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RESEARCH

The Solutrean Antlerworking in Hort de Cortés–Volcán del Faro (Valencia, Spain) in the Southwest Europe Context: a Preliminary Study

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Abstract

In this work, we present a preliminary analysis of the Solutrean antlerworking at Hort de Cortés–Volcán del Faro (Valencia, Spain) (ca. 26–21 ka cal BP). A restudy of its archaeological sequence, which came to encompass the Early Upper Palaeolithic to the Magdalenian period, has been a mandatory subject in the last years. This site became an archaeological reference since the beginning of its excavation in the 1960s but has not been systematically studied. The implementation of more specialized studies is used a) to observe the distribution of technical pieces in the stratigraphy and identify possible stratigraphic alterations and b) to restudy a huge lithic, osseous, and faunal collection which can provide new information that may clarify them. The aim is to develop a systematic study, from a technological point of view, to identify and characterize operational schemes and to define the modalities of antlerworking. The technological analysis of waste products, blanks, rough-outs, and objects allows us to observe how raw material is obtained and transformed into a toolkit following the refitting by default method. It will help us analyze some questions about the raw material acquisition and transformation like (1) selection between hunted and shed antlers and its possible explanation, (2) the existence of planning of tool manufacture, and (3) the step-by-step production of the debitage. We will extract conclusions and analyze different social aspects: (1) by identifying technical traditions and comparing them with other studied sites and periods and (2) by knowing a new aspect of the way of life of these human groups.

Keywords Solutrean · Antlerworking · Osseous technology · Hort de Cortés–Volcán del Faro · Last Glacial Maximum

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Introduction

The study of the Solutrean osseous industry is essential to understanding and determining changes and specificities in bone and antlerworking technology throughout the European Upper Palaeolithic. Its chronological position allows a comparison with the previous (Aurignacian and Gravettian) and later (Badegoulian and Magdalenian) technocomplexes, also providing information on the variability between the regional facies of SW Europe. Solutrean antlerworking had not been characterized in the Mediterranean area of the Iberian Peninsula nor in other areas except for southwestern France (Baumann, 2014; Baumann & Hinguant, 2016; Baumann & Maury, 2013). Until now, the Iberian Solutrean osseous collections have been studied from a morpho-typological perspective and only specific and isolated data on osseous technology are known (i.e., Aura Tortosa et al., 2006; Iturbe et al., 1993; Jordá Cerdá, 1955; Pericot, 1942).

The recovered Solutrean osseous industry in the Iberian Mediterranean region is concentrated in a few sites with a low number of pieces except for Cova del Parpalló. The study of the osseous industry has been focused on objects but not on the technical process of blank production, shaping, and use (Tejero et al., 2023). In some collections, possible blocks of raw material and blanks are mentioned, but there is no systematic description that allows comparisons between sites. It is not possible to have complete data on the employed raw material either although it is intuited that antlers will be used more and more to the detriment of bone.

The first feature to highlight about the osseous industry is its unequal geographical and chronological distribution. In total, 405 objects have been quantified, from five sites (Parpalló, Beneito, Cendres, Ambrosio, and Nerja) and 16 stratigraphic or archaeological units (Table 1). For the central Iberian Mediterranean region, we have the data on Cova del Parpalló (Pericot, 1942), Cova Beneito (Iturbe et al., 1993), Cova de les Cendres (Martínez-Alfaro et al., 2019), and some references to specific pieces for Les Malladetes (Jordá Cerdá, 1955) and Badall (Villaverde et al., 2015). For the southern Iberian Mediterranean region, the data we have is limited to Cueva Ambrosio (Ripoll López, 1988) and Cueva de Nerja (Aura Tortosa et al., 2006). Close to 87% of the Solutrean osseous industry comes from sites in the central Iberian Mediterranean region, specifically from the Valencian nucleus. For its part, the sites in eastern Andalusia account for the remaining 13%. In general, there is a relationship between the number of objects and the diversity of recognized types of tools/weapons.

Regarding the chronological evolution, the different assemblages have been organized into three phases, whose radiocarbon chronology is the one proposed by Aura Tortosa & Jordá Pardo, (2012): Lower Solutrean (ca. 26–24 ka cal BP), Solutrean Fully developed (ca. 24.5–23 ka cal BP), and Evolved Solutrean or Solutrean-Gravettian (ca. 23–21 ka cal BP) (Pericot, 1942; Jordá Cerdá, 1955; Fortea & Jordá Cerdá, 1976; Fullola, 1979; Ripoll López, 1988; Villaverde & Fullola, 1990; Iturbe et al., 1993; Tiffagom, 2006; Aura Tortosa et al., 2012; Aura Tortosa & Jordá Pardo, 2012). The number of classified objects on bone

Table 1 Distribution by sites and periods of the Solutrean osseous industry in the Iberian Mediterranean region. This includes Cueva Beneito, Cova del Parpalló, Nerja Vestíbulo (NV), Cueva Ambrosio, and Cova de les Cendres

Period	Lower Solutrean (26–24.5 ka cal BP)			Solutrean fully developed (24.5–23 ka cal BP)					Evolved Solutrean (23–21 ka cal BP)									
	Proto-Solutrean	Lower Solutrean	Solutrean A	Middle Solutrean	Middle Solutrean		Solutrean B		Evolved Soultrean/SG	Upper Solutrean	Evolved Solutrean	Evolved Solutrean					Solutrean	TOTAL
Typology/sites	Beneito B6	Parpalló	NV10	Beneito B5-B3	Parpalló SM	Ambrosio VI	NV 9	NV 8’	Beneito B2-B1	Parpalló	Parpalló	Cendres XIII	Ambrosio IV	Ambrosio II	NV 8	NV8/s	HC·VF	
Double point		1			5				16	6	4	6			1			39
Simple point		12	1		34				1	28	33	1	1?				1	112
Long point					1					2	1			1				5
Point with poligonal base					3					4	6	2						15
Points with groove															1			1
Bevelled point		1	1			1			1	1	9	3			1		2	20
Flattened bevel point											3							3
Short bevelled point											18							18

Table 1 (continued)

Period	Lower Solutrean (26–24.5 ka cal BP)			Solutrean fully developed (24.5–23 ka cal BP)				Evolved Solutrean (23–21 ka cal BP)									
Point with longitudinal groove	1																1
Flat point											1			1			2
Flat double point		1															1
Long & thin point									1	4							5
Thin point				1									1				2
Double thin point											2						2
Point (fragment)	1		4	8		3	1	3				3	4	5	3		35
Needle		1							1		2	1					5
Awl		8	2	3	23	1		8	26	47	1	3	9				131
Chisel													1			1	2
Spatula						1							2				3
Spatula polisher		2			1				2	2						1	8

Table 1 (continued)

Period	Lower Solutrean (26–24.5 ka cal BP)			Solutrean fully developed (24.5–23 ka cal BP)				Evolved Solutrean (23–21 ka cal BP)									
Total numper by site	2	26	8	12	67	6	1	29	71	127	18	8	18	9	3	5	**410**
Total number by period	36			86				283								5	
Total number of type–period	9 types			9 types				20 types								4 types	

and antler in each phase is variable. Between the first and the second grouping, the number of pieces practically triples and the same occurs between the second and the third phases. The result is that the Evolved Solutrean phase concentrates practically 70% of the Solutrean osseous industry, and Parpalló alone accounts for 56.5% of the whole (Table 1). The increase in the number of objects in the last phase, especially points, can be placed in a long-term transformation of the hunting weaponry. As in the rest of SW Europe, this transformation takes place in the Spanish Mediterranean region, substituting Solutrean stone points for Badegoulian and Magdalenian osseous points (Aura Tortosa, 1995).

Following the typology of I. Barandiarán, (1967), the family of pointed tools contains most of the objects, followed at a great distance by the flattened and perforated ones. Among the points, the simple ones stand out, those with a simple bevel (some short, others with a flattened bevel, sometimes decorated), those with a polygonal base and the fine points. Awls and "reserved base points" (awls with epiphysis in the proximal part) are a large group, possibly related to domestic activities. Some long and grooved points have also been described. The flattened tools are limited to flat points, some chisels and spatulas. As for the perforated ones, they are limited to the mention of a few needles (Pericot, 1942) and a perforated baton (Villaverde et al., 2015). Needles with perforated heads are only documented in Evolved Solutrean layers (Table 1).

