# Reports

## Shell Technology, Rock Art, and the Role of Marine Resources during the Upper Paleolithic

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During the Upper Paleolithic, marine resources have traditionally been considered to be low-efficiency resources. However, in recent years, new data have emerged to demonstrate that their importance for human utilization was probably greater than previously thought. The assessment of their value has generally been from the perspective of their nutritional or ornamental value, not from the technological potential that these resources might have. A use-wear analysis of shells from the Gravettian levels of Fuente del Salín, a cave in northern Spain, has documented their use for a diverse range of production activities, most notably the processing of the red pigments used in artistic representations on the cave walls, as well as for tanning hide. This technological use of shells demonstrates that marine resources were of greater importance to the hunters and gatherers of the Upper Paleolithic and that their utility was more diverse than previously understood.

The importance of marine resources to hunter-gatherers has been defined by the vast accumulations of shells identified in Holocene deposits. Thus, the traditional explanatory model attributes these middens to the beginning of the economic diversification and intensification at the end of the Upper Paleolithic and, more so, to the Mesolithic. According to these models (Binford 1968; Flannery 1969), the importance that mollusks represented to the hunters and gatherers' subsistence strategies is minimized, attributing their exploitation primarily to times of food shortages and economic stress (Osborn 1977). In recent years, new data regarding the exploitation of mollusks and other marine resources have stimulated the creation of new explanatory models that highlight the importance of these resources (Bailey and Flemming 2008; Bicho and Haws 2008). Nonetheless, neither the traditional models nor more recent ones have taken into consideration the technological potential that some of the marine resources may have.

More recently, the development of functional analysis has proved capable of providing information on the technological use of artifacts. Ever since Semenov (1964) published his research, this methodology has been applied to lithic assemblages, including those from Paleolithic contexts along the European Atlantic coast (Ibáñez-Estévez and González-Urquijo 1996, 1998; Ríos-Garaizar 2010). Despite the analytical potential of this methodology for shell, antler, and bone, this type of analysis has been very limited both in Paleolithic contexts (Pétillon 2006) and on marine resources (Pétillon 2008). Nonetheless, this type of analysis is more common in other geographical areas and for other chronological time periods, particularly on bone and antler (Griffits and Bonsall 2001; Jensen 2001; Van Gijn 2005, 2007).

The shell ornaments (Álvarez-Fernández and Jöris 2007; d'Errico et al. 2005, 2008; Vanhaeren and d'Errico 2006; White 2007) and the representations of fish figures in the rock art (Citerne 1998; Citerne and Delluc 2004, Cleyet 1990; Dams 1987) have generally been the basis for describing the relationship between marine resources and the symbolic expressions of hunters and gatherers. The corresponding technological research conducted has tended to identify the tools with which the art was created (Fritz 1997). However, thus far there has been no serious attempt to identify other elements—such as coastal resources—that may have been used in these creations beyond the hypothetical use of shells as receptacles for paints (Moure-Romanillo 1990).

In this article we show evidence of the technological use of marine mollusks of the *Patella vulgata* species in the Gravettian deposits from a cave named Fuente del Salín. Further, we discuss the implications that their use may have on economic and ritual activities for Paleolithic hunters' and gatherers' occupations, as well as the importance of marine resources during this time.

### Location and Description of the Deposit

Fuente del Salín is located in the municipality of Val de San Vicente (Cantabria, Spain), at 15 m above sea level and 3 km

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from the current coastline (fig. 1). The discovery of graphic representations on the cave walls—positive as well as negative hands in black and red (fig. 2) along with nonfigurative lines (González Morales and Moure Romanillo 2008)—stimulated the initial archaeological work in the cave opening. With the objective of verifying the existence of a subsurface archaeological deposit that would serve as an indication of the occupation of the cave by Paleolithic artists, excavations of the cave took place over three short field seasons in 1990, 1991, and 2000. These excavations documented three stratigraphic levels in squares K6 and L6.

The majority of material recovered was primarily from level 2, a hearth consisting of a large quantity of mollusk shells, mainly *Patella vulgata Linne* (1758), as well as remains of terrestrial mammals and salmonidae. Archaeomalacological analysis has identified fire-altered mollusk shells, leading to the interpretation that they were cooked for consumption (Gutiérrez-Zugasti et al., forthcoming *a*). The production of lithic and bone tools was minimal. A series of pendants were recovered: a deer canine tooth (perforated at the root) and 11 *Trivia* shells (nine of which were perforated). An abundance of coloring agents were recovered in the excavation of level 2, particularly of red ochre (González-Morales and Moure-Romanillo 2008; Moure-Romanillo and González-Morales 2000).

Radiocarbon materials for dating this deposit were recovered from level 2 as well as from bone material found on the surface; the occupation is placed at a late stage of the Gravettian (table 1). The characteristics of the settlement, the abundance of ochre stains inside the hearth, and the stylistic homogeneity in the set of hands reflect a short occupation at a site that falls well within the Gravettian. Following this the site was practically fossilized because natural processes blocked the original cave entrance. The limited accumulation of sediment above level 2 also shows that the area was quickly sealed after the occupation. These details support the hypothesis that—due to contamination—the date attributed to the black hand wall painting may actually be earlier. The sea level during the occupation of the cave would have been about 100 m below today's sea level, which suggests that the distance to the coastline would have been 9–10 km.

## Materials and Methodology

A total of 3,587 complete or fragmentary shells were analyzed in this project: 360 fragments of shell from level 1 (192 *Patella vulgata*, 167 *Patella* sp., and 1 *Mytilus* sp.); 3,109 fragments from level 2 (265 *Patella vulgata*, 2,838 *Patella* sp., and 6 *Mytilus* sp.); and 118 fragments from level 3 (68 *Patella vulgata* and 50 *Patella* sp). Because of biodegradation and carbonization, the total assemblage was not amenable to microscopic analysis. Approximately 45% of the sample was analyzed at a macroscopic level, whereas both macro- and microscopic analysis was possible for the rest of the collection.

A Leica S8APO binocular magnifier was used to identify abrasions, rounding, and scarring. A metallographic Leica DM2500 microscope was used to identify the microtraces of use and, when possible, determine how (movement and/or action) and for what (material processed) these were utilized for (Semenov 1964). Recently developed experimental collections were used as comparative models (Cuenca et al. 2010; Gutiérrez-Zugasti et al. 2011) as control of the variables that contribute to the formation of use traces (Clemente 1997; González-Urquijo and Ibáñez-Estévez 1994) on shell artifacts that have processed animal skins, vegetable fibers, or wood. Further, experimentation and analysis has been done to specifically identify the origin of use trace on some artifacts. Given the presence of rock art on the cave walls, experiments were conducted to scrape coloring minerals from blocks of different hardness. In addition, experiments were conducted to identify the impacts of the archaeological research itself, such as excavation or cleaning (Cuenca 2010).

Finally, utilizing the scanning electron microscope (SEM) the chemical elements of shells with use wear were examined for traces of ochre. A JEOL model JSM 5800-LV microscope with an electronic probe for microanalysis (OXFORD Link eXL) was used.

