

# FUNCTIONAL STUDIES OF NEOLITHIC STONE AXES AND ADZES. EXPERIMENTAL PROGRAMME AND ARCHAEOLOGICAL APPLICATIONS

Estudios funcionales de hachas y azuelas de piedra neolíticas. Programa experimental y aplicaciones metodológicas

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**ABSTRACT** This paper reports the results of a series of recent experiments in which stone adzes and axes were used in woodworking, butchering, hide processing and hoeing activities. The aim of this work is to describe progress in the differentiation between the various kinds of use-wear on polished stone surfaces.

The ultimate objective is to create a reference collection suitable for performing the use-wear analysis on polished adzes and axes discovered in archaeological contexts. Particularly, we wish to contribute to the understanding of the role that these tools played in the different economic and ritual activities of the Neolithic communities living in the North East of the Iberian Peninsula around the middle of the 5th and 4th millennium cal. BC.

**Key words:** Neolithic, Experimental Archaeology, Polished Stone Tools, Axe, Adze, Use-Wear Analysis.

**RESUMEN** El presente artículo viene a exponer los resultados de una serie de experimentos llevados a cabo usando hachas y azuelas en diversas actividades de trabajo de la madera, procesado de pieles, descuartizado de animales y cavado de la tierra. Describir nuestros avances a la hora de discriminar las distintas huellas de uso formadas en las superficies líticas después de cada experimento es el objetivo de esta exposición. En última instancia nuestra finalidad es crear una colección de referencia que nos permita llevar a cabo el análisis funcional de hachas y azuelas arqueológicas. Particu-

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larmente, nos interesa crear herramientas para efectuar una aproximación más exacta a la participación de este tipo de útiles en las actividades de tipo ritual y económico que tuvieron lugar entre las comunidades del NE de la Península Ibérica entre el 5.º y el 4.º milenio AC.

**Palabras clave:** Neolítico, Arqueología experimental, herramientas de piedra pulida, hachas, azuelas, huellas de uso.

## INTRODUCTION

The need for an experimental collection to study polished and bevelled artefacts arose in the framework of the project “Aproximación a las primeras comunidades neolíticas del NE peninsular a través de sus prácticas funerarias” (Ministerio de Ciencia e Innovación HAR2011-23149). The project was focused on studying the communities inhabiting the North East of the Iberian Peninsula around the middle of the 5th and 4th millennium cal. BC, which are characterised by a large number of preserved burials, contrasting starkly with the virtual absence of dwellings. Over 650 graves and a large numbers of waste pits belonging to this period have been documented, termed the “*Pit Burials Culture*” (Muñoz, 1965). These communities displayed a consolidated agrarian economy and they settled along the valleys and plains of the coastal Mediterranean region, cultivating wheat, barley and legumes and keeping domesticated animal species such as sheep, goats, cattle and swine (Fontanals *et al.*, 2015).

The funerary contexts usually consist of individual burial pits, where the deceased was deposited accompanied by grave goods such as pottery, foreign flint blades and cores, adzes and axes, bone awls and spatulas, wild boar fangs, as well as stone, shell and bone necklace and bracelet beads, among other elements (Gibaja *et al.*, 2010). The non-funerary structures are mainly storage and refuse pits commonly used for the purpose of waste disposal where adzes, axes, grinding stones, bone and flint artefacts and ceramic fragments are mainly to be found.

Although the funerary and domestic polished and bevelled tools (usually named axes and adzes) have been inventoried and repeatedly referred to as a technological innovation linked to the development of agrarian societies and as a votive object in the funerary record, there is a distinct lack of analytical and empirical approaches to investigating their actual uses and social significance.

In order to fill this gap, an experimental programme combining macroscopic and microscopic use-wear analyses has been implemented within the framework of Alba Masclans’ PhD project (Masclans, 2017). As a result, it has become possible to establish criteria that enable us to distinguish use-wear patterns associated with different activities, worked materials and kinematics. In this article, a summary of the experimental programme and the characterisation of the different use-wear patterns will be presented.

## METHODS

### What could the polished adzes and axes have been used for?

Polished bevelled tools such as axes and adzes have been studied by researchers since the very early days of archaeological investigation, given the sheer numbers of artefact remains of this kind. In the late 19th and early 20th centuries, authors such as Déchelette (1908) or Mortillet (1903) started to classify the morphological attributes of these tools, creating the first typologies, in which they were mechanically associated with wood procurement and processing. As a matter of fact, stone axe and adze tools have been systematically interpreted as nothing other than woodworking instruments.

What a preliminary study of the sample of Neolithic polished and bevelled tools from the North East of the Iberian Peninsula has shown is that their dimensional, morphological and petrographic characteristics, along with the outcome of an exploratory traceological analysis revealing the presence of a very diverse range of wear traces, suggest that, rather than being used for woodworking alone, a large number of functional uses of these tools were possible.

In order to start formulating hypotheses with the purpose of understanding and explaining what those uses were, the first step was to review ethnographic data. This provided an interesting overview of the possible uses of these tools, as well as information regarding tool shape, hafting systems and kinematics. Furthermore, a review of experimental archaeology literature on the subject was also performed.

The research carried out in the field of anthropology, especially in Oceania, was of great importance, as the arrival of professional anthropologists coincided with the presence of the last communities which still used stone tools or whose older members remembered the way they were produced and utilised. Direct and indirect observation of axe and adze uses (both ritual and economic) in ethnographic contexts has allowed an advancement in our understanding of the many possibilities, which can then be extrapolated to the interpretation of archaeological data.

As a whole, ethnographic data lists five recurrent production processes in which polished bevelled stone tools were involved: hoeing (Sonnenfeld, 1962; Steensberg, 1980), butchering (Dickson, 1981; Petrequin and Petrequin, 1993; Steensberg, 1980; Heider, 1970), hide processing (Boas, 1909; Emmonds, 1923) and woodworking (Dickson, 1981; Godelier and Garanger, 1973; Best, 1924; Petrequin and Petrequin, 1993; Heider, 1970; Carneiro, 1974, 1979; Steensberg, 1980; Townsend, 1960). The stone tool production has also frequently attracted the attention of different researchers in Papua New Guinea (Petrequin and Petrequin, 1993; Burton, 1984a, 1984b; Stout, 2002; Best, 1912; Heider, 1970; Hampton, 1999).

Besides, experiments involving stone axes and adzes were also carried out in the very early stages of archaeological investigation, above all addressed at assessing their efficiency and effectiveness in comparison with modern steel tools. Affirming their former use as woodworking tools was a great challenge at a time when the need for use references was so urgent (Pond, 1930; Morris, 1939). These

experiments became more frequent and systematic in the 1960s/1970s, especially replicative experiments focused on measuring the time invested in deforesting or building activities (Coles and Orme, 1983; Jorgensen *et al.*, 1985; Renfrew, 1973; Carneiro, 1979). Currently, these types of experiments still continue to be a matter of great importance (Walter *et al.*, 2013; Elburg *et al.*, 2015).

Concerning the use-wear analysis of polished bevelled artefacts through analytical experimentation, although Semenov's pioneering work (1957) was followed by the work of others, such as Detev (1960), Roodenberg (1982), Olausson (1982) and Binneman and Deaconb (1986), generally speaking, this field of research remained marginal for almost thirty years. Recently, however, there has been significant progress in the development of low magnification macro lithic use-wear studies (Adams, 2014, Adams *et al.*, 2009, Debreuil and Savage, 2014; Delgado, 2008; Lewis *et al.*, 2011). Yet, there does not appear to be many researchers whose investigation focused on the functional analysis of polished axes/adzes, though there are some who have worked with raw materials such as flint (Wentink *et al.*, 2011; Yerkes and Barkai, 2013; Pyżewicz, 2013), shell (Lammers, 2008) and other coarse grained materials, such as greenstone (Fabregas Valcarce, 1992), eclogite/omphacite (Lunardi, 2008), calcareous rock (Ibáñez and González Urquijo, 2013) as well as igneous rocks (Pawlik, 2007).

