

Según las instrucciones de la Escuela de Doctorado para la obtención de la mención internacional del título de doctor (artículo 1b), se debe aportar un resumen que deberá tener una extensión mínima de 15.000 palabras. Dado que mi Tesis Doctoral se presenta como compendios de publicaciones, aunque se añade material inédito que aún no se ha publicado, consideramos que estos 3 artículos, redactados en inglés, resumen de manera precisa los objetivos, la metodología y los resultados más relevantes de la Tesis Doctoral. Por esta razón, se adjunta el abstract, la relación de los 3 artículos y las conclusiones de la Tesis, todo ello redactado en inglés. En total suman más que las 15.000 palabras que se exigen.

Abstract

This PhD dissertation presents the use-wear analysis of a flint lithic assemblage from the stratigraphic unit Xa of the Middle Paleolithic site of El Salt (Alcoy, Alicante). The assemblage has been associated with different archaeostratigraphic units resulting from the dissection of the palimpsest and characterized accordingly by higher temporal resolution. The results of this study have allowed us to identify and describe variations in the activities carried out by different Neanderthal groups that occupied the shelter throughout the formation process of the Xa unit, as each selected analytical framework represents distinct areas of activity that are diachronic with each other. Thus, we have recognized areas where productive activities related to wood working and animal processing took place, compared to other moments in which, in the same areas, only a specific type of material was managed exclusively (e.g. wood). Furthermore, contextualizing the functional data within these temporally constrained frameworks has also allowed us to assess aspects related to the techno-functional characteristics of the lithic tools and the relationship between tool use, mobility patterns, and raw material management. In addition, a significant part of this PhD has also focused on an experimental program on the use-wear traces generated by heat-treated wood, yielding unprecedented results that allow for the traceological differentiation of this type of material from green or dry wood.



Understanding woodworking in Paleolithic times by means of use-wear analysis

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ABSTRACT

Throughout prehistory, wood working was a frequent activity. The indices of this activity comes from rare found wooden remains, and the analysis of use-wear on them. In most recent periods, there are stone polished tools and metal tools, that increase the capability of wood transformation. This is not the case for older times, from which only knapped tools are available. The woodworking *chaîne opératoire* includes activities of selection and acquisition of raw material, but also the transformation and the finish of objects and structures. Use-wear analysis in many sites illustrates this. However, a systematic compilation of published traceological analysis has not been made recently. In this paper, we present a revision of the traceological data currently available, which guides a reflection on the methods of working ligneous vegetable matter with knapped tools. The relationship between this information, the morphological characteristics of tools and the necessary actions to elaborate the preserved wooden objects, tell us about the woodworking techniques that are more common in each period. The results allow us to draw conclusions about the performance of each type of tool, as well as the human technical capabilities for environmental transformation.

1. Introduction

Wood plays a major role in the economic and production activities carried out by human groups during the Middle and Upper Paleolithic, both as fuel and as raw material for the manufacturing of artifacts. Stone tools used for the work of vegetable matter have been found in a great number of archaeological sites. However, wooden objects have not usually been preserved for such old chronologies, since they would need extremely arid, humid or anaerobic conditions to avoid deterioration. This lack of wooden artifacts makes it difficult to construct hypotheses about the possible activities involved in their manufacturing. Nevertheless, thanks to use-wear analysis on stone tools we can obtain some information about the actions and objects they worked on.

Previous publications have collected information and knowledge, although quite general, regarding the use and work of wood and

vegetable resources. It is worth mentioning the researches by Tyldesley and Bahn (1983), or Beyries and Hayden (1993), of a generalist type or focused on a particular period (Owen, 1994).

More recently, a revision of the materials involved in woodworking has been carried out, supported by an experimental programme focused on the use-wear analysis on the stone industry in chronologies of the Middle Paleolithic in West European sites (Claud et al. 2013).

Therefore, the aim of this research is to provide a summary containing information about the stone tools which were suitable for woodworking, including the functional data obtained through traceological studies and use-wear analysis of the wooden objects preserved since the Middle and Upper Paleolithic.

The aims of this research are the following:

- To study the results and knowledge that we currently have about woodworking techniques according to traceological investigations

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of the tools which are available from the remain of each chronology; Middle and Upper Palaeolithic

- From a technological point of view, to identify the features which make a tool suitable for woodworking and the activities in which it may have been used.
- To compare the type of tools and activities involved in these works during the Middle and Upper Paleolithic.
- To collect and present the most important wooden remains which have been preserved since each chronological period and reflect on the possible techniques, actions and tools used for their manufacturing.

2. Materials and methods

In order to carry out the present research, we have compiled all the bibliography covering the issue of woodworking, throughout the chronologies already mentioned. We have selected not only specific, but also traceological, and more general studies in which this type of activity is included. *Grosso modo*, we have analysed the data focusing on the following aspects: typology of the tools used, characteristics of the materials worked, actions carried out and morphology of the active areas (raw material, angles, characteristics of edges, thickness, etc.).

We have also analysed the state of the wooden remains that have been preserved (except for coal), in order to suggest a hypothesis about the type of work and the activities involved in their manufacturing and resulting use-wear.

Due to the fact that the study framework refers to the macro-level documentation on woodworking in the Middle and Upper Paleolithic in Europe, there is an obvious decontextualisation of the results regarding specific archaeological sites, territories and periods at a micro level. The micro approach is largely addressed in the publications of each particular site thus not being the main focus of our research.

Finally, no discrimination has been observed as for raw material (flint, limestone, quartzite, etc.), although some studies emphasize the use of specific raw materials based on the actions observed on wood (i.e. [Lazuen et al., 2011](#)).

3. Results

Next, we will examine how representative woodworking is in the functional studies of the Paleolithic chronology, as well as the tools used and the wooden remains preserved in relation to the working techniques that can be inferred from the use-wear analysis and manufacturing traces on the implements. The publications about use-wear which have been analysed in this research do not present the technological information in a homogeneous or standardized way, since there are many cases in which there is no relation between the activity identified and the morphology of the tools or the active areas, making it impossible to create a complete synthesis graph and leading us to register the most representative cases and examples regarding activities and tools.

3.1. Middle Paleolithic

3.1.1. Use-wear analysis on tools

The functional studies applied to Mousterian remains focus on entire archaeological sites. The results show that the processing of animal matter is generally more usual than woodworking. Although this type of work is present in practically all the sites that have been examined (with various degrees of representation), we can observe some differences between some functional studies which show a high percentage of woodworking ([Anderson-Gerfaud, 1981; 1990; Beyries, 1987; Beyries and Hayden, 1993](#)), and others in which this percentage is lower ([Lemorini, 2000; Claud et al., 2013](#)).

However, it is important to consider the specific characteristics of each site. In Remicourt-En Bia Flo, for instance, there is great evidence

of woodworking ([Jardón Giner and Bosquet, 1999](#)), as compared to Abri Romaní, where despite the finding of wooden tools, the work of this material is less frequent ([Martínez, 2005](#)). Taphonomic reasons could explain these differences.

Abri du Maras (France) is also a remarkable site, where an important set of tools which worked on wood or vegetable fibres has been found and conserved as waste in the active areas ([Hardy et al., 2013](#)). However, recent studies have proposed to take the analyzed residues with caution, since they can be incorporated into processes other than use ([Rots et al., 2016](#)). In addition, as Monnier points out, it is very difficult to identify residues without using high-resolution microscopes ([Monnier et al., 2017](#)).

Some diachronic studies such as the ones conducted in several remains and sites in Atapuerca are also very interesting. These have shown that the use of wood is more intense in mode 3 tools than in mode 1 and 2, ([Márquez et al., 2001](#)). It is also one of the few examples that shows that this work is mainly related to a particular type of tool (denticulate).

Regarding tool typology, there is evidence that most of the typological categories of the Paleolithic were used for woodworking, which indicates the great adaptability of Mousterian tools. We can also observe a preference for retouched tools. In addition, we can distinguish between those tools which were used in direct freehand percussion actions, manufactured in more massive supports, and those smaller tools not used for this type of actions ([Claud et al., 2013; Hortelano, 2016](#)). For example, small artifacts are effective for some actions as scraping or cutting ([Lazuén and Delagnes, 2014; Lazuén and González Urquijo, 2014](#)).

The relation between the morphological features of the tools (angle and delineation of edges, more important, at an experimental level, than tool typology) and their role in woodworking is not always clear. Regarding the activities, use-wear analysis allows us to make a kinematic reading of the tool and the activity, but it is not an easy task to reconstruct the complete *chaîne opératoire* on wood. Direct and indirect percussion, scraping and cutting are the most habitual actions. Given this and the difficulty faced in trying to identify the activity in which the tool under study was involved, few researchers can theorize about the specific processes in which they took part. The archaeological site of San Quirce is one of the examples in which the work of wood and vegetable fibres stands out alongside butchery ([Clemente et al. 2014](#)) and in Biache Saint-Vaast, woodworking has been related to techniques used for the preservation of handles ([Rots, 2011; 2013](#)).

3.1.2. Preserved wooden remains

Although the wooden remains from this chronology are not very abundant, they are well-known, which is why our research will focus on analysing those remains which provide information about possible actions and working techniques.

Regarding the most ancient remains, in the site of Schöningen, with a recently revised chronology of 337–300 Ka B.P. ([Richter and Krbetschek, 2015](#)), several spears presenting cutting marks have been found being their apparent purpose to recondition the side of one of the spearheads ([Schoch et al., 2015](#)). In Poggetti Vecchi, whose remains have been assigned to 171 Ka B.P., 39 implements show cuts and striation traces produced by the use of tools ([Aranguren et al., 2018](#)). In Aranbaltza III, from around 90 Ka B.P., a piece of wood presents two little cutting marks on the surface corresponding to the last stages of the manufacturing of a digging stick ([Rios-Garaizar et al., 2018](#)). Despite showing evidence of their manufacturing, the traces of work on these tools can not always be related to specific activities.

In other archaeological sites such as Königsau ([Mania and Toepfer, 1973; Koller et al., 2001](#)), and Kärlich ([Kulemeyer, 1988](#)) we find wooden and resin remains, which give evidence of actions that involved the barking of wood for its modification (shaft) and the use of techniques for the extraction of tar from the birch tree as well as other resins and tars used as adhesive ([Beyries and Hayden, 1993; Kozowyk et al.,](#)

2017). In fact, there is also evidence of the use of tar as glue since the Middle Pleistocene, as in Campitello, Italy (Mazza et al., 2006), or Inden-Aldorf, Germany (Pawlik and Thissen, 2011), whose remains indicate the use of ligneous resources.

As for the use of fire, in the sites of Poggetti Vecchi and Leheringen the analysis of several pieces altered by temperature has led researchers to believe that fire could have helped to make scraping easier in the case of Poggetti Vecchi (Aranguren et al., 2018), or to make the surface harder, as in Leheringen (Movius, 1950; Thieme and Veil, 1985).

Finally, in order to complete the collection of wooden artifacts from the Middle Paleolithic, it is important to include other wooden remains with no signs of manufacturing on them, such as those found in Abric Romaní, with an approximate chronology of 45–49 Ka B.P. (Carbonell and Castro-Curel, 1992; Castro-Curel and Carbonell, 1995) and the arrowhead found in Ljubljansko Barje (Eslovenia) with a chronology of 37 Ka B.P. (Gaspari et al., 2011).

3.2. Upper Paleolithic

3.2.1. Use-wear analysis on tools

Woodworking during the Upper Paleolithic is evident in most of the archaeological sites analysed, although the amount of tools used for the manufacturing of wooden objects varies and is generally scarce. Blades and *pièces esquillées* were used for the obtention of wood, whereas blades, flakes, end scrapers, burins and piercers (in a smaller quantity) were used for the finishing of works. According to the published analysis, wood working is marginal in Upper Paleolithic. In some of the sites only one, or no stone piece at all, presents use-wear related to wood (Moss, 1983; Plisson, 1985; Calvo, 1997; Cabal et al., 2004; Ortega et al., 2006; Baillet, 2017).

In his study of Hearth 111 in Pincevent, Moss explains the absence of woodworking traces stating that only one tool worked this material, due to woodworking needing to take place in larger spaces away from the hearths. It is probably certain that the cutting down of trees and big branches was probably carried out in bigger spaces, but the space needed for the cleaning and working of animal skins would be similar. Another hypothesis accounts for the specialisation of sites (Plisson, 1985). However, these explanations seem rather improbable due to the great number of sites belonging to different stages of the Upper Paleolithic published.

3.2.2. Preserved wooden remains

Throughout the Upper Paleolithic, the wooden remains which have been preserved are usually located in those sites with more recent chronologies, specifically during the Solutrean and the Magdalenian periods. Some surviving necklace beads found in Las Caldas site have been assigned to the Solutrean period (Corchón, 1999).

The range of elements found belonging to the Magdalenian period is wider. From the early stages, other necklace beads similar to the ones from the Solutrean were found in Cueva de Santa Catalina (Berganza et al., 2018). The interest aroused by these findings adds to the experimental proposal of a reconstruction of the elaboration process. As the authors suggest, the way in which the wood fibres are arranged in the necklace beads indicates the use of a large splinter, showing that its extraction was necessary, although there is no clear information about the specific action through which the splinter was obtained. Piercing was then made using stone piercers.

Remains of bows and arrows have also been found. The analysis of an object of about 110 cm long found in Mannheim confirmed that it was used as a bow (Rosendahl et al., 2006). The manufacturing of this little bow using a thick branch consisted of eliminating the outer part of the wood and preserving the heartwood on the other side. This slimming was obtained through cutting and reducing the wood using stone flakes and blades. The holes where the strings were located were made applying cutting or sawing techniques (Junkmanns, 2001). A second bow was found in the Magdalenian site of Teyjat (Coles and Higgs,

1969) and a third one in Stellmoor (Rausing, 1967). The remains of these bows, arrows and necklace beads underwent cutting, scraping and polishing processes.

Meanwhile, the remains of post-holes in the construction of dwellings in some archaeological sites give evidence of activities not usually documented (Leroi-Gourhan and Brézillon, 1966).

4. Experimental programmes

Throughout the last decades, a great number of replicative, mechanical and sequential experimental programmes including wood-working, have been carried out. Some of the most relevant studies, such as the ones by Semenov and Thompson (1964) Tringham et al. (1974), L.H. Keeley (1980), B. Hayden (1979) have played an essential role not only because they have laid the foundations for protocols to be taken but also because they have confirmed their importance in the validation of functional interpretations.

There is not much information about particular actions or complete working processes, since specific experimentations have only been conducted in very rare occasions. Some examples of researches that have been published and which account for this issue in detail are González and Ibañez (1996), Claud et al. (2013, Claud, 2015), Laborda (2010) or Martín Lerma (2015). These experimentations show a greater presence of cutting, scraping and sawing processes and fewer cases of *percussion lancée* in the cutting down of trees and chopping of logs.

Experimentations with specific tools are not very frequent either, except for biface works (i.e. Claud et al. (2009); Claud (2012)), or the analysis of splintered pieces (i.e. Le Brun-Ricalens, 1989; Gibaja et al., 2007; Jardón et al., 2018). It is thanks to the experimentations focused on typologies, that we can theorize about tools, processes and actions.

Furthermore, experimental studies usually focus on how the tools deteriorate after being used and very rarely do they show use-wear in the manufactured tool, with a few exceptions (Jensen, 1991; Paulsen, 1990; Veil, 1990; Aranguren et al., 2018; Jardón et al., 2018). It is also important that experimental programmes dealing with the effectiveness of the tools used in the different activities become more generalised.

5. Discussion and conclusion

We have been able to confirm the wide range of stone tools used for woodworking despite the scarcity of the remains. This makes hypotheses formulation rather difficult, since the low proportion of manufactured tools sets limits to the information and knowledge about the possible actions and activities involved in their manufacturing. Conversely, it is essential that publications emphasise the importance of formulating functional hypotheses together with traceological results in order to shed some light on the actions and materials being worked.

Actions on wood may be less frequent and of a shorter duration than in latter periods (Mesolithic and Neolithic), which makes it more complicated to identify them (less developed polishing, low surface modification and microscarring). In addition, woodworking use-wear could be affected by taphonomic processes.

We can distinguish several stages of the *chaîne opératoire*. The implements used for woodchopping are generally bifaces and *pièce esquillées*. There is no evidence that other tools, such as wooden wedges or bone pieces used as axes, may have taken part in this type of work, although it has been observed in other cultures lacking metal. It is common to use flakes or blades in shaping actions, knots eliminating, whittling or brushing wood, which matches the interpretations of the traceological analyses applied to prehistoric stone tools. Regarding the finish through scraping, the tools used are scrapers and denticulated during the Middle Paleolithic, and burins and non-retouched edges in the Upper Paleolithic. These would have angles greater than 45°, being the tools most often used due to their active potential.

In any case, both in the Middle and Upper Paleolithic the number of implements connected to wood is lower than 25%. Therefore,

throughout the Upper Paleolithic the increase in the specialization of some types of tools such as end scrapers, does not account for the existence of tools specially designed for the work of wooden vegetable matters. However, the complexity of elaborated objects does increase, namely propellants, handles, arrowheads and bows, most of which have not been preserved. Among tools that present wood use-wear we find burins and piercers, needed for the manufacturing of necklace beads, as in Santa Catalina.

How can we explain the low number of tools presenting wood use-wear in the archaeological register? Earlier on we have discussed the reasons that include the time and space specialisation of the samples under study. Another cause to be taken into account would be related to the difficulty in identifying the material worked, since there is often the non-specific identification of “medium hard organic matter.” As for the identification of use-wear, it is worth considering that there may be a slant in the number of identified woodworking actions, mainly due to the resemblance among materials with a similar hardness, such as wood and antler material (Owen, 1994), or short actions with a great deal of breaking. The conclusions obtained through the use-wear analysis of the material worked are sometimes very vague, identifying the hardness of the material worked as medium, or high instead of determining if it has a ligneous or a bone origin.

The tools studied through traceological analysis are manufactured using siliceous raw materials (flint, chert or siliceous limestone) whose properties for the obtention of cutting edges through carving are well known. However, due to the fragility of this material, they do not fully resist direct freehand percussion, necessary for the cutting down of trees and carried out in later periods using polished stone axes. Can we therefore imply that these circumstances led to a limitation in the supply of wood for object manufacturing? The possibilities of chopping big logs and working in a dry state are then scarce. These tools seem to be more useful in the work of green branches and logs. Therefore, the ultimate solution would lay in the selection of wooden raw material given its shape and original size (Jardón et al., 2018). The later modification may have been possible thanks to the use of fire, as shown in the artifacts found in Poggetti Vecchi (Aranguren et al., 2018).

It is for all this that it is necessary to insist on the importance of ethnographic and experimental studies, whose main aim is to reconstruct the *chaîne opératoire* based on the preserved remains from each period, applying the functional analysis to a wider range of sets and always taking the aim of this work into consideration: the manufacturing of a wooden object.

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Using Fire for Woodworking: An Experimental Exploration of Use-Wear on Lithic Tools

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ABSTRACT

Throughout prehistoric times, woodworking was an essential activity. We know this because of the existence of preserved wooden objects, as well as the use-wear traces recorded on lithic tools. In general terms, functional studies and experimental programs have aimed to analyze and understand the use-wear traces generated by green and dry wood. However, some of the wood remains preserved across time show signs of thermal alteration caused by fire. For this reason, we have carried out an experimental program in which green, dry and thermoaltered wood have been worked in order to study the traces generated on the lithic tools. The results show significant differences between the use-wear traces generated by green and dry woods, and thermally altered wood. This indicates that it would be possible to recognize signs of work with thermoaltered wood on archaeological lithic tools and, therefore, to better understand the working processes of past populations.

KEYWORDS

Use-wear analysis; experimental archaeology; woodworking; thermal alteration; lithic tools

Introduction

Wood has played an important role in the productive processes of human groups throughout prehistory. It has been used both as fuel and as raw material for the manufacturing of objects. However, the low number of well-preserved wooden remains of ancient times limits our knowledge regarding the type of objects created using this material, as well as the actions carried out in the manufacturing processes (e.g. Aranguren et al., 2018; Carbonell & Castro-Curel, 1992; Corchón Rodríguez, 1999; Gaspari et al., 2011; Rios-Garaizar et al., 2018; Thieme, 1997).

Because of this, it is often necessary to resort to the functional analysis of lithic tools in order to know more about the working actions of wooden materials. In this sense, there is a great number of use-wear studies which demonstrate the presence of woodwork in many archaeological sites (e.g. Anderson-Gerfaud, 1981, 1990; Beyries, 1987; Beyries & Hayden, 1993; Claud et al., 2013; Jardón & Bosquet, 1999; Lemorini, 2000; Martínez, 2005; Tyldesley & Bahn, 1983). These studies are of the utmost importance since they allow us to have more information about the type of tools involved in different tasks, as well as the actions carried out with them (Bencomo et al., 2020).

Alongside these functional studies on archaeological material, a great number of experimental programs include woodworking (e.g. González & Ibáñez, 1994; Keeley, 1980; Semenov, 1964; Tringham et al., 1974; Vaughan, 1985), some of which perform very specific actions or even entire processes (e.g. Claud, 2015; Claud et al., 2013; González & Ibáñez, 1996; Laborda, 2010; Martín, 2015). Generally speaking, these experimental programs have taken dry or green wood as the basis for their analysis, except in some cases (e.g. Gutiérrez, 1996), in which thermoaltered wood has also been included without specific attention to the use-wear traces generated when working this type of wood. In the same line and taking into account some remains of thermally modified wood associated with ancient chronological data, an experimental program has been carried out on this matter in order to acquire a deeper knowledge of these kinds of use-wear traces and compare them to those existing on both green and dry wood samples.

Using fire for woodworking in prehistoric times

We are currently aware of the use of fire for woodworking thanks to the state of preservation of some remains.

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Some of the oldest ones were located in the archaeological site of Poggetti Vecchi (Italy), aged approximately to 171Ky BP, and included 39 wooden pieces, with cutting and striation marks produced by tools, with evidence of traces of thermal modification processes to ease scraping actions (Aranguren et al., 2018). Three other pieces belonging to a 2 m-long spear aged to 125Ky BP were also found in Lehringen (Germany), including a conical tip thermally modified with the purpose of hardening the surface (Movius, 1950; Thieme & Veil, 1985). Another piece classified as a digging stick aged to 90Ky BP was located in Aranbaltza III (Spain), whose thermal modification traces indicate the use of fire to facilitate the scraping and hardening of surfaces (Rios-Garaizar et al., 2018).

Although only a few wooden remains present thermal modification evidence, they are very significant in prehistoric times, especially if we contemplate the total number of wooden remains preserved. That is why we need to consider the possibility of fire being used during the work of wooden tools. Some ethnographic references support this hypothesis (e.g. Thomson, 1964; Gould, 1970; Vincent, 1985; McGuire & Stevens, 2017).

All this has led to the appearance of experimental programs on thermally modified wood (López-Bultó et al., 2020; Revedin et al., 2019), whose goal has been to analyze working traces on wooden supports to compare them with archaeological remains, thus allowing us to know more about working processes. Nonetheless, there is not much information about the use-wear traces generated on the lithic tools used in work processes. With this research we aim to analyze the use-wear evidence of thermal modifications during woodworking from a functional point of view, comparing it to that of dry and green wood. Our ultimate goal is to improve archaeological interpretations of prehistoric woodworking processes.

Materials and methods

Three types of wood were used throughout the experimental program: *Pinus halepensis* (aleppo pine), *Pinus nigra* (black pine) and *Taxus baccata* (yew) in their green, dry and thermally altered states. We have selected pine because of its representation as charcoal in some Palaeolithic archaeological record (e.g. Allué et al., 2017; Desprat et al., 2015; Théry-Pariset & Texier, 2006; Vidal-Matutano, 2018), and yew because many of the wooden objects found in Palaeolithic sites are made from this type of wood (e.g. Oakley et al., 1977; Rios-Garaizar et al., 2018; Thieme & Veil, 1985).

The length of the branches varies between 50 cm and 1 m, as well as their diameters, between 2 and 7 cm. In

order to perform wood debarking and sharpening, whittling and scraping actions were carried out. The purpose of focusing only these two actions was to control this variable and assign the differences between use-wear traces to the state of the wood and not to the actions performed. However, it is depending on the state of the wood (specifically the thermally modified one), that more importance has been given to scraping rather than whittling actions, since the physical conditions of wood required this type of action in order to achieve an optimal result.

The total number of tools used was 19. Woodworking was done using Serreta (cf. Molina et al., 2016) and Spiennes (cf. Collet et al., 2014) flint types. The edges of the tools were straight or concave with angles comprising between 40° and 60° mostly. The tool size varies, but they had to be big enough to be handheld.

Most of the research was carried out by the same person, thus the intensity and strength of the tool-user constitute variables that were stable throughout the whole experimental program.

Description of use-wear traces

The description of use-wear traces was made using the terminology proposed by other use-wear analysts (e.g. González & Ibáñez, 1994; Kamminga et al., 1979; Keeley, 1980; Plisson, 1985; Tringham et al., 1974; Vaughan, 1985). Scars, polish, edge-rounding, and striations are described.

Cleaning of tools and use of microscopy

Overall, all the edges used were observed prior to and after the action in order to analyze the traces originated by their use. Microscopic observation was carried out using a Leica Microsystems® M165C stereomicroscope at 3.65–60X, and a Leica Microsystems® DM6000M metallographic microscope at 50–500X.

Lithic tools were generally washed using lukewarm water and mild soap (Hygenia, Magnum Blue). When dirt remained, the tools were cleaned in the ultrasonic cleaner (Metason 120, Struers), using a solution of mild soap, for a limited time (15 min to 1 h). Occasionally, more aggressive methods had to be used, such as acetone or a solution of acetic acid at 5%. Acetone was also used when the area of the tools under study was covered in grease due to constant handling.

For the tools used in thermally modified woodworking, the cleaning process was more difficult due to the presence of charcoal embedded in the edges. In this case, the tools had to be immersed in water for several days so the charcoal could be easily detached.

Table 1. Tools involved in the experimental program on green wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movement		Contact angle	Wood	Working time (minutes)
1	Spiennes	45°	Whittling	Positive	Transversal	Medium/low	<i>Pinus halepensis</i>	40 min
2	Spiennes	70°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	40 min
3	Serreta	45°	Whittling	Positive	Transversal	Medium/low	<i>Pinus nigra</i>	20 min
4	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	20 min
5	Serreta	40°	Whittling	Positive	Transversal	Medium/low	<i>Pinus halepensis</i>	20 min
6	Serreta	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	20 min

Experimental program

We will next describe the experimental program carried out in detail.

Green woodworking

Six tools were used in the woodworking with green wood: four made on Serreta flint type and two made on Spiennes flint type. Four of them were used on *Pinus halepensis* and two on *Pinus nigra*. Three tools

were used in the whittling process in order to perform the debarking of the logs. Another three tools carried out scraping actions to obtain the sharpening of wood. Working times have also varied between some pieces being used for 20 min and other pieces being used for 40 (Table 1, Figure 1).

Dry woodworking

As for the woodworking with dry wood, four tools were used: two made on Serreta flint type and two on



Figure 1. Experimental program on green wood. (A) *P. halepensis* and *P. nigra* used during the experimentation; (B) tool made on Serreta flint type whittling *P. nigra*; (C) tool made on Spiennes flint type whittling *P. halepensis*; (D) location of residues produced during the whittling of *P. halepensis*; (E) tool made on Spiennes flint type scraping *P. halepensis*; (F) location of residues produced during the scraping of *P. halepensis*.

Table 2. Tools involved in the experimental program on dry wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movement	Contact angle	Wood	Working time (minutes)
7	Spiennes	60°	Whittling	Positive	Transversal	<i>Pinus halepensis</i>	40 min
8	Spiennes	55°	Scraping	Negative	Transversal	<i>Pinus halepensis</i>	40 min
9	Serreta	45°	Scraping	Negative	Transversal	<i>Pinus nigra</i>	20 min
10	Serreta	50°	Scraping	Negative	Transversal	<i>Pinus halepensis</i>	20 min

Spiennes flint type. Three tools were used for the work of *Pinus halepensis* and one for *Pinus nigra*. Due to the physical conditions of dry wood, two different processes were performed. On the one hand, two tools were selected, one used for whittling, and the other for scraping. The remaining two tools were used for scraping, achieving debarking and sharpening in the same action. Working times have also varied between 20 and 40 min (Table 2, Figure 2).

Thermally modified woodworking

A total of nine pieces were used for this type of woodworking: five made on Serreta flint type and four on Spiennes flint type. Four tools were used for the work

of *Pinus halepensis*, two for *Pinus Nigra*, two for *Taxus Baccata* and one for *Pinus Nigra* and *Taxus Baccata*. The majority of the tools involved were used in scraping actions, simultaneously obtaining debarking and sharpening thanks to the easy detachment of charred bark after thermally modifying the wood. Working times varied around 25 min, although some were used for 40 min (Table 3, Figure 3).

For the process of thermal modification of wood, a fueling combustion structure was created. The flame was controlled by thermocouples, so we know that the temperatures were in a range between 400°C and 500°C. The wood, which was previously dry, was exposed to fire for short periods of time, between 5 and 10 min



Figure 2. Experimental program on dry wood. (A) *P. halepensis* and *P. nigra* used during the experimentation; (B) tool made on Serreta flint type scraping *P. nigra*; (C) tool made on Spiennes flint type whittling *P. halepensis*; (D) location of residues produced during the whittling of *P. halepensis*; (E) tool made on Spiennes flint type scraping *P. halepensis*; (F) location of residues produced during the scraping of *P. halepensis*.

Table 3. Tools involved in the experimental program on thermoaltered wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movimiento		Contact angle	Wood	Time
11	Serreta	60°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	20 min
12	Serreta	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	20 min
13	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	25 min
14	Serreta	55°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	25 min
15	Spiennes	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	40 min
16	Spiennes	50°	Whittling	Positive	Transversal	Low	<i>Pinus Nigra</i> and <i>Taxus baccata</i>	15 min
17	Spiennes	50°	Whittling	Positive	Transversal	Low	<i>Taxus baccata</i>	8 min
18	Spiennes	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	12 min
19	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Taxus baccata</i>	18 min

depending on the thickness and resistance of the area to be worked upon. The aim of this was to thermally modify the outer area exclusively, preventing wood from

igniting, so the use of fire had to be carefully monitored. The working method consisted of thermally modifying the outer surface of wood and then whittling and



Figure 3. Experimental program on thermoaltered wood. (A) *P. halepensis*, *P. nigra* and *Taxus baccata* used during the experimentation; (B) heating *Taxus baccata* in the combustion structure; (C) tool made on Spiennes flint type scraping *P. nigra*; (D) tool made on Spiennes flint type scraping *P. halepensis*; (E-F) tool made on Serreta flint type scraping *Taxus baccata*.

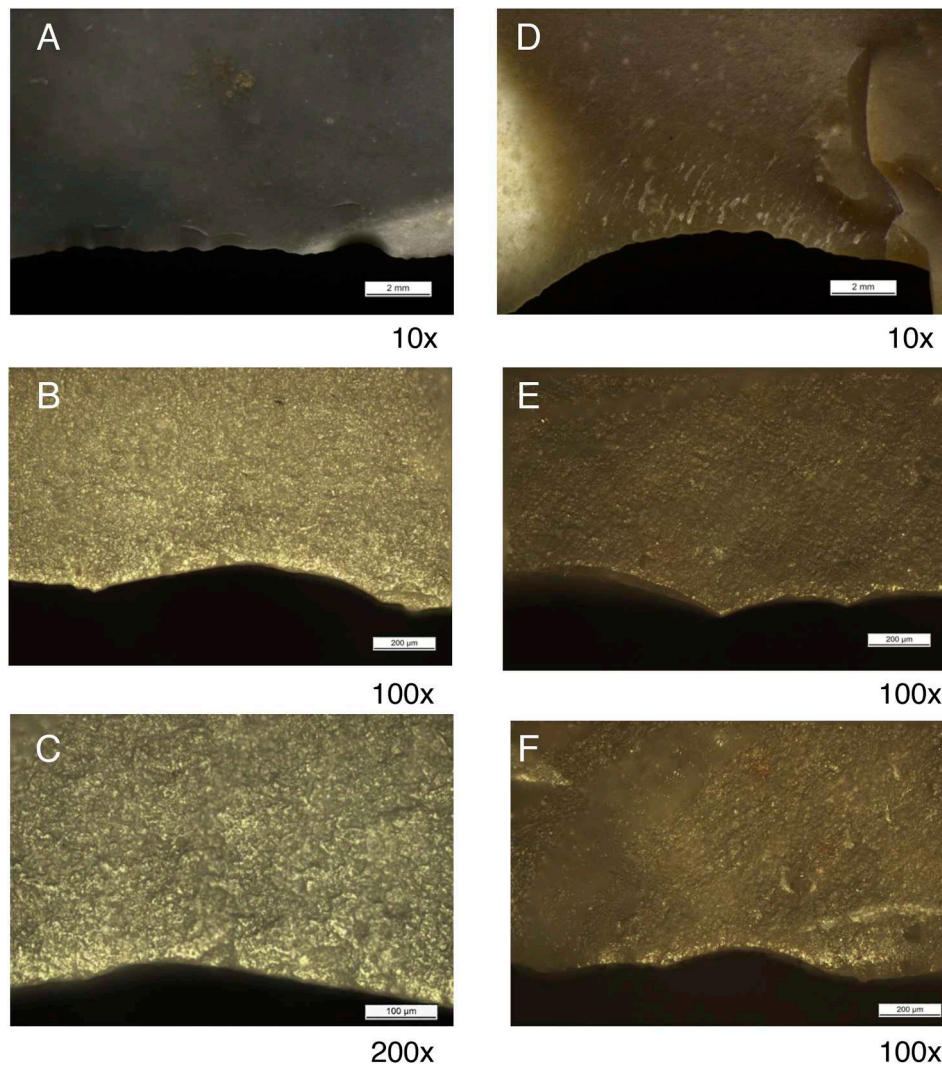


Figure 4. Use-wear traces of green woodworking. (A–C) tool 1 made on Spiennes flint type after whittling *P. halepensis* for 40 min at 10x, 100x and 200x; (D–F) Tool 6 made on Serreta flint type after scraping *P. halepensis* for 20 min at 10x, 100x and 100x.

scraping the surface using flint tools. This process was repeated until smooth and uniform surfaces were obtained.

Results

After carrying out the experimental program, we have observed significant differences between use-wear traces on tools used to work green, dry and thermally modified wood, regardless of the tree species and the type of flint used. The results are therefore presented according to each of the states in which wood is presented. Since scraping is the most common action, mainly on thermally modified seasoned wood, we have particularly examined the use-wear traces resulting from this action. The written description is supported by graphic evidence to provide a better understanding

(Figures 4–9) and tables where the information has been synthesized (Tables 4–6).

Green wood

- Starting with the scars, they have a continuous distribution although in some cases it is discontinuous. The organization is aligned, but in some cases it is superimposed. In general they have a semi-circular morphology and a feather termination. In terms of size, they are small or medium (0.3–1 mm).
- The edge-rounding is weak-average, depending on the time of use.
- The polish is bright, with a rough texture (peaks are altered) and the topography of the peaks is domed. The density is intermediate and the contour tends

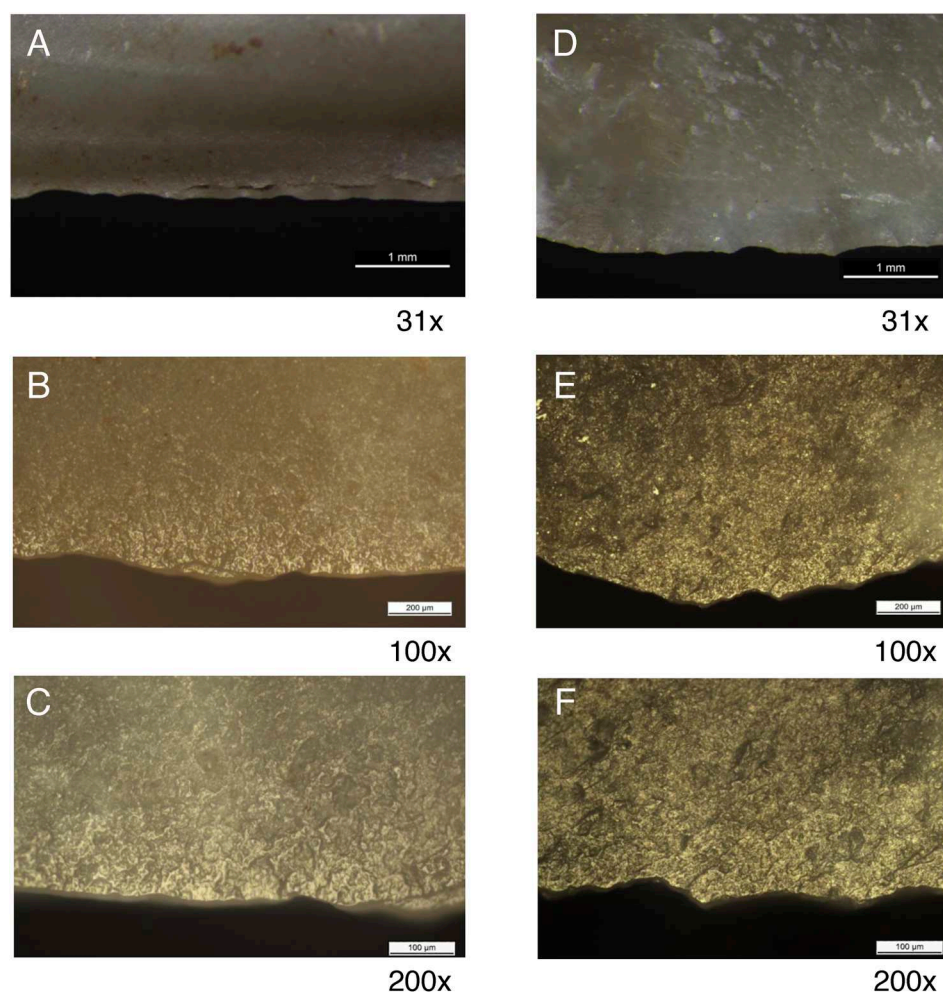


Figure 5. Use-wear traces of dry wood. (A–C) tool 8 made on Spiennes flint type after scraping *P. halepensis* for 40 min at 31x, 100x and 200x; (D–F) tool 9 made on Serreta flint type after scraping *P. nigra* for 20 min at 31x, 100x and 200x.

to be sharp. As for the extension, it is marginal (0.1 mm).

- The striations, with a parallel organization between them and a perpendicular orientation in relation to the edge, have a fine width (< 2 microns), medium length (50–150 microns) and shallow depth.

Dry wood

- The distribution of the scars is continuous. The organization is aligned although in some cases it is superimposed. The aligned ones tend to be semi-circular with a feather termination, and the superimposed ones tend to be quadrangular with a step termination. In general, they have a medium size, except for some cases in which they are small (0.3–1 mm).
- The edge-rounding is weak-average, depending on the time of use.

- The polish is well-developed and bright. The texture is rough (peaks are altered) but tends to be smooth at the edge, and the topography is domed. The polish is dense and the contour tends to be sharp. The extension is marginal (0.1–0.2 mm).
- The striations, with a parallel organization between them and perpendicular orientation regarding the edge, have a fine width (< 2 microns) and medium length (50–150 microns). They are frequent and deep.

Thermoaltered wood

- The distribution of the scars is continuous. The organization is aligned although in some cases it is superimposed. The aligned ones tend to be semi-circular with a feather termination, and the superimposed ones tend to be quadrangular or irregular with a step termination. In general, they have a small or medium size (0.2–1 mm).

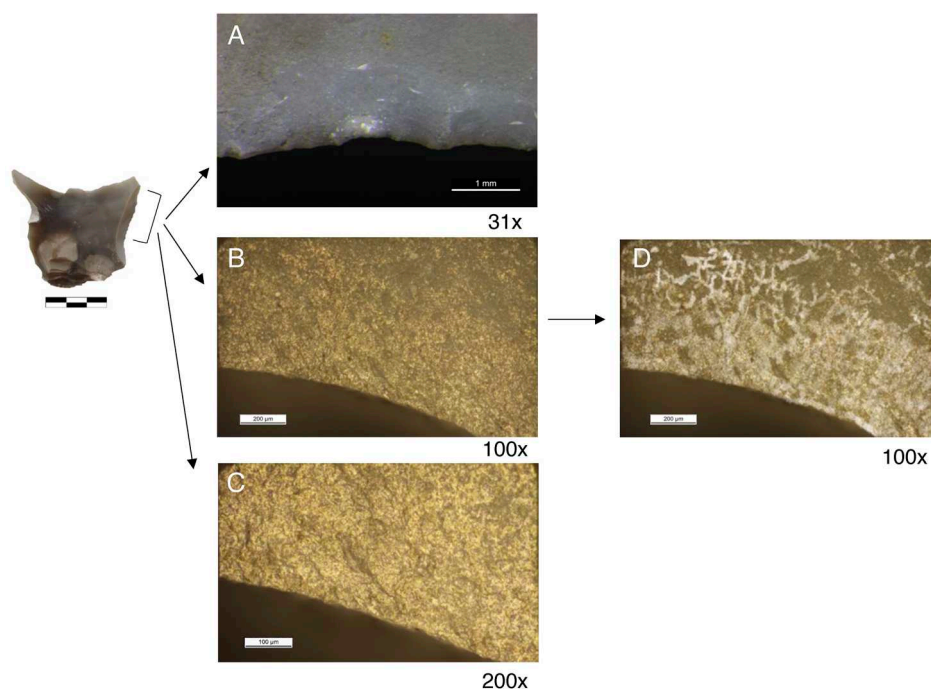


Figure 6. Use-wear traces on tool 15 after scraping thermoaltered *P. nigra* for 40 min. (A) at 31x; (B) at 100x; (C) at 200x; (D) drawing on photograph indicating use-wear traces.

- The edge-rounding is weak-average, depending on the time of use.
- The polish tends to be dull. The texture is rough (but peaks are not very altered) and the topography is domed. The density of the polish is intermediate, but in some cases is dense, and the contour tends to be fuzzy. The extension is moderate-invasive (0.2–0.6 mm).
- The striations, with a parallel organization between them and perpendicular orientation in relation to

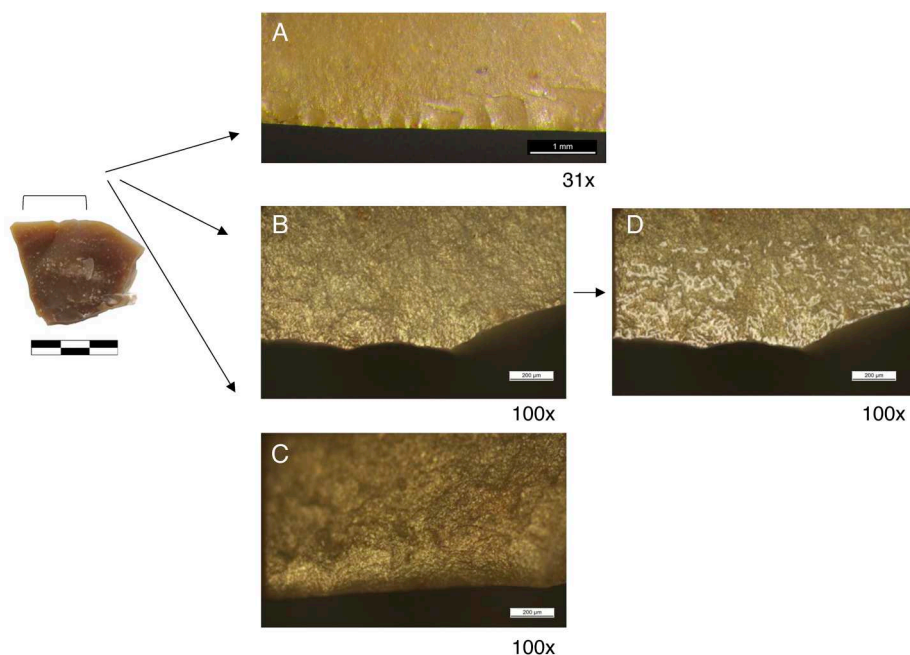


Figure 7. Use-wear traces on tool 11 after scraping thermoaltered *P. halepensis* for 20 min. (A) a 31x; (B) at 100x; (C) at 100x; (D) drawing on photograph indicating use-wear traces.

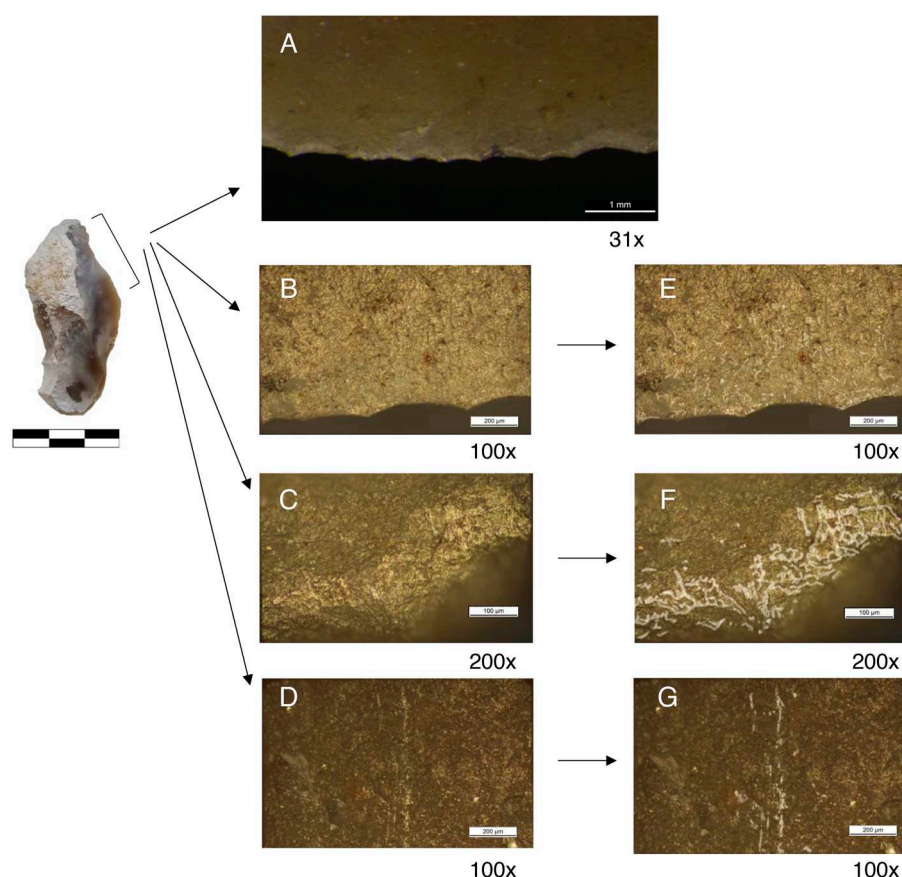


Figure 8. Use-wear traces on tool 12 after scraping thermoaltered *P. nigra* for 20 min. (A) at 31x; (B) at 100x; (C) at 200x; (D) at 100x; (E–G) drawing on photograph indicating use-wear traces.

the edge, are frequent, with a fine width (< 2 microns) and medium length (50–150 microns) and shallow depth.

Discussion

Throughout the experimental program, it has not been possible to carry out the same type of actions when working on the 3 different types of wood, due to the various physical conditions. Therefore, in the case of dry and thermally modified wood, scraping actions have been performed in order to obtain debarking and sharpening simultaneously, whereas in the case of green wood, two differentiated actions had to be sequenced from whittling and scraping making the use of different tools necessary. That is why we have focused mainly on the traces of use generated by scraping.

Despite this, remarkable differences have been observed between use-wear traces generated by working thermally modified and green or dry wood. These differences are particularly obvious when observing the texture, the topography and the extension of the

polish. The texture of thermally modified wood is more rugged than in dry or green wood cases, where peaks tend to be more altered. The topography is also irregular, due to the surface of flint being hardly homogenized, whereas we find a more domed topography in the case of green and dry wood. All this can be related to a less bright appearance of the thermoaltered wood polish. Finally, the extension of the polish is invasive in the tools that worked on thermoaltered wood, whereas the extension of the green and dry wood polish is more moderate.

Having analyzed this information, it seems that thermally modified wood confers less resistance than green and dry wood. In this sense, some studies (e.g. Ennos & Chan, 2016) point out that when wood is thermally modified, it becomes weaker and more breakable. It is because of this that both the texture and the topography of thermoaltered wood are similar to cases of soft material work. On the other hand, the charcoal generated when heating wood has a direct role in forming the extension of polish, from which two points arise: the charcoal detached from the piece of wood during scraping actions is abundant and fragmentary, and this charcoal gets “trapped” between the tool and the log.

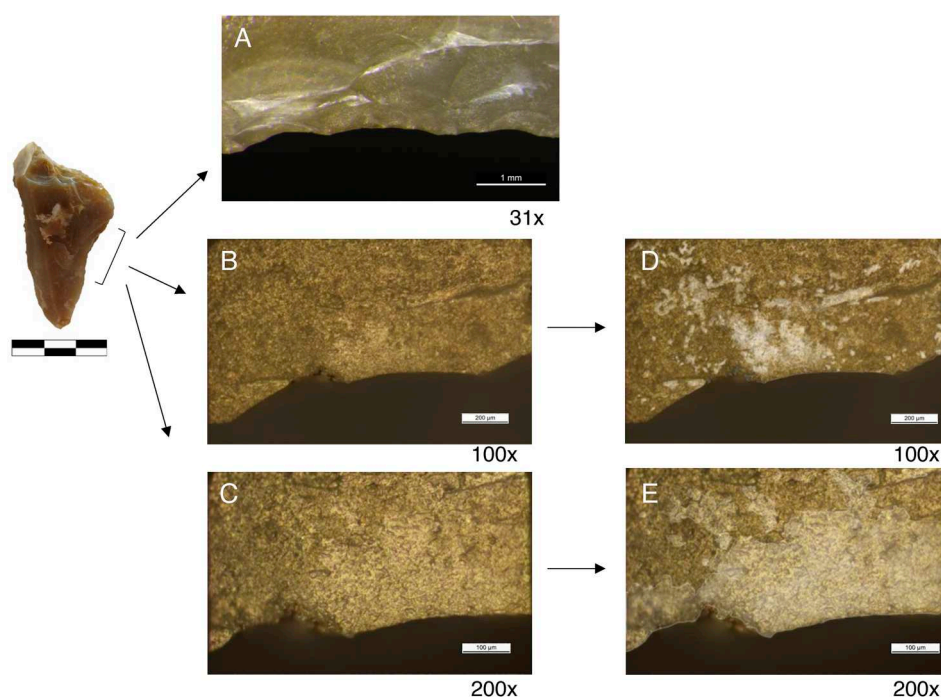


Figure 9. Use-wear traces on tool 19 after scraping *Taxus baccata* for 18 min. (A) at 31x; (B) at 100x; (C) at 200x; (D–E) drawing on photograph indicating use-wear traces.

As the scraping of the log continues to be done to obtain the desired result, the charcoal generates a friction action that results from dragging, thus affecting the invasive extension of polish. We can also assume that charcoal may also be covering the surface of the flake and acting almost as a barrier reducing polish formation, especially in the lower topography, resulting in a less bright polish.

Another interesting fact is the amount of charcoal residues found on the flint surface. While something similar happens with dry and green wood residues (to

a lower extent), it is very hard to get rid of them, since charcoal adheres to the tiny natural cavities of flint making its removal much more difficult than in the other two cases. Although it might seem an obstacle when trying to obtain a clean surface, it actually improves the collection of residues. On the same note, another interesting aspect is the amount of residues generated when working thermally modified wood. In spite of not being more abundant than in the other types of wood (as it depends on the quantity of material being worked upon), there is a substantial difference in

Table 4. Use-wear traces of green wood.

Use-wear traces of green wood		
Scars	Distribution	Continuous, discontinuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular
	Termination	Feather
Polish	Dimension	Small, medium
	Appearance	Bright
	Texture	Rough
	Topography	Domed
	Extension	Marginal
	Contour	Sharp
	Density	Intermediate
Striations	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
	Depth	Shallow
Edge-rounding	Intensity	Weak-average

Table 5. Use-wear traces of dry wood.

Use-wear traces of dry wood		
Scars	Distribution	Continuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular, quadrangular
	Termination	Feather, step
Polish	Dimension	Medium, small
	Appearance	Bright
	Texture	Rough/smooth
	Topography	Domed
	Extension	Marginal
	Contour	Sharp
	Density	Dense
Striations	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
	Depth	Deep
Edge-rounding	Intensity	Weak-average

Table 6. Use-wear traces of thermoaltered wood.

Use-wear traces of thermoaltered wood		
Scars	Distribution	Continuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular, quadrangular
Polish	Termination	Feather/step
	Dimension	Small, medium
	Appearance	Dull
	Texture	Rought
	Topography	Domed
	Extension	Moderate-invasive
	Contour	Fuzzy
Striations	Density	Intermediate-dense
	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
Edge-rounding	Depth	Shallow
	Intensity	Weak-average

the distribution of residues. In this sense, the fragmentary nature of charcoal, which increases its scattering ratio, leads us to consider that, to understand charcoal distribution in archaeological sites, it is necessary to take these types of work into account instead of strictly connecting them to fuel combustion structures.

Finally, it is worth pointing out the manipulative and transformation ability of thermally modified wood as opposed to green and dry wood. In this sense, two main actions had to be performed in order to carry out the debarking and the sharpening of green wood: whittling and scraping. As for the dry one, the debarking and sharpening could be obtained by means of these two actions or by means of scraping only. However, the easiest way to work thermally modified wood is through scraping, due to the fragmentary and weak condition of charcoal. On the other hand, both green and dry wood require a greater amount of time and energy, which are considerably reduced in the case of thermally modified wood. For all these reasons, working thermally altered wood reduces working time and effort.

Conclusion

This research was motivated by two fundamental issues: firstly, the preservation of thermally modified wooden remains belonging to prehistoric times, and secondly, the lack of information about use-wear traces of thermoaltered wood.

All this led to the performance of an experimental program whose goal was to analyze and compare use-wear traces of green, dry and thermally modified wood. The substantial differences observed between thermally modified wood and the two others provide

significant results, especially in the characterization of the polish. So, through use-wear analysis we can obtain indirect evidence of the use of thermal modification of wood despite not being preserved in the archaeological site.

With this research a new proxy through functional analysis has been added in order to gain an understanding of woodworking processes throughout prehistory.

Disclosure statement

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Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale

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Abstract

Use-wear analyses are very useful to increase knowledge about the economic and subsistence dynamics carried out by Neanderthals. In general terms, functional results traditionally came from the analysis of tools belonging to stratigraphic units whose timescale refers to geological time. This is due to the fact that many Neanderthal sites are palimpsests of reiterated occupations over time, which must be dissected to approach us to human timescale. In the stratigraphic unit xa of El Salt (Alcoi, eastern Iberia), high temporal resolution archaeostratigraphic studies have been carried out. Diachronic material assemblages have been identified, allowing us to analyse more precisely the variability of Neanderthal behaviour over time. Amongst these assemblages, three have been selected (i.e. 5.3.1, 5.3.2 and 5.3.3) in order to analyse the lithic material functionality. The results obtained bring out the performance of different tasks within each analytical framework: woodworking in 5.3.1, woodworking and animal processing in 5.3.2, and butchering activity in 5.3.3. These results reflect the existence of a series of diachronic tasks carried out in overlapping activity areas. In this way, this work evidences flint use variability in a specific area of the site across time that could have been recognised only by means of high temporal resolution analytical frameworks.

Keywords Middle Palaeolithic · Use-wear analysis · Palimpsest dissection · Interoccupational variability · El Salt

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Introduction

An increasing number of functional lithic studies since the 1960s has contributed to overcome speculation on use based on artefact typology and improve our understanding of some of the activities carried out by Neanderthal hunter-gatherers (e.g. Beyries 1987; Anderson-Gerfaud 1990; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lazuén & González 2014; Venditti et al. 2019a). The bulk of data has been obtained from the analysis of tools belonging to stratigraphic units (SUs) (e.g. Beyries 1987; Jardón 2000; Lemorini 2000; Rodríguez et al. 2002; Martínez 2005; Rots 2011, 2016; Hortelano 2016; Lemorini et al. 2016; Márquez et al. 2017), which usually are a palimpsest of reiterated occupations whose timescale spans millennia or unknown amounts of time. Therefore, the use of the SU as an analytical frame provides general results that drive us away from human temporality and hamper the analysis of the variability of human behaviour throughout time. Narrowing down the information on stone tool use to timescales at which we can explore behavioural variability and change remains a challenge.

In the last decades, there has been an increasing concern for problems derived from the palimpsest condition of archaeological sites (e.g. Harding 2005; Bailey 2007; Holdaway & Wandsnider 2008; Lucas 2010; Henry 2012). In this framework, the SU xa from the site of El Salt (Alcoi, eastern Iberia) has been the focus of several studies aimed at approaching human single occupation episodes through multiproxy analyses (cf. Marrero et al. 2011; Machado et al. 2011, 2017; Mallol et al. 2013; Machado and Pérez 2015; Vidal et al. 2018; Leierer et al. 2019; Mayor et al. 2020; Pérez et al. 2020). Earlier studies carried out at SU xa showed archaeostratigraphically well-delimited material beds, leading to the definition of analytical frames called archaeostratigraphic units (AUs) (cf. Machado et al. 2011, 2017; Machado and Pérez 2015). Despite displaying a higher temporal resolution, these units constituted a micropalimpsest that was dissected in later studies (cf. Mayor et al. 2020), resulting in new analytical frames (i.e. 5.3.1, 5.3.2 and 5.3.3) that are even more accurate from a temporal perspective and closer to human single occupation episodes.

These studies have allowed the formulation of two main hypotheses related to SU xa:

The activities were carried out generally around hearths, as indicated by material scatters that fit the hearth-related assemblage model (cf. Vaquero & Pastó 2001).

The Neanderthals here did not occupy the place for long periods of time.

In this frame, it is of great interest to analyse the lithic artefacts from discrete and short-spanned activity events

from a functional perspective. In this sense, the utilisation of high temporal resolution analytical frameworks is a differentiating factor of this research regarding other use-wear studies. If we take as examples other Neanderthal sites located within the Mediterranean Iberian coast whose lithic material has been subjected to functional analyses, such as Cova Negra (cf. Moriel 1985), Abric Romaní (cf. Martínez 2005; Martín-Viveros et al. 2020), Abric del Pastor (cf. Galván et al. 2008), La Quebrada (cf. Eixea et al. 2015), Cova del Bolomor (cf. Hortelano 2016), and even El Salt (cf. Rodríguez et al. 2002), we can observe that the SU is employed as an analytical framework, and that the results derived from this tend to homogenise the human behaviours.

Thus, the goal of this research is to explore the potential of lithic functional studies in small timescale analytical frameworks as proxies to identify the tasks performed in a specific space of the site. The study consists in carrying out use-wear analysis on the lithic assemblages from AUs 5.3.1, 5.3.2 and 5.3.3, which are three successive analytical frames that are part of diachronic, discrete, brief human occupations (cf. Mayor et al. 2020). Comparing these analytical frames across time could provide insight into Neanderthal behavioural variability.

The archaeological site of El Salt

The archaeological site of El Salt is an open-air rockshelter at 680 m above sea level located in Alcoi and featuring a 38-m-high travertine wall at the foot of the excavated area (Fig. 1). It has a 6.3-m-thick stratified deposit divided into 13 stratigraphic units (cf. Fumanal 1994), dating mainly from the Upper Pleistocene. Uranium–thorium (U–Th), thermoluminescence (TL) and optically stimulated luminescence (OSL) dating techniques carried out on the site indicated a broad temporal range between 81.5 ± 2.7 ky BP for SU XIII and 44.7 ± 3.2 ky BP for SU v. The first evidence of human occupation is found in stratigraphic unit XII, datable to 60.7 ± 8.9 ky BP (cf. Galván et al. 2014a, b).

Archaeological research at El Salt has been ongoing since 1986 and is geared at approaching human behavioural evolution in the Alcoian valleys from a multidisciplinary perspective. To this date, the resulting data have provided a diversity of geoarchaeological, palaeoanthropological, palaeoenvironmental, palaeodietary and palaeoeconomic information (cf. Fumanal 1994; Rodríguez et al. 2002; Galván et al. 2006; Dorta et al. 2010; Machado et al. 2011; Sistiaga et al. 2011, 2014; Mallol et al. 2012, 2013; Machado and Pérez 2015; Herrejón et al. 2016; Vidal 2016, 2017; Machado et al. 2017; Fagoaga et al. 2018, 2019; Vidal et al. 2018; Leierer et al. 2019; Pérez et al. 2020; Fagoaga 2020; Mayor et al. 2020; Rampelli et al. 2021; Marín et al. 2021).

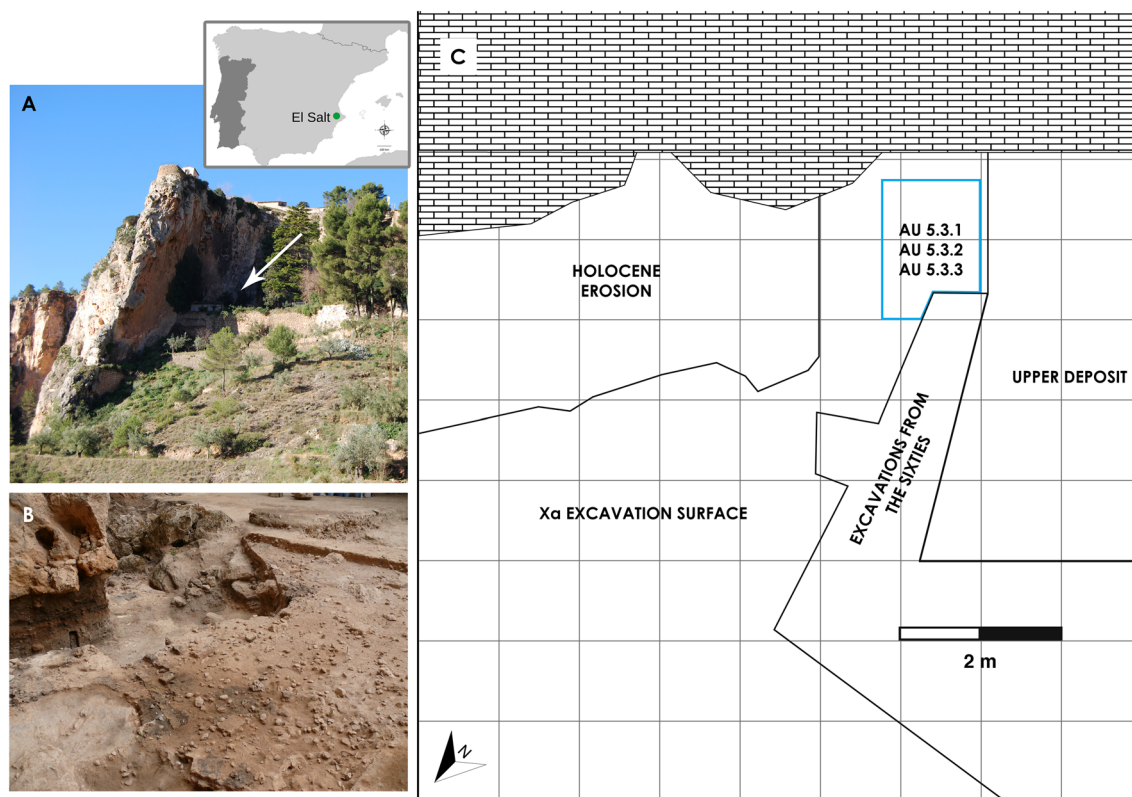


Fig. 1 **A** Location of El Salt. **B** Unit xa excavation surface. **C** Plan illustrating the horizontal position of the AUs

In recent years, research at El Salt has focused on SU xa, dated to 52.3 ± 4.6 ky BP (cf. Galván et al. 2014a, b). This unit is characterised by a rich and diverse archaeological record that includes lithic artefacts, faunal remains and well-preserved combustion structures. The SU xa lithic record comprises cores and both retouched and unretouched flakes manufactured using mainly the Levallois method (cf. Machado 2016; Mayor et al. 2020) on different available flint types: Serreta, Mariola, Beniaia and Font Roja (cf. Molina 2016; Machado 2016).

The SU xa faunal record suggests the exploitation of medium-sized mammals, mainly wild goat (i.e. *Capra pyrenaica*), deer (i.e. *Cervus elaphus*) and horse (i.e. *Equus ferus* and *Equus hydruntinus*). Archaeozoological data indicate hunting and subsistence activities (cf. Pérez 2019). Geoarchaeological data indicates that the SU xa hearths

were simple, flat and short-lived (cf. Mallol et al. 2013) and anthracological data point to pine (i.e. *Pinus nigra*) as the prevalent fuel choice (cf. Vidal 2017; Vidal et al. 2017).

Materials and methods

The materials selected for this study are integrated in AU 5.3, located near the travertine wall and whose archaeological record covers an area of approximately 2m^2 from the 36m^2 of the excavation surface (cf. Machado et al. 2017).