Concerning the osseous technology, the final Solutrean was partially studied in Parpalló (Valencia) and raised some economic information: most antlers are acquired by hunting and the use of percussion techniques and groove and splinter procedure (GSP) in the debitage (P. de Oliveira, personal communication). Another studied site is Cova de les Cendres (XIII) (Alicante) which has no basal parts in the excavated area so there is no information about the raw material acquisition. Regarding the debitage, we observe again the presence of fracture planes on blanks and waste products. It was not possible to establish operational schemas because of the low number of blanks and the absence of roughouts. It is noted by the author the presence in the upper layer of level XIII of a longitudinal fragment of a blank with a groove in the preserved lateral portion, showing that the GSP continues to be used (De Oliveira, 2013; Martínez-Alfaro et al., 2019) as well as in Nerja (NV9) (Málaga) (Aura Tortosa et al., 2006). Other sites like Ambrosio (Almería) or Vale Boi (Portugal) lack a technological description of the whole collection (Évora, 2013).

Our work aims to make a preliminary characterization of the Solutrean antlerworking in Hort de Cortés–Volcán del Faro (henceforth, HC-VF), showing new data on the Solutrean antlerworking in the Mediterranean area of the Iberian Peninsula. The analysis of waste products, blanks, roughouts, and objects allows us to know how raw material is obtained and transformed into a toolkit and to extract techno-economic and cultural interpretations. All this information will allow us to compare the HC-VF Solutrean with other studied sites from the same period.

Technical Traditions: Percussion as a Unifying Thread

While the antlerworking in the Gravettian and Magdalenian periods is characterized and highlighted by the use of the GSP, a long technical tradition persists throughout the time in the southwest European Upper Palaeolithic, namely, direct percussion. Nowadays, we realize that this technique has been underestimated and probably misunderstood as it has been present thought the Upper Palaeolithic showing that it is well adapted and efficient in antlerworking (Baumann & Maury, 2013; Pétillon & Ducasse, 2012).

In the Aurignacian culture, the debitage by cleaving (longitudinal indirect percussion) has been characterized through different experimental programs including on both red deer and reindeer antlers (Liolios, 1999; Tejero, 2010, 2013; Tejero et al., 2012). Nevertheless, the use of direct percussion has been also suggested in the north sector of Abri Castanet, Blanchard, Grotte des Hyènes, and Gatzarria, all of them in France, to produce blanks made on beam sections and rod-shaped flakes taken from beams and tines. The use of this technique is related to shaped intermediate tools involved in antler debitage by cleaving and probably, in woodworking (Tartar, 2012, 2018). Anyway, two reduction sequences by direct percussion have been identified so it confirms the use of this technique in the Aurignacian debitage (Tartar, 2018).

The GSP was introduced during the Gravettian period (Goutas, 2003, 2004, 2009) as a procedure that allows obtaining morphologically predetermined and more standardized blanks. In the context of percussion techniques, the use of double grooving (or not) plus indirect percussion on segments of antlers has been experimentally demonstrated in debitage by partition (Goutas et al., 2018). Finally, the direct percussion technique is employed punctually on middle and small-sized antlers but generally on primary block preparation (Goutas, 2004: 140–141; Villaverde et al., 2019).

We focus the present study on the Solutrean antlerworking. In Laugerie-Haute, Badegoule, Fourneau du Diable, Rochefort, and Roc de Sers (France), it is characterized by the use of direct percussion (splitting) on an anvil when producing pressure flakers, intermediate tools, and projectile points. Segments of beams and tines of antlers are bipartite by transversal direct percussion on an anvil and then, each half is bipartite again following the same technique. Thus, each quarter of the segment constitutes a blank that is transformed into a tool producing no waste products (Baumann, 2014; Baumann & Hinguant, 2016; Baumann & Maury, 2013). The operational schema related to this production is partition. Moreover, the use of operational schema by extraction (GPS) is present too in Roc de Sers, Badegoule, Laugerie-Haute, and Fourneau du Diable (Baumann, 2008, 2014), but it is a consequence of stratigraphic contaminations well delimited (Baumann, 2014). Sectioning is the last operational schema identified, and it is made in three ways: (1) peripheral/unifacial/bifacial cutting direct percussion plus flexion, (2) sawing plus flexion (in tine tips), and (3) flexion (Baumann, 2014).

In the Badegoulian, the direct percussion technique is predominant. The operational schema identified is the progressive reduction of the block because of the several reduction sequences (from the primary block to the configured blank). It is carried out by transversal direct percussion on an anvil, too. The first reduction sequence consists of flaking (consecutive flake removal) a segment of antler to obtain an elongated strip. Then the splinter is reconfigured by direct percussion in another reduction sequence and becomes a rod-shaped flake (Rigaud, 2004;

Averbouh & Pétillon, 2011; Pétillon & Averbouh, 2012; Pétillon & Ducasse, 2012; Rémy, 2013; Averbouh, 2018; Borao et al., 2016; Borao, 2019). Other operational schemas are identified like sectioning to produce blanks in volume.

Finally, the Magdalenian is characterized by the use of GSP in the debitage, but recently debitage by direct percussion has been described in different sites in France and the Iberian Peninsula to manufacture domestic tools (Lefebvre & Pétillon, 2018; Malgarini & Bodu, 2018; Borao, 2019).

So, direct percussion is a technique widely employed and well adapted in antler-working, and it is integrated into the cultural evolution to produce the whole equipment or just domestic tools.

The Archaeological Site of Hort de Cortés–Volcán del Faro

The cave-shelter of the Hort de Cortés–Volcán del Faro is located in Cullera, 30 km south of the city of Valencia (Spain) (Fig. 1). It is situated at 122 m.a.s.l. and 500 m from the current coastline of the Mediterranean Sea. The cave partially collapsed so its morphology now is similar to a sinkhole.

The site was excavated by J. Aparicio between 1968 and 1984. The excavation was divided into four sectors: Norte (north) and A, B, and C reunified as A (Aparicio, 2003). The first publications suggested that HC-VF was an important Palaeolithic site with an archaeological sequence that coincides with the one identified in Cova del Parpalló (Fletcher & Aparicio, 1969). The excavation methodology used and the absence of a detailed description of the sedimentology and its composition introduce limitations in the stratigraphic discussion. The available data is generic and focused on the presence of large blocks and the carbonation processes unevenly affecting the outer and inner squares.

Our study is focused on Sector A which has an extension that exceeds 60 m^2 and an archaeological deposit deeper than 9 m divided into 43 artificial layers (Aparicio, 2003). Previous analysis of archaeological and bioarchaeological materials, in addition to the radiocarbon dating from charcoals, led us to recognize different occupation phases between ca. 28 and 17 ka cal BP with lithic and osseous industries from Gravettian, Solutrean, Badegoulian, and Magdalenian periods (Soler Mayor et al., 2013; Aura Tortosa et al., 2020). It must be advised that the contact between those big occupation cycles is under study.

The few charcoal fragments recovered allowed the identification of cryophilous pines (*Pinus nigra-sylvestris*) and juniper (*Juniperus* sp.) in the local landscape. Although the wood anatomy of *Juniperus* sp. does not allow the identification of the species, cryophilous pine species are currently absent in the study area and their presence reflects supramediterranean bioclimatic conditions (MAT or mean annual temperature of 8–13 °C).

The first research on faunal remains from the HC-VF sector A was published by Davidson (1972, 1989). He pointed out the difficulties in establishing a stratigraphic correlation between layers and grids. The application of new parameters and methodology has yielded new data in this collection. The new revisions have brought to light an amount of 5811 remains, with 64% of the assemblage

