Shell tools and productive strategies of hunter-gatherer groups: Some reflections from a use-wear analysis at the Balma del Gai site (Barcelona, Spain)

David Cuenca-Solana, Ignacio Clemente-Conte, L. Lloveras, P. García-Argüelles, J. Nadal

Highlights:

1) Broaden the technological spectrum linked with the Epipalaeolithic hunter-gatherers.

2) Demonstrate a diversified use of the shells as adornments, food and tools also in archaeological contexts located some distance from the coastline

4) Correlation among the different technological elements that make up the hunter-gatherers' toolkits, through global analysis of the different types of elements that compose them.

5) From a methodological point of view, demonstration of the potential of use-wear methodology to reconstruct the productive strategies of human groups.

Shell tools and productive strategies of hunter-gatherer groups: some reflections from a use-wear analysis at the Balma del Gai site (Barcelona, Spain).

David Cuenca-Solana

Instituto Internacional de Investigaciones Prehistóricas de Cantabria. (Universidad de Cantabria, Gobierno de Cantabria, Grupo Santander). Universidad de Cantabria. Edificio Interfacultativo, Avda. Los Castros s/n.º 39005. Santander, España.

Centre de Recherche en Archéologie, Archeosciences, Histoire (CReAAH), UMR-6566, Rennes (Francia). cuencad@unican.es

Ignacio Clemente-Conte

Arqueología de las Dinámicas Sociales. CSIC- Institución Milá y Fontanals (IMF). ignacio@imf.csic.es

Lluís Lloveras

SERP. Secció de Prehistòria i Arqueología. Universitat de Barcelona.

lluislloveras@ub.edu

Pilar García-Argüelles

SERP. Secció de Prehistòria i Arqueología. Universitat de Barcelona.

garciaarguelles@ub.edu

Jordi Nadal

SERP. Secció de Prehistòria i Arqueología. Universitat de Barcelona.

jordinadal@ub.edu

Abstract

Balma del Gai site is a small rock shelter situated in the municipality of Moià (Barcelona, Spain) at an altitude of 760 metres above sea level and 50 km from the current coastline. The levels of occupation in this context are dated between 13,442 cal BP and 9,552 cal BP, being related to the so-denominated "Epimagdalenian" and "Microlaminar Sauveterroid" complexes. The excavations have provided important mollusc samples, both terrestrial and marine, which have been studied and considered alimentary and adornment resources. In this article, we present the results of the use-wear analyses of the shell tools of *Mytilus galloprovincialis* Lamarck, 1819 and *Glycymeris glycymeris* (Linnaeus, 1758). The results of these analyses and their comparison with analytical experimentation demonstrate that some of these shells were

used as tools for developing diverse productive activities related to the processing of materials of animal, mineral and vegetal origin. In this way, this research contributes to: 1) broaden the technological spectrum registered in this context and in a wider sense for Epipalaeolithic hunter-gatherers (beyond the traditional technological elements), 2) demonstrate a diversified use of the shells as adornments, food and tools in the site; an aspect of great interest especially bearing in mind the distance from the coast.

Key words: Shell tools, use-wear analysis, Epipalaeolithic, hunter-gatherers, Mediterranean coast, perishable materials.

Introduction

The Balma del Gai site is situated in the municipality of Moià (Province of Barcelona, Northeastern Iberia; 2º 08'19" E; 41º 49' 00" N). It is a small rock shelter of 10 metres in length and 5.5 metres in depth, some 760 metres above sea level and nowadays some 50 km from the coastline (Fig. 1). The site is located in a high plateau landscape and it is set among some cliffs, where a stream that shares its name with the rock shelter flows. The archaeological site was discovered in the mid of 1970s by Joan Surroca and was excavated almost immediately during a short period of two years. Later, programmed excavations were carried out until 2016 (Nadal et al., 2017). The sedimentary thickness of the archaeological site is poorly developed and its stratigraphy is simple: it is formed by three levels, the highest (superficial level), with scrambled materials from previous phases and a palimpsest of protohistoric and historic occupations up to the seventeenth century, level I, which is of interest in this study, concentrates different phases of the Epipalaeolithic occupation, which will be commented on, and lastly level II, which is an accumulation of gelifracts precedent from the alteration of the rock shelter wall and which must have been formed in a very cold period at the end of the Pleistocene, and which is archaeologically sterile (Bergadà, 1998).

Figure 1. a) Localization of Balma del Gai. b) Planimetry of the archaeological intervention at the site. C) General view of the rock shelter. d) Diagram showing the stratigraphic development established through the archaeological intervention at the site.

With respect to the level of our focus, level I, the occupations took place between the second half of the XIV millennium and the end of the XI/beginning of the X millennium before present, in calibrated dates (Table 1). During the Epipalaeolithic the existence of two clearly delimited phases has been observed, one older, traditionally defined as the Microlaminar complex is characterized by the presence of micropoints and backed bladelets, and a later one, the

Geometric complex (*facie*s Filador) (García-Argüelles et al., 2013), in which the previous elements were substituted by geometrical microliths –triangles and segments- obtained using the microburin technique. After recent studies, it seems that this division was not so radical and in fact the second period did not suppose a substitution of techno-elements but a minor incorporation of the geometric component into the existing microlithism, so it would be better to speak of two *facies* with no clear discontinuity: Epimagdalenian and Microlaminar Sauveterroid (Román, 2012). This is totally corroborated at the Balma del Gai, where, during the last stage of occupation (from -140 cm to the top of level 1, see figure 1: d), some geometrical microliths were incorporated without there being changes in other aspects such as economic strategies or the areas where raw materials were accessed (Nadal et al., 2017).

Table1. Datings obtained for the site and their chrono-cultural attribution according to lithic typology. Calibrations of datings was done using the IntCal20 Northern Hemisphere curve (Reimer et al., 2020)

Balma del Gai is remarkable for the good preservation of the organic material, and the faunal remains. As for vertebrates, the most abundant species is rabbit-*Oryctolagus cuniculus* (Linnaeus, 1758)-, with thousands of remains which were clearly introduced into the site by anthropogenic action destined to food and use of skins (García-Argüelles et al., 2004; Lloveras et al., 2011a; Rosado-Méndez et al., 2019). Other larger species are represented by ungulates, among which, the most abundant are red deer -*Cervus elaphus* (Linnaeus, 1758)- followed by small bovines -*Rupicapra rupicapra* (Linnaeus, 1758) and *Capra Pyrenaica* (Linnaeus, 1758)-, and wild boar -*Sus scrofa* (Linnaeus, 1758)-, and by carnivores, with remains of Iberian lynx *Lynx pardinus* (Temminck, 1827), wild cat -*Felis silvestris* (Schreber, 1777)- and fox -*Vulpes vulpes* (Linnaeus, 1758)- (Volart et al., 2014; Nadal et al., 2017). Molluscs should have special mention. At the site, in terms of anthropic contributions, large numbers of shells of continental snails and some marine species have been recovered. The continental ones are represented almost exclusively by a large accumulation of *Cepaea nemoralis* Linnaeus 1758. The taphonomic studies and the parallel archaeological ones lead to the interpretation of this accumulation as a result of collection for alimentary purposes (Estrada et al., 2009; Lloveras et al., 2011b). Likewise, there are samples of marine origin, represented by scaphopods, bivalves and gastropods. Although the remains are not very abundant, the distance of the site from the coastline and the taxonomical variability of the assemblage, make them especially interesting. Among these, *Antalis vulgaris* (da Costa, 1778), *Antalis dentalis* (Linnaeus, 1758), *Pecten jacobaeus* (Linnaeus, 1758), *Mytilus galloprovincialis*, *Glycymeris nummaria*, *Glycymeris glycymeris* (as well as elements of *Glycymeris* sp., which have not been specifically determined), *Tritia neritea* (Linnaeus, 1758), *Trivia costulata* (Gmelin, 1791), *Tritia reticulata*

(Linnaeus, 1758) and *Columbella rustica* (Linnaeus, 1758) have been identified (Estrada et al., 2010). Although most of the remains, especially the gastropods and scaphopods, can be considered elements used as ornamentation, in some bivalves, no modifications have been detected for that use, so they are considered suitable for use-wear analysis. The main goal of this study focuses on the analysis and interpretation of these marine malacofaunal remains, particularly on the shells that do not present modifications to be considered as personal ornaments. Through detailed examination of use-wear traces we will show that at least some of these shells were used with technological purposes. Furthermore, the use of these elements in a hunter-gatherer's site located far from the current coastline is interpreted in a social-cultural key.

1. Material and methods

While carrying out this research, all the marine bivalve fragments and complete shells collected in the different interventions at the site were analyzed. Therefore, in this analysis we will ignore the marine gastropods and scaphopods, collected with a purpose oriented to the manufacture of elements for adornment, as is supported by the presence of several elements of this type at the site (Estrada et al., 2010). The species nomenclature applied in this study was that proposed by the World Register of Marine Species (WoRMS, http://www.marinespecies.org/).