This AU was in turn dissected into 3 new AUs conceived as higher resolution analytical frames: 5.3.1, 5.3.2 and 5.3.3 (Table 1) from specific diachrony indicators relating to the three-dimensional position of raw material units, in addition to their relationship with the stratigraphic location of

Table 1 Raw material units (RMU), associated hearths and technological ascription of the 5.3.1, 5.3.2 and 5.3.3 lithic assemblages (cf. Mayor et al. 2020)

AUs	Involved hearths	N of RMUs	Involved RMUs	N of raw material types	Tech. ascription
5.3.1	H31	4	5.3_5, 13, 14, 16	3	RCL with non-L
5.3.2	H29	5	5.3_3, 4, 9, 15, 19	3	RCL
5.3.3	H32	13	5.3_1, 2, 6–8, 10–12, 17, 18, 20–22	5	RCL with non-L

hearths (*cf.* Mayor et al. 2020). These three new archaeostratigraphic units represent contexts that are singular, overlapped between them. Each of these AUs represents potential hearth-related assemblages that are closer to the human timescale and could also signify self-contained activity areas. For this reason, they are optimal frameworks to perform use-wear characterisation aiming to recognise diachronic Neanderthal behaviours.

In total, the three frames comprise 56 objects. Most of them are ascribed to the Levallois method. They are mainly flakes (43: 77%), 15 of which show recurrent centripetal Levallois production features. The remaining are 2 cores and fragments that have not been technologically ascribed. There is only one support that has been retouched as a transversal scraper. The predominant flint type is Serreta (i.e. 46.4%), followed by Mariola (i.e. 30.6%), Beniaia (i.e. 12.5%), Font Roja (i.e. 3.5%) and an undetermined type (i.e. 7%) (*cf.* Mayor et al. 2020). Regarding their dimensions, the lithic objects have been assigned to three different size classes: small (i.e. < 2 cm on its axis), medium (i.e. 2–3 cm) and large (i.e. > 3 cm).

Taking previous research as a reference (*cf.* Mayor et al. 2020), the technological ascription, raw material and measurements of the supports integrating each analytical frame are explained next:

Archaeostratigraphic unit 5.3.1

It includes 9 flakes and a fragment made of Serreta (i.e. 40%), Mariola (i.e. 40%) and Beniaia (i.e. 20%) flint types (Table 2).

Archaeostratigraphic unit 5.3.2

It involves 15 products, mainly flakes, but also a core and a fragment made of Serreta (i.e. 66.67%), Mariola (i.e. 13.33%) and Beniaia (i.e. 20%) flint types (Table 3).

Archaeostratigraphic unit 5.3.3

It includes 31 elements: 21 flakes, a transversal scraper, a core and 8 fragments made on Serreta (i.e. 38.7%), Mariola (i.e. 35.4%), Font Roja (i.e. 6.4%), Beniaia (i.e. 6.4%) and an undetermined flint type (i.e. 12.9%) (Table 4).

Functional analysis

Use-wear analysis has been carried out on 41 of the 56 objects (i.e. 73.2%). The remaining 15 objects have not been analysed due to either the presence of visible physical and chemical alteration or the absence of edges or regular, potentially usable platforms.

Use-wear analysis has been performed from two perspectives: functional and morphopotential. Regarding the functional perspective, we have analysed tool-use, kind of worked materials and kinds of performed actions. Analysis of potentially prehensile areas has also been carried out to detect possible signs of hafting. Functional inference was based on experimental data (see the “[Experimental programme](#)” section for further details) obtained from working different materials using the most relevant predominant flint type (i.e. Serreta). These data were compared and contrasted with other studies (*e.g.* Tringham et al. 1974; Hayden 1979; Keeley 1980; Anderson-Gerfaud 1981, 1990; Vaughan 1985; González & Ibáñez 1994; Gutiérrez 1996; Jardón 2000; Lemorini 2000; Rots 2011).

Regarding the morphopotential approach, we documented edge angles, measured in degrees, and morphologies (i.e. concave, straight, convex) to explore the relationship between shape and function (*e.g.* Venditti et al. 2019b).

Experimental programme

An experimental programme to ensure the reliability of traceological data was carried out using the Serreta flint type. The flakes were comparable in size to the

Table 2 Lithic assemblage belonging to the AU 5.3.1. Technological ascriptions, products, flint types and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.1	×6/31	Unipolar non-Levallois	Flake	Serreta	27×24×12
	×6.7/24	Unipolar non-Levallois	Flake	Serreta	41×6×5
	×5.6/278	RCL	Flake	Beniaia	35×31×8
	×5.6/279	RCL	Flake	Beniaia	15×19×2
	×5/1310	RCL	Flake	Mariola	22×21×5
	×5/1312	RCL	Flake	Mariola	21×17×3
	×5/1028	Undiagnosed	Cortical flake	Mariola	19×22×6
	×5/1313	Undiagnosed	Cortical flake	Mariola	27×25×9
	×4/810	Undiagnosed	Cortical flake	Serreta	30×18×6
	×5/14	Undiagnosed	Cortical fragment	Serreta	16×16×8

RCL means recurrent centripetal Levallois

Table 3 Lithic assemblage belonging to the AU 5.3.2. Technological ascriptions, products, flint types, and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.2	×4/758	RCL	Flake	Mariola	34×17×4
	×5/1322	RCL	Flake	Mariola	24×15×4
	×6/22	RCL	Flake	Serreta	16×16×2
	×5/1545	RCL	Flake	Serreta	17×21×4
	×5/1062	RCL	Flake	Serreta	30×20×2
	×4/781	RCL	Flake	Serreta	23×12×6
	×4/803	RCL	Flake	Serreta	26×9×2
	×5/12	Undiagnosed	Débordant flake	Beniaia	32×22×6
	×4/775	RCL	Flake	Beniaia	30×14×2
	×4/801	RCL	Flake	Beniaia	19×30×2
	×4/826	RCL	Cortical flake	Serreta	30×21×9
	×4/787	RCL	Flake	Serreta	37×25×10
	×4/782	RCL	Flake	Serreta	19×21×7
	×4/789	Recurrent centripetal	Core	Serreta	28×19×8
	×5/990	Undiagnosed	Cortical fragment	Serreta	24×14×9

RCL means recurrent centripetal Levallois

archaeological ones and they were produced replicating the hierarchised centripetal sequences observed in the archaeological record. We conducted mechanical (i.e. repeating a movement mechanically) and replicating (i.e. reproducing and completing an activity) experiments on animal (i.e. *Capreolus capreolus*) and woody matter (i.e. *Pinus nigra* and *Pinus halepensis*), as their remains are abundant at the site. We used the tools for variable amounts of time, from 20 min to over 2 h, depending on the action and the availability of the material to be worked upon (see supplementary information for further details).

Apart from this experimentation, we have conducted an experimental programme on splintered pieces (cf. Jardón et al. 2018), and on thermoaltered woodworking (cf. Bencomo & Jardón 2022).

Tool cleaning and microscopy

We washed the archaeological and experimental artefacts with lukewarm water and mild soap (Hygenia, Magnum Blue), and then with acetone in an ultrasonic bath (Meta-son 120, Struers) for a variable time (i.e. from 10 min to 1 h). For more persistent sediment adherences and concretions, we used acetic acid (5%). Acetone was also used to remove surface grease from recent handling.

Microscopic observation was carried out using a Leica Microsystems® M165C stereomicroscope at 3.65–60 magnifications, and two metallographic microscopes: Leica Microsystems® DM6000M and Zeiss Axio Scope A1, both at 50–500 magnifications.

Results

Our results indicate that around half of the examined artefacts (i.e. 48.78%) show evidence of use (Table 5). Tables 6, 7 and 8 show a summary of the functional data obtained by each AU.

Our data suggest that the tools were used for processing wood and animal tissue (i.e. butchery activity and skin).

The diagnostic features are:

- Regarding wood (fig. S1-S3), there is a slight development of edge rounding. The edges exhibit scars with an aligned organisation, but in some cases, it is superimposed. In general, they have a semicircular morphology and a feather, transverse or step termination. In terms of size, they are small or medium. The polish is bright, with a rough texture, which sometimes tends to be smooth directly on the edge, and the topography is domed, especially on the higher parts of the surface. None of the tools exhibits striations.
- Regarding the work performed on animal tissues (fig. S4-S6), we can distinguish between work on skin and processing of animal carcasses. The former shows scars with a small and medium size, with an aligned organisation (sometimes superimposed), semicircular morphology (sometimes irregular) and a feather or step termination and a well-developed rounding of the edge. The polish is dull with a rough texture and a domed topography in the higher and lower parts of the surface. For the animal carcasses, the tools present small and medium scars with an aligned organisation, a semicir-

Table 4 Lithic assemblage belonging to the AU 5.3.3. Technological ascriptions, products, flint types and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.3	×6/28	Kombewa	Flake	Serreta	21×6×4
	×6/8	Undiagnosed	Flake	Serreta	29×22×10
	×6.7/30	RCL	Flake	Serreta	34×17×5
	×5/1320	Undiagnosed	Fragment	Serreta	15×14×4
	×5/1309	Kombewa	Transversal scraper	Serreta	19×33×5
	×6/15	Kombewa	Flake	Serreta	17×15×3
	×5/1008	Undiagnosed	Flake	Font Roja	13×18×2
	×6.7/12	Unipolar non-Levallois	Flake	Font Roja	34×18×7
	×5/1316	Discoidal	Fragment	Mariola	18×17×3
	×5/1315	Discoidal	Flake	Mariola	27×26×11
	×5/1311	Discoidal	Cortical flake	Mariola	34×36×12
	×5/1553	Non-Levallois	Flake	Undet	27×43×8
	×5/1550	Non-Levallois	Flake	Undet	20×8×6
	×5/1019	RCL	Flake	Mariola	35×50×10
	×5/1025	RCL	Flake	Mariola	15×14×3
	×6/7	RCL	Flake	Serreta	15×22×3
	×5.6/208	RCL	Flake	Serreta	13×15×6
	×5/1024	RCL	Flake	Serreta	15×20×3
	×5/13	RCL	Flake	Serreta	15×22×6
	×5/352	Undiagnosed	Fragment	Beniaia	13×28×7
	×5/1502	Undiagnosed	Fragment	Beniaia	26×43×10
	×6/24	Undiagnosed	Fragment	Mariola	18×12×4
	×5/1547	Undiagnosed	Flake	Mariola	6×15×8
	×4/811	Undiagnosed	Flake	Mariola	31×18×4
	×5/976	Undiagnosed	Flake	Mariola	20×15×5
	×4/764	Undiagnosed	Flake	Mariola	34×24×6
	×4/780	Undiagnosed	Core	Mariola	30×37×27
	×4/607	Undiagnosed	Fragment	Serreta	43×22×13
	×4/614	Undiagnosed	Flake	Serreta	21×14×6
	×6.7/176	Undiagnosed	Fragment	Undet	24×16×8
	×6.7/176	Undiagnosed	Fragment	Undet	18×16×4

RCL means recurrent centripetal Levallois

Table 5 List of tools exhibiting microscopic use-wear

AUs	Total number of tools	Tools views under the microscope	Tools exhibiting use wear
5.3.1	10	9	3
5.3.2	15	13	8
5.3.3	31	19	9

cular morphology and a feather or transverse termination. The polish is fluid (follows the relief without affecting it), the topography is domed and the contour tends to be fuzzy. In some cases, there are large scars with step termination associated with well-developed polished in the highest parts of the topography which means that there was contact with hard material (e.g. cartilage, bone).

Table 6 Use-wear data in AU 5.3.1

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
x6/31	Pentagonal	Straight	60°	Wood	Scraping
		Straight	45°	Wood	Scraping
x6.7/24	Rectangular	Convex	45°	Wood	Scraping
x5.6/278	Heptagonal	Convex	30°	Wood	Undiagnosed

Table 7 Use-wear data in AU 5.3.2

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
× 4/826	Quadrangular	Concave	55°	Meat and skin	Cutting
× 4/781	Rectangular	Straight	20°	Wood	Cutting
× 5/1322	Rectangular	Convex	35°	Dry skin	Cutting
× 5/1545	Rectangular	Straight	30°	Wood	Cutting
× 4/758	Rectangular	Convex	35°	Wood	Scraping
× 5/1062	Rectangular	Concave	30°	Wood	Cutting
× 4/775	Irregular	Convex	30°	Skin, meat in contact with hard material (cartilage, bone...)	Cutting
× 4/787	Irregular	Concave-convex	40°	Dry skin	Cutting

Table 8 Use-wear data in AU 5.3.3

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
x5/1315	Triangular	Straight	40°	Dry skin	Cutting
x6/28	Rectangular	Straight	40°	Dry skin	Scraping
x5/1502	Rectangular	Straight	55°	Meat and hard material (bone, cartilage)	Cutting
x6.7/30	Irregular	Straight	55°	Meat, skin and hard material (bone, cartilage)	Cutting
x5/1311	Quadrangular	Straight	50°	Hard material (bone?)	Percussion
x5/1309	Triangular	Straight	35°	Meat and skin	Cutting
		Straight	70°	Dry skin	Cutting
x6/15	Pentagonal	Convex	45°	Meat and skin	Cutting
x5/1024	Rectangular	Straight	35°	Dry skin	Scraping
x5/13	Rectangular	Convex	35°	Meat and skin	Cutting

Regarding the actions that can be deduced from our analysis, they are cutting (longitudinal movement) and scraping (transversal movement). The distribution of the polish, scars and striations on both sides of a piece suggests a longitudinal action, while the distribution of the polish and striations on one side, and the scars on the other, allows us to speak of a transversal action. On the other hand, the orientation of the traces of use, especially the striations (parallel or perpendicular to the edge) and the scars (perpendicular or oblique) also indicates the type of motion.

As for the morphopotential data, they revealed the following pattern: large and medium-sized flakes with straight or convex edges, with angles mainly between 30 and 45°, were used for woodworking, and large or medium-sized flakes with straight edges and angles between 35 and 55° were used for animal tissue processing.

This is a detailed account of the functional results from each analytical frame:

Archaeostratigraphic unit 5.3.1

Four edges in three lithic tools (i.e. 33.33%) revealed use-wear traces of woodworking mainly in scraping actions (Table 6, Figs. 2, and 3).

Archaeostratigraphic unit 5.3.2

Eight lithic tools (i.e. 61.5%) revealed use-wear traces of woodworking mainly in cutting actions, and animal tissue, both butchery and skin, in cutting actions (Table 7, Figs. 4, 5, 6, and 7).

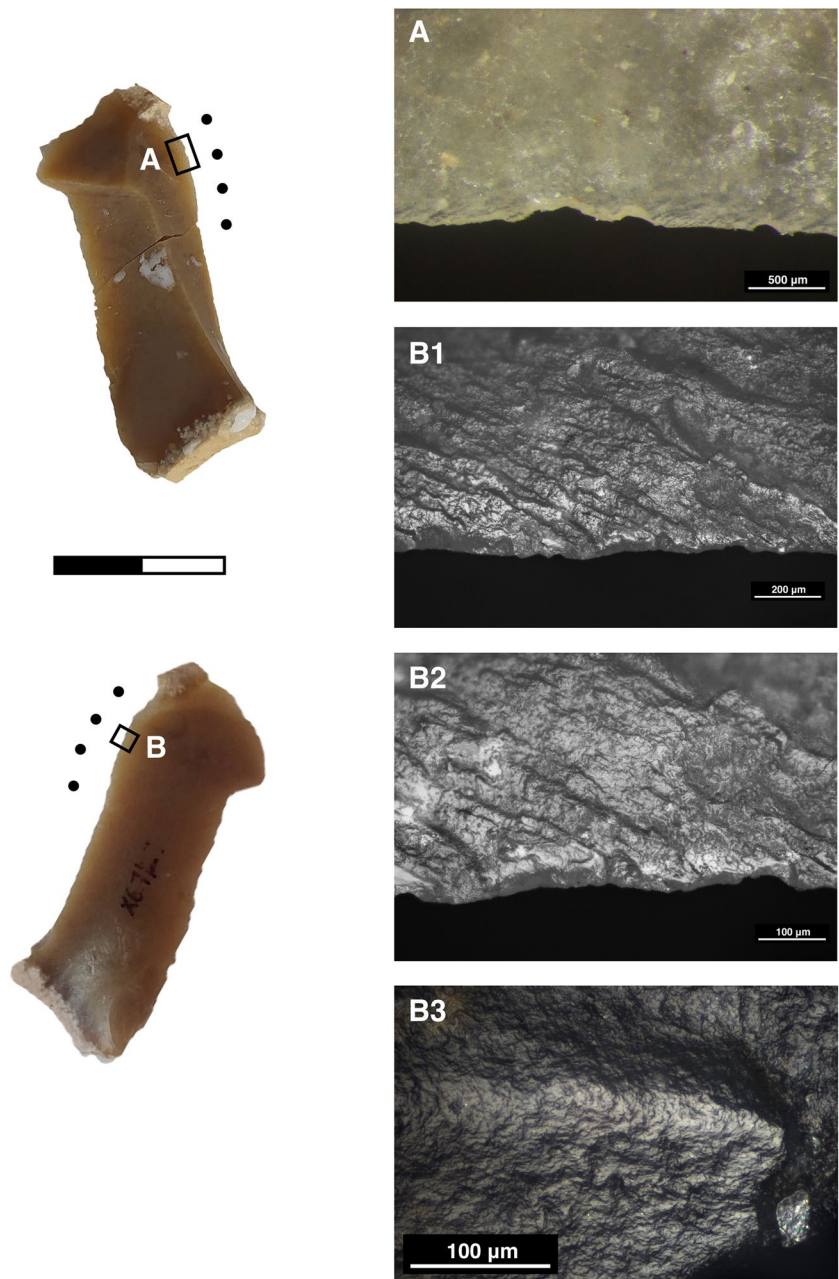
Archaeostratigraphic unit 5.3.3

Ten edges in nine lithic tools (i.e. 47.3%) revealed use-wear traces of animal tissue, related to butchery activities as well as skin processing, with cutting and scraping actions (Table 8, Figs. 8, and 9).

Discussion

Our use-wear analysis has provided information about the kind of activities that were carried out in the frame of three spatially delimited, superimposed high temporal resolution AUs (Fig. 1). According to the functional analysis, we can infer that the tools were employed in a variety of activities

Fig. 2 Tool x6.7/24 with wood-working traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **B** Well-developed and bright polish on the ventral surface, especially on the higher parts, with a rough texture, which tends to be smooth directly on the edge, a domed topography and a development of edge rounding at 100, 200 and 500 $\times$. The black dots represent the area with use-wear traces and the black square represents the area depicted. The same markers are valid for the rest of the figures



across time: AU 5.3.1 shows evidence of woodworking, 5.3.2 displays traces of work on animal tissue and wood, and 5.3.3 exhibits evidence of animal tissue processing.

The preservation state of the analysed tools is acceptable, as well as the rate of tools showing evidence of use (i.e. 5.3.1: 30%; 5.3.2: 53%; 5.3.3: 29%). However, some elements did not present suitable features to be functionally analysed, since they either have a scarce morphopotentiality, or display physicochemical alterations, with variable numbers between each AU. These alterations are mainly due to fire action.

The fact that almost all the elements with use-wear traces are unretouched flakes highlights the multifunctional

characteristics of this kind of product. In the AU 5.3.2, in which tools were used for woodworking and butchering, it is observed a preference for the utilisation of recurrent centripetal Levallois modalities. This remarks the suitability of this knapping strategy to make products with multiple potentially active edges.

Another significant aspect is the fact that two tools with use-wear traces (i.e. x6/15 and x5/1024) are small-sized flakes. Our data join a growing number of Neanderthal contexts with small-sized used tools (e.g. Lazuén & González 2014; Lazuén & Delagnes 2014; Hortelano 2016; Borel et al. 2017).

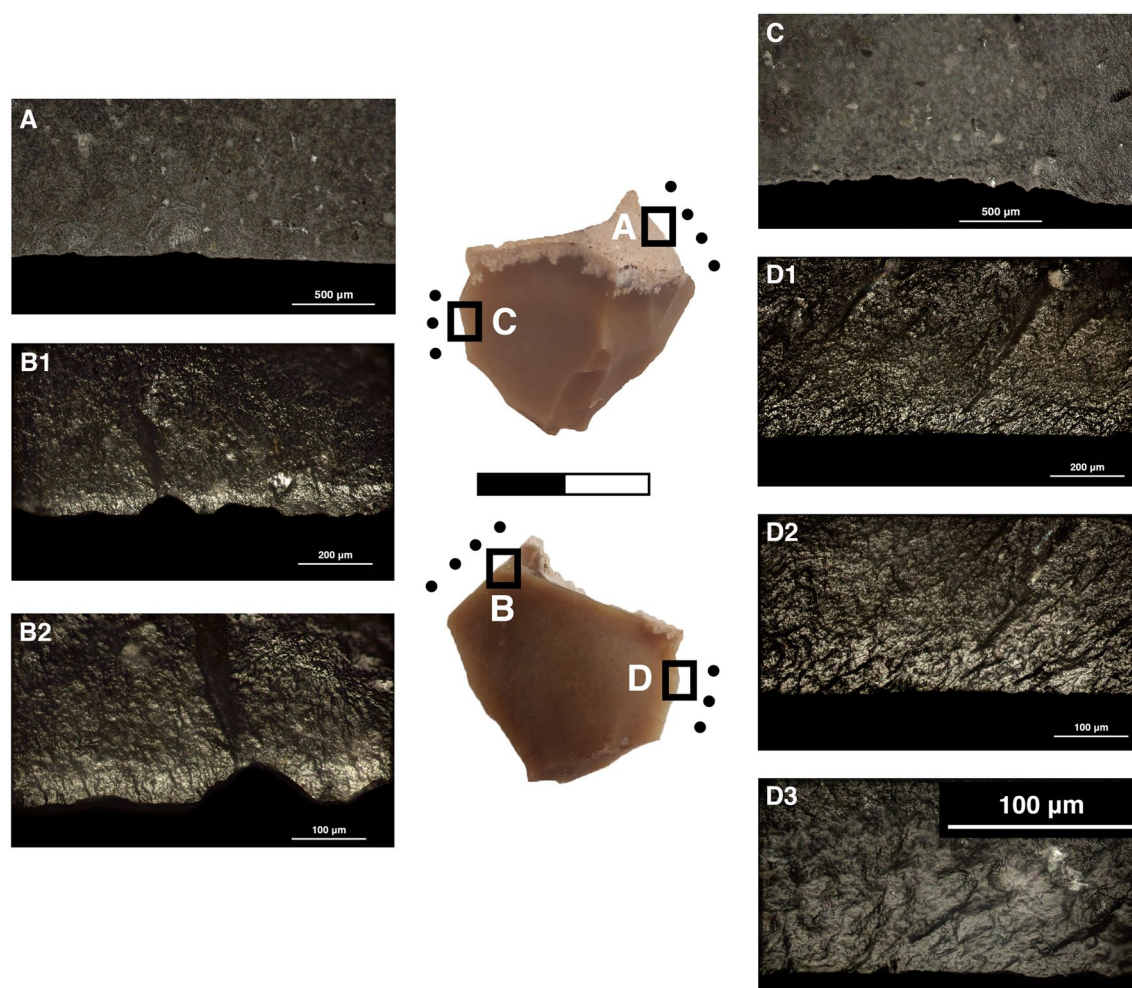


Fig. 3 Tool x6/31 with woodworking traces in a scraping action. **(A)** Small and medium-sized scars on the dorsal surface with an aligned organisation, in some cases superimposed, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **(B)** Bright polish on the ventral surface with a rough texture and a domed topography at 100, 200 $\times$. **(C)** Small scars on the dorsal surface with

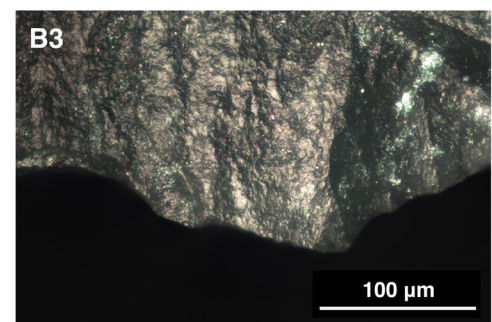
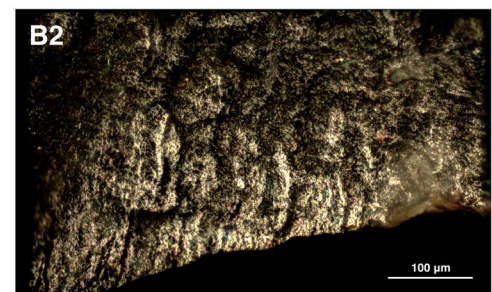
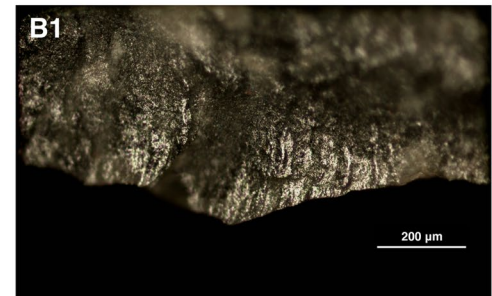
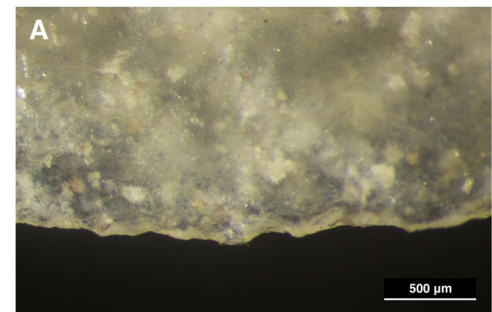
an aligned organisation, a semicircular morphology, feather or transverse termination and perpendicular orientation at 50 $\times$. **(D)** Bright polish on the ventral surface with a rough texture and a domed topography, especially on the higher parts of the surface at 100, 200 and 500 $\times$

Through comparison with experimental tools (*vid.* Supplementary information), we can observe a low development of use-wear traces, from which we deduce that the tools were used during a short lapse of time or for low-intensity purposes, or both. The absence of superposition of possible use-wear traces showing work on different materials brings to the same conclusion. There are only two cases in which more than one edge has been used (Fig. 3). In the same way, the predominant use of unretouched edges, alongside the presence of a single retouched tool with use-wear traces, leads us to deduce that the tools were exclusively used for the above-mentioned activities with no need of resharpening. The absence of clear use-wear traces on thermally altered elements is in the same vein. If polishes were well developed, they could be identified in spite of thermal

alteration (*cf.* Clemente 1997), but this is not our case. Taking all this into consideration, we may conclude that the tasks performed in these activity areas were neither intense nor long-spanned.

As for the prehensile parts of the tools, there is no evidence of them having undergone hafting processes, even if we can not rule out the possibility that no use-wear has been recorded, or traces of another kind of manipulation. Still, it is significant that the totality of the tools, including small-sized ones, can be held by hand. Hafting in Neanderthal contexts has been previously documented (*e.g.* Beyries 1987; Mazza et al. 2006; Rots 2011, 2013, 2014, 2016; Rots et al. 2015; Degano et al. 2019; Niekus et al. 2019). According to Rots (2014, 2016), hafted tools may show an explicit need responding to the recurrency for which a

Fig. 4 Tool x4/758 with wood-working traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **B** Bright polish on the ventral surface with a rough texture and a domed topography especially on the higher parts of the surface at 100, 200 and 500 $\times$



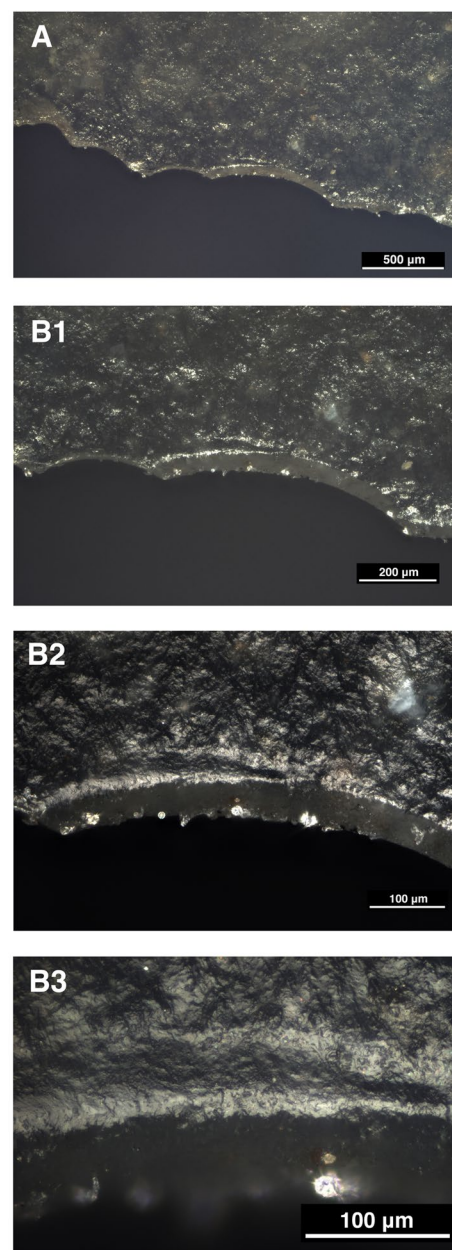
task was performed. The absence of hafting observed in our analysis supports our hypothesis of the low-intensity and short-spanned use of the tools.

Characterising activity areas through functional analysis

Thanks to the functional results obtained through the analysis of the three AUs, we have been able to examine the tasks carried out in each case. As for woodworking, two processes were identified in the AUs 5.3.1 and 5.3.2: cutting and scraping. This enables us to deduce that both frames are related to the processing of woody material. These actions

can be associated with different kinds of activities, such as fuel processing, for which there is much evidence in El Salt (*cf.* Vidal), or even the production of tools. In regards to this, there is a great number of functional studies applied to Neanderthal material collections that evidence woodworking (*e.g.* Beyries 1987; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lasuén & González 2014; Hortelano 2016). In addition, some woody remains in Schöningen (Germany) (*cf.* Thieme 1997), Arambaltza III (Spain) (*cf.* Ríos et al. 2018) or Poggetti Vecchi (Italy) (*cf.* Aranguren et al. 2018) show work traces or even vegetal fibres, as in the case of the remains found in Abri du Maras (France) (*cf.* Hardy et al. 2013, 2020). In the case

Fig. 5 Tool x5/1062 with woodworking traces in a cutting action. **(A)** Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, transverse termination and oblique orientation at 50 $\times$. **(B)** Well-developed polish on the ventral surface with a rough texture, which tends to be smooth, a domed topography, which tends to be flat directly on the edge, and a development of edge rounding at 100, 200 and 500 $\times$



of El Salt, the presence of minor woody taxa being suitable for toolmaking has made possible to suggest their use to that end (cf. Vidal et al. 2018).

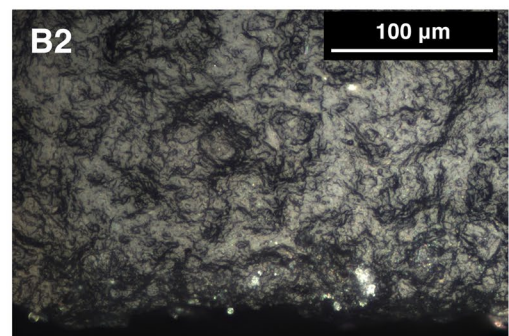
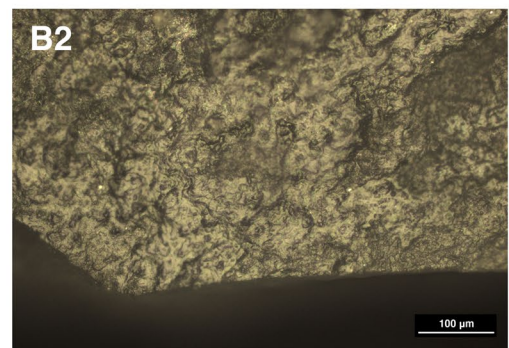
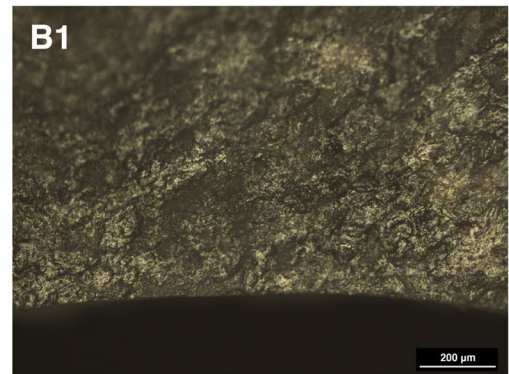
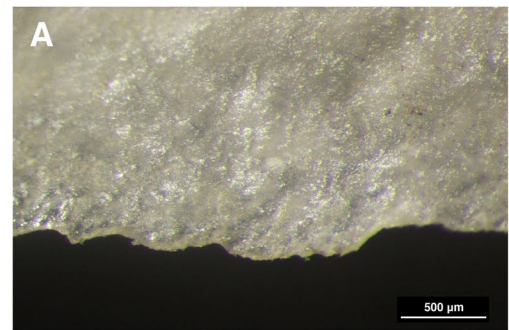
We can also observe different use-wear traces regarding the processing of animal tissues. Prior to the AU 5.3 dissection (cf. Mayor et al. 2020), the archaeozoological investigations also had certified butchering activities in the faunal assemblage (cf. Pérez 2019; Pérez et al. 2020): four specimens ascribed to the *Caprinae* subfamily, four to the *Equidae* family and two to the *Cervidae* family show evidence of activities like skinning, periosteum removal and quartering of preys. These cut marks are very superficial, concurring with the slightly developed use-wear traces

on lithic tools. This allows us to propose the association between the faunal record with cut marks and the lithic record with butchering traces. Taking into account that our functional results ascribe the butchering activity to two of the three events of AU 5.3 (i.e. 5.3.2 and 5.3.3), we suggest the link between the archaeozoological record and these frameworks.

Use-wear analysis applied in high temporal resolution frames

In the Mediterranean Iberian Neanderthal sites, we can observe that woodworking and prey processing were frequent

Fig. 6 Tool $\times 4/775$ with butchering activity traces in a cutting action. **(A)** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, transverse termination and an oblique orientation at $50\times$. **(B)** Dull polish on the dorsal surface with a fluid texture, a domed topography and a fuzzy contour at 100, 200 and $500\times$

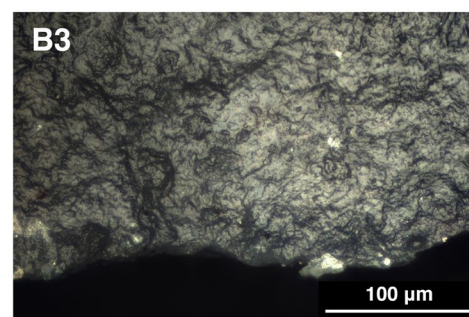
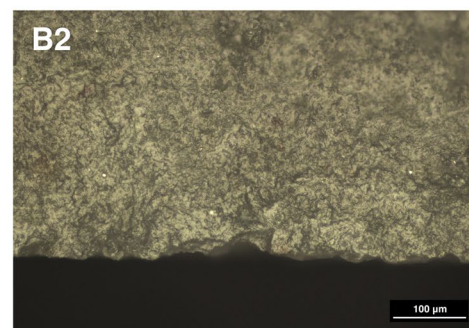
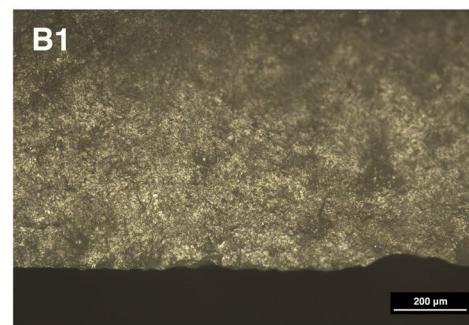
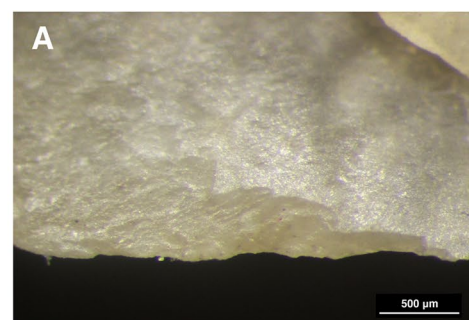


during the Middle Palaeolithic (*cf.* Moriel 1985; Rodríguez et al. 2002; Martínez 2005; Galván et al. 2008; Eixea et al. 2015; Hortelano 2016; Martín-Viveros et al. 2020).

Nevertheless, these studies utilised coarse-time and thus less suitable analytical frameworks to understand human behavioural variability across time.

To date, we only relied on two research works that analysed the function of the lithic tools forming part of a high temporal resolution assemblage. The number of lithic remains comprised in our AUs is along the same lines as that from the Grotta dei Santi 150A unit (n116; *cf.* Spagnolo et al. 2020), or that from the Abric del Pastor AU ivfH17

Fig. 7 Tool x4/787 with dry skin traces in a cutting action. **(A)** Small and medium-sized scars on the ventral surface with an aligned or superimposed organisation, a semicircular or irregular morphology, a feather and step termination and an oblique orientation at 50 $\times$. **(B)** Dull polish on the ventral surface, with a rough texture and a domed topography in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500 $\times$



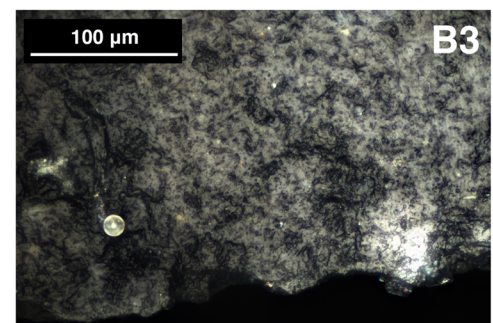
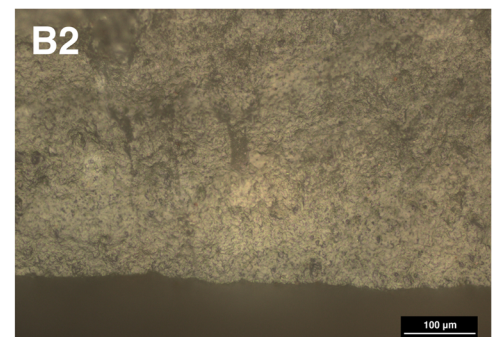
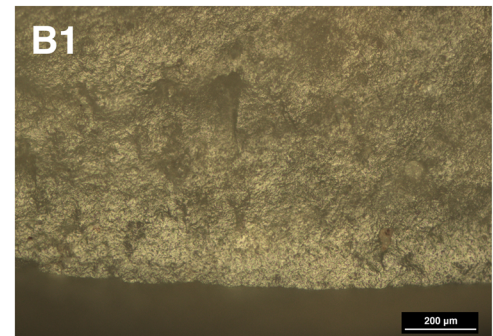
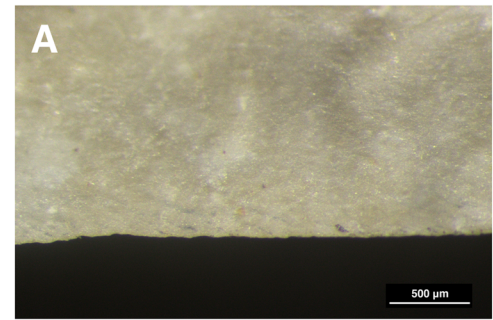
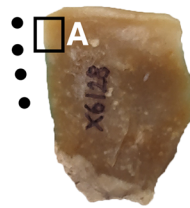
(n11; *cf.* Sossa-Ríos et al. 2022). In all cases, the assemblages are very close to human temporality and the number of remains, even if it could seem scarce, could be explained by the activities performed by the Neanderthal groups.

Furthermore, the results of these studies reflect the exclusive performance of butchering activity, which is analogous to that described for the El Salt AU 5.3.3. This brings out the singular character of tasks carried out not only in determinate activity areas, like this case and that

of Spagnolo et al. (2020), but also in frames representing human single occupations (*cf.* Sossa-Ríos et al. 2022).

In our case, not one but three successive high-resolution AUs have allowed us to read different functional dynamics. These reflect variations of the activities developed in a determinate space of the site across a narrow timescale. It could be indicating diachronic changes in the spatial management, as a proper way to explore human behavioural variability.

Fig. 8 Tool x6/28 with dry skin traces in a scraping action. **(A)** Small scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather termination and perpendicular orientation at 50 $\times$. **(B)** Dull polish on the dorsal surface, with a rough texture and a domed topography, in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500 $\times$



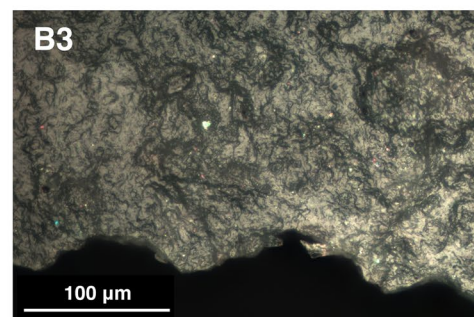
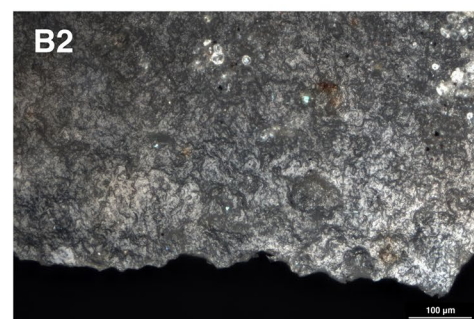
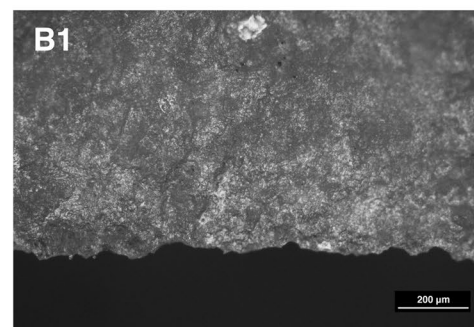
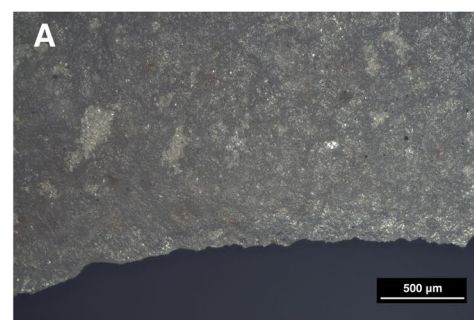
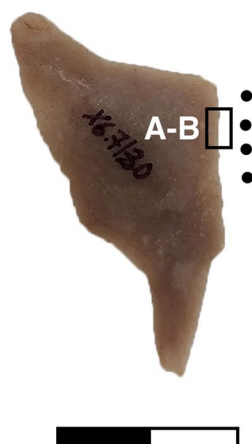
Conclusions

The use-wear analysis applied to the lithic record from three diachronic AUs has allowed us to recognise particular activities performed in different moments: woodworking in 5.3.1, butchering and woodworking in 5.3.2 and butchering in 5.3.3. These results highlight two relevant

issues for analysing the Neanderthal behaviour and its variability:

1. The functional analysis offers determinate temporal markers that can be associated with short-spanned events: the low development of use-wear traces, as well as the absence of superposition of use-wear traces,

Fig. 9 Tool x6.7/30 with butchering activity traces in a cutting action. **(A)** Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather or transverse termination and oblique orientation at 50 $\times$. **(B)** Dull polish on the ventral surface, with a fluid texture and a domed topography, a fuzzy contour and associated with well-developed spots of polish at 100, 200 and 500 $\times$



resharpening or hafting marks. These indicators are common in the three AUs and show a pattern held across time, regardless of the activities represented within each.

2. By means of the high-resolution contexts studied here, we leave behind a scenario derived from functional studies focusing on the SU as a framework, in which Neanderthals performed simultaneously the same tasks (i.e. woodworking, butchering and skinning). With this work,

we evidence a different scenario, in which we observe a dynamic and changeable behaviour: events revealing a lesser variety of activities (i.e. 5.3.1, 5.3.3) in contrast to another one in which the tasks are more diverse (i.e. 5.3.2).

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Declarations

Conflict of interest The authors declare no competing interests.

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Conclusions

Throughout this PhD, the use-wear analysis of 231 artifacts from UE Xa of El Salt has been conducted, integrated within stratigraphic contexts that represent the highest possible temporal resolution for each case. If we evaluate the functional results considering the artifacts as a whole within the framework of stratigraphic unit Xa, the data lead us to recognize a diversity of activities, particularly related to butchery, hide processing, and woodworking, predominantly performed with unmodified flakes. This overview provides us with an image of a site where Neanderthal hunter-gatherer groups engaged in a multitude of activities. Therefore, it is characterized as a multifunctional site where human groups combined different tasks within the same spatiotemporal context. This interpretation is in line with many functional studies conducted to date, focused on the Middle Paleolithic. The similarity of these results is likely due to the fact that most of these functional studies select the stratigraphic unit as the analytical framework, whose temporal significance can encompass an indefinite amount of time, even millennia. Thus, by analyzing tools integrated within stratigraphic units, we would be assessing the activities performed by an indeterminate number of human groups, likely without any direct relationship between them.

In the case of SU Xa of El Salt, we have attempted to dissect this palimpsest, identifying areas of activity that approximate the human temporal scale. Each of these high-resolution frameworks corresponds to a series of specific actions and materials, revealing differences in productive processes that would otherwise go unnoticed.

Our functional results have revealed the existence of specific areas within the site where various activities took place, as well as the organization of specific practices within these areas during different occupations. For example, in AU 3.2.1, tasks involving animal materials and wood processing were carried out, while in AU 4.1.2, only wood processing is documented, and in 4.1.1, it appears that only animal materials were worked. These results demonstrate that Neanderthal groups conducted different activities in each of these areas over time, allowing us to recognize a certain diachronic variability in human behavior, regarding the use of spaces and the development of work processes within defined temporal ranges.

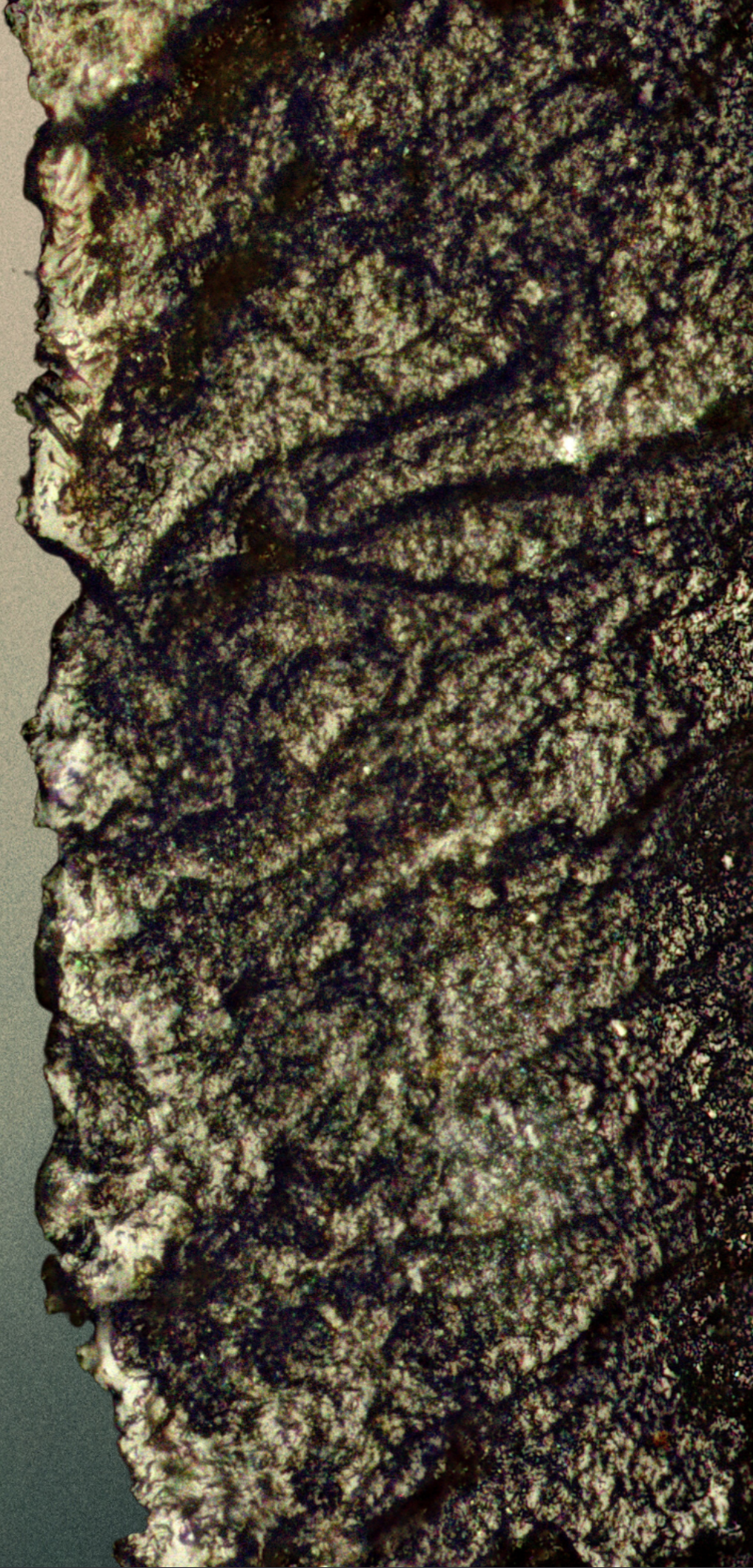
In addition to these general observations, the use of high-resolution analytical frameworks has allowed us to highlight the significance of small-sized tools, primarily associated with butchery actions. Although their presence is minority when considering the total set of analysed artifacts, their role becomes clearer when integrated within high-resolution

contexts. The same applies to products considered as transported elements, forming part of the equipment carried by these human groups. Differences in function and morphopotentiality have been observed compared to pieces integrated within the larger tool assemblage that was likely knapped in situ and used within the settlement itself. These transported pieces have a narrower functional spectrum, being primarily involved in actions related to animal materials, and they exhibit greater morphopotentiality in terms of dimensions, making them more manageable.

These approaches significantly enhance the possibilities of integrating the archaeological record. An evident case is the correlation we have established between lithic tools with butchery traces and the faunal record that presents anthropic marks associated with their processing. Although it has been explained that the temporal resolution of the frameworks to which the faunal assemblage is attributed is lower, it still serves as a research avenue for correlating archaeological materials that, from the perspective of human activity, possess certain characteristics allowing for their association.

On the other hand, considering the low intensity of use-wear observed on the archaeological material (limited development of use-wear traces, absence of overlapping, and absence of resharpening), our results seem to align with the interpretation of short-duration occupations at El Salt. In this sense, the events dissected at this site are characterized by scarce lithic material, fragmented operational sequences, and association with a hearth, following the *hearth-related assemblage* model. Furthermore, through the study of hearths, prolonged time lapses between combustion structures and the absence of reignition have been observed. All of this indicates that these events must have been of short duration, which is consistent with our functional results.

La traceología aplicada a la
disección de palimpsestos:
**variabilidad funcional en el
yacimiento de El Salt (Alcoi)**



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A mis abuelos, Marcelle y Marc, y a mi futuro sobrino, Daniel

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Resumen

En esta Tesis Doctoral se presenta el estudio traceológico de un conjunto lítico de sílex correspondiente a la unidad estratigráfica Xa del yacimiento de Paleolítico medio de El Salt (Alcoy, Alicante). El conjunto ha sido asociado a distintas unidades arqueostratigráficas de análisis producto de la disección del palimpsesto y caracterizadas, consecuentemente, por una mayor resolución temporal. Los resultados de este estudio nos han permitido identificar y describir variaciones en las actividades llevadas a cabo por los distintos grupos neandertales que ocuparon el abrigo a lo largo del proceso de formación de la UE Xa, ya que cada uno de los marcos de análisis seleccionados, representan áreas de actividad, diacrónicas entre sí. Así, hemos reconocido áreas en las que se llevaron a cabo actividades productivas relacionadas con el trabajo de la madera y el procesado de animales, frente a otros momentos en el que, en las mismas zonas, tanto se gestionó de manera exclusiva, un tipo de material concreto (por ejemplo, madera). Por otro lado, la contextualización de los datos funcionales en estos marcos acotados temporalmente ha permitido también valorar aspectos ligados a las características tecnofuncionales del instrumental lítico y a la relación entre el uso de las piezas y los patrones de movilidad y gestión de las materias primas. Además de ello, una parte importante de esta Tesis Doctoral también ha versado en torno a un programa experimental sobre las huellas de uso generadas por la madera termoalterada, obteniendo resultados inéditos que permiten diferenciar traceológicamente este tipo de materia con respecto a la madera verde o seca.

Abstract

This PhD dissertation presents the use-wear analysis of a flint lithic assemblage from the stratigraphic unit Xa of the Middle Paleolithic site of El Salt (Alcoy, Alicante). The assemblage has been associated with different archaeostratigraphic units resulting from the dissection of the palimpsest and characterized accordingly by higher temporal resolution. The results of this study have allowed us to identify and describe variations in the activities carried out by different Neanderthal groups that occupied the shelter throughout the formation process of the Xa unit, as each selected analytical framework represents distinct areas of activity that are diachronic with each other. Thus, we have recognized areas where productive activities related to wood working and animal processing took place, compared

to other moments in which, in the same areas, only a specific type of material was managed exclusively (e.g. wood). Furthermore, contextualizing the functional data within these temporally constrained frameworks has also allowed us to assess aspects related to the techno-functional characteristics of the lithic tools and the relationship between tool use, mobility patterns, and raw material management. In addition, a significant part of this PhD has also focused on an experimental program on the use-wear traces generated by heat-treated wood, yielding unprecedented results that allow for the traceological differentiation of this type of material from green or dry wood.

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1. Introducción y objetivos

El centro de interés de esta Tesis Doctoral ha radicado en profundizar en el comportamiento tecnoeconómico de los grupos neandertales a través del análisis traceológico aplicado tanto a material arqueológico como experimental. En el plano arqueológico, se han analizado un total de 231 piezas del yacimiento de El Salt. Este conjunto, que pertenece a la UE Xa, ha sido integrado en unidades arqueostratigráficas de alta resolución temporal. En este sentido, una de las aportaciones que pretendemos con este trabajo es conocer el potencial del análisis funcional aplicado a conjuntos líticos que forman parte de eventos próximos a la escala humana, para poder analizar así la variabilidad del comportamiento humano. Cabe mencionar que, de manera general, los estudios funcionales emplean la unidad estratigráfica como contextos de análisis, sumando de esta forma conjuntos de materiales que seguramente pertenecieron a distintos grupos humanos que fueron ocupando los yacimientos durante periodos de tiempo muy largos. En este sentido, la resolución temporal es uno de los grandes retos de la arqueología paleolítica en la actualidad, pues constituye una vía propicia para responder a preguntas fundamentales sobre el comportamiento neandertal de una forma más detallada. Las unidades analíticas que estudiamos en esta Tesis representan áreas de actividad diacrónicas cuyo registro, podría reflejar, la variabilidad del comportamiento a lo largo del tiempo. Para este estudio se han seleccionado soportes que se integra en unidades de materias primas de conjunto, interpretadas como piezas talladas y utilizadas *in situ*, y soportes singulares, interpretados como piezas móviles, lo que nos permite obtener una visión global sobre el tipo de actividades que desarrollaban tanto en el yacimiento como en sus desplazamientos. Por ello, los objetivos propuestos han sido:

1. Analizar traceológicamente los soportes integrados en unidades de materia prima de conjunto de cada uno de los marcos analíticos seleccionados, para así reconocer el tipo de materias y acciones realizadas en estas áreas de actividad próximas a la escala humana.

2. Realizar una comparación entre los resultados traceológicos de cada uno de esos marcos, con la finalidad de observar la variabilidad diacrónica del comportamiento

3. Comparar la funcionalidad y morfopotencialidad entre los soportes integrados en unidades de materia prima de conjunto y las piezas singulares, para tratar de reconocer patrones de comportamiento relacionados con la movilidad de las poblaciones neandertales.

Por lo que respecta al programa experimental, se ha tratado de dar respuesta al tipo de estigmas generados por el trabajo sobre madera termoalterada. En este sentido, son significativos los restos de madera conservados durante el Paleolítico que registran marcas de raspado.

Esta Tesis se realiza por la modalidad de compendio de artículos, por ello algunos de los resultados de esta Tesis Doctoral se han publicado en revistas internacionales de impacto, aunque también se presenta el estudio y análisis de material inédito. El primero de los trabajos lleva por título: *Understanding woodworking in Paleolithic times by means of use-wear analysis* y ha sido publicado en el *Journal of Archaeological Science: Reports*. Está integrado en el capítulo del estado de la cuestión ya que se trata de una recopilación de los análisis traceológicos publicados hasta la fecha sobre el trabajo de la madera en el Paleolítico medio y superior, para así obtener una visión general relativa a los soportes utilizados y acciones realizadas en torno a esta materia. El segundo artículo, titulado *Using Fire for Woodworking: An Experimental Exploration of Use-Wear on Lithic Tools*, publicado en *Lithic Technology*, se presenta en el apartado de material y métodos. En él se desarrolla un programa experimental que trata de reconocer huellas de uso propias del trabajo sobre madera termoalterada con respecto a la madera verde o seca. Los resultados muestran diferencias significativas, lo que indica que sería posible reconocer signos de trabajo sobre madera termoalterada en los útiles líticos arqueológicos y, por tanto, comprender mejor los procesos de trabajo de las poblaciones del pasado. Finalmente, el último artículo, titulado *Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale*, publicado en *Archaeological and Anthropological Sciences*, se integra en el apartado de resultados. A través de este estudio se analizó traceológicamente material perteneciente a 3 marcos analíticos de alta resolución temporal (*i.e.* 5.3.1, 5.3.2 y 5.3.3) del yacimiento de El Salt. Los resultados obtenidos pusieron de manifiesto la realización de diferentes tareas dentro de cada marco analítico: trabajo de la madera en la unidad arqueostratigráfica (UA) 5.3.1, trabajo de la madera y procesamiento de animales en la UA 5.3.2, y actividad carnicera en la UA 5.3.3. Estos resultados reflejan la existencia de una serie de tareas diacrónicas realizadas en áreas de actividad que se solapan. De este modo, este trabajo evidencia la variabilidad del uso del sílex en una zona concreta del yacimiento a lo largo del tiempo que sólo podría haberse reconocido mediante marcos analíticos de alta resolución temporal.

2. Estado de la cuestión

2.1. La traceología: breve recorrido desde sus comienzos

El siglo XIX conoció el nacimiento efectivo de la traceología como disciplina propia de los estudios sobre Prehistoria, gracias a un interés creciente por comparar útiles arqueológicos y etnográficos (*e.g.* Evans, 1872; Lubbock, 1865; Nilsson, 1868). Sin embargo, el intento por sistematizar las huellas de uso nace propiamente en la década de 1930, cuando S.A. Semenov, considerado el padre de la disciplina traceológica, escribió sus primeros trabajos en torno a las huellas de uso registradas en el material arqueológico, demostrando que objetos fabricados a partir de diversas materias primas (por ejemplo, sílex, obsidiana, hueso, madera, concha, metal) podían presentar huellas diagnósticas sobre su uso. A partir de sus resultados, comenzaron a proliferar los estudios funcionales, tanto experimentales como arqueológicas. Sin embargo, hubo que esperar hasta 1964, año en el que se tradujo su obra *Prehistoric Technology*, para que sus ideas tuvieran un verdadero impacto en el mundo occidental. Al mismo tiempo, durante esta época, los estudios tipológicos trataron también de determinar la función de las herramientas a partir de la morfología de las piezas (*e.g.* Bordes, 1968, Oakley, 1968; Watson, 1968). Sin embargo, desde el comienzo de la traceología como disciplina, se demostró que la función de una herramienta no podía determinarse simplemente a partir de las formas de los utensilios. Por otro lado, se continuó con la comparación entre las herramientas etnográficas y los artefactos arqueológicos para tratar de explicar cómo pudieron utilizarse las herramientas en el pasado (*e.g.* Gould *et al.*, 1971). Estas inferencias también plantearon problemas. Por ejemplo, los relativos al uso de ciertos términos funcionales basados en la morfología de las herramientas, como el de raspado. Estos conceptos de orientación semántica funcional introducían un componente interpretativo al dato descriptivo que, a menudo, no se correspondía con la realidad.

Con todo, la proliferación de los estudios traceológicos, coincidiendo con la etapa de desarrollo de la Nueva Arqueología, supuso una cierta ruptura con las tendencias anteriores. Fue un salto metodológico y técnico en aras de conseguir que la arqueología fuese una ciencia que pudiese interpretar el registro arqueológico como resultado del comportamiento humano. Durante esta etapa se fueron generando nuevas interpretaciones de carácter funcionalista, dejando a un lado las explicaciones culturalistas que entendían la producción de determinados tipos de útiles como el reflejo de una tradición cultural. Al hilo de esto, la perspectiva funcional en el estudio de las producciones líticas neandertales ha tenido una importancia fundamental, desde el clásico debate entre

Binford y Bordes sobre el sentido de las facies musterienses descritas por el segundo, hasta la actualidad en la que se han superado aquellos viejos planteamientos. En este sentido, la tipología de F. Bordes permitió definir las “facies musterienses” entendidas como derivados de un acervo cultural. De esta forma, cada una de estas facies representaba una cultura diferente, como por ejemplo el Musteriense Típico, el Musteriense de Tradición Achelense o el Musteriense de Denticulados. Frente a esta visión culturalista, L. R. Binford, uno de los máximos exponentes de la Nueva Arqueología, a partir de su obra *In Pursuit of the Past: Decoding the Archaeological Record* (1983), propuso que las diferencias entre facies musterienses no se debían a cuestiones culturales sino funcionales. No obstante, la Tesis de S. Beyries (1987) vendría a intentar resolver esta cuestión mediante la aplicación de estudios traceológicos a las colecciones clásicas de Francia, en las que demostraba que no existía una especialización funcional de las distintas facies.

Desde un punto de vista del desarrollo de la metodología, algunos autores trataron de reconocer la acción y la funcionalidad de los útiles a través del ángulo de los filos (e.g. Broadbent, 1979), aunque no con demasiado éxito, ya que no llegaron a definir el resto de huellas de uso más definitorias (pulidos, melladuras...) para establecer el uso de las herramientas. Así, a partir de estudios de esta misma década, se empezó a profundizar en torno a la caracterización de las huellas de uso. Tringham *et al.* (1974) y los seguidores de este enfoque (e.g. Kamminga, 1982; Lawrence, 1979; Odell, 1977) se centraron en el estudio de la formación de las melladuras para poder precisar la dureza de la materia trabajada, así como la acción realizada. Esto supuso el desarrollo de una tendencia metodológica sustentada en la observación microscópica a bajos aumentos, ya que estos autores, entre otros, empleaban lupas binoculares con un rango de amplificación que en muchos casos no superaba los 80x. Al mismo tiempo, en la década de los 80, comienza a utilizarse de forma más sistemática el microscopio metalográfico de luz reflejada, siendo L.H. Keeley uno de los primeros referentes con respecto a la tendencia metodológica de altos aumentos, tratando de sistematizar con mayor precisión la descripción de las huellas de uso. Uno de sus mayores avances, a partir del uso de estos microscopios de altos aumentos, que alcanzaban aproximadamente los 400 aumentos, es que se logró discriminar entre los pulidos generados por distintos materiales como la piel, la madera, el hueso, etc. (e.g. Keeley, 1974, 1980). La fiabilidad de este método quedó demostrada a partir de varios test ciegos que se realizaron con la finalidad de analizar hasta qué punto se podían llegar a distinguir huellas de uso de distintas materias en el material

arqueológico (e.g. Keeley & Newcomer, 1977; Newcomer & Keeley, 1979). En esta época también se llevó a cabo el congreso en Vancouver, liderado por B. Hayden. Esta fue la primera reunión internacional de la disciplina. Tuvo mucha repercusión, ya que se abordaron las principales problemáticas del momento, quedando todo ello recogido en un compendio de estudios (Hayden, 1979) muchos de los cuales siguen vigentes, como la propuesta sobre la nomenclatura en torno a las melladuras y las fracturas (The Ho Ho classification and nomenclature Committee Report). A partir de este momento se incrementaron los estudios funcionales, con trabajos como los de P. Vaughan (1981a, 1981b, 1985), P. Anderson-Gerfaud (1981, 1990), H. Plisson (1982a, 1982b, 1985, 1986), E. H. Moss (1983; Moss & Newcomer, 1982) S. Beyries (Beyries & Boëda, 1983; Beyries, 1987, 1988) o M.E. Mansur (1986).

