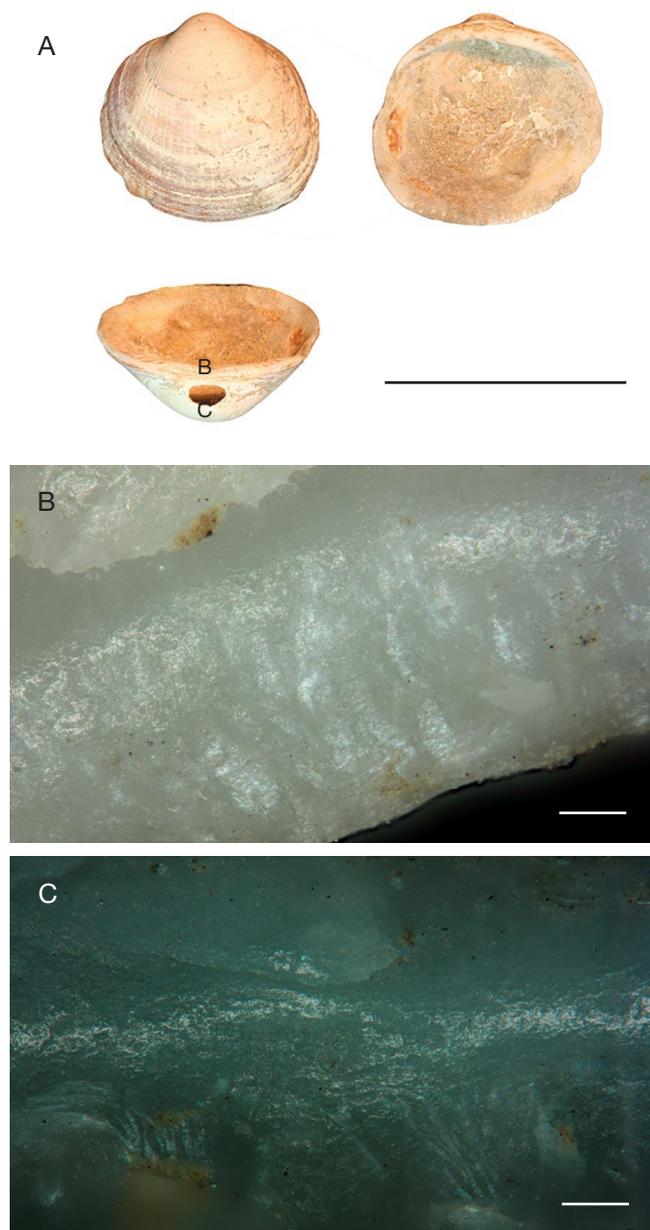


Fig. 9. — **A**, Archaeological shell with use-wear traces of suspension (Cuccuru s'Arriu, Cabras, Italy); **B-C**, use-wear traces localized on the edge of natural perforation (**B**) and on the hinge (**C**). Scale bars: A, 5 cm; B, C, 100 µm.

parable to those produced in experiments by smoothing fresh clay but contact with other substances of mineral origin can also be considered (Figs 10-11). One of these valves presents red dye traces (ochre?) on the dorsal face (Fig. 10B-D); the largest quantity of dye is on the upper edge whereas small traces are dispersed on the dorsal face. The use-wear traces are also distributed on the dorsal face. The micro-polish is not very developed: it is heterogeneous with an irregular flat microrelief and with a compact fabric and soft texture; the contour is progressive, with weak brightness and a marginal extension. The scratches are long, fine and not very deep, dense and parallel to each other. Their orientation indicates a transverse movement in relation to the upper edge.

Another valve bearing use-wear traces related to smoothing clay presents different polish density and scratches with respect to the localization of the traces (Fig. 11); the polish is more accentuated in the central part of the valve and less developed in the peripheral zone. The orientation of the scratches shows that the valve was used for a transverse and longitudinal movement compared to the upper edge.

The third valve only presents localized traces of use on the hinge and on a very limited zone on the edge, on the ventral face (Fig. 12). A polish of weak brightness, with a heterogeneous microtopography and an irregular flat microrelief, a scattered fabric and grainy texture, progressive contour and relatively marginal extension, is accompanied by long secant scratches, of medium width and depth, with furrowed and shiny bases. These traces are similar to those produced in the experiments using the valves as containers for mixing a mineral substance with a natural binder (egg white).

Seven shells present traces of use on the edge, but only four of these were interpreted. They show very different characteristics in terms of localization, distribution and extension. It was only possible to identify the worked matter in contact with the valves on five zones.