## Results

Analysis of the shells recovered at Fuente del Salín has identified 10 tools. They are fragments of *Patella* of different sizes recovered from level 2 (the hearth). A perforator (#82.1), shaped along the edge of a fragment of *Patella vulgata*, was documented in square K6. It shows a pronounced rounded tip, which, along with a polish and rough appearance, suggests that it was utilized (fig. 3). Since there is no evidence of microscarring on it, the steep, rounded tip suggests that it was used to perforate some abrasive material that was not particularly hard; perhaps it was used to work hides. A second perforator (#96.2) of *Patella vulgata* was also recovered from square K6; however, although there is a rounding of the tip, it does not show deliberate modification. Because of the absence of flake scarring and an intense polish, it is difficult to confirm if it was utilized and, if it was, what material it was used to process.

The presence of some pendants from the same context led to some experimentation to perforate *Trivia* species shells using perforators made from *Patella* similar to the archaeological ones. This experimentation demonstrated the low functionality of these tools to accomplish the task.

The smooth microtopography of another four fragments of *Patella vulgata* (two from square K6, #80.1 and #109.1, and two from square L6, #95.1 and #95.2) show a tight polish along the internal edge of the shell, as well as pronounced rounding and micro-scarring in a semicircular shape with occasional linear patterns. The presence of multiple very fine and dark striations that are oriented obliquely and are primarily perpendicular to the edge (fig. 4) is notable. This wear pattern is attributed to transverse and bidirectional

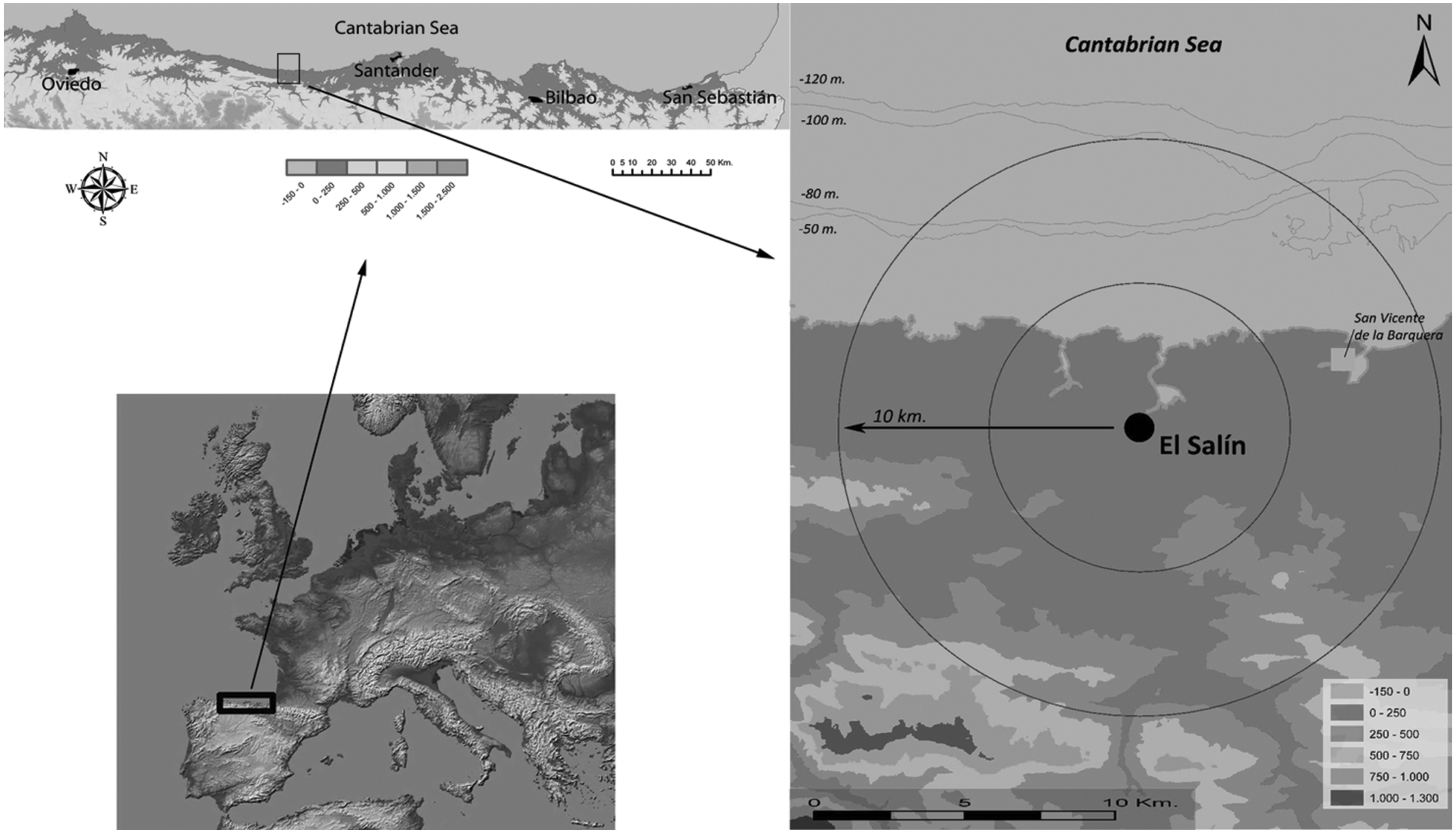


Figure 1. Location of Fuente del Salín.