Siguiendo con el plano metodológico, en 1980, P. Anderson-Gerfaud comenzó a utilizar el microscopio electrónico de barrido (MEB), que alcanzaba hasta los 10.000 aumentos, con la finalidad de identificar los materiales trabajados (colágeno, tejido animal, tendones, pelos, sangre, fitolitos, fibras vegetales, etc.) basándose en la morfología de los residuos combinada con la composición química de éstos. Desde entonces, el uso de MEB ha estado presente en numerosos trabajos (e.g. Fernández, 2021; Jardón, 2000; Mansur, 1983; Martín-Viveros *et al.*, 2020; Ollé & Vergès, 2008, 2014; Van Gijn, 1989; Yamada, 1993), ya que permite una mejor identificación y descripción de las huellas de uso, así como de los residuos.

A lo largo de esta década de los 80 también comenzaron a proliferar teorías en torno a la formación de los pulidos. De manera general, se podrían resumir en dos: La teoría abrasiva, por la cual se considera que el filo se va desgastando al entrar en contacto con la materia trabajada, habiendo una pérdida de materia provocada por la abrasión de la superficie (Diamond, 1979; Jardón, 2000; Levi-Sala, 1993; Ollé, 2003; Unger-Hamilton, 1984; Vergès, 2003; Yamada, 1993) y la hipótesis de la fusión superficial, por la cual se consideraba que el útil, al entrar en contacto con la materia en contacto, genera un calor friccional capaz de fundir el sílice y por ende generar una capa de sílice amorfo que derivaría en una capa de pulido (Anderson-Gerfaud, 1980; Christensen & Walter, 1991; Mansur, 1986). Este debate en torno a la formación de los pulidos continuó durante décadas, volviendo a retomarlo con el estudio experimental de Schmidt *et al.* (2020). En este estudio se demostró, a través de espectroscopía de infrarrojos, que los pulidos se generaban a través de la abrasión, ya que en ningún caso localizaron ninguna capa de sílice amorfo asociado a los pulidos. No obstante, nos parece interesante recoger algunas

de propuestas explicativas que pueden resultar de interés para la discusión de nuestro programa experimental. Concretamente, la de Christensen (1998), quien, dentro de la línea de los pulidos adicionales o fusionales, interpreta los pulidos como el relleno de las irregularidades de la superficie a partir de partículas o residuos desprendidos de la materia trabajada. Además, esta autora apunta a que podría identificarse la materia que ha generado el pulido a partir del análisis de la composición elemental de los residuos. No obstante, esta idea ya la sugirió Anderson-Gerfaud (1981), quien plantea que en el trabajo sobre materiales leñosos se puede producir una capa nueva de sílice en la que quedan atrapados residuos minerales de plantas, como los fitolitos. En ambos estudios se analizó la composición química de los pulidos, cuyos resultados ofrecen valores más allá del propio sílice y que iban en consonancia con las materias que habían trabajado.

Hasta aquí se ha ofrecido una panorámica general sobre las principales aportaciones y problemas en torno a la traceología desde sus comienzos.

A continuación, dedicaremos otro apartado donde se expondrá el estado de la cuestión en torno al trabajo de la madera durante el Paleolítico medio y superior. La finalidad de este partió de una recopilación bibliográfica de los estudios funcionales que contaban con material arqueológica destinado al trabajo de la madera. De esta forma se ha realizado una revisión en torno al tipo de soportes, acciones realizadas y material leñoso conservado para dichas cronologías. Con ello pretendíamos tener una visión general sobre el estado de la cuestión del trabajo de la madera para estas cronologías antiguas (Bencomo *et al.*, 2020).

2.1.1. Understanding woodworking in Paleolithic times by means of use-wear analysis

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Understanding woodworking in Paleolithic times by means of use-wear analysis

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ABSTRACT

Throughout prehistory, wood working was a frequent activity. The indices of this activity comes from rare found wooden remains, and the analysis of use-wear on them. In most recent periods, there are stone polished tools and metal tools, that increase the capability of wood transformation. This is not the case for older times, from which only knapped tools are available. The woodworking *chaîne opératoire* includes activities of selection and acquisition of raw material, but also the transformation and the finish of objects and structures. Use-wear analysis in many sites illustrates this. However, a systematic compilation of published traceological analysis has not been made recently. In this paper, we present a revision of the traceological data currently available, which guides a reflection on the methods of working ligneous vegetable matter with knapped tools. The relationship between this information, the morphological characteristics of tools and the necessary actions to elaborate the preserved wooden objects, tell us about the woodworking techniques that are more common in each period. The results allow us to draw conclusions about the performance of each type of tool, as well as the human technical capabilities for environmental transformation.

1. Introduction

Wood plays a major role in the economic and production activities carried out by human groups during the Middle and Upper Paleolithic, both as fuel and as raw material for the manufacturing of artifacts. Stone tools used for the work of vegetable matter have been found in a great number of archaeological sites. However, wooden objects have not usually been preserved for such old chronologies, since they would need extremely arid, humid or anaerobic conditions to avoid deterioration. This lack of wooden artifacts makes it difficult to construct hypotheses about the possible activities involved in their manufacturing. Nevertheless, thanks to use-wear analysis on stone tools we can obtain some information about the actions and objects they worked on.

Previous publications have collected information and knowledge, although quite general, regarding the use and work of wood and

vegetable resources. It is worth mentioning the researches by Tyldesley and Bahn (1983), or Beyries and Hayden (1993), of a generalist type or focused on a particular period (Owen, 1994).

More recently, a revision of the materials involved in woodworking has been carried out, supported by an experimental programme focused on the use-wear analysis on the stone industry in chronologies of the Middle Paleolithic in West European sites (Claud et al. 2013).

Therefore, the aim of this research is to provide a summary containing information about the stone tools which were suitable for woodworking, including the functional data obtained through traceological studies and use-wear analysis of the wooden objects preserved since the Middle and Upper Paleolithic.

The aims of this research are the following:

- To study the results and knowledge that we currently have about woodworking techniques according to traceological investigations

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of the tools which are available from the remain of each chronology; Middle and Upper Palaeolithic

- From a technological point of view, to identify the features which make a tool suitable for woodworking and the activities in which it may have been used.
- To compare the type of tools and activities involved in these works during the Middle and Upper Paleolithic.
- To collect and present the most important wooden remains which have been preserved since each chronological period and reflect on the possible techniques, actions and tools used for their manufacturing.

2. Materials and methods

In order to carry out the present research, we have compiled all the bibliography covering the issue of woodworking, throughout the chronologies already mentioned. We have selected not only specific, but also traceological, and more general studies in which this type of activity is included. *Grosso modo*, we have analysed the data focusing on the following aspects: typology of the tools used, characteristics of the materials worked, actions carried out and morphology of the active areas (raw material, angles, characteristics of edges, thickness, etc.).

We have also analysed the state of the wooden remains that have been preserved (except for coal), in order to suggest a hypothesis about the type of work and the activities involved in their manufacturing and resulting use-wear.

Due to the fact that the study framework refers to the macro-level documentation on woodworking in the Middle and Upper Paleolithic in Europe, there is an obvious decontextualisation of the results regarding specific archaeological sites, territories and periods at a micro level. The micro approach is largely addressed in the publications of each particular site thus not being the main focus of our research.

Finally, no discrimination has been observed as for raw material (flint, limestone, quartzite, etc.), although some studies emphasize the use of specific raw materials based on the actions observed on wood (i.e. [Lazuen et al., 2011](#)).

3. Results

Next, we will examine how representative woodworking is in the functional studies of the Paleolithic chronology, as well as the tools used and the wooden remains preserved in relation to the working techniques that can be inferred from the use-wear analysis and manufacturing traces on the implements. The publications about use-wear which have been analysed in this research do not present the technological information in a homogeneous or standardized way, since there are many cases in which there is no relation between the activity identified and the morphology of the tools or the active areas, making it impossible to create a complete synthesis graph and leading us to register the most representative cases and examples regarding activities and tools.

3.1. Middle Paleolithic

3.1.1. Use-wear analysis on tools

The functional studies applied to Mousterian remains focus on entire archaeological sites. The results show that the processing of animal matter is generally more usual than woodworking. Although this type of work is present in practically all the sites that have been examined (with various degrees of representation), we can observe some differences between some functional studies which show a high percentage of woodworking ([Anderson-Gerfaud, 1981; 1990; Beyries, 1987; Beyries and Hayden, 1993](#)), and others in which this percentage is lower ([Lemorini, 2000; Claud et al., 2013](#)).

However, it is important to consider the specific characteristics of each site. In Remicourt-En Bia Flo, for instance, there is great evidence

of woodworking ([Jardón Giner and Bosquet, 1999](#)), as compared to Abri Romaní, where despite the finding of wooden tools, the work of this material is less frequent ([Martínez, 2005](#)). Taphonomic reasons could explain these differences.

Abri du Maras (France) is also a remarkable site, where an important set of tools which worked on wood or vegetable fibres has been found and conserved as waste in the active areas ([Hardy et al., 2013](#)). However, recent studies have proposed to take the analyzed residues with caution, since they can be incorporated into processes other than use ([Rots et al., 2016](#)). In addition, as Monnier points out, it is very difficult to identify residues without using high-resolution microscopes ([Monnier et al., 2017](#)).

Some diachronic studies such as the ones conducted in several remains and sites in Atapuerca are also very interesting. These have shown that the use of wood is more intense in mode 3 tools than in mode 1 and 2, ([Márquez et al., 2001](#)). It is also one of the few examples that shows that this work is mainly related to a particular type of tool (denticulate).

Regarding tool typology, there is evidence that most of the typological categories of the Paleolithic were used for woodworking, which indicates the great adaptability of Mousterian tools. We can also observe a preference for retouched tools. In addition, we can distinguish between those tools which were used in direct freehand percussion actions, manufactured in more massive supports, and those smaller tools not used for this type of actions ([Claud et al., 2013; Hortelano, 2016](#)). For example, small artifacts are effective for some actions as scraping or cutting ([Lazuén and Delagnes, 2014; Lazuén and González Urquijo, 2014](#)).

The relation between the morphological features of the tools (angle and delineation of edges, more important, at an experimental level, than tool typology) and their role in woodworking is not always clear. Regarding the activities, use-wear analysis allows us to make a kinematic reading of the tool and the activity, but it is not an easy task to reconstruct the complete *chaîne opératoire* on wood. Direct and indirect percussion, scraping and cutting are the most habitual actions. Given this and the difficulty faced in trying to identify the activity in which the tool under study was involved, few researchers can theorize about the specific processes in which they took part. The archaeological site of San Quirce is one of the examples in which the work of wood and vegetable fibres stands out alongside butchery ([Clemente et al. 2014](#)) and in Biache Saint-Vaast, woodworking has been related to techniques used for the preservation of handles ([Rots, 2011; 2013](#)).

3.1.2. Preserved wooden remains

Although the wooden remains from this chronology are not very abundant, they are well-known, which is why our research will focus on analysing those remains which provide information about possible actions and working techniques.

Regarding the most ancient remains, in the site of Schöningen, with a recently revised chronology of 337–300 Ka B.P. ([Richter and Krbetschek, 2015](#)), several spears presenting cutting marks have been found being their apparent purpose to recondition the side of one of the spearheads ([Schoch et al., 2015](#)). In Poggetti Vecchi, whose remains have been assigned to 171 Ka B.P., 39 implements show cuts and striation traces produced by the use of tools ([Aranguren et al., 2018](#)). In Aranbaltza III, from around 90 Ka B.P., a piece of wood presents two little cutting marks on the surface corresponding to the last stages of the manufacturing of a digging stick ([Rios-Garaizar et al., 2018](#)). Despite showing evidence of their manufacturing, the traces of work on these tools can not always be related to specific activities.

In other archaeological sites such as Königsau ([Mania and Toepfer, 1973; Koller et al., 2001](#)), and Kärlich ([Kulemeyer, 1988](#)) we find wooden and resin remains, which give evidence of actions that involved the barking of wood for its modification (shaft) and the use of techniques for the extraction of tar from the birch tree as well as other resins and tars used as adhesive ([Beyries and Hayden, 1993; Kozowyk et al.,](#)

2017). In fact, there is also evidence of the use of tar as glue since the Middle Pleistocene, as in Campitello, Italy (Mazza et al., 2006), or Inden-Aldorf, Germany (Pawlik and Thissen, 2011), whose remains indicate the use of ligneous resources.

As for the use of fire, in the sites of Poggetti Vecchi and Leheringen the analysis of several pieces altered by temperature has led researchers to believe that fire could have helped to make scraping easier in the case of Poggetti Vecchi (Aranguren et al., 2018), or to make the surface harder, as in Leheringen (Movius, 1950; Thieme and Veil, 1985).

Finally, in order to complete the collection of wooden artifacts from the Middle Paleolithic, it is important to include other wooden remains with no signs of manufacturing on them, such as those found in Abric Romaní, with an approximate chronology of 45–49 Ka B.P. (Carbonell and Castro-Curel, 1992; Castro-Curel and Carbonell, 1995) and the arrowhead found in Ljubljansko Barje (Eslovenia) with a chronology of 37 Ka B.P. (Gaspari et al., 2011).

3.2. Upper Paleolithic

3.2.1. Use-wear analysis on tools

Woodworking during the Upper Paleolithic is evident in most of the archaeological sites analysed, although the amount of tools used for the manufacturing of wooden objects varies and is generally scarce. Blades and *pièces esquillées* were used for the obtention of wood, whereas blades, flakes, end scrapers, burins and piercers (in a smaller quantity) were used for the finishing of works. According to the published analysis, wood working is marginal in Upper Paleolithic. In some of the sites only one, or no stone piece at all, presents use-wear related to wood (Moss, 1983; Plisson, 1985; Calvo, 1997; Cabal et al., 2004; Ortega et al., 2006; Baillet, 2017).

In his study of Hearth 111 in Pincevent, Moss explains the absence of woodworking traces stating that only one tool worked this material, due to woodworking needing to take place in larger spaces away from the hearths. It is probably certain that the cutting down of trees and big branches was probably carried out in bigger spaces, but the space needed for the cleaning and working of animal skins would be similar. Another hypothesis accounts for the specialisation of sites (Plisson, 1985). However, these explanations seem rather improbable due to the great number of sites belonging to different stages of the Upper Paleolithic published.

3.2.2. Preserved wooden remains

Throughout the Upper Paleolithic, the wooden remains which have been preserved are usually located in those sites with more recent chronologies, specifically during the Solutrean and the Magdalenian periods. Some surviving necklace beads found in Las Caldas site have been assigned to the Solutrean period (Corchón, 1999).

The range of elements found belonging to the Magdalenian period is wider. From the early stages, other necklace beads similar to the ones from the Solutrean were found in Cueva de Santa Catalina (Berganza et al., 2018). The interest aroused by these findings adds to the experimental proposal of a reconstruction of the elaboration process. As the authors suggest, the way in which the wood fibres are arranged in the necklace beads indicates the use of a large splinter, showing that its extraction was necessary, although there is no clear information about the specific action through which the splinter was obtained. Piercing was then made using stone piercers.

Remains of bows and arrows have also been found. The analysis of an object of about 110 cm long found in Mannheim confirmed that it was used as a bow (Rosendahl et al., 2006). The manufacturing of this little bow using a thick branch consisted of eliminating the outer part of the wood and preserving the heartwood on the other side. This slimming was obtained through cutting and reducing the wood using stone flakes and blades. The holes where the strings were located were made applying cutting or sawing techniques (Junkmanns, 2001). A second bow was found in the Magdalenian site of Teyjat (Coles and Higgs,

1969) and a third one in Stellmoor (Rausing, 1967). The remains of these bows, arrows and necklace beads underwent cutting, scraping and polishing processes.

Meanwhile, the remains of post-holes in the construction of dwellings in some archaeological sites give evidence of activities not usually documented (Leroi-Gourhan and Brézillon, 1966).

4. Experimental programmes

Throughout the last decades, a great number of replicative, mechanical and sequential experimental programmes including wood-working, have been carried out. Some of the most relevant studies, such as the ones by Semenov and Thompson (1964) Tringham et al. (1974), L.H. Keeley (1980), B. Hayden (1979) have played an essential role not only because they have laid the foundations for protocols to be taken but also because they have confirmed their importance in the validation of functional interpretations.

There is not much information about particular actions or complete working processes, since specific experimentations have only been conducted in very rare occasions. Some examples of researches that have been published and which account for this issue in detail are González and Ibañez (1996), Claud et al. (2013, Claud, 2015), Laborda (2010) or Martín Lerma (2015). These experimentations show a greater presence of cutting, scraping and sawing processes and fewer cases of *percussion lancée* in the cutting down of trees and chopping of logs.

Experimentations with specific tools are not very frequent either, except for biface works (i.e. Claud et al. (2009); Claud (2012)), or the analysis of splintered pieces (i.e. Le Brun-Ricalens, 1989; Gibaja et al., 2007; Jardón et al., 2018). It is thanks to the experimentations focused on typologies, that we can theorize about tools, processes and actions.

Furthermore, experimental studies usually focus on how the tools deteriorate after being used and very rarely do they show use-wear in the manufactured tool, with a few exceptions (Jensen, 1991; Paulsen, 1990; Veil, 1990; Aranguren et al., 2018; Jardón et al., 2018). It is also important that experimental programmes dealing with the effectiveness of the tools used in the different activities become more generalised.

5. Discussion and conclusion

We have been able to confirm the wide range of stone tools used for woodworking despite the scarcity of the remains. This makes hypotheses formulation rather difficult, since the low proportion of manufactured tools sets limits to the information and knowledge about the possible actions and activities involved in their manufacturing. Conversely, it is essential that publications emphasise the importance of formulating functional hypotheses together with traceological results in order to shed some light on the actions and materials being worked.

Actions on wood may be less frequent and of a shorter duration than in latter periods (Mesolithic and Neolithic), which makes it more complicated to identify them (less developed polishing, low surface modification and microscarring). In addition, woodworking use-wear could be affected by taphonomic processes.

We can distinguish several stages of the *chaîne opératoire*. The implements used for woodchopping are generally bifaces and *pièce esquillées*. There is no evidence that other tools, such as wooden wedges or bone pieces used as axes, may have taken part in this type of work, although it has been observed in other cultures lacking metal. It is common to use flakes or blades in shaping actions, knots eliminating, whittling or brushing wood, which matches the interpretations of the traceological analyses applied to prehistoric stone tools. Regarding the finish through scraping, the tools used are scrapers and denticulated during the Middle Paleolithic, and burins and non-retouched edges in the Upper Paleolithic. These would have angles greater than 45°, being the tools most often used due to their active potential.

In any case, both in the Middle and Upper Paleolithic the number of implements connected to wood is lower than 25%. Therefore,

throughout the Upper Paleolithic the increase in the specialization of some types of tools such as end scrapers, does not account for the existence of tools specially designed for the work of wooden vegetable matters. However, the complexity of elaborated objects does increase, namely propellants, handles, arrowheads and bows, most of which have not been preserved. Among tools that present wood use-wear we find burins and piercers, needed for the manufacturing of necklace beads, as in Santa Catalina.

How can we explain the low number of tools presenting wood use-wear in the archaeological register? Earlier on we have discussed the reasons that include the time and space specialisation of the samples under study. Another cause to be taken into account would be related to the difficulty in identifying the material worked, since there is often the non-specific identification of “medium hard organic matter.” As for the identification of use-wear, it is worth considering that there may be a slant in the number of identified woodworking actions, mainly due to the resemblance among materials with a similar hardness, such as wood and antler material (Owen, 1994), or short actions with a great deal of breaking. The conclusions obtained through the use-wear analysis of the material worked are sometimes very vague, identifying the hardness of the material worked as medium, or high instead of determining if it has a ligneous or a bone origin.

The tools studied through traceological analysis are manufactured using siliceous raw materials (flint, chert or siliceous limestone) whose properties for the obtention of cutting edges through carving are well known. However, due to the fragility of this material, they do not fully resist direct freehand percussion, necessary for the cutting down of trees and carried out in later periods using polished stone axes. Can we therefore imply that these circumstances led to a limitation in the supply of wood for object manufacturing? The possibilities of chopping big logs and working in a dry state are then scarce. These tools seem to be more useful in the work of green branches and logs. Therefore, the ultimate solution would lay in the selection of wooden raw material given its shape and original size (Jardón et al., 2018). The later modification may have been possible thanks to the use of fire, as shown in the artifacts found in Poggetti Vecchi (Aranguren et al., 2018).

It is for all this that it is necessary to insist on the importance of ethnographic and experimental studies, whose main aim is to reconstruct the *chaîne opératoire* based on the preserved remains from each period, applying the functional analysis to a wider range of sets and always taking the aim of this work into consideration: the manufacturing of a wooden object.

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2.2. Traceología y resolución temporal: la importancia de los marcos analíticos

La proliferación de los estudios funcionales ha resultado de gran utilidad para comprender aspectos relativos a las actividades productivas de las poblaciones cazadoras-recolectoras paleolíticas, especialmente porque han evidenciado el uso de materias perecederas no conservadas en la actualidad, como la piel o la madera, así como las acciones destinadas a trabajar distintas materias (e.g. Claud, 2008; Clemente *et al.*, 2014; Hortelano, 2016; Jardón & Bosquet, 1999; Lazuén & González, 2015; Lemorini, 1996, 2000). Sin embargo, una valoración global de las temáticas planteadas y de los resultados obtenidos evidencia que más allá de esto, comprender la variabilidad del comportamiento de las poblaciones paleolíticas a lo largo del tiempo es una tarea compleja, dada la naturaleza de los depósitos arqueológicos, ya que muchos de ellos comprenden un palimpsesto de reiteradas ocupaciones difíciles de disectar. En muchos casos se ha empleado la unidad estratigráfica para tratar caracterizar el modo de vida de las poblaciones cazadoras recolectoras. Sin embargo, la escala temporal de las UE responde a criterios geológicos, integrandos conjuntos arqueológicos que temporalmente distan mucho entre sí. Por esta razón, los estudios que emplean la UE como marco de análisis aglutinan el comportamiento de múltiples grupos sin posibilidad de observar el comportamiento específico y particular de cada uno de ellos. En este sentido, numerosos resultados funcionales derivan del estudio de útiles pertenecientes a unidades estratigráficas (e.g. Beyries, 1987; Borel *et al.*, 2017; Hortelano, 2016; Jardón 2000; Keeley, 1980; Lemorini *et al.*, 2016; Lemorini, 2000; Márquez *et al.*, 2017; Martínez, 2005; Ollé, 2003; Plisson, 1985; Rodríguez *et al.*, 2002; Rots, 2011, 2016; Vaughan, 1985). De esta forma, el uso de la UE como marco de análisis permite obtener resultados cuya naturaleza hace posible caracterizar la función de los utensilios, pero desde una temporalidad laxa que dificulta reconocer patrones de uso en el marco de ocupaciones concretas y en ese sentido, explorar la variabilidad del comportamiento humano a lo largo del tiempo.

En las últimas décadas se ha tratado de superar los problemas derivados de la condición de palimpsesto de los yacimientos (e.g. Bailey, 2007; Harding, 2005; Henry, 2012; Holdaway & Wandsnider, 2008; Lucas 2010). A partir de indicadores de diacronía se han podido generar unidades analíticas de mayor resolución temporal que en algunos casos se aproxima a la escala temporal humana. Así, en contextos de alta resolución, se han podido definir lechos de material estratigráficamente bien definidos y separados

diacrónicamente por capas estériles (e.g. Machado, 2016; Mayor *et al.*, 2020; Sossa *et al.*, 2022; Spagnolo *et al.*, 2020a, 2020b; Vallverdú *et al.*, 2010; Vallverdú *et al.* 2005; Vaquero, 2008; Vaquero *et al.*, 2004). A través de estos estudios de alta resolución se han podido caracterizar conjuntos que, estando próximos a la escala humana, parecen responder a ocupaciones de corta duración. La huella arqueológica de estas ocupaciones se caracteriza generalmente por la presencia de una actividad de talla (cuya cadena operativa en muchos casos está fragmentada), restos de fauna y útiles líticos tanto tallados y utilizados *in situ* como herramientas singulares interpretados como piezas transportadas (e.g. Deschamps *et al.*, 2022; Mayor *et al.*, 2020; Sossa *et al.*, 2022;). Dicho material se suele organizar en torno a hogares, siguiendo el modelo de “*Hearth-Related Assemblage*” (Vaquero & Pastó 2001).

En estos marcos de alta resolución, el análisis traceológico se presenta como una vía idónea para caracterizar áreas de actividad u ocupaciones humanas y, consecuentemente, explorar la función o funciones de los asentamientos. Sin embargo, los estudios funcionales aplicados a marcos analíticos de alta resolución siguen siendo escasos, lo que limita la interpretación de esos conjuntos y por tanto el conocimiento sobre el comportamiento humano.

Hasta la fecha sólo contamos con yacimientos como Grotta dei Santi (cf. Spagnolo *et al.* 2020a), El Abric del Pastor (cf. Sossa-Ríos *et al.* 2022) y Cueva Antón (cf. Deschamps *et al.* 2022) en los que se ha aplicado el análisis funcional al material lítico perteneciente a unidades analíticas de alta resolución. Los conjuntos analizados en cada uno de estos yacimientos están muy próximos a la temporalidad humana y parecen representar ocupaciones de corta duración y poco intensas en las que los grupos humanos llevaron a cabo actividades de carnicería (cf. Spagnolo *et al.*, 2020a; Sossa-Ríos *et al.*, 2022) o una alternancia de trabajos sobre materia animal o materia leñosa en función de la estacionalidad (Deschamps *et al.*, 2022). Estos resultados ponen de manifiesto el carácter singular de las tareas desarrolladas no sólo en áreas de actividad, como el caso de Grotta dei Santi y Cueva Antón, sino sobre todo en marcos representativos de ocupaciones únicas, como en El Abric del Pastor.

En otro orden de cosas, los estudios funcionales en muchos casos se han centrado en el estudio del material arqueológico sin hacer referencia o diferencia entre las piezas talladas y utilizadas *in situ* y las piezas singulares. En este sentido, se suelen seleccionar conjuntos heterogéneos provenientes de unidades estratigráficas, tal y como ya se ha mencionado, o bien conjuntos tipológicos concretos (e.g. Claud *et al.*, 2012; Jardón, 2000;

Lemorini *et al.*, 2016; Márquez & Baena, 2002; Márquez *et al.*, 2017; Shea, 1988, 1993). Por esta razón dedicaremos un breve apartado al estado de la cuestión en torno a las piezas talladas y utilizadas *in situ* y las piezas singulares, ya que suponen un punto importante en este trabajo. Uno de los objetivos de esta Tesis Doctoral es analizar y comparar la funcionalidad entre los soportes tallados y utilizados *in situ*, que conforman unidades de materia prima de conjunto, y las piezas singulares, cada una de las cuales forma en sí misma una única unidad de materia prima y que se han catalogado tradicionalmente como piezas transportadas. Así, desde la traceología trataremos de arrojar luz en torno a esta cuestión a partir del material seleccionado en UE Xa de El Salt.

2.3. La traceología en el contexto de las unidades de materia prima

Las primeras alusiones en torno a las piezas transportadas se formularon desde la etnografía, observándose cómo grupos de cazadores recolectores seleccionaban una serie de herramientas que utilizaban en sus desplazamientos. L. Binford fue el principal investigador que en la década de los 80 hablaba del *personal gear* (Binford 1973, 1977, 1979). A su vez, Binford establece el concepto de *curated*, con el que relacionó las piezas transportadas, estableciendo que son objetos con un alto coste de inversión tecnológica, localizados lejos de su lugar de fabricación y seleccionados para hacer trabajos a futuro, lo que evidencia un grado de predeterminación y anticipación.

Si bien esta clasificación propuesta por Binford ha sido bastante útil para caracterizar estos conjuntos, debemos tener en cuenta que son conceptos que emanan de la observación etnográfica. Por esta razón, su definición es bastante ambigua, por lo que en muchos casos ha sido complicado aplicar sus explicaciones a conjuntos arqueológicos.

De hecho, a lo largo de las últimas décadas, se ha tratado de concretar su definición desde distintos enfoques. Si atendemos a cuestiones tecnológicas, serían piezas en las que hay un mayor esfuerzo por mantenerlas y reciclarlas (*e.g.* Bamforth, 1986), por lo que, de manera general, se ha aceptado que suelen ser piezas retocadas, aunque esto no siempre se cumple (*e.g.* Vaquero, 2008), llegando a ser incluso los núcleos los que se transportan (*e.g.* Moncel *et al.*, 2021). Desde un punto de vista morfológico, serían más cómodas a la hora de manejarlas (*e.g.* Tomka, 2001), e incluso se ha propuesto que estarían relacionadas con secuencias de producción más complejas (*e.g.* Binford 1977; Keeley, 1982; Odell, 1996). En relación a esto, algunos autores han propuesto que deben ser poco pesadas (*e.g.* Shott, 1996; Torrence, 1983) e incluso de pequeño tamaño para maximizar su utilidad potencial en relación con el coste del transporte (*e.g.* Kuhn, 1994). La

disponibilidad de las materias primas también juega un papel importante (e.g. Bamforth, 1986), aunque no se excluye que puedan estar fabricadas en materias primas cercanas (e.g. Machado, 2016; Mayor *et al.*, 2020; Sossa *et al.*, 2022). Con respecto a la funcionalidad, se consideran piezas más eficientes y con mayor grado de uso que las fabricadas y utilizadas *in situ* y que deben ser multifuncionales (e.g. Bamforth, 1986; Shott, 1996).

La realidad es que sigue sin haber un consenso claro, pues la casuística es muy amplia. Esto dificulta su caracterización en conjuntos arqueológicos, en los que, además, se integran piezas singulares y piezas talladas *in situ*. Por otra parte, observamos que el estudio de estas piezas se ha tratado, de manera general, desde el punto de vista de la tecnología lítica y las materias primas. Pocas veces se han estudiado las piezas transportadas desde un punto de vista funcional, aunque como ya se ha comentado, de forma apriorísticas se les ha atribuido un uso más intenso que a las piezas talladas y utilizadas *in situ* (e.g. Bamforth, 1986; Shott, 1996). Más allá de esto, los estudios funcionales centrados en las piezas transportadas siguen siendo escasos (e.g. Berruti *et al.*, 2023; Claud *et al.*, 2012; Martín-Viveros *et al.*, 2020).

En este sentido, los contextos de alta resolución son idóneos para establecer ambas categorías. Un ejemplo de ello es el estudio de El Abric del Pastor de Sossa *et al.* (2022). En este trabajo se han podido reconocer, por un lado, piezas talladas y utilizadas *in situ*, clasificadas a través de los remontajes o las unidades de materia prima, y piezas singulares, por sí mismas conforman una única UMP, interpretándose como piezas móviles. En ambos casos, desde el punto de vista tecnológico, son soportes de bajo coste, cuya materia prima es local, y su funcionalidad está relacionada con la actividad carnicera. Este caso nos servirá, entre otros, como referencia para realizar nuestro estudio en los marcos analíticos de alta resolución temporal seleccionados para este trabajo y donde se integran tanto piezas talladas y utilizadas *in situ* como piezas singulares.

3. Material y método

3.1. El yacimiento arqueológico de El Salt

El yacimiento de El Salt (Fig. 1) es un abrigo rocoso localizado en Alcoy (Alicante, España), a 680 m.s.n.m. protegido por una pared travertínica de 38 m. Cuenta con un depósito de 6.3 metros de potencia dividido en 13 unidades litoestratigráficas (Fumanal, 1994), enmarcadas principalmente en el Pleistoceno superior. Las dataciones realizadas en el yacimiento, mediante las técnicas de Uranio-Torio (U-Th), Termoluminiscencia (TL) y OSL, sitúan la secuencia entre el 81.5 ± 2.7 Ka (UE XIII) y el 44.7 ± 3.2 Ka (UE V). La presencia humana se evidencia a partir de la UE XII, con una cronología de 60.7 ± 8.9 Ka. (Galván et al., 2014a; 2014b).

Desde las excavaciones de finales de los años 80, realizadas por la Dra. Bertila Galván, El Salt ha sido estudiado desde una perspectiva multidisciplinar con la finalidad de analizar el poblamiento neandertal en los valles alcoyanos. Producto de este trabajo continuado e intenso se han publicado numerosos trabajos que nos permiten conocer tanto las dinámicas socioeconómicas de estos grupos cazadores-recolectores, como las características del entorno y las condiciones paleoambientales de estas poblaciones (e.g. Dorta *et al.*, 2010; Fagoaga, 2020; Fagoaga *et al.*, 2018, 2019; Fumanal, 1994; Galván *et al.*, 2006; Herrejón *et al.*, 2016; Leierer *et al.*, 2019; Machado & Pérez, 2015; Machado *et al.*, 2011, 2016; Mallol *et al.*, 2012; Marin-Monfort et al., 2021; Mayor *et al.*, 2020; Mayor *et al.* 2022; Pérez *et al.*, 2020; Rampelli *et al.*, 2021; Rodríguez *et al.*, 2002; Sistiaga *et al.*, 2011, 2014; Vidal-Matutano, 2016, 2017; Vidal-Matutano *et al.*, 2018)

De manera general, se ha excavado una superficie de 36 m² con respecto a los 300 m² que representa el yacimiento. En esta superficie, donde se ubica la UE Xa, se ha recuperado abundante material arqueológico. Atendiendo a la industria lítica, a grandes rasgos, incluye desde núcleos a soportes retocados y no retocados, adscritos preferentemente a la talla Levallois (Machado, 2016; Mayor *et al.*, 2020). La materia prima que predomina es el sílex de tipo Serreta, aunque también hay presencia de sílex tipo Mariola, Beniaia y Font Roja. La cercanía de fuentes de aprovisionamiento de estos tipos de sílex permite afirmar que el radio de captación de los recursos es local (Molina 2015). En cuanto al registro faunístico, nos remite a un aprovechamiento de mamíferos de talla media, especialmente los caprinos (*Capra pyrenaica*), cérvidos (*Cervus elaphus*) y équidos (*Equus ferus* y *Equus hydruntinus*), cuyas marcas de manipulación antrópica son reflejo de las actividades cinegéticas y de subsistencia (Pérez 2019).

En cuanto a los estudios antracológicos, el taxón más representativos es el *Pinus nigra*, con valores de entre 75 y 85%. También destacan otras especies, como el tejo (*Taxus baccata*), presentes en los estudios carpológicos, relacionando su uso con otros fines más allá de la combustión (Vidal-Matutano, 2017; Vidal-Matutano *et al.*, 2017, 2018).

Por otro lado, las estructuras de combustión cuentan con un diámetro aproximado de 50 cm, y con un espesor de 1 a 3 cm. El grado de termoalteración bajo (< 400°C), observándose además lapsos de tiempo prolongados entre estructuras de combustión y la ausencia de reencendidos (e.g. Leierer *et al.*, 2019; Mallol *et al.*, 2013).

3.1.1. El proceso de disección en el yacimiento de El Salt

Uno de los aspectos fundamentales que ha motivado y orientado la investigación en El Salt ha sido la disección del palimpsesto, con la finalidad de acceder a un registro arqueológico que permita caracterizar a los grupos humanos históricamente. El proceso de su disección ha sido posible gracias a la óptima conservación del depósito y a una exhaustiva metodología de excavación constantemente sujeta a procesos de reflexión y crítica en el seno del equipo de investigación. Los primeros estudios (e.g. Machado *et al.*, 2011, 2016; Machado & Pérez, 2015; Mallol *et al.*, 2013; Marrero *et al.*, 2011) centraron sus esfuerzos en acotar temporal y espacialmente lechos de material arqueoestratigráficamente bien definidos, separados por capas sedimentarias estériles. De esta forma, la unidad de análisis pasaba de ser la UE, a ser una nueva unidad arqueoestratigráfica de mayor resolución temporal (UA). No obstante, la UA comprende en sí mismo un micropalimpsesto que ha sido posible diseccionar en los últimos estudios (Mayor *et al.*, 2020), generando nuevas unidades analíticas, que comienzan a acercarse a ocupaciones individualizadas. A lo largo de todo este proceso de disección, han sido fundamentales no sólo los estudios arqueosedimentarios, sino también los remontajes de sílex y de fauna, la determinación y análisis de las unidades de materias primas (UMP) (Machado *et al.*, 2017; Molina *et al.*, 2016), la zooarqueología (Pérez, 2019; Pérez *et al.*, 2020), la distribución de los hogares (ya que las capas negras suponen el testigo principal de los paleosuelos) (Mallol *et al.*, 2012; 2013) y la distribución espacial del material (empleando un sistema de información geográfica tridimensional [GIS]) (Machado *et al.*, 2017, Mayor, 2020).

La visión multidisciplinar derivada de estos estudios ha permitido determinar la existencia de varios episodios de ocupación humana, definidos por lechos de materiales

cuya distribución responde al modelo *hearth related-assemblage* (Vaquero & Pastó, 2001; Mayor *et al.*, 2020). Cada uno de estos eventos de ocupación se asocia a su vez a uno o varios hogares. Por otro lado, dentro del conjunto lítico, se han distinguido las piezas que han sido talladas y utilizadas *in situ*, de las piezas singulares. Esta diferenciación se ha realizado a partir de dos criterios fundamentales: por un lado, las unidades de materia prima, y por otro, los remontajes. Así, las piezas talladas *in situ* comprenden al menos dos soportes que forman parte de la misma unidad de materia prima, y en algunos casos se ha podido obtener un remontaje. Por el contrario, las piezas singulares no remontan con ningún otro soporte y además forman en sí mismas una única unidad de materia prima.

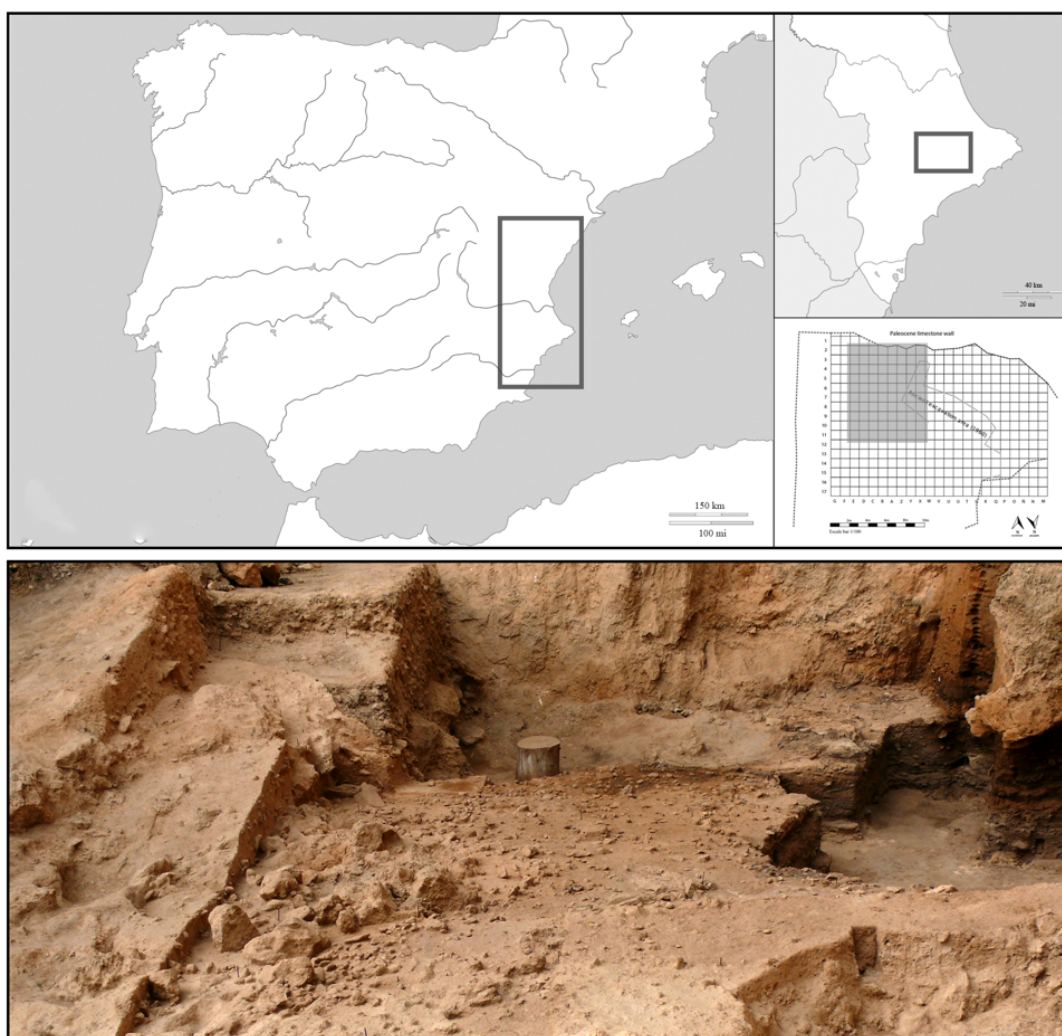


Fig. 1. Localización geográfica y superficie de excavación de la UE Xa de El Salt.

3.2. Material lítico seleccionado de la UE Xa de El Salt

En esta Tesis Doctoral se ha seleccionado un total de 259 soportes líticos procedentes en su integridad de la UE Xa de El Salt. Cada uno de ellos ha podido ser adscrito a unidades concretas, de diferente grado de resolución temporal, como consecuencia del estudio arqueostratigráfico realizado con este estrato, dirigido a la disección del denso palimpsesto que representa. Así, contamos con una serie de micropalimpsesto (*i.e.* 3.2., 4.1. y 5.2) y con otros marcos analíticos cuya temporalidad es aún más estrecha, de tal manera que probablemente se hallen muy próximos a la escala de tiempo de la actividad humana (*i.e.* 3.2.1, 4.1.1, 4.1.2 y 5.1).

Cada uno de estos conjuntos se generó mediante la identificación de distintos indicadores de diacronía y su asociación espacial y estratigráfica con el registro material. En este sentido, los marcos analíticos que aún están conformados como un micropalimpsesto, es decir contienen registros diacrónicos que no han podido ser aislados, cuentan en su composición con un mayor número de materiales, mientras que las unidades de mayor resolución temporal están integradas por conjuntos más limitados de restos, pero muy significativos desde el punto de vista de su capacidad para reflejar las actividades realizadas durante las ocupaciones singulares. Con ello, queremos señalar que estas diferencias cuantitativas reflejan, consecuentemente, el aporte de elementos por parte de estos grupos neandertales, determinando así que la cantidad de objetos arqueológicos que forman parte de cada unidad analítica de alta resolución.

A lo largo de este apartado se expondrán una serie de tablas con las características básicas de los materiales seleccionados, distinguiendo entre de las piezas adscritas a unidades de materia prima de conjunto, y por otro, las piezas singulares.

Material lítico de unidades de materia prima de conjunto de las unidades arqueoestratigráficas 3.2 y 3.2.1

La UA 3.2. es resultado del proceso de disección de la UE Xa realizado en la Tesis Doctoral de J. Machado (Machado *et al.*, 2017). Esta unidad representaba un micropalimpsesto con una superficie de 32 m² de los 36m² que componían el área de excavación. En trabajos posteriores, pudo aislarse en su interior la unidad 3.2.1 que cuenta con 13 piezas líticas, asociadas al hogar H22 y cubriendo un área muy específica de apenas unos m² (Mayor *et al.*, 2020) El resto de piezas líticas de la UA 3.2 (*i.e.* 257), siguen representando un micropalimpsesto que aglutina una cantidad indefinida de ocupaciones (Fig. 2)

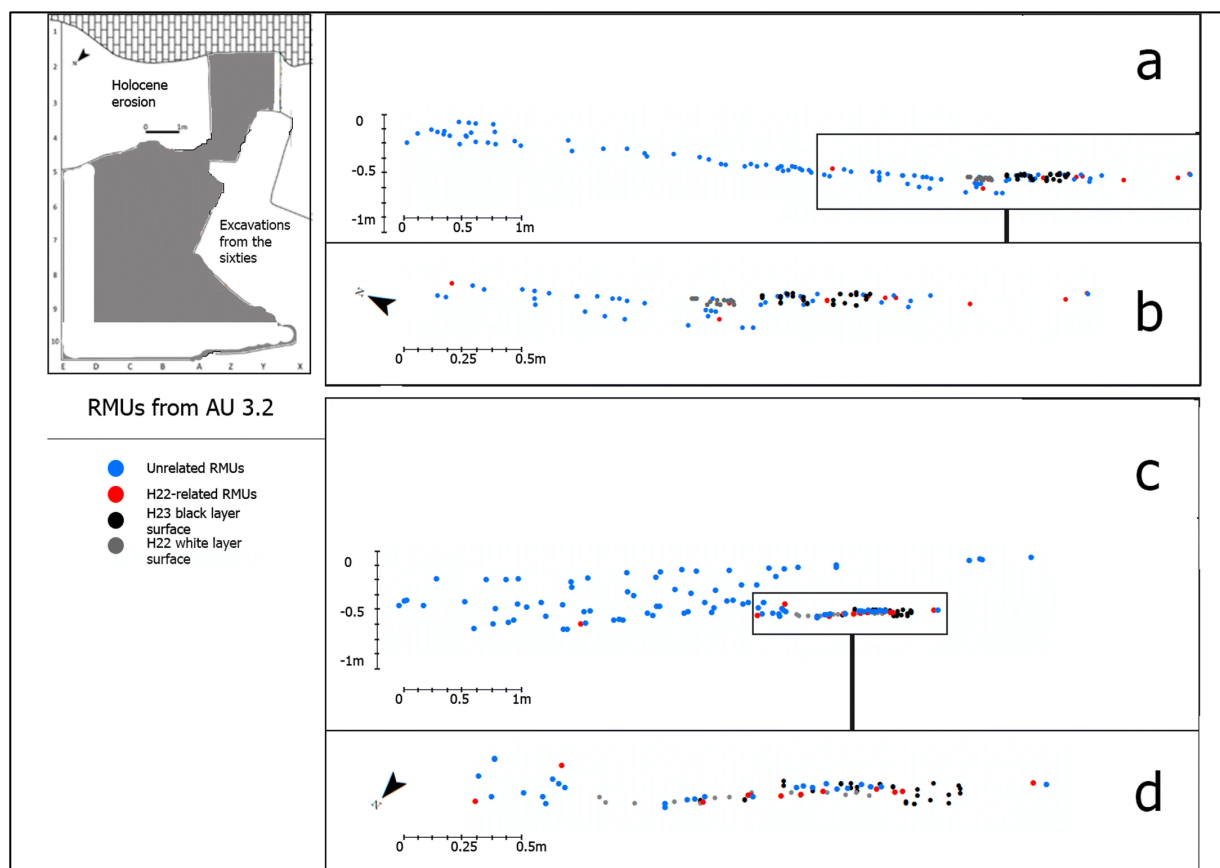


Fig. 2. Distribución espacial de las unidades de materia prima de conjunto relativas a la UA 3.2. y a la 3.2.1 asociada al hogar H22 (Mayor *et al.*, 2020)

En nuestro estudio traceológico, se seleccionaron 69 piezas del total de los 257 objetos integrados en la UA 3.2. Se incluyó material retocado y sin retocar, de distintas dimensiones, teniendo en cuenta los ángulos de los filos potencialmente activos y las características morfológicas de los soportes. En concreto de la UA 3.2 se seleccionaron 42 lascas, 22 raederas, 1 denticulado, 2 fragmentos y 2 núcleos (Tabla 1).

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
3.2	X4.5/695	Lasca	Mariola	34x24x9
	X4.5/53	Lasca	Mariola	60x45x24
	X4.5/460	Lasca	Serreta	26x26x5
	X2/11	Lasca cortical	Serreta	24x15x13
	X5.6/154	Fragmento	Serreta	46x25x14
	X3/2	Lasca cortical	Serreta	17x18x5
	X4.5/502	Núcleo	Font Roja	50x46x36
	UA2/3	Lasca	Serreta	32x32x5
	UA2/42	Raederas doble	Mariola	35x22x6
	X4.5/374	Lasca	Serreta	45x35x7
	X2.3/54	Lasca	Serreta	25x13x4
	X2/15	Lasca	Serreta	21x17x8
	X5.6/235	Lasca	Serreta	30x16x5
	X4.5/572	Lasca	Serreta	28x30x8
	X3/64	Lasca	Mariola	41x35x13
	X2.3/43	Lasca	Mariola	21x18x6
	X4.5/457	Núcleo	Serreta	45x46x16
	X5.6/187	Lasca	Serreta	25x28x6
	X2/8	Lasca	Serreta	23x19x7
	X5.6/204	Lasca	Beniaia	30x27x5
	X4/152	Lasca	Beniaia	37x23x8
	X4/144	Lasca	Beniaia	22x19x9
	X3/89	Lasca	Serreta	34x15x3
	X4.5/54	Lasca	Font Roja	22x19x12
	X5.6/233	Lasca	Serreta	28x18x7
	X2/7	Lasca	Serreta	14x16x4
	X2/25	Lasca	Serreta	27x21x7
	UA2/2	Fragmento	Mariola	19x17x10
	UA2/16	Lasca	Mariola	23x20x7
	X2/26B	Lasca	Serreta	17x22x4
	X2/22	Lasca	Serreta	14x13x3
	UA2/32	Lasca	Beniaia	12x10x2

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
3.2	X2.3/62	Lasca	Serreta	11x13x1
	X2.3/48	Lasca	Serreta	19x11x3
	X4.5/778	Raeder lateral	Beniaia	44x31x8
	X4/207	Raeder lateral	Serreta	30x33x11
	X4.5/456	Raeder lateral	Serreta	63x30x10
	X5.6/62	Lasca	Serreta	34x26x9
	X5.6/175	Raeder transversal	Beniaia	59x43x20
	X5.6/185	Raeder lateral	Serreta	42x28x9
	X4.5/240	Raeder lateral	Serreta	50x22x17
	X4/209	Lasca	Serreta	39x24x11
	X2/33	Lasca	Mariola	62x39x8
	X4/142	Lasca	Beniaia	38x70x10
	X4/208	Denticulado	Mariola	50x39x14
	X4.5/53	Lasca	Serreta	52x37x15
	X4.5/371	Raeder transversal	Serreta	31x20x8
	X4.5/304	Raeder lateral	Mariola	49x31x12
	X5.6/142	Raeder lateral	Serreta	47x24x10
	X4/141	Lasca cortical	Mariola	40x50x14
	X5.6/11	Raeder lateral	Beniaia	42x32x11
	X4/77	Lasca cortical	Beniaia	60x40x11
	X2.3/63	Raeder transversal	Serreta	48x40x18
	X4.5/503	Lasca	Serreta	44x13x14
	X4.5/252	Raeder transversal	Font Roja	29x35x9
	UA2/13	Raeder lateral	Serreta	48x36x11
	X4/206	Raeder lateral	Indeterminada	42x24x7
	X1.2/11	Raeder lateral	Serreta	39x22x5
	X4/154	Raeder lateral	Serreta	54x23x9
	X4.5/206	Raeder lateral	Beniaia	44x30x11
	X3/108	Lasca	Beniaia	44x36x12
	X3/24	Lasca	Mariola	37x29x12
	X5.6/183	Raeder lateral	Indeterminada	42x29x11
	X5.6/186	Raeder lateral	Serreta	44x23x13
	X5.6/232	Lasca	Mariola	51x27x7
	X5.6/119	Raeder lateral	Beniaia	43x30x10
	X2/27	Lasca	Beniaia	38x28x6
	X4/36	Lasca	Serreta	42x46x8
	X4.5/7	Raeder lateral	Beniaia	43x32x10

Tabla 1. Relación de material lítico de unidades de materia prima de conjunto de la UA 3

Por lo que respecta a la UA 3.2.1, cuenta con 13 soportes líticos, de pequeños a grandes, siendo 8 lascas, 4 fragmentos y un núcleo. A continuación, se adjunta la tabla donde se especifica cada material (Tabla 2):

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
3.2.1	X2.3/45	Fragmento	Font Roja	29x12x5
	X1.2/4	Núcleo	Font Roja	52x40x19
	X3/107	Lasca	Serreta	25x20x13
	X2/21	Fragmento	Serreta	23x16x10
	X2/20	Lasca	Serreta	24x23x9
	X3/87A	Lasca cortical	Beniaia	21x19x7
	X3/87B	Fragmento	Beniaia	7x8x4
	X2/17	Fragmento	Mariola	17x13x2
	X4/740	Lasca cortical	Mariola	22x22x10
	X1.2/17	Lasca	Serreta	28x21x5
	X5/978	Lasca	Serreta	18x23x5
	X2/16	Lasca	Beniaia	24x22x4
	X4/629	Lasca	Beniaia	33x15x5

Tabla 2. Relación de material lítico de unidades de materia prima de conjunto de la UA 3.2.1

Material lítico de unidades de materia prima de conjunto de las unidades arqueoestratigráficas 4.1 y 4.1.1 y 4.1.2

Otra de las unidades generadas en la disección de la UE Xa fue 4.1 (Machado *et al.*, 2017). En estudios posteriores se aislaron dos nuevas subunidades: 4.1.1 y 4.1.2. La primera cuenta con 10 soportes líticos y se asocia al hogar H26. La segunda está integrada por 24 soportes y se asocia al hogar H25. Ambos eventos cubren un área de pocos m² (Mayor *et al.*, 2020). 26 piezas líticas no pudieron asociarse a ninguna de las dos subunidades indicadas (Fig. 3).

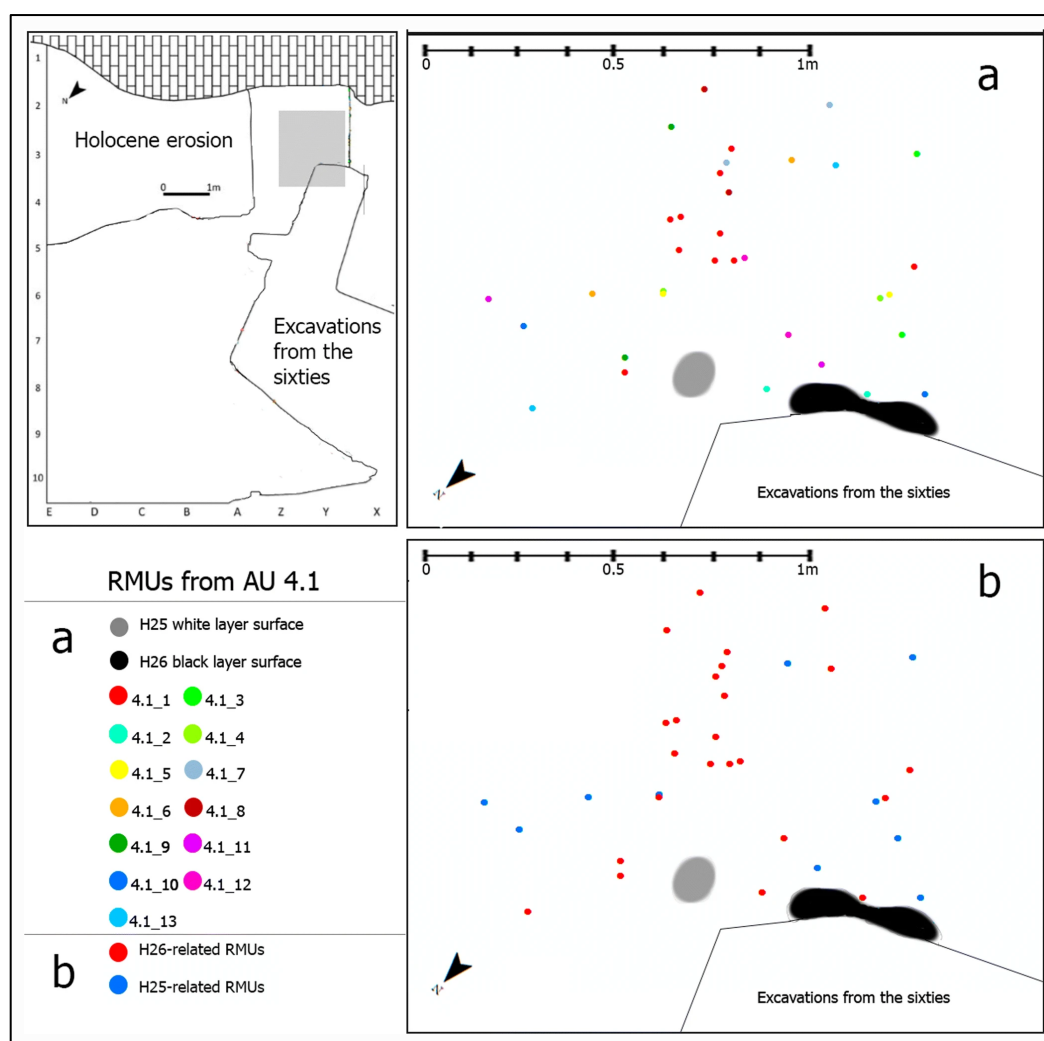


Fig. 3. Distribución espacial de las unidades de materia prima de conjunto relativas a la UA 4.1, la 4.1.1 asociada al hogar H26, y la 4.1.2 asociada al hogar H25 (Mayor *et al.*, 2020)

La UA 4.1 cuenta con un total de 26 soportes líticos, de pequeños a grandes, siendo 20 lascas, 3 fragmentos y 3 núcleos (Tabla 3).

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
4.1	X4/620	Lasca cortical	Serreta	29x27x6
	X4/686	Lasca	Mariola	35x20x4
	X4/708	Núcleo	Serreta	24x30x26
	X4/709	Fragmento cortical	Mariola	31x23x24
	X4/624	Fragmento	Serreta	38x27x14
	X4/676	Lasca cortical	Mariola	23x31x8
	X4/809	Lasca	Mariola	39x23x11
	X3/92	Lasca	Serreta	15x15x3
	X4/639	Lasca cortical	Serreta	25x32x8
	X4/675	Lasca cortical	Serreta	22x26x6
	X4/718	Lasca cortical	Serreta	33x20x7
	X4/814	Lasca cortical	Serreta	32x32x14
	X4/517	Lasca cortical	Serreta	24x25x6
	X4/699	Lasca	Serreta	36x25x8
	X5/311	Lasca	Serreta	28x13x5
	X4/684	Lasca cortical	Mariola	39x20x13
	X2/24	Lasca	Mariola	25x32x4
	X4/667	Lasca fragmentada	Mariola	23x22x5
	X4/808	Núcleo	Mariola	27x36x17
	X4/603	Lasca	Serreta	23x19x3
	X4/694	Núcleo	Serreta	20x25x21
	X4/677	Lasca	Serreta	27x18x4
	X4/642	Lasca	Serreta	23x17x5
	X5/970	Lasca	Serreta	34x17x11
	X5/306	Fragmento	Caliza silícea	20x15x8
	X4/716	Lasca	Serreta	18x14x13

Tabla 3. Relación de material lítico de unidades de materia prima de conjunto de la UA 4.1

Por lo que respecta a la UA 4.1.1, cuenta con 10 soportes líticos, de pequeños a grandes: 7 lascas, 2 núcleos y un fragmento (Tabla 4).

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
4.1.1	X4/736	Lasca	Font Roja	38x35x6
	X4/659	Lasca	Font Roja	35x13x4
	X4/714	Fragmento	Mariola	19x17x6
	X4/678	Núcleo	Mariola	58x48x31
	X4/741	Lasca	Serreta	26x15x5
	X4/738	Lasca	Serreta	27x25x5
	X4/681	Lasca fragmentada	Mariola	27x26x5
	X4/647	Núcleo	Mariola	39x37x14
	X4/728	Lasca	Serreta	32x26x6
	X5/308	Lasca fragmentada	Serreta	31x31x5

Tabla 4. Relación de material lítico de unidades de materia prima de conjunto de la UA 4.1.1

La UA 4.1.2 tiene 24 soportes líticos, de pequeños a grandes, todos pertenecen a la categoría de lascas (Tabla 5).

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
4.1.2	X4/601	Lasca	Mariola	23x17x4
	X4/645	Lasca	Beniaia	43x24x7
	X4/652	Lasca	Serreta	29x24x3
	X4/657	Lasca	Serreta	21x27x5
	X4/680	Lasca	Serreta	29x29x6
	X4/687	Lasca	Serreta	45x45x5
	X4/706	Lasca cortical	Serreta	27x30x4
	X4/710	Lasca cortical	Serreta	14x17x3
	X4/711	Lasca fragmentada	Serreta	7x8x3
	X4/712	Lasca	Serreta	14x16x3
	X4/716	Lasca	Serreta	18x14x3
	X4/717	Lasca cortical	Serreta	22x17x4
	X4/718B	Lasca	Beniaia	38x48x10
	X4/720B	Lasca	Serreta	26x24x5
	X4/721	Lasca	Mariola	29x23x4
	X4/726	Lasca	Serreta	34x22x5
	X4/733	Lasca	Beniaia	33x11x3

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
4.1.2	X4/737	Lasca	Beniaia	20x20x4
	X4/742	Lasca	Serreta	34x21x5
	X4/745	Lasca cortical	Serreta	29x21x5
	X4/748	Lasca	Serreta	23x18x6
	X4/807	Lasca cortical	Serreta	36x37x10
	X4/815	Lasca	Serreta	20x17x5
	X4/816	Lasca cortical	Serreta	25x30x6

Tabla 5. Relación de material lítico de unidades de materia prima de conjunto de la UA 4.1.2

Material lítico de unidades de materia prima de conjunto de la unidad arqueoestratigráfica 5.1

Esta unidad se consideró un evento singular desde los primeros trabajos de disección (Machado *et al.*, 2017), cubriendo un espacio relativamente pequeño de aproximadamente 2 m² y con un registro que se vincula al hogar H28 (Fig. 4)

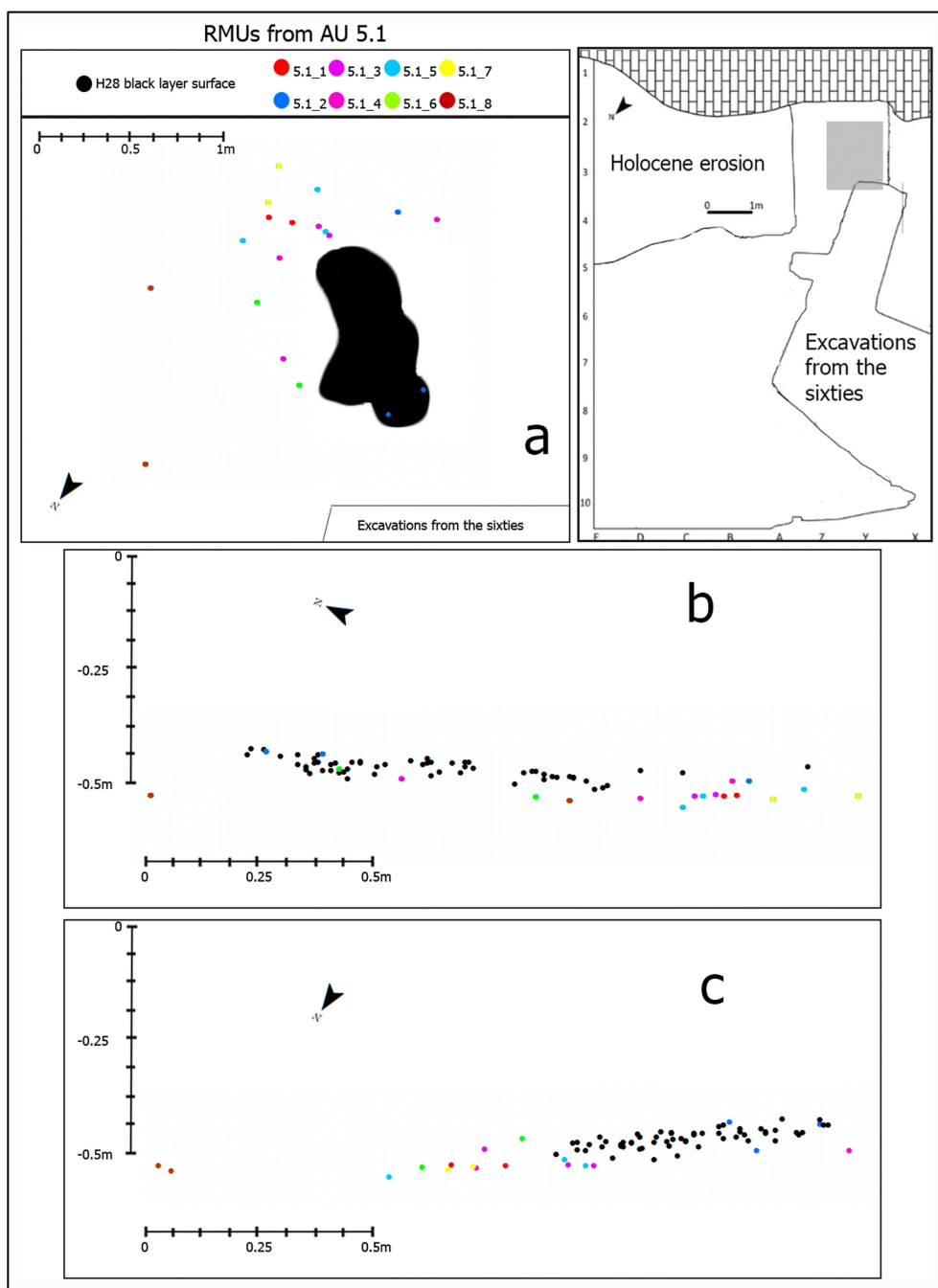


Fig. 4. Distribución espacial de las unidades de materia prima de conjunto relativas a la UA 5.1 asociada al hogar H28 (Mayor *et al.*, 2020).