One of them presents use traces related to friction against a mineral material (Fig. 13B). It presents linearly distributed traces on the edge of the ventral face, in a central position, which extend to 1 cm inside the valve. The polish is not very intense, of low to medium brightness, with a grainy texture and a scattered and scattered fabric. The scratches are perpendicular, very broad and with a furrowed base. The edge bears a rounded polish with a linear distribution, a scattered fabric

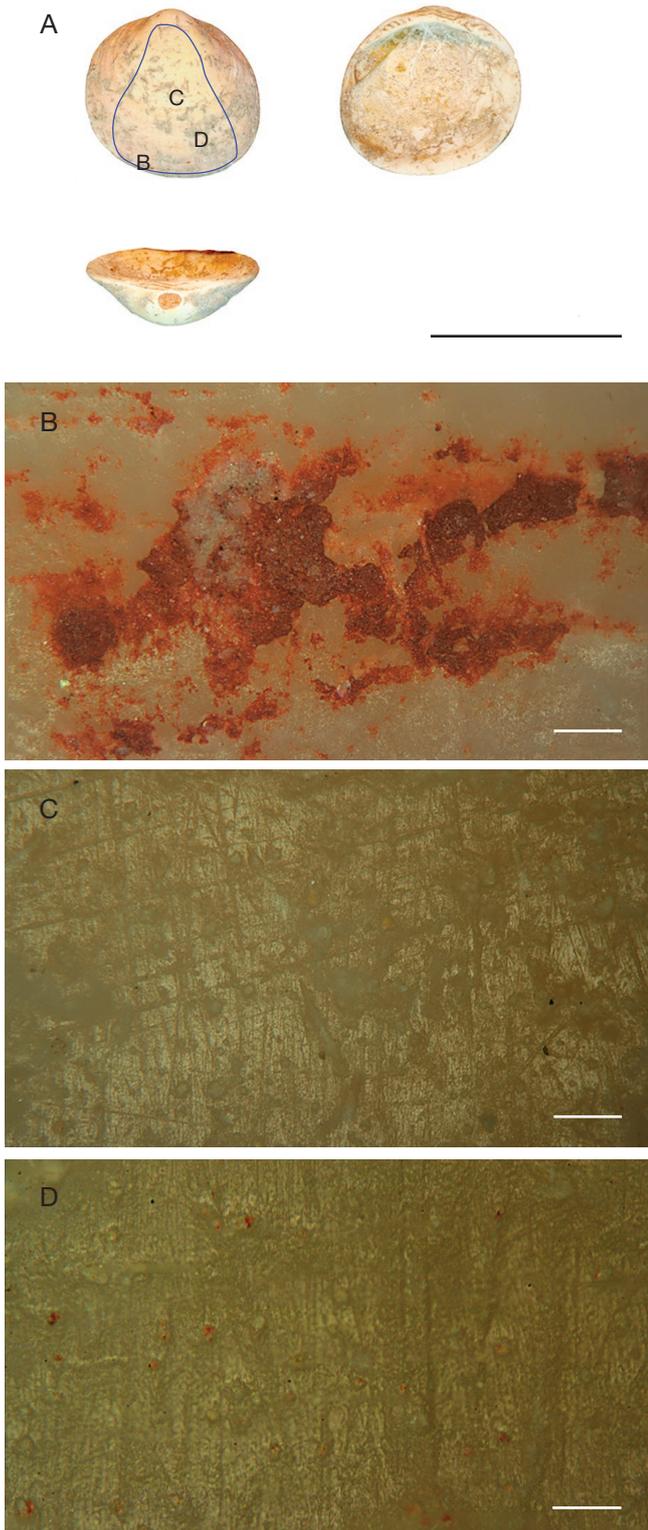


FIG. 10. — **A**, Archaeological shell with use-wear traces (**C-D**) and red-dye traces (ochre?) (**B**) on the dorsal face (Cuccuru s'Arriu, Cabras, Italy) related to contact with a mineral matter, clay. Scale bars: A, 5 cm; B, C, D, 100 µm.

and an irregular contour, on the higher zones. This zone also presents small circular depressions. These traces could correspond to the scraping of a harder mineral material than clay.