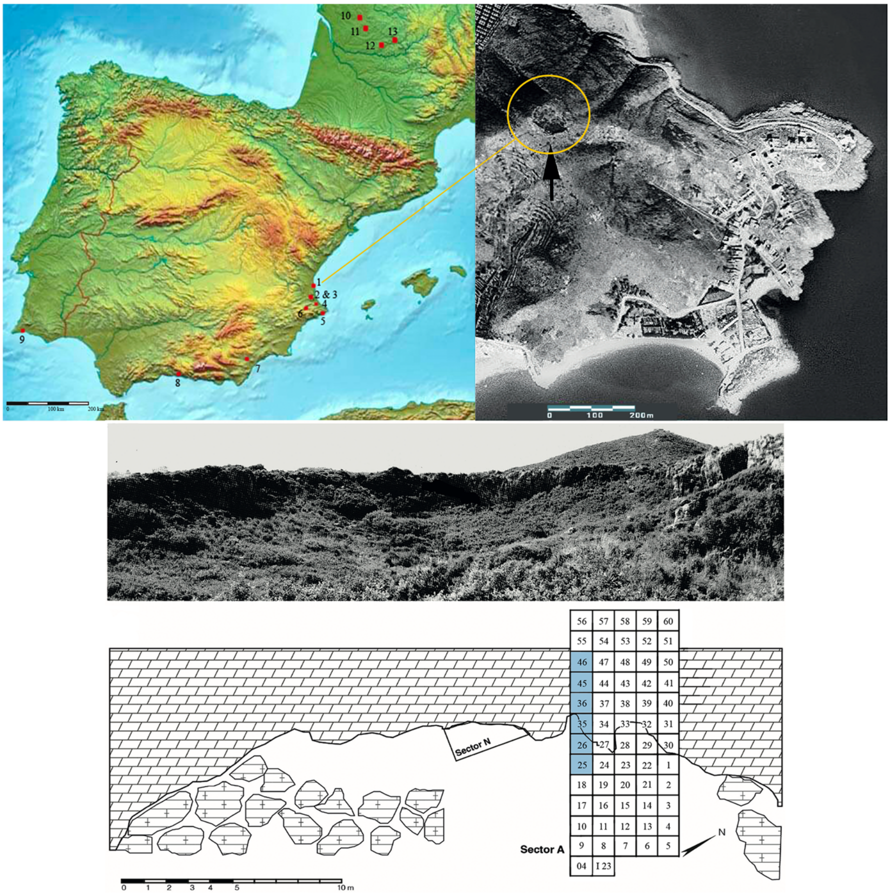

Fig. 1 Geographic location of Hort de Cortés–Volcán del Faro (Cullera, Valencia, Spain) and other Solutrean sites cited in the text ((1) Hort de Cortes-Volcán del Faro; (2) Cova del Parpalló; (3) Malladetes; (4) Badall; (5) Cova de les Cendres; (6) Beneito; (7) Ambrosio; (8) Nerja; (9) Vale Boi; (10) Roc de Sers; (11) Fourneau de Diable; (12) Laugerie-Haute; (13) Badegoule) and the planimetry of the excavation (selected transect in blue) (modified from Aura Tortosa et al., 2020: Fig. 1)

determined at a taxonomic level, indicating the predominance of rabbit (*Oryctolagus cuniculus*) bones (93.2%), followed far behind by red deer (*Cervus elaphus*) (5.8%), wild goats (*Capra pyrenaica*) (0.5%), horses (*Equus* sp.) (0.3%), and carnivores (0.1%). The remaining 36% of remains have been associated with individuals with different weight sizes (72.7%) and indeterminate fragments (27.3%) (Pérez et al., manuscript in preparation). Thus, we observe that among ungulates, red deer is the most numerous taxa, followed from afar by goats and horses. This context leads us to think that the mouth of the Xúquer River (next to the site) was possibly a place that attracted herds of herbivores but also humans, due to the presence of a diversity of nutritional possibilities and raw materials.

Materials and Methods

We selected a transect of six squares from Sector A (25, 26, 35, 36, 45, and 46) (Fig. 1) to try to establish the stratigraphy. Due to the absence of a complete stratigraphic description, the identification of the Solutrean layers has been based on the presence of Solutrean lithic characters (heat treatment, pressure touch-up, and Solutrean tips, cf. Tiffagom, 2006). The technological and typological analysis of lithic industries in layers 27 to 30 reveals the presence of certain features associated with the Solutrean. Lamino-lamellar exploitations are detected (Fig. 2: (1)–(4)), as well as the presence of heat treatment in some of the recovered blades and blocks. Regarding retouched pieces, in square 36, layer 27, a plane unifacial retouched flake has been identified which could be a foliaceous preform. The retouch shows typical features of shaping by pressure technique with heat treatment. These are two distinctive Solutrean traits. In the same square layer 29, a tanged point is shaped by a bifacial and plane retouch (Fig. 2 (1)). Cobbles and anvils have been identified but have not been studied yet (Aparicio, 2003: Fig. 83 and 84). In addition, the radiocarbon dates are compatible with the regional Solutrean chronology. A *Pinus nigra-sylvestris* charcoal fragment was dated 24,840–24,264 cal BP (Beta-517926) (Aura et al.,

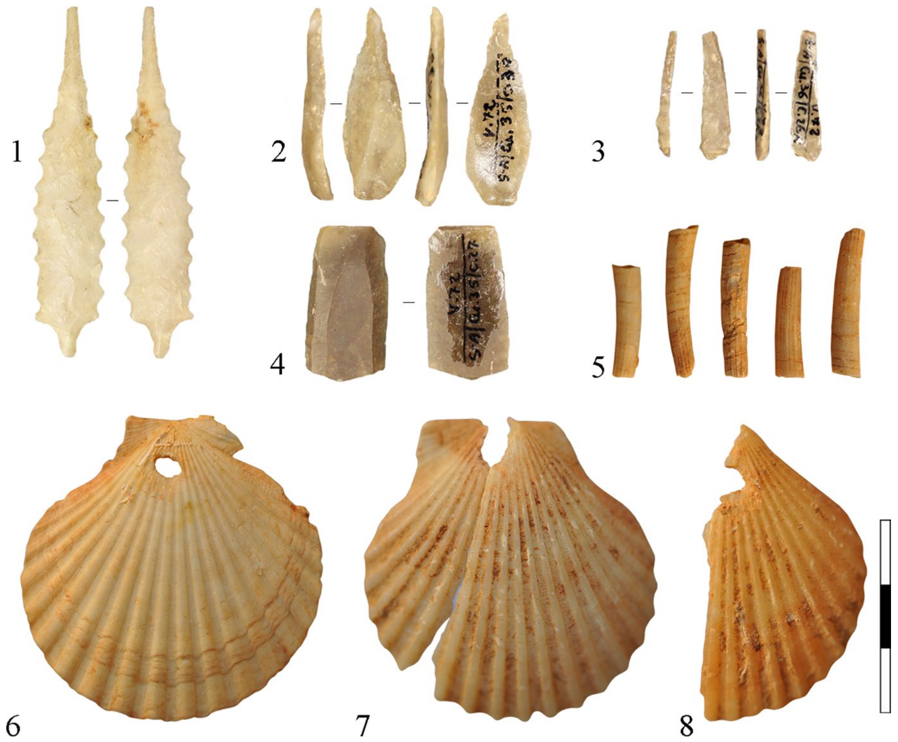

Fig. 2 Solutrean lithic industries and ornaments: (1) tanged point; (2) and (3) armatures; (4) blade; (5) *Antalis* sp., 6 to 8, *Karnekampia sulcata*

in prep.), coinciding with the LGM. Finally, selected specimens for ornamentation are used to assess the sequence. Only eight remains are counted: five *Antalis* sp. and three *Karnekampia sulcata*. *Karnekampia sulcata* is a scallop found in Mediterranean waters and the three remains display anthropic perforations (Soler Mayor et al, 2013) (Fig. 2, 5 and 8). *Antalis* sp. together with *Theodoxus fluviatilis* are the specimens that dominate the Solutrean sequence (Aura Tortosa & Jordá Pardo, 2012; Aura Tortosa et al., 2012). All in all, the lithic techno-typology and the chosen species for ornaments are characteristic of the Mediterranean Solutrean facies.

The Solutrean layers in those squares are 27 to 30, located between ± 3.75 and 4.5 m deep, and they were excavated during the 1972 fieldwork (Aparicio, 2003). Due to the topography of the shelter, these layers do not exist in the inner squares.

The Methodology Employed in the Osseous Technological Analysis

The technological study has been made following the "refitting by default" method coined by Averbouh, (2000, 2001). This methodology has as an aim a mental reconstruction of operational sequences of acquisition of raw material and its transformation into a tool when direct refitting is not possible (common in osseous technology). Osseous materials are classified by raw material and size (module). Then, we characterize the technical features of each piece (manufacture traces) to understand how they were detached from their original block and how they were shaped. Once the description of technical stigmas has been made, we classify the pieces between the different product categories (waste products, blanks, roughouts, and objects) when possible. The fragments, taphonomically altered and/or with little or no shaped, are always difficult to classify. Then, the refitting by default method can be used to suggest operational schemas and, if it is possible, characterize technically an osseous assemblage. The operational schemas and the techniques may allow us to characterize a cultural period, territorial specificities, and exogen elements, but stratigraphic inconsistencies also (Goutas & Tejero, 2016). This methodology is widely spread so it has been adapted and amplified following the different assemblage characteristics (e.g., Christensen, 1999; Christensen & Goutas, 2018; Goutas, 2004; Pétillon, 2006; Tartar, 2009; Tejero, 2013). The vocabulary has been translated into English following the "Multilingual lexicon of bone industries" (Averbouh, 2010).

The preservation of the osseous collection is classified as good when there are no post-depositional factors that alter the piece, medium when there are some alterations but the technical stigmata are visible, and low when traces are not preserved (Tejero, 2010, 2013). In this way, we consider the presence of root and teeth marks, concretions, loss of material, and atmospheric alterations. Fire is another factor to observe as it can be a post-depositional factor (accidental) or a technical issue. Its color, location, and extension are studied as well as its context in the site when possible (Averbouh, 2000: 72).