La UA 5.1. Se compone de 19 piezas líticas, tanto pequeñas como medianas y grandes: 16 lascas, 2 fragmentos y un núcleo (Tabla 6):

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
5.1	X4/615	Lasca	Serreta	21x21x5
	X4/788	Lasca	Serreta	25x20x4
	X5/8	Fragmento	Serreta	23x22x13
	X5/17	Lasca cortical	Serreta	24x23x6
	X5/16	Lasca	Serreta	31x28x10
	X5/7	Fragmento	Serreta	17x16x7
	X4/725	Lasca	Serreta	26x27x7
	X4/754	Lasca	Serreta	32x29x7
	X4/765	Lasca cortical	Serreta	22x21x6
	X4/797	Lasca	Serreta	19x15x4
	X4/774	Lasca	Mariola	26x14x2
	X4/805	Lasca	Mariola	15x18x4
	X4/612	Lasca	Mariola	17x22x3
	X4/747	Lasca	Serreta	25x22x5
	X4/819	Lasca	Serreta	26x14x3
	X5/1549	Núcleo	Mariola	34x27x24
	X5/1500	Lasca	Mariola	23x23x5
	X4.5/849	Lasca	Mariola	19x20x4
	X5/972	Lasca	Mariola	24x15x3

Tabla 6. Relación de material lítico de unidades de materia prima de conjunto de la UA 5.1

Material lítico de unidades de materia prima de conjunto de la unidad arqueoestratigráfica 5.2

En esta unidad, cuenta con 25 piezas asociadas a los hogares H24 y H27. Por falta de indicadores de diacronía, esta unidad sigue manteniéndose como un micropalimpsesto (Fig. 5)

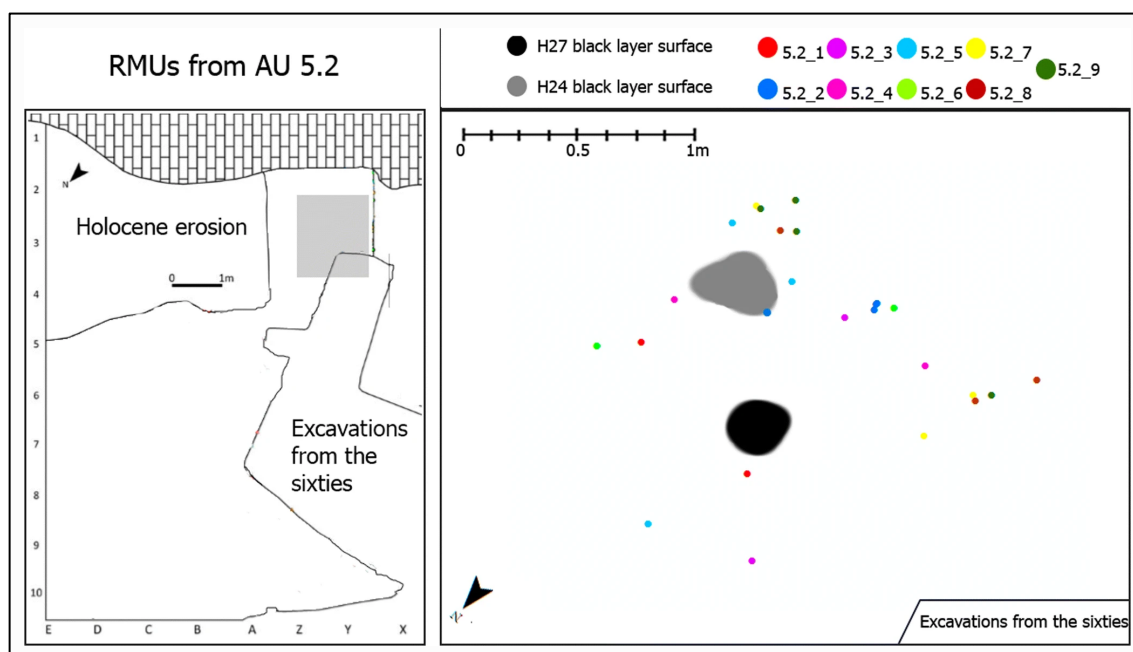


Fig. 5. Distribución espacial de las unidades de materia prima de conjunto relativas a la UA 5.2, asociada a los hogares H24 y H27 (Mayor *et al.*, 2020)

La UA 5.2 se caracteriza por tener piezas desde grandes a pequeñas: 21 lascas, 3 fragmentos y un núcleo (Tabla 7):

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
5.2	X5.6/283	Lasca	Beniaia	29x13x6
	X5/316	Núcleo	Beniaia	36x30x15
	X4/798	Fragmento	Serreta	27x14x8
	X4/799	Lasca	Serreta	14x12x2
	X4/804	Fragmento	Serreta	14x27x3
	X4/604	Lasca	Serreta	21x31x4
	X4/802	Lasca	Serreta	23x18x3
	X5/973	Lasca	Serreta	27x20x7
	X5/217	Lasca	Beniaia	16x10x3
	X4.5/850	Lasca	Beniaia	15x20x3

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
5.2	X4/821	Lasca	Serreta	29x14x5
	X5/1066	Lasca	Serreta	23x13x4
	X5/971	Lasca	Serreta	33x33x10
	X5/314	Lasca	Serreta	21x20x2
	X4/779	Lasca	Serreta	42x37x12
	X5/1070	Lasca	Mariola	19x13x4
	X5/11	Lasca	Mariola	20x15x5
	X5/1319	Lasca	Mariola	21x17x4
	X5/766	Fragmento	Serreta	20x23x11
	X4/606	Lasca	Serreta	20x13x5
	X5/1308	Lasca	Serreta	29x24x11
	X6/17	Lasca cortical	Mariola	52x43x13
	X6/18	Lasca cortical	Mariola	11x21x6
	X6/10	Lasca cortical	Mariola	26x11x6
	X6/5	Lasca cortical	Mariola	19x12x5

Tabla 7. Relación de material lítico de unidades de materia prima de conjunto de la UA

Piezas singulares asociadas a la unidad arqueostratigráfica 4.1

Las piezas singulares asociadas a la unidad estratigráfica 4.1 suman un total de 7. Todas son de gran tamaño y se corresponden con 4 raederas y 3 lascas (Tabla 8):

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
4.1	X4/662	Lasca	Beniaia	34x26x9
	X4/670	Lasca	Beniaia	38x33x5
	X4/671	Raederas lateral	Serreta	36x17x8
	X4/759	Raederas lateral	Serreta	45x35x10
	X4/825	Lasca	Beniaia	33x37x8
	X5/305	Raederas lateral	Beniaia	48x42x4
	X5/310	Raederas lateral	Indeterminado	37x24x9

Tabla 8. Relación de piezas singulares asociadas a la unidad arqueostratigráfica 4.1

Piezas singulares asociadas a la unidad arqueostratigráfica 5.3

Las piezas singulares asociadas a la unidad estratigráfica 5.3 suman un total de 10. Todas ellas son de gran tamaño a excepción de una mediana. En total son 6 lascas, 3 raederas y una lasca-núcleo (Tabla 9)

UA	Signatura	Soporte	Tipo de sílex	Medidas (mm)
5.3.	X6/32	Raederas lateral	Mariola	39x20x13
	X5/769	Lasca cortical	Serreta	31x29x11
	X4/608	Lasca cortical	Serreta	26x28x8
	X5/1061	Raederas lateral	Serreta	41x28x8
	X5/1071	Lasca	Serreta	45x19x6
	X4/786	Raederas lateral	Serreta	49x21x16
	X4/793	Lasca-núcleo	Serreta	32x29x12
	X6.7/11	Lasca	Beniaia	44x35x9
	X4/777	Lasca	Indeterminado	37x27x7
	X5/814	Lasca	Serreta	38x20x4

Tabla 9. Relación de piezas singulares asociadas a la unidad arqueostratigráfica 5.3

3.3 Limpieza del material arqueológico y experimental

Tanto el material arqueológico como experimental se lavó siguiendo un protocolo exhaustivo. En primer lugar, se lavaron las piezas con agua destilada y jabón neutro (Hygenia, Magnum Blue® o Derquim ® LM02 al 2%) en la cubeta de ultrasonidos (Metason 120, Struers) durante unos 10 minutos aproximadamente. Cada material iba contenido en una bolsa de plástico zip para evitar el roce con la propia cubeta o con otros materiales que pudieran estar limpiándose en ese momento. Posteriormente se dejaban secar y se volvían a lavar con acetona, siguiendo el mismo protocolo en la cubeta de ultrasonidos, con tiempos variables en función de la necesidad de cada pieza. Generalmente con este protocolo las piezas quedaban limpias. No obstante, en algunos casos en el que la concreción persistía, se empleó ácido acético al 5%, en lapsos de tiempo muy cortos, de 1 a 5 minutos, para tratar de eliminar la suciedad. También se empleó acetona para eliminar los restos de grasa que pudieran quedarse adheridos a las piezas mientras se estaban manipulando.

3.4. Aparatos de microscopía

Para el análisis traceológico se empleó una lupa binocular Leica Microsystems® M165C, que alcanza los 60 aumentos, y el microscopio metalográfico de luz reflejada Leica Microsystems® DM6000M que alcanza los 500 aumentos. Ambos se localizan en las instalaciones del Departamento de Prehistoria, Arqueología e Historia Antigua de la Universidad de Valencia. También se empleó otro microscopio metalográfico, el Zeiss Axio Scope A1®, que alcanza los 500 aumentos y se localiza Institut Català de Paleoecologia Humana i Evolució Social (IPHES) de Tarragona.

3.5. Análisis traceológico y morfométrico del material lítico

El análisis del material arqueológico se ha realizado desde dos perspectivas: traceológico y morfopotencial. En cuanto a la perspectiva traceológica, se ha analizado el uso de las herramientas con respecto al tipo de materiales trabajados y el tipo de acciones realizadas. También se han analizado las zonas potencialmente prensiles y los posibles signos de enmangue. La inferencia funcional se ha basado en datos experimentales propios, pero también recurriendo a otros estudios de referencia en los que se describen las huellas de uso de cada materia y acción realizada (e.g. Anderson-Gerfaud 1981, 1990; Gutiérrez, 1996; Hayden, 1979; Jardón, 2000; Keeley, 1980; Lemorini 2000; Rots 2011;

Tringham et al., 1974). No obstante, el manual que más se ha consultado ha sido el de González & Ibáñez (1994) *Metodología de análisis funcional de instrumentos tallados en sílex*, ya que se explica de manera muy exhaustiva el tipo de huellas que genera cada materia, prestando la máxima atención tanto a la formación de los pulidos, las melladuras, las estrías y el redondeamiento del borde.

Por lo que respecta a la relación entre morfología y función, se ha realizado un análisis de las piezas con estigmas de uso para tratar de observar posibles relaciones entre la morfología de las piezas, de los filos, ángulos y tamaños con respecto a las materias trabajadas.

3.6. Programa experimental

A lo largo de esta Tesis Doctoral se han llevado a cabo una serie de experimentaciones que sirven de base comparativa a las determinaciones funcionales en el material arqueológico. Por un lado, se realizó un programa experimental en torno a las piezas astilladas (Jardón *et al.*, 2018), por otro lado, una experimentación sobre las huellas de uso generadas por el trabajo sobre madera termoalterada (Bencomo & Jardón, 2022), el cual se explicará en el capítulo siguiente, y finalmente un programa experimental en torno los estigmas derivados del trabajo sobre madera verde y seca y sobre distintos tipos de material animal.

Comenzando por este último, se llevó a cabo un programa experimental tanto mecánico (es decir, repitiendo un movimiento mecánicamente), como replicativo (es decir, tratando de reproducir y completar una actividad). Para ello se emplearon herramientas de dimensiones similares a las arqueológicas, asemejándose a la morfología y ángulos de los bordes. Todos los soportes se realizaron sobre sílex tipo Serreta (Molina, 2016), por ser la variedad más abundante en los marcos analíticos seleccionados.

De manera general, tanto para el trabajo sobre madera como para la materia animal, se llevaron a cabo distintos tipos de acciones, siendo principalmente de corte, serrado, raspado y rebajado. Para ello se llevaron a cabo movimientos longitudinales bidireccionales (para serrar), movimientos longitudinales unidireccionales (para cortar), movimientos transversales negativos con ángulos altos o medios (para raspar) y movimientos transversales positivos con ángulos aproximadamente bajos (para rebajar)

En cuanto a la madera, se utilizó tanto *Pinus nigra* como *Pinus halepensis* en estado seco y verde (Tabla 10) *P. nigra* es el taxón más representativo en el registro antracológico dentro de la secuencia de El Salt (Vidal-Matutano, 2016), de ahí su importancia en el programa experimental. No obstante, también se utilizó *P. halepensis* para evaluar posibles modificaciones en función de la especie arbórea. De forma general, para el trabajo de la madera se llevaron a cabo acciones de raspado (Fig. 6 y 8) y de serrado o corte (Fig. 7). Por otro lado, dada la abundancia de la madera con la que contábamos, fue posible desarrollar dos tipos de experimentos: por un lado, diferentes acciones durante un tiempo limitado y, por otro, diferentes acciones hasta casi agotar las herramientas. En el primer caso, se utilizaron 10 herramientas, cada una de ellas durante 20 minutos, con el fin de controlar el desarrollo de las huellas generadas por diferentes acciones durante el mismo tiempo de uso. Las herramientas restantes se utilizaron durante

un periodo de tiempo más largo, con el fin de analizar la formación de huellas de uso a medida que aumentaba la duración del trabajo.

En cuanto al material animal, se procesó un *Capreolus capreolus* (Tabla 11). Se llevó a cabo el mayor número de acciones posible, sobre todo de corte y raspado, como el despellejado (Fig. 9), el raspado de piel (Fig. 10), el desollado, o el desarticulado (Fig. 11) o. Algunas de estas acciones se basaron en la presencia de huellas de actividades carniceras en el conjunto faunístico de El Salt, como desollamiento, desmembramiento, desarticulación, etc. (Pérez, 2019; Pérez *et al.*, 2020). En cuanto a los tiempos de uso, debido a la limitada disponibilidad de materia animal con la que contábamos, variaron en función de la actividad realizada, pero en general oscilaron en torno a los 50 minutos.

A lo largo de la experimentación, se tuvieron en cuenta las siguientes variables: el tipo de actividad, el ángulo del filo, el movimiento realizado, el ángulo de contacto durante el trabajo, el material sobre el que se realizó el trabajo y el tiempo de utilización. Cabe destacar que el ángulo de trabajo es aproximado, ya que durante el trabajo se adecuó el movimiento y el ángulo a lo largo de la actividad para ganar en eficacia y alcanzar el objetivo. Por lo tanto, no se puede, ni es eficaz, mantener un ángulo constante. Consecuentemente, no podemos relacionarlo con un valor numérico. Según esto, se han establecido 3 tipos de ángulos de trabajo: alto ($>50^\circ$ es decir, el filo dispuesto perpendicular al material que se trabaja), bajo ($<40^\circ$ es decir, el filo dispuesto casi paralelo al material que se trabaja) y medio (entre 40 y 50°) En este sentido, el ángulo de trabajo y el tipo de movimiento (longitudinal o transversal) determinan la distribución y orientación de los desgastes de uso.

Las herramientas experimentales se analizaron antes y después de utilizarlas, estableciendo puntos de control para observar *a posteriori* las deformaciones que se producían. Antes de su uso, también se realizaron moldes del borde de las herramientas, con resina (Light Body, Schmidt) para poder analizar el borde original en caso necesario.

Nº de pieza	Tipo de sílex	Ángulo del filo	Acción	Movimiento	Ángulo de contacto	Material trabajado	Especie	Tiempo de trabajo
1	Serreta	40°	Serrar	Longitudinal bidireccional	Alto	Madera verde	<i>Pinus halepensis</i>	15 min
2	Serreta	45°	Rebajar	Transversal positivo	Bajo	Madera verde	<i>Pinus halepensis</i>	2 horas, 10 min
3	Serreta	40°	Serrar	Longitudinal bidireccional	Alto	Madera verde	<i>Pinus halepensis</i>	1 hora, 15 min
4	Serreta	70°	Raspar	Transversal negativo	Alto	Madera verde	<i>Pinus halepensis</i>	3 horas
5	Serreta	50°	Serrar	Longitudinal bidireccional	Alto	Madera semiseca	<i>Pinus halepensis</i>	1 hora, 50 min
6	Serreta	60°	Rebajar	Transversal positivo	Bajo	Madera semiseca	<i>Pinus halepensis</i>	2 horas, 3 minutos
7	Serreta	55°	Raspar	Transversal negativo	Alto	Madera seca	<i>Pinus halepensis</i>	2 horas
19	Serreta	60°	Serrar	Longitudinal bidireccional	Alto	Madera verde	<i>Pinus nigra</i>	20 min
17	Serreta	45°	Rebajar	Transversal positivo	Bajo	Madera verde	<i>Pinus nigra</i>	20 min
20	Serreta	50°	Raspar	Transversal negativo	Alto	Madera verde	<i>Pinus nigra</i>	20 min
16	Serreta	45°	Serrar	Longitudinal bidireccional	Alto	Madera verde	<i>Pinus halepensis</i>	20 min
14	Serreta	40°	Rebajar	Transversal positivo	Bajo	Madera verde	<i>Pinus halepensis</i>	20 min
18	Serreta	40°	Raspar	Transversal negativo	Medio	Madera verde	<i>Pinus halepensis</i>	20 min
26	Serreta	50°	Cortar	Longitudinal unidireccional	Alto	Madera seca	<i>Pinus nigra</i>	20 min
27	Serreta	50°	Serrar	Longitudinal bidireccional	Alto	Madera seca	<i>Pinus halepensis</i>	20 min
28	Serreta	45°	Rebajar/raspar	Transversal positivo y negativo	Alto y bajo	Madera seca	<i>Pinus nigra</i>	20 min
29	Serreta	50°	Rebajar/raspar	Transversal positivo y negativo	Alto y bajo	Madera seca	<i>Pinus halepensis</i>	20 min

Tabla 10. Relación de material experimental involucrado en el trabajo de la madera

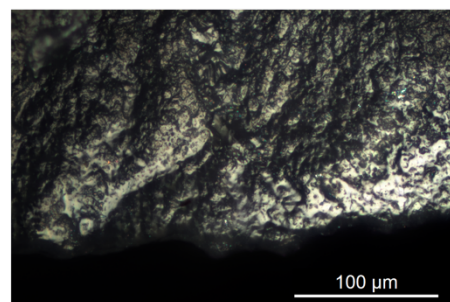
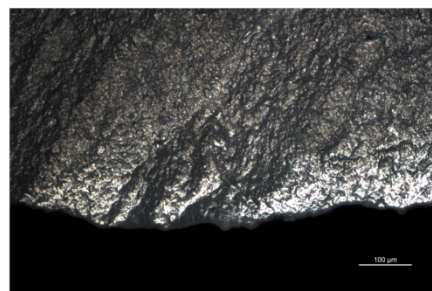
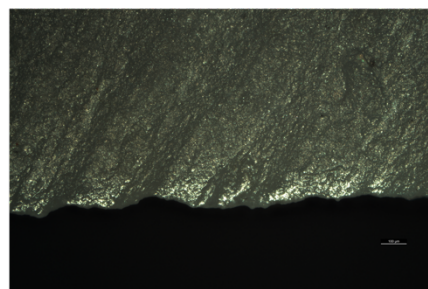
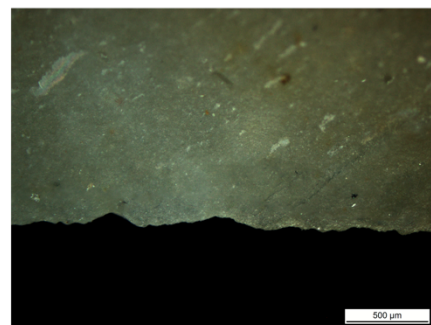


Fig. 6. Pieza 4, en una acción de raspado de *Pinus halepensis*. A) Huellas de uso en la cara dorsal a 50x, B) Huellas de uso en la cara ventral a 100x, 200x y 500x.

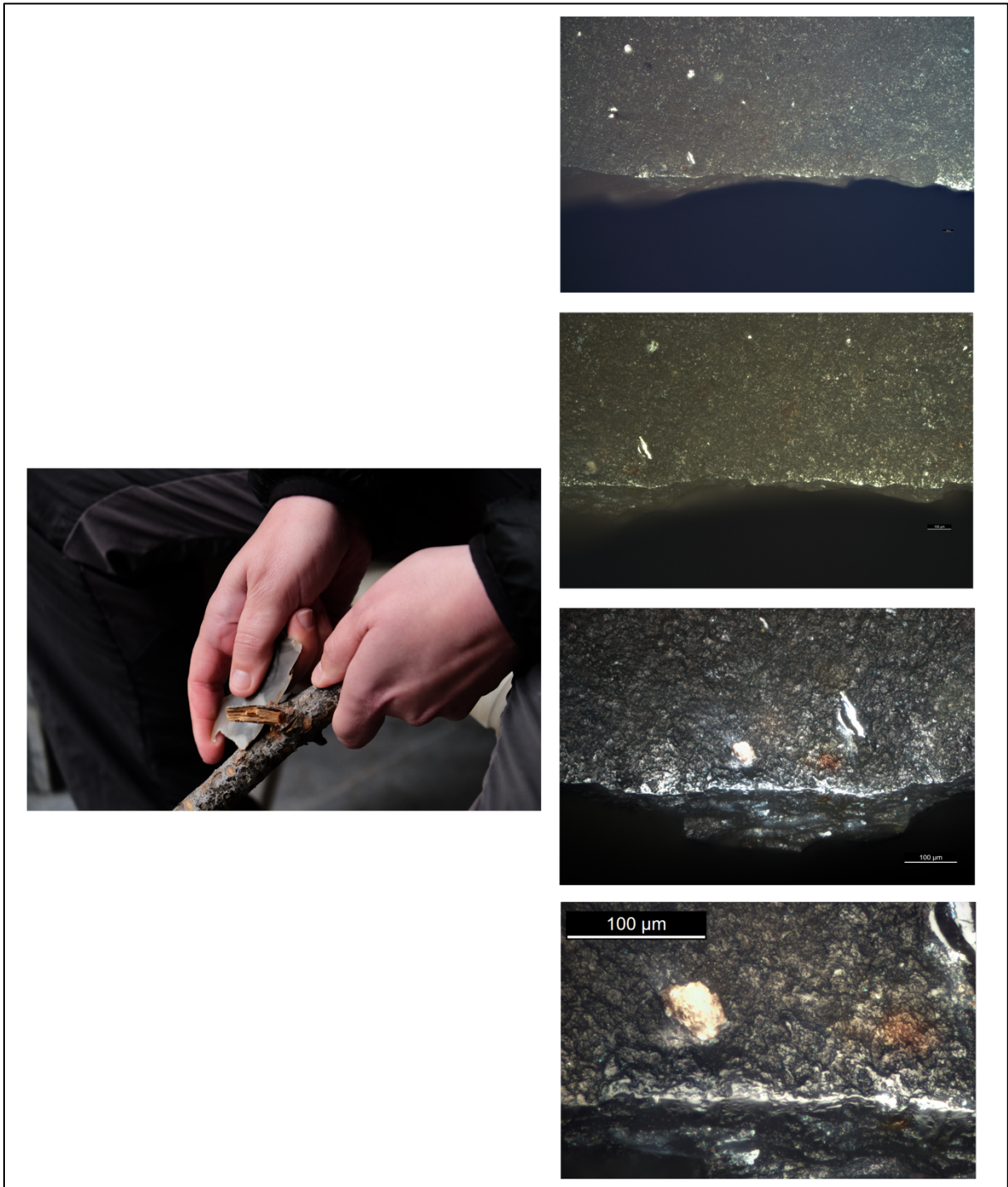


Fig. 7. Pieza 26 en una acción de corte de *Pinus nigra*. A-B) Huellas de uso en la cara ventral a 50x, 100x, 200x y 500x.

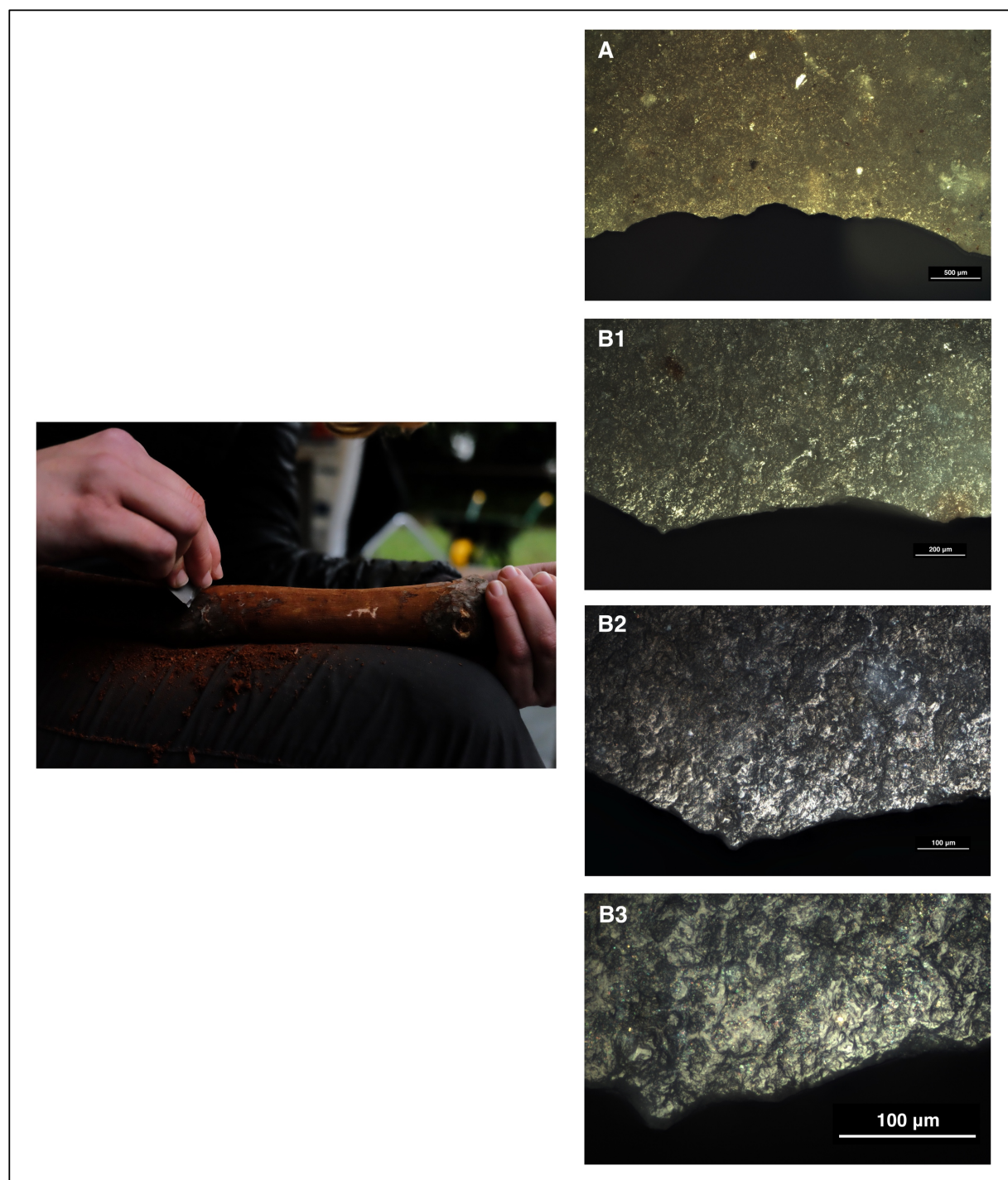


Fig. 8. Pieza 29 en una acción de raspado y rebajado sobre *Pinus halepensis*.
 A) Huellas de uso en la cara dorsal a 50x, B) Huellas de uso en la cara ventral a 100x, 200x y 500x.

Nº de la pieza	Tipo de sílex	Ángulo del filo	Acción	Movimiento	Ángulo de contacto	Material trabajado	Especie	Tiempo de trabajo
8	Serreta	40°	Cortar	Longitudinal unidireccional	Bajo	Carne, tendones y hueso	<i>Capreolus capreolus</i>	60 min
9	Serreta	35°	Cortar	Longitudinal unidireccional	Alto	Carne, tendones y hueso	<i>Capreolus capreolus</i>	22 min
10	Serreta	20°	Cortar	Longitudinal unidireccional	Alto y bajo	Carne, tendones y hueso	<i>Capreolus capreolus</i>	40 min
11	Serreta	20°	Raspar	Transversal negativo	Alto	Carne y hueso	<i>Capreolus capreolus</i>	40 min
12	Serreta	45°	Raspar	Transversal negativo	Alto	Hueso	<i>Capreolus capreolus</i>	7 min
13	Serreta	20°	Cortar	Longitudinal unidireccional	Alto	Piel fresca	<i>Capreolus capreolus</i>	40 min
15	Serreta	25°	Cortar	Longitudinal unidireccional	Alto y bajo	Carne, tendones y hueso	<i>Capreolus capreolus</i>	15 min
21	Serreta	70°	Cortar	Longitudinal unidireccional	Alto	Carne, tendones y hueso	<i>Capreolus capreolus</i>	1 hora, 5 min
22	Serreta	50°	Cortar	Longitudinal unidireccional	Alto	Carne, tendones y hueso	<i>Capreolus capreolus</i>	1 hora, 15 min
23	Serreta	55°	Cortar	Longitudinal unidireccional	Alto	Piel y carne	<i>Capreolus capreolus</i>	20 min
23	Serreta	55°	Cortar	Longitudinal unidireccional	Alto	Piel y carne	<i>Capreolus capreolus</i>	1 hora, 40 min
24	Serreta	80°	Cortar	Longitudinal unidireccional	Alto y bajo	Piel y carne	<i>Capreolus capreolus</i>	1 hora, 40 min
25	Serreta	70°	Rebajar	Transversal positivo	Bajo	Piel seca	<i>Capreolus capreolus</i>	3 horas
30	Serreta	65°	Raspar	Transversal negativo	Alto	Piel seca	<i>Capreolus capreolus</i>	20 min
31	Serreta	60°	Serrar	Longitudinal bidireccional	Alto	asta	<i>Capreolus capreolus</i>	25 min
32	Serreta	60°	Raspar	Transversal negativo	Alto	asta	<i>Capreolus capreolus</i>	20 min

Tabla 11. Relación de material experimental involucrado en trabajo sobre materia animal

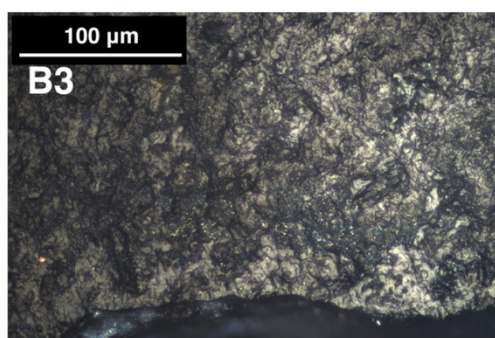
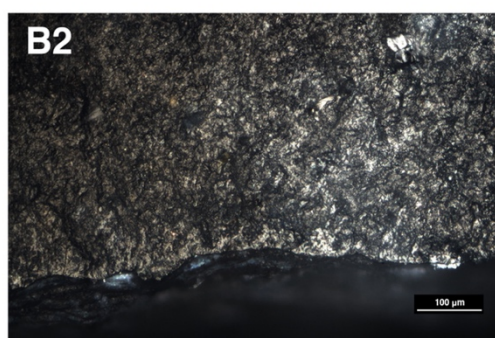
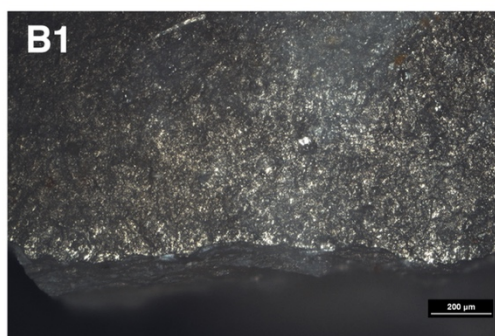
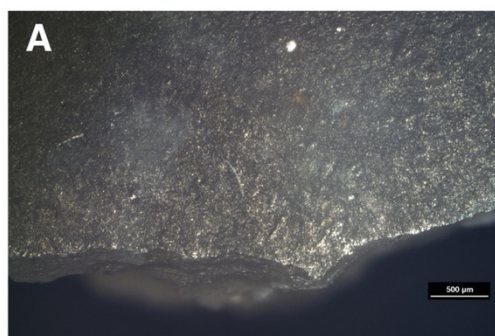


Fig. 9. Pieza 24, en una acción de corte sobre *Capreolus capreolus*. A-B) Huellas de uso en la cara dorsal a 50x, 100x, 200x y 500x.

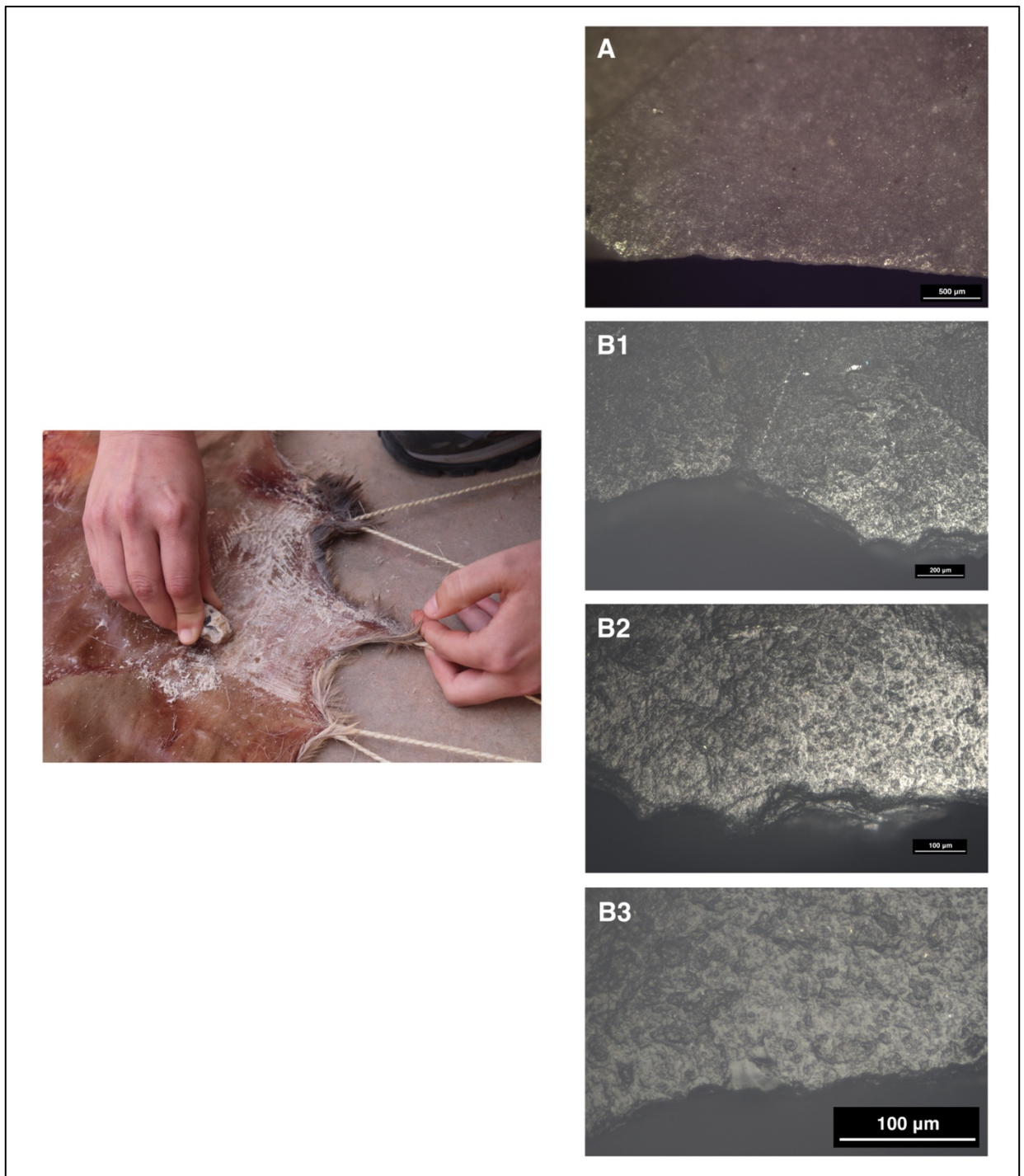


Fig. 10. Pieza 25, en una acción de rebajado de piel seca de *Capreolus capreolus*. A) Huellas de uso en la cara dorsal a 50x, B) Huellas de uso en la cara ventral a 100x, 200x y 500x.

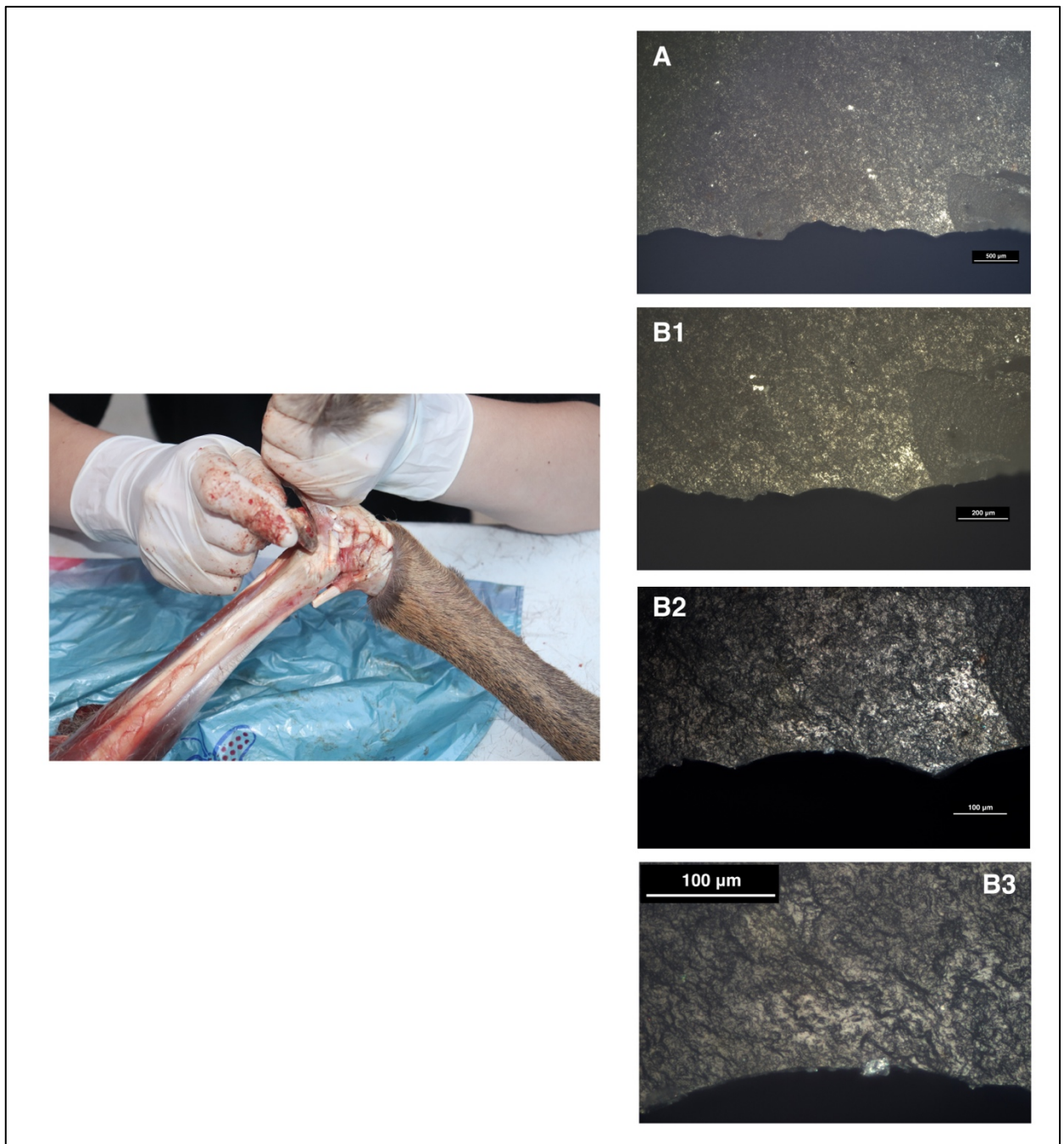


Fig. 11. Pieza 22, en una acción de corte sobre *Capreolus capreolus*. A-B) Huellas de uso en la cara ventral a 50x, 100x, 200x y 500x.

3.7. Using Fire for Woodworking: An Experimental Exploration of Use-Wear on Lithic Tools

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Using Fire for Woodworking: An Experimental Exploration of Use-Wear on Lithic Tools

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ABSTRACT

Throughout prehistoric times, woodworking was an essential activity. We know this because of the existence of preserved wooden objects, as well as the use-wear traces recorded on lithic tools. In general terms, functional studies and experimental programs have aimed to analyze and understand the use-wear traces generated by green and dry wood. However, some of the wood remains preserved across time show signs of thermal alteration caused by fire. For this reason, we have carried out an experimental program in which green, dry and thermoaltered wood have been worked in order to study the traces generated on the lithic tools. The results show significant differences between the use-wear traces generated by green and dry woods, and thermally altered wood. This indicates that it would be possible to recognize signs of work with thermoaltered wood on archaeological lithic tools and, therefore, to better understand the working processes of past populations.

KEYWORDS

Use-wear analysis; experimental archaeology; woodworking; thermal alteration; lithic tools

Introduction

Wood has played an important role in the productive processes of human groups throughout prehistory. It has been used both as fuel and as raw material for the manufacturing of objects. However, the low number of well-preserved wooden remains of ancient times limits our knowledge regarding the type of objects created using this material, as well as the actions carried out in the manufacturing processes (e.g. Aranguren et al., 2018; Carbonell & Castro-Curel, 1992; Corchón Rodríguez, 1999; Gaspari et al., 2011; Rios-Garaizar et al., 2018; Thieme, 1997).

Because of this, it is often necessary to resort to the functional analysis of lithic tools in order to know more about the working actions of wooden materials. In this sense, there is a great number of use-wear studies which demonstrate the presence of woodwork in many archaeological sites (e.g. Anderson-Gerfaud, 1981, 1990; Beyries, 1987; Beyries & Hayden, 1993; Claud et al., 2013; Jardón & Bosquet, 1999; Lemorini, 2000; Martínez, 2005; Tyldesley & Bahn, 1983). These studies are of the utmost importance since they allow us to have more information about the type of tools involved in different tasks, as well as the actions carried out with them (Bencomo et al., 2020).

Alongside these functional studies on archaeological material, a great number of experimental programs include woodworking (e.g. González & Ibáñez, 1994; Keeley, 1980; Semenov, 1964; Tringham et al., 1974; Vaughan, 1985), some of which perform very specific actions or even entire processes (e.g. Claud, 2015; Claud et al., 2013; González & Ibáñez, 1996; Laborda, 2010; Martín, 2015). Generally speaking, these experimental programs have taken dry or green wood as the basis for their analysis, except in some cases (e.g. Gutiérrez, 1996), in which thermoaltered wood has also been included without specific attention to the use-wear traces generated when working this type of wood. In the same line and taking into account some remains of thermally modified wood associated with ancient chronological data, an experimental program has been carried out on this matter in order to acquire a deeper knowledge of these kinds of use-wear traces and compare them to those existing on both green and dry wood samples.

Using fire for woodworking in prehistoric times

We are currently aware of the use of fire for woodworking thanks to the state of preservation of some remains.

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Some of the oldest ones were located in the archaeological site of Poggetti Vecchi (Italy), aged approximately to 171Ky BP, and included 39 wooden pieces, with cutting and striation marks produced by tools, with evidence of traces of thermal modification processes to ease scraping actions (Aranguren et al., 2018). Three other pieces belonging to a 2 m-long spear aged to 125Ky BP were also found in Lehringen (Germany), including a conical tip thermally modified with the purpose of hardening the surface (Movius, 1950; Thieme & Veil, 1985). Another piece classified as a digging stick aged to 90Ky BP was located in Aranbaltza III (Spain), whose thermal modification traces indicate the use of fire to facilitate the scraping and hardening of surfaces (Rios-Garaizar et al., 2018).

Although only a few wooden remains present thermal modification evidence, they are very significant in prehistoric times, especially if we contemplate the total number of wooden remains preserved. That is why we need to consider the possibility of fire being used during the work of wooden tools. Some ethnographic references support this hypothesis (e.g. Thomson, 1964; Gould, 1970; Vincent, 1985; McGuire & Stevens, 2017).

All this has led to the appearance of experimental programs on thermally modified wood (López-Bultó et al., 2020; Revedin et al., 2019), whose goal has been to analyze working traces on wooden supports to compare them with archaeological remains, thus allowing us to know more about working processes. Nonetheless, there is not much information about the use-wear traces generated on the lithic tools used in work processes. With this research we aim to analyze the use-wear evidence of thermal modifications during woodworking from a functional point of view, comparing it to that of dry and green wood. Our ultimate goal is to improve archaeological interpretations of prehistoric woodworking processes.

Materials and methods

Three types of wood were used throughout the experimental program: *Pinus halepensis* (aleppo pine), *Pinus nigra* (black pine) and *Taxus baccata* (yew) in their green, dry and thermally altered states. We have selected pine because of its representation as charcoal in some Palaeolithic archaeological record (e.g. Allué et al., 2017; Desprat et al., 2015; Théry-Pariset & Texier, 2006; Vidal-Matutano, 2018), and yew because many of the wooden objects found in Palaeolithic sites are made from this type of wood (e.g. Oakley et al., 1977; Rios-Garaizar et al., 2018; Thieme & Veil, 1985).

The length of the branches varies between 50 cm and 1 m, as well as their diameters, between 2 and 7 cm. In

order to perform wood debarking and sharpening, whittling and scraping actions were carried out. The purpose of focusing only these two actions was to control this variable and assign the differences between use-wear traces to the state of the wood and not to the actions performed. However, it is depending on the state of the wood (specifically the thermally modified one), that more importance has been given to scraping rather than whittling actions, since the physical conditions of wood required this type of action in order to achieve an optimal result.

The total number of tools used was 19. Woodworking was done using Serreta (cf. Molina et al., 2016) and Spiennes (cf. Collet et al., 2014) flint types. The edges of the tools were straight or concave with angles comprising between 40° and 60° mostly. The tool size varies, but they had to be big enough to be handheld.

Most of the research was carried out by the same person, thus the intensity and strength of the tool-user constitute variables that were stable throughout the whole experimental program.

Description of use-wear traces

The description of use-wear traces was made using the terminology proposed by other use-wear analysts (e.g. González & Ibáñez, 1994; Kamminga et al., 1979; Keeley, 1980; Plisson, 1985; Tringham et al., 1974; Vaughan, 1985). Scars, polish, edge-rounding, and striations are described.

Cleaning of tools and use of microscopy

Overall, all the edges used were observed prior to and after the action in order to analyze the traces originated by their use. Microscopic observation was carried out using a Leica Microsystems® M165C stereomicroscope at 3.65–60X, and a Leica Microsystems® DM6000M metallographic microscope at 50–500X.

Lithic tools were generally washed using lukewarm water and mild soap (Hygenia, Magnum Blue). When dirt remained, the tools were cleaned in the ultrasonic cleaner (Metason 120, Struers), using a solution of mild soap, for a limited time (15 min to 1 h). Occasionally, more aggressive methods had to be used, such as acetone or a solution of acetic acid at 5%. Acetone was also used when the area of the tools under study was covered in grease due to constant handling.

For the tools used in thermally modified woodworking, the cleaning process was more difficult due to the presence of charcoal embedded in the edges. In this case, the tools had to be immersed in water for several days so the charcoal could be easily detached.

Table 1. Tools involved in the experimental program on green wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movement		Contact angle	Wood	Working time (minutes)
1	Spiennes	45°	Whittling	Positive	Transversal	Medium/low	<i>Pinus halepensis</i>	40 min
2	Spiennes	70°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	40 min
3	Serreta	45°	Whittling	Positive	Transversal	Medium/low	<i>Pinus nigra</i>	20 min
4	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	20 min
5	Serreta	40°	Whittling	Positive	Transversal	Medium/low	<i>Pinus halepensis</i>	20 min
6	Serreta	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	20 min

Experimental program

We will next describe the experimental program carried out in detail.

Green woodworking

Six tools were used in the woodworking with green wood: four made on Serreta flint type and two made on Spiennes flint type. Four of them were used on *Pinus halepensis* and two on *Pinus nigra*. Three tools

were used in the whittling process in order to perform the debarking of the logs. Another three tools carried out scraping actions to obtain the sharpening of wood. Working times have also varied between some pieces being used for 20 min and other pieces being used for 40 (Table 1, Figure 1).

Dry woodworking

As for the woodworking with dry wood, four tools were used: two made on Serreta flint type and two on



Figure 1. Experimental program on green wood. (A) *P. halepensis* and *P. nigra* used during the experimentation; (B) tool made on Serreta flint type whittling *P. nigra*; (C) tool made on Spiennes flint type whittling *P. halepensis*; (D) location of residues produced during the whittling of *P. halepensis*; (E) tool made on Spiennes flint type scraping *P. halepensis*; (F) location of residues produced during the scraping of *P. halepensis*.

Table 2. Tools involved in the experimental program on dry wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movement	Contact angle	Wood	Working time (minutes)
7	Spiennes	60°	Whittling	Positive	Transversal	<i>Pinus halepensis</i>	40 min
8	Spiennes	55°	Scraping	Negative	Transversal	<i>Pinus halepensis</i>	40 min
9	Serreta	45°	Scraping	Negative	Transversal	<i>Pinus nigra</i>	20 min
10	Serreta	50°	Scraping	Negative	Transversal	<i>Pinus halepensis</i>	20 min

Spiennes flint type. Three tools were used for the work of *Pinus halepensis* and one for *Pinus nigra*. Due to the physical conditions of dry wood, two different processes were performed. On the one hand, two tools were selected, one used for whittling, and the other for scraping. The remaining two tools were used for scraping, achieving debarking and sharpening in the same action. Working times have also varied between 20 and 40 min (Table 2, Figure 2).

Thermally modified woodworking

A total of nine pieces were used for this type of woodworking: five made on Serreta flint type and four on Spiennes flint type. Four tools were used for the work

of *Pinus halepensis*, two for *Pinus Nigra*, two for *Taxus Baccata* and one for *Pinus Nigra* and *Taxus Baccata*. The majority of the tools involved were used in scraping actions, simultaneously obtaining debarking and sharpening thanks to the easy detachment of charred bark after thermally modifying the wood. Working times varied around 25 min, although some were used for 40 min (Table 3, Figure 3).

For the process of thermal modification of wood, a fueling combustion structure was created. The flame was controlled by thermocouples, so we know that the temperatures were in a range between 400°C and 500° C. The wood, which was previously dry, was exposed to fire for short periods of time, between 5 and 10 min



Figure 2. Experimental program on dry wood. (A) *P. halepensis* and *P. nigra* used during the experimentation; (B) tool made on Serreta flint type scraping *P. nigra*; (C) tool made on Spiennes flint type whittling *P. halepensis*; (D) location of residues produced during the whittling of *P. halepensis*; (E) tool made on Spiennes flint type scraping *P. halepensis*; (F) location of residues produced during the scraping of *P. halepensis*.

Table 3. Tools involved in the experimental program on thermoaltered wood: flint type, edge angle, action, movement, contact angle and working time.

Tool ID	Flint type	Edge angle	Action	Movimiento		Contact angle	Wood	Time
11	Serreta	60°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	20 min
12	Serreta	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	20 min
13	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	25 min
14	Serreta	55°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	25 min
15	Spiennes	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus nigra</i>	40 min
16	Spiennes	50°	Whittling	Positive	Transversal	Low	<i>Pinus Nigra</i> and <i>Taxus baccata</i>	15 min
17	Spiennes	50°	Whittling	Positive	Transversal	Low	<i>Taxus baccata</i>	8 min
18	Spiennes	40°	Scraping	Negative	Transversal	Medium/high	<i>Pinus halepensis</i>	12 min
19	Serreta	50°	Scraping	Negative	Transversal	Medium/high	<i>Taxus baccata</i>	18 min

depending on the thickness and resistance of the area to be worked upon. The aim of this was to thermally modify the outer area exclusively, preventing wood from

igniting, so the use of fire had to be carefully monitored. The working method consisted of thermally modifying the outer surface of wood and then whittling and



Figure 3. Experimental program on thermoaltered wood. (A) *P. halepensis*, *P. nigra* and *Taxus baccata* used during the experimentation; (B) heating *Taxus baccata* in the combustion structure; (C) tool made on Spiennes flint type scraping *P. nigra*; (D) tool made on Spiennes flint type scraping *P. halepensis*; (E-F) tool made on Serreta flint type scraping *Taxus baccata*.

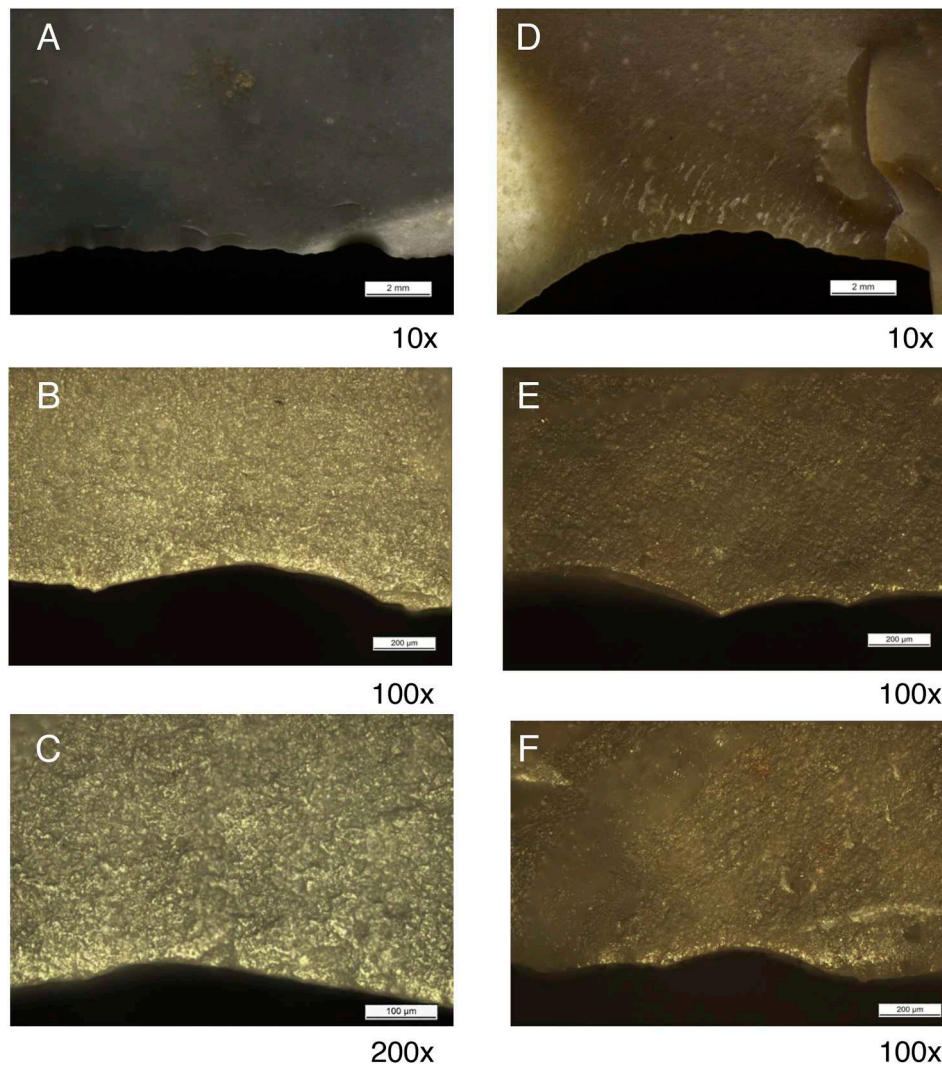


Figure 4. Use-wear traces of green woodworking. (A–C) tool 1 made on Spiennes flint type after whittling *P. halepensis* for 40 min at 10x, 100x and 200x; (D–F) Tool 6 made on Serreta flint type after scraping *P. halepensis* for 20 min at 10x, 100x and 100x.

scraping the surface using flint tools. This process was repeated until smooth and uniform surfaces were obtained.

Results

After carrying out the experimental program, we have observed significant differences between use-wear traces on tools used to work green, dry and thermally modified wood, regardless of the tree species and the type of flint used. The results are therefore presented according to each of the states in which wood is presented. Since scraping is the most common action, mainly on thermally modified seasoned wood, we have particularly examined the use-wear traces resulting from this action. The written description is supported by graphic evidence to provide a better understanding

(Figures 4–9) and tables where the information has been synthesized (Tables 4–6).

Green wood

- Starting with the scars, they have a continuous distribution although in some cases it is discontinuous. The organization is aligned, but in some cases it is superimposed. In general they have a semi-circular morphology and a feather termination. In terms of size, they are small or medium (0.3–1 mm).
- The edge-rounding is weak-average, depending on the time of use.
- The polish is bright, with a rough texture (peaks are altered) and the topography of the peaks is domed. The density is intermediate and the contour tends

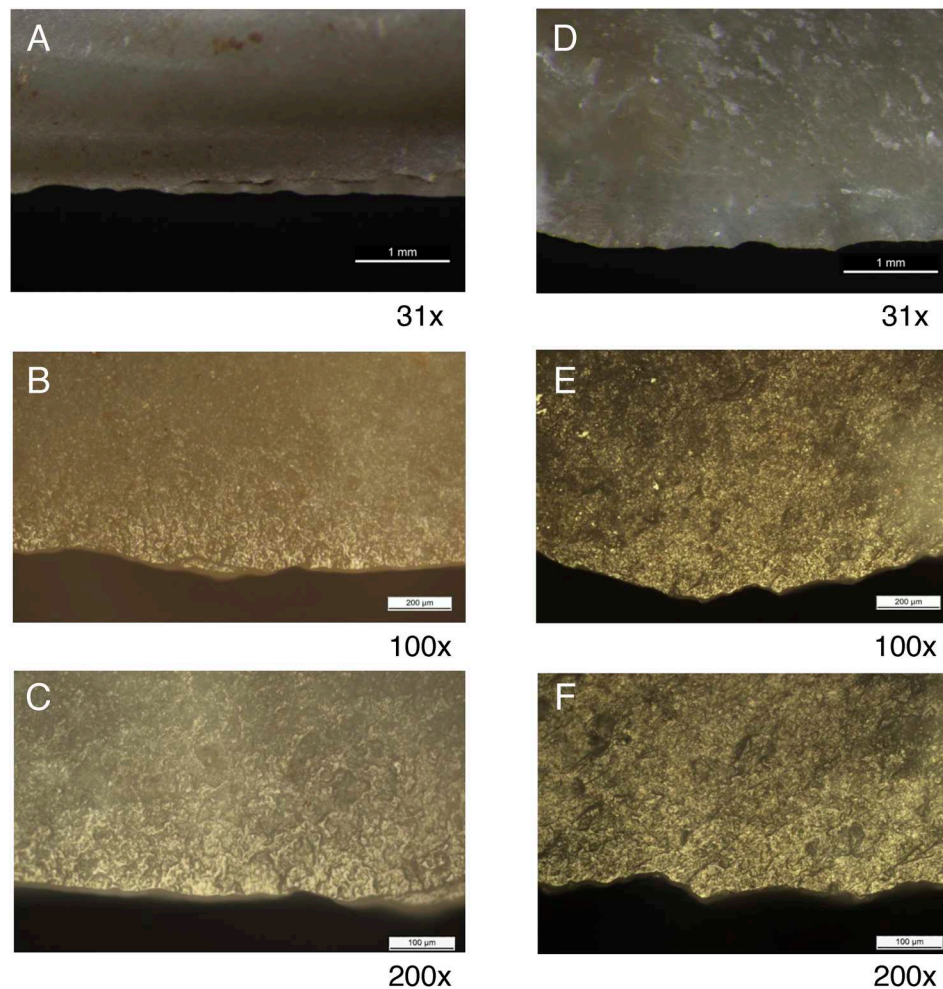


Figure 5. Use-wear traces of dry wood. (A–C) tool 8 made on Spiennes flint type after scraping *P. halepensis* for 40 min at 31x, 100x and 200x; (D–F) tool 9 made on Serreta flint type after scraping *P. nigra* for 20 min at 31x, 100x and 200x.

to be sharp. As for the extension, it is marginal (0.1 mm).

- The striations, with a parallel organization between them and a perpendicular orientation in relation to the edge, have a fine width (< 2 microns), medium length (50–150 microns) and shallow depth.

Dry wood

- The distribution of the scars is continuous. The organization is aligned although in some cases it is superimposed. The aligned ones tend to be semi-circular with a feather termination, and the superimposed ones tend to be quadrangular with a step termination. In general, they have a medium size, except for some cases in which they are small (0.3–1 mm).
- The edge-rounding is weak-average, depending on the time of use.

- The polish is well-developed and bright. The texture is rough (peaks are altered) but tends to be smooth at the edge, and the topography is domed. The polish is dense and the contour tends to be sharp. The extension is marginal (0.1–0.2 mm).
- The striations, with a parallel organization between them and perpendicular orientation regarding the edge, have a fine width (< 2 microns) and medium length (50–150 microns). They are frequent and deep.

Thermoaltered wood

- The distribution of the scars is continuous. The organization is aligned although in some cases it is superimposed. The aligned ones tend to be semi-circular with a feather termination, and the superimposed ones tend to be quadrangular or irregular with a step termination. In general, they have a small or medium size (0.2–1 mm).

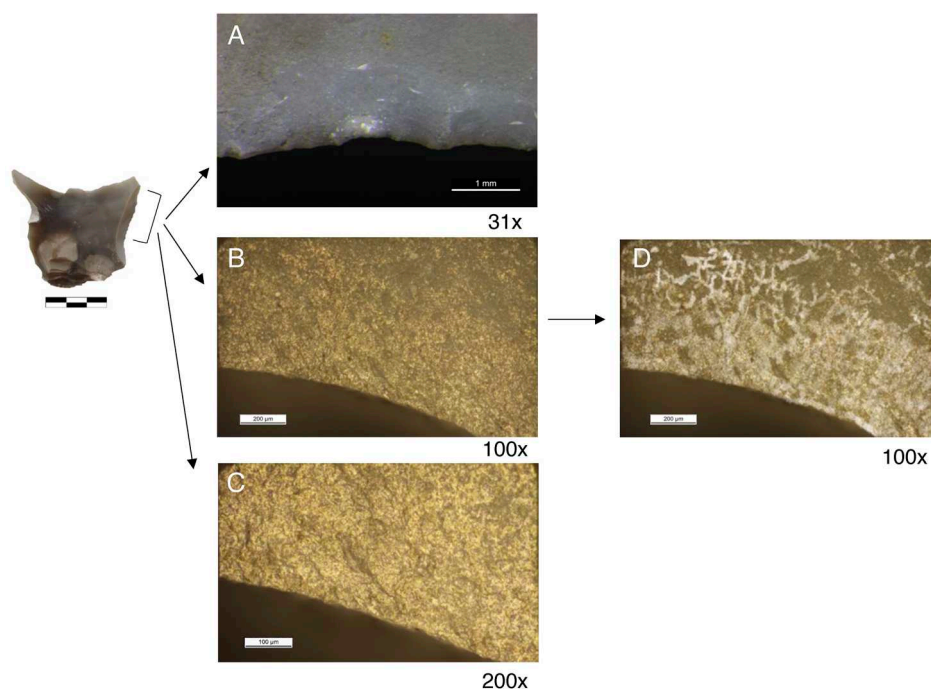


Figure 6. Use-wear traces on tool 15 after scraping thermoaltered *P. nigra* for 40 min. (A) at 31x; (B) at 100x; (C) at 200x; (D) drawing on photograph indicating use-wear traces.