The anthropological, archaeological and experimental data has led to wider and more systematic applied studies being performed in different parts of the world (Buret, 1984; Davis and Edmonds, 2011; Duff, 1970; Petrequin *et al.*, 2012; Thirault, 2001; Turner, 2000). Still, the research interests are mainly confined to the reconstruction of the artefact *chaîne opératoire* and the regional and inter-regional networks of axe/adze production and distribution. Nevertheless, although only a few researchers have developed studies involving the use-wear analysis looking at the use of axes/adzes in woodworking, these attempts have generally provided positive results. We see this fact as an encouragement to go even further and make a contribution by extending both the range of the studied raw materials and the methods employed on them.

## **Objectives of the experimental programme**

Given the information extracted from the archaeological and anthropological data, it was determined that a comprehensive experimental programme was needed to inform the correct interpretation of stone adzes and axes. It was decided that the experimental programme had to be directed at characterising the use-wear traces produced during hoeing, butchering, hide processing and woodworking.

To date, a total of 34 experimental artefacts have been manufactured and 80 experiments have been carried out with positive results based on 6,341 minutes of experimenting. Of those experiments, 34 were assigned to create fresh technological active areas, 25 to woodwork activities, 4 to butchering activities and 2 more to hoeing.

The aim of this work was to observe the progression of the wear development over time when working the same material, which means that some artefacts were used for more than one experiment. In this way, after every interval, the used artefact was cleaned and analysed in the laboratory in order to achieve a more accurate survey of the wear development over time. The use-wear traces were then recorded by making acetate casts of the active areas between each experiment.

## **Making and using the experimental artefacts**

### *Making the experimental artefacts*

The first step in our programme consisted of making the experimental artefacts from hornfels, jadeite and eclogite rocks. The selection of these lithologies was done according to the main rock types used by the 'Pit Burial' communities in the North East of the Iberian Peninsula. As previously pointed out, 34 experimental artefacts were made, of which 27 were made from hornfels, 4 from jadeite and 3 from eclogite rocks. The hornfels pebbles, collected in the Ter River basin (Girona, Catalonia) (fig. 1:B), were cut off by means of a radial saw with a diamond blade and manually polished using a sandstone block with fine clay as an abrasive agent (fig. 1:A). Since our research is focused on the wear damage produced on the edge of the artefacts, it was decided to polish only the bevel. The polishing of the bevels took between 30 and 50 minutes per hornfels artefact.

In the case of the eclogite and jadeite artefacts, the same procedure was employed. Here, the bevel polishing process extended to three/six hours, which is logical bearing in mind the greater hardness of these materials. The eclogite and jadeite blocks were collected in Mont Viso, Oncino and Vallon de Porco (Cuneo, Piemonte, Italy, fig. 1:C) by Dr. Pierre Pétrequin, who kindly donated them to us.

Measurements such as weight, length, width, cutting edge angle, and edge morphology were taken, being the dependent variables of the production process. Still, these values are not used in this paper since the relationship between this data and the use-wear development is currently being processed and is not yet ready to be published.

### *Understanding the raw material: hornfels, jadeite and eclogite rock*

As a general classification, hornfels, jadeite and eclogite are rocks produced by metamorphism: medium/high contact metamorphism in the first case and high regional in the second and third.

Eclogite, jadeite and hornfels develop a crystalloblastic texture, formed in the process of crystalloblastesis, which completely alters the protolith texture. Specifically, we are talking about artefacts with a granoblastic texture. That is to say that they display a comprehensive range of medium and fine grain sizes. As for the fabric and structure, it is generally isotropic.

A)



B)



C)

Fig. 1.—A) Experimental artefact making process, B) Place of hornfels gathering, C) Place of jadeite and eclogite gathering (Photo by Pétrequin *et al.*, 2011, 66).

Hornfels are pelitic greywackes with a conchoidal fracture. They are rich in biotites and dull minerals such as ilmenite and other iron oxides. Often one can see pseudophenocrysts which give them a mottled appearance (Clop, 2004). Hornfels is easy to find in the North East of the Iberian Peninsula. There are irregular outcrops in the Pyrenees axial zone and the mountains of the coastal area, while the detritic river basin deposits of the Segre and Ter rivers are rich in hornfels pebbles.

By contrast, eclogites are considered mafic rocks produced by high regional metamorphism (Castro Dorado, 1988) whose principal components are Na-pyroxenes, garnets and other secondary minerals like quartz (Amico, 2005). Jadeites are also produced by high regional metamorphism (Castro Dorado, 1988), with their principal components being albite, quartz, muscovite, omphacite, glaucophane, calcite, aragonite, analcime and zeolite (Lafuente *et al.*, 2015). They outcrop on the Alpine Piedmont slopes, in the Swiss Valais and in the Ligurian-Piemontese Apennines, not to mention their presence as secondary deposits in the glacial and alluvial areas derived from the outcrop places (Ricq-de Bouard, 1996).

All this information will be useful given that the different components and grades of cohesion of these rocks will have a significant impact on the wear development. In line with this, it is to be expected that the active areas of the less cohesive hornfels rocks will be more fragile and likely to be affected by micro-chipping, while the micro-polish development will probably be less extensive in their active surfaces than in the jadeite and eclogite active areas.

On the other hand, the fact that the three lithologies contain different kinds of crystals, like quartz crystals, dictates that the use-wear approximation has to be done at different scales including an analysis of the matrix rock and a study of the crystals and other secondary minerals.

### *Using the experimental artefacts in woodworking activities*

The woodworking activities included making 16 experimental artefacts and conducting 25 experiments that involved tree felling, bark removal and several craft activities such as planing timber, making digging sticks and bows (table 1, fig. 2). The worked material was fresh wood of diverse hardness from *Quercus ilex*, *Quercus robur*, *Pinus pinaster*, *Buxus sempervirens*, *Taxus bacatta*, *Quercus robur* and *Betula pendula* specimens.

Four different groups of experiments were carried out depending on the working kinematics, the force application, the active area symmetry and the hafting system: axe experiments, adze experiments, scraping experiments and hollowing out experiments.

**Axe Experiments.** They were carried out through direct percussion (translated from *Percussion lancée*, after Leroi Gourhan 1988), using a wooden direct right mortise as a haft with the blade positioned parallel to the haft. The tools have symmetrical working angles and were used by swinging the tool from the waist, cutting flat notches by placing the tool at 45° to the tree. In the case of axe DE17,