The possibility of successfully carrying out an analysis of use-wear depends directly on the state of preservation of the samples under study. In this sense, the shells analyzed presented an adequate state of preservation, which has enabled their successful study. Only some of the samples, especially the *Glycymeris glycymeris* shells, presented concretions that covered important parts of their surface. Several of these were cleaned for 50 minutes using an Ulsonix Proclean 2.0 ultrasonic cleaner using soap and water. This cleaning is oriented to remove these concretions and did not produce any degradation of the surfaces of shells analyzed by use-wear methodology.

On the whole, a total of 30 shells, 18 of *Glycymeris glycymeris* and 12 of *Mytilus galloprovincialis*, were studied through use-wear analysis methodology (Semenov, 1964) (Table 2). That is, observing them macro and microscopically to document the alterations generated through the use of these shells as tools and analysing them experimentally to verify or refute the interpretation of these traces. To perform the analysis, a binocular Leica S8APO lens was used to search for macro-polishing, abrasions, rounding and scars. Moreover, a Leica DM2500M metallographic microscope was used to identify the micro-polishing and striations of use and to determine, when possible, how (movement and/or action) and what material was processed with these tools. For documentation of these use-wear traces a Leica MC190HD Camera was adapted

for both devices. In this way, the sample was studied using high and low magnifications between 10X and 400X (Cuenca-Solana et al., 2017).

To interpret the use-wear traces, we used the results obtained from different analytical experimental programmes carried out in the last years (Cuenca-Solana, 2010, 2013, 2015, Cuenca-Solana et al, 2013, 2015, 2016a, 2016b). This analytical experimental program comprising more than 150 experiments oriented to process mineral (ocher, shells or clay), vegetable (wood and plant non wood) and animal (skin, leather and fish, among others) matters using shell tools. Also, the aim of some of these experiments has been to understand and describe the influence of different taphonomic processes in the preservation of shell surfaces.

Table 2. Shell taxa from Balma del Gai analyzed through use-wear methodology.

2. Results

The use-wear analysis of the 30 shells from the Balma del Gai site enabled the documentation of the confirmed use of 8 of them and the probable use of another 2 specimens (Table 3). Specifically, the fragment of *Glycymeris glycymeris* #525 and the fragments of *Mytilus galloprovincialis* #1329, #234, #131, #47, #173, #114 and #416 were determined as a tool. A probable use was shown for the fragment of *Glycymeris glycymeris* #82 as well as the fragment of *Mytilus galloprovincialis* #C1. Furthermore, another 3 shells of *Glycymeris glycymeris* (specimens #147, #160-165 and #174) also showed traces linked to their use. However, in these cases the disposition and characteristics of traces, along with the presence in the 3 pieces of perforations made in the umbo zone, seem to link these shells to probable use as personal ornaments.

Table 3. Functional interpretation of the shell tools documented at La Balma del Gai site.

The level of development of the use-wear on two probable tools (#C1 and #82) has not enabled us to link their use with any activity or a specific worked material. In both cases, we can only indicate that they were probably used to process a medium-hard material with a transverse action, in the case of piece #82, and interleaved transverse and longitudinal actions in the case of piece #C1 (Table 3).

Nevertheless, it was possible to establish deeper interpretations about the functionality of the other shell tools. We have documented the use of tools to process material of animal, vegetal and mineral origin. As for the tools used to process material of animal origin, the use-wear traces documented on the *Glycymeris glycymeris* #525 shell indicate its use to be linked with a dry or semidry skin-processing activity. This functional interpretation is based on the

characteristics presented by the traces on the edge of the shell that has served as active zones. Therefore, in this case, the use-wear traces are characterized by the presence of polishing with a rough, not very greasy aspect, with a matt sheen. Small, short and irregular striations can be observed on the inner face, mostly with an orientation perpendicular to the edge. The presence of semicircular micro-holes that accentuate the roughness of the surface should also be highlighted. Likewise, at microscopic level, some small ochre stains can be seen. In addition, the distribution of the use-wear traces on the edge indicates that there is a significant chance that this shell was fractured during its use.

Moreover, 4 fragments of *Mytilus galloprovincialis* present use-wear traces which enable us to link their use to the processing of mineral material, although with some slight differences. The fragments of *Mytilus galloprovincialis* #47 (Fig. 2) and #114 present a shiny and compact micro-polishing with great development of very chaotic striations, oriented predominantly transverse to the edge, and to a lesser extent also longitudinal and oblique. The characteristics of the use-wear traces relate this piece to use oriented to scraping a mineral material, probably ochre, through a principally transverse action.

Fig. 2. Fragment of *Mytilus galloprovincialis* #47 (above) and detail of the use-wear traces (below) interpreted as generated by scraping of a block of ochre at 100X. Scale 3cm.

Pieces #1329 and #416 (Fig.3) present a less shiny polishing than fragments #47 and #114, with a lesser degree of striations and on the contrary a greater presence of micro-holes developed on the inner face of the shell that has functioned as the driving face during its use. In this case, this piece could be related to the processing of a mineral material, but probably in contact with skin. Thus, we consider that these 2 working tools could have been used to spread ochre on a skin during the leather tanning process.

Fig. 3. Fragment of *Mytilus galloprovincialis* #416 (above) and detail of the use-wear traces (below) interpreted as generated by for spread ochre on a skin at 200X. Scale 3cm.

Moreover, it was possible to reassemble 2 of the pieces analyzed, as both were part of the same shell before fracture. These were the fragments of *Mytilus galloprovincialis* #234 and #131 (Fig. 4), which present in their respective active zones, localized on the edge of the shell, use-wear traces linked to an activity oriented to processing vegetal origin material. Specifically, both pieces present quite penetrating polishing, rough, slightly shiny and closed, with some more compact zones. Furthermore, multidirectional and irregular striations have been documented on these pieces, always with a dark bottom. Taking into account all these characteristics of the use-wear traces, these fragments would have been used, before fracture of

the shell, to extracting or stretching vegetable fibres, through scraping, in predominantly transverse actions, maybe on a hard surface like a stone, which would have generated roughness and more compact micro-polishing in specific areas of these tools.

Fig. 4. Fragment of *Mytilus galloprovincialis* #131(above) and detail of the use-wear traces (below) interpreted as generated by for scraping, stretching and/or extracting fibres through transverse actions at 100X. Scale 3cm.

Finally, another fragment of *Mytilus galloprovincialis* also showed evidence of use oriented to processing a material of vegetable origin, although with distinct characteristics. It is piece #173 (Fig. 5), which presents, in its active zone, compact micro-polishing, with a remarkable presence of multi-striated zones principally oriented transverse to the edge, in which the external face of the shell was used. At the macroscopic level, there is an accentuated rounding of these edges, with deep striations and scars. Evaluating these characteristics, based on the experimental work carried out (Cuenca-Solana, 2013), we consider that this shell fragment of *Mytilus galloprovincialis* would have been used to smoothen and/or polish hard wood.

Fig. 5. Fragment of *Mytilus galloprovincialis* #173 (below) and detail of the use-wear traces (above) interpreted as generated by for smoothening and/or polishing hard wood, at 100 and 200X.

3. Discussion

The results obtained after use-wear analysis of the malacological collection of Balma del Gai provided information to establish a more complete interpretation on the productive activities of the human groups who occupied this context during the Epipalaeolithic. One of the first aspects to be highlighted is that 30% of the marine bivalves found in the site were used as tools. In this way, 10 of the 30 remains of marine malacofauna analyzed present use-wear traces that enabled their use to be confirmed. In relation to this aspect, the presence of several shells collected *post mortem*, especially *Glycymeris glycymeris*, can be highlighted. This seems to indicate that this small set of marine shells was collected on the coast, located at some 50 Km from the rock shelter, and transported to the Balma del Gai exclusively oriented to their use as raw material for shell tools. This use of these marine resources as a raw material, also documented in other contexts of hunter-gatherers previously analyzed (Cuenca-Solana, 2013, 2015, 2016a, 2016b), implies planning relate in relation to the overall management of toolkits. All raw materials processed using shell tools in La Balma del Gai had already been previously identified in contexts located in the Iberian Peninsula. Thus, in this previous research it has been possible

253 recognize the use of these tools to processing mineral (ocher) (Cuenca-Solana et al, 2013;
254 2016a, 2016b), vegetable (wood and plant non-wood) (Cuenca -Solana et al., 2013, 2016b) and
255 animal materials (skin and leather) (Cuenca-Solana, 2013; Cuenca-Solana et al., 2013, 2015).
256 Moreover, the use of shell tools is documented at Balma del Gai in all the phases of occupation,
257 from XIV to X millennium before the present. This continuity with respect to the management
258 of these tools was maintained even with the progressive increase in lithic carving and
259 principally with the use of geometric microliths from the end of the XI millennium,
260 approximately. The constancy in the use of shell tools along all the archaeological sequence in
261 the site is one more evidence that supports the previously mentioned clear continuity in
262 subsistence and technology along the two Epipalaeolithic facies, the Epimagdalenian and the
263 Microlaminar Sauveterroid,. (Nadal et al., 2017).
264 With respect to the functional interpretation of these tools, the comparison with the results
265 obtained from different analytical experimental programmes carried out (Cuenca-Solana, 2010,
266 2013, 2015, Cuenca-Solana et al, 2013, 2015, 2016a, 2016b) enables the confirmation of their
267 use to effect different productive activities oriented to processing materials of animal, plant and
268 mineral origin (Fig. 6). In this sense, the data obtained through analysis of other evidence found,
269 especially fauna and anthracological remains, are also very coherent with this interpretation.
270 Thus, the presence of *Buxus sempervirens* in different periods of occupation of the site (Allué et
271 al., 2007), as well as the documentation of more than 15000 remains of *Oryctolagus cuniculus*,
272 many of them with cut traces directly linked to obtaining skin (Rosado-Méndez et al., 2019),
273 enable the relation of the use of these tools to some of the productive activities in this context.
274 Likewise, the result of our analysis indicates that the exploitation of at least a part of the more
275 than 270 remains of ochre found at la Balma del Gai (Estrada et al., 2011) could have been done
276 with shell tools.