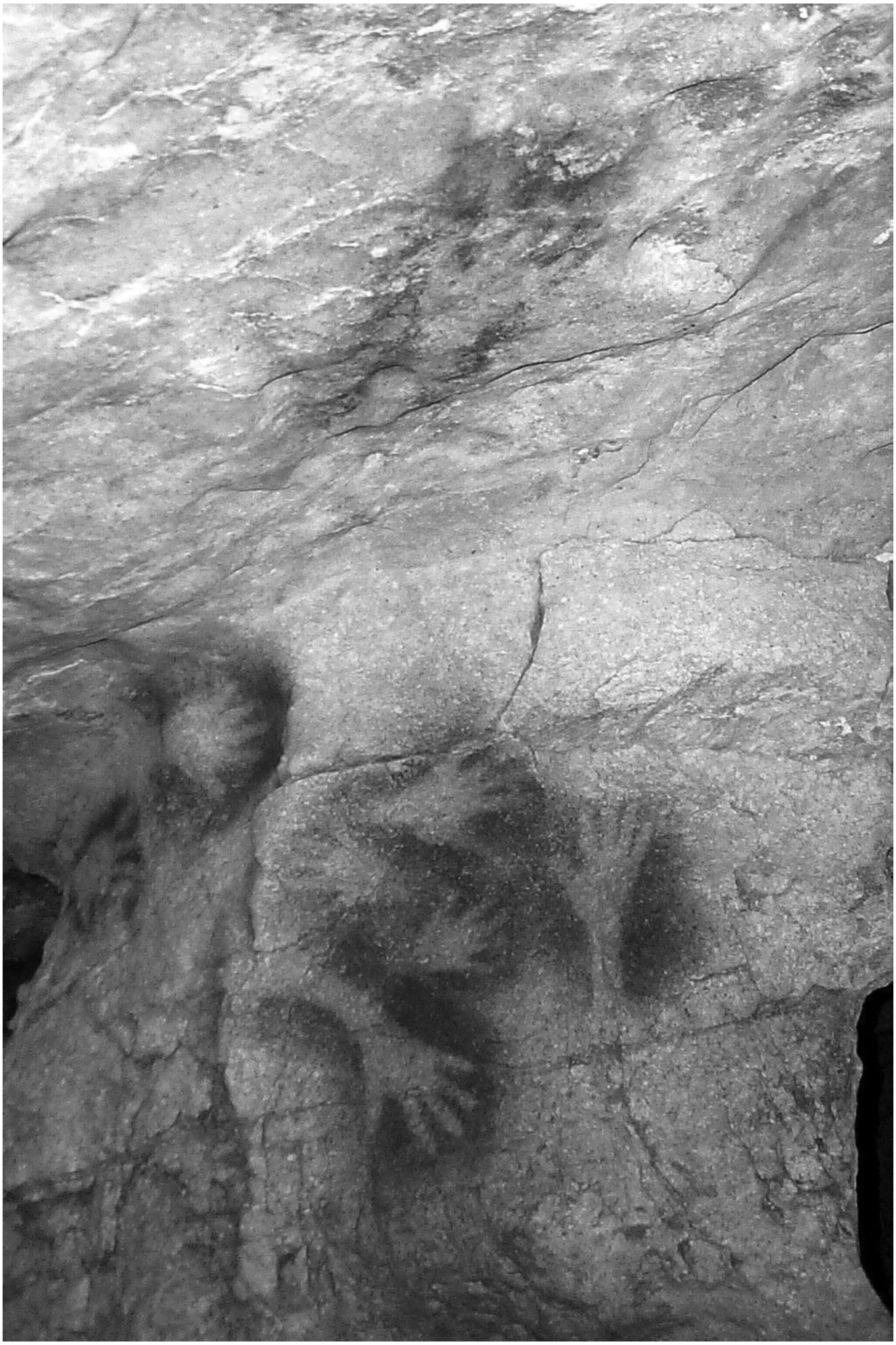

Figure 2. Wall panel situated above a structure with red ochre representing negative hands.

Table 1. Radiocarbon dates from Fuente del Salín

| Context | Material | Date BP | Cal date BP | Reference Laboratory | δ C13 |
|---|---|---|---|---|---|
| Hand, black, negative | Charcoal | 18,200 ± 70 | 21,880 ± 240 | GX-27757-AMS | −24.50% |
| Hearth, level 2 | Charcoal | 22,340 + 510/−480 | 26,850 ± 740 | GrN-18574 | — |
| Hearth, level 2 | Charcoal | 22,580 ± 100 | 27,340 ± 290 | GX-27756-AMS | −26.60% |
| Surface | Bone | 23,190 ± 900 | 27,810 ± 1,200 | GX-29438 | −21.50% |

Note. BP = before present.

movement (scraping), since in all cases there have been macro- and microscopic alterations on the external face of the shell as well.

Comparison of these results to use-wear experimental studies on modern shells confirms that the tools were used to process minerals of midranged hardness. The characteristics of the polish and particularly the appearance of multiple striations result from the abrasive quality of the mineral, as well as the dragging of tiny fractured shell fragments when coming into contact with the material processed during the scraping movement (fig. 5*D*–5*F*). The experimentation to process vegetable fibers shows similar patterns of striations, but these are wider and more irregular (fig. 5*C*).

This experimentation also shows a major development in polish, with an increased compaction along the contact area between rock ledge and ground surface (fig. 5*B*). None of the microscarring that is observed on pieces that have processed ochre has been observed on pieces that have processed fibers (fig. 5*E*). Several broad and irregular striations have also been identified along with a rounding along the edge (fig. 5*A*). Thus, the use wear on the experimental pieces that were used to process fibers on a rock surface is different from the wear observed on the archaeological artifacts. The experimental pieces that have processed hard ochre (in comparison to those that processed softer ochre) show greater edge polish (fig. 5*G*) and is particularly compact on the inside face (fig. 5*H*) and has wider and more irregular striations (fig. 5*I*). These results show a great similarity between the use wear of the archaeological and experimental samples when processing soft ochre.

Another four fragments of *Patella* species from square K6 (#96.2, #109.2, #109.3, and #109.4) show a very different use wear than those above. Sample #96.1 shows the inside face to have a compact polish with a dull shine. It does not have scoring or striations but has fine scratches against a dark background, oriented obliquely and transversally along the edge, and diverse microscarring. It shows a medium-high rounded edge and clearly visible scarring. The linear orientation indicates a transverse action (scraping), and because of the characteristics of the polish suggests use on a hard material that could not be identified in experimentation.

The fragments of samples #109.3 and #109.4 show very different use wear than the previous sample, such as to suggest use to process other materials or to perform some other activities. They show only a dull polish on the inside and outside faces and only marginally along the edge. The polish is closed with a rough microtopography; short and wide striations against a dark background are oriented perpendicular to the sharpened edge and the edge shows a midgrade. The limited polishing and light evidence of use wear suggests that it has been utilized only briefly to process an abrasive material, but not as hard as ochre. Taking into consideration the analytical experimentation (Cuenca et al. 2010), this use wear is suggestive of hide working.

Although fragment #109.2 shows very little polish, the striations oriented in a perpendicular and oblique direction indicate a transverse direction of scraping. This motion has altered both faces of the shell since it involves bidirectional action. However, since it is barely apparent, we can only suggest its possible use but cannot confirm it or the type of material on which this artifact was used.

Analysis of the surface of the shell artifacts from Fuente del Salín with the SEM has confirmed the presence of iron ore on the tools that were used to process soft minerals. The presence of different proportions of iron is attributed to ochre coloring pigments, since iron is one of its primary components. The iron content is variable, varying between 0.76% and 2.14% weight percentage and 0.40% and 1.07% atomic percentage. Shells without use traces have also been subjected to chemical analysis. Two samples have been randomly taken from each subsquare from which tools have been collected. A total of 10 samples were analyzed; eight were taken from square K6 (subsquares 2, 6, 7, and 8), and two more from square L6 (subsquare 7). In all cases, at least one of the samples showed traces of iron on its surface, with values between 2.23% and 5.16% weight percentage, and 1.16% and 2.63% atomic percentage.

The proportionately high content of iron in unutilized shells from the random sample must be tempered by the fact that the active edges of shell tools were cleaned prior to functional analysis. To demonstrate the extent to which the cleaning may have affected the iron content in the samples, experimental pieces to process ochre were analyzed with the SEM before and after cleaning. The results show a variable loss of iron content in 40% of the cleaned samples.