TABLE 1  
WOODWORKING ACTIVITIES THROUGH DIRECT PERCUSSION

Artefact	Worked material state and species	Activity performed	Raw material	Act 1	Act 2	Act 3	Total time
DE2	Fresh <i>Pinus</i>	Debarking and cutting trees	Hornfels	30'	30'	—	60'
DE4	Fresh <i>Quercus ilex</i>	Debarking and cutting trees	Hornfels	30'	60'	—	90'
DE5	Fresh <i>Quercus ilex</i>	Debarking and cutting trees	Hornfels	45'	45'	—	90'
AE6	Fresh <i>Taxus baccata</i>	Preparation of a bow	Hornfels	311'	—	—	311'
DE7	Fresh <i>Pinus</i>	Debarking and cutting trees	Hornfels	30'	30'	60'	120'
AE9	Fresh <i>Pinus</i>	Debarking and cutting trees	Hornfels	60'	—	—	60'
AE10b	Fresh <i>Buxus sempervirens</i>	Preparation of a pointed stick	Hornfels	60'	—	—	60'
DE17	Fresh <i>Quercus ilex</i>	Debarking and cutting trees	Hornfels	30'	30'	30'	90'
AE19	Fresh <i>Buxus sempervirens</i>	Preparation of a pointed stick	Hornfels	60'	—	—	60'
DE22	Fresh <i>Quercus ilex</i>	Debarking and cutting trees	Hornfels	15'	30'	30'	75'
AE26	Fresh <i>Taxus baccata</i>	Preparation of a bow	Hornfels	149'	—	—	149'
AE30	Burned <i>Quercus ilex</i>	Debarking	Hornfels	45'	—	—	45'
AE37	Fresh <i>Quercus Robur</i>	Planing timber	Jadeïte	30'	—	—	30'
AE27	Soaked <i>Betula pendula</i>	Scraping bark	Hornfels	60'	—	—	60'
AE33	Soaked <i>Betula pendula</i>	Scraping bark	Hornfels	40'	—	—	40'
CIS35	Fresh <i>Quercus ilex</i>	Hollowing out timber	Jadeïte	60'	—	—	60'

a short section of deer antler was employed as a sheath, mounting it on a hole made in the handle. Six artefacts were used to work fresh *Quercus ilex* and *Pinus pinaster* (DE2, DE4, DE5, DE7, DE17, DE22) (fig. 2:A). The making of these tools was modelled on the wooden implements found in European palafittes such as Egolzwill (Stordeur, 1987; Wyss, 1994) and the anthropological tools from Irian Jaya (Pétrequin and Pétrequin, 1993).

**Adze Experiments.** They were carried out through direct percussion using a direct knee bend handle (translated from *Percussion lancée*, after Leroi Gourhan, 1988). The blades of the adzes were asymmetrical in cross-section and hafted transverse to the handle. The tools were used by notching the wood frontally at an acute angle in different activities such as planing timber, debarking wood and elaborating pointed sticks and bows. Six artefacts were used to work fresh *Quercus ilex*, *Buxus sempervirens*, *Taxus bacatta*, *Quercus robur* and *Pinus pinaster* (AE6, AE9, AE10b, AE19, AE26, AE27) and one used to work burned *Quercus ilex* (AE30) (fig. 2:B). In this case, the making of the tools was modelled on the wooden implements found in the early Neolithic site of la Draga (Girona), where the relationship between the stone tools and the worked wood has been studied extensively (Bosch *et al.*, 2008; Palomo *et al.*, 2013).

**Scraping Experiments.** They were carried out through pressure (translated from *percussion posée* after Leroi Gourhan, 1988) using direct terminal-axial hafts and blades that were asymmetrical in cross-section. The blades of the scraping tools



were placed on a wooden handle which had been split in two pieces and then tied together using a vegetal cord to work fresh *Betula pendula* (AE27, AE33) (fig. 2:C).

**Hollowing out Experiments.** An experiment was carried out through indirect percussion (translated from *Percussion avec percuteur* after Leroi Gourhan, 1988), using direct terminal-axial hafts and blades that were asymmetrical in cross-section. The stone blade was inserted in a hole made in the axial part of a wooden stick and fixed in place using vegetal resin. The artefact was used to work *Quercus ilex* (CIS35) (fig. 2:E).



Fig. 2.—Using the experimental artefacts in woodworking activities. A) Axe used in felling trees, B) Adze used in debarking and cutting wood, C) Adze used in the preparation of a bow, D) Tool used in scrapping bark, E) Tool used in hollowing out timber.

*Using the experimental artefacts in butchering activities*

Four experimental artefacts were made and the same number of experiments were carried out during which the ribcage, limbs and the spinal column of three *Sus scrofa* and one *Ovis aries* were chopped and the meat cut by means of direct percussion using a wooden direct right mortise as a haft with the blade positioned parallel to the haft. The tools have symmetrical working angles and were used to chop at an angle of 45° with the animal in the vertical position (fig. 3). The artefacts used for this purpose were DE21, DE23, DE28 and DE 34 (table 2).

TABLE 2  
BUTCHERING ACTIVITIES THROUGH DIRECT PERCUSSION

<i>Artefact</i>	<i>Worked material</i>	<i>Activity performed</i>	<i>Raw material</i>	<i>Total time</i>
DE21	Wild boar flesh and bone	Chopping ribcage and spinal column	Hornfels	45'
DE23	Wild boar flesh and bone	Chopping ribcage and spinal column	Hornfels	20'
DE28	Ovis aries flesh and bone	Chopping ribcage and spinal column	Eclogite	90'
DE34	Wild boar flesh and bone	Chopping ribcage and spinal column	Jadeite	60'

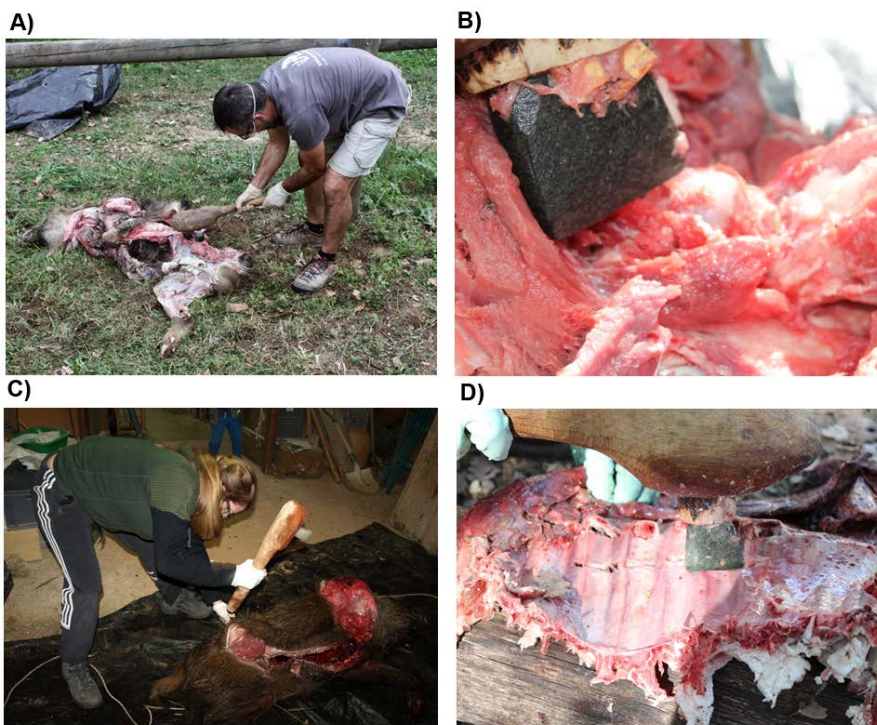


Fig. 3.—Using the experimental artefacts in butchering activities. A/C) General views of the activity, B) Chopping meat, D) Chopping the ribcage.

*Using the experimental artefacts in hide processing activities*

The hide-processing activities included making 12 experimental artefacts, with which 15 experiments were conducted (table 3, fig. 4). They were carried out through pressure transverse actions and direct percussion using direct terminal-axial hafts and blades that were asymmetrical in cross-section. The blades were placed on a wooden handle which had been split in two pieces and then tied together using a vegetal cord to work fresh, dry and soaked *Sus scrofa* hides. In one case (AE12) the blade was hafted transverse to a direct knee bend handle.