277 Fig. 6. Shell tools from the experimental analytical program used to establish the functional
278 interpretation at La Balma del Gai. a) Detail of the use-wear traces generated on *Mytilus*
279 *galloprovincialis* shell use to spread ochre on skin at 200X. b) Use-wear traces on *Patella* sp.
280 shell generated by extracting and stretching fibres of *Juncus* sp. at 100X. c) Use-wear traces
281 generated on *Mytilus galloprovincialis* shell used to smoothen wood of *Buxus sempervirens* at
282 100X. d) Use-wear traces generated on *Mytilus galloprovincialis* shell used to scrape a block of
283 ochre to obtain powder at 100X.
284
285 Anyway, taking into account the results of our study and their relation to other evidence found,
286 fauna and anthracological remains, it seems that the shells of the Balma del Gai could have been
287 used to carry out actions oriented to the manufacture and production of elements linked to the
288 management and exploitation of skin, especially with the high quantitative presence of

Oryctolagus cuniculus. This link would have developed directly and indirectly through carrying out different productive activities. Thus, only the shell of *Glycymeris glycymeris* #525 could have been used directly to process skin. The low percentage of shell tools oriented to carry out this activity is explained from the preliminary results obtained in the use-wear study of lithic tools, that seem to indicate that the processing of skin was carried out principally through the use of these elements. (Mangado et al., 2006). These studies were mainly conducted on endscrapers and showed clear evidences that these tools were used for the processing of dry skins, specifically 75% of the identified use-wear marks indicated this activity (García-Argüelles et al., 2004). Moreover, the use of the fragments of *Mytilus galloprovincialis* #47 (Fig. 2) and #114 would have been oriented to obtaining ochre powder by scraping blocks of this mineral. Likewise, from the comparison of the results obtained in the experimental programme developed (Cuenca-Solana, 2013, Cuenca-Solana et al, 2013, 2016a, 2016b), we can interpret that the fragments of *Mytilus galloprovincialis* #1329 and #416 (Fig.3) could have been used to extend this ochre over the skins, during the leather tanning process. In this sense, other researchers have previously demonstrated the variety of techniques and materials used to carry out the leather tanning process (Beyries, 2008) both in ethnographic and archaeological contexts. The use of ochre as an additive to carry out this activity through the use of lithic tools has been documented through use-wear analysis in different archaeological contexts (Gijn, 1989; Ríos Garaizar et al., 2002, among others). The benefit of this use is based on the antiseptic characteristics of ochre, which contributes to better preservation of skin (Audouin and Plisson, 1982). From the viewpoint of use-wear analysis, the use of this additive to scrape skin is characterized, due to its abrasive character, by greater development of the micro-polish and rounding, and above all, greater presence of micro-holes on the surface of the tools used for this activity (Clemente, 1997; González Urquijo and Ibáñez Estévez, 1994; Vaughan, 1985).

Furthermore, the fragments of *Mytilus galloprovincialis* #234 and #131 (Fig. 4), used to extract and stretch vegetable fibres, and the piece #173 (Fig. 5), linked to the smoothening or polishing of hard wood, maybe could have been oriented to manufacturing infrastructures, such as string and wooden frames, necessary to stretch and tan skin. The importance of these tools resides in the possibility of demonstrating the use of perishable elements, such as vegetable fibres and wood, which are therefore only identifiable indirectly in this context.

On the other hand, the presence of seashells in inland sites that are not interpreted as decorative elements, because they do not present modifications for this purpose (*Glycymeris*) or because their use as a support for the manufacture of personal ornaments has never been detected, could be related to the relationship of these inland sites and synchronous occupations hitherto little known on the Mediterranean coast of the Iberian Peninsula. In fact, new discoveries as well as the revision of old excavated sites are showing that the Mediterranean hunter-gatherer settlements are more numerous than previously thought (Román et al., 2020). In addition, other

investigations have highlighted that the number of marine malacofaunistic specimens recovered in Epipaleolithic and Mesolithic sites from NE Iberia decrease in quantity and diversity as we move away from the seacoast. Lloveras et al. (2019) showed how the diversity keeps wide up to distances between 30 and 50 km from the current coast line. However, from these distances, the taxonomic diversity is reduced to a few species, mainly small gastropods and scaphopods, used exclusively with ornamental purposes. These data is consistent with the idea that hunter-gatherers that had direct contact with the seashore (e.g. during some months along the year, in seasonal camps) displayed more diversity and quantity of shells in their inland seasonal camps compared to the groups that only acceded to these items from interchange with other groups. In this sense, Balma del Gai behaves as those sites displaying great diversity of molluscs, as might be expected. The fact of finding shells that do not have an exclusive ornamental, but a technological purpose would reinforce the hypothesis that these groups did not obtain the marine shells indirectly by exchanges but directly in the coast, probably in seasonal coastal settlements situated in their annual range area. In Balma del Gai, we only have clear evidence of occupations corresponding to late summer or autumn, as evidenced by the growth stage of some of the red deer antlers recovered and the presence of charred blackthorn endocarps (Estrada et al., 2011). Besides, the great amounts of *Cepaea nemoralis* shells accumulated in the site, considered as result of gathering for human consumption also reinforce this idea, as the land snails would be active only in wet and cool seasons. In these coast sites, the molluscs also had a nutritional function. In the seasons that those communities moved to the inland sites, they would transport with them not only ornamental objects but also unmodified or scarcely transformed pieces, collected already dead from the coast or as by-products of food, for their technological use in the inland sites. In this sense, the identification of shell tools from inland sites is not unusual during the Palaeolithic and Mesolithic periods, since many of the sell tools used by hunter-gatherers groups are located at distances between 20 and 40 km from the coastline (Cuenca-Solana et al., 2015). In addition, from a taxonomic perspective the results obtained in La Balma del Gai show a preference for the use of two species of shells (*Mytilus galloprovincialis* and *Glycymeris glycymeris*) exploited more or less frequently during the Palaeolithic and the Mesolithic in the Mediterranean coast (Román et al., 2020). Furthermore, the documentation of shell tools of both species previously in other archaeological contexts (Courtin & Vigié, 1987; Gutiérrez Zugasti et al, 2011, Clemente & Cuenca-Solana, 2011, Manca, 2016, among others), and also the development of different experimental protocols (Tumung et al., 2015; Cuenca-Solana, 2013) show that shells of both taxa have a very suitable morphology and hardness for their potential technological use.

From the results obtained in this research and other studies previously carried out (Cuenca-Solana, 2013; 2015; Cuenca-Solana et al., 2013, 2016a, 2016b, among others) we can establish some reflections about the role of shell tools for the development of the productive strategies of

hunter-gatherer groups: a) Shell tools should be considered as part of the toolkits potentially used by hunter-gatherer groups. In this sense, in recent years there has been an increasing body of evidence of technological use of these marine resources that justifies this approach (Barton & White, 1993, Schmidt et al., 2001, Cristiani et al., 2005, Choi and Driwantoro, 2007, Jones and Keegan, 2001, Szabó et al., 2007; Szabó, 2008; Szabó and Koppel, 2015, Lammers, 2008, Mansur & Clemente-Conte, 2009, Douka, 2011, Douka & Spinapolice, 2012, Cuenca-Solana, 2013, 2015, Cuenca-Solana et al., 2013, 2016a, 2016b, Romagnoli et al., 2015, Tumung et al., 2015, among others). Furthermore, this interpretation is also supported by numerous and varied ethnographic information, an aspect that we have previously shown (Cuenca-Solana et al., 2011). b) From a methodological perspective, in addition to studying this evidence typologically and technologically, it must also be assessed from a functional viewpoint through use-wear analysis. The potential of this methodology lies in its ability to establish an interpretation of tools that is linked with the role played within the survival strategies of human groups. In addition, as the results obtained in the Balma del Gai have shown, from the application of this methodology, it is possible to recognize the presence of perishable materials, usually unperceived in the archaeological record, although probably fundamental for the development of numerous and varied activities carried out by the hunter-gatherer groups. c) The correlation among the different technological elements that make up the hunter-gatherers' toolkits, through global analysis of the different types of elements that compose them, is the only way to develop an objective scientific approach to the tool management carried out by these groups, and therefore to increase our knowledge about technological and economic aspects linked to their ways of life.