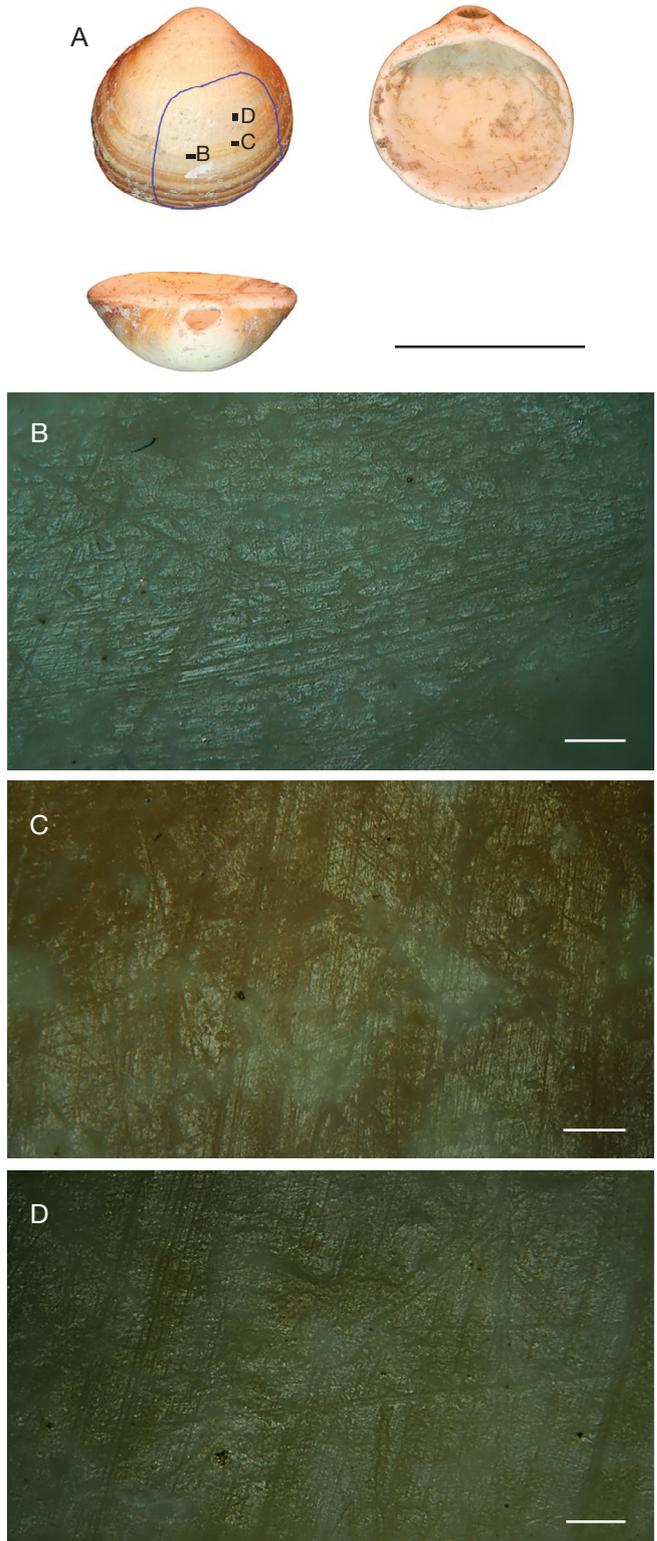


FIG. 11. — **A**, Archaeological shell with use-wear traces (**B-D**) on the dorsal face (Cuccuru s'Arriu, Cabras, Italy) related to contact with a mineral matter, clay. Scale bars: A, 5 cm; B, C, D, 100 µm.

A second valve presents mineral colouring residues on the ventral face, near the upper edge (Fig. 14B); the polish and the scratches located near the higher edge of the dorsal face