## Discussion

The use of shell artifacts has been well documented in the technological tool kit for some European Mesolithic and Neolithic deposits (Cantillo et al. 2010; Clemente and Cuenca

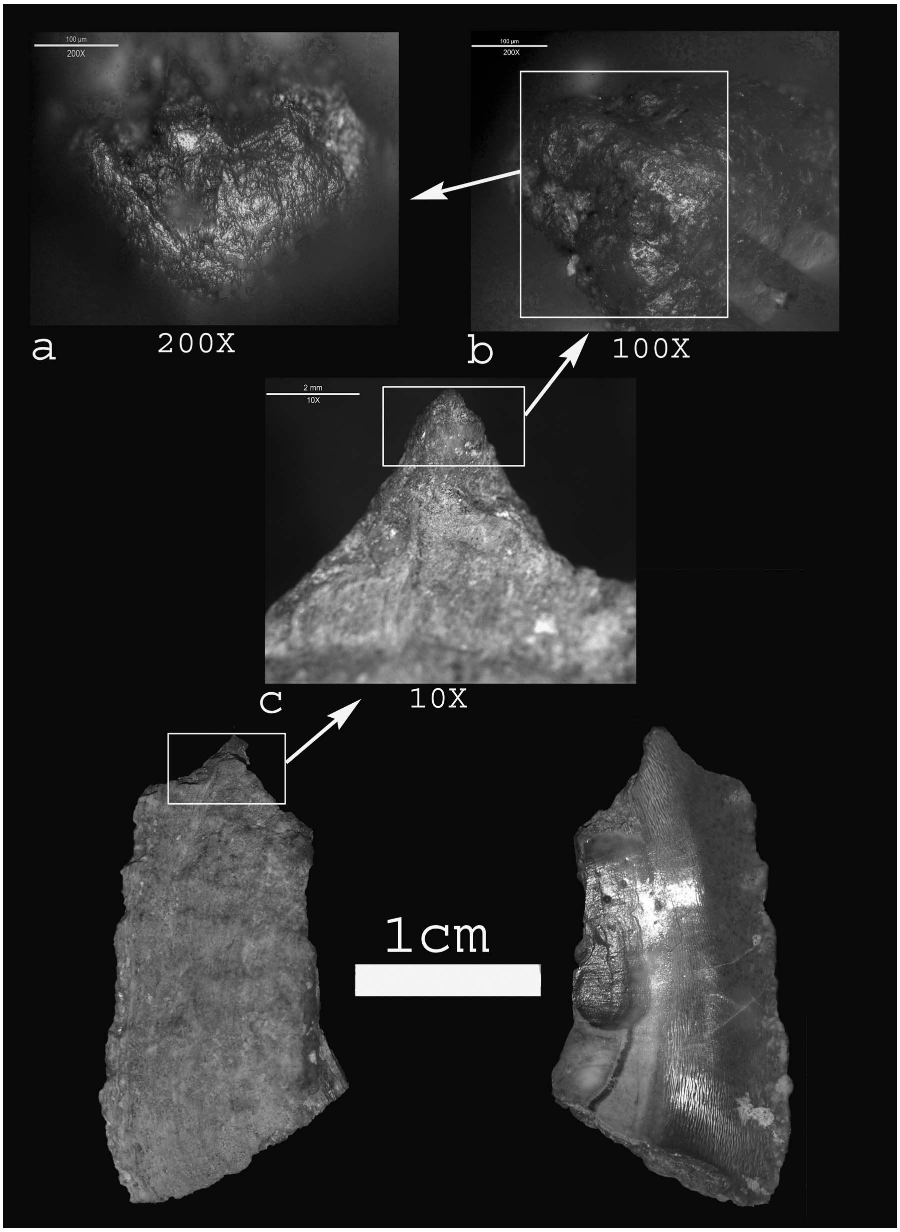


Figure 3. Fragment of Patella (#82.1) used to perforate hide. *A*, *B*, Details of fine and rough polish on the active face. *C*, Rounded perforator tip.

2011; Cuenca et al. 2010; Gutiérrez-Zugasti et al. 2011), as well as in the Middle Paelolithic (Cristiani et al. 2005). Further, other tools have been identified from other geographic (Lammers 2008; Mansur and Clemente 2009; Szabó 2008; Szabó et al. 2007) and chronological contexts, including Paleolithic occupations (Choi and Driwantoro 2007; Douka 2011). In the case of the Gravettian levels of Fuente del Salín, this is the first evidence of the use of shell artifacts for the Upper Paleolithic in Atlantic Europe.

Comparison of the use wear on shells from Fuente del Salín to previous studies (Cuenca et al. 2010), as well as to the specific experimental samples created for this project, has assisted in the documentation of 10 shell tools. Condition of preservation, extent of use wear, and the comparative information derived from experimentation has allowed us to infer the activities performed with these artifacts. On the other hand, critical evaluation of ethnographic information has allowed us to establish a hypothesis with which to approach the archaeological assemblage from Fuente del Salín. For example, the use of shell perforators is documented in different geographical areas for production activities, such as in some proto-agricultural deposits of Cuba, where the shells are

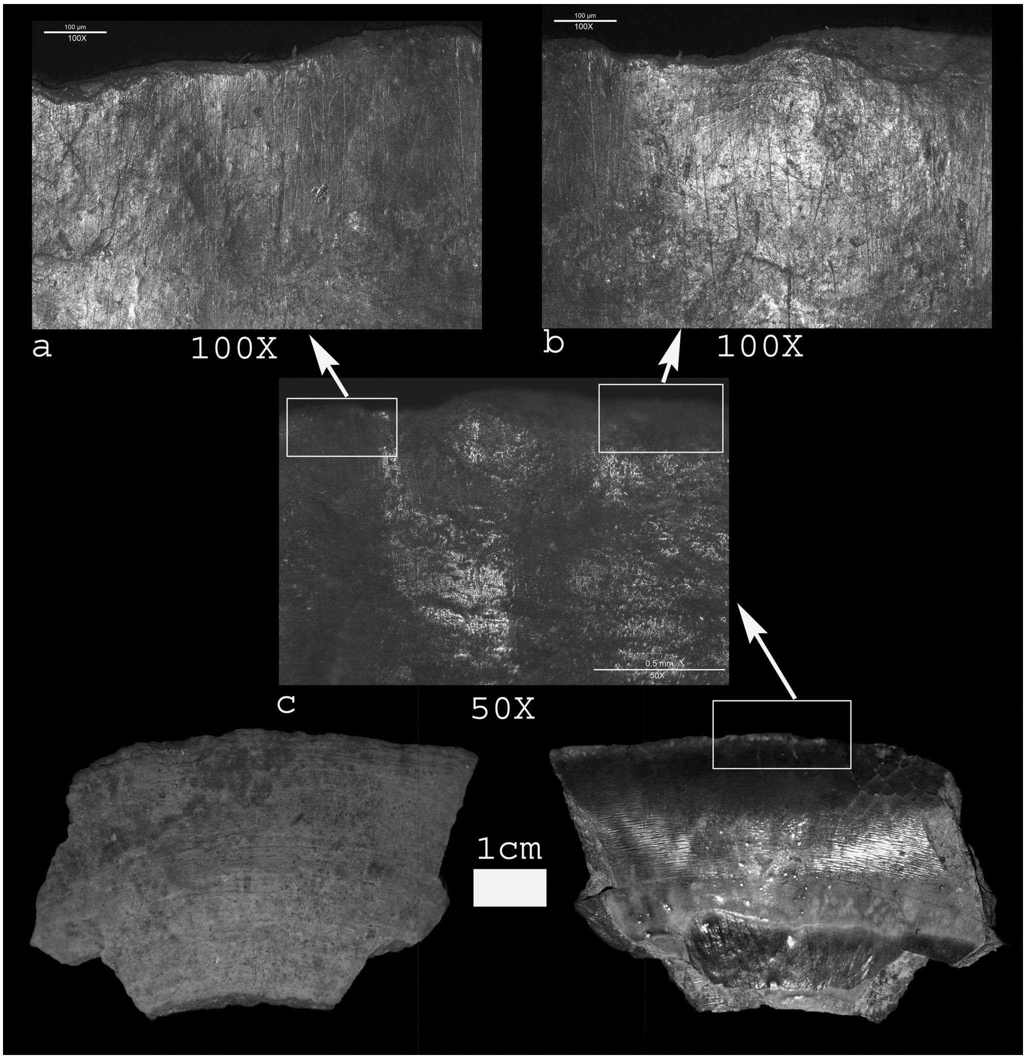


Figure 4. Fragment of *Patella* (#109.1) showing use wear from processing soft mineral (ochre). *A*, *B*, Finely polished and smoothed microtopography with multiple fine striations with a dark background, oriented obliquely and perpendicular to the edge. *C*, Inside face of rounded edge.

worked by percussion (Dacal-Moure and Rivero de la Calle 1984). The use of shells for hide processing is documented among the Alacalufes in Chile; they use shells to scrape seal and nutria skins (Cuenca et al. 2011; Emperaire 1958).