TABLE 3  
HIDE-PROCESSING ACTIVITIES THROUGH INDIRECT PRESSURE

<i>Artefact</i>	<i>Worked material</i>	<i>Activity performed</i>	<i>Raw material</i>	<i>Act 2</i>	<i>Act 3</i>	<i>Act 4</i>	<i>Total time</i>
AE8	Fresh wild boar hide	Direct percussion and pressure	Hornfels	120'	100'	—	220'
AE11	Fresh wild boar hide	Direct percussion and pressure	Hornfels	120'	90'	—	210'
AE12	Fresh wild boar hide	Direct percussion and pressure	Hornfels	120'	40'	—	280'
AE13	Fresh wild boar hide + ochre	Pressure	Hornfels	90'	—	—	90'
AE15	Fresh wild boar hide + ashes	Pressure	Hornfels	120'	—	—	120'
AE18	Fresh wild boar hide + ochre	Pressure	Hornfels	120'	—	—	120'
DE20	Fresh wild boar hide + ashes	Pressure	Hornfels	120'	—	—	120'
DE23	Fresh wild boar hide	Direct percussion and pressure	Hornfels	90'	—	—	90'
AE24	Dry wild boar hide + ochre	Pressure	Hornfels	180'			180'
AE25	Dry wild boar hide + ashes	Pressure	Hornfels	120'			120'
AE27	Fresh wild boar hide	Direct percussion and pressure	Hornfels	150'	—	—	150'
AE39	Dry wild boar hide + ashes	Pressure	Jadeite	90'			90'
AE27	Dry wild boar hide	Pressure	Eclogite	180'			180'

Four different groups of experiments were carried out depending on the working kinematics, the force application, the presence of an abrasive agent and the state of the worked material (dry, soaked, fresh).

Five artefacts were used during the first hide-processing step, which consisted in separating the fat and meat from the hide. In this process, the artefacts were used in a combination of direct percussion and scraping movements, without using abrasives (AE8, AE11, AE12, AE23, AE27) (fig. 4:A/B).

Four artefacts were used in the second step, when the task was reduced to cleaning only small particles of organic material using ash and ochre as abrasives. In those cases, a scraping movement was chosen (AE13, AE15, AE18, AE20) (fig. 4). Two artefacts were used in scraping dry hides with ash and ochre as abrasives (AE24, AE25) (fig. 4:C/D), whereas one artefact was used in scraping soaked hide with ash as an abrasive agent (AE39).





Fig. 4.—Using the experimental artefacts in hide processing activities. A/B) Fresh hide processing, C) Fresh hide processing with ochre as abrasive, D) Fresh hide processing with ash as abrasive.

### *Using the experimental artefacts in hoeing activities*

The hoeing activities involved making 2 experimental artefacts and conducting 2 experiments (table 4, fig. 5). The first experiment was carried out in a shaded area specially prepared to be used as a garden. The land had previously been cleaned of stones bigger than 2 cm and there was a dense green vegetation cover. The second experiment was carried out in “La Draga” (Banyoles, Girona), in a place prepared as an experimental cropping field. Rocks bigger than 2 cm had been removed. The soil humidity was high given the proximity to the lake; vegetation was scarce.

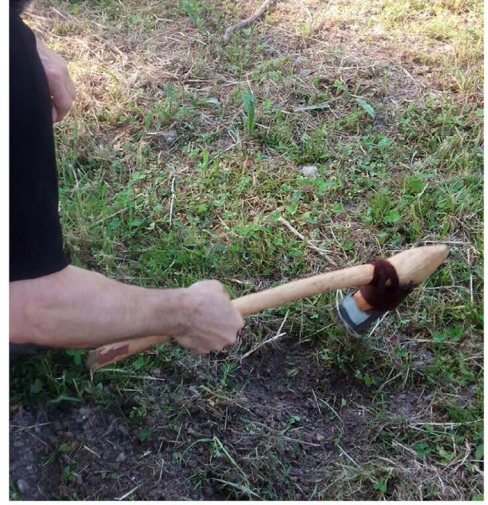
TABLE 4  
HOEING ACTIVITIES THROUGH DIRECT PERCUSSION

<i>Artefact</i>	<i>Worked material</i>	<i>Activity performed</i>	<i>Raw material</i>	<i>Act 2</i>	<i>Total time</i>
DE1	Non-rocky soft soil	Hoeing	Hornfels	60'	60'
DE36	Soft soil with small rocks	Hoeing	Hornfels	60'	60'

A)



B)



C)



Fig. 5.—Using the experimental artefacts in hoeing activities. A/B/C) Different perspectives of the hoeing work.

The experiments were carried out through direct percussion using a direct knee bend handle modelled on the wooden hoes observed in Kauman communities of Papua New Guinea (Niles, 1942). The blades of the adzes were asymmetrical in cross-section and hafted transverse to the handle. The tools were used by notching the ground frontally at an acute angle.

## Materials and methods

### *Residue distribution and cleaning*

After each experimental use, the residues were removed with an ultrasonic cleaner. In order to eliminate the tree resin, the implement was left for at least 10 minutes inside the ultrasonic machine with a 10% aqueous NaCl solution. It came to our attention that tree resin remains, observed at high magnification, could be confused with use traces. As seen in figure 6, resin residues leave a dull micro-polish with an irregular micro-topography and a semi-closed pattern. It can be seen up to 4 mm from the edge and often exhibits extensive surfaces and numerous linear features.

In order to eliminate the fat and meat residues, the implement was left for at least 15 minutes in the ultrasonic machine with a 30% hydrogen peroxide solution, after cleaning the artefacts with soap.

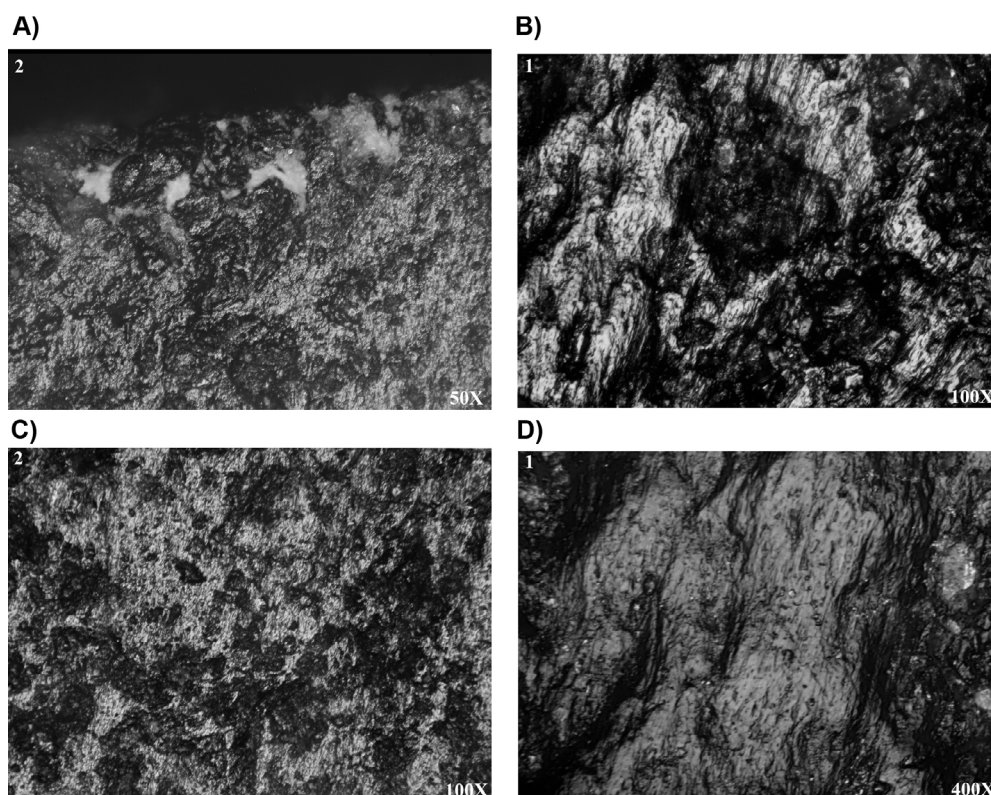


Fig. 6.—Woodworking micro-residues. A) Wood residues at 100x, B/C) Wood residues at 100x, D) Wood residues at 400x.