- The edge-rounding is weak-average, depending on the time of use.
- The polish tends to be dull. The texture is rough (but peaks are not very altered) and the topography is domed. The density of the polish is intermediate, but in some cases is dense, and the contour tends to be fuzzy. The extension is moderate-invasive (0.2–0.6 mm).
- The striations, with a parallel organization between them and perpendicular orientation in relation to

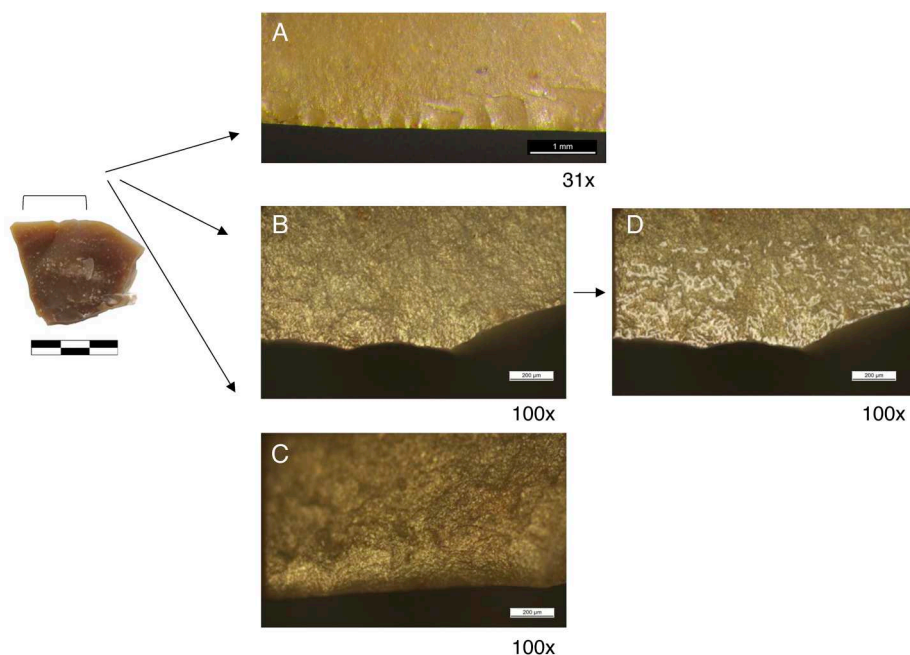


Figure 7. Use-wear traces on tool 11 after scraping thermoaltered *P. halepensis* for 20 min. (A) a 31x; (B) at 100x; (C) at 100x; (D) drawing on photograph indicating use-wear traces.

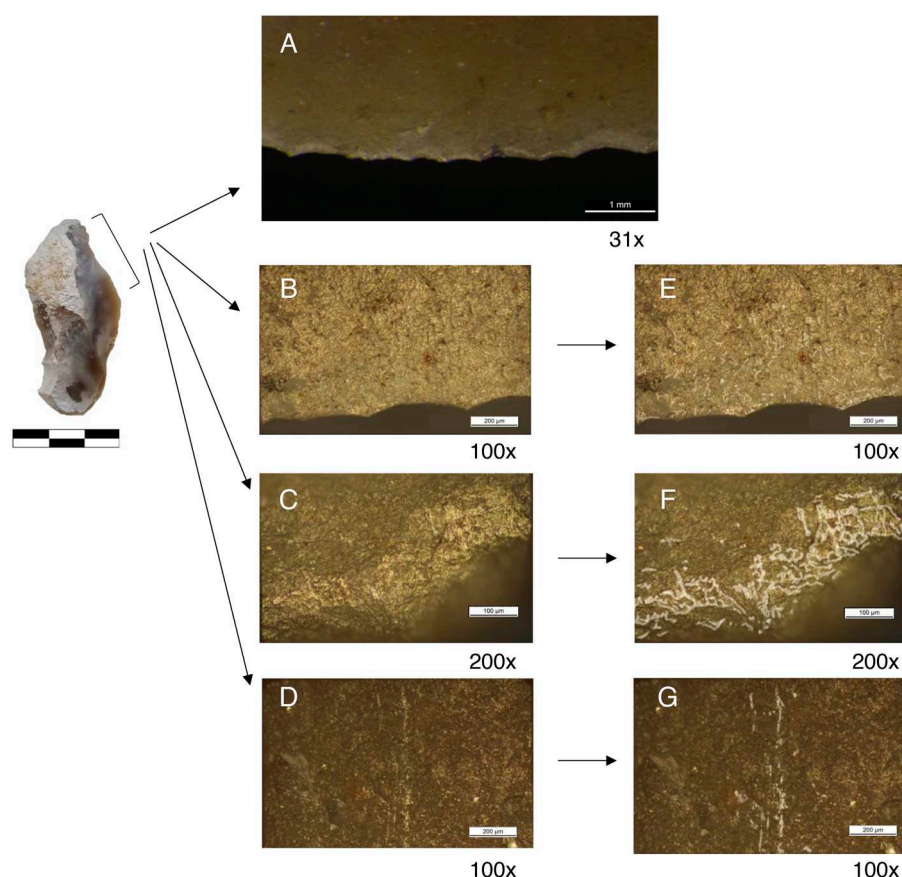


Figure 8. Use-wear traces on tool 12 after scraping thermoaltered *P. nigra* for 20 min. (A) at 31x; (B) at 100x; (C) at 200x; (D) at 100x; (E–G) drawing on photograph indicating use-wear traces.

the edge, are frequent, with a fine width (< 2 microns) and medium length (50–150 microns) and shallow depth.

Discussion

Throughout the experimental program, it has not been possible to carry out the same type of actions when working on the 3 different types of wood, due to the various physical conditions. Therefore, in the case of dry and thermally modified wood, scraping actions have been performed in order to obtain debarking and sharpening simultaneously, whereas in the case of green wood, two differentiated actions had to be sequenced from whittling and scraping making the use of different tools necessary. That is why we have focused mainly on the traces of use generated by scraping.

Despite this, remarkable differences have been observed between use-wear traces generated by working thermally modified and green or dry wood. These differences are particularly obvious when observing the texture, the topography and the extension of the

polish. The texture of thermally modified wood is more rugged than in dry or green wood cases, where peaks tend to be more altered. The topography is also irregular, due to the surface of flint being hardly homogenized, whereas we find a more domed topography in the case of green and dry wood. All this can be related to a less bright appearance of the thermoaltered wood polish. Finally, the extension of the polish is invasive in the tools that worked on thermoaltered wood, whereas the extension of the green and dry wood polish is more moderate.

Having analyzed this information, it seems that thermally modified wood confers less resistance than green and dry wood. In this sense, some studies (e.g. Ennos & Chan, 2016) point out that when wood is thermally modified, it becomes weaker and more breakable. It is because of this that both the texture and the topography of thermoaltered wood are similar to cases of soft material work. On the other hand, the charcoal generated when heating wood has a direct role in forming the extension of polish, from which two points arise: the charcoal detached from the piece of wood during scraping actions is abundant and fragmentary, and this charcoal gets “trapped” between the tool and the log.

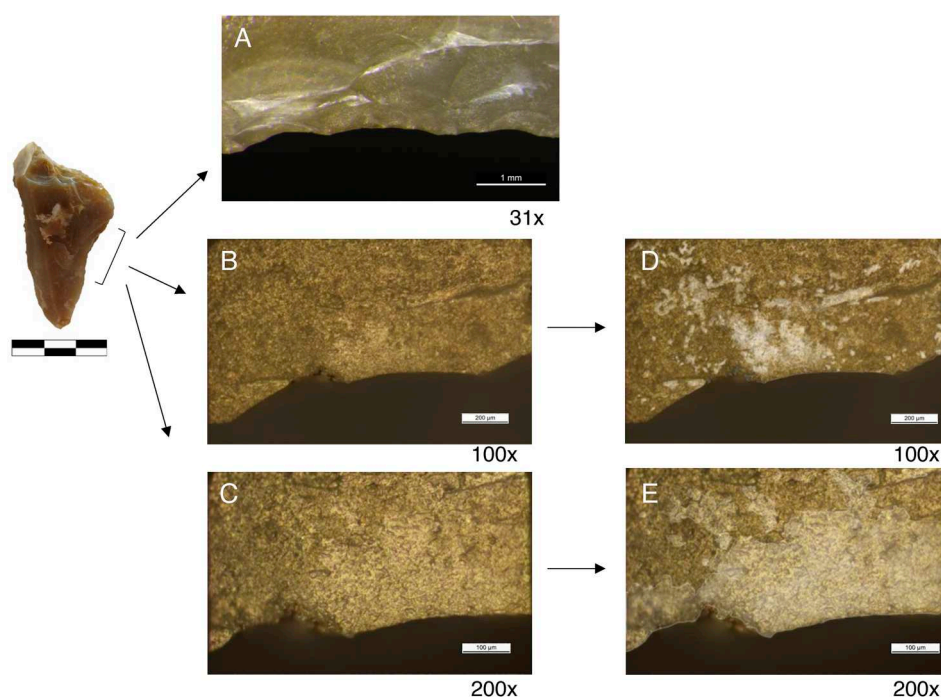


Figure 9. Use-wear traces on tool 19 after scraping *Taxus baccata* for 18 min. (A) at 31x; (B) at 100x; (C) at 200x; (D–E) drawing on photograph indicating use-wear traces.

As the scraping of the log continues to be done to obtain the desired result, the charcoal generates a friction action that results from dragging, thus affecting the invasive extension of polish. We can also assume that charcoal may also be covering the surface of the flake and acting almost as a barrier reducing polish formation, especially in the lower topography, resulting in a less bright polish.

Another interesting fact is the amount of charcoal residues found on the flint surface. While something similar happens with dry and green wood residues (to

a lower extent), it is very hard to get rid of them, since charcoal adheres to the tiny natural cavities of flint making its removal much more difficult than in the other two cases. Although it might seem an obstacle when trying to obtain a clean surface, it actually improves the collection of residues. On the same note, another interesting aspect is the amount of residues generated when working thermally modified wood. In spite of not being more abundant than in the other types of wood (as it depends on the quantity of material being worked upon), there is a substantial difference in

Table 4. Use-wear traces of green wood.

Use-wear traces of green wood		
Scars	Distribution	Continuous, discontinuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular
	Termination	Feather
Polish	Dimension	Small, medium
	Appearance	Bright
	Texture	Rough
	Topography	Domed
	Extension	Marginal
	Contour	Sharp
	Density	Intermediate
Striations	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
	Depth	Shallow
Edge-rounding	Intensity	Weak-average

Table 5. Use-wear traces of dry wood.

Use-wear traces of dry wood		
Scars	Distribution	Continuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular, quadrangular
	Termination	Feather, step
Polish	Dimension	Medium, small
	Appearance	Bright
	Texture	Rough/smooth
	Topography	Domed
	Extension	Marginal
	Contour	Sharp
	Density	Dense
Striations	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
	Depth	Deep
Edge-rounding	Intensity	Weak-average

Table 6. Use-wear traces of thermoaltered wood.

Use-wear traces of thermoaltered wood		
Scars	Distribution	Continuous
	Organization	Aligned, superimposed
	Morphology	Semi-circular, quadrangular
Polish	Termination	Feather/step
	Dimension	Small, medium
	Appearance	Dull
	Texture	Rought
	Topography	Domed
	Extension	Moderate-invasive
	Contour	Fuzzy
Striations	Density	Intermediate-dense
	Organization (between them)	Parallel
	Orientation (in relation to the edge)	Perpendicular
	Width	Fine
	Length	Medium
Edge-rounding	Depth	Shallow
	Intensity	Weak-average

the distribution of residues. In this sense, the fragmentary nature of charcoal, which increases its scattering ratio, leads us to consider that, to understand charcoal distribution in archaeological sites, it is necessary to take these types of work into account instead of strictly connecting them to fuel combustion structures.

Finally, it is worth pointing out the manipulative and transformation ability of thermally modified wood as opposed to green and dry wood. In this sense, two main actions had to be performed in order to carry out the debarking and the sharpening of green wood: whittling and scraping. As for the dry one, the debarking and sharpening could be obtained by means of these two actions or by means of scraping only. However, the easiest way to work thermally modified wood is through scraping, due to the fragmentary and weak condition of charcoal. On the other hand, both green and dry wood require a greater amount of time and energy, which are considerably reduced in the case of thermally modified wood. For all these reasons, working thermally altered wood reduces working time and effort.

Conclusion

This research was motivated by two fundamental issues: firstly, the preservation of thermally modified wooden remains belonging to prehistoric times, and secondly, the lack of information about use-wear traces of thermoaltered wood.

All this led to the performance of an experimental program whose goal was to analyze and compare use-wear traces of green, dry and thermally modified wood. The substantial differences observed between thermally modified wood and the two others provide

significant results, especially in the characterization of the polish. So, through use-wear analysis we can obtain indirect evidence of the use of thermal modification of wood despite not being preserved in the archaeological site.

With this research a new proxy through functional analysis has been added in order to gain an understanding of woodworking processes throughout prehistory.

Disclosure statement

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Notes on contributors

Mariel Bencomo is a Ph.D. student with a grant from the Spanish Ministry of Culture, Education and Sports. Her work focuses on use-wear analysis in the Middle Palaeolithic. Her Bachelor's Degree Dissertation focused on a bibliographical analysis on the importance of the traceological contributions to the context of the Middle Palaeolithic in Europe. Subsequently, she obtained a Master's Degree in "Professional Archeology and Heritage Management" from the University of Alicante with a work focused on a case study on lithic tools from the El Abric del Pastor deposit. Her Ph.D. is focused on the use-wear analysis of the stratigraphic unit Xa from the El Salt field (Alcoi, Alicante) under the direction of J. Emili Aura Tortosa, Paula Jardón Giner and Bertila Galván Santos.

Paula Jardón Bachelor's Degree in Geography and History at the University of Valencia. She obtained her PhD at the same university, with the thesis: "Scrapers in the Upper Paleolithic: typology, technology and function in the Cova del Parpalló (Gandia, Spain) and the Grotte Gazel (Sallèles-Cabardès, France)". She was founding partner of the company "SL Darqueo study and dissemination of the Heritage". Her professional activity was developed both in the field of university and extra-university teaching, as well as in heritage management in Museums and in archaeological activities. Her scientific research activity is integrated into projects with teams from the University of Valencia, the University of Liège, the Royal Institute of Natural Sciences of Brussels, the CNRS Laboratory of Carcassonne and the French Mission in Central Asia, the University of San Luis Potosí (Mexico), University of La Laguna and l'École Normale Supérieure de Lyon (France). Currently, she works as a professor at the University of Valencia, at the University Institute of Creativity and Educational Innovation.

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3.8. Los estigmas de uso derivados del trabajo sobre madera termoalterada: primeras valoraciones sobre sus implicaciones.

Los resultados del programa experimental en torno al trabajo sobre madera termoalterada nos remitían a un tipo de huellas o estigmas que podían diferenciarse en función del estado de la madera en estado verde o seco. Para ello se empleó tanto una lupa binocular como un microscopio metalográfico, tal y como explica en el artículo. En esta primera fase, el protocolo de limpieza fue utilizar agua destilada con jabón neutro (Hygenia, Magnum Blue®) en la cubeta de ultrasonidos, y si de visu el carbón persistía en la superficie se utilizaron productos más agresivos, como la acetona, o el ácido acético al 5% pero en lapsos de tiempo muy cortos, solo hasta observar que la superficie no estaba ennegrecida por el carbón.

En aras de profundizar en torno al tipo de huellas generadas por la madera termoalterada, se decidió analizar 2 piezas experimentales con el MEB. Este estudio se realizó en las instalaciones del Institut Català de Paleoecologia Humana i Evolució Social (IPHES) de Tarragona. Este análisis, más en profundidad sobre las huellas de uso, permitiría caracterizar con mayor precisión los estigmas de uso, en particular el pulido. Para ello se volvieron a analizar las piezas, en este caso con el microscopio metalográfico Zeiss Axio Scope A1, con la finalidad de seleccionar puntos concretos en los bordes donde se observaban claramente los estigmas de uso. Antes de seleccionar dichos puntos, se volvieron a limpiar las piezas, siguiendo el siguiente protocolo: 10 minutos de limpieza con agua destilada y jabón neutro (Derquim ® LM02 al 2%) en la cubeta de ultrasonidos, dejar secar la pieza, y posteriormente volver a lavar las piezas durante 10 minutos con acetona pura nuevamente en la cubeta de ultrasonidos. De esta forma nos asegurábamos que las piezas estarían limpias para su visionado en el MEB. A continuación, se adjuntan las fotografías obtenidas a través del microscopio metalográfico de la pieza experimental número 19 donde se observaban las huellas de uso explicadas en el artículo Bencomo & Jardón (2022) (Fig. 12).

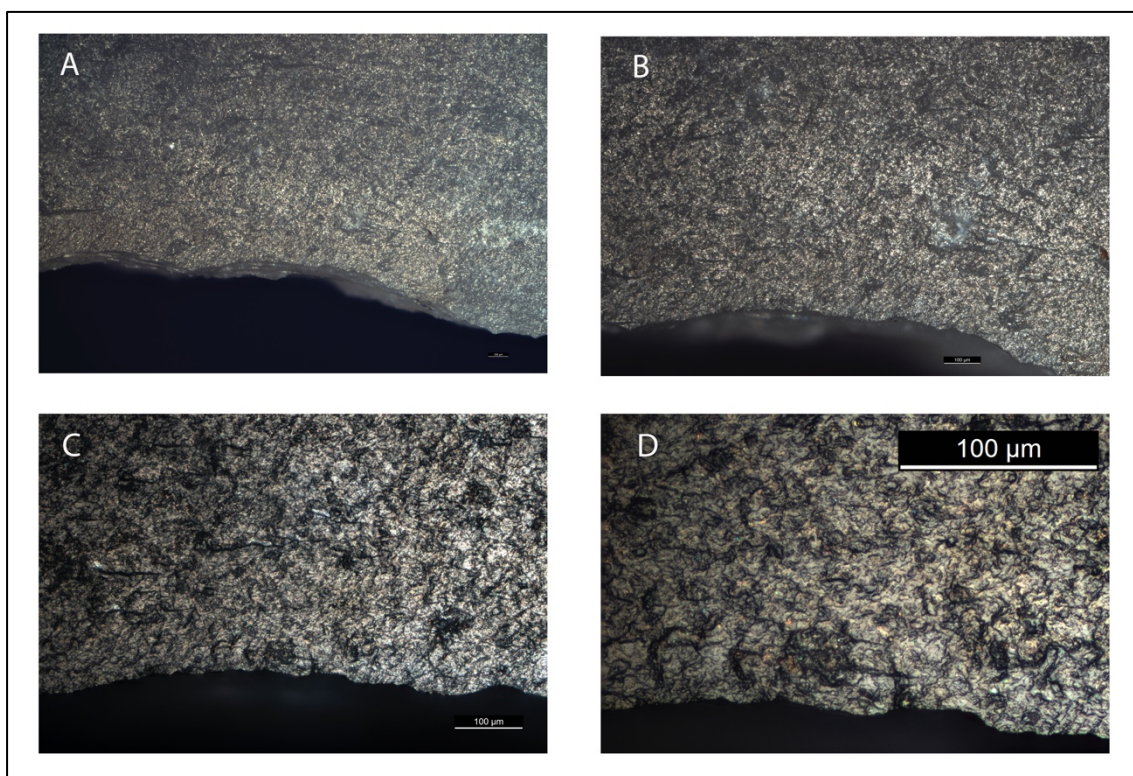


Fig. 12. Pieza experimental 19. Estigmas de uso al raspar madera termoalterada A) 50x B) 100x C) 200x D) 500x

Una vez limpias y con las zonas seleccionados, procedimos al análisis de las piezas con el MEB. En esta fase de análisis se observa que la superficie de las piezas seleccionadas no muestra ningún tipo de alteración, es decir, la superficie del sílex no estaba modificada. A continuación, se adjuntan las imágenes extraídas del MEB en las que se observa claramente que la superficie parece completamente fresca, sin observar ningún tipo de abrasión (Fig. 13).

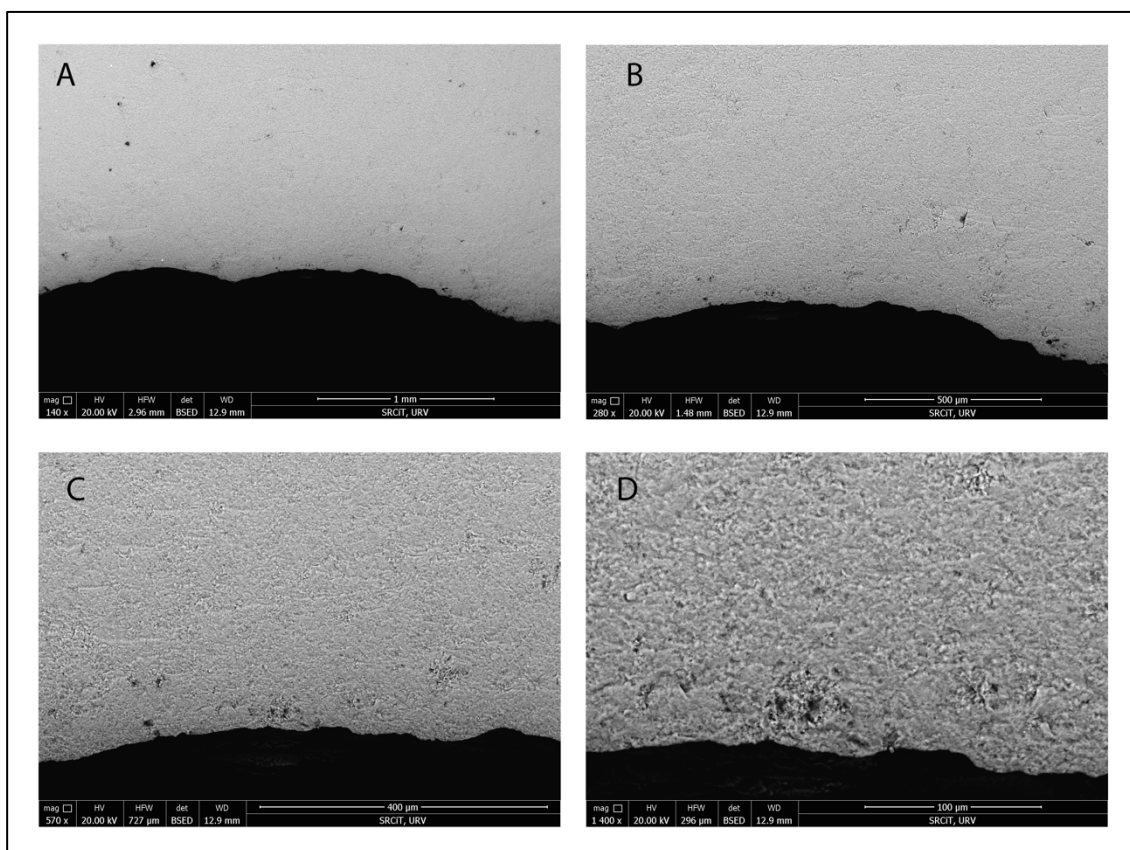


Fig. 13. Superficie de la pieza experimental número 19 vista al MEB

Una vez analizadas las superficies y observando la ausencia de alteraciones, procedimos a hacer un mapeo de elementos químicos a través de la técnica dispersión de energía de rayos X (EDS). Los resultados obtenidos, aparte de sílice y oxígeno, ofrecieron un porcentaje, aunque menor, de carbono. A continuación, se adjunta la gráfica obtenida (Fig. 14).

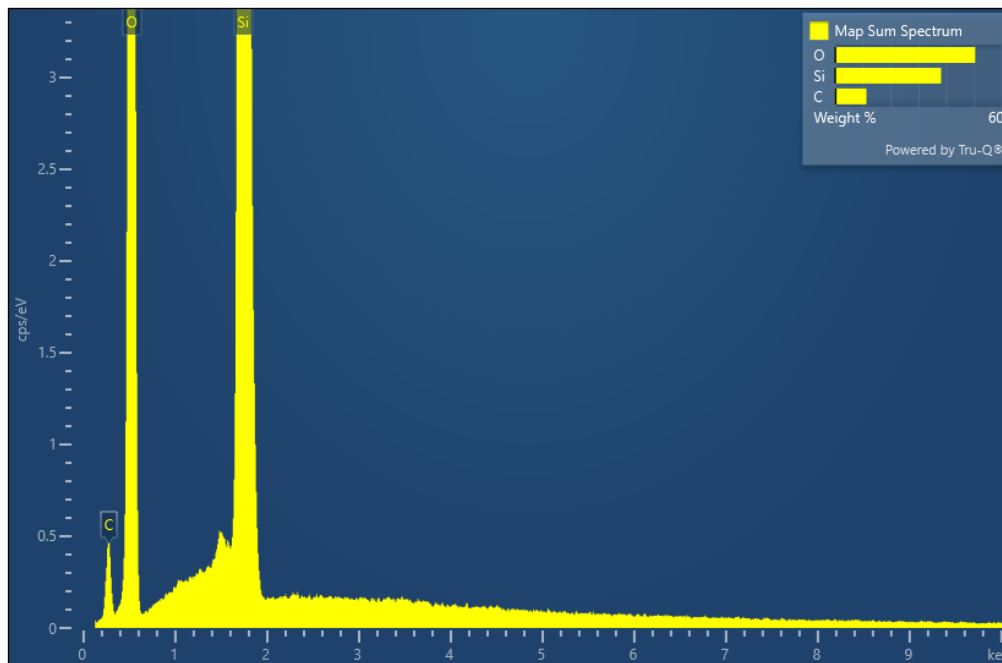


Fig. 14. Valores de los elementos químicos a través de EDS de la pieza experimental número 19.

Atendiendo a estos valores, sumado a la ausencia de alteración en las superficies, consideramos la posibilidad de que lo que habíamos diagnosticado como pulido, quizás fuese una capa de residuo de carbón adherido. Para comprobar esta hipótesis, decidimos realizar una limpieza más agresiva. Si bien las piezas ya se habían limpiado 10 minutos con agua destilada y jabón neutro, y otros 10 minutos con acetona, en este momento empleamos agua oxigenada pura (peróxido de hidrógeno al 30%). Para el caso de la pieza 19, se limpió, en la cubeta de ultrasonidos, en 3 fases de 10 minutos, sumando un total de 30 minutos. Una vez realizado este procedimiento, se retomó el microscopio metalográfico para observar los resultados. En este momento se observó que la superficie de la pieza, en los mismos puntos donde se observada el “pulido”, estaba inalterada y sin brillo, aunque sí se observan algunos puntos muy reducidos y dispersos de pulido inespecífico (Fig. 15).

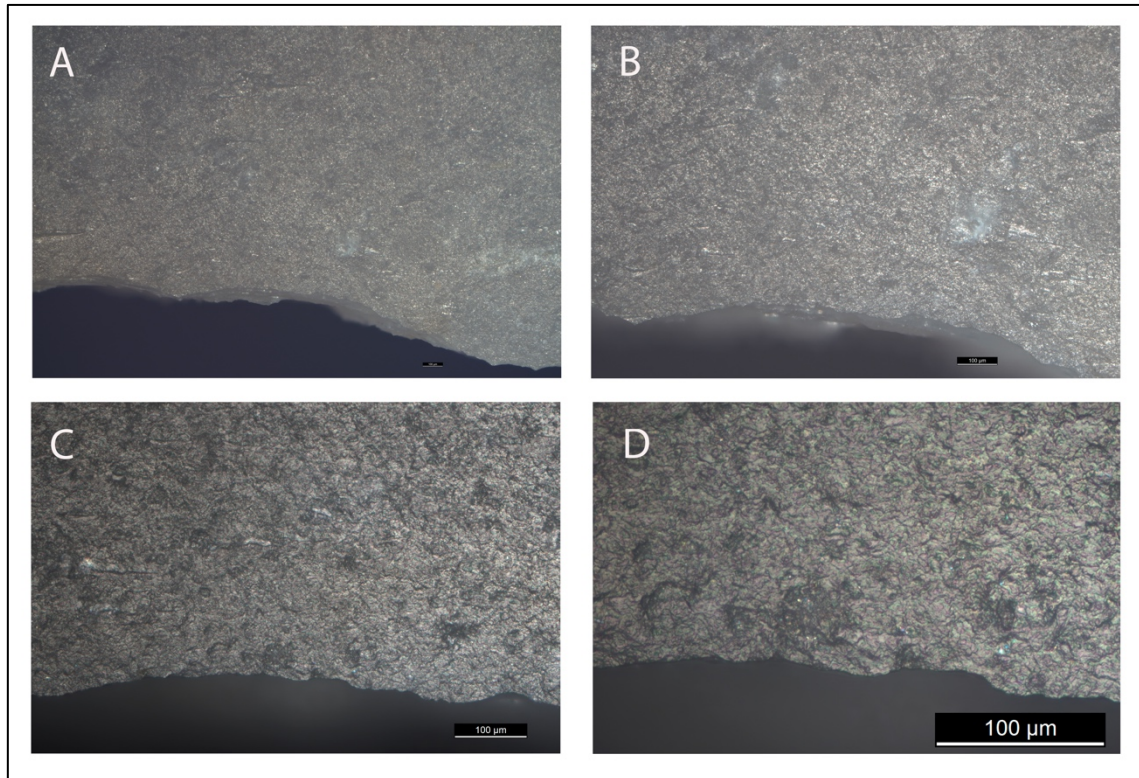


Fig. 15. Superficie de la pieza experimental 19 después 30 minutos de limpieza con agua oxigenada pura A) 50x B) 100x C) 200x D) 500x

Si bien son resultados preliminares, pues se seleccionaron sólo 2 piezas para proceder a este análisis, podemos concluir que lo que observamos a través del microscopio metalográfico no era un pulido generado por la fricción con la madera termoalterada, sino una capa de residuo a base de carbón que, a la luz del microscopio, y habiendo pasado por un protocolo de limpieza estándar, se asemejaba bastante.

4. Resultados

De las 259 piezas seleccionadas para realizar este estudio, se realizó un estudio traceológico sobre 231. Las piezas que han quedado fuera de este estudio se caracterizan principalmente por ser soportes muy pequeños (fragmentos de talla) o soportes cuya morfopotencialidad era escasa.

Los resultados se dividirán en función a las unidades arqueoestratigráficas ya mencionadas en el apartado de materiales, comenzando con el artículo publicado (Bencomo *et al.*, 2023) y prosiguiendo con los resultados funcionales inéditos.

4.1. Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale

Bencomo, M., Mayor, A., Sossa-Ríos, S., Jardón, P., Galván, B., Mallol, C., Hernández, C.M. (2013). Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale. *Archaeological and Anthropological Sciences*, 15 (92). DOI: 10.1007/s12520-023-01787-4



Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale

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Abstract

Use-wear analyses are very useful to increase knowledge about the economic and subsistence dynamics carried out by Neanderthals. In general terms, functional results traditionally came from the analysis of tools belonging to stratigraphic units whose timescale refers to geological time. This is due to the fact that many Neanderthal sites are palimpsests of reiterated occupations over time, which must be dissected to approach us to human timescale. In the stratigraphic unit xa of El Salt (Alcoi, eastern Iberia), high temporal resolution archaeostratigraphic studies have been carried out. Diachronic material assemblages have been identified, allowing us to analyse more precisely the variability of Neanderthal behaviour over time. Amongst these assemblages, three have been selected (i.e. 5.3.1, 5.3.2 and 5.3.3) in order to analyse the lithic material functionality. The results obtained bring out the performance of different tasks within each analytical framework: woodworking in 5.3.1, woodworking and animal processing in 5.3.2, and butchering activity in 5.3.3. These results reflect the existence of a series of diachronic tasks carried out in overlapping activity areas. In this way, this work evidences flint use variability in a specific area of the site across time that could have been recognised only by means of high temporal resolution analytical frameworks.

Keywords Middle Palaeolithic · Use-wear analysis · Palimpsest dissection · Interoccupational variability · El Salt

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Introduction

An increasing number of functional lithic studies since the 1960s has contributed to overcome speculation on use based on artefact typology and improve our understanding of some of the activities carried out by Neanderthal hunter-gatherers (e.g. Beyries 1987; Anderson-Gerfaud 1990; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lazuén & González 2014; Venditti et al. 2019a). The bulk of data has been obtained from the analysis of tools belonging to stratigraphic units (SUs) (e.g. Beyries 1987; Jardón 2000; Lemorini 2000; Rodríguez et al. 2002; Martínez 2005; Rots 2011, 2016; Hortelano 2016; Lemorini et al. 2016; Márquez et al. 2017), which usually are a palimpsest of reiterated occupations whose timescale spans millennia or unknown amounts of time. Therefore, the use of the SU as an analytical frame provides general results that drive us away from human temporality and hamper the analysis of the variability of human behaviour throughout time. Narrowing down the information on stone tool use to timescales at which we can explore behavioural variability and change remains a challenge.

In the last decades, there has been an increasing concern for problems derived from the palimpsest condition of archaeological sites (e.g. Harding 2005; Bailey 2007; Holdaway & Wandsnider 2008; Lucas 2010; Henry 2012). In this framework, the SU xa from the site of El Salt (Alcoi, eastern Iberia) has been the focus of several studies aimed at approaching human single occupation episodes through multiproxy analyses (cf. Marrero et al. 2011; Machado et al. 2011, 2017; Mallol et al. 2013; Machado and Pérez 2015; Vidal et al. 2018; Leierer et al. 2019; Mayor et al. 2020; Pérez et al. 2020). Earlier studies carried out at SU xa showed archaeostratigraphically well-delimited material beds, leading to the definition of analytical frames called archaeostratigraphic units (AUs) (cf. Machado et al. 2011, 2017; Machado and Pérez 2015). Despite displaying a higher temporal resolution, these units constituted a micropalimpsest that was dissected in later studies (cf. Mayor et al. 2020), resulting in new analytical frames (i.e. 5.3.1, 5.3.2 and 5.3.3) that are even more accurate from a temporal perspective and closer to human single occupation episodes.

These studies have allowed the formulation of two main hypotheses related to SU xa:

The activities were carried out generally around hearths, as indicated by material scatters that fit the hearth-related assemblage model (cf. Vaquero & Pastó 2001).

The Neanderthals here did not occupy the place for long periods of time.

In this frame, it is of great interest to analyse the lithic artefacts from discrete and short-spanned activity events

from a functional perspective. In this sense, the utilisation of high temporal resolution analytical frameworks is a differentiating factor of this research regarding other use-wear studies. If we take as examples other Neanderthal sites located within the Mediterranean Iberian coast whose lithic material has been subjected to functional analyses, such as Cova Negra (cf. Moriel 1985), Abric Romaní (cf. Martínez 2005; Martín-Viveros et al. 2020), Abric del Pastor (cf. Galván et al. 2008), La Quebrada (cf. Eixea et al. 2015), Cova del Bolomor (cf. Hortelano 2016), and even El Salt (cf. Rodríguez et al. 2002), we can observe that the SU is employed as an analytical framework, and that the results derived from this tend to homogenise the human behaviours.

Thus, the goal of this research is to explore the potential of lithic functional studies in small timescale analytical frameworks as proxies to identify the tasks performed in a specific space of the site. The study consists in carrying out use-wear analysis on the lithic assemblages from AUs 5.3.1, 5.3.2 and 5.3.3, which are three successive analytical frames that are part of diachronic, discrete, brief human occupations (cf. Mayor et al. 2020). Comparing these analytical frames across time could provide insight into Neanderthal behavioural variability.

The archaeological site of El Salt

The archaeological site of El Salt is an open-air rockshelter at 680 m above sea level located in Alcoi and featuring a 38-m-high travertine wall at the foot of the excavated area (Fig. 1). It has a 6.3-m-thick stratified deposit divided into 13 stratigraphic units (cf. Fumanal 1994), dating mainly from the Upper Pleistocene. Uranium–thorium (U–Th), thermoluminescence (TL) and optically stimulated luminescence (OSL) dating techniques carried out on the site indicated a broad temporal range between 81.5 ± 2.7 ky BP for SU XIII and 44.7 ± 3.2 ky BP for SU v. The first evidence of human occupation is found in stratigraphic unit XII, datable to 60.7 ± 8.9 ky BP (cf. Galván et al. 2014a, b).

Archaeological research at El Salt has been ongoing since 1986 and is geared at approaching human behavioural evolution in the Alcoi valleys from a multidisciplinary perspective. To this date, the resulting data have provided a diversity of geoarchaeological, palaeoanthropological, palaeoenvironmental, palaeodietary and palaeoeconomic information (cf. Fumanal 1994; Rodríguez et al. 2002; Galván et al. 2006; Dorta et al. 2010; Machado et al. 2011; Sistiaga et al. 2011, 2014; Mallol et al. 2012, 2013; Machado and Pérez 2015; Herrejón et al. 2016; Vidal 2016, 2017; Machado et al. 2017; Fagoaga et al. 2018, 2019; Vidal et al. 2018; Leierer et al. 2019; Pérez et al. 2020; Fagoaga 2020; Mayor et al. 2020; Rampelli et al. 2021; Marín et al. 2021).

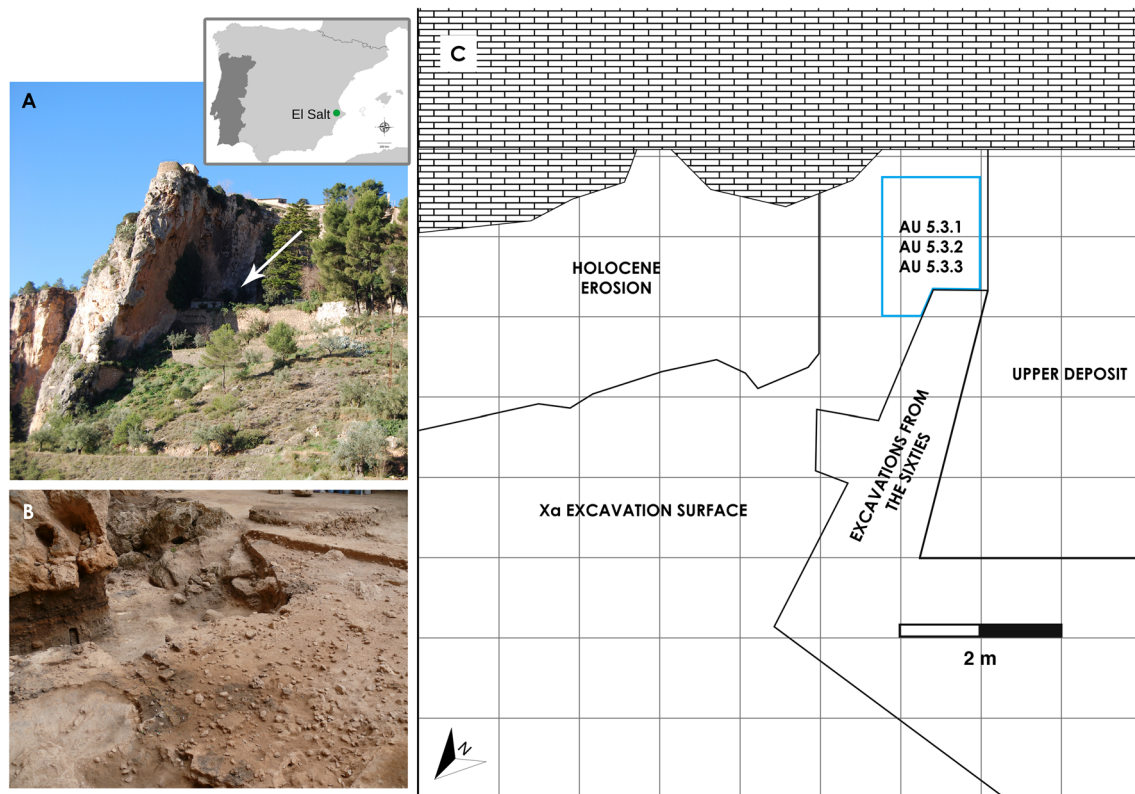


Fig. 1 A Location of El Salt. B Unit xa excavation surface. C Plan illustrating the horizontal position of the AUs

In recent years, research at El Salt has focused on SU xa, dated to 52.3 ± 4.6 ky BP (cf. Galván et al. 2014a, b). This unit is characterised by a rich and diverse archaeological record that includes lithic artefacts, faunal remains and well-preserved combustion structures. The SU xa lithic record comprises cores and both retouched and unretouched flakes manufactured using mainly the Levallois method (cf. Machado 2016; Mayor et al. 2020) on different available flint types: Serreta, Mariola, Beniaia and Font Roja (cf. Molina 2016; Machado 2016).

The SU xa faunal record suggests the exploitation of medium-sized mammals, mainly wild goat (i.e. *Capra pyrenaica*), deer (i.e. *Cervus elaphus*) and horse (i.e. *Equus ferus* and *Equus hydruntinus*). Archaeozoological data indicate hunting and subsistence activities (cf. Pérez 2019). Geoarchaeological data indicates that the SU xa hearths

were simple, flat and short-lived (cf. Mallol et al. 2013) and anthracological data point to pine (i.e. *Pinus nigra*) as the prevalent fuel choice (cf. Vidal 2017; Vidal et al. 2017).

Materials and methods

The materials selected for this study are integrated in AU 5.3, located near the travertine wall and whose archaeological record covers an area of approximately 2m^2 from the 36m^2 of the excavation surface (cf. Machado et al. 2017).

This AU was in turn dissected into 3 new AUs conceived as higher resolution analytical frames: 5.3.1, 5.3.2 and 5.3.3 (Table 1) from specific diachrony indicators relating to the three-dimensional position of raw material units, in addition to their relationship with the stratigraphic location of

Table 1 Raw material units (RMU), associated hearths and technological ascription of the 5.3.1, 5.3.2 and 5.3.3 lithic assemblages (cf. Mayor et al. 2020)

AUs	Involved hearths	N of RMUs	Involved RMUs	N of raw material types	Tech. ascription
5.3.1	H31	4	5.3_5, 13, 14, 16	3	RCL with non-L
5.3.2	H29	5	5.3_3, 4, 9, 15, 19	3	RCL
5.3.3	H32	13	5.3_1, 2, 6–8, 10–12, 17, 18, 20–22	5	RCL with non-L

hearths (*cf.* Mayor et al. 2020). These three new archaeostratigraphic units represent contexts that are singular, overlapped between them. Each of these AUs represents potential hearth-related assemblages that are closer to the human timescale and could also signify self-contained activity areas. For this reason, they are optimal frameworks to perform use-wear characterisation aiming to recognise diachronic Neanderthal behaviours.

In total, the three frames comprise 56 objects. Most of them are ascribed to the Levallois method. They are mainly flakes (43: 77%), 15 of which show recurrent centripetal Levallois production features. The remaining are 2 cores and fragments that have not been technologically ascribed. There is only one support that has been retouched as a transversal scraper. The predominant flint type is Serreta (i.e. 46.4%), followed by Mariola (i.e. 30.6%), Beniaia (i.e. 12.5%), Font Roja (i.e. 3.5%) and an undetermined type (i.e. 7%) (*cf.* Mayor et al. 2020). Regarding their dimensions, the lithic objects have been assigned to three different size classes: small (i.e. < 2 cm on its axis), medium (i.e. 2–3 cm) and large (i.e. > 3 cm).

Taking previous research as a reference (*cf.* Mayor et al. 2020), the technological ascription, raw material and measurements of the supports integrating each analytical frame are explained next:

Archaeostratigraphic unit 5.3.1

It includes 9 flakes and a fragment made of Serreta (i.e. 40%), Mariola (i.e. 40%) and Beniaia (i.e. 20%) flint types (Table 2).

Archaeostratigraphic unit 5.3.2

It involves 15 products, mainly flakes, but also a core and a fragment made of Serreta (i.e. 66.67%), Mariola (i.e. 13.33%) and Beniaia (i.e. 20%) flint types (Table 3).

Archaeostratigraphic unit 5.3.3

It includes 31 elements: 21 flakes, a transversal scraper, a core and 8 fragments made on Serreta (i.e. 38.7%), Mariola (i.e. 35.4%), Font Roja (i.e. 6.4%), Beniaia (i.e. 6.4%) and an undetermined flint type (i.e. 12.9%) (Table 4).

Functional analysis

Use-wear analysis has been carried out on 41 of the 56 objects (i.e. 73.2%). The remaining 15 objects have not been analysed due to either the presence of visible physical and chemical alteration or the absence of edges or regular, potentially usable platforms.

Use-wear analysis has been performed from two perspectives: functional and morphopotential. Regarding the functional perspective, we have analysed tool-use, kind of worked materials and kinds of performed actions. Analysis of potentially prehensile areas has also been carried out to detect possible signs of hafting. Functional inference was based on experimental data (see the “[Experimental programme](#)” section for further details) obtained from working different materials using the most relevant predominant flint type (i.e. Serreta). These data were compared and contrasted with other studies (*e.g.* Tringham et al. 1974; Hayden 1979; Keeley 1980; Anderson-Gerfaud 1981, 1990; Vaughan 1985; González & Ibáñez 1994; Gutiérrez 1996; Jardón 2000; Lemorini 2000; Rots 2011).

Regarding the morphopotential approach, we documented edge angles, measured in degrees, and morphologies (i.e. concave, straight, convex) to explore the relationship between shape and function (*e.g.* Venditti et al. 2019b).

Experimental programme

An experimental programme to ensure the reliability of traceological data was carried out using the Serreta flint type. The flakes were comparable in size to the

Table 2 Lithic assemblage belonging to the AU 5.3.1. Technological ascriptions, products, flint types and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.1	×6/31	Unipolar non-Levallois	Flake	Serreta	27×24×12
	×6.7/24	Unipolar non-Levallois	Flake	Serreta	41×6×5
	×5.6/278	RCL	Flake	Beniaia	35×31×8
	×5.6/279	RCL	Flake	Beniaia	15×19×2
	×5/1310	RCL	Flake	Mariola	22×21×5
	×5/1312	RCL	Flake	Mariola	21×17×3
	×5/1028	Undiagnosed	Cortical flake	Mariola	19×22×6
	×5/1313	Undiagnosed	Cortical flake	Mariola	27×25×9
	×4/810	Undiagnosed	Cortical flake	Serreta	30×18×6
	×5/14	Undiagnosed	Cortical fragment	Serreta	16×16×8

RCL means recurrent centripetal Levallois

Table 3 Lithic assemblage belonging to the AU 5.3.2. Technological ascriptions, products, flint types, and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.2	×4/758	RCL	Flake	Mariola	34×17×4
	×5/1322	RCL	Flake	Mariola	24×15×4
	×6/22	RCL	Flake	Serreta	16×16×2
	×5/1545	RCL	Flake	Serreta	17×21×4
	×5/1062	RCL	Flake	Serreta	30×20×2
	×4/781	RCL	Flake	Serreta	23×12×6
	×4/803	RCL	Flake	Serreta	26×9×2
	×5/12	Undiagnosed	Débordant flake	Beniaia	32×22×6
	×4/775	RCL	Flake	Beniaia	30×14×2
	×4/801	RCL	Flake	Beniaia	19×30×2
	×4/826	RCL	Cortical flake	Serreta	30×21×9
	×4/787	RCL	Flake	Serreta	37×25×10
	×4/782	RCL	Flake	Serreta	19×21×7
	×4/789	Recurrent centripetal	Core	Serreta	28×19×8
	×5/990	Undiagnosed	Cortical fragment	Serreta	24×14×9

RCL means recurrent centripetal Levallois

archaeological ones and they were produced replicating the hierarchised centripetal sequences observed in the archaeological record. We conducted mechanical (i.e. repeating a movement mechanically) and replicating (i.e. reproducing and completing an activity) experiments on animal (i.e. *Capreolus capreolus*) and woody matter (i.e. *Pinus nigra* and *Pinus halepensis*), as their remains are abundant at the site. We used the tools for variable amounts of time, from 20 min to over 2 h, depending on the action and the availability of the material to be worked upon (see supplementary information for further details).

Apart from this experimentation, we have conducted an experimental programme on splintered pieces (cf. Jardón et al. 2018), and on thermoaltered woodworking (cf. Bencomo & Jardón 2022).

Tool cleaning and microscopy

We washed the archaeological and experimental artefacts with lukewarm water and mild soap (Hygenia, Magnum Blue), and then with acetone in an ultrasonic bath (Meta-son 120, Struers) for a variable time (i.e. from 10 min to 1 h). For more persistent sediment adherences and concretions, we used acetic acid (5%). Acetone was also used to remove surface grease from recent handling.

Microscopic observation was carried out using a Leica Microsystems® M165C stereomicroscope at 3.65–60 magnifications, and two metallographic microscopes: Leica Microsystems® DM6000M and Zeiss Axio Scope A1, both at 50–500 magnifications.

Results

Our results indicate that around half of the examined artefacts (i.e. 48.78%) show evidence of use (Table 5). Tables 6, 7 and 8 show a summary of the functional data obtained by each AU.

Our data suggest that the tools were used for processing wood and animal tissue (i.e. butchery activity and skin).

The diagnostic features are:

- Regarding wood (fig. S1-S3), there is a slight development of edge rounding. The edges exhibit scars with an aligned organisation, but in some cases, it is superimposed. In general, they have a semicircular morphology and a feather, transverse or step termination. In terms of size, they are small or medium. The polish is bright, with a rough texture, which sometimes tends to be smooth directly on the edge, and the topography is domed, especially on the higher parts of the surface. None of the tools exhibits striations.
- Regarding the work performed on animal tissues (fig. S4-S6), we can distinguish between work on skin and processing of animal carcasses. The former shows scars with a small and medium size, with an aligned organisation (sometimes superimposed), semicircular morphology (sometimes irregular) and a feather or step termination and a well-developed rounding of the edge. The polish is dull with a rough texture and a domed topography in the higher and lower parts of the surface. For the animal carcasses, the tools present small and medium scars with an aligned organisation, a semicir-

Table 4 Lithic assemblage belonging to the AU 5.3.3. Technological ascriptions, products, flint types and size classes are indicated

AU	ID	Tech. ascription	Product	Flint type	Size (mm)
5.3.3	×6/28	Kombewa	Flake	Serreta	21×6×4
	×6/8	Undiagnosed	Flake	Serreta	29×22×10
	×6.7/30	RCL	Flake	Serreta	34×17×5
	×5/1320	Undiagnosed	Fragment	Serreta	15×14×4
	×5/1309	Kombewa	Transversal scraper	Serreta	19×33×5
	×6/15	Kombewa	Flake	Serreta	17×15×3
	×5/1008	Undiagnosed	Flake	Font Roja	13×18×2
	×6.7/12	Unipolar non-Levallois	Flake	Font Roja	34×18×7
	×5/1316	Discoidal	Fragment	Mariola	18×17×3
	×5/1315	Discoidal	Flake	Mariola	27×26×11
	×5/1311	Discoidal	Cortical flake	Mariola	34×36×12
	×5/1553	Non-Levallois	Flake	Undet	27×43×8
	×5/1550	Non-Levallois	Flake	Undet	20×8×6
	×5/1019	RCL	Flake	Mariola	35×50×10
	×5/1025	RCL	Flake	Mariola	15×14×3
	×6/7	RCL	Flake	Serreta	15×22×3
	×5.6/208	RCL	Flake	Serreta	13×15×6
	×5/1024	RCL	Flake	Serreta	15×20×3
	×5/13	RCL	Flake	Serreta	15×22×6
	×5/352	Undiagnosed	Fragment	Beniaia	13×28×7
	×5/1502	Undiagnosed	Fragment	Beniaia	26×43×10
	×6/24	Undiagnosed	Fragment	Mariola	18×12×4
	×5/1547	Undiagnosed	Flake	Mariola	6×15×8
	×4/811	Undiagnosed	Flake	Mariola	31×18×4
	×5/976	Undiagnosed	Flake	Mariola	20×15×5
	×4/764	Undiagnosed	Flake	Mariola	34×24×6
	×4/780	Undiagnosed	Core	Mariola	30×37×27
	×4/607	Undiagnosed	Fragment	Serreta	43×22×13
	×4/614	Undiagnosed	Flake	Serreta	21×14×6
	×6.7/176	Undiagnosed	Fragment	Undet	24×16×8
	×6.7/176	Undiagnosed	Fragment	Undet	18×16×4

RCL means recurrent centripetal Levallois

Table 5 List of tools exhibiting microscopic use-wear

AUs	Total number of tools	Tools views under the microscope	Tools exhibiting use wear
5.3.1	10	9	3
5.3.2	15	13	8
5.3.3	31	19	9

cular morphology and a feather or transverse termination. The polish is fluid (follows the relief without affecting it), the topography is domed and the contour tends to be fuzzy. In some cases, there are large scars with step termination associated with well-developed polished in the highest parts of the topography which means that there was contact with hard material (e.g. cartilage, bone).

Table 6 Use-wear data in AU 5.3.1

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
x6/31	Pentagonal	Straight	60°	Wood	Scraping
		Straight	45°	Wood	Scraping
x6.7/24	Rectangular	Convex	45°	Wood	Scraping
x5.6/278	Heptagonal	Convex	30°	Wood	Undiagnosed

Table 7 Use-wear data in AU 5.3.2

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
× 4/826	Quadrangular	Concave	55°	Meat and skin	Cutting
× 4/781	Rectangular	Straight	20°	Wood	Cutting
× 5/1322	Rectangular	Convex	35°	Dry skin	Cutting
× 5/1545	Rectangular	Straight	30°	Wood	Cutting
× 4/758	Rectangular	Convex	35°	Wood	Scraping
× 5/1062	Rectangular	Concave	30°	Wood	Cutting
× 4/775	Irregular	Convex	30°	Skin, meat in contact with hard material (cartilage, bone...)	Cutting
× 4/787	Irregular	Concave-convex	40°	Dry skin	Cutting

Table 8 Use-wear data in AU 5.3.3

Tool ID	Tool morphology	Edge morphology	Edge angle	Worked material	Action
x5/1315	Triangular	Straight	40°	Dry skin	Cutting
x6/28	Rectangular	Straight	40°	Dry skin	Scraping
x5/1502	Rectangular	Straight	55°	Meat and hard material (bone, cartilage)	Cutting
x6.7/30	Irregular	Straight	55°	Meat, skin and hard material (bone, cartilage)	Cutting
x5/1311	Quadrangular	Straight	50°	Hard material (bone?)	Percussion
x5/1309	Triangular	Straight	35°	Meat and skin	Cutting
		Straight	70°	Dry skin	Cutting
x6/15	Pentagonal	Convex	45°	Meat and skin	Cutting
x5/1024	Rectangular	Straight	35°	Dry skin	Scraping
x5/13	Rectangular	Convex	35°	Meat and skin	Cutting

Regarding the actions that can be deduced from our analysis, they are cutting (longitudinal movement) and scraping (transversal movement). The distribution of the polish, scars and striations on both sides of a piece suggests a longitudinal action, while the distribution of the polish and striations on one side, and the scars on the other, allows us to speak of a transversal action. On the other hand, the orientation of the traces of use, especially the striations (parallel or perpendicular to the edge) and the scars (perpendicular or oblique) also indicates the type of motion.

As for the morphopotential data, they revealed the following pattern: large and medium-sized flakes with straight or convex edges, with angles mainly between 30 and 45°, were used for woodworking, and large or medium-sized flakes with straight edges and angles between 35 and 55° were used for animal tissue processing.

This is a detailed account of the functional results from each analytical frame:

Archaeostratigraphic unit 5.3.1

Four edges in three lithic tools (i.e. 33.33%) revealed use-wear traces of woodworking mainly in scraping actions (Table 6, Figs. 2, and 3).

Archaeostratigraphic unit 5.3.2

Eight lithic tools (i.e. 61.5%) revealed use-wear traces of woodworking mainly in cutting actions, and animal tissue, both butchery and skin, in cutting actions (Table 7, Figs. 4, 5, 6, and 7).

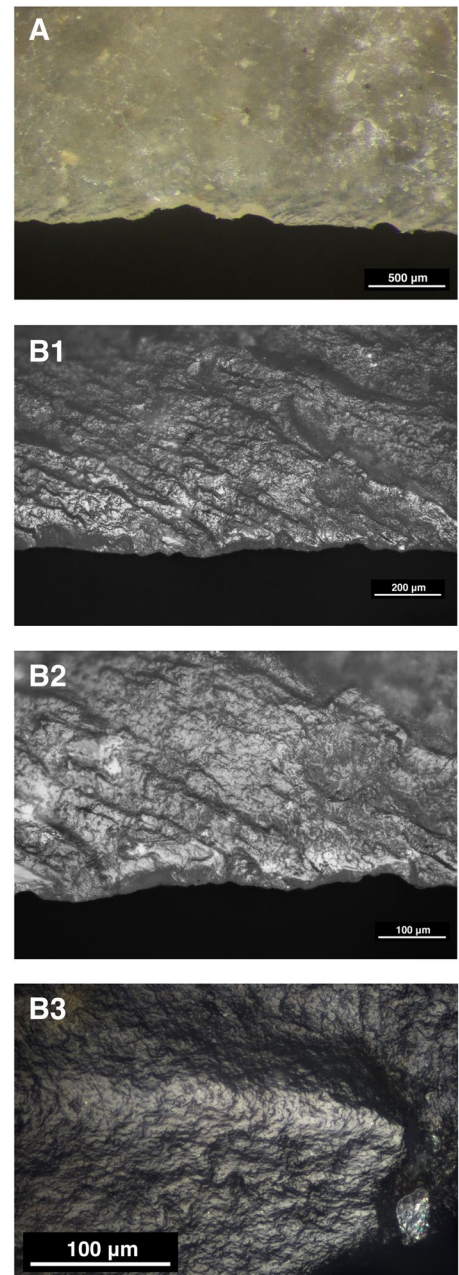
Archaeostratigraphic unit 5.3.3

Ten edges in nine lithic tools (i.e. 47.3%) revealed use-wear traces of animal tissue, related to butchery activities as well as skin processing, with cutting and scraping actions (Table 8, Figs. 8, and 9).

Discussion

Our use-wear analysis has provided information about the kind of activities that were carried out in the frame of three spatially delimited, superimposed high temporal resolution AUs (Fig. 1). According to the functional analysis, we can infer that the tools were employed in a variety of activities

Fig. 2 Tool x6.7/24 with wood-working traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **B** Well-developed and bright polish on the ventral surface, especially on the higher parts, with a rough texture, which tends to be smooth directly on the edge, a domed topography and a development of edge rounding at 100, 200 and 500 $\times$. The black dots represent the area with use-wear traces and the black square represents the area depicted. The same markers are valid for the rest of the figures



across time: AU 5.3.1 shows evidence of woodworking, 5.3.2 displays traces of work on animal tissue and wood, and 5.3.3 exhibits evidence of animal tissue processing.

The preservation state of the analysed tools is acceptable, as well as the rate of tools showing evidence of use (i.e. 5.3.1: 30%; 5.3.2: 53%; 5.3.3: 29%). However, some elements did not present suitable features to be functionally analysed, since they either have a scarce morphopotentiality, or display physicochemical alterations, with variable numbers between each AU. These alterations are mainly due to fire action.

The fact that almost all the elements with use-wear traces are unretouched flakes highlights the multifunctional

characteristics of this kind of product. In the AU 5.3.2, in which tools were used for woodworking and butchering, it is observed a preference for the utilisation of recurrent centripetal Levallois modalities. This remarks the suitability of this knapping strategy to make products with multiple potentially active edges.

Another significant aspect is the fact that two tools with use-wear traces (i.e. x6/15 and x5/1024) are small-sized flakes. Our data join a growing number of Neanderthal contexts with small-sized used tools (e.g. Lazuén & González 2014; Lazuén & Delagnes 2014; Hortelano 2016; Borel et al. 2017).

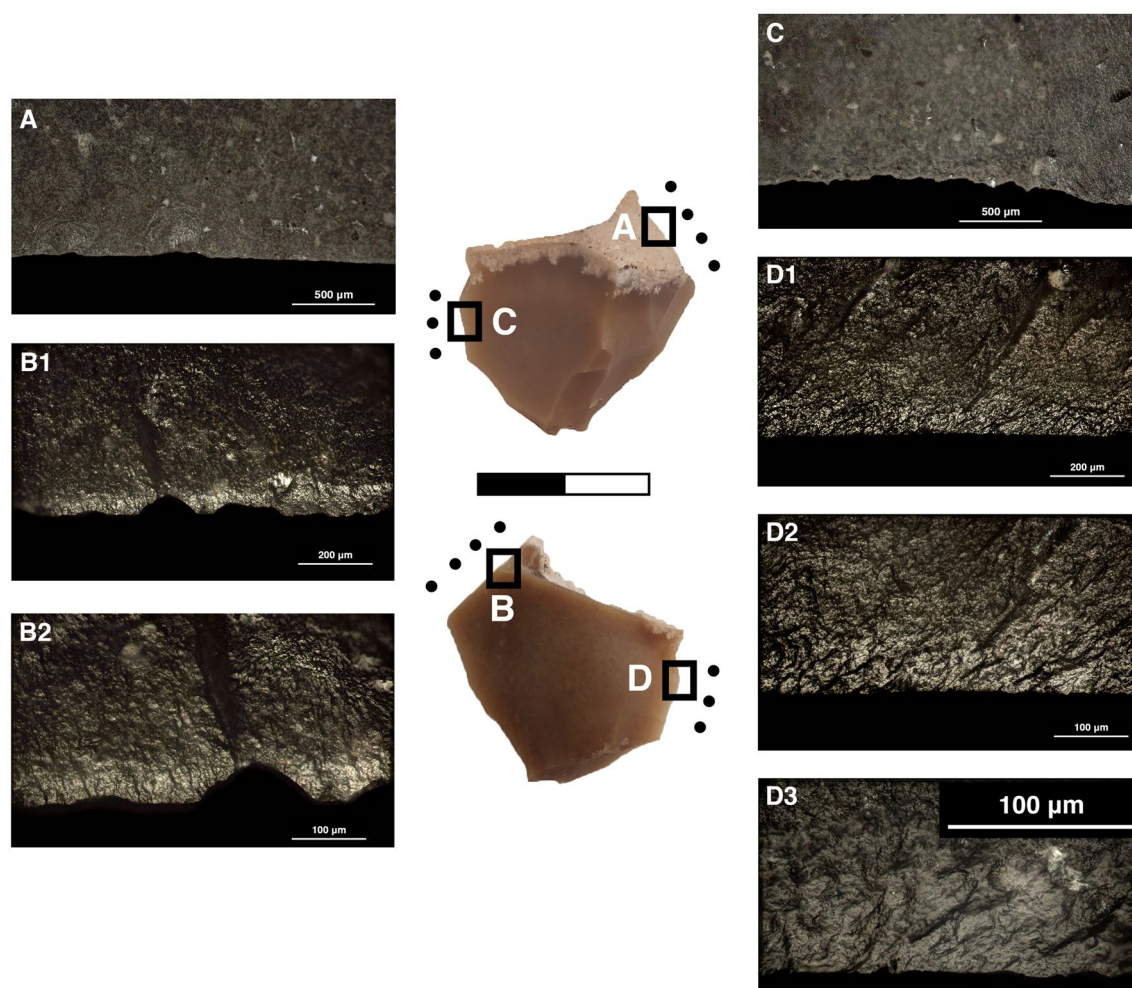


Fig. 3 Tool x6/31 with woodworking traces in a scraping action. **(A)** Small and medium-sized scars on the dorsal surface with an aligned organisation, in some cases superimposed, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **(B)** Bright polish on the ventral surface with a rough texture and a domed topography at 100, 200 $\times$. **(C)** Small scars on the dorsal surface with

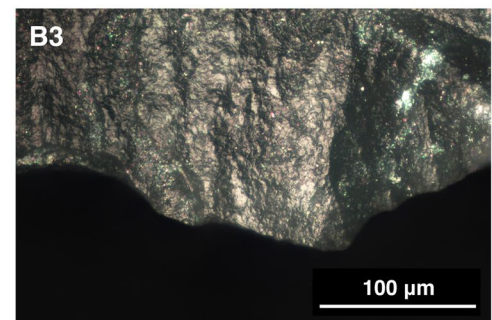
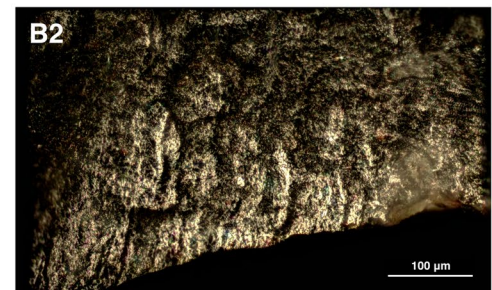
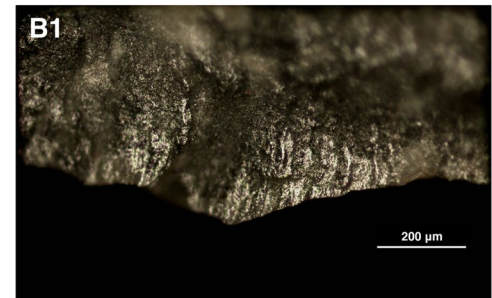
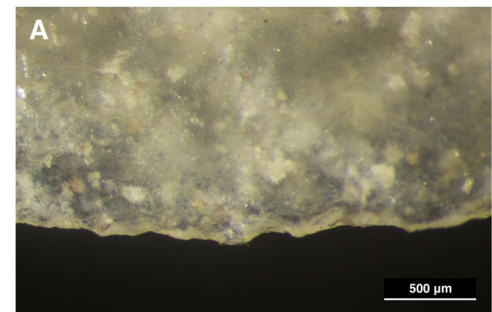
an aligned organisation, a semicircular morphology, feather or transverse termination and perpendicular orientation at 50 $\times$. **(D)** Bright polish on the ventral surface with a rough texture and a domed topography, especially on the higher parts of the surface at 100, 200 and 500 $\times$

Through comparison with experimental tools (*vid.* Supplementary information), we can observe a low development of use-wear traces, from which we deduce that the tools were used during a short lapse of time or for low-intensity purposes, or both. The absence of superposition of possible use-wear traces showing work on different materials brings to the same conclusion. There are only two cases in which more than one edge has been used (Fig. 3). In the same way, the predominant use of unretouched edges, alongside the presence of a single retouched tool with use-wear traces, leads us to deduce that the tools were exclusively used for the above-mentioned activities with no need of resharpening. The absence of clear use-wear traces on thermally altered elements is in the same vein. If polishes were well developed, they could be identified in spite of thermal

alteration (*cf.* Clemente 1997), but this is not our case. Taking all this into consideration, we may conclude that the tasks performed in these activity areas were neither intense nor long-spanned.