4. Conclusions

From the results obtained in this research and their comparison with other data obtained from the different studies carried out at La Balma del Gai, faunal and anthracological studies and use-wear analysis of lithic tools, we can establish a general interpretation of a part of the productive activities carried out by the hunter-gatherer groups that occupied this site between the second half of the XIV millennium and the end of the X before the present. In this way, the results of the set of studies done fit with a seasonal occupation, principally centred on the summer-autumn and with the exploitation of a wide range of resources with clear predominance of hunting activity oriented to the capture of rabbits to use both their skin and meat. In this context, the shell tools had an important role within the set of technological elements employed to carry out these subsistence activities. They were especially linked to the treatment of perishable materials (vegetable fibres and wood) and carrying out actions oriented to obtaining and processing elements that were related to the most intense activities in this context, which was obtaining and

preparing skin. In this sense, the shell tools use could be oriented to some specific moments of the "chaîne opératoire" while most of the skinning process was performed with lithic tools, specifically endscrapers. From another perspective, the use of shell tools at La Balma del Gai fits with the general pattern demonstrated by hunter-gatherer groups, since the Palaeolithic, with respect to the use of this type of technological elements (Cuenca Solana, 2013, 2015, 2016a, 2016b): that is, carrying out short-duration actions within productive processes for which the use of very specialized technology is not necessary. This use could have been oriented to saving and protecting the correct functionality of the lithic and bone tools.

The development of this analysis of use-wear traces enables the demonstration of the potential of this methodology to reconstruct the productive strategies of human groups. Finally, the results obtained also constitute a good sample of the diversified potential use of shells as food, adornment or as tools, an aspect of great interest when reconsidering the true role played by malacological resources within the productive strategies of hunter-gatherer groups.

Finally, the identification of unmodified but used (presenting use-wear traces) shells in the site reinforces the idea that Balma del Gai was an inland seasonal occupation of hunter-gatherer populations with a catchment territory that at some time in the year also included coastal settlements where people had access to this type of materials. Future archaeological data would allow us to corroborate or not this hypothesis.

Acknowledgements

While carrying out the analyses making up this research DCS was financed by the Fyssen Foundation through a postdoctoral grant from UMR 6566 CReAAH. During the period of writing of the manuscript DCS was financed by the Ministerio de Ciencia, Innovación y Universidades through the Juan de la Cierva Research Programme - Incorporación (IJCI-2014-20590). Ll. Lloveras was financed by a postdoctoral contract (BP-B00140-2014) from the Departament d'Universitats, Recerca i Societat de la Informació de la Generalitat de Catalunya and the COFUND programme (Marie Curie Actions). We are also grateful for the finance received for the projects HAR2017-86509 and SGR2017-00011. The use-wear analyses and the photographic registers were carried out by DCS and ICC in the laboratories of the Institution Milá y Fontanals (IMF-CSIC).

References

Allué, E., Nadal, J., Estrada, A. & García-Argüelles, P. (2007). Los datos antracológicos de la Balma del Gai (Bages, Barcelona): una aproximación al conocimiento de la vegetación y la

explotación de los recursos forestales durante el tardiglaciar en el NE peninsular. *Trabajos de Prehistoria* 64 (1): 87-97.

Audouin, F., and Plisson. H. 1982. Les ocres et leurs temoins au pale´olithique en France: enquete et experiences sur leur validite archeologique. Cahiers du C.R.P. de l'Universite Paris I 8:33–80.

Barton, H. & White, J. P. (1993). Use of stone and shell artifacts of Balof 2, New Ireland, Papua New Guinea, *Asian Perspectives* 32 (2): 169-181.

Bergadà, M.M. (1998). *Estudio geoarqueológico de los asentamientos prehistóricos del Pleistoceno superior y el Holoceno en Catalunya*. Oxford: BAR international Series, 742.

Beyries, S. (2008). Modélisation du travail du cuir en ethnologie : proposition d'un système ouvert à l'archéologie. *Anthropozoologica* 43 (1):9-42.

Choi, K. & Driwantoro, D. (2007). Shell tool use by early members of Homo erectus in Sangiran, central Java, Indonesia: cut mark evidence, *Journal of Archaeological Science* 34: 48-58.

Clemente, I. (1997). *Los instrumentos líticos de Tunel VII: una aproximación etnoarqueológica*, CSIC-UAB Treball d'etnoarqueología, 2, Barcelona.

Clemente, I. & Cuenca Solana, D. (2011). "Instrumentos de trabajo de concha en el yacimiento Neolítico de La Draga", El poblat lacustre del neolític antic de la Draga. Excavacions 2000-2005 (Bosch Lloret, A., Chinchilla Sánchez, J. & Tarrús Galter, J., coords.), *Monografies del CASC* 9, Museu d'Arqueologia de Catalunya y Centre d'Arqueologia Subaquàtica de Catalunya, Girona, pp. 106-112.

Courtin, J. & Vigié, B. (1987). Le problème des coquillages *à bord dentelé* dans la Préhistoire du midi de la France, *Mésogée* 47: 93-98.

Cristiani, E., Lemorini, C. Martini, F. & Sarti, L. (2005). Scrappers of Callista chione from Grotta del Cavallo (Middle Paleolithic cave in Apulia): evaluating use-wear potential. In H. Luik; A. M. Chayke; C. E. Batey & L. Lougos, (eds.). *From hooves to horns, from mollusc, to mammoth. Manufacture and use of bone artefacts from prehistoric times to the present*. Procedings of the 4th meeting of the ICAZ Worked bone Research Group at Tallin: 319-324.

Cuenca-Solana, D. (2010). Los efectos del trabajo arqueológico en conchas de Patella sp. y Mytilus galloprovincialis y su incidencia en el análisis funcional. *Férvedes* 6, 43-51.

Cuenca-Solana, D. (2013). *Utilización de instrumentos de concha para la realización de actividades productivas en las formaciones económico-sociales de los cazadores- recolectores-pescadores y primeras sociedades tribales de la fachada atlántica europea*. Publican. Servicio de publicaciones de la Universidad de Cantabria.

Cuenca-Solana, D. (2015). The use of shells by hunter-fisher-gatherers and farmers from the early upper Palaeolithic to the Neolithic in the European Atlantic façade: a technological perspective. *Journal of Island and Coastal Archaeology* 10 (1): 52-75.

Cuenca-Solana, D., Gutiérrez-Zugasti, I. & Clemente-Conte, I. (2011). The use of molluscs as tools by coastal human groups: contribution of the ethnographical studies to research on Mesolithic and early Neolithic technologies in Northern Spain. *Journal of Anthropological Research*. 67. 77-102.

Cuenca-Solana, D., Gutiérrez-Zugasti, I., González Morales, M. R., Setién, J.; Ruiz, E., García Moreno, A. & Clemente Conte, I. (2013). Shell technology, rock art and the role of coastal resources in the upper Palaeolithic. *Current Anthropology* 54 (3): 370-380.

Cuenca-Solana, D., Dupont, C. & Hamon, G. (2015). Instrumentos de concha y producción cerámica en los grupos tribales neolíticos de la costa atlántica del oeste de Francia. In Gutiérrez-Zugasti, I., Cuenca-Solana D. & González Morales, M.R. (eds.), *Actas de la IV Reunión de Arqueomalacología de la Península Ibérica. Publican*, (pp. 101-111). Servicio de Publicación de la Universidad de Cantabria.

Cuenca-Solana, D., Gutiérrez-Zugasti, I., Ruiz Redondo, A., González Morales, M. R., Setién Marquínez, J., Ruiz Martínez, E., Palacio Pérez, E., de las Heras Martín, C., Prada Freixedo, J. A. & Lasheras Corruchaga, A. (2016a). Painting Altamira Cave? Shell tools for ochre-processing in the Upper. *Journal of Archaeological Science* 74 :135–151.

Cuenca-Solana, D., Gutiérrez-Zugasti, I. & González Morales, M. R. (2016b). Shell Tools and Subsistence Strategies during the Upper Palaeolithic in Northern Spain. In C. Dupont et G. Marchand (Dir). *Archéologie des chasseurs-cueilleurs maritimes. De la fonction des habitats à l'organisation de l'espace littoral/Archaeology of maritime hunter-gatherers. From settlement function to the organization of the coastal zone*. Actes de la séance de la Société préhistorique française de Rennes, 10-11 avril 2014. Paris, Société préhistorique française, 2016 (Séances de la Société préhistorique française, 6), p. 59-68.

Cuenca-Solana, D., Gutiérrez-Zugasti, I. & González Morales, M. R. (2017). Use-wear analysis: optimal methodology for the study of the shell tools. *Quaternary International* 427 (A): 192–200.

499 Douka, K. (2011). An Upper Palaeolithic shell scraper from Ksar Akil (Lebanon). *Journal of*
500 *Archaeological Science* 38: 429-437.

501 Douka, K. & Spinapolice, E. E. (2012). Neanderthal Shell Tool Production: Evidence from
502 Middle Palaeolithic Italy and Greece. *Journal of World Prehistory* 25:45–79.