Comparison of the use wear on experimental and archaeological samples has confirmed samples #80.1, #95.1, #95.2, and #109.1 were used to process soft minerals. Further, beyond use wear, the presence of iron on the surface of these artifacts confirms the hypothesis that these fragments were used to obtain coloring pigments for use in artistic representations that used the color red. Ochre stains generated from use are microscopically visible on the interior of some of the microscopic scarring on samples #80.1 and #95.2. The presence of iron on shells that do not exhibit use wear can be explained by other factors. Taking into consideration the existence of a fire structure directly below one of the walls with paintings, it is possible that pigment may have spilled onto any materials that may have been on the ground surface at the time the paintings were done or even at the time the block of ochre was processed to obtain the pigments. In any case, the documentation of several pigments—in particular, red ochre—demonstrates that the processing of pigments was done in situ before and/or during the time the paintings were created. The use of ochre as an additive for hide processing with lithic tools has been documented through functional analysis in several archaeological contexts (Gijn 1989; Ríos-Garaizar et al. 2002). Because of its antiseptic properties, ochre aids in the preservation of hide (Audouin and Plisson 1982). Use of this as an abrasive additive for activities associated to hide processing can explain the polish and rounding of the sharpened edge, and, above all, the presence of microholes on the surface of the artifact used for tanning (Clemente 1997;

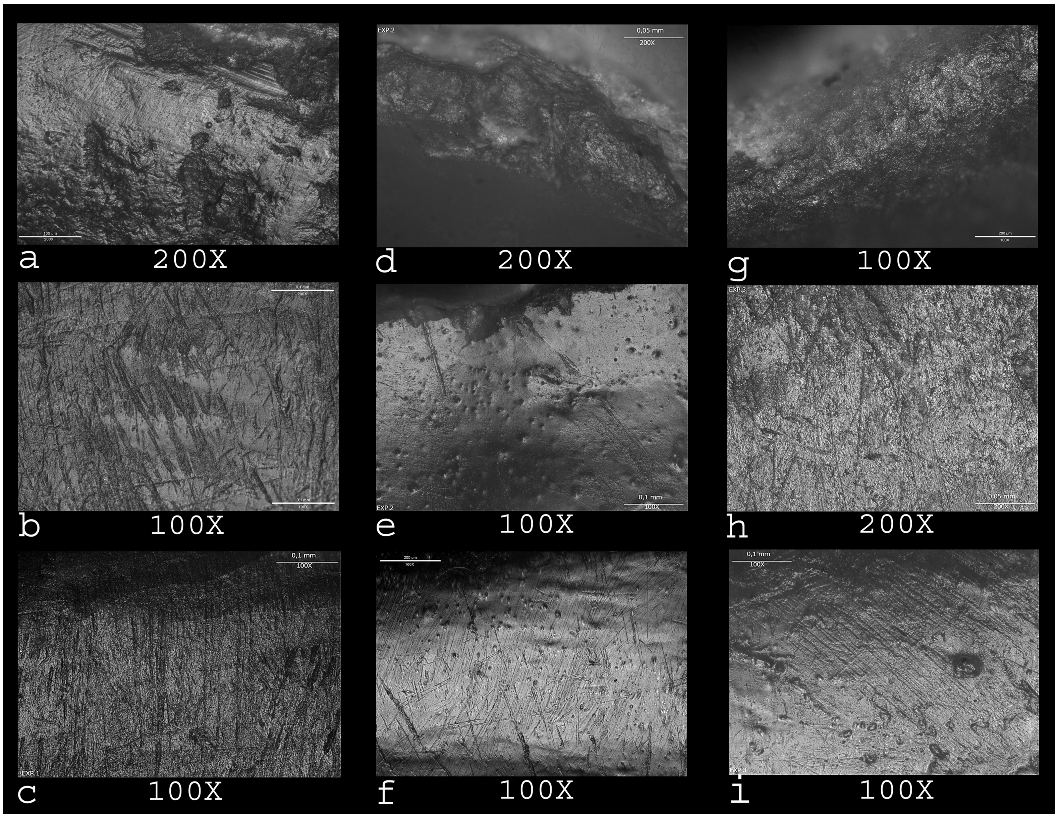


Figure 5. Comparison of use wear on experimental samples. *A*, *B*, *C*, Scraping and cutting of fibers on rock surface. *D*, *E*, *F*, Scraping of soft ochre block. *G*, *H*, *I*, Scraping of hard ochre block.

González-Urquijo and Ibáñez-Estévez 1994; Vaughan 1985). This type of use wear has not been documented in the shell artifacts for hide processing from Fuente del Salín; therefore, in this case ochre was not utilized for the processing of skins.

The origins of ochre use as a coloring agent have been contextualized in relation to the development of human behavior (Bar-Yosef Mayer et al. 2009; Henshilwood et al. 2011). During the Upper Paleolithic, this material was utilized for a great variety of activities, including symbolic representation such as those found in rock art. Most research on the activities related to rock art have focused on the application techniques of the pigments (Lorblanchet 2010), the composition of the pigments (Arias et al. 2011; Garate et al. 2004; Lorblanchet 1995; Menu and Walter 1996), or the processing of the coloring agents through heating blocks of hematite (Clottes et al. 1990; Pomiès et al. 1999). None, however, has focused on identifying the artifacts that were used to obtain the pigment. Along these lines, the presence of shell fragments and shell powder has been identified in the pigments used to create paintings at Tito Bustillo (Asturias, Northern Spain; Balbín-Behrman and Alcolea-González 2009). An extraction and processing area for ochre has been documented at this site along with the presence of shell powder and shell fragments (Balbín-Behrman and Alcolea-González 2009); further complete shells of *Patella vulgata* were found in the excavated area below Panel XI, which is attributed to the Early Upper Magdalenian (Moure-Romanillo 1990; Moure-Romanillo and González-Morales 1988). In this part of the cave, the presence of large *Patella* shells containing an abundance of ochre has been interpreted as possibly having used these as receptacles (Moure-Romanillo 1990). On the other hand, the presence of powder or shell fragments in the composition of some of the pigments used for the paintings has been interpreted as having been part of the recipe to mix the pigment to the right consistency for application (Balbín-Behrman and Alcolea-González 2009) similar to the use of other additives such as clay in the caves of Arenaza (Gárate et al. 2004), Ekain (Chalmin et al. 2002) or El Pendo (García-Díez 2001), or amber at Altamira (Cabrera 1978).