As for the prehensile parts of the tools, there is no evidence of them having undergone hafting processes, even if we can not rule out the possibility that no use-wear has been recorded, or traces of another kind of manipulation. Still, it is significant that the totality of the tools, including small-sized ones, can be held by hand. Hafting in Neanderthal contexts has been previously documented (*e.g.* Beyries 1987; Mazza et al. 2006; Rots 2011, 2013, 2014, 2016; Rots et al. 2015; Degano et al. 2019; Niekus et al. 2019). According to Rots (2014, 2016), hafted tools may show an explicit need responding to the recurrency for which a

Fig. 4 Tool x4/758 with wood-working traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50 $\times$. **B** Bright polish on the ventral surface with a rough texture and a domed topography especially on the higher parts of the surface at 100, 200 and 500 $\times$



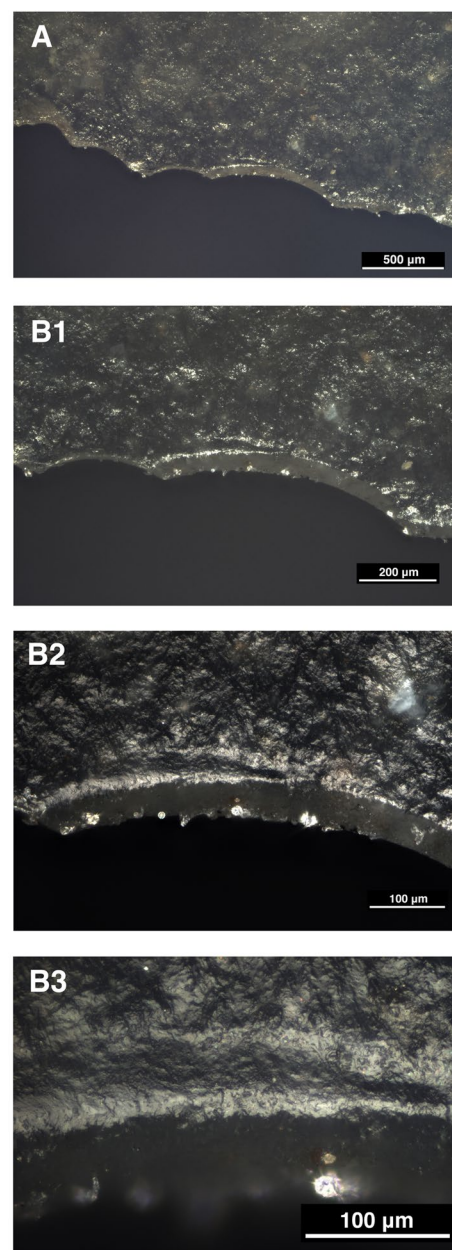
task was performed. The absence of hafting observed in our analysis supports our hypothesis of the low-intensity and short-spanned use of the tools.

Characterising activity areas through functional analysis

Thanks to the functional results obtained through the analysis of the three AUs, we have been able to examine the tasks carried out in each case. As for woodworking, two processes were identified in the AUs 5.3.1 and 5.3.2: cutting and scraping. This enables us to deduce that both frames are related to the processing of woody material. These actions

can be associated with different kinds of activities, such as fuel processing, for which there is much evidence in El Salt (*cf.* Vidal), or even the production of tools. In regards to this, there is a great number of functional studies applied to Neanderthal material collections that evidence woodworking (*e.g.* Beyries 1987; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lasuén & González 2014; Hortelano 2016). In addition, some woody remains in Schöningen (Germany) (*cf.* Thieme 1997), Arambaltza III (Spain) (*cf.* Ríos et al. 2018) or Poggetti Vecchi (Italy) (*cf.* Aranguren et al. 2018) show work traces or even vegetal fibres, as in the case of the remains found in Abri du Maras (France) (*cf.* Hardy et al. 2013, 2020). In the case

Fig. 5 Tool x5/1062 with woodworking traces in a cutting action. **(A)** Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, transverse termination and oblique orientation at 50 $\times$. **(B)** Well-developed polish on the ventral surface with a rough texture, which tends to be smooth, a domed topography, which tends to be flat directly on the edge, and a development of edge rounding at 100, 200 and 500 $\times$



of El Salt, the presence of minor woody taxa being suitable for toolmaking has made possible to suggest their use to that end (cf. Vidal et al. 2018).

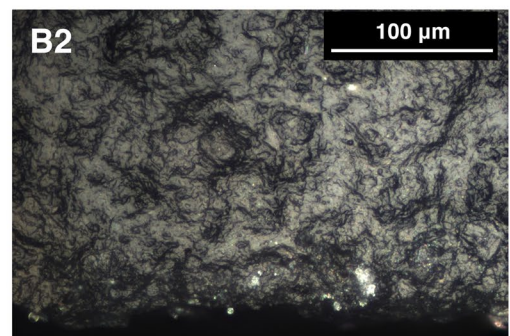
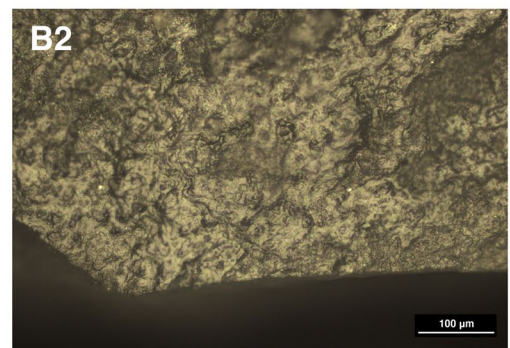
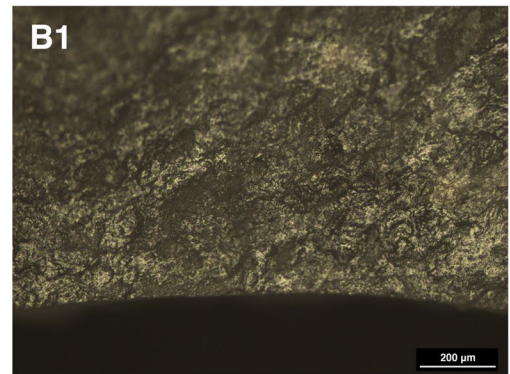
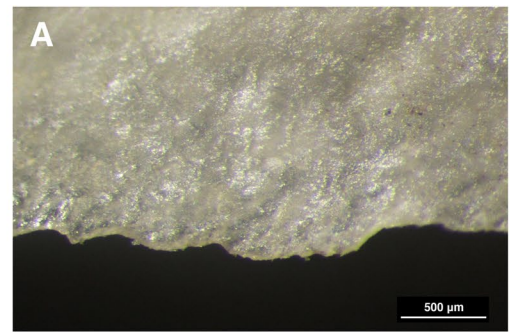
We can also observe different use-wear traces regarding the processing of animal tissues. Prior to the AU 5.3 dissection (cf. Mayor et al. 2020), the archaeozoological investigations also had certified butchering activities in the faunal assemblage (cf. Pérez 2019; Pérez et al. 2020): four specimens ascribed to the *Caprinae* subfamily, four to the *Equidae* family and two to the *Cervidae* family show evidence of activities like skinning, periosteum removal and quartering of preys. These cut marks are very superficial, concurring with the slightly developed use-wear traces

on lithic tools. This allows us to propose the association between the faunal record with cut marks and the lithic record with butchering traces. Taking into account that our functional results ascribe the butchering activity to two of the three events of AU 5.3 (i.e. 5.3.2 and 5.3.3), we suggest the link between the archaeozoological record and these frameworks.

Use-wear analysis applied in high temporal resolution frames

In the Mediterranean Iberian Neanderthal sites, we can observe that woodworking and prey processing were frequent

Fig. 6 Tool $\times 4/775$ with butchering activity traces in a cutting action. **(A)** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, transverse termination and an oblique orientation at $50\times$. **(B)** Dull polish on the dorsal surface with a fluid texture, a domed topography and a fuzzy contour at 100, 200 and $500\times$

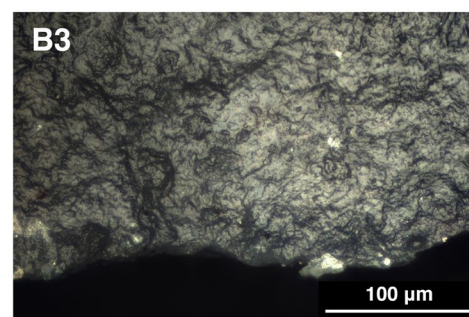
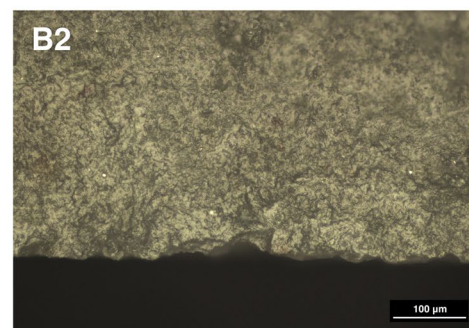
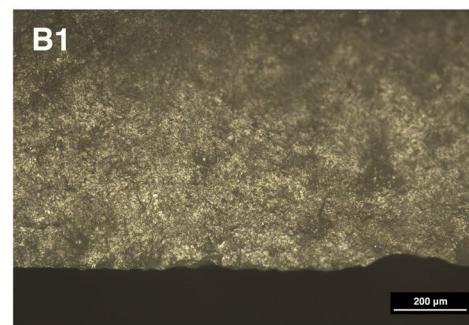
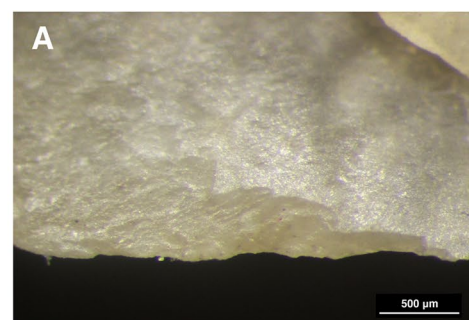


during the Middle Palaeolithic (*cf.* Moriel 1985; Rodríguez et al. 2002; Martínez 2005; Galván et al. 2008; Eixea et al. 2015; Hortelano 2016; Martín-Viveros et al. 2020).

Nevertheless, these studies utilised coarse-time and thus less suitable analytical frameworks to understand human behavioural variability across time.

To date, we only relied on two research works that analysed the function of the lithic tools forming part of a high temporal resolution assemblage. The number of lithic remains comprised in our AUs is along the same lines as that from the Grotta dei Santi 150A unit (n116; *cf.* Spagnolo et al. 2020), or that from the Abric del Pastor AU ivfH17

Fig. 7 Tool x4/787 with dry skin traces in a cutting action. (A) Small and medium-sized scars on the ventral surface with an aligned or superimposed organisation, a semicircular or irregular morphology, a feather and step termination and an oblique orientation at 50 $\times$. (B) Dull polish on the ventral surface, with a rough texture and a domed topography in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500 $\times$



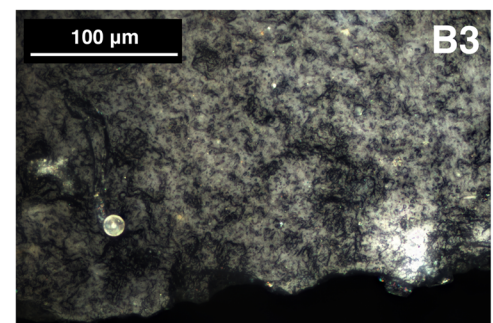
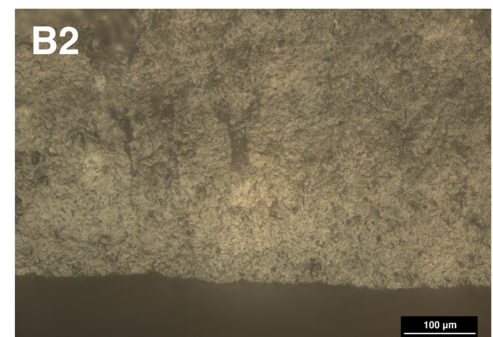
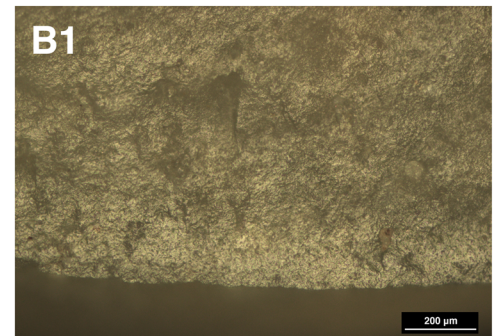
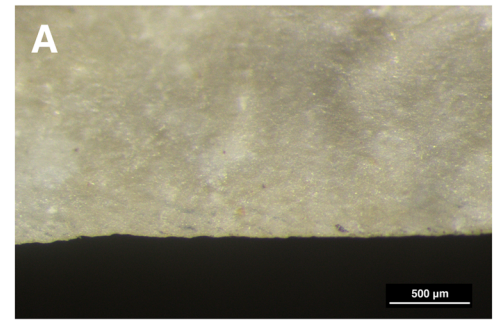
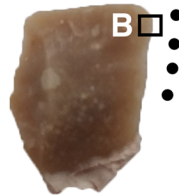
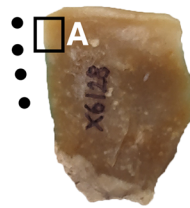
(n11; *cf.* Sossa-Ríos et al. 2022). In all cases, the assemblages are very close to human temporality and the number of remains, even if it could seem scarce, could be explained by the activities performed by the Neanderthal groups.

Furthermore, the results of these studies reflect the exclusive performance of butchering activity, which is analogous to that described for the El Salt AU 5.3.3. This brings out the singular character of tasks carried out not only in determinate activity areas, like this case and that

of Spagnolo et al. (2020), but also in frames representing human single occupations (*cf.* Sossa-Ríos et al. 2022).

In our case, not one but three successive high-resolution AUs have allowed us to read different functional dynamics. These reflect variations of the activities developed in a determinate space of the site across a narrow timescale. It could be indicating diachronic changes in the spatial management, as a proper way to explore human behavioural variability.

Fig. 8 Tool x6/28 with dry skin traces in a scraping action. **(A)** Small scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather termination and perpendicular orientation at 50 $\times$. **(B)** Dull polish on the dorsal surface, with a rough texture and a domed topography, in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500 $\times$



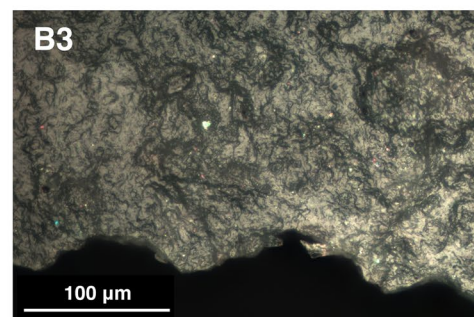
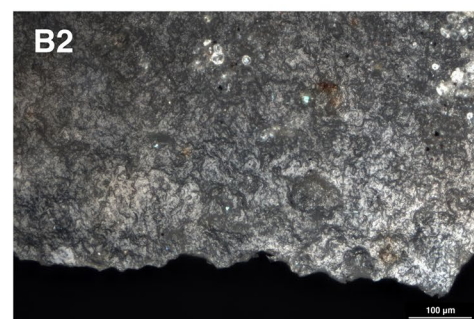
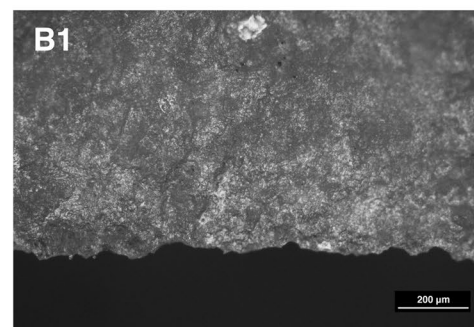
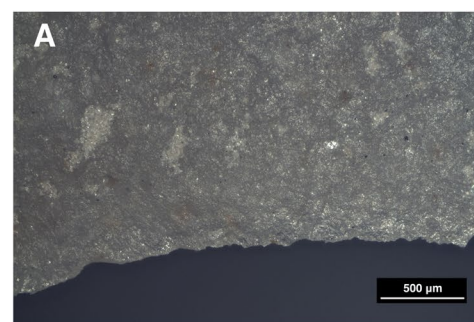
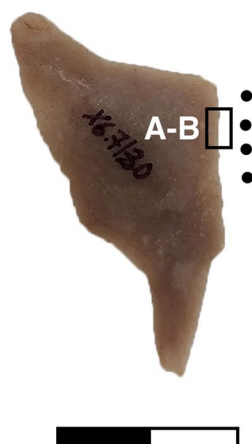
Conclusions

The use-wear analysis applied to the lithic record from three diachronic AUs has allowed us to recognise particular activities performed in different moments: woodworking in 5.3.1, butchering and woodworking in 5.3.2 and butchering in 5.3.3. These results highlight two relevant

issues for analysing the Neanderthal behaviour and its variability:

1. The functional analysis offers determinate temporal markers that can be associated with short-spanned events: the low development of use-wear traces, as well as the absence of superposition of use-wear traces,

Fig. 9 Tool x6.7/30 with butchering activity traces in a cutting action. **(A)** Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather or transverse termination and oblique orientation at 50 $\times$. **(B)** Dull polish on the ventral surface, with a fluid texture and a domed topography, a fuzzy contour and associated with well-developed spots of polish at 100, 200 and 500 $\times$



resharpening or hafting marks. These indicators are common in the three AUs and show a pattern held across time, regardless of the activities represented within each.

2. By means of the high-resolution contexts studied here, we leave behind a scenario derived from functional studies focusing on the SU as a framework, in which Neanderthals performed simultaneously the same tasks (i.e. woodworking, butchering and skinning). With this work,

we evidence a different scenario, in which we observe a dynamic and changeable behaviour: events revealing a lesser variety of activities (i.e. 5.3.1, 5.3.3) in contrast to another one in which the tasks are more diverse (i.e. 5.3.2).

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Declarations

Conflict of interest The authors declare no competing interests.

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4.2. Resultados en torno a otras unidades arqueostratigráficas de alta resolución temporal de El Salt

La unidad arqueostratigráfica 3.2

De las 69 piezas seleccionadas, se ha realizado el análisis traceológico en todas ellas. Las que presentan huellas de uso suman un total de 22 piezas, con 24 filos utilizados (Tabla 16). 10 de ellas, con 11 filos activos, estuvieron involucradas en procesamiento carnicero (Fig. 16-20), realizando acciones longitudinales (n 9) y transversales (n 3). 4 estuvieron involucradas en el trabajo de la piel (Fig. 21), realizando acciones longitudinales (n 3) y transversales (n 1). Por lo que respecta a las materias que no han podido definirse con mayor precisión, contamos con 7 piezas que procesaron materia blanda en acciones longitudinales, una pieza trabajó materia semidura de manera transversal y otra pieza estuvo involucrada en un trabajo de materia dura en una acción transversal.

Destaca la presencia de 20 piezas que cuentan con alteraciones postdeposicionales, relacionadas con la acción del fuego, impidiendo su análisis.

Finalmente, no se han reconocido estigmas de enmangamiento en ninguna de las piezas analizadas.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
3.2	UA2/13	Rectangular	Recto	60°	Carnicería	Longitudinal	Cortar	Raedera lateral	Serreta	48x36x11
			Convexo	65°	Carnicería	Longitudinal	Cortar	Raedera lateral, pero se usó el filo vivo opuesto		
	X1.2/11	Triangular	Recto	45°	Carnicería	Longitudinal	Cortar	Raedera lateral	Serreta	39x22x5
	X2/27	Rectangular	Recto	60°	Carnicería	Longitudinal	Cortar	Lasca	Beniaia	38x28x6
	X2/33	Rectangular	Cóncavo	55°	Carnicería	Longitudinal	Cortar	Lasca	Mariola	62x39x8
	X3/89	Triangular	Recto	35°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	34x15x3
	X4/208	Triangular	Cóncavo	60°	Carnicería	Transversal	Raspar	Denticulado	Mariola	50x39x14
	X4/209	Rectangular	Convexo	55°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	39x24x11
	X5.6/185	Rectangular	Recto	75°	Materia dura, seguramente hueso	Transversal	Raspar	Raedera lateral, pero se usó un filo vivo opuesto	Serreta	42x28x9
			Recto	60°	Carnicería	Longitudinal	Cortar	Raedera lateral		
	X5.6/175	Semicircular	Recto	65°	Carnicería	Longitudinal	Cortar	Raedera transversal	Beniaia	59x43x20

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
3.2	X5.6/119	Rectangular	Recto	65°	Carnicería	Transversal	Raspar	Raedera lateral	Beniaia	43x30x10
	X4.5/371	Semicircular	Convexo	90°	Piel	Transversal	Raspar	Raedera transversal	Serreta	31x20x8
	X4/154	Triangular	Recto	55°	Piel	Longitudinal	Cortar	Raedera lateral	Serreta	54x23x9
	X2/15	Rectangular	Recto	90	Piel	Transversal	Raspar	Lasca	Serreta	21x17x8
	X4.5/529	Rectangular	Recto	75	Piel	Transversal	Raspar	Lasca	Serreta	52x37x15
	X4.5/53	Rectangular	Recto	45°	Materia blanda	Longitudinal	Cortar	Lasca	Mariola	60x45x24
	X4.5/460	Rectangular	Cóncavo	50°	Materia blanda	Longitudinal	Cortar	LCR	Serreta	26x26x5
	X2/11	Cuadrangular	Convexo	35°	Materia blanda	Longitudinal	Cortar	Lasca	Serreta	24x15x13
	X5.6/154	Irregular	Cóncavo	60	Materia blanda	Longitudinal	Cortar	Fragmento	Serreta	46x25x14
	X3/2	Rectangular	Convexo	30	Materia blanda	Longitudinal	Cortar	Lasca	Serreta	17x18x5
	X5.6/235	Cuadrangular	Recto	35	Materia blanda	Longitudinal	Cortar	Lasca Kombewa	Serreta	30x16x5
	X4/207	Cuadrangular	Convexo	65°	Materia blanda	Longitudinal	Cortar	Raedera lateral	Serreta	30x33x11
	X2.3/63	Cuadrangular	Convexo	70°	Materia semidura	Transversal	Raspar	Raedera transversal	Serreta	48x40x18

Tabla 16. Relación de material con huellas de uso de la UA 3.2

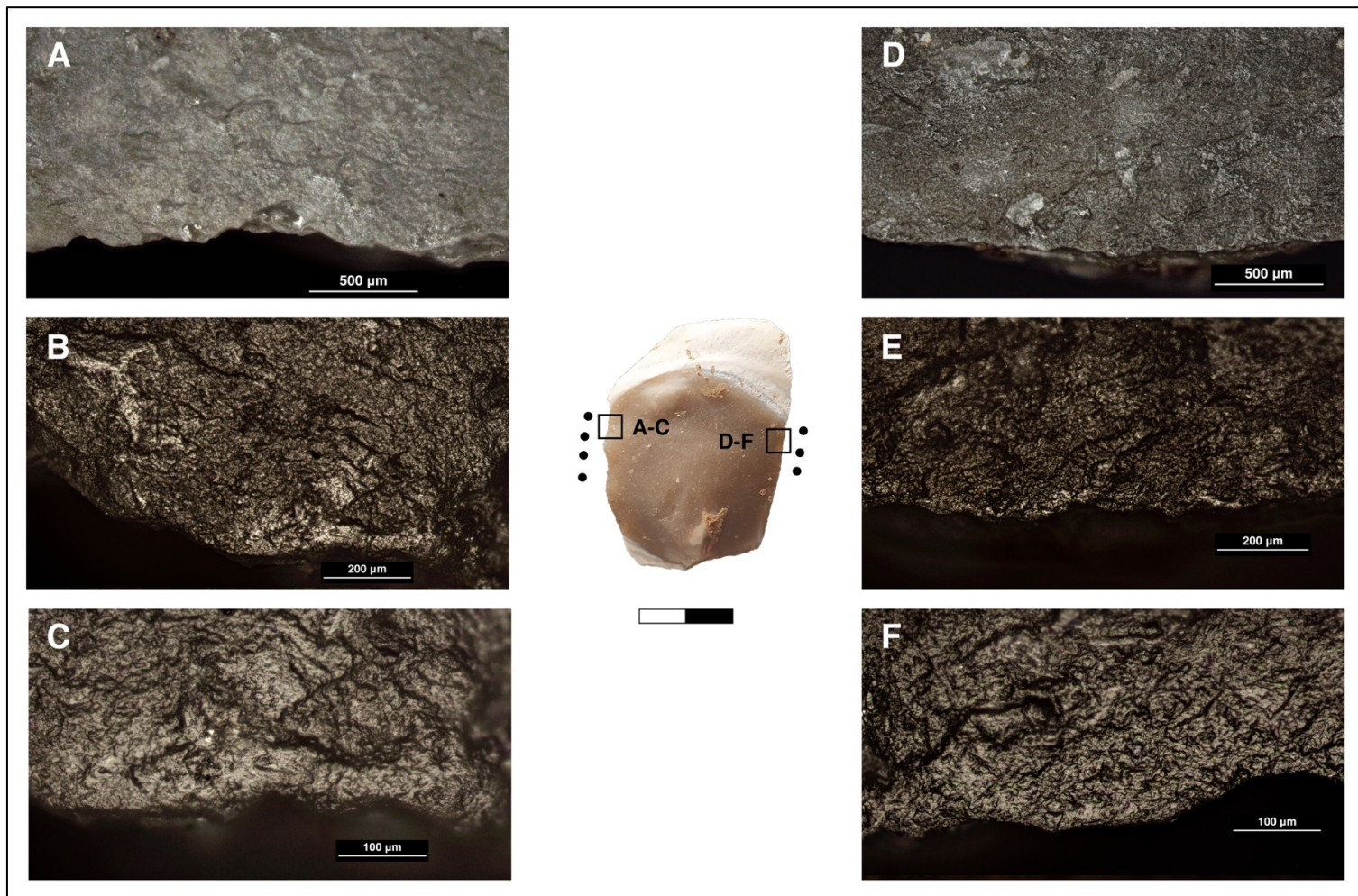


Fig. 16. Pieza UA2/13, con dos zonas de uso, relacionada con una acción de carnicería en acciones de corte. A) 50x, B) 100x, C) 200x, D), 50x, E) 100x, F) 200x

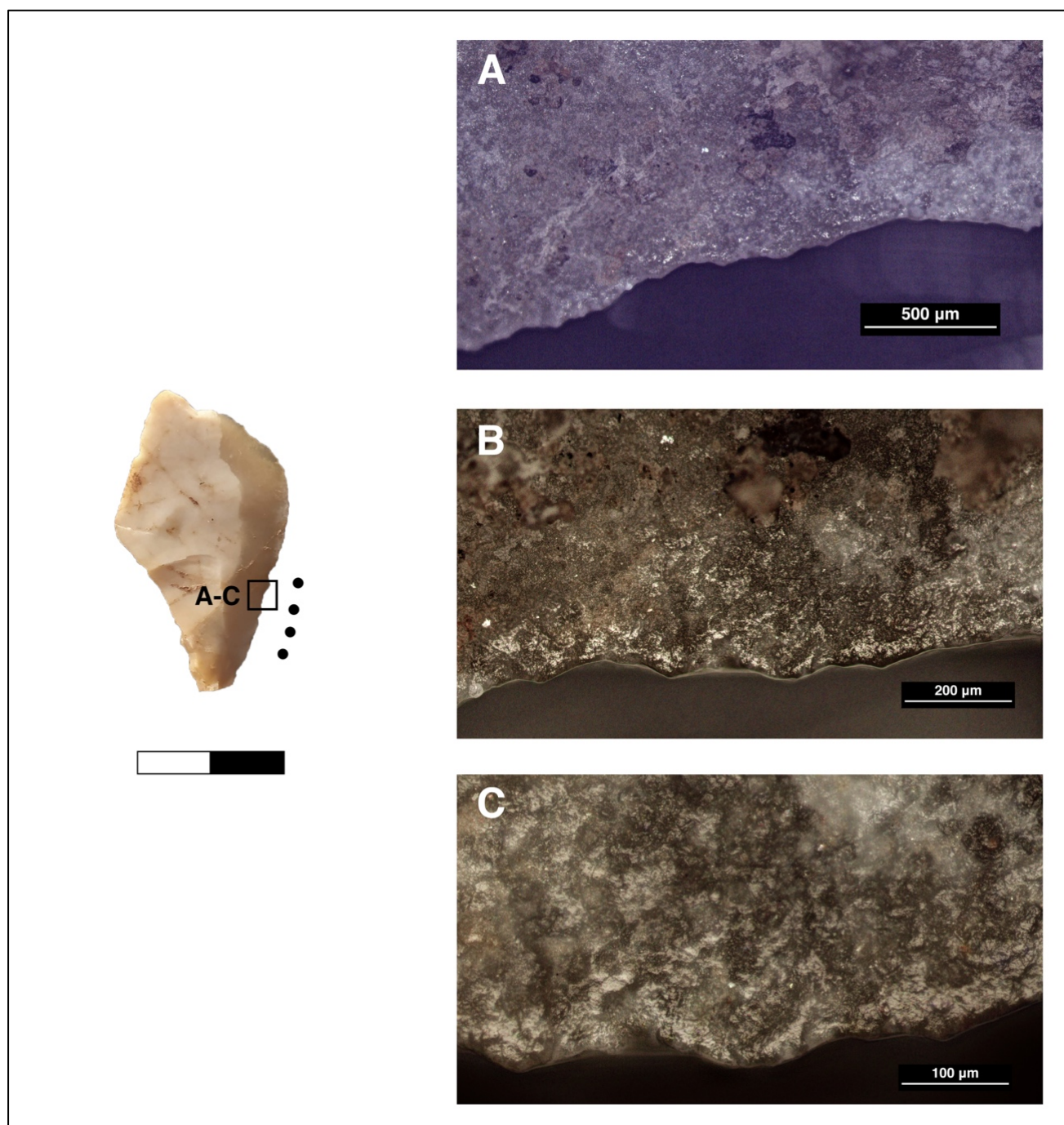


Fig. 17. Pieza X1.2/11 relacionada con una acción de carnicería en una acción de corte.
A) 50x, B) 100x, C) 200x

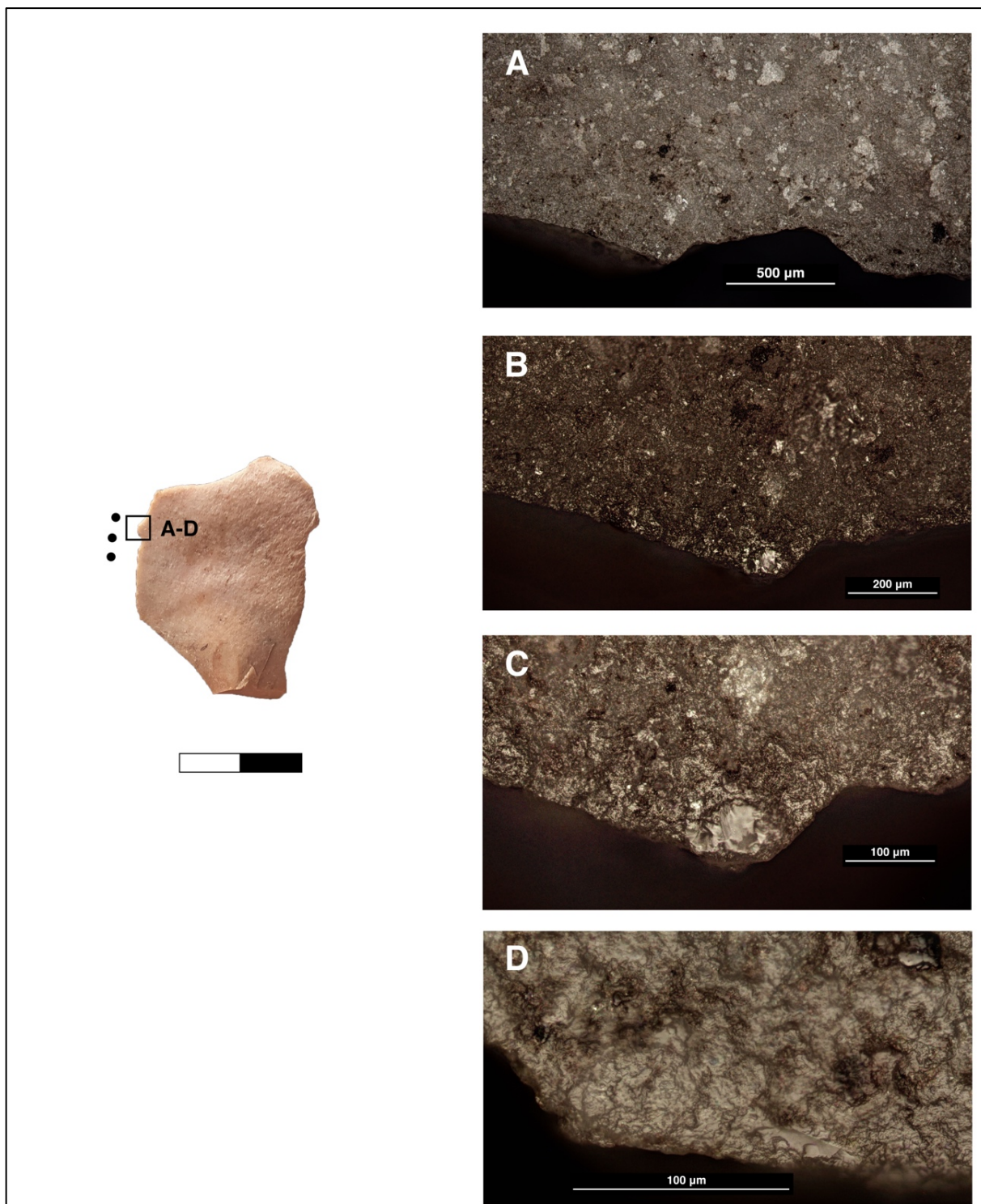


Fig. 18. Pieza X2/27 relacionada con una acción de carnicería en una acción de corte.
A) 50x, B) 100x, C) 200x, D) 500x

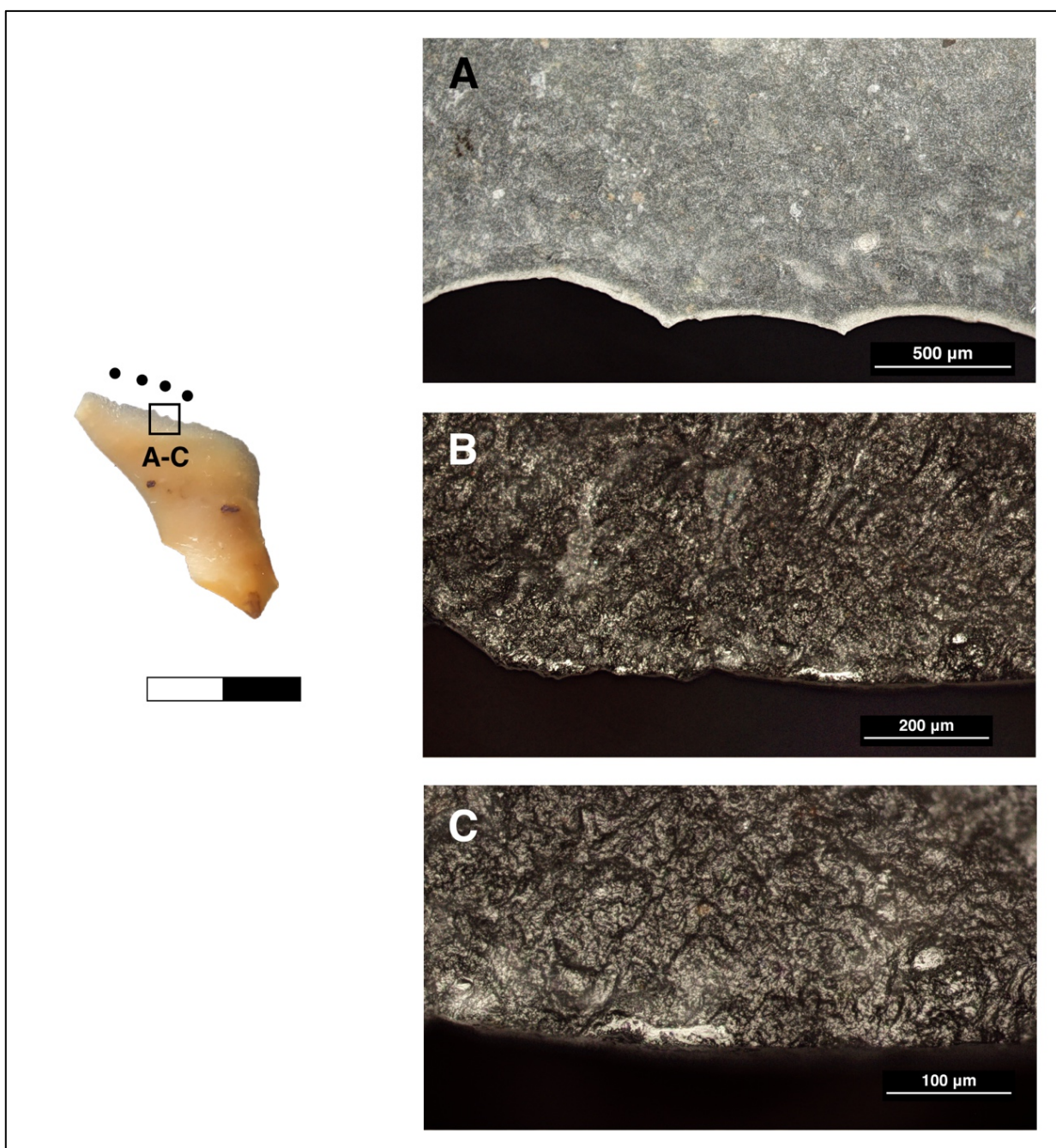


Fig. 19 Pieza X3/89 relacionada con una acción de carnicería en una acción de corte.
A) 50x, B) 100x, C) 200x

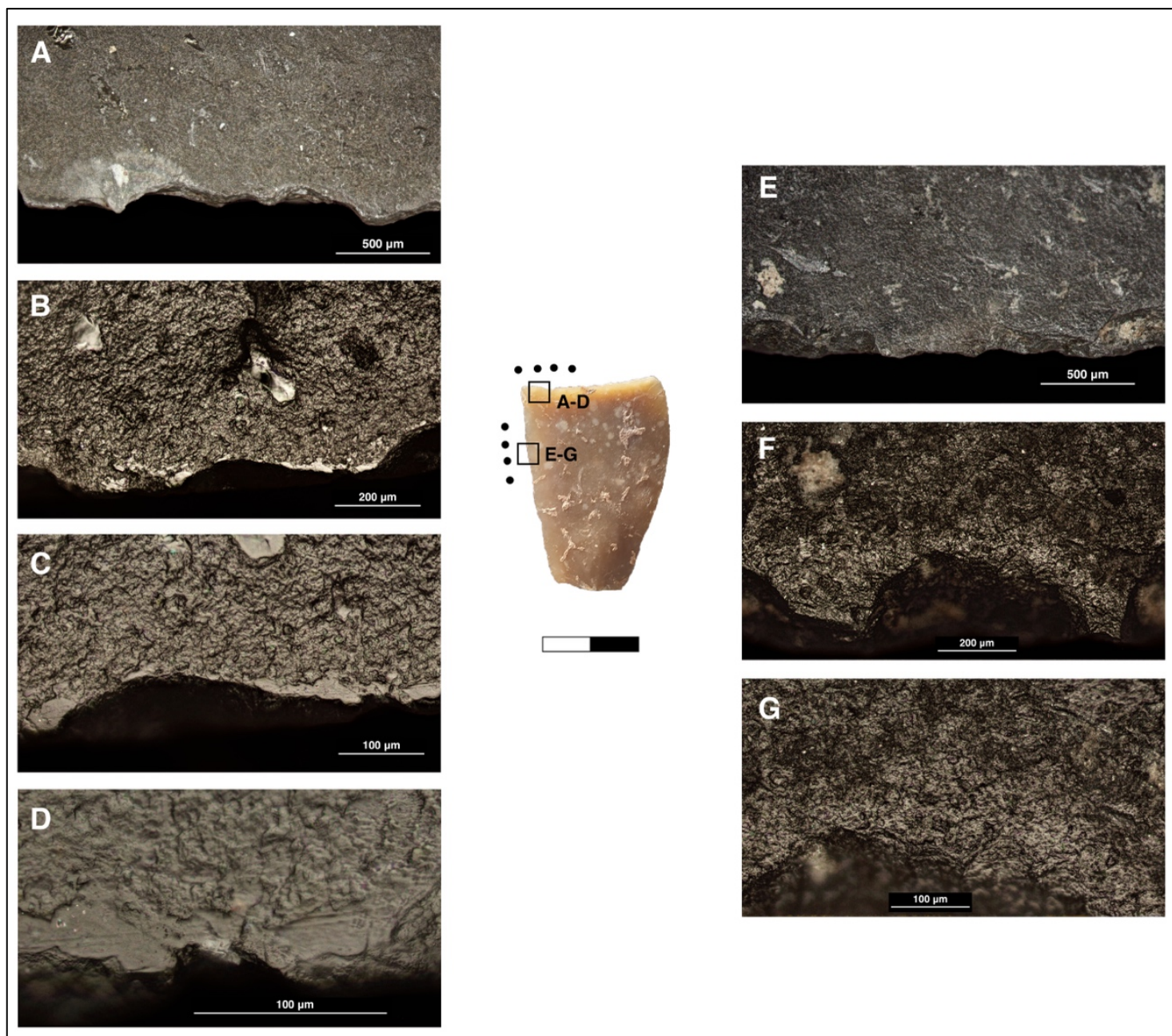


Fig. 20. Pieza X5.6/185, con dos zonas de uso, una relacionada con una acción de carnicería en una acción de corte, y otra en una acción de raspado sobre materia dura. A) 50x, B) 100x, C) 200x, D), 500x, E) 50x, F) 100x, G) 200x

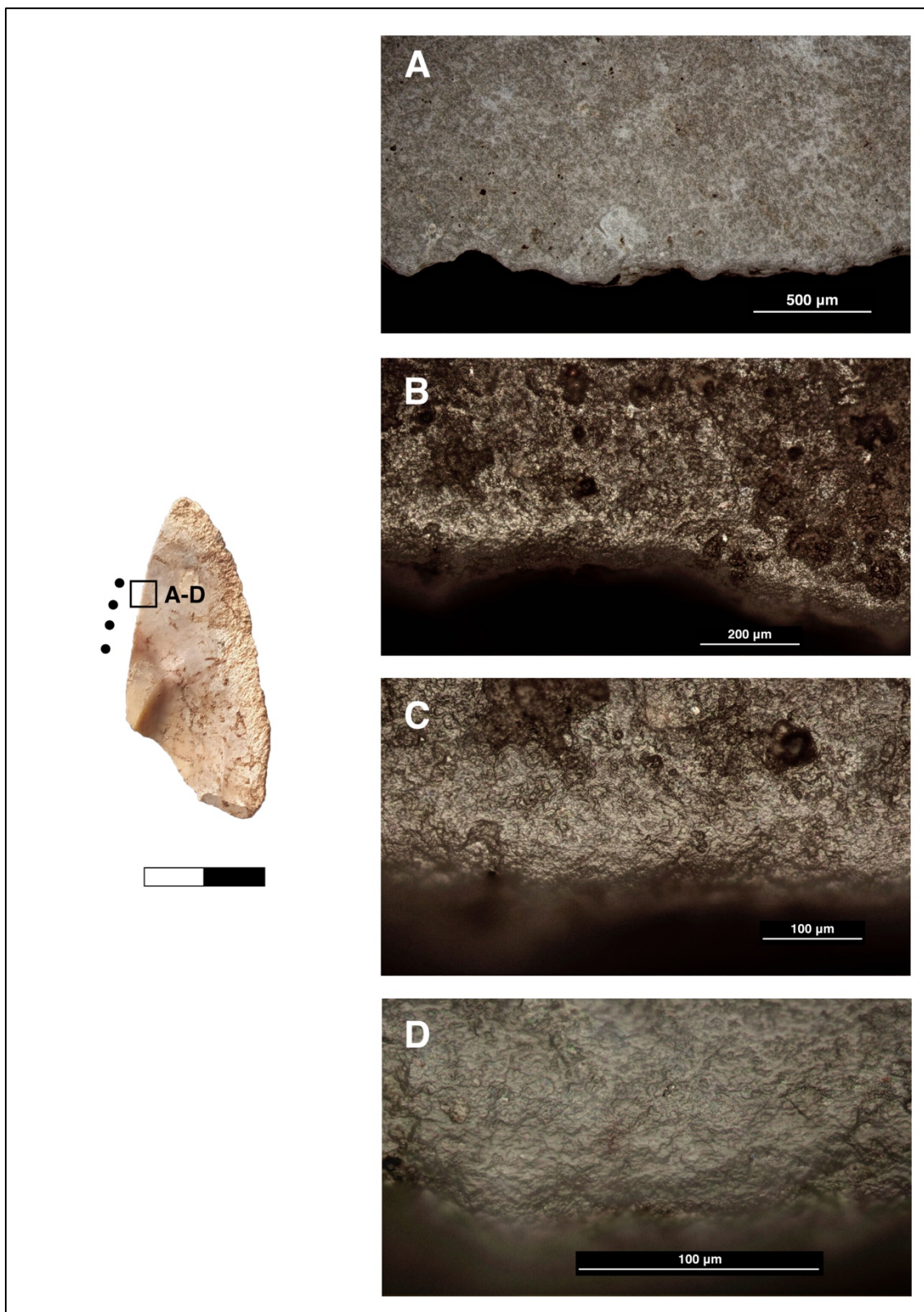


Fig. 21. Pieza X4/154 relacionada con una acción de cortar sobre piel. A) 50x, B) 100x, C) 200x, D) 500x

La unidad arqueostratigráfica 3.2.1

De las 13 piezas que integran la unidad 3.2.1, se analizaron traceológicamente un total de 9. De entre ellas, 4 cuentan con huellas de uso (Tabla 17): una estuvo en contacto con madera realizando un movimiento longitudinal (Fig. 22), otra estuvo involucrada en una acción de carnicería realizando también un movimiento longitudinal (Fig. 23), y dos estuvieron en contacto con una materia semidura, tanto longitudinal como transversalmente.

No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
3.2.1	X2/16	Cuadrangular	Recto	40°	Madera	Longitunal	Cortar	Lasca	Beniaia	24x22x4
	X3/107	Rectangular	Convexo	50°	Carnicería	Longitunal	Cortar	Lasca	Serreta	25x20x13
	X2/20	Irregular	Convexo	60°	Materia semidura	Transversal	Raspar	Lasca	Serreta	24x23x9
	X4/629	Rectangular	Recto	50°	Materia semidura,	Longitunal	Cortar	Lasca	Beniaia	33x15x5

Tabla 17. Relación de material con huellas de uso de la UA 3.2.1

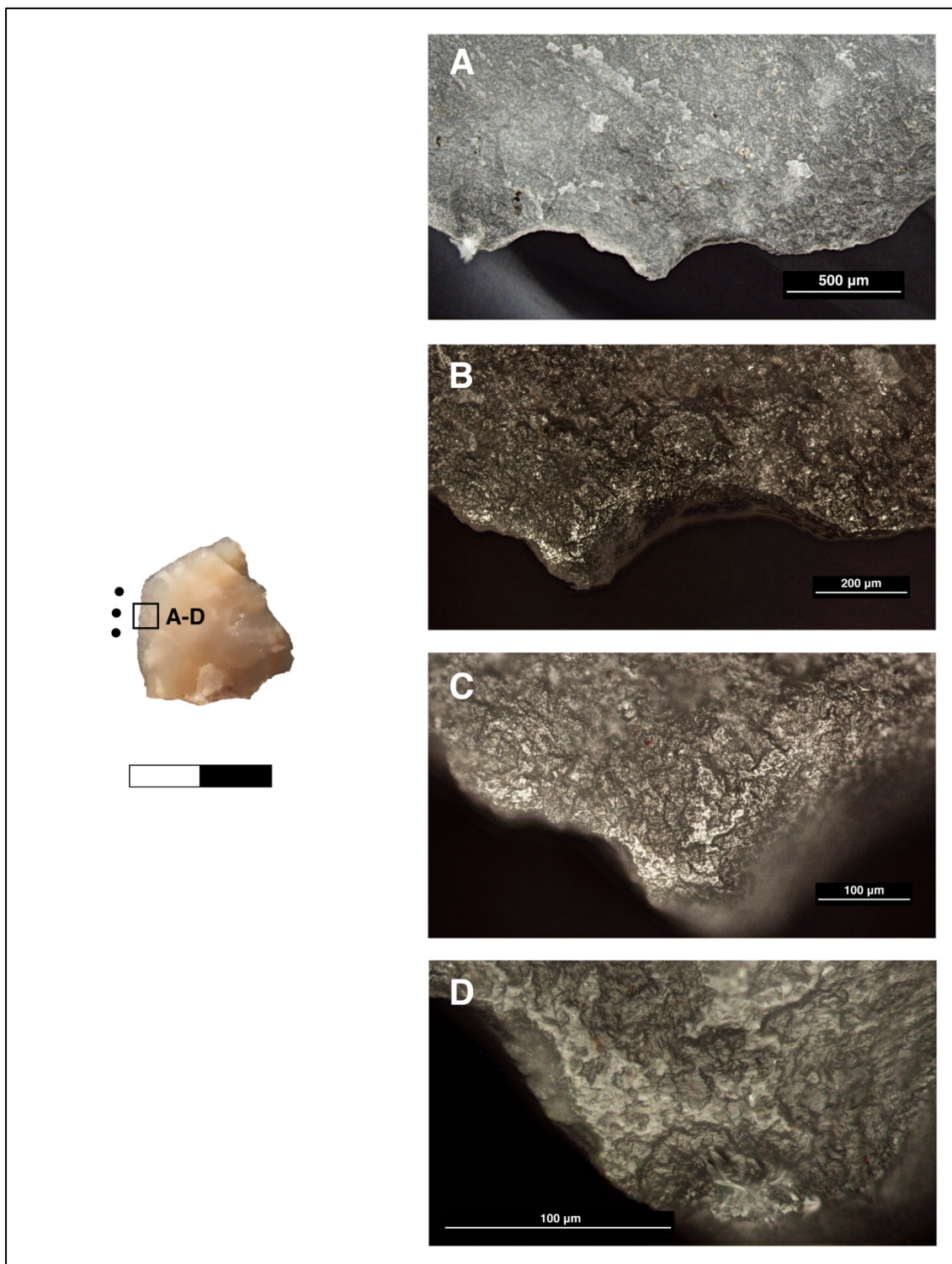


Fig. 22. Pieza X2/16 relacionada con una acción de cortar sobre madera. A) 50x, B) 100x, C) 200x, D) 500x

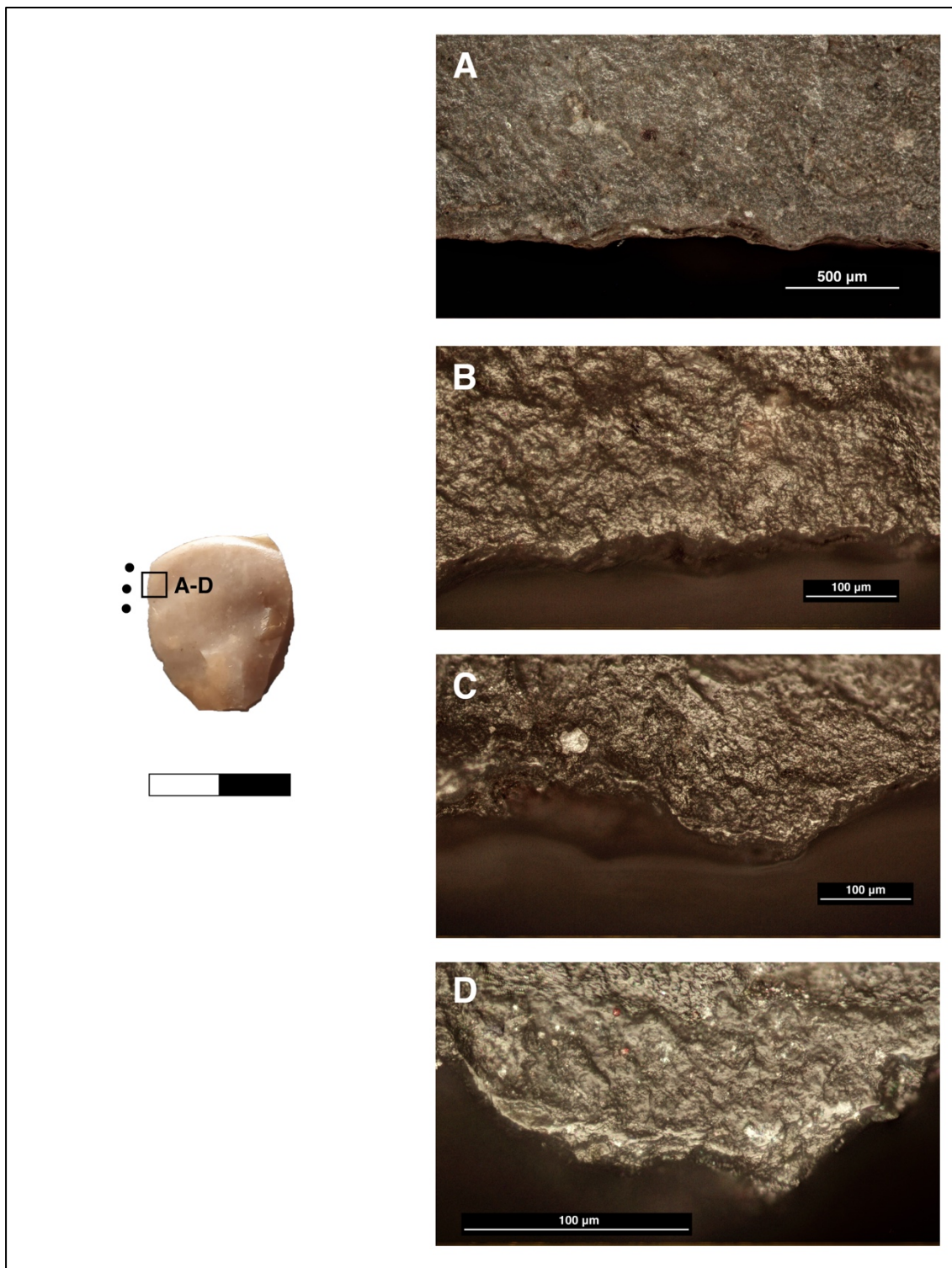


Fig. 23. Pieza X3/107 relacionada con un trabajo carnicero en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

La unidad arqueostratigráfica 4.1

Esta unidad cuenta con un total de 26 piezas líticas, de entre las cuales se han analizado un total de 21. 9 cuentan con huellas de uso (Tabla 18): 4 de ellas trabajaron madera realizando movimientos transversales (Fig. 27), 2 estuvieron involucrados en un proceso carnicero (Fig. 24) realizando movimientos longitudinales, 2 de ellas trabajaron piel en acciones tanto longitudinal como transversalmente (Fig. 25 y 26), y una última pieza trabajo una materia dura de manera longitudinal.

No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
4.1	X4/639	Semicircular	Cóncavo	75°	Madera	Transversal	Raspar	Lasca	Serreta	25x32x8
	X4/675	Cuadrangular	Recto	50°	Madera	Transversal	Raspar	Lasca	Serreta	22x26x6
	X4/676	Cuadrangular	Convexo	90°	Madera	Transversal	Raspar	Lasca	Mariola	23x31x8
	X4/620	Semicircular	Recto	85°	Madera	Transversal	Raspar	Lasca	Serreta	29x27x6
	X4/716	Rectangular	Recto	40°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	18x14x13
	X4/517	Irregular	Cóncavo	60°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	24x25x6
	X4/686	Rectangular	Convexo	65	Piel seca	Longitudinal	Cortar	Lasca	Mariola	35x20x4
	X5/970	Rectangular	Convexo	60°	Piel seca	Transversal	Raspar	Lasca	Serreta	34x17x11
	X4/684	Rectangular	Recto	55°	Materia dura	Longitudinal	Cortar	Lasca	Mariola	39x20x13

Tabla 18. Relación de material con huellas de uso de la UA 4.1

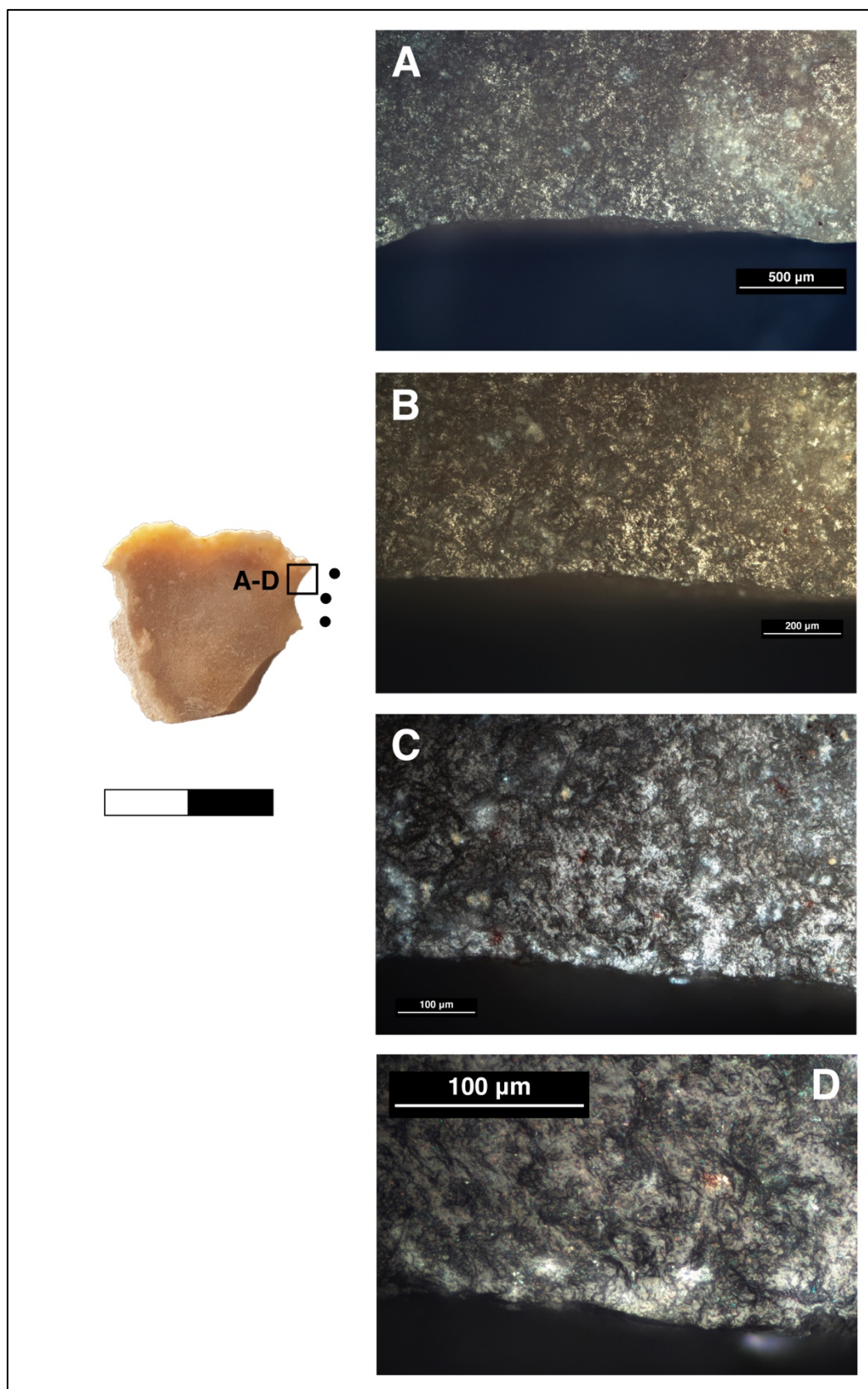


Fig. 24. Pieza X4/517 relacionada con un trabajo carnicero asociado a una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

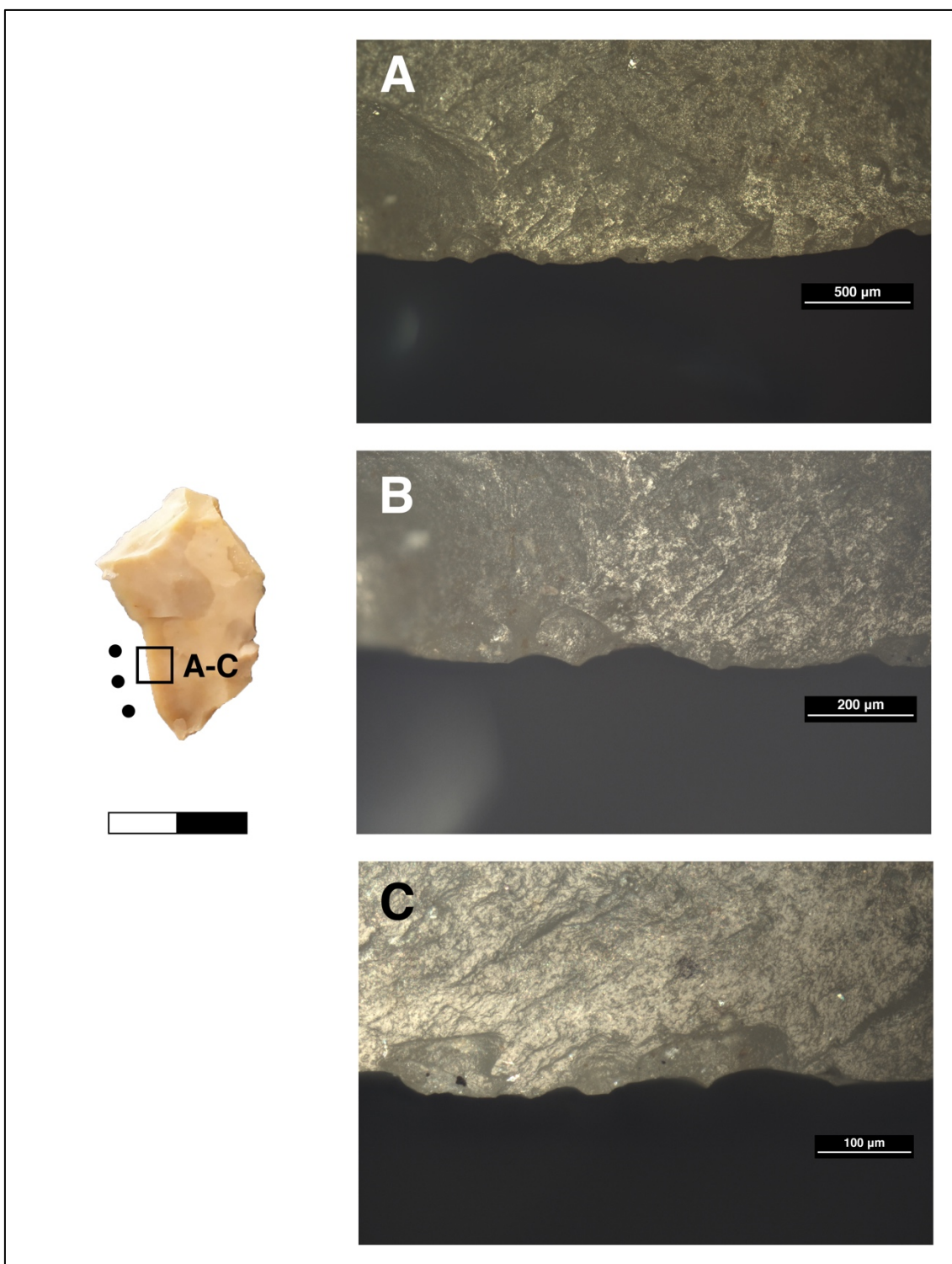


Fig. 25. Pieza X4/686 relacionada con un trabajo sobre piel seca en una acción de corte.
A) 50x, B) 100x, C) 200x

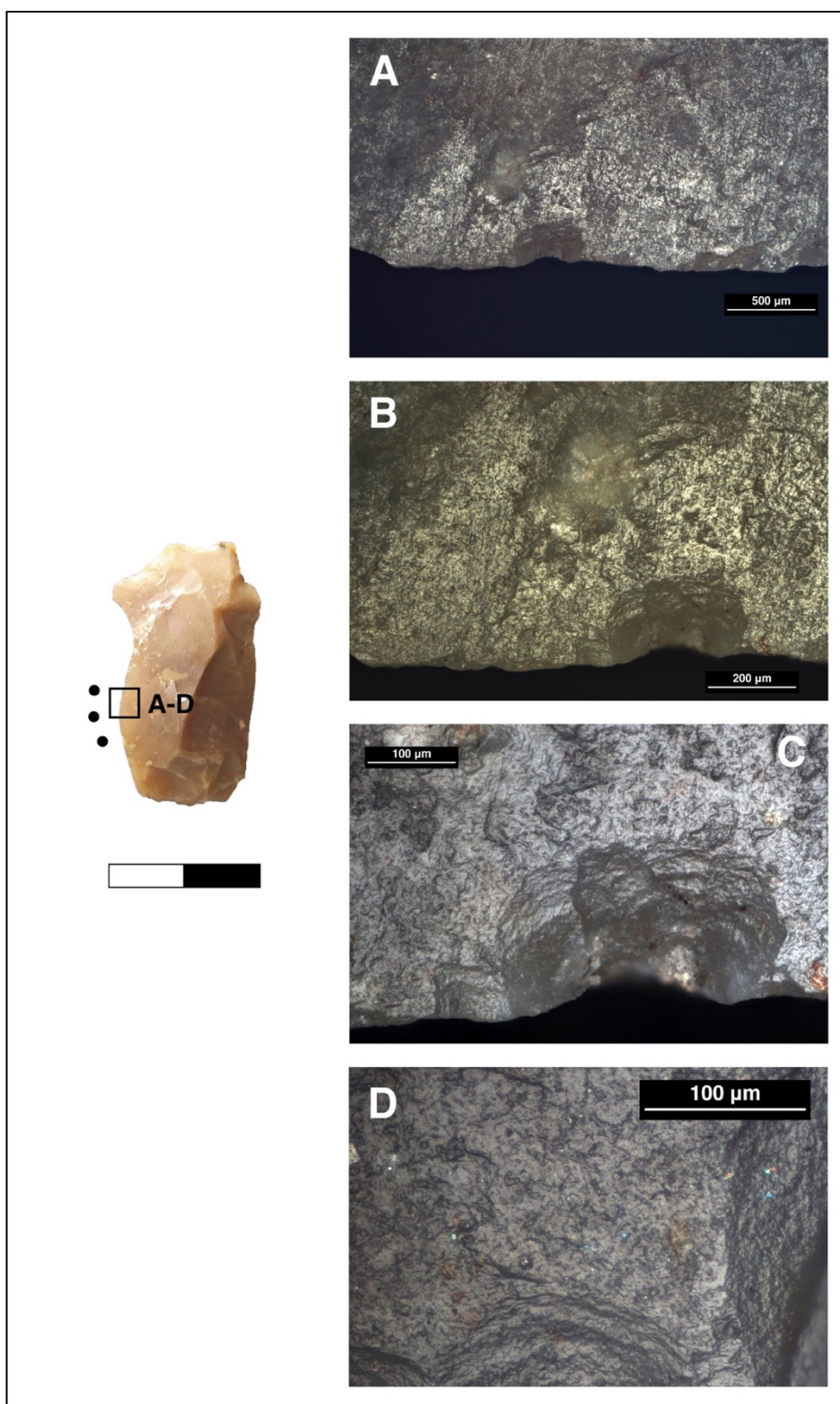


Fig. 26. Pieza X5/970 relacionada con un trabajo sobre piel seca en una acción de raspado. A) 50x, B) 100x, C) 200x, D) 500x

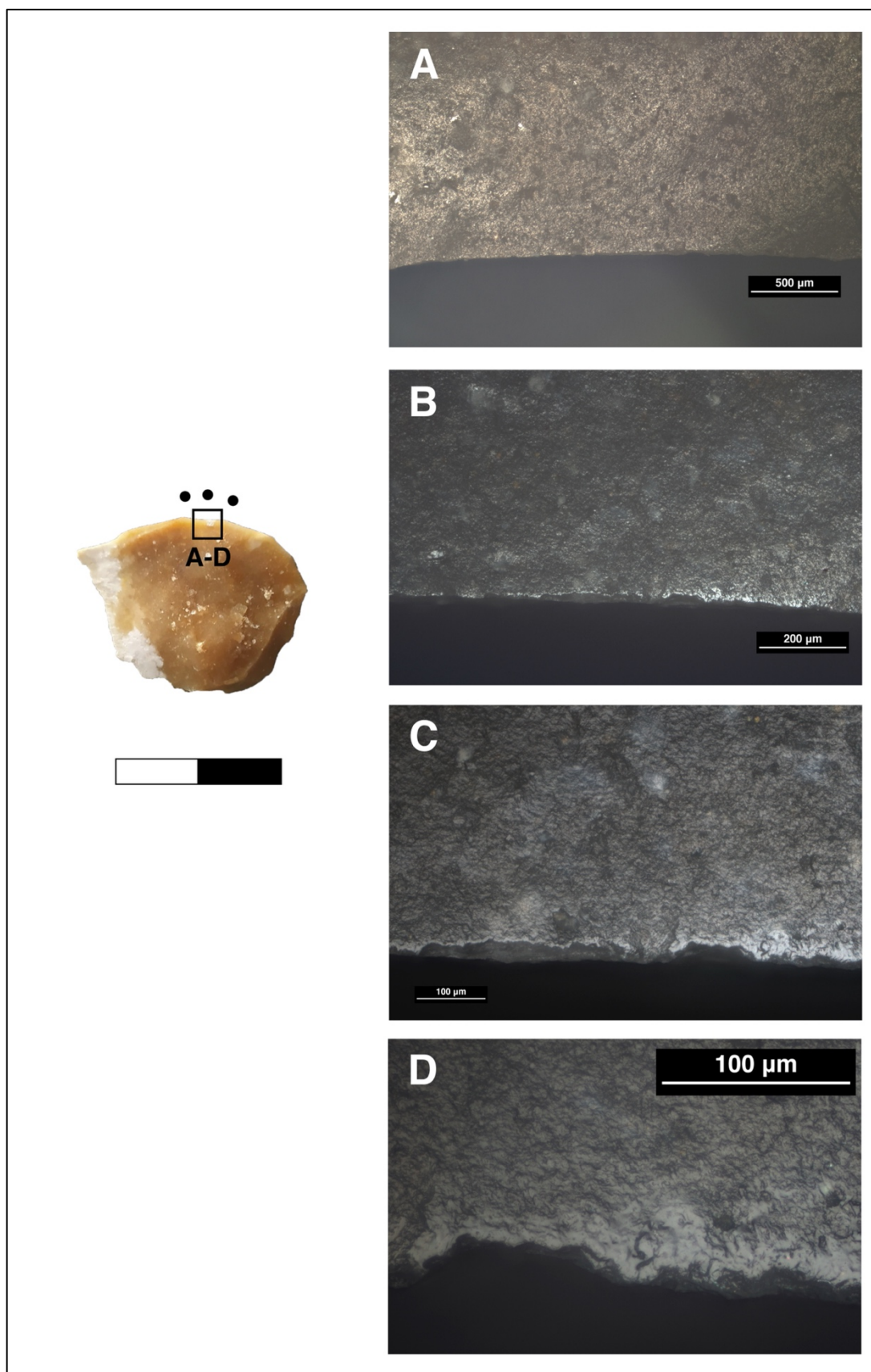


Fig. 27. Pieza X4/676 relacionada con un trabajo sobre madera en una acción de raspado. A) 50x, B) 100x, C) 200x, D) 500x

La unidad arqueostratigráfica 4.1.1

De las 10 piezas que integran esta unidad, se analizaron un total de 8. 3 cuentan con huellas de uso (Tabla 19): 2 relacionadas a trabajos de carnicería (Fig. 28 y 29) realizando movimientos longitudinales y una sobre materia semidura también en un movimiento longitudinal.