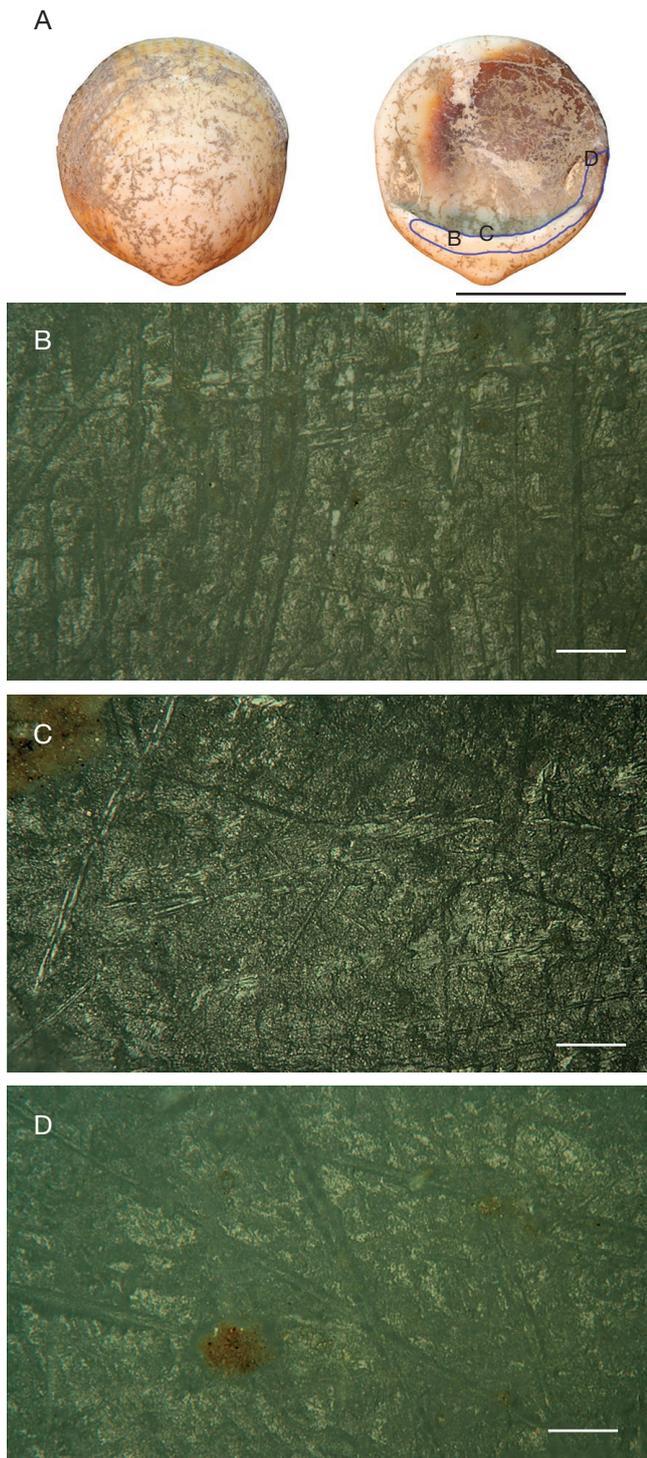


FIG. 12. — **A**, archaeological shell with use-wear traces (**B-D**) on the ventral face (Cuccuru s'Arriu, Cabras, Italy) related to contact with a mineral matter: utilization as a container for mixing mineral substances. Scale bars: A, 5 cm; B, C, D, 100 µm.

are however not linked to an activity with ochre or mineral substances. These traces are not developed enough or sufficiently characteristic (Fig. 14C) to be attributed with certainty to one of the experimental activities of our comparative corpus.

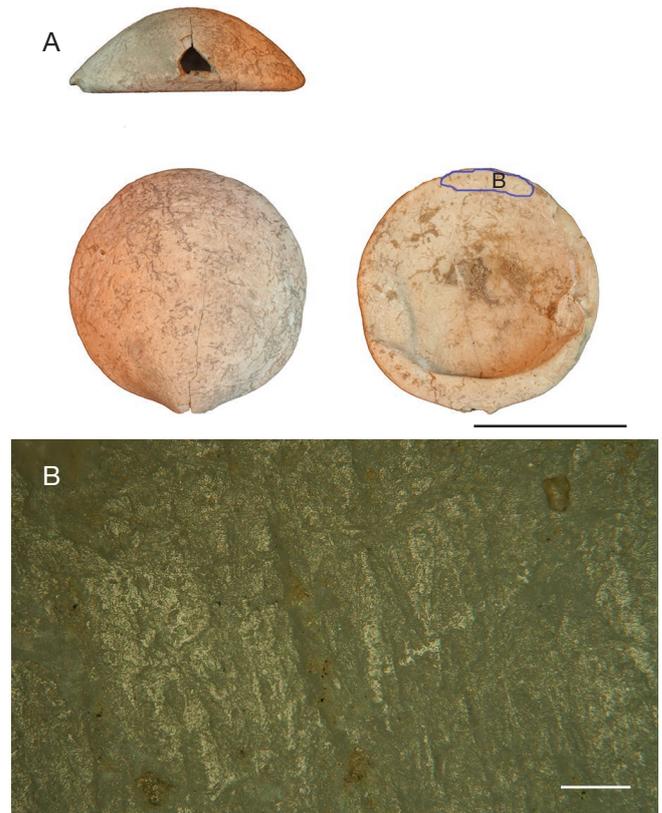


FIG. 13. — Archaeological shells with use-wear traces on the ventral face (Cuccuru s'Arriu, Cabras, Italy) related to contact with an indeterminate mineral matter. Scale bars: A, 5 cm; B, 100 µm.

Nevertheless, the absence of perforation and the localization of the residues seem to imply that the presence of the dye is not related to the decoration of the valve, or its use as a pendant or decorative object. We can thus assume that the valve may have been used as a small container to mix dye for a short period of time. We saw, through our experiments, that this activity leaves very few traces, even after 30 minutes or one hour of use. This is however only a supposition.

The contact with medium-soft material (soft woody plant matter, dry skin) is observed on the edge of two valves (Fig. 14C, E-H; Fig. 15).

A large-sized *Glycymeris* valve (70 mm long, 71 mm wide and 22 mm thick) presents a hole of natural origin on the umbo (Fig. 14D). Traces of use are localized on the upper edge, in a central position, over a length of 30 mm. Correspondingly, the traces develop over a few millimetres from the edge towards the ventral face of the valve. This localization indicates that the valve was used at a vertical or slightly oblique angle.

The traces (Fig. 14H) extend over the whole width of the edge. They are characterized by a polish on the homogeneous zones of the microtopography with a regular rounded micro-relief and a tight fabric and by very fine scratches of medium to superficial depth. The latter are parallel to each other and are perpendicular in relation to the completely blunted working edge. The polish on the ventral face is particularly marked