*Acetate casting*

Once the artefact had been cleaned, an acetate mould was cast for each bevel of the experimental tools. Given that axes and adzes are rather large objects, moulding is a very useful way of providing a convenient surface that can easily be placed in an electron microscope, thus simplifying image taking.

This operation was carried out after each use, with the technological surface being the first to be moulded. This was a very practical action which facilitated the study of the wear development of each experimental artefact, since replicas were obtained of the same tool edge area reflecting the different stages of wear.

*Use-wear study*

A microscope and binocular microscope study was carried out after every use. For the low power magnification observation, the 10X and 40X objectives of an Olympus BX51TRF binocular microscope were used. In this observation, the criteria proposed by Adams (Adams *et al.*, 2009), concerning topographic variations, levelling, linear traces, pits, grain extraction and cracks were followed.

For the high power magnification observation, required for quartzite and other heterogeneous rocks (Clemente, 1997), the crystals from the matrix were analysed differently, using an electron microscope. Furthermore, the widely irregular nature of the hornfels surface topography made the observation at 100X, 200X and 400X magnification essential, because of how rarely extensive micro-polish developed on these surfaces. To date, the methodology we have used has been a combination of methodologies previously proposed by various authors, further adapted to meet our needs (Clemente, 1997; González and Ibáñez, 1994; Vaughan, 1983). The observation was carried out from three perspectives: vertical, horizontal and slightly inclined. The image procurement was achieved by means of a multifocal system.

During the analysis, the flint, quartzite and quartz experimental reference collection in the IMF-CSIC's Laboratory of Prehistoric Technology was often referred to. It was extremely useful for studying the different features that appeared in our experimental artefacts.

**RESULTS AND CONCLUSIONS****Results***Technological wear*

## Macroscopic wear pattern (fig. 7)

In the first place, what we see when we analyse the technological surface of a polished adze or axe is the result of the contact between two very hard surfaces: the



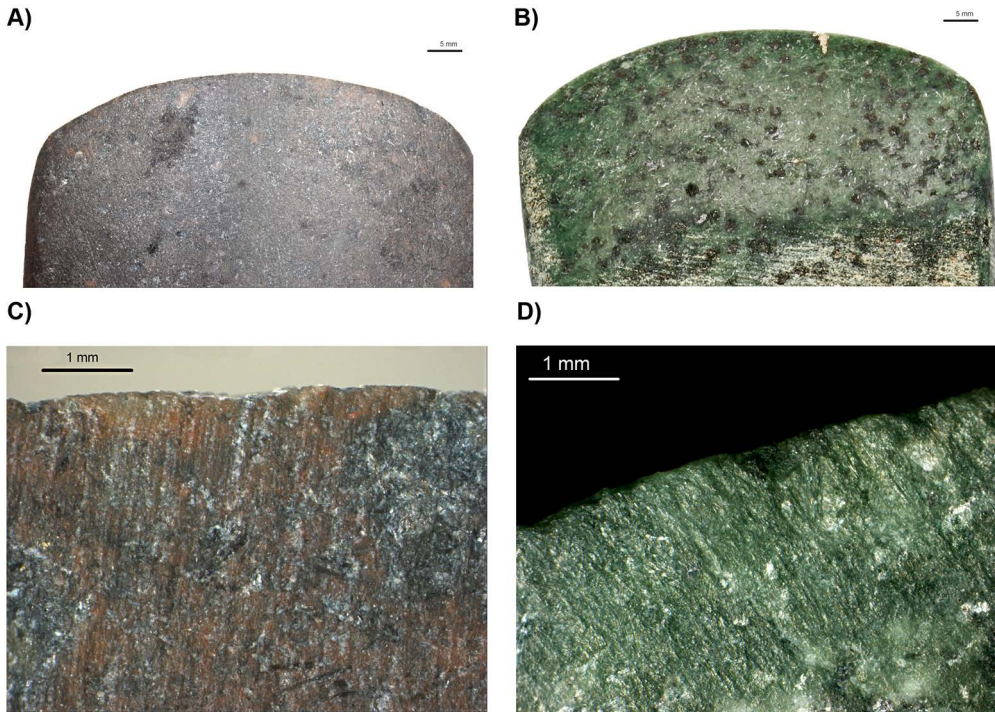


Fig. 7.—Technological macroscopic wear pattern. A) Hornfels macroscopic view. DE20, B) Eclogite macroscopic view. DE22, C) Hornfels macro-wear traces. DE18, D) Eclogite macro-wear traces. DE22.

tools and the abrasive sandstone. What occurs during this process is the fracture of the more superficial parts of the original topography, grain extraction and the abrasion of grains, rock particles and dust cementation, ultimately leading to the surface becoming levelled. As a result of incremental abrasion and transversal polishing kinematics, long linear traces perpendicular to the edge appear on the bevel (fig. 7:C and fig. 7:D).

As a general rule, it is obvious that grain size and cohesion is a matter of great importance in the wear development. Consequently, although the same wear pattern can be identified in both in eclogite/jadeite and hornfels, the greater hardness of the alpine rocks provokes a more severe damage in the abraded surfaces. Therefore, the harder and more compact the rock is, the more linear traces will appear and the more regular the final surface will be.

Regarding the hornfels axes, the aspect of their topography can be considered as flat at low magnification (fig. 7:A and fig. 7:B). In relation to the surface roughness, it varies from regular to irregular depending on the grain cohesion, with the more compact being more regular. There is an evident process of grain extraction and fracture which leads to the formation of micro-pits and the emergence of broken crystals. The linear traces have a loose closed distribution, appearing perpendicular/



oblique to the working edge and parallel to each other, with lengths between 0.5 mm and 2 mm and widths between 0.02 mm and 0.05 mm. They are U-shaped in cross-section.

Micro-chipping damage only appears in the coarse-grained artefacts. These traces are usually isolated and half-moon shaped, and no bigger than 1 mm. This damage provokes the apparition of fresh rock surfaces with angular grains.

In eclogite/jadeite, the production process generates a very levelled and regular technological surface, crossed by connected and covered linear traces of 0.5 – 1 mm in length and 0.05 mm in width. There are isolated micro-chippings that are never bigger than 1 mm (fig. 7:D).

### Microscopic wear pattern (fig. 8)

The microscopic wear pattern is characterised by a generic weak non-diagnostic micro-polish that can be seen all over the polished area (fig. 8:A). This micro-polish can be more close-patterned at some small spots in the most superficial areas of the micro-topography of the very edge, developing a dull and irregular surface. The recognition of this technological wear resulting from the manufacturing process is essential so as not to confuse it with the result of working a hard or semi-hard material.

Regarding the linear indicators identified in our experimental artefacts, it was possible to distinguish between scratches, striations, grooves, polished striations and directional micro-polish, although the last of these is not very extensive. Scratches appear as short and wide features (150 µm in width, 800 µm in length) (fig. 8:B) that can include internal striation and whose topography is flat and very bright. They appear isolated, close to one another and perpendicular to the edge. Grooves are unpolished wider figures, “U”-shaped in cross-section, and can measure up to 200 µm in width. They appear isolated starting on the edge. Polished striations are quite common, they are long (100 µm) and narrow (2-5 µm) and often appear grouped in clusters oriented perpendicularly to the edge (fig. 8:E). Striations are features similar to the ones above but wider (15 µm wide) and without polish.