503 Estrada, A., Lloveras, L., Nadal, J., García-Argüelles, P., & Costa, J. (2009). El consum de
504 gasterópodes durant les ocupacions epipaleolítiques a la Balma del Gai: dades tafonómiques,
505 paleoecológiques i paleonutricionals. *Modilianum* 41, 21-33.

506 Estrada, A., Nadal, J., Lloveras, L., García-Argüelles, P., & Álvarez, R. (2010). La malacofuna
507 marina en el yacimiento de la Balma del Gai (provincia de Barcelona) y su contextualización en
508 el registro arqueomalacológico del Epipaleolítico catalán. *Férvedes* 6, 115-120.

509 Estrada, A., Nadal, J., García-Argüelles, P.; Lloveras, L., & Costa, J. (2011). *Els darrers*
510 *caçadors-recol·lectors del Moianès. La Balma del Gai. Moià:* Museu de Moià.

511 García-Argüelles, P., Nadal, J., & Estrada, A. (2004). Balma del Gai Rock shelter: an
512 Epapalaeolithic rabbit skinning Factory. *Actes du XIVème Congrès UISPP*. Section 7: Le
513 Mésolithique. Oxford: BAR International Series, 1302. 115-120.

514 García-Argüelles,P., Fullola, J.M., Román, D., Nadal, J. & Bergadà, M.M. (2013). El modelo
515 epipaleolítico geométrico tipo Filador 40 años después: vigencia y nuevas propuestas. In
516 Rasilla, M. de la (coord.) *F. Javier Fortea Pérez. Universitatis Ovetensis magister. Estudios en*
517 *Homenaje*, (pp. 151 165). Oviedo.

518 Gijn, A. L. Van. (1989). *The wear and tear of flint*. Analecta Prahestorica Leidensia 22.
519 University of Leiden.

520 González Urquijo, J. E. & Ibáñez Estévez, J. J. (1994). *Metodología de análisis funcional de*
521 *instrumentos tallados en sílex*. Universidad de Deusto Cuadernos de Arqueología 14.

522 Gutiérrez Zugasti, F. I., Cuenca Solana, D., Clemente Conte, I., González Sainz, C., López-
523 Quintana, J. C. (2011). "Instrumentos de trabajo y elementos de adorno en conchas de molusco
524 de la cueva de Santimamiñe (Kortezubi, Bizkaia)". La cueva de Santimamiñe: revisión y
525 actualización (2004-2006) (López Quintana, J. C., dir.), *Kobie. Serie Excavaciones*
526 *Arqueológicas en Bizkaia* 1, Bilbao, pp. 155-170.

527 Jones, S. & Keegan, W. F. (2001). Expedient Shell Tools from the Northern West Indies, *Latin*
528 *American Antiquity* 12 (3): 274-290.

Lammers, Y. M. (2008). *Tracing Traces from Present to past. A funtional analysis of pre-Columbian shell and stone artefacts from Anse á la Gourde and Morel, Guadaloupe, FWI*. Leiden Universoty Press, The Netherlands.

Lloveras, L., Moreno, M., Nadal, J., García-Argüelles, P., & Estrada, A. (2011a). Aproximación experimental al procesado de carcasas de lepóridos durante el epipaleolítico. El caos de la Balma del Gai (Moià, provincia de Barcelona, España). In Morgado, A., Baena, J., & García, D. (eds) *La investigación experimental aplicada a la Arqueología*. (pp. 337-342). Ronda: Universidad de Granada.

Lloveras, L., Nadal, J., García-Argüelles, P., Fullola, J.M., & Estrada, A. (2011b). The land snail midden from Balma del Gai (Barcelona, Spain) and the evolution of terrestrial gastropod consumption during the Late Palaeolithic and Mesolithic in Eastern Iberia. *Quaternary International* 244(1), 37-44.

Lloveras, Z., Nadal, J.,Lloveras, L. (2019). Una mar llunyana? Relacions de les darreres comunitats caçadores-recol·lectores I la costa a Catalunya a través de l'estudi de la malacofauna marina I els SIG. In J.L. Pascual & Sanchis, A. (eds) *Recursos marins en el Passat. IV Jornades d'Arqueozoologia del Museu de Prehistòria de València*. (pp.63-84). Valencia: Museu de Prehistòria de València.

Manca, L. (2016). The shell industry in Final Neolithic societies in Sardinia: characterizing the production and utilization of Glycymeris da Costa, 1778 valves. *Anthropozoologica*, 51 (2): 149-171.

Mangado, J., Calvo, M., Nadal, J., Estrada, A., & Garcia-Argüelles, P. (2006) Raw material resource management during the Epiapalaeolithic in North-Eastern Iberia. The site of Gai Rock shelter (Moià, Barcelona): a case study. In Bressy, C., Burke, A., Chalard, P. & Martin, H. (dir) *Notions de territoire et de mobilité. Exemples de l'Europe et des premières nations en Amérique du nord avant le contact européen*. ERAUL 116. (pp. 91-98) Liège: Université de Liège.

Mansur, M. E. & Clemente-Conte, I. (2009). ¿Tecnologías invisibles? Confección, uso y conservación de instrumentos de valva en Tierra del Fuego. In F. Oliva; N. de Grandis & J. Rodríguez (eds.) *Arqueología Argentina en los inicios de un nuevo siglo*. Vol. 2. XIV Congreso Nacional de Arqueología Argentina, Rosario. Universidad Nacional de Rosario. Argentina: 359-367.

Nadal, J., Lloveras, L., García-Argüelles, P., & Costa, J. (2017). La Balma del Gai. Vint anys de recerca en un campament de caçadors-recol·lectors entre el plistocè final i l'holocèa l'altiplà del Moianès. *Tribuna d'Arqueologia* 2014-15, 69-83.

562 Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., . . . Talamo, S.
563 (2020). The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal
564 kBP). *Radiocarbon* 62(4): 725-757. doi:10.1017/RDC.2020.41

565 Ríos Garaizar, J., Ortega Cordellat, I., Ibáñez Estévez, J. J. & González Urquijo J. E. (2002). El
566 aporte del análisis funcional para el conocimiento del yacimiento auriñaciense de Barbas III.
567 Primeros resultados. In Clemente, I., Risch, R. & Gibaja, J. F. (eds.), *Análisis Funcional: su*
568 *aplicación al estudio de sociedades prehistóricas*. (pp.141-150). BAR International Series 1073.

569 Romagnoli, F., Martini, F. & Sarti, L., (2015). Neanderthal use of Callista chione shells as raw
570 material for retouched tools in south-east Italy. Analysis of Grotta del Cavallo Layer L
571 assemblage by a new methodology. *Journal of Archaeological Method and Theory* 22:1007-
572 1037.

573 Román, D. (2012). Nouveutés sur la sequence du Pléistocéne final et l'Holocène initial dans la
574 versant méditerranéen de la Péninsule Ibérique à travers l'industrie litique. *L'Anthropologie*
575 116, 665-679.

576 Román, D., Martínez-Andreu, M., Aguilella, G., Fullola, J.M. & Nadal, J. (2020) Shellfish
577 collectors on the seashore: the exploitation of the marine environment between the end of the
578 Paleolithic and the Mesolithic in the Mediterranean Iberia. *The Journal of Island and Coastal*
579 *Archaeology*. DOI: 10.1080/15564894.2020. 1755395

580 Rosado-Méndez, N., Lloveras, Ll., García-Argüelles, P. & Nadal J. (2019). The role of small
581 prey in hunter-gatherers subsistence strategies from the Late Pleistocene- Early Holocene
582 transition site in NE Iberia: The leporid accumulation from the Epipalaeolithic level of Balma
583 del Gai site. *Archaeological and Anthropological Sciences*. 11, 2507–2525.

584 Schmidt, L., Anderson, A. & Fullagar, R. (2001). Shell and Bone Artefacts from the Emily Bay
585 Settlement Site, Norfolk Island. *Records of the Australian Museum*, Supplement 27: 67–74.

586 Semenov, S.A. (1964). *Prehistoric Technology*. London: Cory, Adams & Mackay, 211 pp.

587 Szabó, K. 2008. Shell as a Raw Material: Mechanical Properties and Working Techniques in the
588 Tropical Indo-West Pacificic. *Archaeofauna* 17: 125-138.

589 Szabó, K., Adam, B. & Bellwood, P. (2007). Shell artefact production at 32.000-28.000 BP in
590 Island Southeast Asia. Thinking across media? *Current Antropology* 48 (5): 701-723.

591 Szabó, K. & KoppeL, B., (2015). Limpet shells as unmodified tools in Pleistocene Southeast
592 Asia: an experimental approach to assessing fracture and modification. *Journal of*
593 *Archaeological Science* 54: 64-76

594 Tumung, L., Bazgir, B. & A. Ollé. (2015). Applying SEM to the study of use-wear on
595 unmodified shell tools: an experimental approach, *Journal of Archaeological Science* 59: 179-
596 196.

597 Vaughan, P. C. (1985). *Use-wear análisis of flaked stone tools*. The University of Arizona
598 Press.

599 Volart, E., Lloveras, L., Nadal J., García-Argüelles, P. & Costa, J. (2014). La gestió dels
600 recursos animals de baixa aportació càrnia durant les ocupacions epipaleolítiques de la Balma
601 del Gai (Moià, Barcelona). *Modilianum* 51, 5-14.