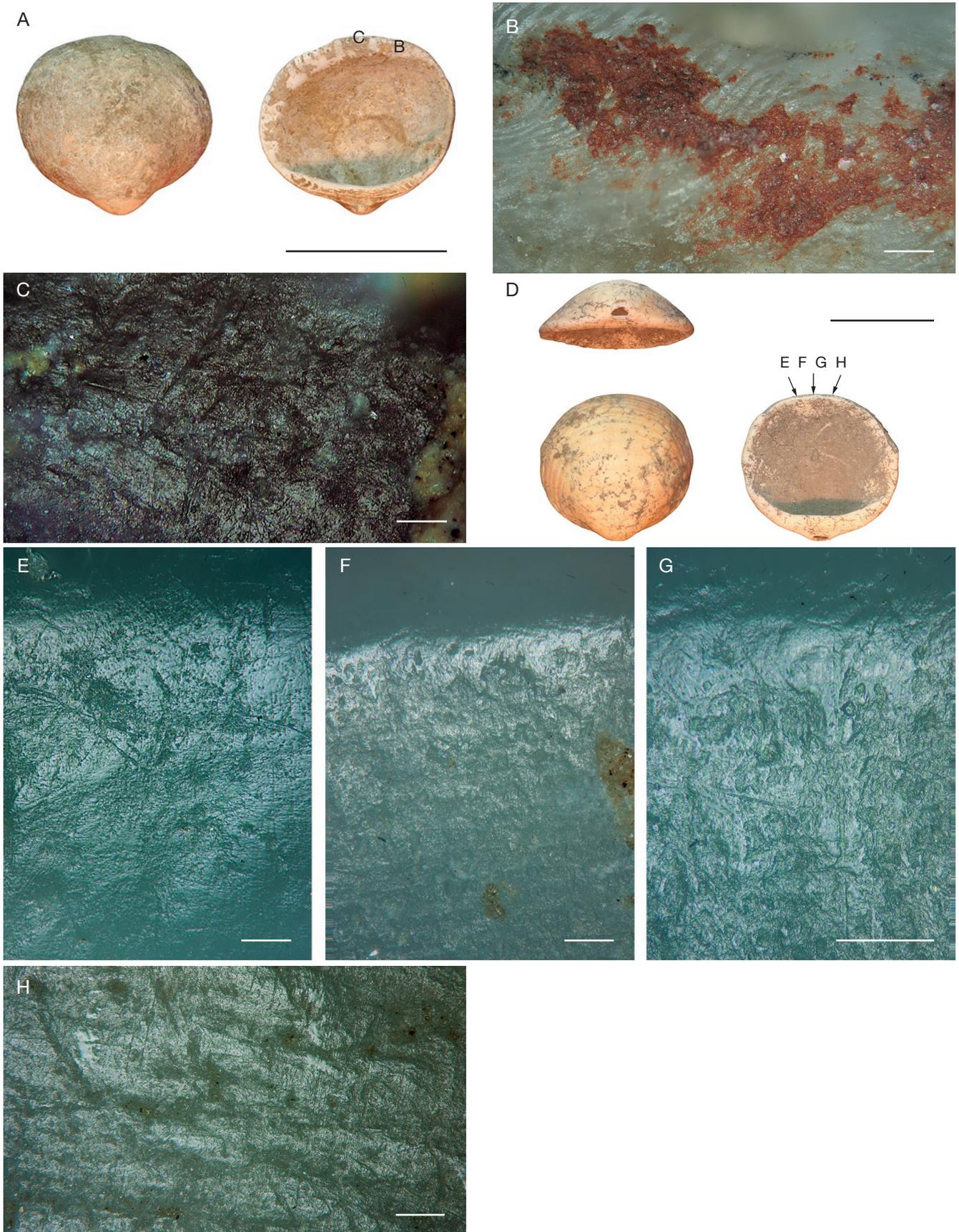


FIG. 14. — **A**, archaeological shells with use-wear traces on the edge (Cuccuru s'Arriu, Cabras, Italy); **B**, valve with mineral colouring residue on the ventral face, near the upper edge; **C**, indeterminate use-wear traces; **D**, valve with use-wear traces (**E-H**) related to contact with plant matter. Scale bars: **A**, **D**, 5 cm; **B**, **C**, **E-H**: 100 μ m.