The whole range of crystal wear can be seen: complete, banished, medium-abraded and only bottom conservation. Crystals can appear smashed, cracked or with internal micro-pits. There is no crystal polishing but crystal extraction and striations are frequent (fig. 8:C). Regarding the micro-chipping damage, half-moon, triangular and square-shaped features appear alongside one another but rarely superimposed.

In the case of the eclogite/jadeite artefacts, the wear is very different from that found on hornfels tools. The entire surface is affected by a very bright semi-closed directional micro polish covered by polished striation. The polished striation follows the polishing kinematic, mainly perpendicular to the edge, and is grouped in clusters of striations parallel to each other, although in certain places some transversal striations can be found superimposed on the first ones (fig. 8:D-E-F). The striation width is around 5 µm, while the length varies between 500-700 µm. Pronounced

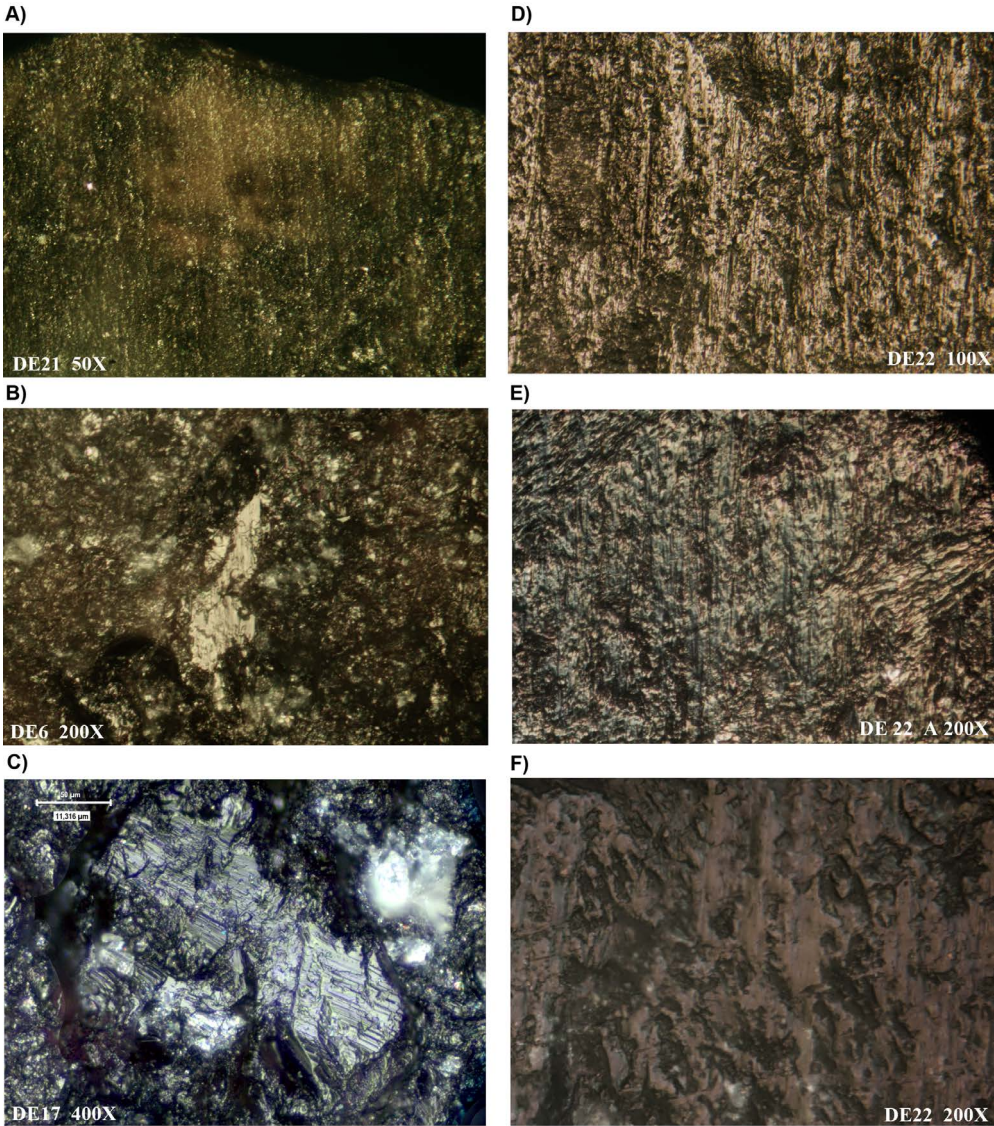


Fig. 8.—Technological microscopic wear pattern. A) Hornfels showing an open micro-polish perpendicular to the edge. DE21, B) Hornfels technological scratch. DE6, C) Hornfels crystal displaying striation. DE17, D/E/F) Eclogite technological bright, semi-closed, directional micro-polish covered by polished striation. DE22.

rounding is not found on these artefacts. Regarding crystal wear, quartz particles appear extremely abraded, so the crystal characterisation used in the hornfels analysis is not applicable in this case.

*Butchering wear*

## Macroscopic wear pattern (fig. 9)

The butchering artefacts exhibit a mixture of wear resulting from contact with a very hard material (bone) and a very soft one (meat), causing abrupt and fresh edge damage combined with a slight rounding. In this case also, grain size and cohesion is a matter of great importance in the wear development given that the more cohesive materials (jadeite and eclogite, fig. 9:C) present less macro-wear and more micro-wear damage than hornfels (fig. 9:B).

Macro-chipping damage appears on the coarse grained bevels as continuous and superimposed features, displaying half-moon, triangular or trapezoidal shapes between 2 and 6 mm wide (fig. 9:C). This damage provokes the apparition of new fresh rock surfaces with angular grains on the inside of the chips, combined with a slight rounding in the superficial areas of the micro-topography between the micro-chippings.

At low magnification (10-15X, fig. 9:C), the eclogite and jadeite macroscopic aspect appears barely changed in comparison with the technological surface. The punctual apparition of angular-shaped micro-chippings can be observed here,

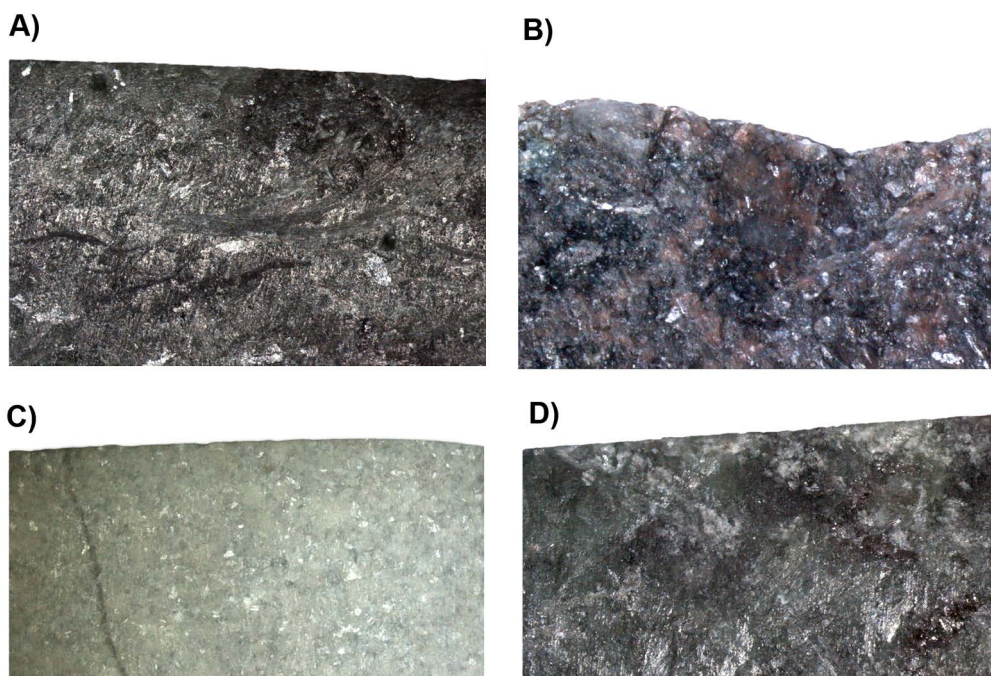


Fig. 9.—Experimental artefacts displaying macro-wear after butchering activities. A) Linear traces drawing an arch-like curve. DE28.30X, B) Fresh, superimposed and abrupt chips. DE21.30X, C) Non- affected surface. DE34.5X, D) Linear traces oblique to the edge DE28.30X.