The technical pieces were identified after an in depth revision of the faunal remains.

Fracture planes have been classified and described following the established parameters (Averbouh & Pétillon, 2011; Pétillon & Averbouh, 2012; Pétillon &

Ducasse, 2012; Baumann & Maury, 2013; Tejero et al., 2012; Tejero, 2013). So, a fracture plane is generally considered to be anthropogenetic if it occurs on fresh material. On fresh antlers, the fracture plane is acute (less than 45°) with a fibrous texture. There are percussion points and notches as well as cracks or "tongue" on the fracture plane. Those fracture planes with an angle close to 90° that do not achieve the "fresh" characteristics and whose surface is rough with a chalkier texture and a different color (from that of the artefact), often lighter, are not considered anthropogenetic, so they are post-depositional and discarded in a technological study (Fig. 3a).

We must point out that we have included those materials that preserve one fresh fracture plane at least.

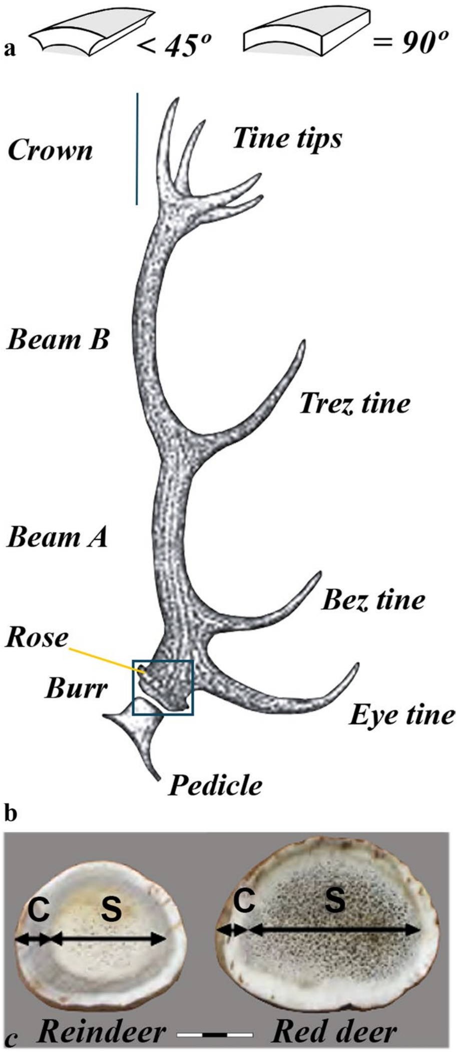

Fig. 3 **a** Technical (<45°) and post-depositional (=90°) fracture planes (modified from Baumann & Maury, 2013: Fig. 2). **b** Red deer antler anatomical parts (modified from Goutas, 2003: Fig. 1). **c** Sections of red deer and reindeer (modified from Tejero, 2010: Fig. 18)

The Methodology Employed in the Archaeozoological Study

All faunal remains were taxonomically and anatomically identified, except for bone fragments without anatomical characters or with a high degree of taphonomic modifications that have been classified by weight sizes. The abundance measures employed are reduced to the number of remains (NR), the number of identified specimens (NISP), the minimal number of elements (MNE), and the minimal number of individuals (MNI) and the minimal animal units and their percentage (MAU and %MAU) (Lyman, 1994; Reitz & Wing, 2008). All dimensions (length, width, and thickness) were measured for each bone fragment and the fracture analysis followed the criteria established by Villa & Mahieu, (1991) and the morphotypes created by Real et al., (2022). Bone surface modifications were observed under a microscope Leica M165C stereo light and quantified to identify damage caused by anthropogenic activity, as well as the diverse diagenetic processes that produce alterations on bone surfaces (Blasco, 1992; Denys & Patou-Mathis, 2014; Fernández-Jalvo & Andrews, 2016).

Red Deer Antler as Raw Material

Red deer antler is the employed raw material in the Solutrean antlerworking in HC-VF. Red deer antler comes from males and sheds following an annual growth cycle (Billamboz, 1977, 1979; Christensen, 1999, 2004). All of them are different but they share common anatomic elements (Crigel et al., 2001) (Fig. 3b). The antler section shows two kinds of tissues. In the outer part, a compact tissue thinner than reindeer antlers surrounds the spongy tissue which is bigger and more open than reindeer's (Averbouh, 2000; Bouchud, 1974; Christensen, 2004) (Fig. 3c). The compact tissue has different thicknesses depending on the red deer's age, ambient conditions, and the anatomical part (it is thicker closer to the basal part) (Billamboz, 1979). It has on the surface longitudinal, radial, and circular blood vessels (ridging and grooving) to irrigate blood while it runs by the spongy tissue through the pedicle (Christensen, 1999, 2004). The physical properties vary depending on the age of the antler. During its development, it is soft and becomes hard before it is shed because of its calcification (Provenzano, 2001). After it is shed, it becomes more breakable as it loses its collagen (Behrensmeyer, 1978, cited by Baumann & Maury, 2013).

The antlers' compact tissue is measured to classify it between large (greater than 5 mm for adults), medium (4 to 5 mm for adults and young adults) or small (less than 4 mm for young deers) modules following Tejero's classification (Tejero, 2010). The measure of the compact tissue is variable depending on the age of the red deer, the anatomic origin, and the environmental conditions (Billamboz, 1979). So, this classification is always approximate as these parameters are not constant (Goutas, 2004). The relation between compact tissue and spongiosa is another factor for size classification, but as most of the pieces are fragments of antler, this parameter has not been analyzed. We mainly take these data to observe the chosen modules in the manufacturing process, and if possible, to compare the results with the archaeozoological study.

The Solutrean Osseous Industry

The assemblage from HC-VF (sector A) is made up of 63 pieces (60 on antler and three on bone), of which seven are objects (four on antler and three on bone). The rest of the pieces ($n = 56$) are distributed between the different product categories (Table 2). There are seven pieces which do not preserve any technical stigmata.

Finally, the antlerworking assemblage is composed of 53 pieces in the selected squares, layers 27 to 30 from Sector A.

Preservation

The preservation of the red deer antler assemblage is, in general, medium. Several post-depositional factors have affected the collection (Table 3). Concretions and loss of material are the principal alterations, and in some cases, they are very significant. Roots and atmospheric alterations (highlighting the dehydration of the material due to its exposure to strong changes in temperature, cracking possibly caused by gelifraction or the presence of calcareous solutions) are marginal or anecdotal. Fire only affects 9.8% of the osseous assemblage, and we do not associate it, so far, with the technical treatment of the raw material as it produces a loss of elasticity and, consequently, it is less resistant and durable (Averbouh, 2000: 72).

Table 2 Product categories

Product category	Antler	Bone	Total
Objects	4	3	7
Bevelled point	2	-	2
Point	-	2	2
Chisel	1	-	1
Smoother	1	-	1
Awl	-	1	1
Roughouts	-	-	-
Blanks	8	-	8
Waste products	41	-	41
Basal	3	-	3
Tines	2	-	2
Tine tips	3	-	3
Fragments	22	-	22
1st blank reduction/shaping fragments	9	-	9
2nd blank reduction/shaping fragments	2	-	2
Total	53	3	56

Table 3 Preservation

Level of preservation	%
Good	34.4%
Middle	52.5%
Low	13.1%
Fire	9.8%
Roots	1.6%
Concretion	54%
Loss of material	55.7%
Atmospheric alterations	9.8%

Despite these circumstances, the technological study of the collection is feasible except for the 13.1% of pieces on which the surface is not preserved, among which one is an object (a bevelled point).

Fractures are another factor to consider in the preservation of hard animal materials. Then, 39.3% of the studied pieces show at least one recent fracture, and 26.2% show one ancient post-depositional fracture. So, the collection shows a high degree of fragmentation as 68.8% of the pieces have a post-depositional fracture.

Results

Red Deer Exploitation

Among the determined taxa in our study, it has been possible to identify 215 red deer faunal remains (Table 4). Of these, 60 pieces are antler fragments (objects included), and 53 have technological stigmas. After quantification, it has been possible to establish a minimum of 111 anatomical elements belonging to a minimum of five individuals with ages ranging from juvenile (NMI: 1), prime adults (NMI: 2), and old adults (NMI: 2) based on the age of fusion and tooth eruption/wear (Azorit et al., 2002; Mariezkurrena, 1983). The skeletal representation of red deer reflects a high percentage of remains of the cranial skeleton, in the case of teeth, hemimandibles, and antlers (46%), followed by the remains of the anterior and posterior appendicular skeleton (ca. 15%) and a low presence of the axial skeleton (7%). At the taphonomic level, we found a group with a high percentage of fragmentation (97%), with only some dental remains, joint bones, phalanges, and residual metapodes remaining complete. Regarding the evidence of manipulation of the carcasses, the data related to the acquisition of the antlers reveal the hunting of red deer while the males still had their antlers, with the consequent use of the prey for both nutritional and technological levels. Among the remains (bones and teeth), there is much evidence of anthropogenic manipulations, like fresh fractures (39%), percussion marks, cutmarks, and thermal alterations (12%). The other agents such as carnivores are only attested to in one score mark on a rib fragment.