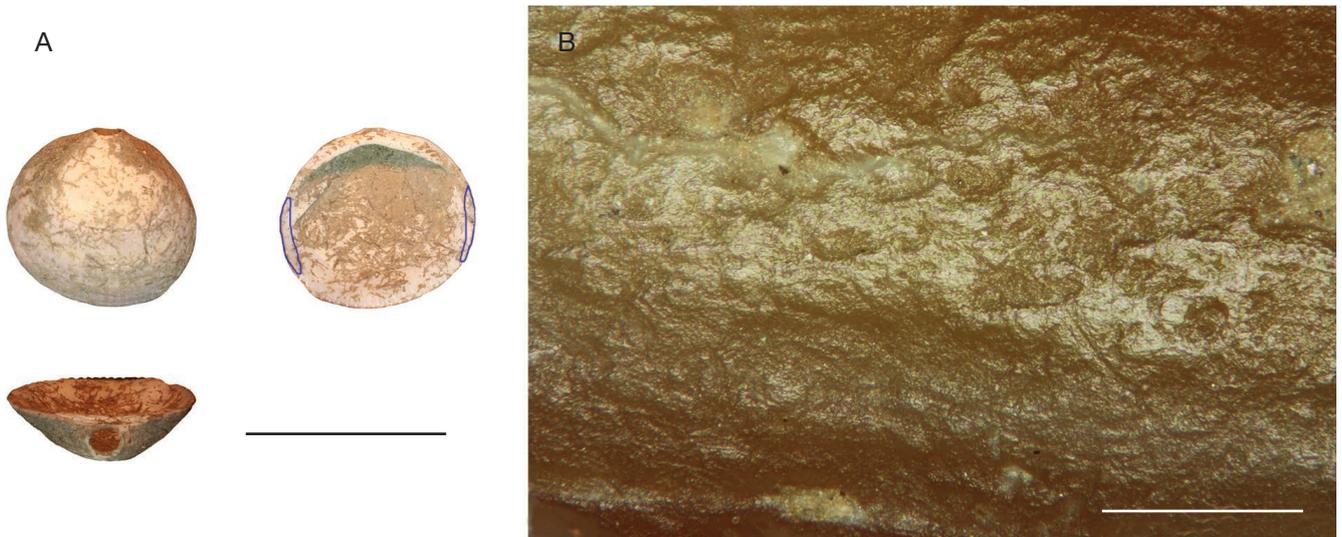


FIG. 15. — **A**, archaeological shells with use-wear traces on the edge (Cuccuru s'Arriu, Cabras, Italy); **B**, use-wear traces related to contact with plant matter. Scale bars: A, 5 cm; B, 100 µm.

on the edge and diminishes towards the interior of the valve (Fig. 14F). The scratches only affect the part nearest the edge and are more randomly oriented (Fig. 14E). The other characteristics are identical to those described on the edge. The morphology of the polish and the scratches are similar to the traces produced in experiments by working plant materials (polish and scratches located on the edge) and those produced by friction against more supple materials, such as skin (ventral face: more invasive polish, rarer scratches). There is no doubt that the comparative corpus used for the analysis of the archaeological remains is not yet sufficiently rich to accurately interpret all the traces. Nevertheless, it was possible to identify the active part and, in a generic way, the material with which it was in contact: in this case, one or several soft and medium-hard materials.

The second valve presents traces on the higher edge and the ventral face as well as on the side edges (Fig. 15). The polish affects the heterogeneous microtopography with a regular rounded microrelief and presents a tightened fabric, with a glossy surface and rare very fine scratches.

One of the two shell valves presented traces related to suspension as well as traces caused by friction with other materials. The latter are comparable to those obtained by smoothing fresh clay (Fig. 16C, D). These traces are localized on an extended zone of the dorsal face, and are parallel or slightly obliquely oriented in relation to the longitudinal axis of the valve. The characteristics of the polish suggest prolonged use because they are similar to those produced during 15 minutes of activity. The scratches are parallel, of variable thickness and depth, and transversely oriented, indicating the direction of the gesture. The hinge and the umbo present a polish and scratches indicating the suspension of the shell.

The second valve bears traces of bifacial use: they occupy a semi-circular part of the valve, parallel to the higher edge of the valve on the dorsal face, and extend towards the centre of the

valve with a more significant depth in the central part. They extend a few millimetres from the edge of the ventral face, only covering one linear zone out of 1 centimetre (Fig. 16E). These traces remain unspecified.

DISCUSSION

CONTRIBUTION TO SHELL INDUSTRY STUDIES

Our study is part of recent scientific research on use-wear traces on shells (Mansur & Clemente-Conte 2009; Cuenca-Solana *et al.* 2010, 2013, 2015; Tumung *et al.* 2015), and brings new elements concerning the Glycymeridae family: *Glycymeris glycymeris* (Linnaeus, 1758), *Glycymeris pilosa* (Linnaeus, 1767) and *Glycymeris nummaria* (Linnaeus, 1758).

The macroscopic and microscopic observation of the natural valve surfaces resulted in the identification of parameters for distinguishing natural microscopic traces from human-made ones: localization, texture and fabric of micro-polishes and the localization, density and morphology of striations. The valves of this species have a crossed-lamellar structure, with high density and rigidity, and moderate resistance to deformation and to hardness (Taylor & Layman 1972). Due to these features, scraping or smoothing soft or medium-hard materials leaves practically no macrotraces, and only microscopic analysis can help to characterize use-wear traces. The valves were used for various activities on different raw materials (animal, plant and mineral materials), and the combination of a low-power approach using a metallographic microscope and a medium-power approach with stereomicroscopic observations, led to the characterization and differentiation of the micro-polishes and striations resulting from the various activities.