generally smaller than 2 mm in width. Concerning the surface roughness, some of the technological linear traces can appear slightly altered, while the edge shows initial signs of rounding and smoothing. Over the technological surfaces new linear traces are developed, presenting a concentrated separated distribution drawing an arch-like curve placed at 2 mm from the active edge (fig. 9:A and fig. 9:D). These traces are U-shaped in cross, 1-2 mm long and 0.2-0.1 mm wide.

#### Microscopic wear pattern (fig. 10)

On both hornfels and jadeite/eclogite active areas, the butchering microscopic wear pattern is characterised by an extensive, dull, irregular and open micro-polish developed in the superficial areas of the micro-topography. This micro-polish extends between 2-3 mm from the edge. Generally, there are no differences between Face A and Face B in this kind of activity.

Regarding harder materials such as eclogite/jadeite, in the area up to 0.5 mm from the edge of the bevel, the micro-polish network pattern becomes semi-open, displaying smooth micro-topography (fig. 10:B). Punctually, a very bright and

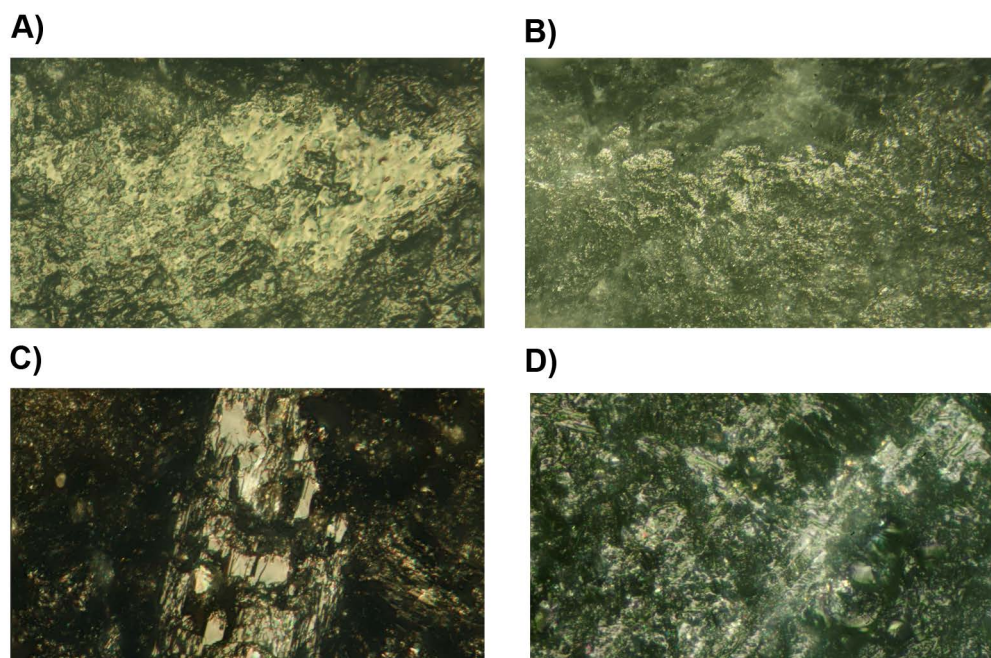


Fig. 10.—Experimental artefacts micro-wear after butchering activities. a) Bright and compact micro-polish with flat/undulating micro-topography. DE28.200X, B) Semi-open, bright irregular micro-polish DE28.100X, C) Crystal displaying abrupt and large extractions DE21.200X, D) Linear traces oblique to the edge DE34. 200X.

compact-networked micro-polish with flat/undulating micro-topography appears, located in isolated plaques near the edge (fig. 10:A). A loss of the technological surface can be observed in the area extending up to 1 cm from the edge, where the technological striations are altered by an irregular and shiny micro-polish (fig. 10:D).

Micro-chippings are abrupt, with plenty of fresh fractures in irregular, quadrangular and triangular forms. These features are more commonplace in hornfels than in eclogite/jadeite, in the former, the fractures are more abrupt and the degree of association more continuous and superimposed.

The combination of animal matter abrasion and powerful impacts against a very hard material produce a mixture of complete fresh crystals, medium abraded and totally abraded ones. There are large crystal extractions showing straight fractures with no striation (fig. 10:C). A shiny, smooth micro-polish can be identified in the medium abraded crystals.

### *Hoeing wear*

#### Macroscopic wear pattern (fig. 11)

Low magnification observation of the hoeing artefacts shows severe alterations in hornfels active areas, displaying big chips between 7-3 mm wide and an intense edge blunting that extends 1 cm from the edge, at least on the contact face (fig. 11:A). All the technological edge surfaces are completely altered by the abrading action of the soil, fundamentally exhibiting non-polished grooves and pecking.

Important differences between Face A (the contact face) and Face B can be observed. Face A contains most of the linear traces and rounding but hardly bears any trace of micro-chipping occurring on the edge (fig. 11:A). The loss of the technological surfaces is also more pronounced in this area, since the entire bevel displays covered-closed and covered-concentrated striation, with grooves that are U-shaped in cross-section and perpendicularly oriented to the edge. On Face B (the non-contact face, or the face which is exposed to less contact) the macroscopic alterations (pecking and blunting) are developed as far as 1 cm from the active edge (fig. 11:B). The edge damage is concentrated on this face: the damage features are abrupt, superimposed, with shapes varying between half-moon, triangular and irregular.

#### Microscopic wear pattern (fig. 11)

Face A displays an irregular, dull, semi-open-patterned micro-polish, formed inside and between micro-chippings, and displaying linear indicators extending 1.5 mm from the edge. Regarding linear traces, these are deep striations ending in a "U" shape, which are located between micro-chippings. They appear concentrated-closed