Table 4 Skeletal profile from red deer from HC-VF

	Cervus elaphus				
	NISP	MNE	NMEi	MAU	%MAU
Antler	58	3	2	0.25	25.0
Cranial	1	1	1	0.25	25.0
Hemimandibule	12	5	2	0.63	62.5
Teeth	26	26	32	0.20	20.3
Cervical vertebra	1	1	7	0.04	3.6
Thoracic vertebra	1	1	13	0.02	1.9
Lumbar vertebra	1	1	7	0.04	3.6
Ribs	13	4	26	0.04	3.8
Floating rib	1	1	-	-	-
Scapula	3	1	2	0.13	12.5
Humerus	7	4	2	0.50	50.0
Ulna	3	2	2	0.25	25.0
Radius	4	2	2	0.25	25.0
Carpal	6	6	12	0.13	12.5
Metacarpal	13	8	2	1.00	100.0
Coxal	3	3	1	0.75	75.0
Femur	9	3	2	0.38	37.5
Tibia	10	5	2	0.63	62.5
Calcaneo	1	1	2	0.13	12.5
Tarsal	1	1	6	0.04	4.2
Metatarsal	11	6	2	0.75	75.0
Metapodial	9	5	4	0.31	31.3
Residual metapodial	2	2	-	-	-
Phalanx	4	3	24	0.03	3.1
First phalanx	7	7	8	0.22	21.9
Second phalanx	5	5	8	0.16	15.6
Third phalanx	1	1	8	0.03	3.1
Sesamoids	2	2	-	-	-
	215	110	179		

Operational Schema of Acquisition

Red deer antlers, or at least a portion of them, are obtained by hunting as all the identified basal parts preserve the pedicle connected to the antler ($n = 3$). We have not observed the presence of a necrosis line on the pedicle, so the antlers were not close to being shed. Nevertheless, the compact tissue does not show porosity, suggesting that the antler would have completed its growth. The compact tissue variability (analyzed on 52 antler pieces because one is a pedicle, so it has no compact/spongy tissue) shows a higher percentage (51.9%) of pieces in which compact tissue is lower than 4 mm (Table 5). It could indicate possible specialized exploitation of

Table 5 Cortical thickness

	Waste products	Blanks	1st reduction fragments	2nd reduction fragments	Objects	Total
< 4 mm	18	3	3	1	2	27
4–5 mm	8	1	4	1	1	15
> 5 mm	3	4	2	-	1	10
Total	29	8	9	2	4	52

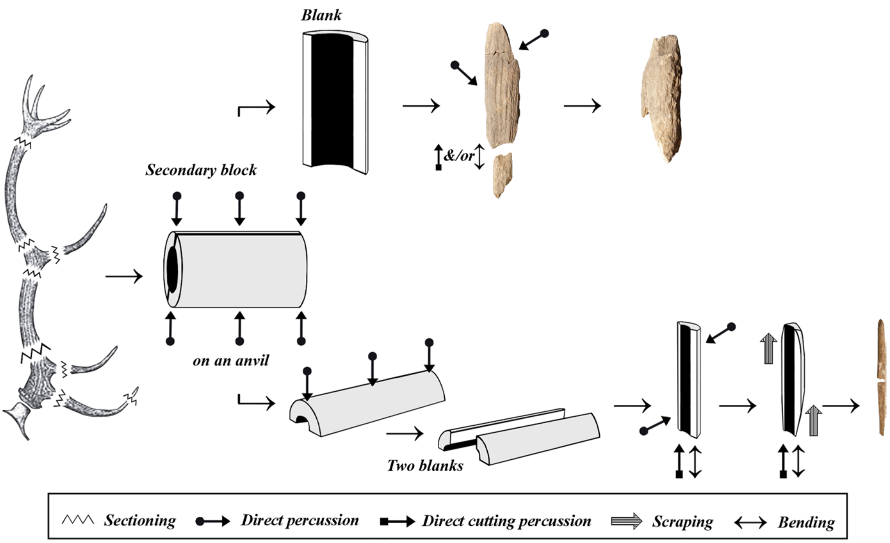

Fig. 4 Operational schema by partition

antlers that come from young-adult specimens. If we compare these data with the results from the bones and teeth, the age of hunted red deer is diverse (NMI: juvenile 1, prime adult 2, old adult 2) and it cannot be conclusive.

Operational Schema of Transformation

We have identified the operational schema by partition (Fig. 4) from thirty waste products, eight blanks, nine shaping waste products, two waste products from blanks recalibration, and four objects. This classification has been made following their technical features and morphology.

First, there is a minor operation where the primary block is prepared. The basal part is sectioned above the bez tine ($n=2$) by direct percussion producing several fracture planes (Fig. 5 (1)) and flakes (one of them refits) (Fig. 5 (2a–c)). Tines and tine tips are sectioned too by unifacial cutting direct percussion plus flexion or just flexion/direct percussion. In the case of direct cutting percussion, it is identifiable by the little irregular scalariform removal scars. Flexion and percussion are identified by the presence of fracture planes. Tines become possible secondary blocks to be debited later ($n=2$), and tine tips are wasted ($n=3$) (Fig. 6 (a) and (b)). Then, the two beams are sectioned by direct percussion wasting the central part at the height of the trez tine, probably because of its irregular section ($n=1$) (Fig. 6 (c)). This wasted fragment shows sawtooth fracture planes produced by the direct percussion technique. Both beams are now considered secondary blocks. There are no