The experimental use-wear observed on valves used for processing skin generally consists of a bright polish with a compact fabric and an invasive extension associated with

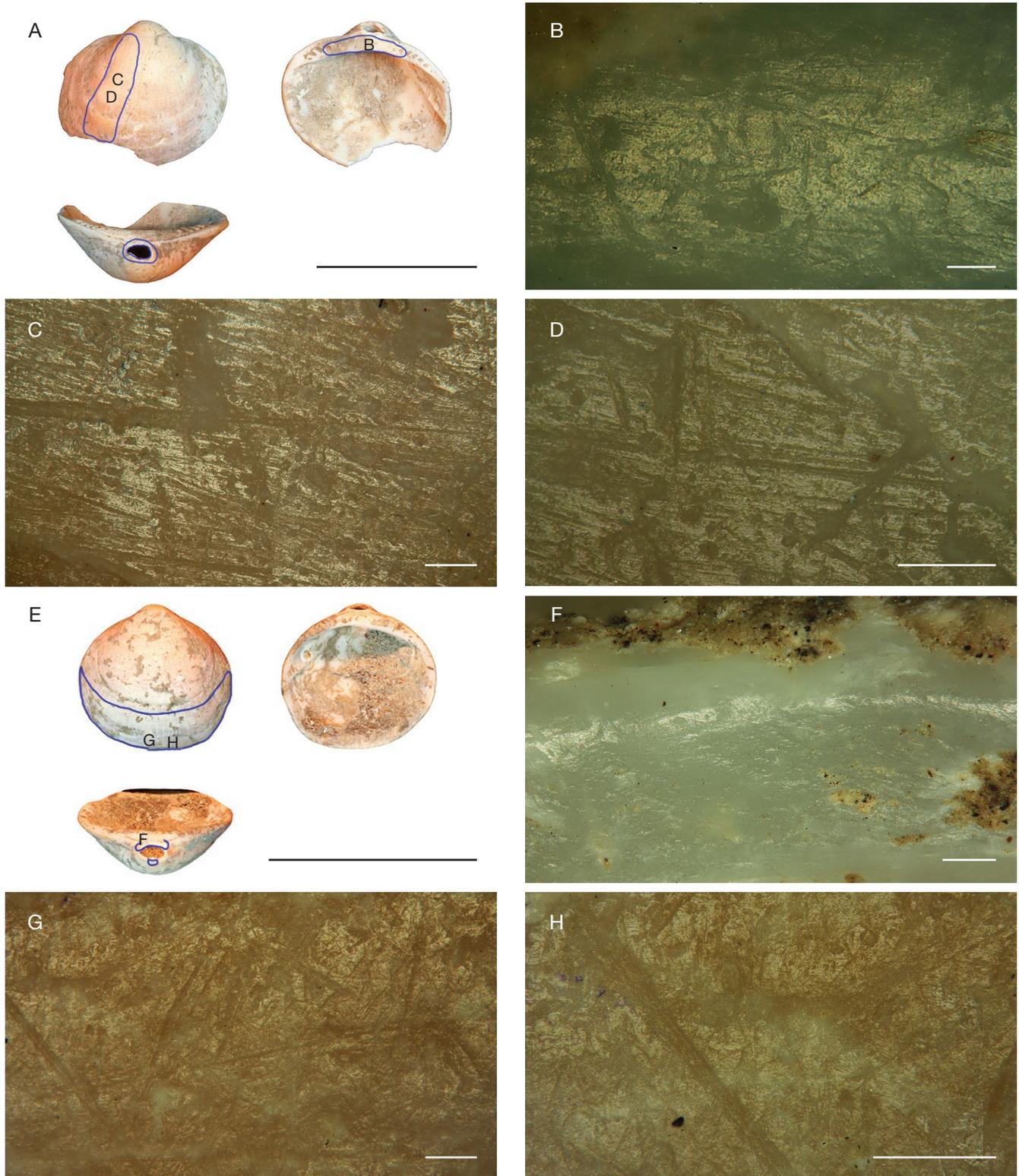


FIG. 16. — Archaeological shells with use-wear traces on the edge (Cuccuru s'Arriu, Cabras, Italy). **A**, valve with use-wear traces (**B**, **C**, **D**) related to contact with a mineral matter, clay; **E**, Valve with use-wear traces (**F**, **G**, **H**) related to the contact with indeterminate mineral matter. Scale bars: 100 µm.

long striations. The differences observed between the use-wear traces produced during the softening and scraping of dry skin include a more regular surface and more variability in the width and depth of striations for the softening activity.

The scraping of dry skin with the addition of ochre tends to increase the width and depth of the striations, which present irregular edges, making the surface slightly grainy. Processing plant materials results in use-wear traces characterized by a

grainy polish generally only extending to the areas in direct contact with the worked material when the woody material is hard and dry (wood, flax), and extends over a much larger surface, using the same working angle, when the material is soft and fresh (bark, rush). The same characteristics appear to have induced a higher degree of surface erosion for the valves used for working wood and flax. The striations also present unusual characteristics: they are generally superficial and short, but are denser, deeper and longer after processing boxwood and flax wood. The use-wear traces produced by processing mineral materials are characterized by a dull, nearly opaque polish, and by the presence of long, deep and intersecting striations.

Although these preliminary results are very promising, these experiments are currently limited in terms of variants (processing activities, inclination of tools in relation to the worked surface, working time), and in terms of the number of valves used for each experiment and the *taxa* considered for working animal and vegetal materials. These should be multiplied and increased in order to characterize use-wear traces with greater precision.