No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
4.1.1	X4/738	Irregular	Convexo	50°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	27x25x5
	X4/659	Rectangular	Cóncavo	50°	Carnicería	Longitudinal	Cortar	Lasca	Font Roja	35x13x4
	X4/728	Irregular	Recto	45°	Materia semidura	Longitudinal	Cortar	Lasca	Serreta	32x26x6

Tabla 19. Relación de material con huellas de uso de la UA 4.1.1

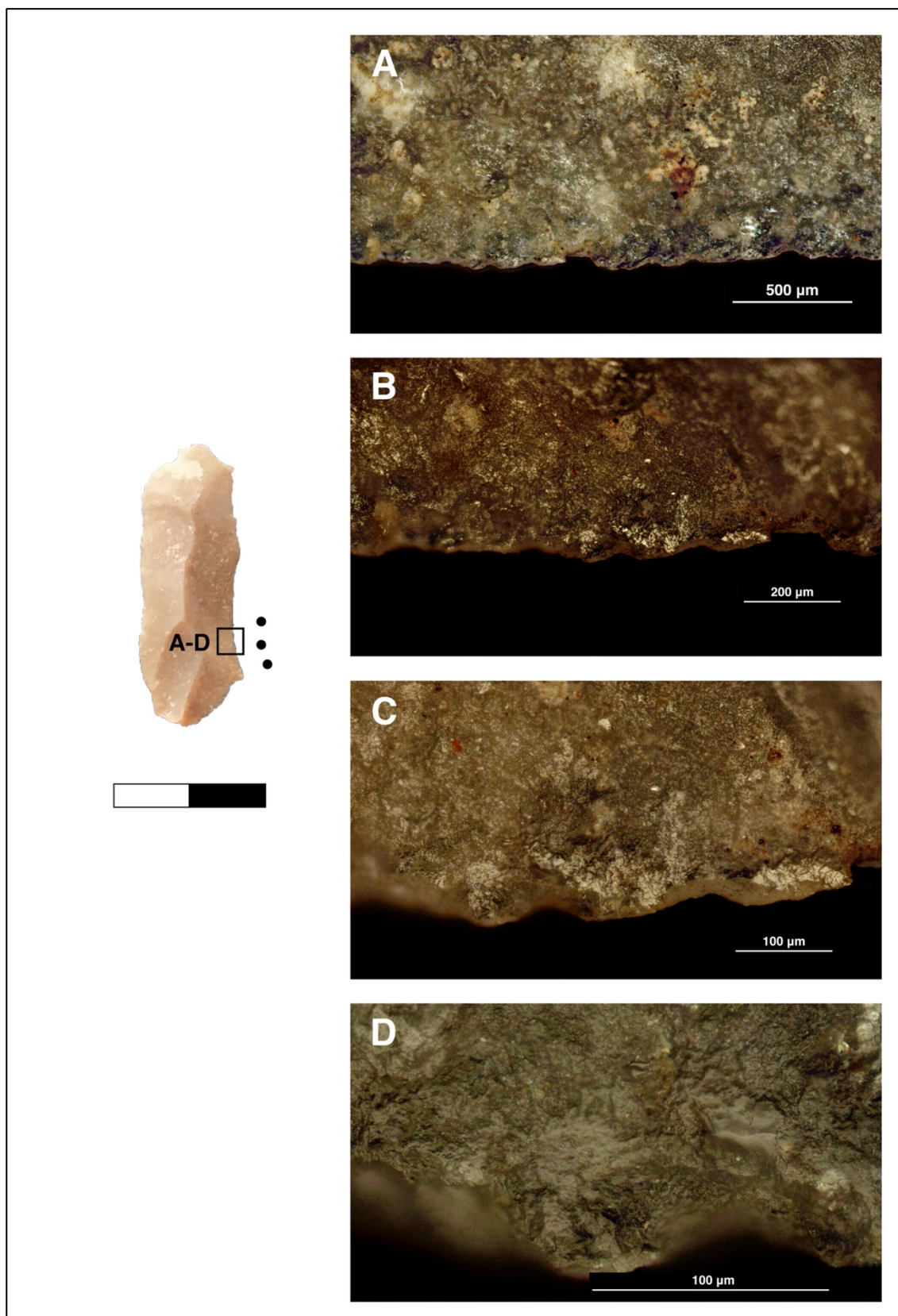


Fig. 28. Pieza X4/659 relacionada con un trabajo carnívorico, con puntos de pulido más desarrollados a lo largo del borde, en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

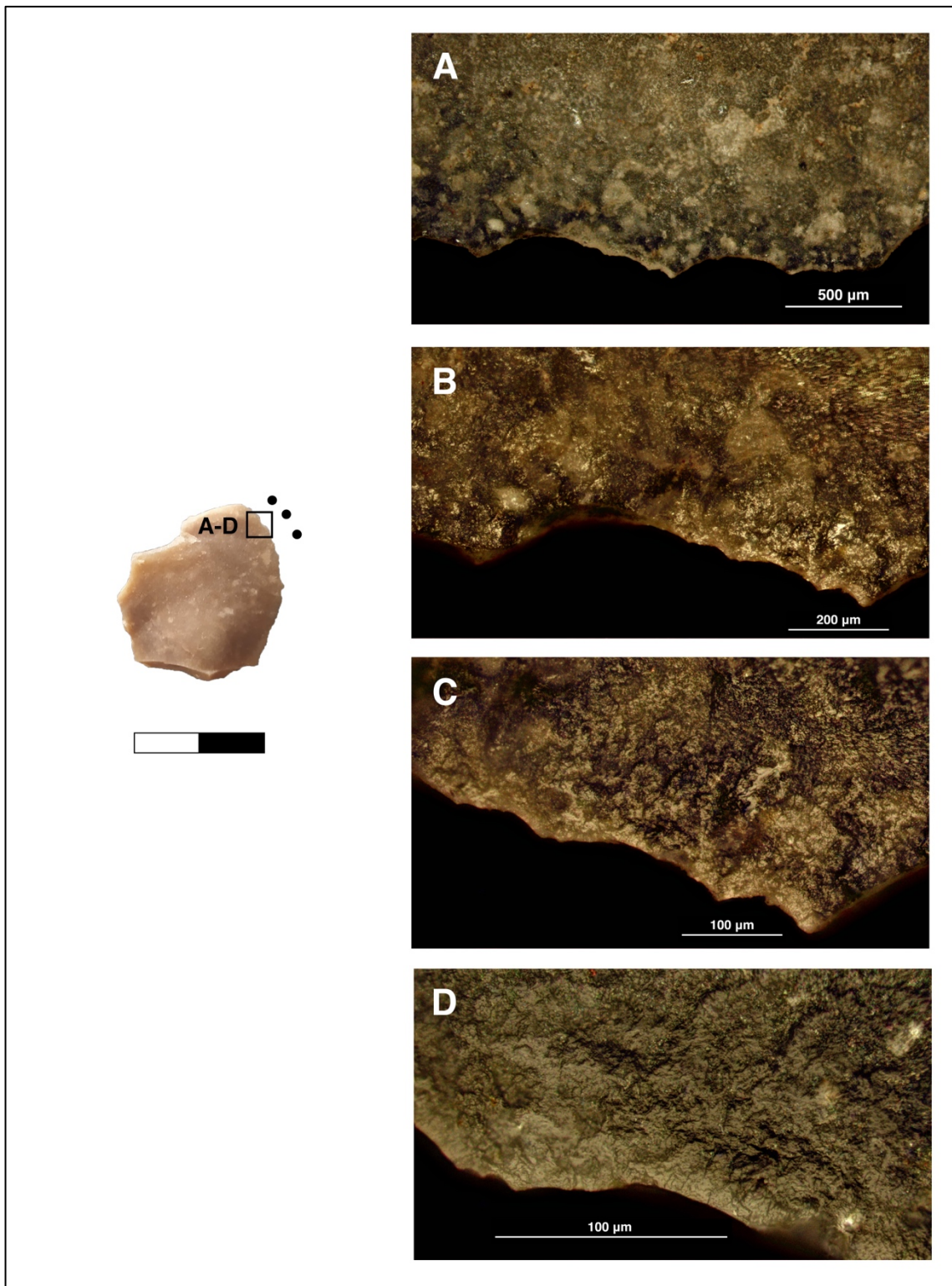


Fig. 29. Pieza X4/738 relacionada con un trabajo carnívoros en una acción de corte.
A) 50x, B) 100x, C) 200x, D) 50

La unidad arqueoestratigráfica 4.1.2

De las 24 piezas que integran esta unidad, se analizaron un total de 22. Sólo 5 presentan huellas de uso (Tabla 20), 4 ellas asociadas a una trabajo sobre madera, una de ellas interpretada como madera termoalterada (Fig. 30), en movimientos transversales (n 3) (Fig. 31) y uno longitudinal.

Una pieza se empleó sobre una materia semidura realizando un movimiento transversal.

No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
4.1.2	X4/720B	Irregular	Recto	55°	¿Madera termoalterada?	Transversal	Raspar	Lasca	Serreta	26x24x5
	X4/687	Rectangular	Recto	55°	Madera	Transversal	Raspar	Lasca	Serreta	45x45x5
	X4/742	Rectangular	Cóncavo	65°	Madera	Longitudinal	Cortar	Lasca	Serreta	34x21x5
	X4/657	Irregular	Cóncavo	60°	Madera	Transversal	Raspar	Lasca	Serreta	21x27x5
	X4/733	Rectangular	Convexo	45°	Materia dura	Transversal	Raspar	Lasca	Beniaia	33x11x3

Tabla 20. Relación de material con huellas de uso de la UA 4.1.2

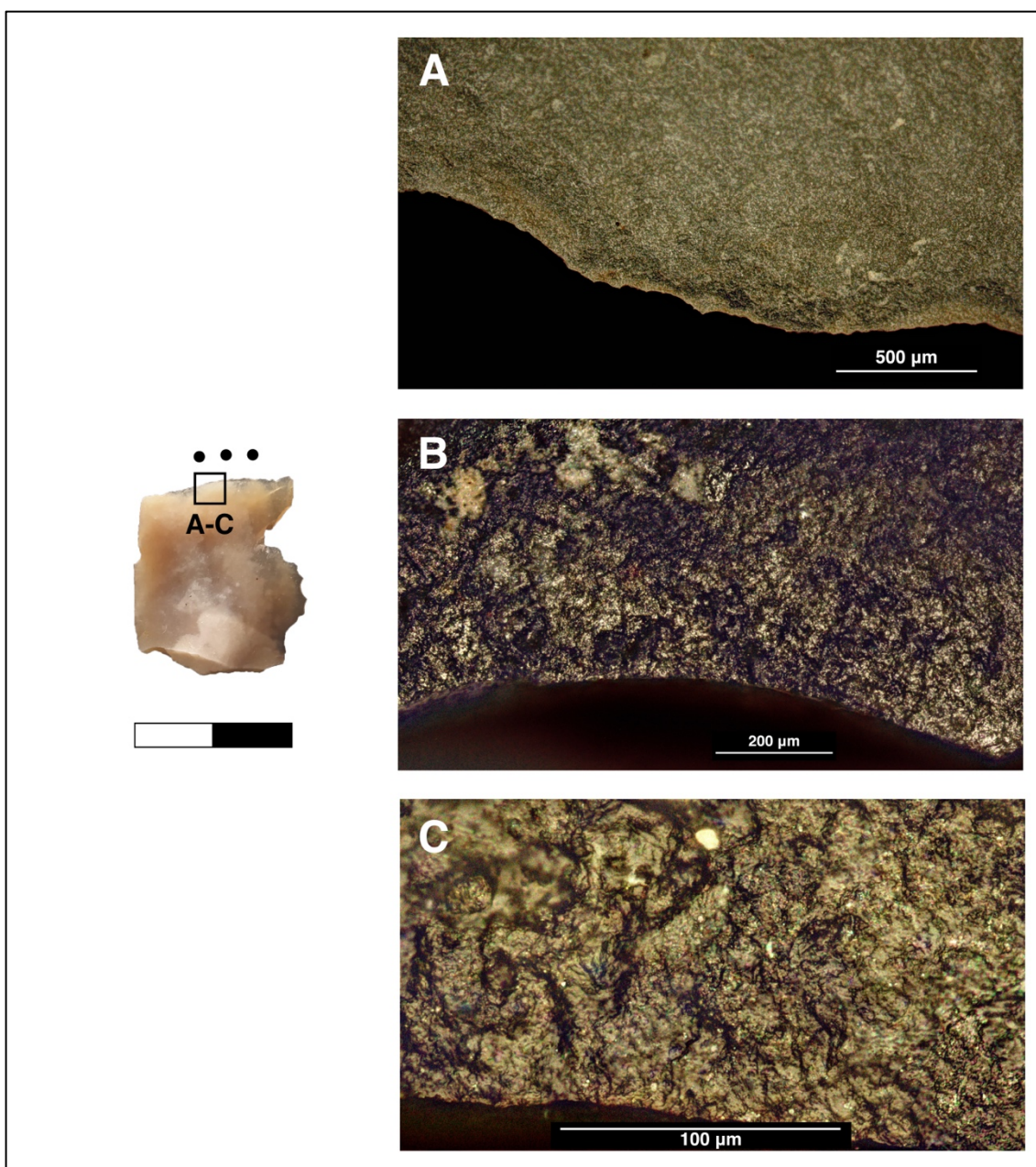


Fig. 30. Pieza X4/720B relacionada con un trabajo sobre madera termoalterada en una acción de raspado. A) 50x, B) 100x, C) 200x

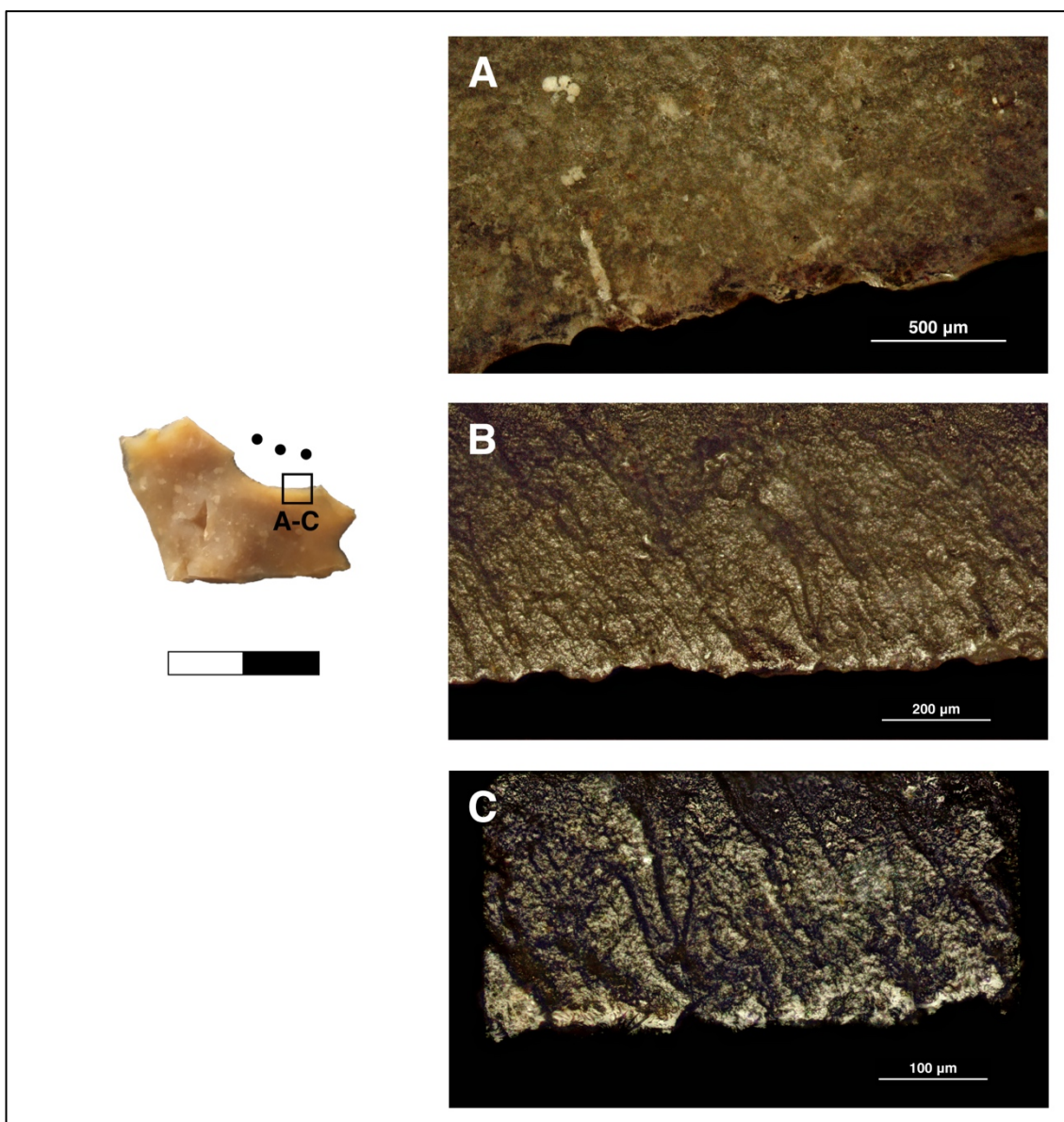


Fig. 31. Pieza X4/657 relacionada con un trabajo sobre madera en una acción de raspado. A) 50x, B) 100x, C) 200x

La unidad arqueoestratigráfica 5.1

De las 19 piezas que conforman esta unidad se analizaron todas. De entre ellas, 8 cuentan con huellas de uso (Tabla 21): 4 relacionados con trabajos de piel en acciones de corte salvo un caso de raspado (Fig. 32 y 33), y 4 relacionadas con trabajos de carnicería en acciones de corte (fig. 34). No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
5.1	X4/754	Cuadrangular	Recto	50°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	32x29x7
	X4.5/849	Irregular	Recto	40°	Carnicería	Longitudinal	Cortar	Lasca	Mariola	19x20x4
	X4/797	Rectangular	Recto	50°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	19x15x4
	X4/774	Rectangular	Recto	40°	Carnicería	Longitudinal	Cortar	Lasca	Mariola	26x14x2
	X5/17	Cuadrangular	Recto	90°	Piel	Transversal	Raspar	Lasca	Serreta	24x23x6
	X5/16	Irregular	Recto	70°	Piel	Longitudinal	Cortar	Lasca	Serreta	31x28x10
	X4/788	Rectangular	Convexo	55°	Piel	Longitudinal	Cortar	Lasca	Serreta	25x20x4
	X4/819	Rectangular	Recto	40°	Piel	Longitudinal	Cortar	Lasca	Serreta	26x14x3

Tabla 21. Relación de material con huellas de uso de la UA 5.1

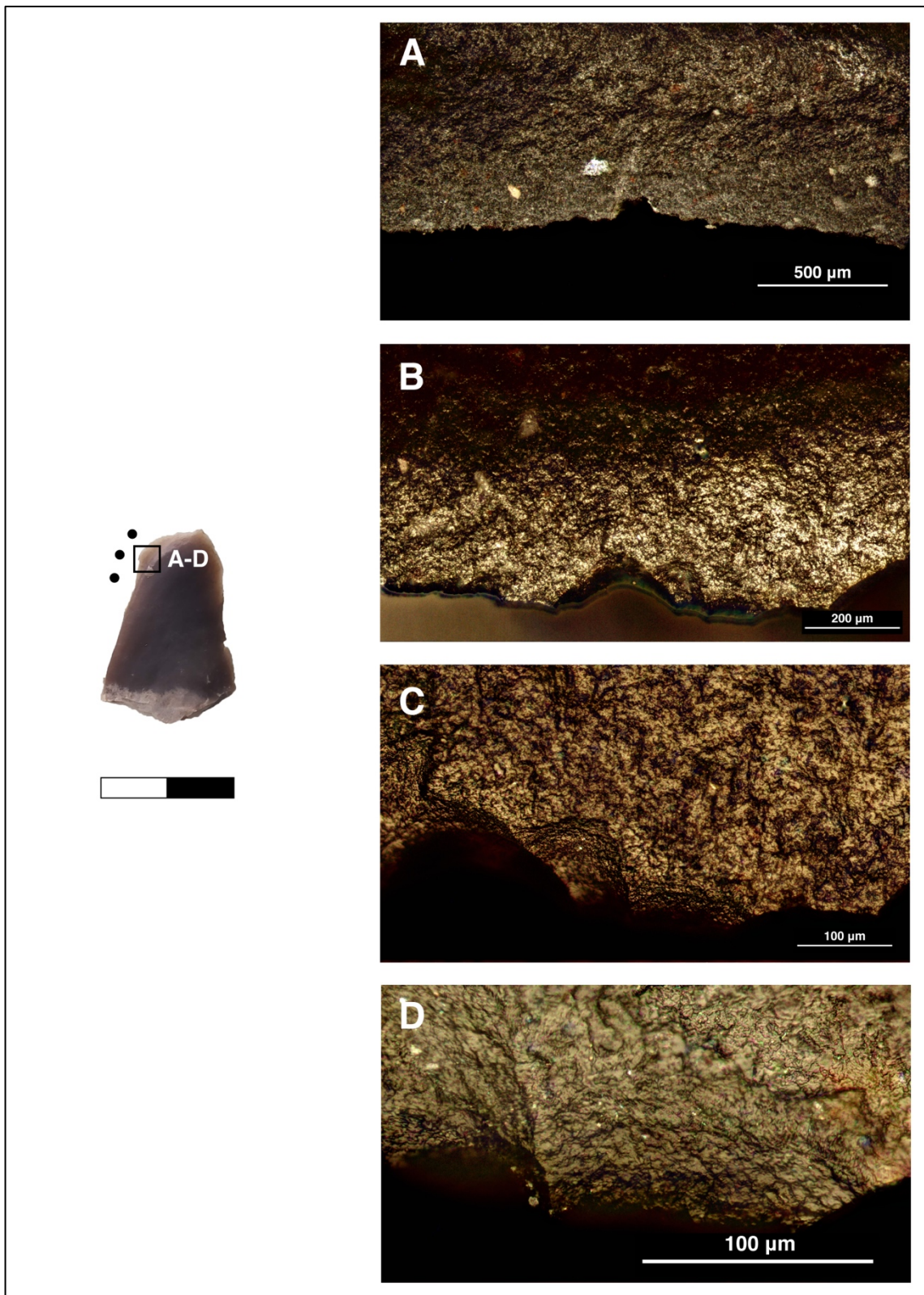


Fig. 32. Pieza X4/788 relacionada con un trabajo sobre piel en una acción de corte.
A) 50x, B) 100x, C) 200x, D) 500x

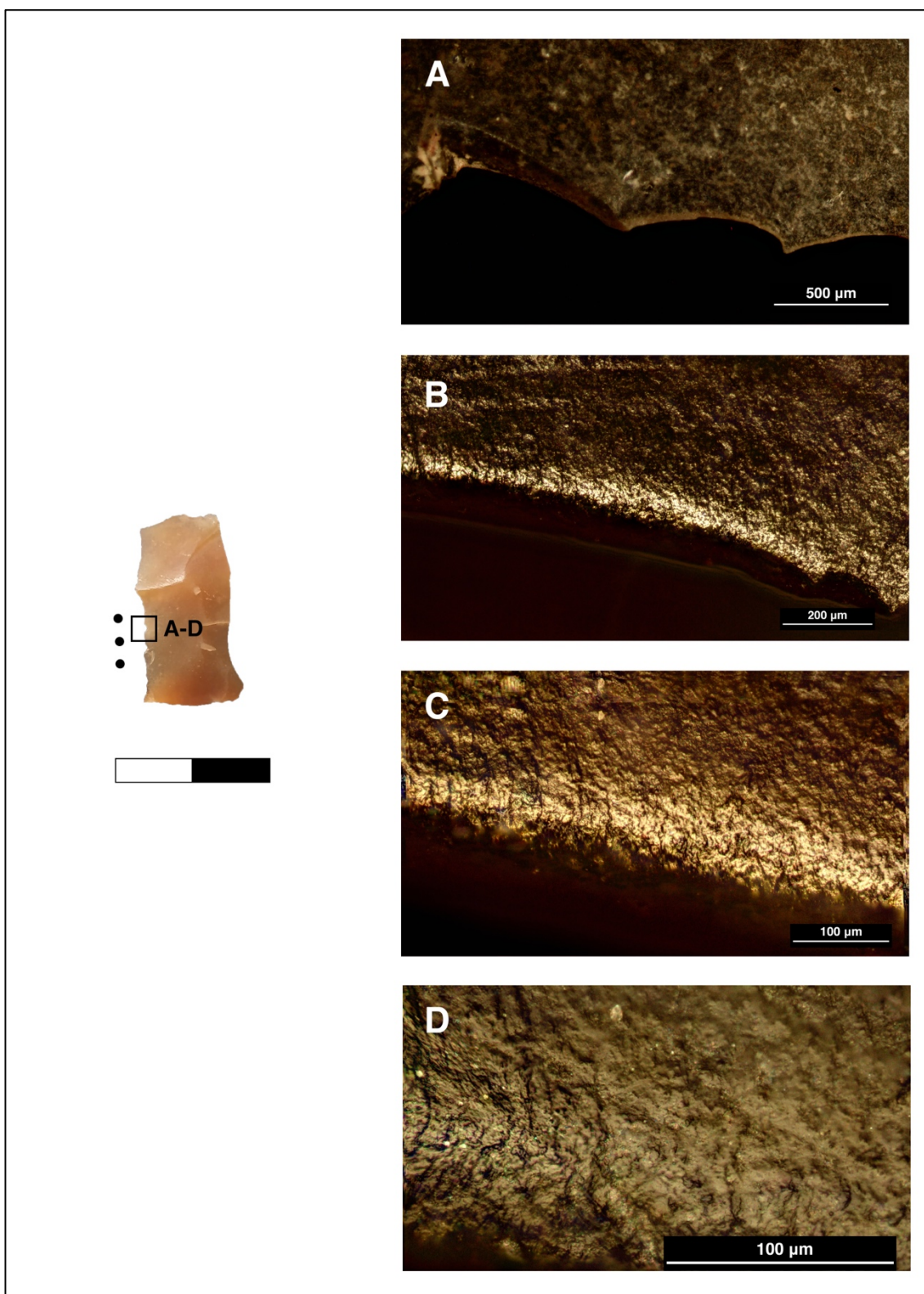


Fig. 33. Pieza X4/819 relacionada con un trabajo sobre piel en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

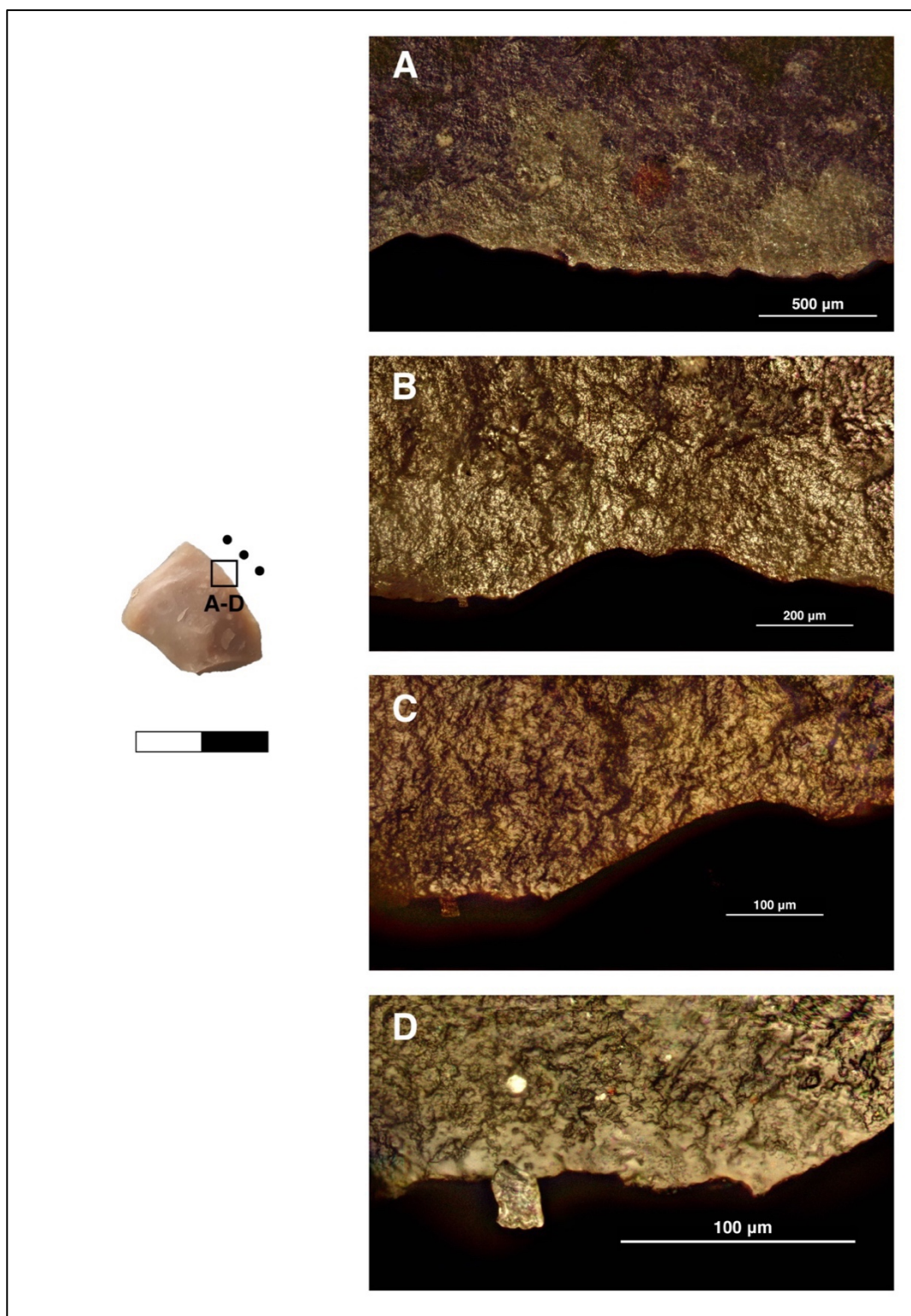


Fig. 34. Pieza X4/797 relacionada con un trabajo de carnicería en una acción de corte. Se observan puntos de pulidos más desarrollados a lo largo del filo. A) 50x, B) 100x, C) 200x, D) 500x

La unidad arqueoestratigráfica 5.2

De las 25 piezas que integran esta unidad, se analizaron todas. No se observaron estigmas de uso en ninguna de ellas. Por el contrario, se ha observado que la superficie de las piezas está completamente alterada en ambas caras, aunque suele destacar en una de ellas. Este proceso postdeposicional, que imposibilita el análisis traceológico, no se deba seguramente a la acción del fuego sino a otro tipo de variables que se comentarán en la discusión. A continuación, se adjuntan una serie de figuras que ejemplifican lo comentado anteriormente (Fig.35-38).

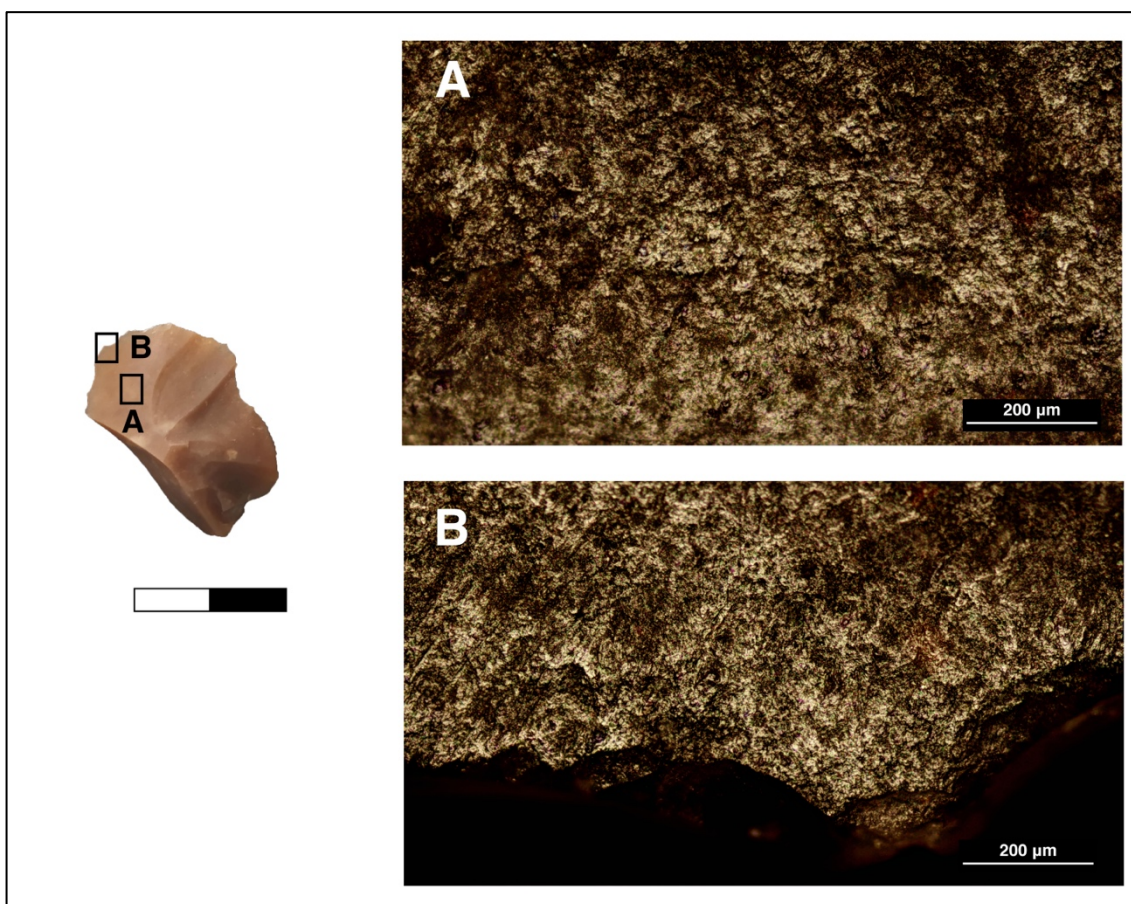


Fig. 35. Pieza X5/973 con alteración postdeposicional tanto en el filo como en el interior de la pieza. A) 100x, B) 100

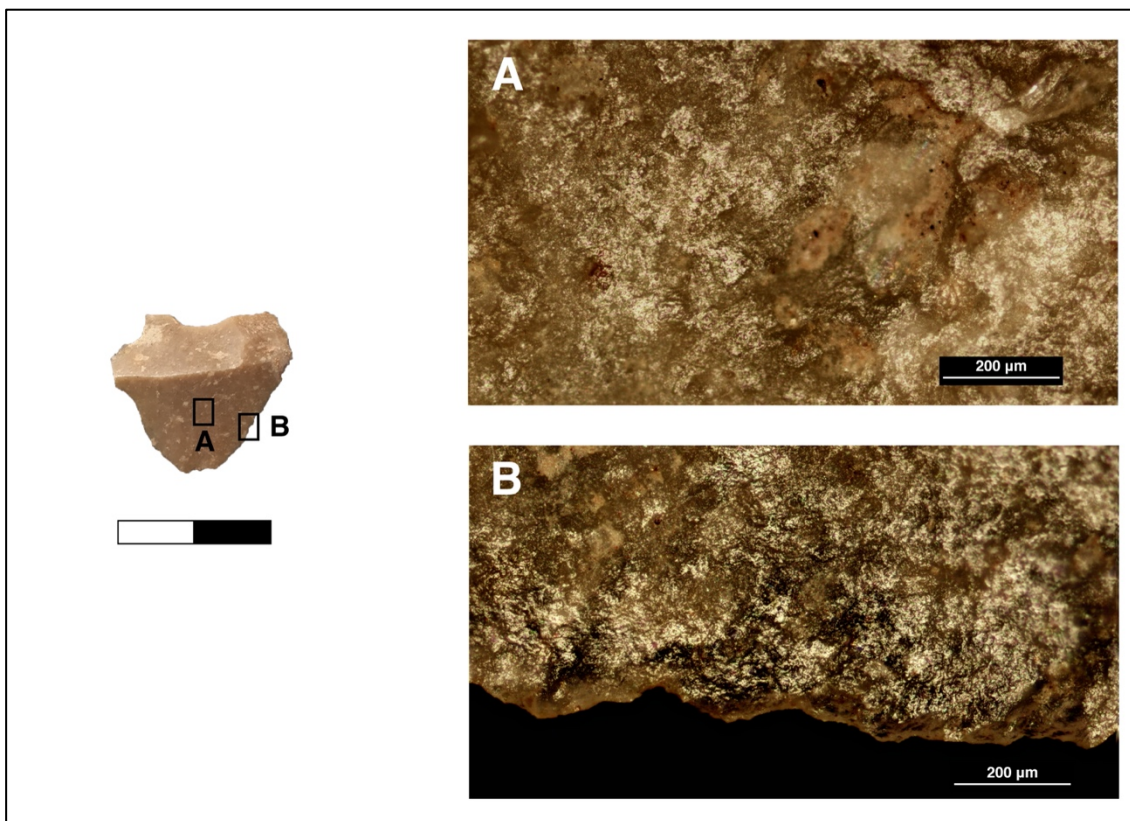


Fig. 36. Pieza X5/314 con alteración postdeposicional tanto en el filo como en el interior de la pieza. A) 100x, B) 100x

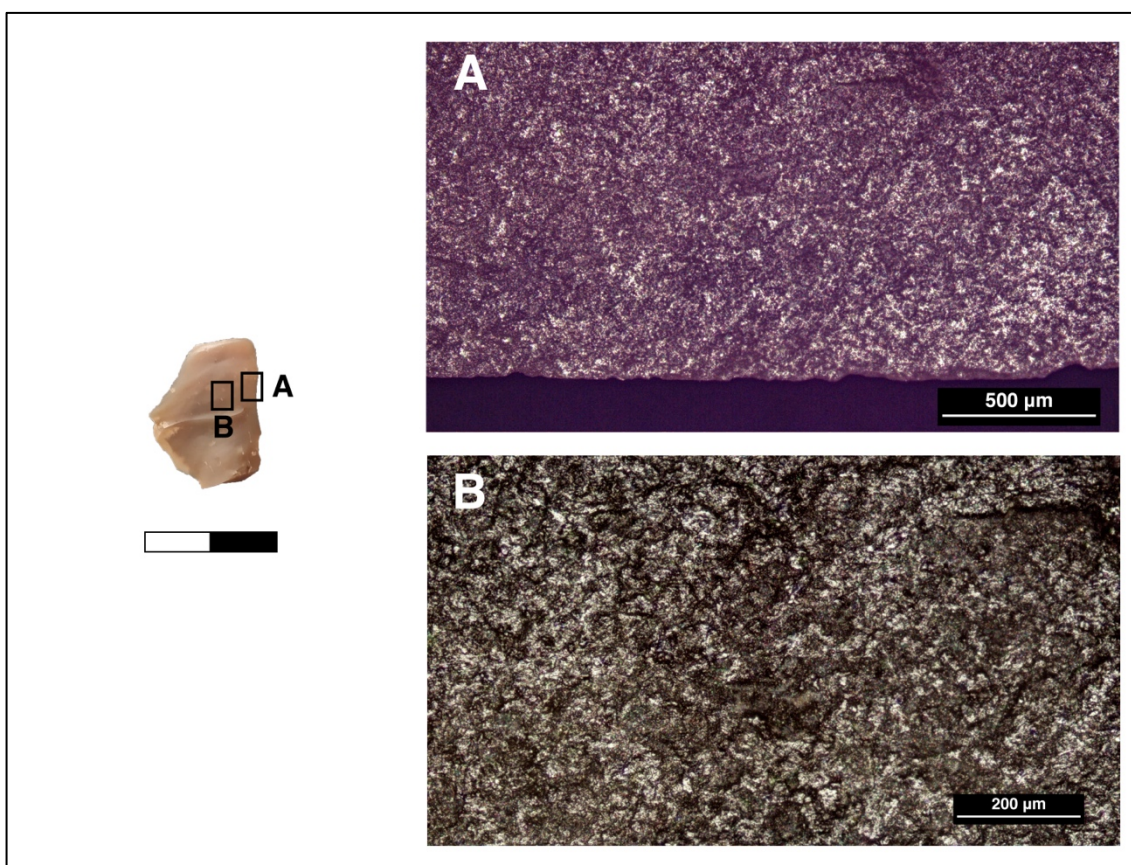


Fig. 37. Pieza X4/802 con alteración postdeposicional tanto en el filo como en el interior de la pieza. A) 50x, B) 100x

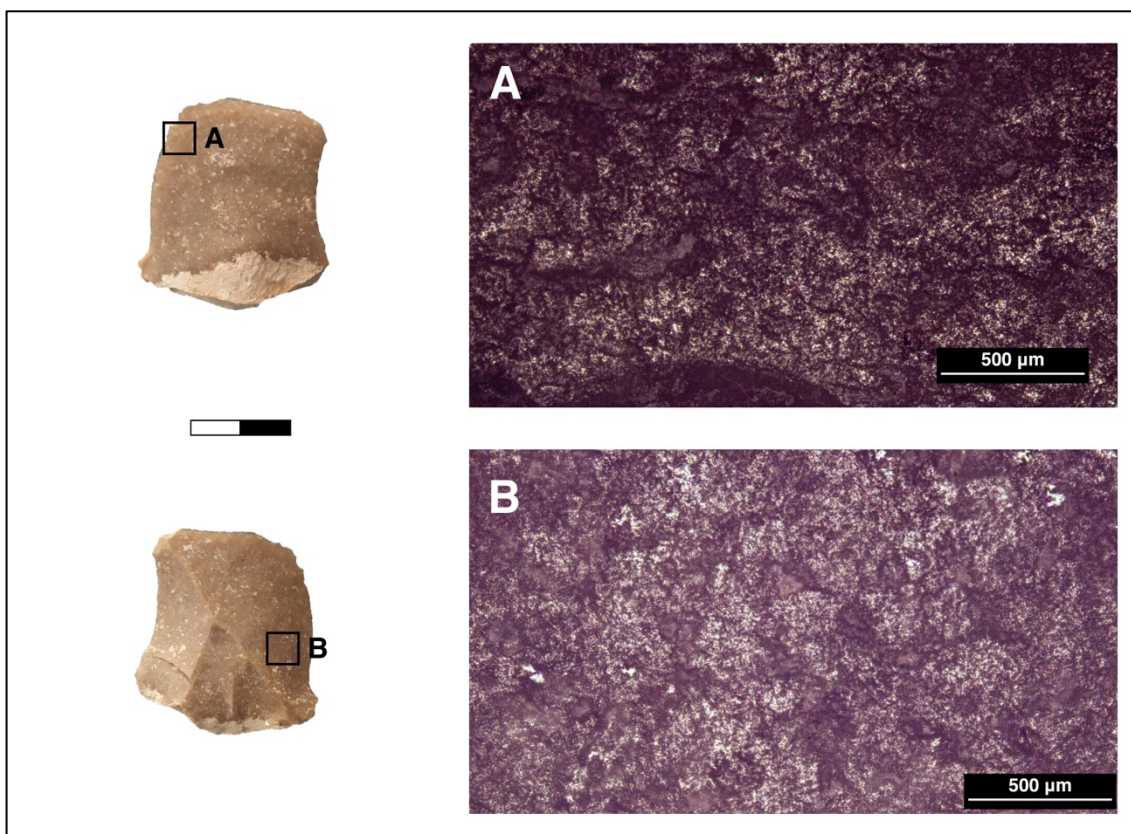


Fig. 38. Pieza X4/ 779 con alteración postdeposicional tanto en el filo como en el interior de la pieza. A) 50x, B) 50x

Piezas singulares asociadas a las unidades arqueoestratigráficas 5.3. y 4.1

Las piezas singulares analizadas en este estudio suman un total de 17, las cuales se han estudiado en su totalidad. Por la similitud de sus resultados, los valoraremos de forma conjunta en este epígrafe. De entre ellas, 10 cuentan con huellas de uso (Tabla 22), habiendo 11 zonas usadas. Todas estas piezas nos remiten a trabajos de carnicería en acciones de corte (Fig. 39, 40, 42 y 43) y una sobre trabajo de piel (Fig. 41). No se han observado procesos postdeposicionales en las piezas analizadas ni tampoco estigmas de enmangamiento. Sin embargo, sí hemos observado que en el interior de las piezas hay una abrasión de la superficie cuya interpretación se realizará en la discusión de este trabajo.

UA	Signatura	Morfología de la pieza	Morfología del borde	Ángulo del borde	Materia trabajada	Movimiento	Acción	Soporte	Tipo de sílex	Dimensiones (mm)
4.1	X4/825	Cuadrangular	Convexo	65°	Carnicería	Longitudinal	Cortar	Lasca	Beniaia	33x37x8
	X4/671	Triangular	Convexo	60°	Carnicería	Longitudinal	Cortar	Raeder lateral	Serreta	36x17x8
	X5/305	Triangular	Convexo	75°	Carnicería	Longitudinal	Cortar	Raeder lateral	Beniaia	48x42x4
5.3	X4/608	Semicircular	Convexo	55°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	26x28x8
	X4/786	Triangular	Convexo	60°	Carnicería	Longitudinal	Cortar	Raeder lateral	Serreta	49x21x16
	X5/814	Rectangular	Recto	55°	Piel	Longitudinal	Cortar	Lasca	Serreta	38x20x4
	X5/1061	Rectangular	Convexo	50°	Carnicería	Longitudinal	Cortar	Raeder lateral	Serreta	41x28x8
	X5/1071	Rectangular	Cóncavo	45°	Carnicería	Longitudinal	Cortar	Lasca	Serreta	45x19x6
			Convexo	65°	Carnicería	Longitudinal	Cortar			
	X6.7/11	Cuadrangular	Recto	55°	Carnicería	Longitudinal	Cortar	Lasca	Beniaia	44x35x9
	X6/32	Rectangular	Recto	55°	Carnicería	Longitudinal	Cortar	Raeder lateral	Mariola	39x20x13

Tabla 22. Relación de piezas singulares asociadas de las unidades arqueostratigráfica 4.1 y 5.3

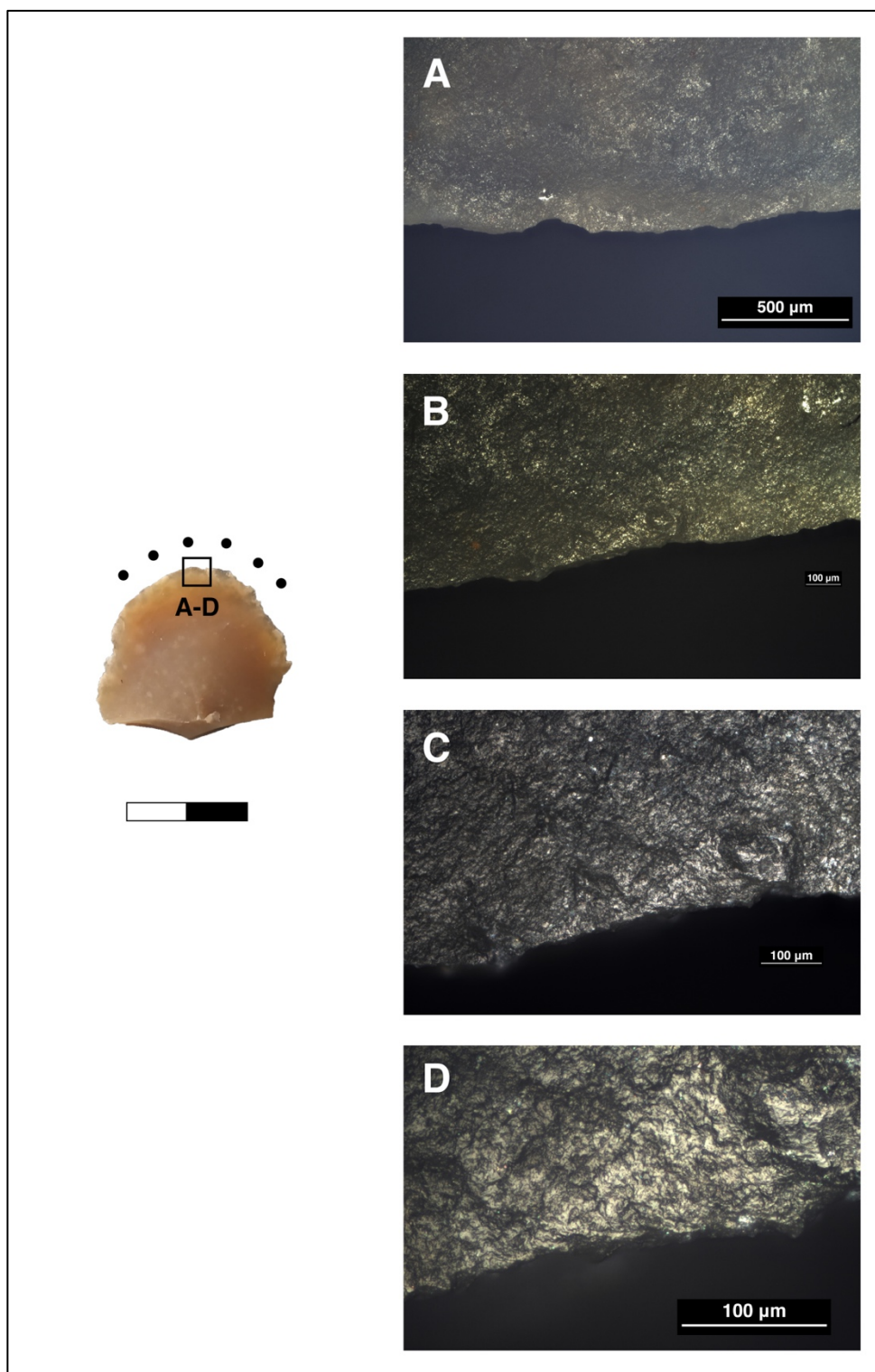


Fig. 39. Pieza singular X4/608 relacionada con una acción de carnicería en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

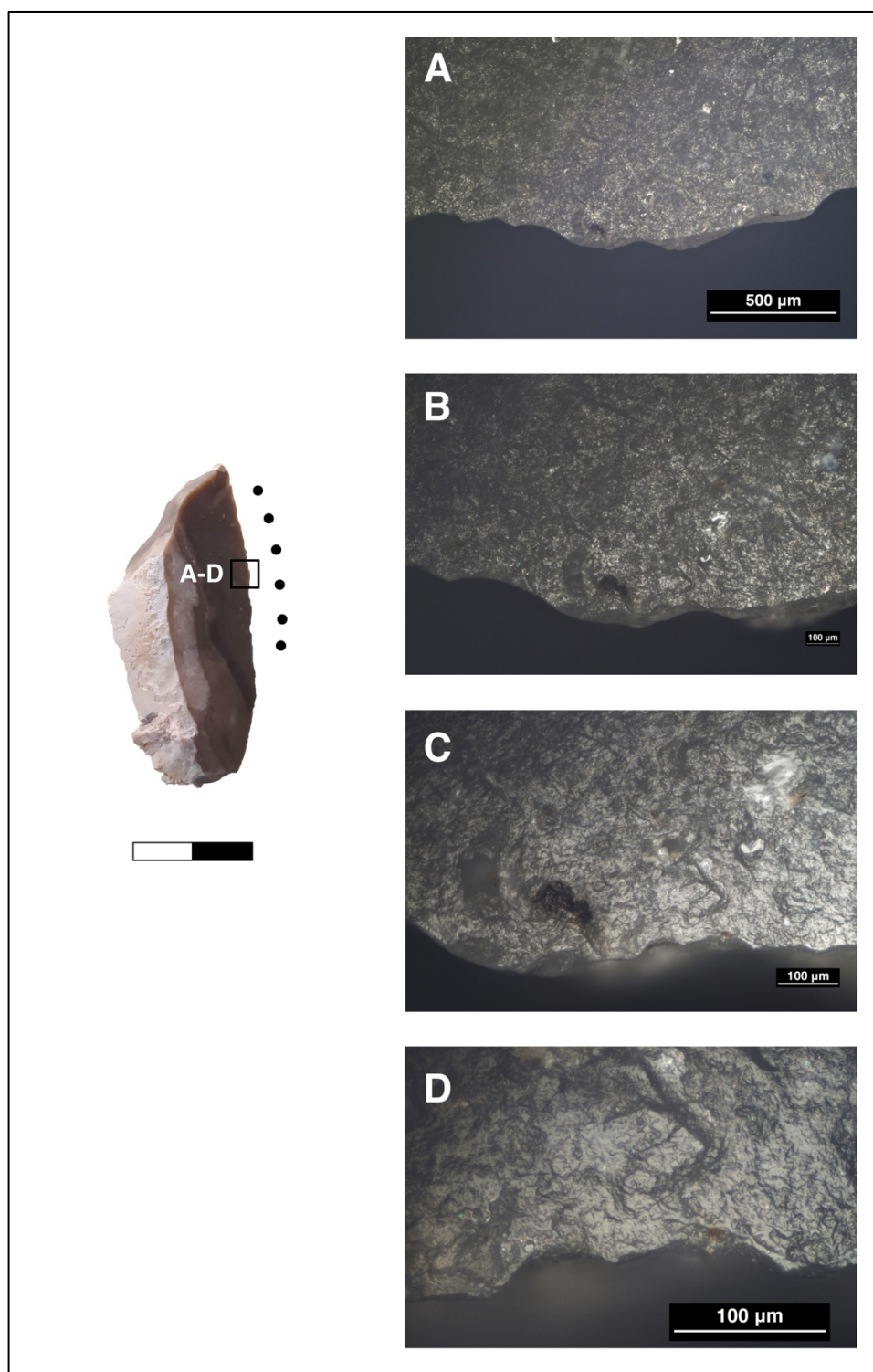


Fig. 40. Pieza singular X4/786 relacionada con una acción de carnicería en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

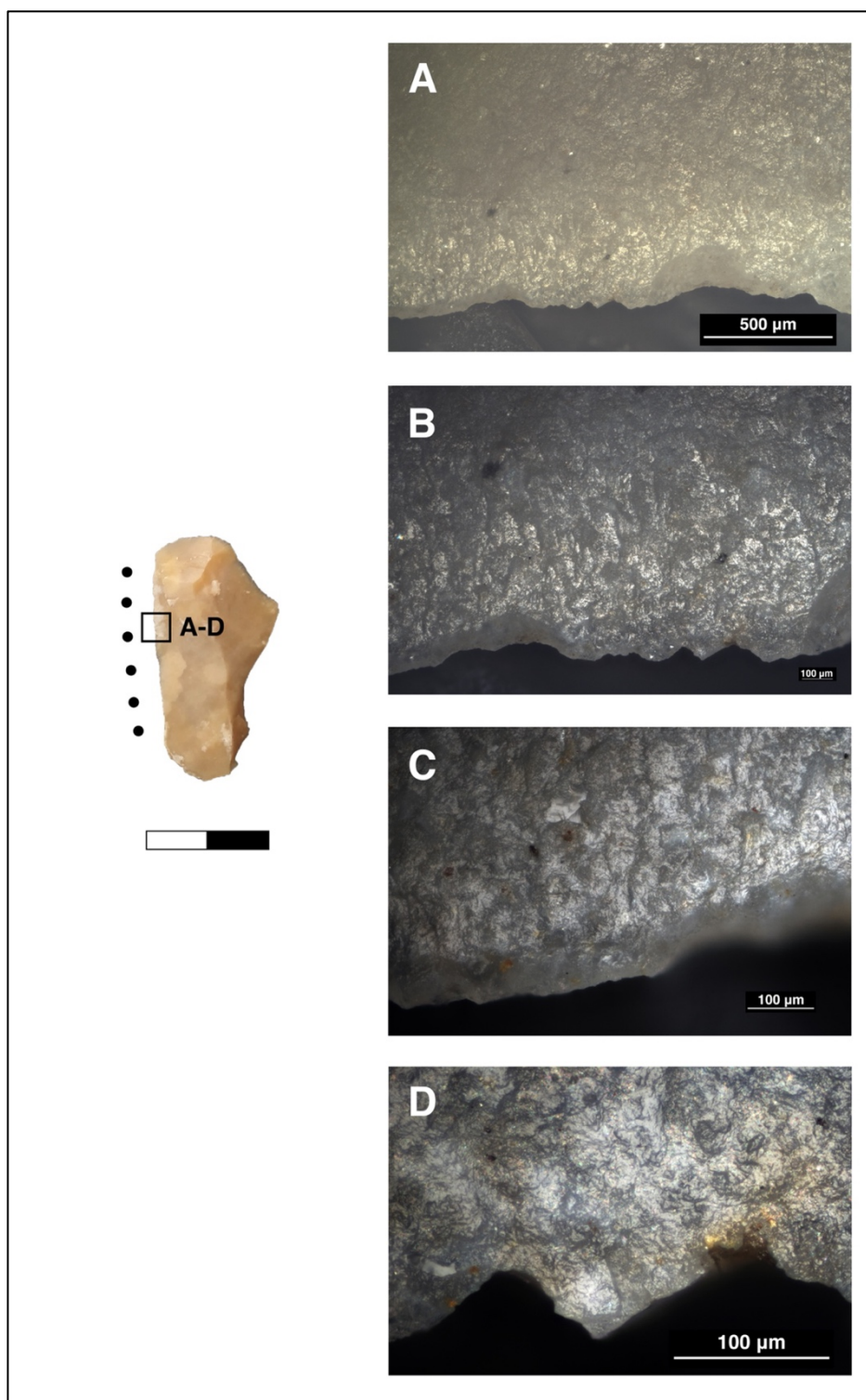


Fig. 41. Pieza singular X5/814 relacionada con un trabajo sobre piel en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

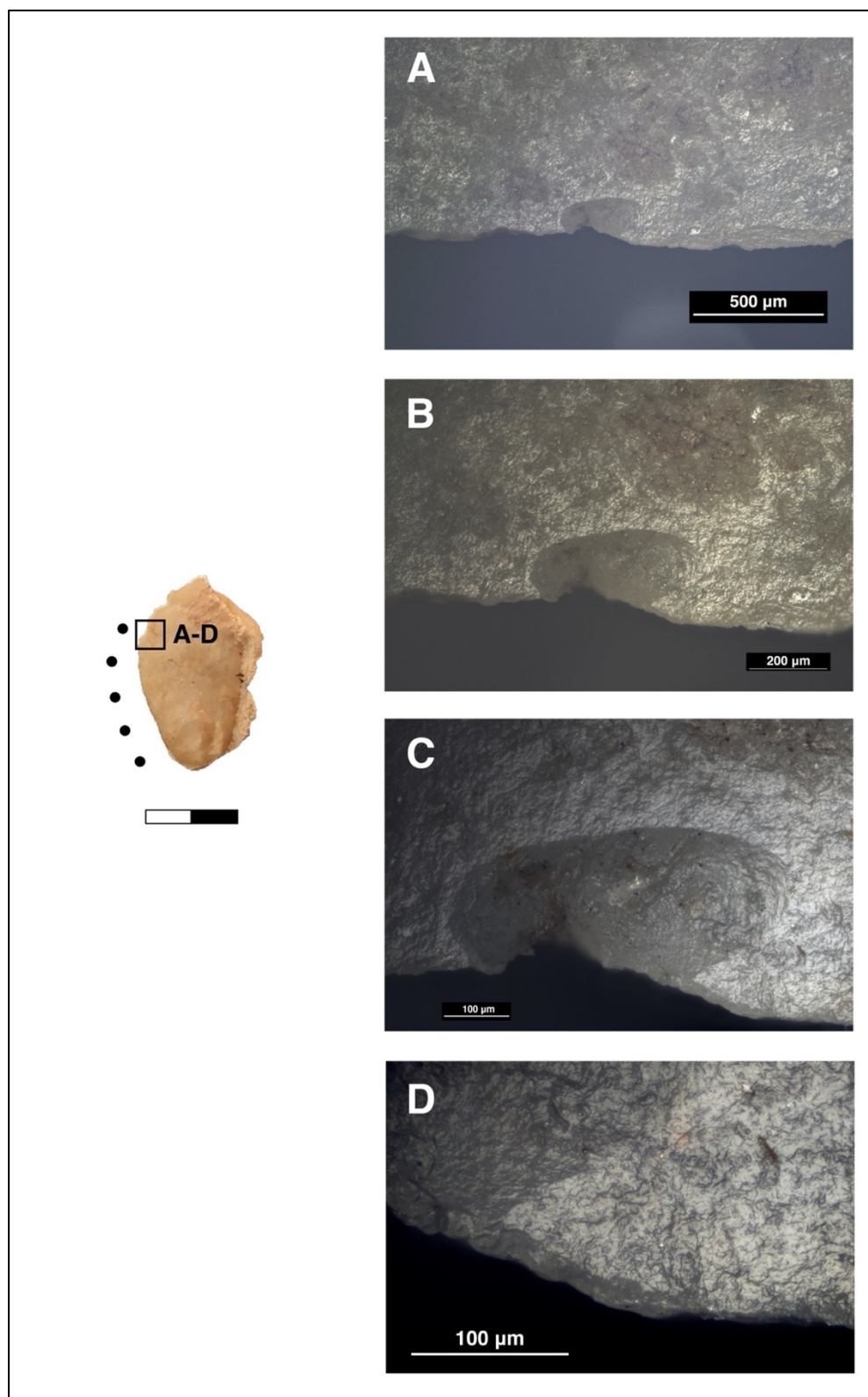


Fig. 42. Pieza singular X5/1061 relacionada con una acción de carnicería en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

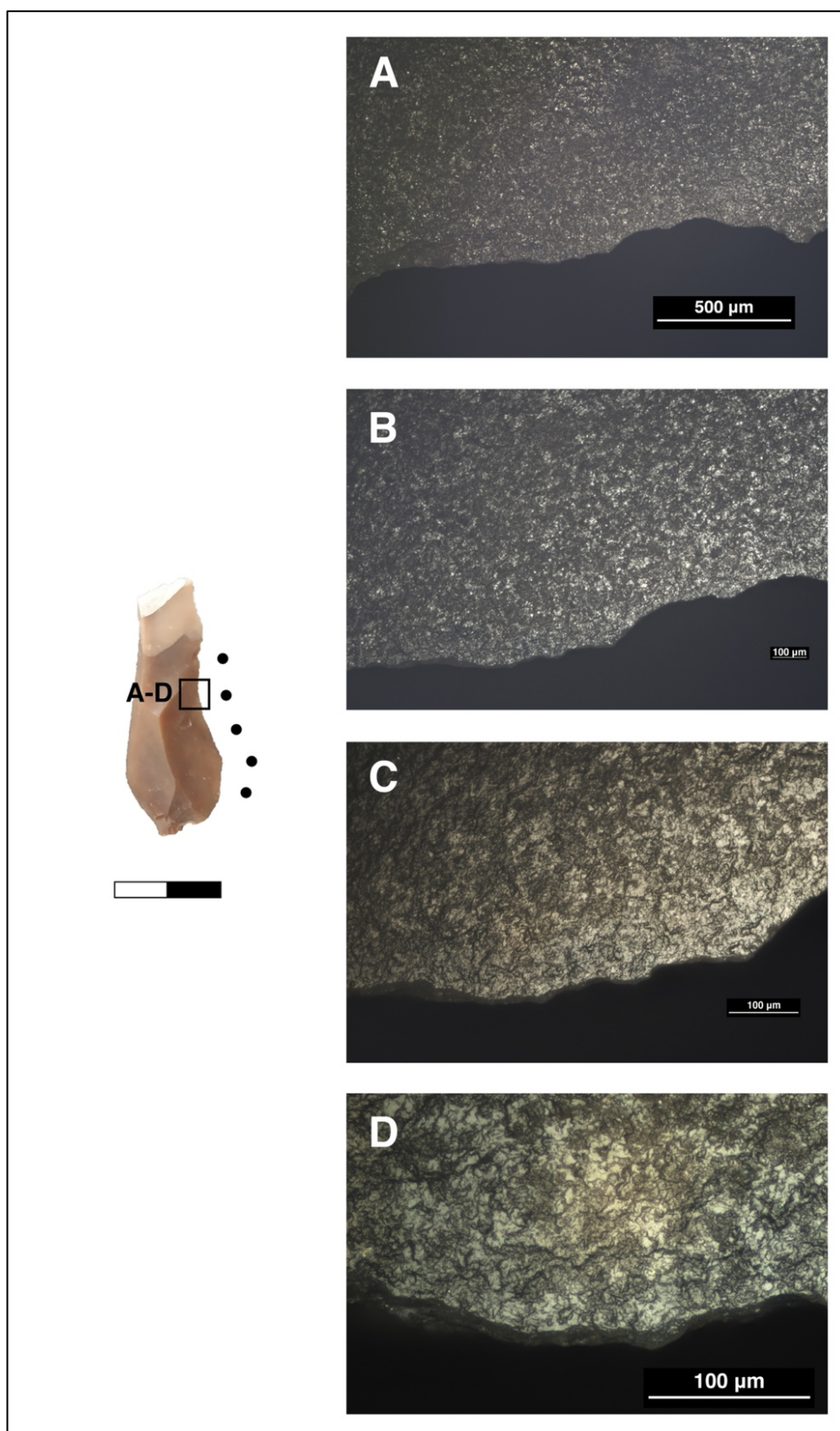


Fig. 43. Pieza singular X5/1071 relacionada con una acción de carnicería en una acción de corte. A) 50x, B) 100x, C) 200x, D) 500x

5. Discusión

La variabilidad del comportamiento humano es un aspecto fundamental en el estudio de los grupos cazadores-recolectores y, en particular, neandertales. Asimismo, en lo que concierne a las interpretaciones derivadas de los análisis funcionales del registro lítico, esta variabilidad resulta, además controvertida, especialmente en lo relacionado tanto con la caracterización cultural de los grupos humanos como con la diversidad de estrategias tecnológicas. En las propuestas de solución a esta controversia no se ha prestado excesiva atención a las implicaciones interpretativas que encierra la amplitud temporal de los procesos de formación de los registros arqueológicos en contextos sedimentarios de baja resolución.