Figure 2

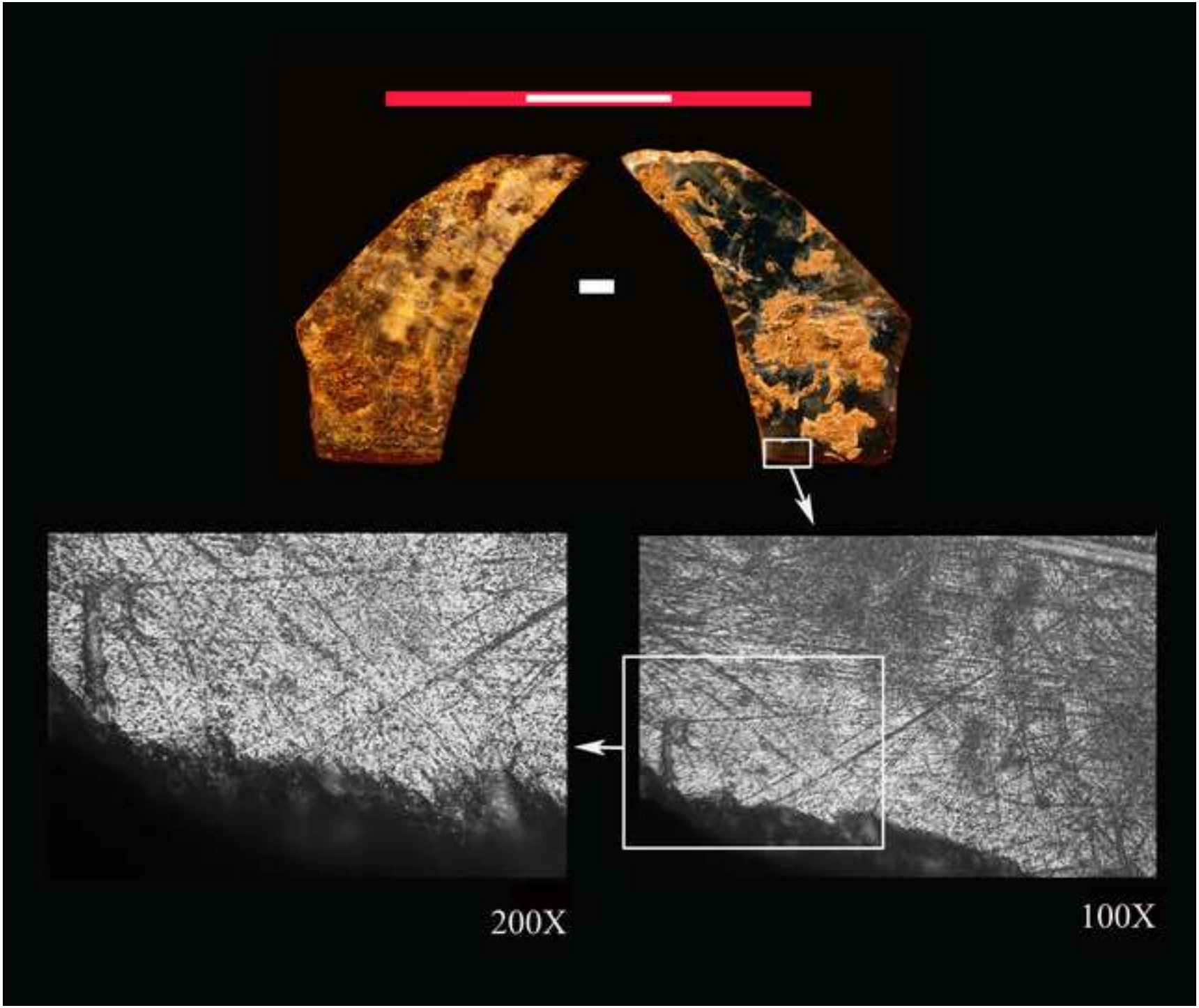

Figure 3

Click here to access/download;Figure;Cuenca-Solana et al. Fig. 3.TIF

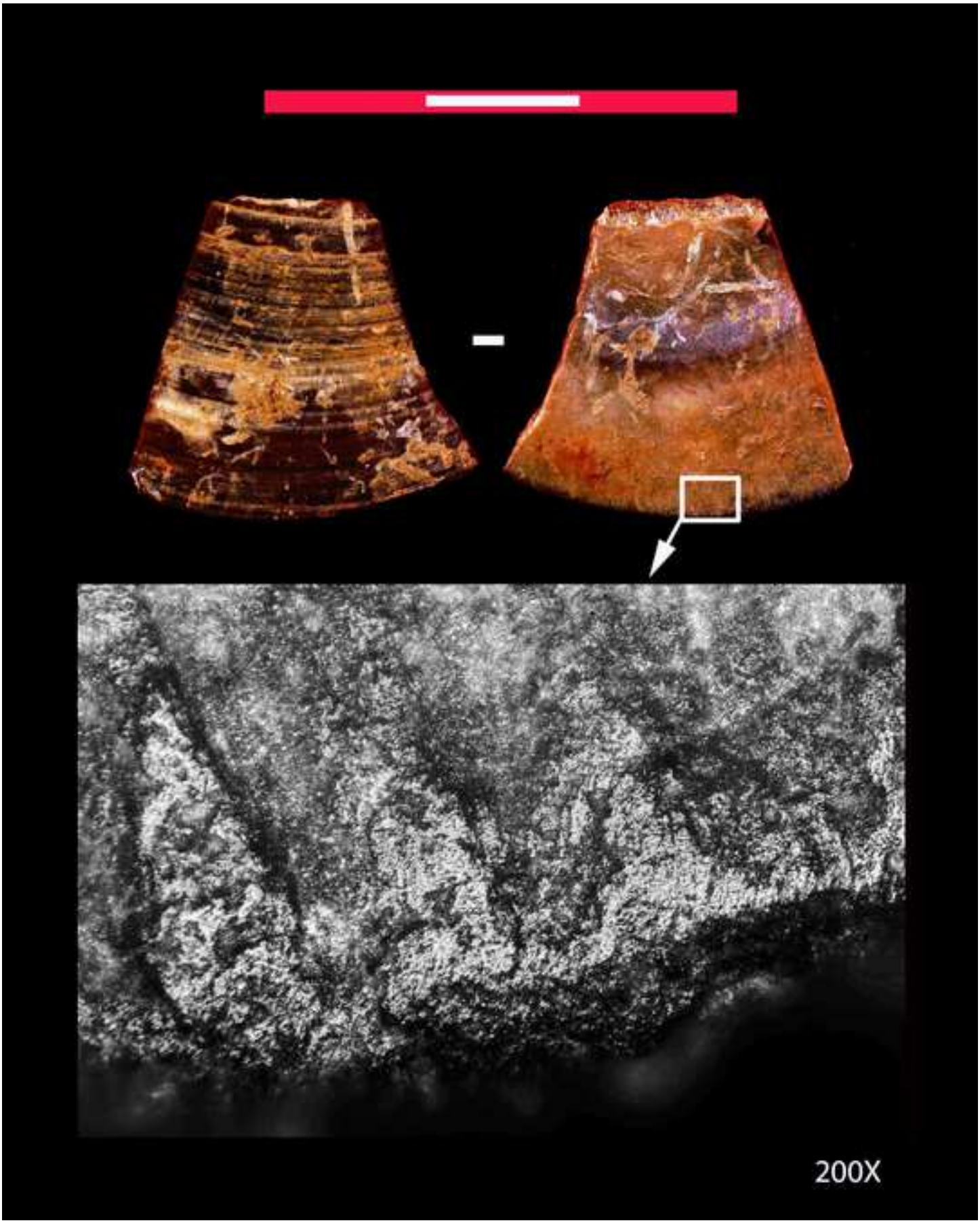

Figure 4

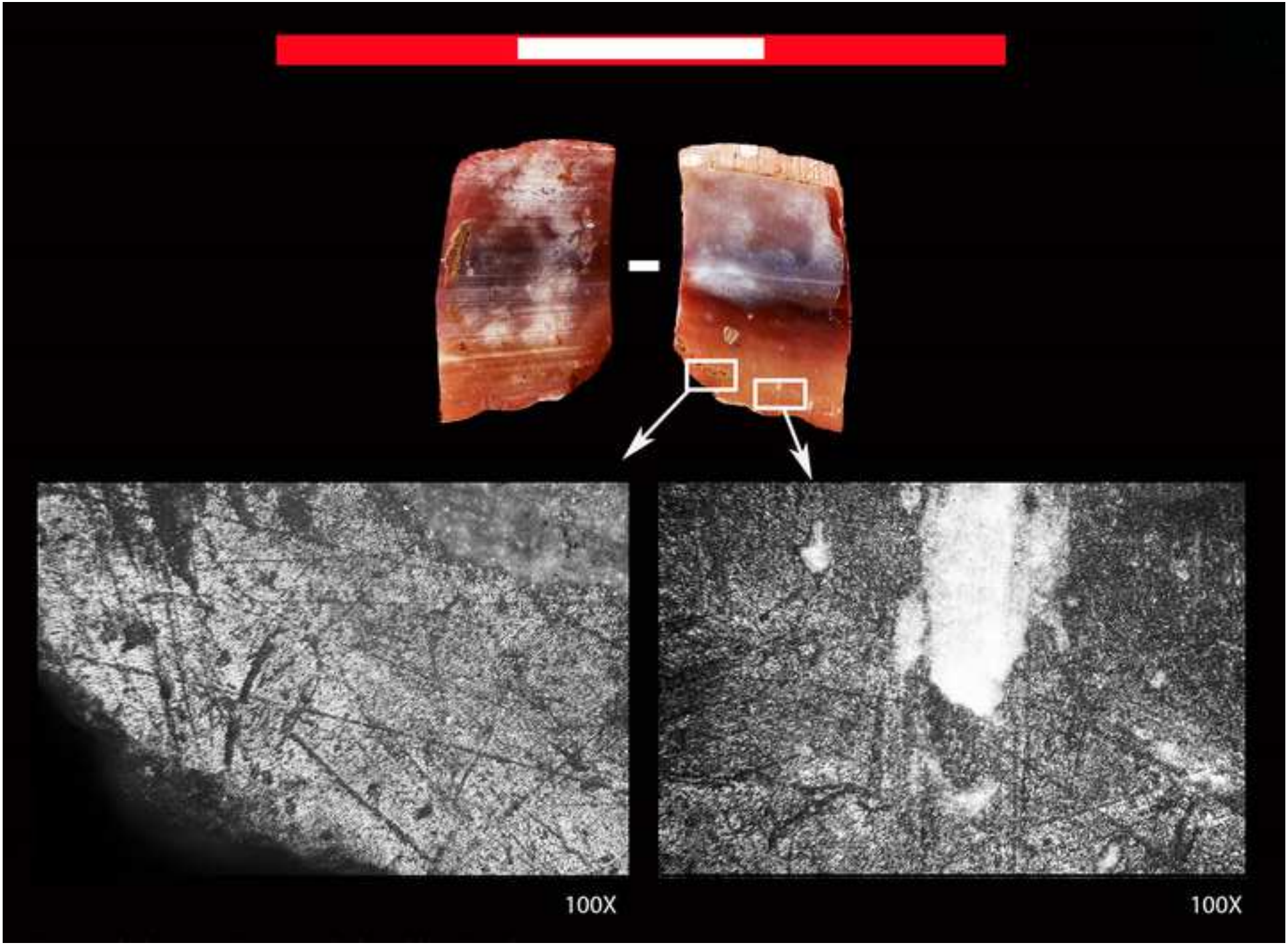

Figure 5

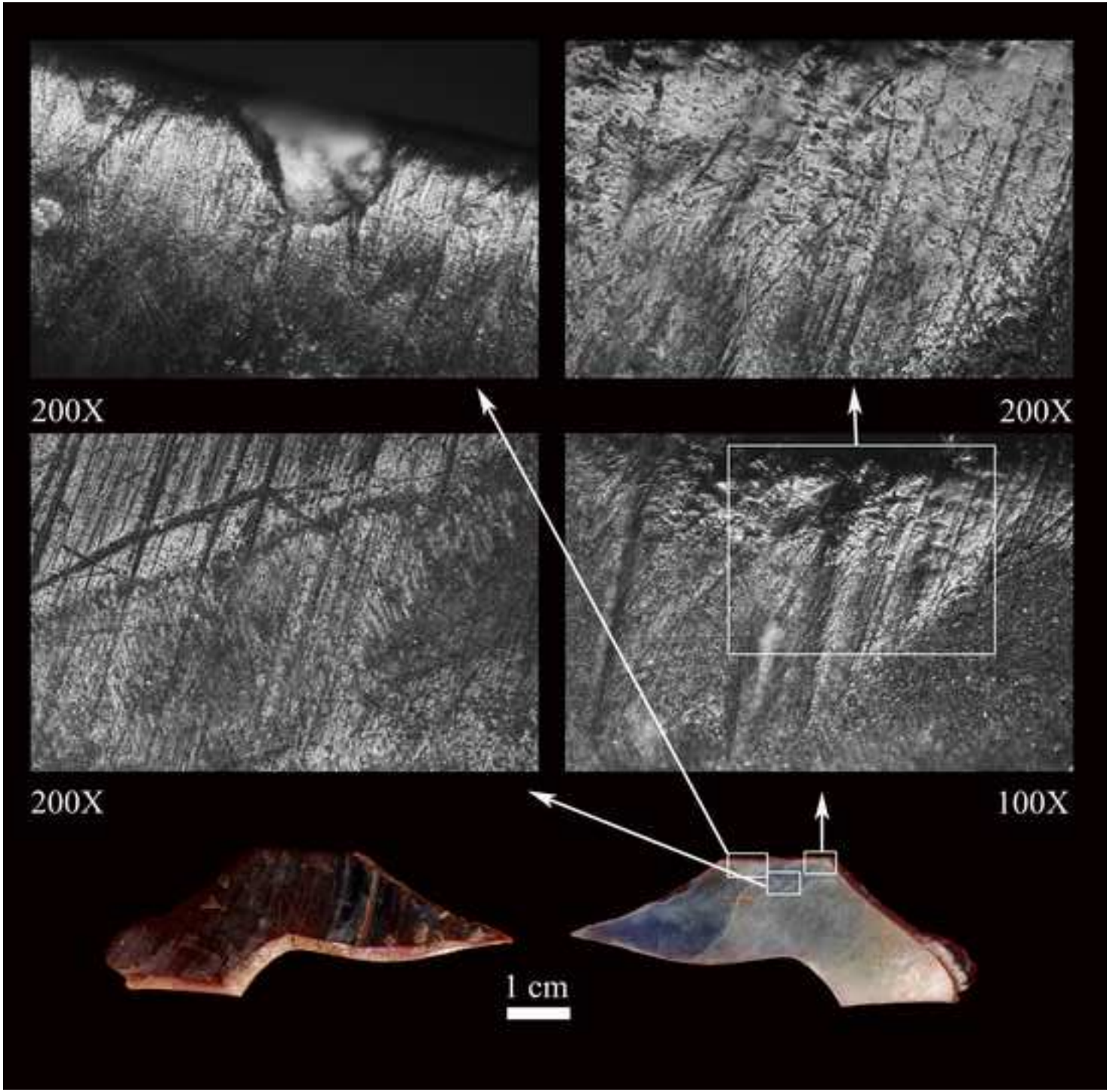

Figure 6

Click here to access/download;Figure;Cuenca-Solana et al. Fig. 6.tif

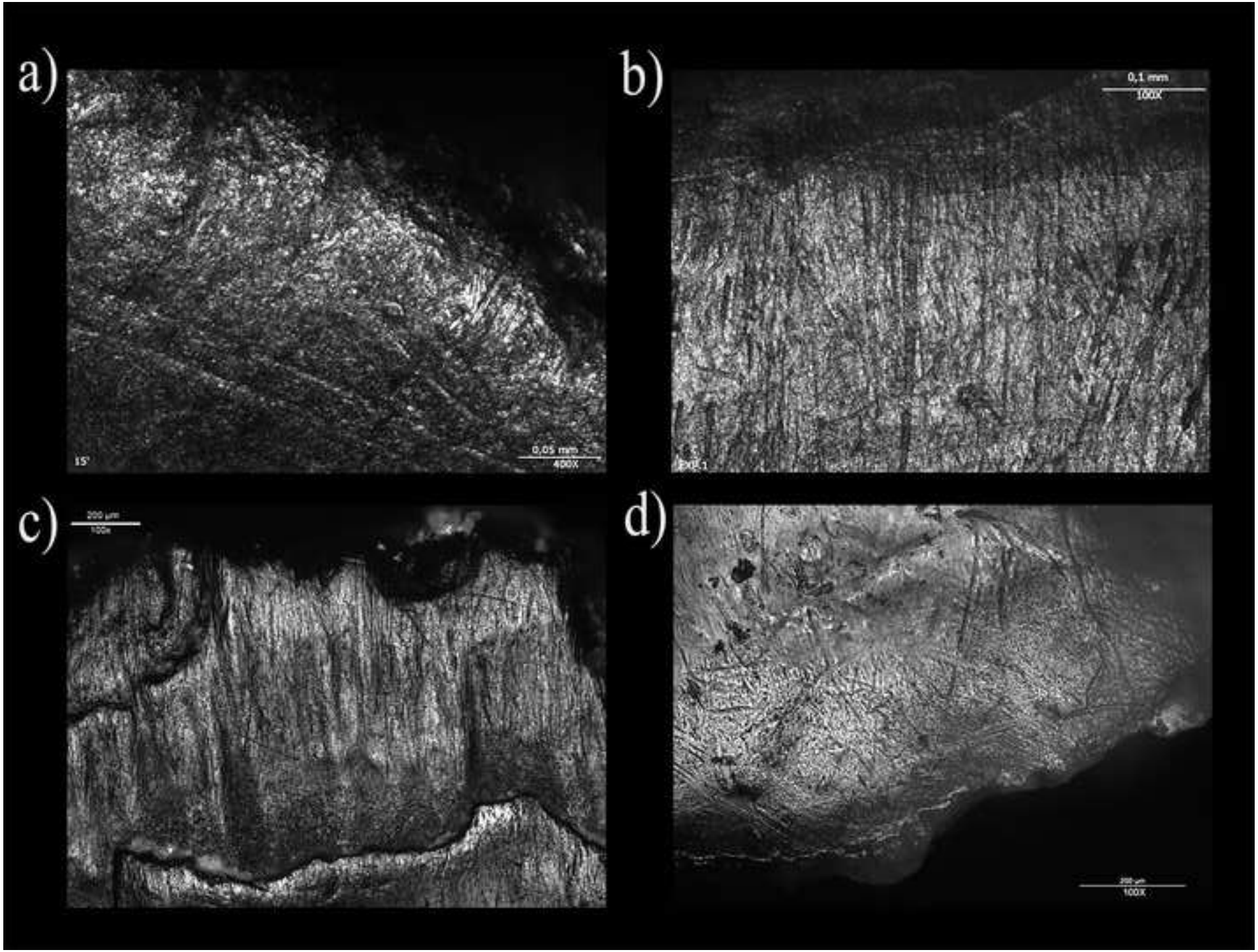

Figure 1

Click here to access/download;Figure;Cuenca-Solana et al. Fig. 1.tif

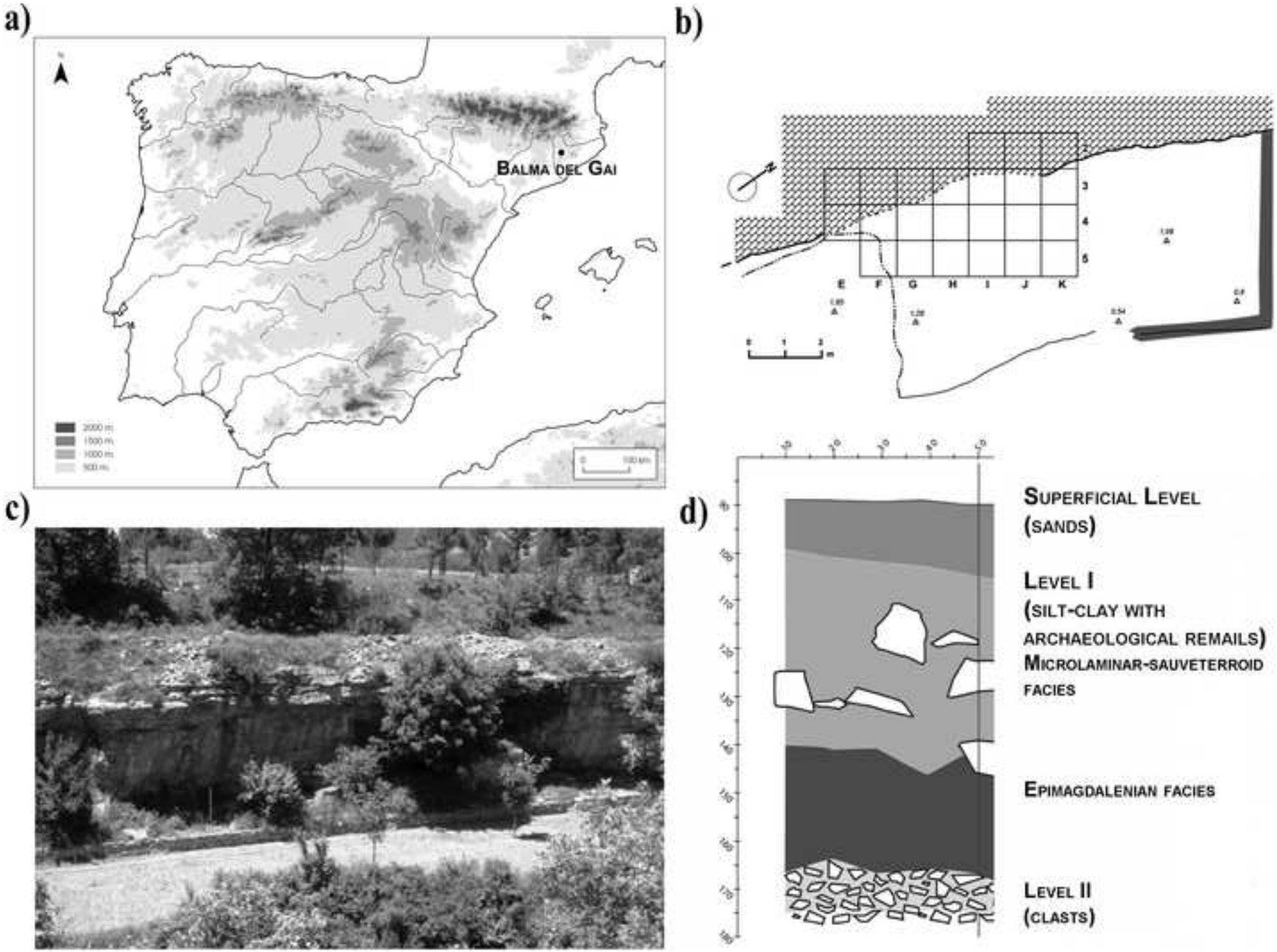

Table 1

Facies	Lab ref.	radiocarbon dates	Cal BP (2-sigma)
	OxA-29608	11,440 ± 50 BP	13,442-13,180
Epimagdalenian	Gif-10029	11,170 ± 160 BP	13,340-12,759
	Mc-2140	11,050 ± 160 BP	13,240-12,731
Transition	Gif-95617	10,260 ± 90 BP	12,476-11,648
	OxA-27437	10,200 ± 45 BP	12,002-11,651
Microlaminar	Mc-2141	10,030 ± 160 BP	12,440-11,177
Sauveterroid	Mc-1418	9,840 ± 400 BP	12,616-10,290
	Gif-10028	8,930 ± 140 BP	10,368-9,552

Table 2

Species	Level	Square	Sample id.
Glycymeris glycymeris	I	F.4.3	1048
	I	K3	530
	I	F4.3	525
	I	J3-Q2	639
	I	H4 (2)	376
	I	I4	147
	I	J4	1177
	I	I3	160-165
	I	G3	174
	I	E4	278
	SUP/I	H3	23