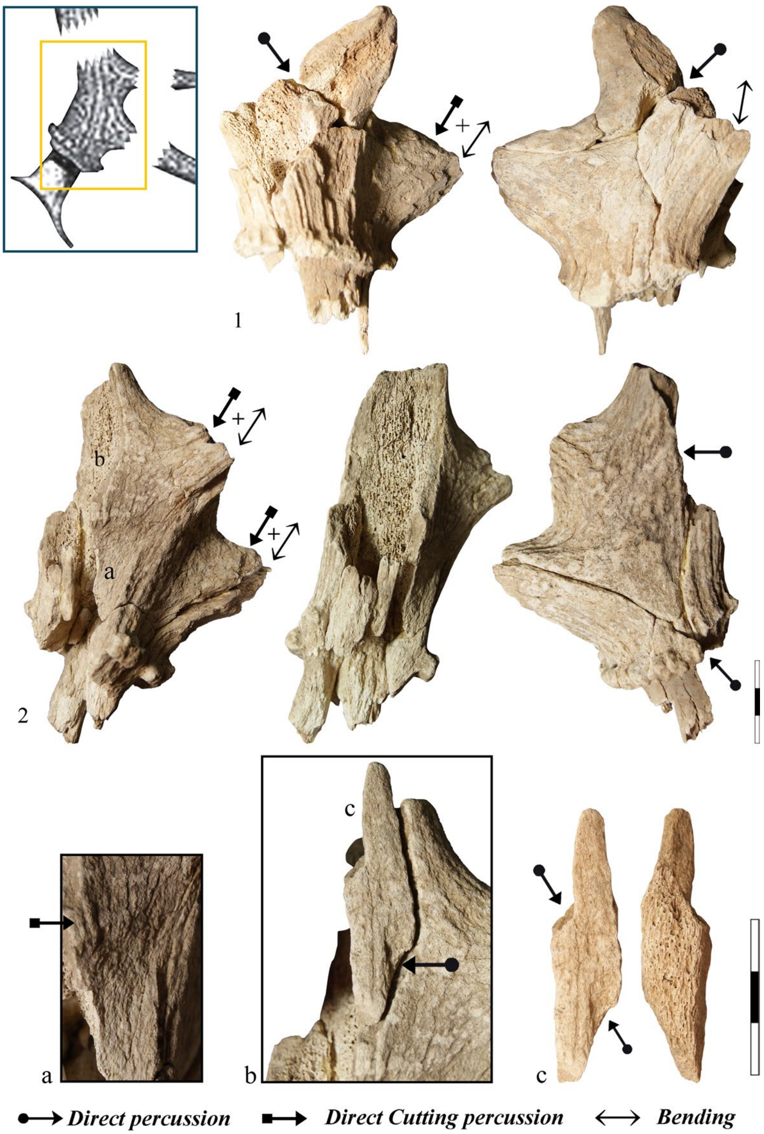

Fig. 5 Waste products from the basal part of the antler

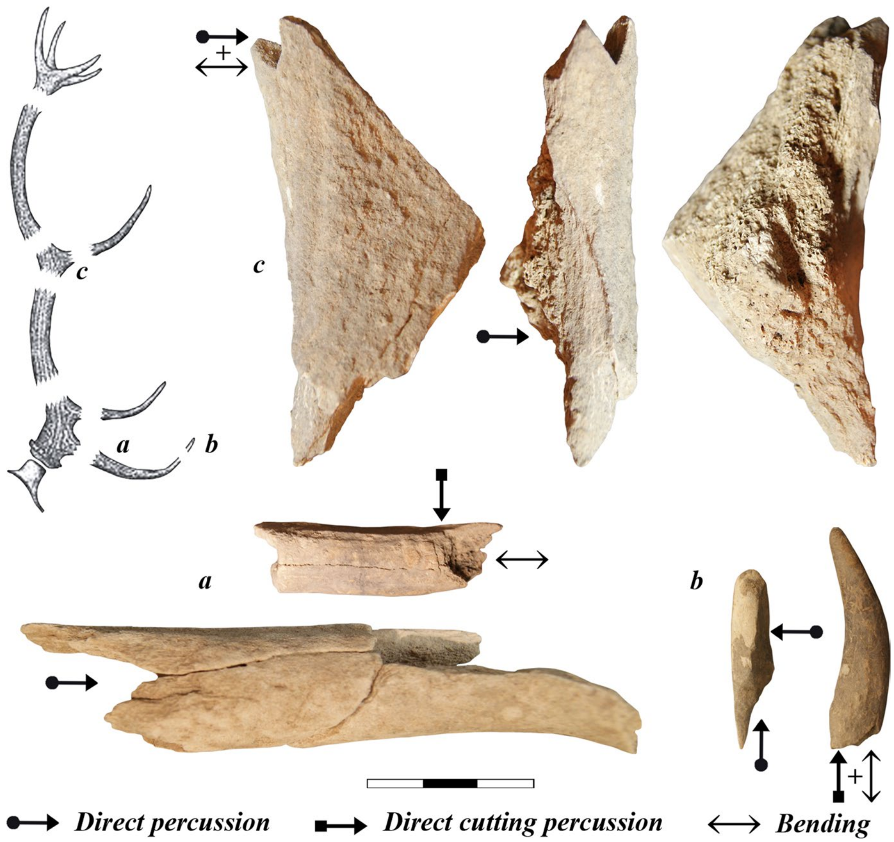

Fig. 6 Waste products: (**a**) from beam a–b connector, (**b**) tines, and (**c**) tine tips

preserved secondary blocks from beams, so we assume that all of them have been processed or transported to be split elsewhere.

Once the primary block is prepared and secondary blocks are produced, the debitage phase takes place. Those secondary blocks are longitudinally split by direct percussion on an anvil. In theory, this phase does not produce waste products (Baumann & Maury, 2013), but several fragments could correspond to flakes from this phase, from the primary block preparation, or to minor operations of recalibrating the blank (Fig. 7 (1)–(3)). In general, the classification of these wasted flakes in the different transformation phases is very difficult and it must be taken with caution.

The direct percussion on an anvil is made by striking along the segment of the antler producing a longitudinal fracture plane. At the same time, a reflected fracture plain is produced on the opposite side because of the use of an anvil. In this way, the waste product that we have identified as a "debitage mistake" (Fig. 7 (4)) has a "bipartite" section in the distal part where there is a notch. The impact produced an oblique fracture plane along the piece and the bipartition was not achieved. The presence of this notch shows that direct percussion may begin in an extremity of

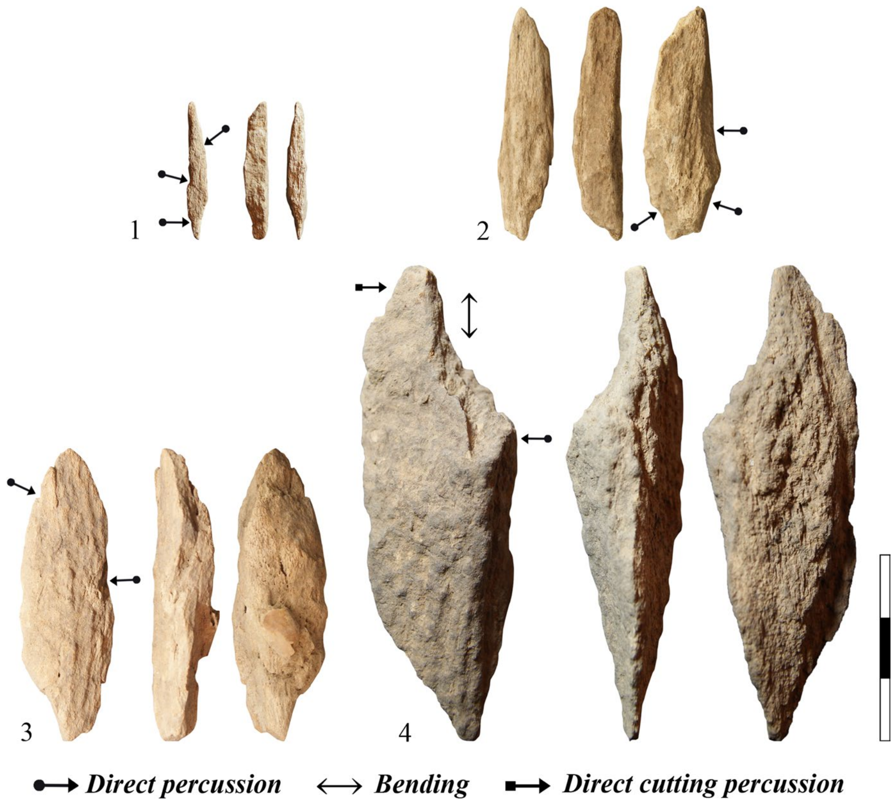

Fig. 7 Waste products: fragments

the segment of the antler. Another piece, classified as a blank (Fig. 8 (1)), shows the notch in the medial area, indicating that the percussion may be done along the segment. In total, we have two bipartite pieces that can be considered blanks (Fig. 8 (1)) to produce domestic tools like chisels or smothers by scraping their edges and extremities.

For the manufacture of the weaponry (projectile points), the debitage continues with a quadripartition (a bipartition on bipartite) following the same technique. These quadripartite results now are blanks with a rectangular outline (Fig. 8 (2)–(4)) and show different impact points along the blank. Next, the blank is shaped by direct percussion, and thereby, the outline is corrected by wasting flakes (Fig. 9 (1)–(6)). The morphology of these flakes is elongated and thin with longitudinal fracture planes at the main axis of the antler structure (from edges) and wider when they show a transverse fracture plane at the main axis of the antler structure (from distal or proximal parts). The elongated ones are obtained by direct percussion, while the wider ones are produced by direct percussion/ flexion (Fig. 9 (5)) and cutting direct percussion plus flexion (Fig. 9 (6)). In Fig. 9

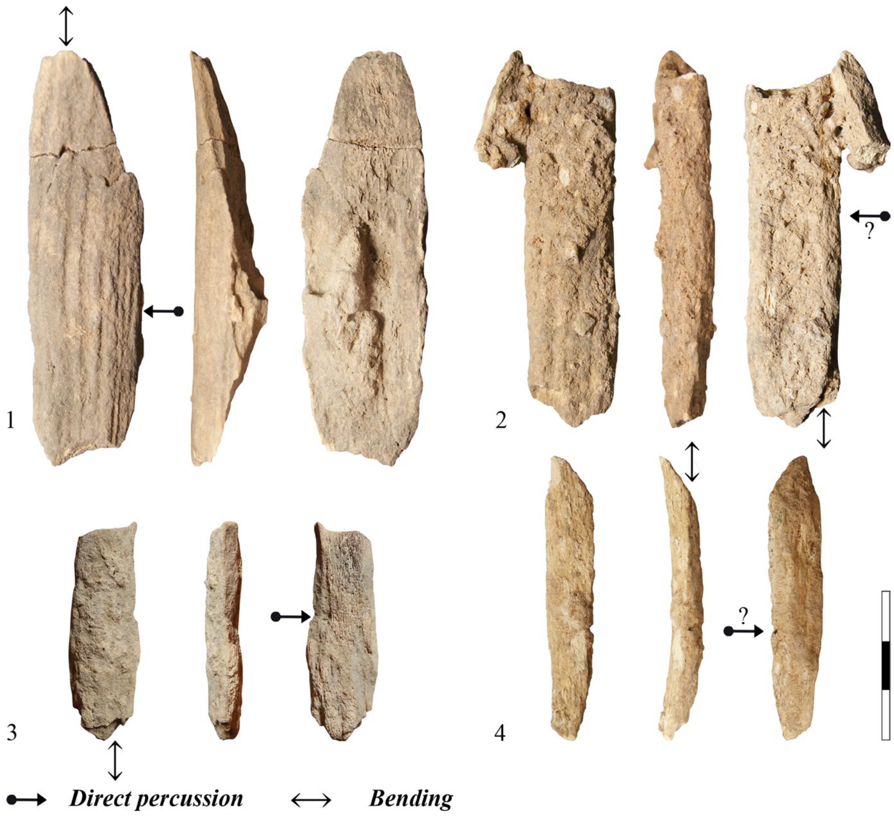

Fig. 8 Bipartite and quadripartite blanks

(1)–(4), we propose some flakes that could fit with this phase, but as we said before, they could correspond to any other previous phase.