A lo largo de este trabajo se ha tratado de dar respuesta a una serie de preguntas en torno al comportamiento de las poblaciones neandertales. Para ello se ha empleado el análisis traceológico aplicado tanto a material arqueológico como experimental. El desarrollo de esta discusión se dividirá por tanto en dos grandes bloques, tratando, por un lado, el material arqueológico y por otro el experimental.

5.1. La importancia de los marcos analíticos a la hora de interpretar el comportamiento humano

El análisis funcional llevado a cabo sobre el registro lítico de los grupos neandertales nos ha permitido reconocer un mayor o menor grado de variabilidad de su comportamiento, en función de la resolución temporal de los marcos analíticos utilizados. En los contextos de alta resolución, más cercanos a escala temporal humana, se observa frecuentemente una menor diversidad de actividades, reflejando así una mayor variabilidad diacrónica en el comportamiento de estos grupos cuando los comparamos entre sí. A pesar de que los estudios de huellas de uso en el material lítico inciden directamente en estos aspectos, los aplicados a contextos de alta resolución siguen siendo escasos (*e.g.* Deschamps *et al.*, 2022; Sossa-Ríos *et al.*, 2022; Spagnolo *et al.*, 2020a) ya que por norma general predominan los análisis referidos a la UE como marco de análisis (*e.g.* Beyries, 1987; Hortelano, 2016; Jardón, 2000; Lemorini, 2000; Lemorini *et al.*, 2016; Márquez *et al.*, 2017; Martínez, 2005; Rodríguez *et al.*, 2002; Rots, 2011, 2016).

El trabajo realizado en esta Tesis Doctoral constituye un ejemplo de lo que se viene señalando y nos permite comparar la lectura que se deriva de los datos traceológicos, dependiendo de la resolución de los contextos de estudios. Discutiremos en primer lugar las características morfopotenciales, tecnológicas y funcionales de los

útiles líticos en el marco de la UE Xa de El Salt y en un segundo momento exploraremos la variabilidad diacrónica de las actividades llevadas a cabo en contextos de mayor resolución temporal, como elemento de reflexión sobre las dinámicas funcionales de estos grupos neandertales. Esto nos dará la oportunidad de valorar el tipo de inferencia funcional que se deriva del conjunto lítico, en función de la resolución temporal del contexto arqueológico de referencia.

5.2. Los utensilios líticos en la UE Xa de El Salt. Características generales

En este apartado haremos una valoración general sobre las características de los utensilios líticos estudiados en la UE Xa de El Salt, distinguiendo entre los útiles que forman parte de unidades de materias primas de conjunto, los cuales hemos interpretado como productos tallados y utilizados *in situ*, y aquellos otros que se corresponden con objetos singulares, interpretados como piezas transportadas. De esta forma evaluaremos las semejanzas y diferencias morfopotenciales y funcionales de cada uno de estos conjuntos para establecer el impacto de la movilidad de estos grupos cazadores-recolectores en la configuración tecnofuncional de los utensilios.

En cuanto a la materia prima de los soportes tallados y utilizadas *in situ* observamos la presencia de los tres litotipos principales, con predominio del sílex Serreta. Sus rasgos postgenéticos permiten plantear una captación en depósitos secundarios, de naturaleza coluvial, localizados tanto en el curso alto del río Serpis, como en el valle de Alcalà. En este caso, los utensilios fabricados en el propio yacimiento reflejan los ámbitos de aprovisionamiento que ya fueron identificados para el conjunto de materiales líticos en la misma unidad estratigráfica (Molina, 2016). A partir de la muestra estudiada, no parece haber una selección específica en torno a una materia prima para realizar determinadas acciones o trabajar materias específicas.

La totalidad de utensilios tallados *in situ* que han sido analizados corresponden a lascas corticales y a soportes de plena producción obtenidos mediante modalidades centrípetas del método Levallois. Se observa una fragmentación de la cadena operativa debido a la notable ausencia de productos (Mayor *et al.*, 2020). Esta ausencia de productos permite plantear la hipótesis en torno al desplazamiento y quizás posterior uso de determinados elementos que no se localizan en las zonas donde han sido tallados.

Por otro lado, si atendemos a los rasgos morfopotenciales generales de los útiles, observamos que hay una preferencia por el uso de lascas de gran o mediano tamaño (entre 2 y 3 cm en cualquiera de sus ejes para las medianas, y superior a 3 cm para las

grandes). La morfología de estas piezas tiende a ser rectangular o cuadrangular con bordes rectos o convexos. Los ángulos de los filos varían en función de la acción: entre 30 y 65° para las de tipo longitudinal y entre 35 y 90° en acciones transversales.

Destacamos, asimismo, la presencia de útiles de pequeñas dimensiones (inferiores a 2 cm en sus ejes) empleados en actividades relacionadas con materia animal o sobre materia blanda. El uso de piezas pequeñas ya se ha documentado en yacimientos del Paleolítico medio (*e.g.* Martínez 2002; Lazuén & González 2015; Lazuén & Delagnes 2014; Hortelano 2016; Borel *et al.* 2017) e incluso para cronologías anteriores (*e.g.* Ollé 2003; Barkai *et al.* 2010; Venditti *et al.* 2019a; Lemorini *et al.*, 2022). Esto lo podemos poner en relación con la existencia de núcleos de reducidas dimensiones que son explotados por los sistemas técnicos habituales en el yacimiento hasta su exhaustión.

Los soportes retocados pertenecientes a este grupo de productos tallados *in situ* suman un total de 13 (12 raederas y un denticulado). Todos ellos superan los 3 cm y, por tanto, se encuentran entre los objetos líticos de mayor tamaño, aunque no los únicos. Cuentan con una morfología triangular, rectangular o cuadrangular, bordes generalmente rectos o convexos y ángulos que varían en función de la acción: para acciones longitudinales se emplean ángulos entre 45 y 70° y para acciones transversales entre 60 y 90°. Destacan 3 raederas en las que se identificaron dos zonas de uso, correspondientes al filo retocado y a su opuesto, que también fue usado sin reconfigurar.

Por lo que respecta a las zonas potencialmente prensiles, no se han observado estigmas de enmangues, ni tampoco rebajes ventrales que pudieran indicar su preparación para adecuar el uso de mangos. De hecho, todas las piezas, incluso las de pequeño tamaño, pueden sujetarse con la mano, dejando libre el filo utilizado. Aunque el uso de mangos durante el Paleolítico medio ha quedado atestiguado por numerosos estudios (*e.g.* Beyries, 1987; Borel *et al.*, 2017; Hardy *et al.*, 2001; Martín-Viveros *et al.*, 2023; Mazza *et al.*, 2006; Niekus *et al.*, 2019; Rots, 2011, 2014, 2015, 2016) este no parece haber sido el caso de los conjuntos analizados en el marco de esta Tesis Doctoral.

Una vez comentados los rasgos generales de las piezas talladas y utilizadas *in situ*, pasaremos a comentar los rasgos morfológicos característicos de las piezas transportadas. Como ya se ha comentado, la clasificación de las piezas transportadas se ha hecho en base a la ausencia de remontajes y porque cada una de ellas supone una unidad de materia prima por sí misma. En total se han analizado 17 piezas transportadas y sus características principales se comentan a continuación.

En cuanto a la materia prima, las piezas transportadas se tallaron preferentemente con sílex de tipo Serreta o Beniaia, ambos son litotipos locales, disponible en el curso alto del Río Serpis (Machado *et al.*, 2017, Mayor *et al.*, 2020; Molina, 2016). Esto contrasta con la idea defendida por algunos autores según la cual las piezas transportadas tienden a ser producidas en materia primas exógenas (Berruti *et al.*, 2023; Kuhn, 1994), En nuestro caso este patrón no se cumple, pero El Salt no es el único yacimiento en el que se ha observado esto, ya que se ha identificado también en otros contextos (Martín-Viveros *et al.*, 2020; Mayor *et al.*, 2020; Sossa-Ríos *et al.*, 2022). Observamos así que las áreas de captación debieron ser las mismas para las piezas talladas y utilizadas *in situ* y para los utensilios transportados por los grupos humanos durante sus dinámicas de gestión y explotación de los territorios.

Contamos con 5 raederas y 5 lascas con huellas de uso, todas ellas grandes. La morfología de estas piezas tiende a ser rectangular, cuadrangular o triangular, con bordes convexos o rectos y cuyos ángulos varían entre los 45 y los 75°. En este sentido, nos gustaría resaltar que, a proporción, hay mayor porcentaje de soportes retocados y de gran tamaño frente a las piezas talladas y utilizadas *in situ*. La dimensión de los filos utilizados también es mayor si comparamos con las *in situ*. Esta cuestión también nos gustaría ponerla en relación con el espesor de las piezas, ya que en el caso de las transportadas se aprecia un aumento de esta variable frente a las piezas utilizadas *in situ*. Sin embargo, lo que pretendemos con esta apreciación es que el tamaño y el espesor, facilitan el agarrarse con la mano.

Por otro lado, nos gustaría remarcar que entre el conjunto de piezas transportadas contamos con útiles retocados y sin retocar. En este sentido, de manera general se suele tener en cuenta el retoque a la hora de definir si una pieza es transportada o no. Si bien es cierto que en algunos contextos parece ser que sí hay una preferencia por el uso de piezas retocadas (*e.g.* Bamforth, 1986; Kuhn 1994; Turq *et al.*, 2013) como por ejemplo los soportes con retoque Quina (Claud *et al.*, 2012; Delagnes & Rendu, 2011), nuestro estudio indica que tanto piezas retocadas como sin retocar podían formar parte de las piezas transportadas, como también ocurre en otros contextos (*e.g.* Martín-Viveros *et al.*, 2020, Sossa *et al.*, 2022).

Por otra parte, el conjunto de piezas transportadas incluye una lasca-núcleo, que, si bien no cuenta con huellas de uso, la podemos poner en relación con las propuestas en torno a que los núcleos forman parte de los conjuntos transportados, al tratarse de masas

explotables en cualquier momento (Mayor *et al.*, 2020; Sossa-Ríos *et al.*, 2022; Turq *et al.*, 2017).

Por otro lado, ninguna de las piezas muestra evidencias de haber sido enmangada. Este dato es interesante, ya que algunos autores apuntaban a que las piezas transportadas estarían relacionadas con secuencias de producción más complejas como el enmangamiento (Binford, 1977; Keeley, 1982; Odell, 1996).

5.3. Relación entre funcionalidad y soportes utilizados

En este epígrafe trataremos de correlacionar los tipos de soportes empleados con las acciones y materias trabajadas. Esta comparación se realizará atendiendo a todo el conjunto analizado.

Los resultados funcionales ponen de manifiesto que la población neandertal, de manera recurrente, realizó una serie de actividades dirigidas al procesado carnicero, al de la piel y al trabajo de la madera. Cada una de éstas ha podido reconocerse en el conjunto analizado aunque con porcentajes variables. La actividad carnicera es la que está presente en un mayor número de elementos (n 27 con un total de 28 zonas activas). En segundo lugar, destaca el trabajo de la piel (n 16) y la madera (n 16 con 17 zonas activas). En tercer lugar, se sitúan los trabajos sobre materias no identificadas más allá de su naturaleza de blanda (n 7), semidura (n 4), y dura (n 3). Este mismo panorama caracterizado por una relativa baja diversidad de actividades realizadas sobre carne, piel y madera, principalmente, parece repetirse en numerosos yacimientos neandertales (e.g. Beyries, 1987,1988; Borel *et al.*, 2017; Claud *et al.*, 2012, 2015; Clemente-Conte *et al.*, 2014; Daffara *et al.*, 2014; Hortelano, 2016; Lazuén *et al.*, 2011; Lazuen & Delagnes, 2014; Lemorini, 2000; Márquez & Baena, 2002; Rots, 2013), en algunos de los cuales la actividad carnicera también parece ser la más recurrente (e.g. Claud *et al.*, 2012; Gibaja, 2007; Lemorini *et al.*, 2022; Martínez, 2005; Martín-Viveros *et al.*, 2023)

El procesado carnicero está representado, sobre todo, por acciones longitudinales (n 25) realizadas con útiles retocados y con lascas usadas a filo vivo, frente a las transversales (n 2) efectuadas con una raedera y un denticulado, a la que se suma un caso de percusión para el que se empleó una lasca cortical. La carnicería fue ejecutada con piezas grandes (n 16) medianas (n 7) y pequeñas (n 4), éstas últimas implicadas exclusivamente en acciones de corte. En algunos yacimientos de Paleolítico medio se observa una preferencia por el empleo de útiles retocados para actividades de carnicería, (e.g. Claud *et al.*, 2012; Martínez 2005; Rots, 2013). En relación con esto, nos gustaría

destacar el caso de El Abric Romaní, donde se analizaron denticulados pertenecientes a distintos niveles del yacimiento, concluyendo que en unos niveles estuvieron destinados principalmente al descuartizado de animales, mientras que en otros niveles estuvieron destinados al trabajo de la madera (Martínez & Rando, 2001; Martínez, 2005). Por otro lado, resulta significativa la presencia de piezas pequeñas implicadas en acciones de carnicería, ya que para el trabajo de otras materias son mucho más anecdóticas, como se ha documentado en otros contextos de Paleolítico medio (e.g. Claud *et al.*, 2012; Lazuén & Delagnes, 2014) incluso para cronologías más antiguas (e.g. Barkai *et al.*, 2010; Lemorini *et al.*, 2022; Ollé, 2003; Venditti *et al.*, 2019a).

El procesado de pieles ha sido reconocido 16 piezas, 13 lascas y 3 raederas. Las acciones llevadas a cabo son tanto longitudinales (n9) como transversales (n7). Para las acciones longitudinales se emplearon soportes sin retocar y 2 retocados, y para las acciones transversales se emplearon soportes sin retocar y un retocado. De manera general el tamaño de las piezas es grande (n 8) o mediano (n 7) o pequeño (n 1). Esta dinámica de uso combinado de soportes retocados y sin retocar para trabajar las pieles la observamos en otros contextos de Paleolítico medio, aunque hay algunos casos en los que parece observarse y un uso preferente de soportes retocados para este tipo de actividades (e.g. Claud *et al.*, 2012; Gibaja 2007).

Los utensilios que presentan huellas compatibles con actividades realizadas sobre material leñoso suman un total de 16 lascas, con 17 zonas de uso. En una de estas piezas no ha podido determinarse la acción realizada. De forma general, la madera se trabajó principalmente mediante acciones de raspado (n 11) y corte (n 5). Estas evidencias contrastan con las publicadas para otros yacimientos asociados a población neandertal, en los que el trabajo de la madera se reconoce, fundamentalmente, en raederas y denticulados (e.g. Anderson-Gerfaud 1981; Beyries 1987, 1988; Lemorini, 2000), lo cual dista mucho de los soportes empleados en la UE Xa de El Salt.

Por lo que respecta a la materia blanda, se emplearon 6 lascas y 1 raedera lateral. En todos los casos se identificaron en acciones longitudinales. En cuanto al tamaño de estas piezas son grandes (n 3) medianas (n 3) y 1 pequeña.

Otras 4 piezas, 3 lascas y una raedera transversal, cuentan con huellas de uso provocadas por el contacto con una materia semidura. Las acciones llevadas a cabo son longitudinales (n 2) y transversales (n 2). Las piezas son grandes (n 3) y una mediana.

Por último, 3 piezas de tamaño grande cuentan con huellas de materia dura. Una de ellas es una raedera lateral, de la que no se utilizó el filo retocado sino uno de sus filos

naturales, y las otras dos son lascas. Las acciones llevadas a cabo por estas piezas son transversales (n 2) y una longitudinal.

Entre los materiales transportados se han identificado 10 con huellas de uso. 5 raederas y 5 lascas, todas ellas de grandes dimensiones a excepción de una mediana. En cuanto a las materias trabajadas, dominan las acciones de corte, llevadas a cabo preferentemente en actividades relacionadas con el desollado y descuartizado de presas. Este uso preferente de las piezas transportadas también se observa en otros contextos de Paleolítico medio (e.g. Berruti *et al.*, 2023; Claud *et al.*, 2012; Martín-Viveros *et al.*, 2020; Sossa *et al.*, 2022). Por otra parte, también se ha observado que la superficie de las piezas está más alterada que las piezas talladas *in situ*, lo que ponemos en relación con el roce de estos soportes durante su transporte, seguramente al entrar en contacto con algún tipo de contener, como piel, en el que se almacenaron, tal y como explican Mazzuco y Clemente (2013).

Observamos por tanto dos cuestiones importantes con respecto a las piezas talladas y utilizadas *in situ*: por un lado, la diversidad de materias trabajadas de las piezas utilizadas *in situ* frente a la exclusividad del trabajo sobre materia animal en las piezas transportadas, y por otro, el mayor porcentaje de piezas retocadas dentro del conjunto de piezas transportadas con respecto a las utilizadas *in situ*.

5.4. El papel de la escala temporal en la interpretación de los datos funcionales: de lo estático a lo dinámico en los comportamientos humanos

Como ya se ha mencionado a lo largo de este trabajo, son muchos los estudios funcionales que emplean la UE como marco de análisis (e.g. Beyries, 1987; Hortelano, 2016; Jardón, 2000; Lemorini, 2000; Lemorini *et al.*, 2016; Márquez *et al.*, 2017; Martínez, 2005; Rodríguez *et al.*, 2002; Rots, 2011, 2016). En este sentido, los resultados funcionales de nuestro trabajo, reflejan un panorama muy semejante al descrito para otros conjuntos del mismo período. Si los interpretásemos como conjunto dentro de la UE Xa de El Salt, destacaríamos que en este yacimiento tuvieron lugar, al menos durante las ocupaciones de la UE Xa, las actividades de carnicería, seguidas del trabajo sobre madera y sobre piel. Generaríamos por tanto una interpretación compatible con la caracterización de los asentamientos neandertales como un conjunto de áreas de actividad polifuncional donde confluyen distintas actividades en un mismo espacio. Como ya se ha comentado anteriormente, este tipo de interpretaciones en torno a la recurrencia de distintas actividades, se observa en otros yacimientos de Paleolítico medio (e.g. Beyries,

1987,1988; Borel *et al.*, 2017; Claud *et al.*, 2012, 2015; Clemente-Conte *et al.*, 2014; Daffara *et al.*, 2014; Gibaja, 2007; Hortelano, 2016; Lazúen *et al.*, 2011; Lazuen & Delagnes, 2014; Lemorini, 2000; Lemorini *et al.*, 2022; Rots, 2013; Márquez & Baena, 2002; Martín-Viveros *et al.*, 2023).

Sin embargo, nuestros resultados funcionales, insertos en marcos analíticos de alta resolución temporal, evocan una imagen muy distinta sobre el uso de los espacios en los yacimientos asociados a poblaciones neandertales. Frente a la lectura habitual de áreas polifuncionales, observamos aquí una dinámica cambiante y una menor coexistencia de actividades diversas. Los datos que hemos identificado ponen de manifiesto áreas en las que se realizaron tareas concretas sobre una materia determinada, o bien áreas donde se llevaron a cabo un mayor número de tareas relacionadas con más de una materia. Esta visión individualizada de cada evento refleja variaciones en la funcionalidad de los mismos espacios a lo largo del tiempo.

Para comenzar, retomaremos los resultados obtenidos en la UA 5.3, que conformaba un micropalimpsesto disectado a partir de indicadores de diacronía en 3 conjuntos (*i.e.* 5.3.1, 5.3.2 y 5.3.3) (Mayor *et al.*, 2020). Cada uno de éstos representan un evento cuya temporalidad se aproxima a la escala humana, interpretándose como ocupaciones cortas, poco intensas, que siguen el modelo “*hearth-related assemblage*” (Vaquero & Pastó 2001). Estas unidades, diacrónicas, superpuestas entre sí y localizadas en la misma zona del yacimiento, eran propicias para analizar la variabilidad del comportamiento a lo largo del tiempo a partir del estudio del material arqueológico. Así pues, se llevó a cabo el análisis funcional sobre el material lítico tallado y utilizado *in situ*, obteniendo la evidencia funcional de que los grupos neandertales desarrollaron tareas diferentes en cada UA: en la UA 5.3.1 se trabajó exclusivamente madera, en la UA 5.3.2 madera y materia animal, y en la UA 5.3.3 únicamente materia animal. Además, en este estudio posibilitó la correlación del conjunto faunístico con marcas antrópicas, englobado en la UA 5.3. (*cf.* Pérez 2019; Pérez *et al.*, 2020), con dos unidades de mayor resolución temporal (*i.e.* 5.3.2 y 5.3.3) cuyos útiles contaban con huellas de procesado carnicero.

Este estudio permitió reconocer, a través del análisis funcional, variaciones en el comportamiento de los grupos neandertales a lo largo del tiempo. Además, con los resultados inéditos de las piezas transportadas de esta unidad, podemos observar diferencias funcionales y morfopotenciales con respecto a las piezas talladas y utilizadas *in situ*. Así, se observa una recurrencia de los trabajos de carnicería, empleando para ello soportes grandes retocados y sin retocar. Esto dista de los resultados en torno a las piezas

talladas y utilizadas *in situ*, en las que se observa una mayor variabilidad en torno a las actividades desarrolladas y soportes empleados. Por lo que respecta a la intensidad de uso, no observamos huellas más desarrolladas en las piezas transportadas, pero sí hemos apreciado que éstas abarcan una mayor superficie del filo utilizado, por lo que podríamos concluir que se han utilizado de manera más exhaustiva.

Las unidades arqueostratigráficas 4.1, 4.1.1 y 4.1.2

Los primeros estudios en torno a la disección de la UE Xa dieron lugar a una serie de unidades más acotadas espacial y temporalmente. Una de ellas es la 4.1, que en estudios posteriores pudo volver a disectarse, reconociendo dos eventos próximos a la escala temporal humana (*i.e.* 4.1.1 y 4.1.2). No obstante, parte del material de la UA 4.1 no pudo correlacionarse estratigráficamente a ninguno de esos dos eventos. En este caso se ha estudiado todo el material perteneciente tanto a la 4.1 como a la 4.1.1 y la 4.1.2

La UA 4.1.1, cuenta con 3 piezas con huellas de uso, dos asociadas a un trabajo carnicero y 1 a un trabajo sobre materia semidura, todas ellas en acciones longitudinales. Estos resultados difieren de los obtenidos para la UA 4.1.2, en la que destaca la presencia de huellas de uso relacionadas con el trabajo sobre madera (n 4), en acciones transversales (n3) y una de tipo longitudinal, a lo que se suma 1 pieza con estigmas propios de trabajar materia dura en una acción de raspar.

A la luz de estos resultados, observamos que cada UA refleja un patrón funcional diferente: la UA 4.1.1 estuvo relacionada con el procesado de presas y la UA 4.1.2 con el trabajo de la madera. Se repite, por tanto, el mismo esquema descrito en la UA 5.3.1 y la UA 5.3.3 (Bencomo *et al.*, 2023).

A pesar de que las materias trabajadas son diferentes, observamos una similitud en torno al tipo de soportes: en el evento 4.1.1 se emplearon 2 lascas grandes y una mediana con ángulos entre 45 y 50° y en la UA 4.1.2 se emplearon 3 lascas grandes y 2 medianas con ángulos comprendidos entre los 55 y los 65°. Todas ellas presentan una morfología rectangular o irregular. Parece evidenciarse que la elección de los soportes no sigue unos criterios específicos, lo que pone de manifiesto nuevamente la idoneidad de las lascas, con estas características morfopotenciales, para trabajar distintas materias.

Una vez analizados estos dos marcos analíticos de alta resolución temporal, pasaremos a comentar los resultados obtenidos en la UA 4.1, cuya resolución temporal es menor. En este caso contamos con trabajos que se relacionan tanto con la madera (n 4) como con el procesado carnicero (n 2), la piel (n2), así como con una materia dura (n 1).

Los soportes empleados se caracterizan por ser lascas, cuyos rasgos morfopotenciales varían en función de la materia trabajada. Sin embargo, observamos dos cuestiones interesantes: en las acciones longitudinales sobre materia animal los ángulos son muy similares a los de la UA 4.1.1, mientras que para las acciones transversales sobre madera se emplean algunos ángulos mayores que en la UA 4.1.2, en torno a los 75 y 90°. Atendiendo a esta última cuestión, la diferencia de ángulos nos podría remitir a acciones diferentes. En este sentido, en acciones transversales, el uso de bordes con 55° o 90° podría estar relacionado con acciones diferentes, ya que para el rebajado o afilado se suelen requerir filos con ángulos más agudos que para las acciones de raspado. Esta variabilidad de ángulos nos podría remitir a la cadena operativa en torno a las distintas acciones que se pueden llevar a cabo para la confección de objetos (e.g. raspado, rebajado etc.). Sin embargo, la falta de correlación entre el material de la UA 4.1 y la UA 4.1.2 no nos permiten afirmar este tipo de interpretaciones.

Finalmente, como resumen, podemos concluir que los marcos de alta resolución temporal, representados aquí por las UA 4.1.1 y 4.1.2, nos ofrecen una información más precisa en torno al tipo de acciones y materias trabajadas en dos áreas de actividad concretas, mientras que la UA 4.1, que cuenta con una resolución temporal menor, aglutina las características que observamos de manera individualizada en la 4.1.1 y la 4.1.2. Así, este caso pone de manifiesto la importancia de los marcos analíticos de alta resolución, ya que si la UA 4.1 no se hubiese disectado, habríamos obtenido nuevamente una visión homogénea en torno a un área multifuncional sin poder apreciar la variabilidad del comportamiento a lo largo del tiempo.

Por otro lado, de manera similar que para en el caso de la UA 5.3 (Bencomo *et al.*, 2023), para estas unidades también podemos correlacionar el conjunto faunístico con marcas antrópicas (i.e. *Cervus elaphus* (n 3), *Equus ferus* (n 3) y *Capra pirenaica* (n 1) englobadas en la UA 4.1. (*cf.* Pérez 2019; Pérez *et al.*, 2020), con los útiles con marcas de carnicería de la UA 4.1.1. y de la 4.1

Finalmente, analizando las piezas transportadas, resaltamos una serie de diferencias con respecto a las piezas talladas y utilizadas *in situ*, ya que de las 3 piezas que cuentan con huellas de uso, 2 son raederas y la tercera una lasca, todas ellas de gran tamaño. En este sentido, las piezas utilizadas *in situ* son todo lascas. Esto parece indicar una preferencia de soportes retocados para ser utilizados en sus desplazamientos. Por otro lado, las 3 piezas transportadas se relacionan con acciones de carnicería, como se observó ya en la UA 4.1.1. Sin embargo, al igual que para la UA 5.3 las huellas de uso abarcan

una superficie mayor que las piezas utilizadas *in situ*, con lo que de nuevo podemos interpretar que estas piezas se han utilizado de manera más recurrente.

Las unidades arqueostratigráficas 3.2 y 3.2.1

La disección de la UE Xa acotó, entre otros, un conjunto de materiales que pasaron a formar la UA 3.2, con un total de 270 piezas líticas (Machado *et al.* 2017). Ésta representaba un micropalimpsesto de reiteradas ocupaciones al que se pudo proporcionar una mayor resolución temporal a partir de la identificación de un conjunto más cercano a la escala temporal humana, que cuenta con 13 piezas líticas (*i.e.* 3.2.1) (Mayor *et al.*, 2020). El resto de piezas (*i.e.* 257), siguen formando parte de un micropalimpsesto que aglutina una cantidad indefinida de ocupaciones sin indicadores de diacronía evidentes hasta el momento.

Debe tomarse en consideración que no se ha estudiado todo el material lítico integrado en la UA 3.2 (69 de 257) y que tanto en la UA 3.2 como en la 3.2.1, no ha podido precisarse la funcionalidad concreta de todos los útiles que presentaban estigmas de uso.

En la UA 3.2 se observa un predominio de la actividad carnicera (n 10 con 11 zonas de uso), seguida por el trabajo de la piel (n 4), materia blanda (n 7), semidura (n 1) y dura (n 1), mientras que en la UA 3.2.1 se reconoce trabajo sobre madera (n 1), carnicería (n 1) y materia semidura (n 2).

Si atendemos a la morfopotencialidad de los útiles empleados, y centrándonos en la actividad carnicera y en el trabajo de materia semidura como nexo común entre ambas unidades, observamos diferencias. Para el procesado de presas, en la UA 3.2 se emplearon soportes sin retocar (4 lascas) y soportes retocados (5 raederas y un denticulado), mientras que, para esta misma actividad, en la UA 3.2.1 se empleó una lasca. En lo que respecta al trabajo de la materia semidura ocurre lo mismo, en la UA 3.2 se empleó una raedera y la UA 3.2.1 se emplearon dos lascas. Las acciones realizadas también varían: para la actividad carnicera se observan acciones longitudinales y transversales en la UA 3.2, mientras que en la 3.2.1 sólo se observa una acción de corte. Esto nos remite a procesos de trabajo diferentes, ya que las acciones de corte las podríamos poner en relación con el despellejado, el descuartizado o el fileteado, mientras que las acciones transversales se pueden relacionar con un raspado de la carne sobrante de las pieles o huesos. Observamos por tanto diferencias entre soportes y acciones realizadas entre una unidad y otra, reflejando por tanto una variabilidad en el comportamiento.

La existencia de una pieza con huellas de uso sobre madera aporta una mayor singularidad al evento 3.2.1. Además, pese a estar representado tan sólo por un elemento lítico, su presencia en un marco analítico cercano a la temporalidad humana le confiere un carácter más significativo que si formara parte de un contexto de menor resolución, en el que su baja incidencia cuantitativa otorgaría una representatividad anecdótica a este tipo de trabajo. Estos resultados apuntan al gran potencial interpretativo que poseen los marcos analíticos de mayor resolución temporal y conducen a una pregunta clave: ¿qué grado de variabilidad se encuentra oculta en los micropalimpsestos conformado aparentemente por un único tipo de trabajo? Si tenemos en cuenta que las acciones derivadas de éste y los soportes utilizados pueden variar, tal y como se ha observado en este caso, el margen de variabilidad potencial que la traceología puede aprehender se amplía de forma notable.

Por otra parte, esta variabilidad potencial cobra aún más sentido si se considera la información aportada por el conjunto faunístico incluido en 3.2. Se trata de al menos 13 individuos: *Capra pyrenaica* (n 3), *Cervus elaphus* (n 3), *Equus ferus* (n 3), *Sus scrofa* (n 1), *Bos primigenius* (n 1) y *Testudo hermanni* (n 1) (Pérez, 2019). A partir de los estudios tafonómicos se han observado marcas de procesado que remiten a acciones como el despellejado, la remoción del periostio y la desarticulación de las presas. Estos datos indican que dicha variabilidad potencial es también una realidad documentada en las diferentes actividades vinculadas al procesado animal a partir del registro arqueozoológico. Sin embargo, la diversidad de acciones observada se reduce significativamente en contextos de alta resolución temporal, como también ocurre en 5.3 y en 4.1. Todo ello refuerza la idea de la diacronía interna propia de los micropalimpsestos que contribuye a homogeneizar la imagen de los comportamientos de estos grupos humanos a lo largo del tiempo.

La unidad arqueostratigráfica 5.1

A diferencia de las unidades arqueostratigráficas expuestas anteriormente, la UA 5.1 se consideró un evento singular desde los primeros estudios de Machado *et al.* 2017. Los resultados funcionales aplicados al conjunto nos remiten a trabajos sobre materia animal. Así, de las 8 piezas que cuentan con estigmas de uso, 4 estuvieron destinadas a carnicería y otras 4 al procesado de la piel. Las acciones llevadas a cabo son de corte a excepción de un caso, en el que trató la piel mediante una acción de raspado. Los útiles empleados en estas tareas son muy similares: lascas de morfología rectangular (n4),

cuadrangular (n2) o irregular (n2) con filos preferentemente rectos a excepción de uno convexo que se empleó en una acción de corte sobre piel. Los ángulos de trabajo varían, ya que en las actividades de carnicería se ciñen a 40 y 50°, mientras que, para el trabajo de la piel, además de ángulos de 40-50°, también se empleó uno de 70° en una acción de corte y uno de 90° en la acción de raspado. En cuanto al tamaño de los soportes, generalmente son grandes o medianos, pero destaca la presencia de 2 piezas de pequeño tamaño que estuvieron involucradas en el trabajo carnicero. Esto también se observa en la UA 5.3.3 en la UA 4.1 y en la UA 3.2 en la que una lasca pequeña estuvo involucrada en una acción longitudinal sobre materia blanda. Este tipo de soportes en contextos de alta resolución, sólo se han identificado en 5.3.3 y 5.1, mientras que en el resto de marcos de similar escala temporal los soportes son exclusivamente medianos o grandes. Llama la atención que estas piezas de dimensiones reducidas se circunscriban a eventos en los que se ha documentado únicamente trabajos en torno a la materia animal.

Finalmente, el material zooarqueológico asociado a esta unidad está integrado por un número mínimo de 6 individuos con marcas antrópicas: *Equus ferus* (n 3) *Capra pyrenaica* (n 2) y un individuo del género *Rupicapra* sp. (cf. Pérez, 2019; Pérez *et al.*, 2020). En este caso, la asociación entre los restos de fauna con marcas antrópicas y los útiles con huellas de uso relacionadas con una actividad carnicera parece obvia, pues los resultados funcionales de esta unidad nos remiten exclusivamente a un trabajo sobre materia animal.

La Unidad arquoestratigráfica 5.2

Esta unidad cuenta con un total de 25 piezas asociadas a los hogares H24 y H27. Por falta de indicadores de diacronía, sigue manteniéndose como un micropalimpsesto. El material lítico de esta unidad presenta una alteración postdeposicional que modifica sus respectivas superficies, impidiendo el estudio funcional. En este sentido, las alteraciones postdeposicionales son muy frecuentes en yacimientos paleolíticos, lo que ha derivado en un corpus bibliográfico dedicado a los procesos de alteración del material lítico y su implicación a la hora de poder establecer estigmas de uso (*e.g.* Asryan *et al.*, 2014; Clemente-Conte, 1997; González & Ibáñez 1994; Jardón, 1996; Keeley 1980; Levi-Sala 1986, 1996; Moss 1983; Plisson 1985; Plisson & Mauger, 1988; Van Gjin 1989). En nuestro caso, se trata de una abrasión de la superficie, generando un pulido brillante e irregular, que sigue a la topografía de la superficie. Se localiza en ambas caras de la pieza, pero sobresale especialmente en una de ellas, tanto en los bordes como en el interior.

Algunas presentan melladuras y un ligero redondeamiento del borde, pero no son trazas diagnósticas por sí solas para determinar el uso. Así, en caso de que las piezas se hayan usado, se debieron generar pulidos tan ligeros, que han quedado enmascarados por abrasión postdeposicional. El probable bajo desarrollo de estos estigmas podría relacionarse con tratamiento de materias blandas, con actividades de corta duración o con una combinación de ambas.

Descartamos que esta alteración sea debida al pisoteo, sobre todo porque este fenómeno genera melladuras con una distribución errática (*e.g.* Thringam *et al.*, 1974), que sólo están presentes en algunas de estas piezas. También descartamos la acción del fuego, ya que las piezas no presentan los estigmas característicos de la termoalteración, ni a escala macroscópica ni microscópica (*e.g.* Clemente-Conte 1997). Esta alteración no es perceptible en otros elementos del conjunto si tenemos en cuenta la conservación del material zooarqueológico (Pérez, 2019), así como el estado de preservación de los hogares y de otras estructuras sedimentarias, a escala microscópica (Carolina Mallol comunicación personal). Así, tal y como apuntaban en otros estudios Keeley (1980) y Plisson (1985), llama la atención que a simple vista hay piezas que se encuentran en contextos sedimentarios bien conservados y sin embargo están alteradas. Cabe la posibilidad de que esta alteración esté reflejando la exposición de las piezas a procesos de meteorización (*e.g.* Van Gjin, 1989).

Este comportamiento homogéneo del sílex recuperado en la UA 5.2 parece estar indicando un cambio en la ratio de sedimentación y, abre la posibilidad de conectar áreas del yacimiento cuyo registro silíceo muestre el mismo tipo de alteración.

5.5. Infiriendo la duración de las ocupaciones a partir del análisis funcional

En los últimos años, la caracterización de las ocupaciones paleolíticas ha derivado del estudio de conjuntos que forman parte de marcos analíticos de alta resolución temporal (*e.g.* Deschamps *et al.*, 2021; Machado *et al.*, 2017; Moncel *et al.*, 2021; Picin & Cascalheira 2020; Spagnolo *et al.* 2020a, 2020b; Sossa-Ríos *et al.*, 2022)

De manera general, estas ocupaciones se han caracterizado por ser de corta duración, con material lítico poco abundante y cuya cadena operativa está fragmentada, con restos de fauna y generalmente asociados a un hogar, siguiendo el modelo de “*hearth-related assemblage*” (Vaquero & Pastó 2001). Para el caso que nos compete, cada uno de estos marcos de análisis de alta resolución parece responder a un área de actividad cuya funcionalidad reflejaría, en mayor o menor medida, la variabilidad de comportamiento

entre los grupos neandertales que ocuparon El Salt. No obstante, aún no hemos tratado la duración de las ocupaciones desde una perspectiva funcional. En este sentido, consideramos que hay ciertos indicadores que nos remiten a la corta duración de las ocupaciones, los cuales se describirán brevemente a continuación:

- La gran mayoría de las piezas con huellas de uso presentan estigmas poco intensos. En este sentido, no parece que las piezas se hayan utilizado durante lapsos de tiempo prolongados. De hecho, aparentemente, muchos de los filos continúan “frescos” de tal forma que no se emplearon hasta agotarse.

- Por otro lado, hay pocas piezas (n 3) que cuenten con más de una zona activa y no existe ninguna con más de dos. En este sentido, muchos útiles presentan varios filos morfológicamente adecuados para su uso (en dimensión, ángulo y morfología) y, sin embargo, no presentan huellas de uso. Aparentemente esto implica que no hay necesidades inmediatas que requieran el uso de todos los filos potencialmente usables, por lo que sus requerimientos están cubiertos con una cantidad de filos menor de los que disponen.

- Por otro lado, sólo hay 12 piezas retocadas y ninguna reavivada, lo que nos permite deducir que seguramente la mayor parte de los útiles intervinieron exclusivamente en los trabajos mencionados. Esta interpretación también queda sustentada por el hecho de que no se han observado solapamientos de huellas de uso de diferentes materias o acciones, como si se ha observado en otros contextos (e.g. Lemorini *et al.*, 2022; Martín-Viveros *et al.*, 2023)

- Finalmente, tal y como se ha comentado previamente, no se reconocen estigmas de enmangamiento ni rebajes ventrales que nos permitan interpretar el uso de mangos. En este sentido, tal y como comenta V. Rots (e.g. 2013, 2014, 2016) las piezas enmangadas parecen responder a una elección explícita impulsada por la repetición de una tarea. Como ya se ha ido comentando, nuestros datos funcionales no reflejan trabajos de larga duración o intensos, lo que concuerda con el planteamiento de V. Rots ya que las actividades desarrolladas no tendrían un alto grado de frecuencia y, por ende, el enmangue de las piezas no estaría justificado.

Estos datos van en consonancia con el resto de estudios que han tratado de aproximarse a la escala temporal de las ocupaciones humanas de El Salt. En este sentido, los eventos disectados en este yacimiento se han caracterizado por su escaso material lítico, cuya cadena operativa está fragmentada, asociados a un hogar, siguiendo el modelo *hearth related-assemblage* (Machado *et al.*, 2017, Mayor *et al.*, 2020) y con restos de

fauna fragmentada que en ocasiones no es de origen antrópico (Pérez 2019). Por lo que respecta al estudio de los hogares, se han observado lapsos de tiempo prolongados entre estructuras de combustión y la ausencia de reencendidos (e.g. Leierer *et al.*, 2019; Mallol *et al.*, 2013). Todo ello indica que estos eventos debían de ser de corta duración, aspecto que va en consonancia con nuestros resultados funcionales.

5.6. Discusión en torno a los resultados sobre los estigmas de uso de la madera termoalterada

El programa experimental en torno al trabajo sobre la madera termoalterada nos ha ofrecido unos resultados que, *grosso modo*, podemos separar en 4 fases. La primera de ellas fue la obtención de resultados traceológicos a partir de la observación con el microscopio metalográfico, pudiendo definir un tipo de huellas de uso, entre ellas el pulido, que se diferenciaban de la madera verde o seca. En la segunda fase, a través del análisis de las piezas experimentales con el MEB, observamos que la superficie de las piezas apenas había sufrido alteración, por lo cual, lo que habíamos considerado como pulido, parecía no serlo. La tercera fase fue la realización del mapeo de elementos químicos a través de la técnica EDS, cuyos resultados nos remitían a una capa de residuo formada por carbón, de tal forma que la mayor parte de lo que habíamos considerado como pulido era carbono, no presente en la materia prima y por lo tanto procedente de la materia trabajada en forma de residuo. La cuarta fase consistió en aplicar un protocolo de limpieza agresivo sobre la superficie de las piezas, cuyo resultado fue el desprendimiento de la capa de residuo, dejaban al descubierto una superficie prácticamente inalterada. Con estos resultados nos gustaría hacer una serie de reflexiones que se comentan a continuación.

En primer lugar, nos gustaría retomar las teorías en torno a la formación de pulidos aditivos, como la de Christensen (1998), quien interpreta los pulidos como el relleno de las irregularidades de la superficie a partir de residuos desprendidos de la materia trabajada. En nuestro caso, no consideramos que sea un pulido aditivo en sí, ya que se ha observado, tras la limpieza de las piezas, que el residuo adherido a la superficie del sílex, se desprende. No obstante, no podemos obviar que se haya producido una modificación en la superficie, aunque sea superficial, ya que elementos como el carbón, la ceniza o la arena generan abrasiones intensas en las superficies. Sin embargo, por falta de datos, ya que es un programa experimental que está iniciándose, nos centraremos en la diferencia entre qué es un pulido, siendo una modificación de la superficie, y qué son residuos,

siendo elementos que se adhieren a la misma. Atendiendo además a los resultados preliminares que hemos obtenido, consideramos que esta capa de residuo puede funcionar como una barrera que limita la posibilidad de generar algún tipo de pulido, ya que, seguramente, entre la madera trabajada y el útil empleado, se acumula una capa de carbón que protege la superficie del sílex. Por ello, para el caso que nos ocupa, hablaremos de residuos y no de pulido aditivo.

En este sentido, en las últimas décadas, el análisis de residuos se ha desarrollado en paralelo a los estudios funcionales, para así comprender mejor la funcionalidad de los útiles líticos. Así, hay estudios de residuos que han relacionado material lítico con piezas cárnicas animales (*e.g.* Venditti *et al.*, 2019a, 2019b) con materiales leñosos o vegetales (*e.g.* Hardy *et al.*, 2020; Hardy & Moncel, 2011), como evidencia de enmangues (*e.g.* Lombard, 2005) o incluso con el uso de ceniza (*e.g.* Lemorini *et al.*, 2020). No obstante, el análisis de residuos ha venido acompañado de numerosas críticas que han señalado la posible degradación y contaminación de los mismos y, por ende, su dificultad a la hora de estudiarlos (*e.g.* Pedergrana *et al.*, 2016; Xhauflair *et al.*, 2017). El análisis de residuos en material experimental suele conllevar menos problemas, ya que son contextos más controlados donde hay menor probabilidad de contaminación. En este sentido, son de destacar las colecciones de referencia a partir de experimentos controlados que se suman al corpus de información en torno a esta temática (Lemorini *et al.*, 2014; Lynch & Miotti, 2017; Nucara *et al.*, 2020; Pedergrana & Olle, 2018).

Para nuestro programa experimental, el carbón adherido a la superficie representa prácticamente la única evidencia a partir de la cual poder determinar el trabajo sobre madera termoalterada. En este sentido, los estudios de residuos suelen compaginarse con estudios funcionales, de forma que se obtiene información sobre la funcionalidad del útil a través de dos tipos de análisis diferentes. En nuestro caso, las huellas de uso son muy sutiles, pues sólo contaríamos con las melladuras, que apenas son diagnósticas, y además no se han analizado los filos desde un punto de vista cenital, donde se podrían generar puntos de pulido más intensos. Pese a esto, es imprescindible el reconocimiento y la caracterización del residuo de carbón adherido a la superficie del útil para la identificación del trabajo sobre madera termoalterada. Entendemos a su vez que el carbón, conservado en numerosos yacimientos paleolíticos, también debería de conservarse en los útiles que pudiesen haber estado en contacto con madera termoalterada, más teniendo en cuenta que la superficie irregular del sílex puede proveer de mayor resguardo al residuo. No obstante,

también cabría pensar el carbón puede provenir del mismo sedimento o de haber estado en contacto con contextos de hogares.

Esto nos conduce a la siguiente reflexión, en torno a los protocolos de limpieza del material arqueológico. Como ya se ha explicado a lo largo de este trabajo, las primeras limpiezas aplicadas al material experimental se realizaron con jabón neutro y posteriormente con acetona o ácido acético al 5% en lapsos de tiempo muy cortos. Siguiendo este protocolo, el residuo más adherido a la superficie no se vio alterado. Sin embargo, cuando empleamos un protocolo de limpieza más agresivo, con agua oxigenada pura durante 30 minutos, el residuo se desprendió, eliminando cualquier evidencia del trabajo sobre madera termoalterada. Esto implica que, para poder reconocer este tipo de trabajo en piezas arqueológicas, no se pueden emplear protocolos de limpiezas agresivas, como ácidos o agua oxigenada durante mucho tiempo, ya que eliminaría cualquier rastro. En este sentido, en el material analizado para esta Tesis, una de las piezas (X4/675) cuenta con un “pulido” que se asemeja bastante al que definimos al comienzo de esta experimentación y explicado en el artículo Bencomo & Jardón (2022). Esta pieza, cuya funcionalidad la hemos definido *a priori* a partir de estos rasgos, queda pendiente de su estudio en el MEB, para verificar si se trata de una capa de carbón y por tanto contamos con una evidencia directa sobre el trabajo de madera termoalterada, o si bien estamos ante un pulido indeterminado.

Nos gustaría finalizar remarcando que se trata de resultados preliminares, por lo que se debe profundizar en torno a esta cuestión en futuras experimentaciones, con la intención de seguir definiendo y caracterizando el trabajo sobre la madera termoalterada.

6. Conclusiones

A lo largo de esta Tesis Doctoral se ha realizado el estudio traceológico de 231 piezas de la UE Xa de El Salt, integradas a su vez en contextos estratigráficos que representan la mayor resolución temporal posible para cada caso. Si valoramos los resultados funcionales considerando a las piezas como un conjunto en el marco de la unidad estratigráfica Xa, los datos nos remiten al reconocimiento de una diversidad de trabajos, especialmente relacionados con la carnicería, el procesado de piel y de madera, realizados prácticamente con lascas sin retocar. Este panorama nos ofrece la imagen de un yacimiento en el que los grupos cazadores recolectores neandertales realizaron multiplicidad de actividades. Se caracteriza, por tanto, como un yacimiento multifuncional en el que los grupos humanos, al ocupar el sitio, combinaban distintas tareas en el mismo contexto crono-espacial. Esta interpretación iría en consonancia con muchos de los estudios funcionales, centrados en el Paleolítico medio, realizados hasta la fecha. Esta semejanza de resultados se debe, seguramente, a que la mayor parte de estos estudios funcionales seleccionan la UE como marco de análisis, cuyo significado temporal puede abarcar una cantidad indefinida de tiempo, incluso milenios. De esta forma, al analizar útiles integrados en unidades estratigráficas, estaríamos valorando en conjunto las actividades realizadas por un número indeterminado de grupos humanos, probablemente sin relación alguna entre ellos.

Para el caso de la UE Xa de El Salt, se ha tratado de disectar dicho palimpsesto, reconociendo áreas de actividad que se aproximan a la escala temporal humana. Cada uno de estos marcos de alta resolución temporal nos remite a una serie de acciones y materias específicas, llegando a reconocer diferencias en los procesos productivos que, de otro modo, pasarían desapercibidas.

Nuestros resultados funcionales han puesto de manifiesto la existencia de áreas concretas del yacimiento en las que se llevaron a cabo actividades diversas, pero también, la organización de prácticas específicas, en esos mismos ámbitos y durante ocupaciones diferentes. Por ejemplo, en la UA 3.2.1 se realizaron tareas sobre materia animal y sobre madera, mientras que en la UA 4.1.2 solo se documenta el procesado de la madera y en la 4.1.1 únicamente parece haberse trabajado materia animal. Estos resultados ponen de manifiesto que los grupos neandertales llevaron a cabo actividades diferentes en cada una de estas áreas a lo largo del tiempo, lo que nos permite reconocer una cierta variabilidad diacrónica del comportamiento humano en el uso de los espacios y de los procesos de trabajo que fueron desarrollados en horquillas temporales acotadas.

Además de estas apreciaciones generales, el empleo de marcos analíticos de alta resolución nos ha permitido poner en valor una serie de útiles, como los de pequeñas dimensiones, relacionados principalmente con acciones de carnicería, cuya presencia es minoritaria si atendemos al conjunto total de piezas analizadas, pero cuyo papel se evidencia de forma más clara al estar integrados en contextos de alta resolución. Lo mismo ocurre con las piezas consideradas como elementos transportados, formando parte del equipamiento que llevan consigo estos grupos humanos. Así, se han observado diferencias funcionales y morfopotenciales con respecto a las piezas integradas en UMP de conjunto y, consecuentemente talladas *in situ* y utilizadas en el propio asentamiento en el que han sido fabricadas, ya que presentan un espectro funcional menos amplio, ya que sólo estuvieron involucradas en acciones relacionadas con materia animal y además cuentan con una morfopotencialidad mayor en cuanto a dimensiones, lo que las hace más manejables.

Este tipo de aproximaciones amplía de forma significativa las posibilidades de integración del registro arqueológico. Un caso evidente lo representa la correlación que hemos podido establecer entre los útiles líticos con huellas de uso carnicero y el registro faunístico que presenta marcas antrópicas vinculadas con su procesado. Aunque ya se ha explicado que la resolución temporal de los marcos a los que se adscribe el conjunto faunístico es menor, no deja de ser una vía de investigación para correlacionar material arqueológico que, desde el punto de vista de una actividad humana, presentan una serie de características que permiten su asociación.

Por otro lado, atendiendo a la poca intensidad de las huellas de uso observadas en el material arqueológico (poco desarrollo de las huellas de uso, ausencia de solapamientos y ausencia de reavivados), parece que nuestros resultados van en consonancia con la lectura de ocupaciones definidas como de corta duración en El Salt. En este sentido, los eventos disectados en este yacimiento se han caracterizado por su escaso material lítico, cuya cadena operativa está fragmentada, asociados a un hogar, siguiendo el modelo *hearth related-assemblage*. Además, a través del estudio de los hogares, se han observado lapsos de tiempo prolongados entre estructuras de combustión y la ausencia de reencendidos. Todo ello indica que estos eventos debían de ser de corta duración, aspecto que va en consonancia con nuestros resultados funcionales.

Conclusions

Throughout this PhD, the use-wear analysis of 231 artifacts from UE Xa of El Salt has been conducted, integrated within stratigraphic contexts that represent the highest possible temporal resolution for each case. If we evaluate the functional results considering the artifacts as a whole within the framework of stratigraphic unit Xa, the data lead us to recognize a diversity of activities, particularly related to butchery, hide processing, and woodworking, predominantly performed with unmodified flakes. This overview provides us with an image of a site where Neanderthal hunter-gatherer groups engaged in a multitude of activities. Therefore, it is characterized as a multifunctional site where human groups combined different tasks within the same spatiotemporal context. This interpretation is in line with many functional studies conducted to date, focused on the Middle Paleolithic. The similarity of these results is likely due to the fact that most of these functional studies select the stratigraphic unit as the analytical framework, whose temporal significance can encompass an indefinite amount of time, even millennia. Thus, by analyzing tools integrated within stratigraphic units, we would be assessing the activities performed by an indeterminate number of human groups, likely without any direct relationship between them.

In the case of SU Xa of El Salt, we have attempted to dissect this palimpsest, identifying areas of activity that approximate the human temporal scale. Each of these high-resolution frameworks corresponds to a series of specific actions and materials, revealing differences in productive processes that would otherwise go unnoticed.

Our functional results have revealed the existence of specific areas within the site where various activities took place, as well as the organization of specific practices within these areas during different occupations. For example, in AU 3.2.1, tasks involving animal materials and wood processing were carried out, while in AU 4.1.2, only wood processing is documented, and in 4.1.1, it appears that only animal materials were worked. These results demonstrate that Neanderthal groups conducted different activities in each of these areas over time, allowing us to recognize a certain diachronic variability in human behavior, regarding the use of spaces and the development of work processes within defined temporal ranges.

In addition to these general observations, the use of high-resolution analytical frameworks has allowed us to highlight the significance of small-sized tools, primarily associated with butchery actions. Although their presence is minority when considering the total set of analysed artifacts, their role becomes clearer when integrated within high-

resolution contexts. The same applies to products considered as transported elements, forming part of the equipment carried by these human groups. Differences in function and morphopotentiality have been observed compared to pieces integrated within the larger tool assemblage that was likely knapped in situ and used within the settlement itself. These transported pieces have a narrower functional spectrum, being primarily involved in actions related to animal materials, and they exhibit greater morphopotentiality in terms of dimensions, making them more manageable.

These approaches significantly enhance the possibilities of integrating the archaeological record. An evident case is the correlation we have established between lithic tools with butchery traces and the faunal record that presents anthropic marks associated with their processing. Although it has been explained that the temporal resolution of the frameworks to which the faunal assemblage is attributed is lower, it still serves as a research avenue for correlating archaeological materials that, from the perspective of human activity, possess certain characteristics allowing for their association.

On the other hand, considering the low intensity of use-wear observed on the archaeological material (limited development of use-wear traces, absence of overlapping, and absence of resharpening), our results seem to align with the interpretation of short-duration occupations at El Salt. In this sense, the events dissected at this site are characterized by scarce lithic material, fragmented operational sequences, and association with a hearth, following the *hearth-related assemblage* model. Furthermore, through the study of hearths, prolonged time lapses between combustion structures and the absence of reignition have been observed. All of this indicates that these events must have been of short duration, which is consistent with our functional results.

7. Perspectivas de futuro

A continuación, se comentarán algunas propuestas de futuro que consideramos fundamentales para proseguir con los estudios traceológicos.

Comenzando con el tipo de materia prima seleccionada para esta Tesis Doctoral, sólo se han analizado soportes fabricados sobre sílex, pero no de caliza, presente, aunque de forma minoritaria, en El Salt. En este sentido, en otros yacimientos, como la Cova de Bolomor, se observó que los útiles de sílex y los de caliza estuvieron destinados a realizar actividades distintas (Hortelano, 2016). Realizar un estudio sobre las calizas de El Salt nos podría aportar información sobre procesos de trabajo o materias que no estamos reconociendo a través del estudio traceológico del sílex.

Por otro lado, también tenemos en cuenta que una evaluación crítica y comparativa de los resultados obtenidos a partir de estudios tecnológicos y traceológicos, sería de especial relevancia para comprender mejor las finalidades técnicas y funcionales de los soportes empleados por los grupos neandertales.

Finalmente, atendiendo al programa experimental sobre la madera termoalterada, a lo largo de esta Tesis Doctoral se ha pretendido responder a una serie de preguntas en torno a los procesos de trabajo realizados por los grupos neandertales sobre el uso del fuego para trabajar la madera. Esta experimentación, como ya se ha ido explicando, ha pasado por distintas fases de desarrollo, permitiendo abrir una nueva línea de investigación en torno a la conservación de residuos y protocolos de limpieza que permitan la caracterización de este trabajo a nivel experimental y arqueológico. Así, nuestra finalidad es continuar con esta línea de investigación con experimentos controlados sobre los residuos de las materias trabajadas y establecer protocolos de limpieza y observación para un desarrollo metodológico específico. Además, los resultados que hemos ido obteniendo con el MEB y con la técnica EDS, deberían ser comprobadas en otras materias trabajadas y realizando otro tipo de acciones (por ejemplo, de corte), para ver si los resultados son parecidos.

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