The shells at Fuente del Salín that show use wear for the processing of ochre must be considered when assessing the validity of the interpretation that the utilized pigments showing traces of calcium carbonates were used intentionally as an additive for a specific recipe (Balbín-Behrman and Alcolea-González 2009). In reality, these traces may merely represent the residue of the shells having been used as an instrument for obtaining the ochre powder. In any case, the experimentation has shown that it is not necessary to have a highly specialized technology to obtain the pigment. The shell tools have proved to be very useful for scraping blocks of different hardness, producing 3 g of pigment in 15 minutes.

Despite the availability of lithic pieces from this context—both lithic debris and retouched pieces—Gravettian hunter-gatherers probably used *Patella* shells to perform this task with the objective of not damaging the lithic pieces and thus maintaining their functionality. In this way, once the mollusks were cooked and utilized as a food source, the shells would have been used for a technological purpose, resulting in saving the more effective and lasting lithic artifacts to be used for other purposes. Beyond being linked to obtaining pigment dyes, shells were also used for other activities, such as drilling and processing hides. The use of shells for these tasks is well documented archaeologically in Neolithic sites along the Atlantic (Santimamiñe) and Mediterranean coasts (La Draga), of the Iberian Peninsula (Clemente and Cuenca 2011; Cuenca et al. 2010).

With respect to the role that mollusks played within the economic and symbolic systems in the Early Upper Paleolithic and more specifically, in the Gravettian, it is necessary to highlight the frequent use of shells as ornaments in numerous European assemblages (Álvarez-Fernández 2006; Álvarez-Fernández and Jöris 2007). However, evidence of the dietary use of mollusks from this time period is limited. Other than Fuente del Salín (Gutiérrez-Zugasti et al., forthcoming *a*), the only clear examples of mollusks as a food source are found at Vale Boi (Portugal), Riparo Mochi (Italy), and La Garma A (Álvarez-Fernández 2007; Manne and Bicho 2009; Stiner 1999). This scarcity of data during the Upper Paleolithic has traditionally been explained by the presumed low value that the human populations attributed to marine resources and the assumption that these resources were consumed only in times of food shortages associated with population growth (Osborn 1977; Parmalee and Klippel 1974). Nonetheless, these interpretations are based on theoretical assumptions that give paramount importance to hunting as a subsistence strategy.

In recent years, new models have been proposed that attempt to step beyond this limited perspective and reassess the previously underestimated role of marine resources. These models emphasize the bias that is created by the rise in the sea level, which would have obliterated Upper Paleolithic sites along the coast and thus their settlement systems (Bailey and Flemming 2008). They maintain that the productivity of marine resources would have been greater than during the Holocene and, as such, could have been utilized by prehistoric populations with ease and in great abundance at the beginning of the Upper Paleolithic (Bicho and Haws 2008). Further, they maintain that the nutritional value of mollusks is far greater than originally considered (Manne and Bicho 2011) and that these types of resources were exploited at least since the Early Upper Paleolithic (Stiner 2001). However, at present, few studies have emphasized the technological qualities of marine resources (Pétillon 2008), particularly of mollusks as a basis with which to evaluate these resources in terms of subsistence strategies or in the symbolic systems of the Upper Paleolithic prehistoric populations.

In this way the data from Fuente del Salín have documented three different uses—dietary, ornamental, and technological—which reflect a significant utilization of these resources for a broad range of activities. While it is true that some indicators suggest that the exploitation of marine resources was not particularly intensive during the Early Upper Paleolithic (Gutiérrez-Zugasti et al. forthcoming *a*, forthcoming *b*), their continuous presence attests to their importance in the economic, social, and ritual systems.

## Conclusion

The identification of shell tools in the Gravettian levels of Fuente del Salín represents a new example of utilization of marine resources during the Upper Paleolithic. It also provides new perspectives regarding the painting techniques on cave walls and insights into their production by hunters and gatherers during this time period. Beyond their dietary and decorative value, the use of shells in the prehistoric technology confers a new value to them that we must take into consideration when we assess the importance of marine resources to Paleolithic hunters and gatherers.

The documentation of *Patella* fragments associated to the procurement of pigments for creating paintings represents an advance in understanding the technological processes involved in the creation of this art form, particularly since little is known and/or researched on the topic, not only because of the difficult criteria for their analysis but also because the central focus of these investigations are the paintings themselves. On the other hand, the utilization of shells for other activities, such as hide working, shows that shells were used in multiple activities and became an important multifunctional tool because of its abundance and the ease of its use.

In order to understand the life ways of prehistoric populations, it is essential to analyze the productive activities that ensured their biological success. This can be achieved by examining archaeological data using a sophisticated methodology for functional analysis to meet the challenge. In this way the documentation of shell tools from Fuente del Salín contributes to expanding the information about the technology and the tool kit employed during the Paleolithic period, opening new avenues for researching prehistoric societies.


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## References

Álvarez Fernández, E. 2006. Los objetos de adorno-colgantes del Paleolítico Superior y del Mesolítico en la cornisa cantábrica y en el valle del Ebro: una visión europea. Colección Vitor 195. Salamanca: Ediciones Universidad de Salamanca.

———. 2007. La explotación de los moluscos marinos en la Cornisa Cantábrica durante el Gravetiense: primeros datos de los niveles E y F de La Garma A (Omoño, Cantabria). *Zephyrus* LX:43–58.

Álvarez-Fernández, E., and O. Jöris. 2007. Personal ornaments in the early Upper Paleolithic of Western Eurasia: an evaluation of the record. *Eurasian Prehistory* 5(2):31–44.

Arias, P., E. Laval, M. Menu, C. González-Sainz, and R. Ontañón. 2011. Les colorants dans l'art pariétal et mobilier paléolithique de La Garma (Cantabrie, Espagne). *L'anthropologie* 115:425–445.

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

Bailey, G. N., and N. C. Flemming. 2008. Archaeology of the continental shelf: marine resources, submerged landscapes, and underwater archaeology. *Quaternary Science Reviews* 27:2153–2165.

Balbín-Behrman, R., and J. J. Alcolea-González. 2009. Les colorants de l'art paléolithique dans les grottes et en plein air. *L'anthropologie* 113:559–601.

Bar-Yosef Mayer, D. E., B. Vandermeersch, and O. Bar-Yosef. 2009. Shells and ochre in Middle Paleolithic Qafzeh Cave, Israel: indications for modern behavior. *Journal of Human Evolution* 56:307–314.

Bicho, N., and J. Haws. 2008. At the land's end: marine resources and the importance of fluctuations in the coastline in the prehistoric hunter-gatherer economy of Portugal. *Quaternary Science Reviews* 27:2166–2175.

Binford, L. R. 1968. Post-Pleistocene adaptations. In *New perspectives in archaeology.* S. R. Binford, ed. Pp. 313–341. Chicago: Aldine.

Cabrera, J. M. 1978. Les matériaux de peinture de la caverne d'Altamira: actes de la cinquième réunion triennale du comité de conservation de l'ICOM. (ICOM Committee for Conservation 5th Triennial Meeting, Zagreb, Croatia, Oct. 1–8, 1978.) Paris: International Council of Museums.

Cantillo, J. J., J. Ramos, M. Soriguer, M. Pérez, E. Vijande, D. Bernal, S. Domínguez-Bella, C. Zabala, J. Hernando, and I. Clemente. 2010. La explotación de los recursos marinos por sociedades cazadoras-recolectoras-mariscadoras y tribales comunitarias en la región histórica del Estrecho de Gibraltar. In *Ia Reunión de Arqueomalacología de la Península Ibérica.* E. González Gómez, V. Bejega García, C. Fernández Rodríguez, and N. Fuertes Prieto, eds. *Férvedes* 6:105–113.