Finally, the shaping phase of the weaponry is carried out by scraping. Once the blank is scraped or during the scraping, it can be recalibrated by unifacial cutting percussion plus flexion (Fig. 9 (7)) or by peripheral deep scraping plus flexion (Fig. 9 (8)). The blank is then completely worked by scraping, finished and transformed into an object (Fig. 10 (1) and (2)). The weaponry is composed of two bevelled points, one of them almost complete with use fractures in its extremities, and the other is the basal part.

The toolkit lacks the shaping phase in both pieces. The possible smoother (Fig. 10 (3)) only preserves on the right side a fracture plane from the debitage and on the left side a polish of use. Regarding the fragment of the chisel (Fig. 10 (4)), it is not shaped by scraping either so the bipartite is directly employed as a chisel showing the debitage fracture planes and the osseous fibres flattened in the preserved extremity.

To complete this analysis, we want to focus on the morphometric features between the different product categories to determine whether there is some correspondence.

Fig. 9 Waste products: first blank reduction

It will be an approximation as most of the pieces are not complete. Among the tools made on bipartite (with rectangular or subrectangular outline), the biggest is the chisel which reaches more than 72.2 mm in length (it is broken), 22.5 mm in width, and 11.9 mm in thickness. The two identified tools show different compact tissue thicknesses, one < 4 mm and the other > 5 mm. The most complete blank is 80.5-mm

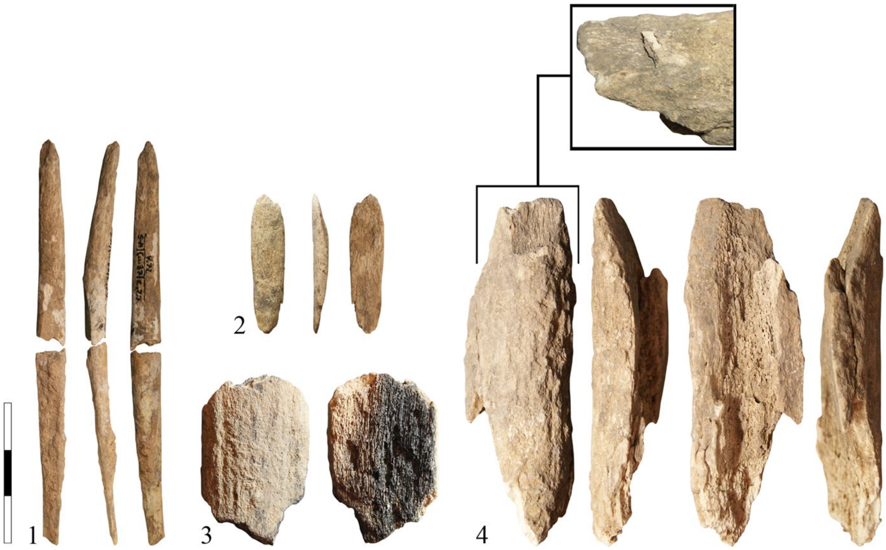

Fig. 10 Objects: (1) and (2) bevelled points; (3) smoother fragment; and (4) chisel

long, 24.1-mm wide, and 12.2-mm thick and is composed of compact tissue with the same parameters as tools. This allows us to establish a morphometrical correspondence between chisels and bipartite blanks. If we compare the most complete weapon with the quadripartite blanks, the weapon is 85-mm long (it could reach 104 mm), 5.8-mm wide, and 5.2-mm thick. The compact tissue of weapons is < 4 mm in two pieces and between 4 and 5 mm in one. Again, the blanks are fragmented and the longer one is a fragment (medial and one extremity) 67.7-mm long. The width of the blanks is between 14 and 18 mm, and the thickness is between 7 and 86 mm. The compact tissue is in three pieces > 5 mm and in one piece 4–5 mm. So, the weapons may have been made from quadripartite blanks.

Discussion

HC-VF was excavated between 1968 and 1984. Unfortunately, the use of an old methodology resulted in the loss of important information regarding different stratigraphic parameters (Davidson, 1989). The reduced information about the stratigraphy makes it necessary to establish a stratigraphic reference. That is why we chose and focused our study on the selected transect from sector A. For this purpose, we started with the study of the lithic industry (Soler Mayor et al., 2020). The lithic features (foliate preform with heat treatment and tanged point) and the radiocarbon dating results coincide with Solutrean Mediterranean technical and typological characteristics traits (Tiffagom, 2006). This allowed us to define a preliminary stratigraphic limit that has been corroborated in this work discovering a technical homogeneity in the antler working.

Analyzing the stratigraphic distribution of osseous technological remains, we observe a special concentration on the upper layer 27. This situation is perhaps random and may be caused by the limited surface studied in this work. It is a matter that must be analyzed in the archaeological sequence of both Gravettian and Badegoulian assemblages. Nevertheless, given the current state of knowledge, the antler technology at the HC-VF site, due to the predominant use of direct percussion (on an anvil), is comparable to that of other Solutrean assemblages where a technological analysis has been achieved. This study then becomes one more step in accomplishing two purposes: first, to preliminarily define the Mediterranean facies antlerworking that shares common features with the French area, and second, to try to identify possible stratigraphic inconsistencies in the future when we can contrast our results with other sectors and/or stratigraphic levels of HC-VF and with other well-defined stratigraphies.

Raw Material Acquisition

The red deer antlers are procured by hunting, and red deer are exploited for all of their resources. Those antlers are not close to shedding, but they have grown enough to have the physical–chemical properties of a developed antler but not as hard as those calcified when they shed. This circumstance has placed the hunting of deer in summer when they become mature, in autumn and in winter. This choice has been observed in different sites and periods in the Mediterranean facies (Borao, 2012, 2013, 2019; Borao et al., 2016; Villaverde et al., 2016), and it may be due to a combination of four factors: (1) their physical–chemical properties, (2) the compact tissue thickness of red deer antlers, (3) the chosen techniques, and/or (4) to a question of seasonality.

The analysis of compact tissue thickness does not show preferential exploitation, nor the result obtained from the faunal remains (1 juvenile, 2 prime adults, and 2 old adults). The compact tissue < 4 mm is more abundant among the waste products group but in the rest of the product categories it is more balanced. Most < 4 mm waste products can be related to the primary block preparation (crown, tines, and tine tips). Some can be attributed to the debitage phase as this thickness is well represented in the other product categories. Anyway, the high number of < 4 mm pieces may be related to wasting those anatomical parts with a thinner compact tissue and not necessarily with the hunting of young specimens. Regarding the 4–5 mm, the higher number of pieces is focused on waste products and waste products from the shaping of the blank. In this case, there is only one object with this thickness, and it can be explained because the shaping by scraping on the compact tissue reduces its thickness. Finally, the > 5 mm thickness is present with a higher number of blanks compared with other thicknesses but only in one object. Once more, it can be associated with shaping that reduces compact tissue thickness. Anyway, it is not possible to reach economic conclusions only with compact tissue measurements. These data must be crossed with the possible anatomic location of the pieces. Unfortunately, it has not been possible to establish the relationship between some pieces (blanks, flakes, and objects) and their anatomic origin because of the absence of anatomic features. We can gather from this data that given antlers of different sizes, the bigger compact tissues are preferable for the manufacture of tools and weapons as their compact tissue is reduced in the shaping phase.

Another question that must be considered is the antler's resistance when struck by direct percussion. If the use of hunted antlers is a cultural, economic, or symbolic choice, it is a matter that may be indirectly analyzed from an experimental point of view to test its technical behavior and possible advantages (in manufacture and/or use) and by comparing it with other sites in the Mediterranean facies. Unfortunately, we have not tested yet if the physical properties of antlers obtained around the rutting season have different behaviour when struck in comparison with shed antlers. We can not forget that the absence of shed basal parts could be connected to occupation seasonality, but perhaps it is convenient to wait to gather more data to raise this discussion and deal with experimentations.