THE ROLE OF THE SHELL INDUSTRY IN THE EXPLOITATION OF MARINE RESOURCES: NEW ACQUISITIONS IN THE FINAL NEOLITHIC IN SARDINIA

The first evidence of the presence of shells collected for non-food purposes at the Cuccuru S'Arriu site was recorded during archaeozoological studies of Middle Neolithic remains from the first occupation phase of the site (Bignon *et al.* 2008). Later, the discovery of a large number of shells in the Final Neolithic fauna raised questions as to the role of these remains in the socio-economic activities of these Neolithic groups. The results obtained from the analysis of natural shells and their comparison with the experimental and archaeological valves showed that some shells collected for non-food purposes were used as tools. The valves bear use-wear traces indicating various production activities: smoothing fresh clay, processing plant, animal and mineral materials and the use of valves as containers for mineral materials. These results thus confirm the initial assumption that valves were collected for purposes related to the shell industry.

During the late Neolithic, the inhabitants of the Cuccuru S'Arriu site exploited other raw materials of animal origin, such as bone and antler (Manca 2013). The former is extremely important for the production of sharp instruments and, to a lesser extent, for the production of blunt objects. In contrast, all of the tools used for scraping and smoothing are almost exclusively obtained from shells. This raw material also presents specific characteristics at all stages of the technical production system, from acquisition to use. Bone and horn raw materials are obtained through breeding (for domestic species) and hunting (for wild species), whereas shell valves are acquired by collecting them on the shoreline.

Valves could have potentially been collected in the vicinity of the site, on the beaches of the central-western coast of the island. Valves of the Glycymeridae family were identified on Pesaria beach, to the south of the current city of Oristano and

at three other beaches located outside the Gulf (Spano *et al.* 2002, pers. obs.): Tharros (Tharros West), San Giovanni di Sinis and Su Maimoni (Fig. 1). The location of potential collection zones contributes to the identification of the territories frequented by the inhabitants of Cuccuru s'Arriu. However, the introduction of these raw materials to the site may also result from exchanges with other communities: archaeological evidence on the Sinis Peninsula points to an area of intense attendance during Ozieri I (Stiglitz 1998: 30; Melis 2011). In any event, we can consider that, unlike bone raw materials, shells are available outside the site and therefore access to them is not direct. In addition, from an economical point of view, valve collecting requires a certain investment in terms of human resources.

However, the technical investment for the production of finished shell objects is minimal. On account of the characteristics of the raw material (morphology, hardness and resistance), the valves are suitable for productive activities without extensive modifications. Direct shell shaping only concerns rare cases (20 pieces out of 65), and modifies the active part of the valve, the edge, by abrasion or direct percussion (for technical vocabulary see Averbouh 2000, 2001, 2010). This transformation concerns the valves with no use-wear traces (11 pieces out of 33), with abrasion marks on the edge (1 piece), for creating a side-scraper or for the perforation of umbo (10 pieces). Moreover, the valves used as ornamental objects (5 pieces out of 20) and those used as tools (4 pieces out of 12) present marks showing anthropogenic perforation. The first case (presence of technical marks and absence of use-wear traces) can be explained by two hypotheses: the first is based on the state of preservation of the pieces, that is, the non-preservation of use-wear traces; the second, on the transformation of the raw material during a previous phase of use. The second case (anthropogenic perforation and use of valves as ornamental objects) detects a compatibility between transformation and use. The third case (anthropogenic perforation and the use of the valve as a tool) suggests that for certain valves, the primary objective is not transformation (perforation, then suspension), but the secondary use of shells as tools. This suggests that certain valves could have been transformed and stocked as raw material reserves and used occasionally for purposes other than those for which they were initially collected and shaped.

This hypothesis is supported by economic aspects connected to raw material productivity: each valve can only produce one tool or one ornamental object. This low productivity is accentuated by the availability of the raw material (the shells are not renewable directly on the site).

These elements converge to define the techno-economical aspects of the Glycymeridae industry and provide important data concerning the management of marine resources. It is also important to bear in mind that the accessibility of collection areas is not the only factor to consider in determining raw material availability. Supply rhythms and raw material management in the society must also play an important role. We do not know who collected the valves, when or how this type of resource was distributed. As for supply rhythms, no

archaeozoological or palynological data point to a seasonal use of the site of Cuccuru s'Arriu, although this hypothesis is advanced for the Middle Neolithic phase (Bignon *et al.* 2008).

CONCLUSIONS

The identification and analysis of *Glycymeris* shells bearing natural erosion marks among the faunal remains of Cuccuru s'Arriu show the techno-economic importance of this industry in Final Neolithic societies. This analysis also enhances our knowledge of the exploitation of marine resources and raises question as to the accessibility and availability of shell materials, the potential exploitation of territories and potential exchanges between groups. These data illustrate the relationship between the inhabitants of a site near the coast, and show the necessity of extending these studies to other inland sites in order to define the role of the shell industry on this insular island during the Final Neolithic and successive phases (Manca 2014).

On a wider scale, these initial results call for more detailed analyses of the shell industry in the western Mediterranean in order to define their relationship with other technical systems and their role in the technical and economic activities of prehistoric societies, at a regional and trans-maritime level.

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