Chalmin, E., M. Menu, and J. Altuna. 2002. Les matières picturales de la grotte d'Ekain (Pays Basque, Espagne). *Munibe* 54:35–51.

Choi, K., and D. Driwantoro. 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.

Citerne, P. 1998. Le théme du poisson dans l'art paléolothique des Pyrénées. *Bulletin de la Société Préhistorique Ariège-Pyrénées* LIII:17–64.

Citerne, P., and G. Delluc. 2004. Les représentantions paléolithiques de salmonidés: mise en lumière de phénomènes culturels par lanalyse statistique des caractères formels. In *Ĺart pariétal paléolithique dans son contexte naturel.* M. Lejeune, ed. Actes du colloque 8.2, Congrès de lUISPP (Liège, IX, 2001). *ERAUL* (*Etudes et recherches archèologiques de l'Universitè de Liège*) 107:95–113.

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

Clemente-Conte, I., and D. Cuenca-Solana. 2011. Instrumentos de trabajo de concha en el yacimiento Neolítico de La Draga. In *El poblat lacustre del neolític antic de la Draga. Excavacions 2000–2005.* Monografies del CASC 9. A. Bosch Lloret, J. Chinchilla Sánchez and J. Tarrús Galter, eds. Pp. 137–145. Barcelona: Museu d'Arqueologia de Catalunya. Centre d'Arqueologia Subaquàtica de Catalunya.

Cleyet, J. J. 1990. *La Prehistoire de la peche.* Paris: Ed. France, col. des Hesperides.

Clottes, J., M. Menu, and P. H. Walter. 1990. La préparation des peintures magdaléniennes des cavernes ariégeoises. *Bulletin de la Société préhistorique française* 87(6):170–192.

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

Cuenca, D. 2010. Los efectos del trabajo arqueológico en conchas de *Patella species* y *Mytilus galloprovincialis* y su incidencia en el análisis funcional. In *La reunión de Arqueomalacología de la Península Ibérica.* E. González Gómez, V. Bejega García, C. Fernández Rodríguez, and N. Fuertes Prieto, eds. *Férvedes* 6:43–51.

Cuenca, D., I. Clemente, and I. Gutiérrez-Zugasti. 2010. Utilización de instrumentos de concha durante el Mesolítico y Neolítico inicial en contextos litorales de la región cantábrica: programa experimental para el análisis de huellas de uso en materiales malacológicos. *Trabajos de Prehistoria* 67:211–225.

Cuenca, D., I. Gutiérrez-Zugasti, and I. Clemente. 2011. The use of molluscs as tools by coastal human groups: contribution of ethnographical studies to research on Mesolithic and early Neolithic contexts in Northern Spain. *Journal of Anthropological Research* 67(1):77–102.

Dacal-Moure, R., and M. Rivero de la Calle. 1984. *Arqueología aborigen de Cuba.* Habana, Cuba: Editorial Gente Nueva.

Dams, L. R. 1987. Poissons et contours de type pisciforme dans lart pariétal paléolithique. *Bulletin de la Societé royale belge dÁnthropologie Préhistorique* 98:81–132.

d'Errico, F., C. Henshilwood, M. Vanhaeren, and K. Van Niekerk. 2005. *Nassarius kraussianus* shell beads from Blombos Cave: evidence for symbolic behavior in the Middle Stone Age. *Journal of Human Evolution* 48(1):3–24.

d'Errico, F., M. Vanhaeren, and L. Wadley. 2008. Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. *Journal of Archaeological Science* 35(10):2675–2685.

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

Emperaire, J. 1958. *Los nómadas del mar.* Santiago, Chile: Lom Ediciones.

Flannery, K. V. 1969. Origins and ecological effects of early domestication in Iran and the Near East. In *The Domestication and Exploitation of Plants and Animals.* P. Ucko and G. W. Dimbleby, eds. Pp. 73–100. Chicago: Aldine.

Fritz, C. 1997. Vers une reconstitution des procédés artistiques magdaléniens: contribution de lanalyse microscopique dans le domaine de lart mobilier. *Trabajos de Prehistoria* 54(2):43–59.

Gárate, D., E. Laval, and M. Menu. 2004. Étude de la matière colorante de la grotte d'Arenaza (Galdames, Pays Basque, Espagne). *L'Anthropologie* 108(2):251–289.

García, M. 2001. Estudio de la materia colorante de las pinturas del Friso de las Pinturas. In *La cueva de El Pendo: Actuaciones Arqueológicas, 1994–2000.* R. Montes and J. Sanguino, eds. Pp. 223–231. Santander, Spain: Ayuntamiento de Camargo-Consejería de Cultura. Turismo y Deporte del Gobierno e Cantabria.

González-Morales, M. R., and A. Moure-Romanillo. 2008. Excavaciones y estudio de arte rupestre en la cueva de la Fuente del Salín (Muñorrodero, Val de San Vicente). Campaña de 2000. In *Actuaciones Arqueológicas en Cantabria 2000–2003.* R. Ontañón, ed. Pp. 79–82. Santander, Spain: Gobierno de Cantabria, Consejería de Cultura, Turismo y Deporte.

González-Urquijo, J. E., and J. J. Ibáñez-Estévez. 1994. *Metodología de análisis funcional de instrumentos tallados en sílex.* Cuadernos de Arqueología, 14. Bilbao: Universidad de Deusto.

Griffits, J., and C. Bonsall. 2001. Experimental determination of the function of antler and bone "bevelended tools" from prehistoric shell middens in Western Scotland. In *Crafting bone: Skeletal technologies through time and space.* Proceedings of the 2nd Meeting of the (ICAZ) Worked Bone Research

Group. A. M. Choyke and L. Bartosiewicz, eds. Pp. 207–220. British Archaeological Reports, International Series 937. Oxford: Archaeopress.

Gutiérrez-Zugasti, F. I., D. Cuenca-Solana, I. Clemente-Conte, C. González-Sainz, and J. C. López-Quintana. 2011. Instrumentos de trabajo y elementos de adorno en conchas de molusco de la cueva de Santimamiñe (Kortezubi, Bizkaia). In *Excavaciones en la cueva de Santimamiñe: Campañas 2004–2006*. J. C. López Quintana, dir. Bizkaiko Foru Aldundia-Diputación Foral de Bizkaia. *Kobie Serie Excavaciones* 1:155–170.

Gutiérrez-Zugasti, F. I., D. Cuenca-Solana, M. R. González Morales, and A. Garcia Moreno. Forthcoming *a*. *Exploitation of molluscs as food during the Gravettian at Fuente del Salín cave (Cantabria, Northern Spain). Ancient maritime communities and the relationship between people and environment along the European Atlantic coasts*. British Archaeological Reports International Series. Oxford: Archaeopress.

Gutiérrez-Zugasti, F. I., D. Cuenca-Solana, P. Rasines-Del Río, E. Muñoz-Fernández, S. Santamaría-Santamaría, and J. M. Morlote Expósito. Forthcoming *b*. The role of shellfish in hunter-gatherer societies during the early Upper Palaeolithic: a view from El Cuco rockshelter, Northern Spain. *Journal of Anthropological Archaeology*.