However, there are two issues related to the acquisition that we must take into consideration. Although we propose a specific period of the year for obtaining it, this does not have to coincide with the occupation of HC-VF. The antlers are not a perishable raw material in the short term (depending on temperature, humidity, biological activity, etc.), and they can be obtained and transported or stored (e.g., Averbouh, 2000; Goutas, 2004). Antler acquisition has been located around the rutting period; they could have been obtained in other places and brought to the site later. Until we have a seasonality study of the skeletal remains, this is a possible option. Secondly, given that our study sample is limited to a specific part of the site, it is possible that the MNI is not coincident between the antlers used for the osseous industry and the hunting raids, so its comparison in future works is an aspect to consider giving perhaps a better explanation about human subsistence patterns in the site.

Transformation

The operational schema identified is partition. It was used to obtain bi-partite and quadripartite blanks that were transformed into chisels, smoothers, and projectile points. At the beginning of this research, bipartition did not show any problem in its identification but quadripartition did. The quadripartite blanks had similar features to those identified in Badegoulian blanks (fracture planes on their edges and a subrectangular outline). Furthermore, a large number of waste products led us to think about an operational schema by progressive reduction of the block. Those waste products, in many cases, share common patterns with those materials studied in the Badegoulian from Parpalló (Borao, 2019), but we did not find the wide flakes involved in that debitage. We then realized that what is reduced progressively are blanks in the shaping phase by direct percussion and not the block. So, once the quadripartite is obtained, there are minor operations to reduce and configure the blank outline by direct percussion before and during the scraping. Thereby, those flakes did not belong to the debitage, and the mental conception is to divide longitudinally a segment of raw material once and twice to obtain blanks approximately standardized. The key here is the absence of waste products in the debitage, so the block is not progressively reduced but partitioned and then, the operational schema fits with the partition one.

There are no significant differences if we compare our results with those obtained in southwest France (Baumann, 2014; Baumann & Hinguant, 2016; Baumann & Maury, 2013). The main issue is the raw material acquisition because the reindeer antlers in France are obtained mostly by gathering (shed antlers). In this way, we find the first difference apart from the absence of red deer antlers since the two regions' environmental conditions and fauna are different. The operational schema of transformation is the same. Both geographical areas use direct percussion on an anvil in the debitage to obtain bi-partite and quadripartite blanks. The only difference identified comes from the shaping phase. In France, the blank is reduced by tangentially chopping the lateral edges with a large flint blade. It has as a consequence the absence of waste products (or too small to be identified or even preserved) from this phase. In HC-VF, it is made by direct percussion, producing elongated flakes. Finally, the recalibration of the shaped blank is a common pattern as we find the same waste products.

The lack of technological information on the osseous industry in the Iberian Peninsula, and more specifically in the Mediterranean area, makes this study a relevant contribution not only from a technological point of view but also to the use of the diversity of resources. The absence of this type of work demonstrates how the study of prehistory has traditionally revolved around lithic studies to characterize a culture, leaving aside information that might give a different picture of how technical traditions change over time and space. The comparison of this Solutrean assemblage with other studied periods in the Mediterranean area is an issue to analyze. Until now, the only characterized periods are Badegoulian and Magdalenian (Borao, 2012, 2013, 2019, 2022; Borao et al, 2016; Villaverde et al, 2016). Compared with those assemblages, we observe the continuity in the use of direct percussion technique in the debitage but involved in different operational schemes of transformation: partition in the Solutrean and progressive reduction of the block in the Badegoulian and Magdalenian. So, using different mental conceptions, they have a common objective: obtaining rod-shaped blanks.

Regarding the Magdalenian, the use of direct percussion in the debitage continues but is secondary. The main operational schema of transformation in the Magdalenian is extraction. Secondarily, we were able to identify the progressive reduction of the block and partition operational schemas of transformation. Partition was identified in the manufacture of bevelled tools (intermediate tools), and they were manufactured by bilateral grooving and not by direct percussion (Borao, 2019). Progressive reduction of the block has direct percussion as the main technique, and it was designated to manufacture domestic tools like awls being identified in Parpalló and different sites in France (Lefebvre & Pétillon, 2018; Malgarini & Bodu, 2018; Borao, 2019). Thus, despite great differences in other aspects like typology and technical conceptions, the use of direct percussion thrives.

Typologically, the number of objects is reduced so we can not compare our assemblage with others until a future study of other sectors. Future work on this aspect will illustrate the variability of the different Solutrean facies in the Iberian Peninsula and SW Europe. At a regional level, the current data indicates an increase in typological diversity, especially at the bases of points in the Evolved Solutrean (Table 1). This diversity is higher in assemblages with a greater number of pieces, marking differences between the assemblages of the central Mediterranean region, where the number of sites and objects is more numerous and the southern Mediterranean region. The sample of HC-VF objects studied for this work is limited (one simple point, two single-bevelled points, one awl, and one spatula) but its morpho-typology coincides with the main types identified in the regional Solutrean. The main contribution, in this case, is the technical evidence that has been presented here.

Conclusions

The number of different categories of products studied from the possible Solutrean layers of sector A of Hort de Cortés–Volcán del Faro is small, but significant results have been obtained.

The raw material is acquired by hunting red deer when their antlers are well enough developed but not yet close to shedding. This will result in a more difficult antler exploitation because the antlers have more collagen that absorbs impacts in contrast with more mineralized antlers close to being shed. The presence of higher levels of collagen on antlers may provide desirable proprieties in the weaponry but not in the debitage as it makes more difficult the propagation of the shock wave into a fracture plane (hence the use of an anvil). Anyway, it is a matter that must be corroborated experimentally by mechanical tests on the different types of antlers as we have observed this option in different periods in the Mediterranean facies (Borao, 2012, 2019; Borao et al, 2016). In addition, we must consider that in the Solutrean, lithic points make up most of the weaponry, and osseous projectile points are usually secondary in assemblages.

Regarding the antler compact tissue, there is a predominance of blanks with a thickness greater than 5 mm because of the exploitation of antlers from older individuals, anatomic parts closer to the basal part, and a possible cultural choice to produce thicker objects. Antlers from other anatomical parts (upper parts) and/or younger individuals are debited too as we find a high number of blanks and other product categories with a cortical thickness lower than 4 mm. If we compare these data with the age of the hunted red deer, we find a similar diversification that may indicate that there is no specialization in the age of hunted red deer, nor on the size of the antler or the selected anatomical parts. We can not forget that this kind of raw material acquisition could be linked to other factors related to cultural or seasonality issues.

To conclude the transformation issue, we think that the partition operational schema is preliminarily defined. We have identified a preparation of the block phase wasting tine tips and the basal part. Then, secondary blocks are produced by sectioning beams and tines. Beam A and B are sectioned too resulting in a wasting of the central part. The debitage is carried out through direct percussion on an anvil on those segments of antler. It is made by striking along the segment of the antler producing a longitudinal fracture plane which is reflected on the opposite side because of the use of an anvil. There are then two bipartite pieces that can be considered blanks to produce domestic tools like chisels or smothers by scraping their edges and extremities. Quadripartition (a bipartition on bipartite) is made to manufacture the weaponry using the same procedure but obtaining narrower blanks with a morphology closer to the desired object (projectile points). The blank is shaped by direct percussion wasting flakes and scraping.

This work must be amplified by studying materials from other excavated areas to corroborate our results. In addition, we have observed several technical parameters that should be tested experimentally. First, the longitudinal partition by direct percussion has not been tested on red deer antlers. An experimental program would corroborate if direct percussion has the same technical behavior as reindeer does because of the different proportions of compact/spongy tissue. The second question is the choice of hunted antlers. It has not been verified that technical behavior could be the same for direct percussion with developed antlers that are not close to being shed. Regarding the debitage, it would be necessary to test the use of an anvil (identified in the studied area) and the kind of anvil and check how it reflects the fracture plane. It will be interesting to study the different morphologies of impacts on the surface and the different fracture planes produced as it was done in reindeer antlers (Baumann & Maury, 2013). So, we think that after a complete study of the whole Solutrean osseous industry of HC-VF (Sector N and complete Sector A), it would be truly interesting to perform an experimental program to properly characterize this operational chain.

Finally, it must be taken into account that a selection of grids has been studied, and it has provided a significant sample with the first data on Solutrean osseous technology in the Mediterranean region. The results obtained as to what Solutrean antlerworking concerns corroborate that this material belongs to this framework in comparison with other studied sites. Continuing with this line of work and expanding the sample with the study of the materials of the N sector of HC-VF will contribute to a better understanding of Solutrean osseous technology in HC-VF and its stratigraphy but also to that of southwest Europe.

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Data Availability This is not applicable.

Declarations

Ethical Approval This is not applicable.

Competing Interests The authors declare no competing interest.

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