	I	I3	400
	SUP/I	K4	82
	I	H3	1823
	?	H35	S/N
	I	J3	1273
	I	H3	1761
	I	E4	130
Mytilus galloprovincialis	I	K3	872
		H32	c1
	I	F43	804
	I	H3	1329
	I	E4	234
	I	E4	131
	SUP	I4	47
	SUP	F.4.2	173
	SUP	H5	114
	I	F4.3	416
	I	I3-Q2	217
	SUP	G4	35

Table 3

Species	Level	Square	Sample id	Use-wear result
Glycymeris glycymeris	I	F4.3	525	Use
Glycymeris glycymeris	I	I4	147	Personal ornaments?
Glycymeris glycymeris	I	I3	160-165	Personal ornaments?
Glycymeris glycymeris	I	G3	174	Personal ornaments?
Glycymeris glycymeris	SUP/I	K4	82	Probable use
Mytilus galloprovincialis		H32	C1	Probable use
Mytilus galloprovincialis	I	H3	1329	Use
Mytilus galloprovincialis	I	E4	234	Use
Mytilus galloprovincialis	I	E4	131	Use
Mytilus galloprovincialis	SUP	I4	47	Use
Mytilus galloprovincialis	SUP	F.4.2	173	Use
Mytilus galloprovincialis	SUP	H5	114	Use
Mytilus galloprovincialis	I	F4.3	416	Use

Action	Processed matter
Transversal scraping	Dry/semidry skin
Suspension/Transport?	
Suspension/Transport?	
Suspension/Transport?	
Transversal scraping	Medium-hard material
Transversal and longitudinal action	Medium-hard material
Transversal and longitudinal action	Mineral (Ocher) + skin
Transversal scraping	Vegetal
Transversal scraping	Vegetal
Transversal scraping	Mineral (Ocher)
Transversal scraping	Hard wood
Transversal scraping	Mineral (Ocher)
Transversal and longitudinal action	Mineral (Ocher) + skin

Functional interpretation
Cleaning the skin during the tanning process

Indeterminate
Indeterminate
Extend ochre on skin
Extracting/stretching fibres
Extracting/stretching fibres
Ocher powden obtention
Polishing/smoothen hard wood sticks
Ocher powden obtention
Extend ochre on skin

Author statement;

David Cuenca-Solana; Conceptualization, Methodology, Formal análisis, Validation, Investigation, Writing - Original Draft, Writing - Review & Editing, Supervision, Data Curation, Funding acquisition.

Ignacio Clemente-Conte; Methodology, Formal análisis, Resources.

Lluís Lloveras; Investigation, Writing - Original Draft, Writing - Review & Editing, Supervision, Data Curation, Funding acquisition.

Pilar García-Argüelles; Investigation, Funding acquisition, Data Curation.

Jordi Nadal; Investigation, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition, Project administration, Data Curation.