Henshilwood, C., F. D'errico, K. van Niekerk, Y. Coquinot, Z. Jacobs, S. E. Lauritzen, M. Menu, and R. García-Moreno. 2011. A 100,000-year-old ochre-processing workshop at Blombos Cave, South Africa. *Science* 334: 219–222.

Ibáñez-Estévez, J. J., and J. E. González-Urquijo. 1996. *From tool use to site function: use-wear analysis in some Final Palaeolithic sites in the Basque country*. British Archaeological Reports, International Series 658, Tempus Reparatum. Oxford: Archaeopress.

———. 1998. The production and use of lithic tools at the end of the Upper Palaeolithic in the Basque country (Spain). In *From raw-material procurement to tool production: lithic technology in Late Glacial and Postglacial Europe*. S. Milliken, ed. Pp. 17–38. British Archaeological Reports, International Series 700. Oxford: Archaeopress.

Jensen, G. 2001. Macrowear patterns on Danish late Mesolithic antler axes. In *Crafting bone: skeletal technologies through time and space*. A. M. Choyke and L. Bartosiewicz, eds. Pp. 165–170. Proceedings of the 2nd Meeting of the (ICAZ) Worked Bone Research Group, Budapest. British Archaeological Reports, International Series 937. Oxford: Archaeopress.

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: Leiden University Press.

Lorblanchet, M. 1995. *Les Grottes ornées de la préhistoire: nouveaux regards*. Arles: Editions Errance.

———. 2010. *Art Pariétal: grottes ornées du Quercy*. Arles: Editions de Rouergue.

Manne, T., and N. F. Bicho. 2009. Vale Boi: Rendering new understandings of resource intensification and diversification in southwestern Iberia. *Before Farming: The Archaeology of Old World Hunter-Gatherers* 2:1–21.

———. 2011. Prying new meaning from limpet harvesting at Vale Boi during the Upper Paleolithic. In *Trekking the shore: changing coastlines and the antiquity of coastal settlement*. N. F. Bicho, J. Haws, and L. G. Davis, eds. Pp. 273–289. New York: Springer.

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

Menu, M., and P. Walter. 1996. Les rythmes de lart préhistorique. *Techne* 3: 11–23.

Moure-Romanillo, A. 1990. La cueva de Tito Bustillo (Ribadesella, Asturias): el yacimiento paleolítico. In *Excavaciones arqueológicas en Asturias 1983–1986*. Pp. 107–127. Oviedo, Spain: Servicio de Publicaciones del Principado de Asturias.

Moure-Romanillo, J. A., and M. R. González-Morales. 1988. El contexto del arte parietal: la tecnología de los artistas en la cueva de Tito Bustillo (Asturias). *Trabajos de Prehistoria* 45:19–49.

———. 2000. Excavaciones y documentación del arte rupestre de la cueva de la Fuente del Salín (Muñorrodero, Val de San Vicente). In *Actuaciones Arqueológicas en Cantabria 1984–1999*. R. Ontañón, ed. Pp. 149–150. Santander, Spain: Gobierno de Cantabria.

Osborn, A. J. 1977. Strandloopers, mermaids and other fairy tales: Ecological determinants of marine resource utilization—the Peruvian case. In *For theory building in archaeology*. L. Binford, ed. Pp. 157–205. London: Academic Press.

Parmalee, P. W., and W. E. Klippel. 1974. Freshwater mussels as a prehistoric food resource. *American Antiquity* 39:421–434.

Pétillon, J. M. 2006. *Des Magdaléniens en Armes: technologie de projectile en Bois de Cervidé du Magdalénien Supérieur d'Isturitz (Pyrénées-Atlantiques)*. Artefacts, 10. Treignes, Belgium: CEDARC.

———. 2008. First evidence of a whale-bone industry in the western European Upper Paleolithic: Magdalenian artifacts from Isturitz (Pyrénées-Atlantiques, France). *Journal of Human Evolution* 54:720–726.

Pomiès, M. P., M. Barbaza, M. Menu, and C. Vignaud. 1999. Préparation des pigments rouges préhistoriques par chauffage. *L'Anthropologie* 103:503–518.

Ríos-Garaizar, J. 2010. Organización económica de las sociedades neandertales: el caso del nivel VII de Amalda (Zestoa, Guipuzkoa). *Zephirus* 65:15–37.

Ríos-Garaizar, J., I. Ortega-Cordellat, J. J. Ibáñez-Estévez, and J. E. González-Urquijo. 2002. El aporte del análisis funcional para el conocimiento del yacimiento auriñaciense de Barbas III: primeros resultados. In *Análisis funcional: su aplicación al estudio de sociedades prehistóricas*. I. Clemente, R. Risch, and J. F. Gibaja, eds. Pp. 141–150. British Archaeological Reports, International Series 1073. Oxford: Archaeopress.

Semenov, S. A. 1964. *Prehistoric technology*. London: Evelyn Adams & Mackay.

Stiner, M. C. 1999. Paleolithic mollusc exploitation at Riparo Mochi (Balzi Rossi, Italy): food and ornaments from the Aurignacian through Epigravettian. *Antiquity* 73:735–754.

———. 2001. Thirty years on the "Broad Spectrum Revolution" and Paleolithic demography. *Proceedings of the National Academy of Sciences of the United States of America* 98:6993–6996.

Szabó, K. 2008. Shell as a raw material: Mechanical properties and working techniques in the tropical Indo-West Pacificic. *Archaeofauna* 17:125–138.

Szabó, K., A. Brumm, and P. Bellwood. 2007. Shell artefact production at 32.000–28.000 BP in Island Southeast Asia. Thinking across media? *Current Anthropology* 48(5):701–723.

van Gijn, A. L. 1989. *The wear and tear of flint*. Analecta Prahestorica Leidensia 22. Leiden: University of Leiden.

———. 2005. A functional analysis of some Late Mesolithic bone and antler implements from the Dutch coastal zone. In *From hooves to horns, from mollusc to mammoth: manufacture and use of bone artefacts from prehistoric times to the present*. H. Luik, A. M. Choyke, C. E. Batey, and L. Lougas, eds. Pp. 47–66. Proceedings of the 4th Meeting of the ICAZ Worked Bone Research Group at Tallinn. Tallinn, Estonia: Tallinn Books.

———. 2007. The use of bone and antler tools: two examples from the Late Mesolithic in the Dutch coastal zones. In *Bones as tools: current methods and interpretations in worked bone studies*. C. Gates and R. Walker, eds. Pp. 81–92. British Archaeological Reports, International Series 1622. Oxford: Archaeopress.

Vanhaeren, M., and F. dÉrrico. 2006. Aurignacian ethnolinguistic geography of Europe revealed by personal ornaments. *Journal of Archaeological Science* 33(8):1105–1128.

Vaughan, P. C. 1985. *Use-wear análisis of flaked stone tools*. Tucson: University of Arizona Press.

White, R. 2007. Systems of personal ornamentation in the Early Upper Palaeolithic: methodological challenges and new observations. In *Rethinking the human revolution: new behavioral and biological perspectives on the origin and dispersal of modern humans*. P. Mellars, K. Boyle, O. Bar Yosef, and C. Stringer, eds. Pp. 287–302. Cambridge: McDonald Institute for Archaeological Research.