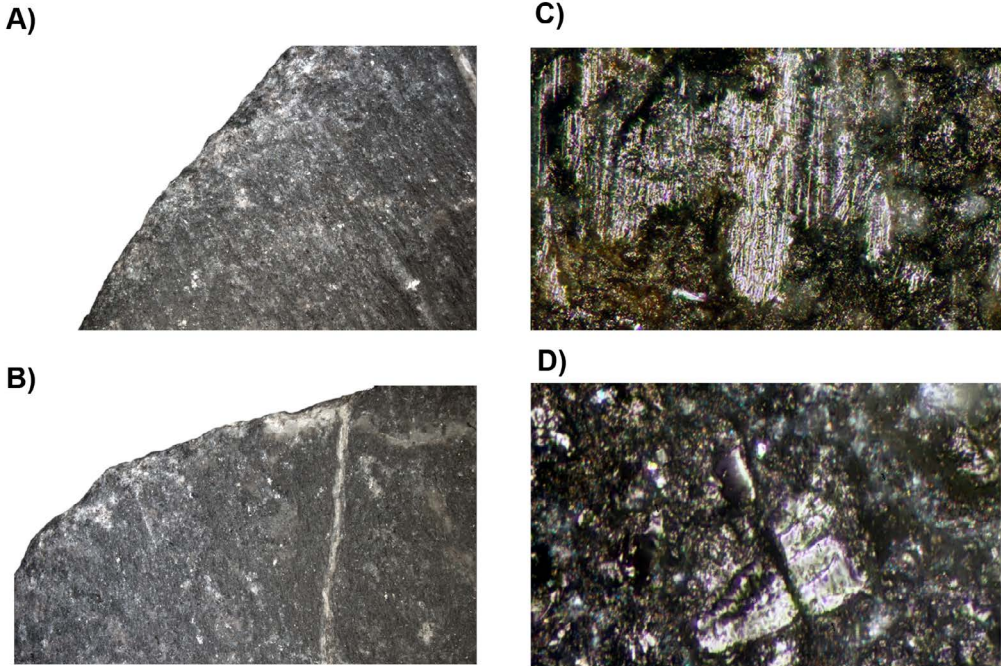


Fig. 11.—Hoeing macroscopic and microscopic wear traces. A) Contact face showing perpendicular to the edge grooves and pecking. DE1.15x, B) Non- contact face with less rounding and linear traces than face A. DE1.15x, C) Directional, compact, bright micro-polish. DE36.100x, D) Crystal displaying undulating micro-polish and pecking. DE1.200x.

and oriented perpendicularly to the edge (fig. 11:C). This micro-polish development is less intense on Face B, as the wear here does not extend further than 1 mm from the edge. An open/semi-open, dull, irregular micro-polish is developed inside and between micro-chippings, punctually displaying directional indicators.

Due to the fact that this activity consists in beating a very hard and abrading worked material, the crystals appear both very fresh and much abraded. In these cases, there is a very scarce presence of micro-polish crystals, which are generally shiny and displaying slightly pecked undulating surfaces (fig. 11:D). Micro-chipping features are irregular, abrupt and superimposed, appearing rounded in most of the cases.

### *Woodworking wear*

#### Macroscopic wear pattern (fig. 12)

Low magnification observation of woodworking artefacts did not show severe alterations on the surfaces of the hornfels artefacts (fig. 12:C). Micro-chipping



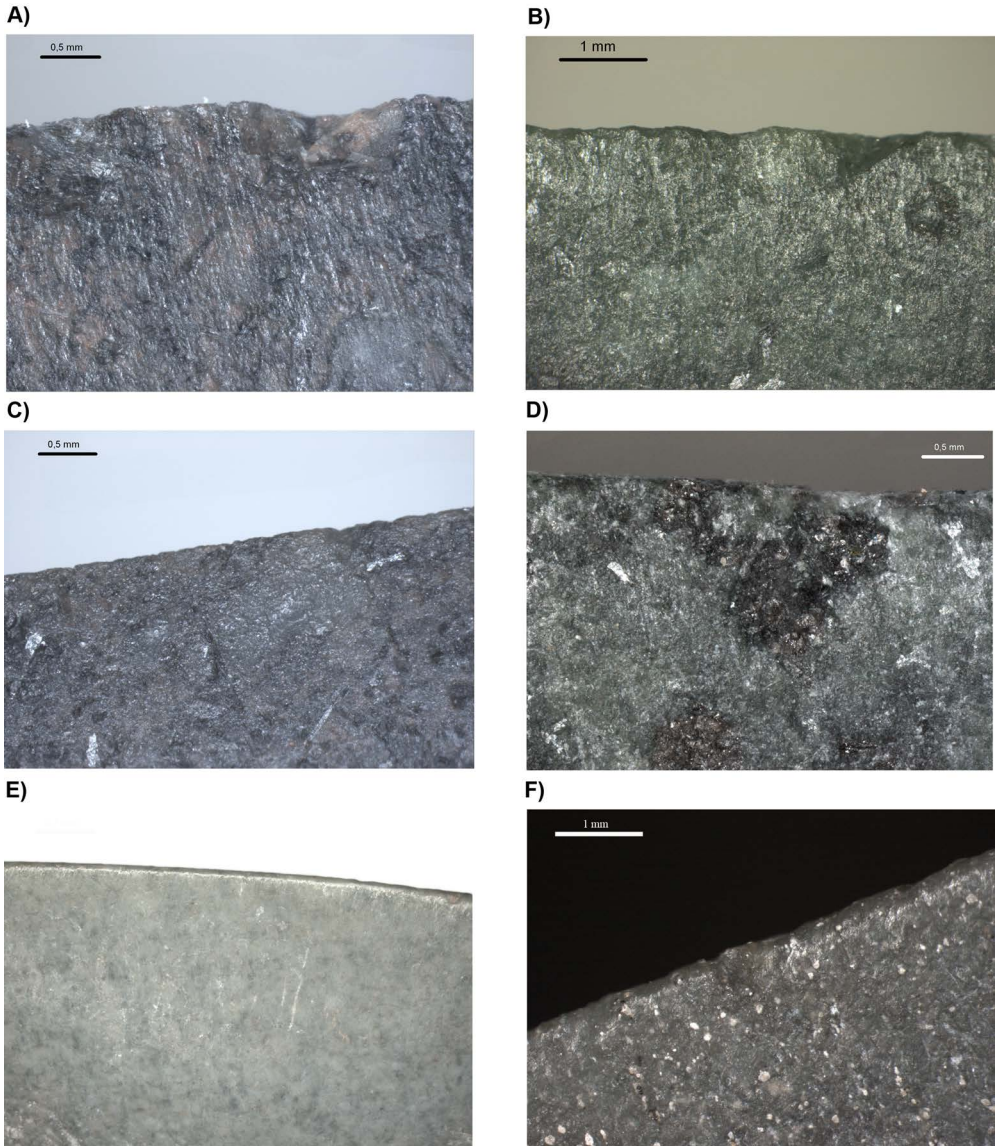


Fig. 12.—Woodworking and hide processing macroscopic wear pattern. A) Hornfels displaying isolated, half –moon, fresh chips after woodworking. DE17, B) Eclogite presenting an angular, isolated micro-chip after woodworking. DE22, C) Hornfels with an isolated micro-chip inferior to 0,3 mm wide after woodworking. DE5, D) Eclogite used to work fresh hide showing a very slight edge rounding. AE27, E) Jadeite edge rounding and linear traces after working a soaked hide with ash as abrasive. AE39.10x, F) Hornfels displaying high rounding after working a fresh hide. AE11.

damage between 1-4 mm wide was formed, displaying a range of half-moon, quadrangular, cylindrical and irregular shapes (fig. 12:A). Still, this damage occurred as isolated elements and only appeared when the artefact had been used for more than an hour. In the case of the tools made from eclogite/jadeite, the extreme hardness of the rock prevented the formation of chipping and striation damage, so these features were very scarce (fig. 12:B).

In some cases, the technological linear grooves resulting from the manufacturing process disappeared with the increase of cementation and levelling. Macroscopic differences between Faces A and B on woodworking tools are present in some of the artefacts hafted with the blade oriented perpendicularly to the haft. In these cases, micro-chipping tends to be concentrated on the contact edge.

Regarding AE30 (debarking burned wood), the contact face displayed an intense rounding, smoothing and levelling of the technological linear grooves, without a significant chipping formation. As for AE27 and AE22, used to scrape soaked bark, only AE22, made of hornfels rock, was affected by the creation of abrupt and continuous micro-chipping on the central contact face. Finally, CIS35, made of jadeite and used to hollow out fresh timber, did not display significant changes with respect to the original technological surfaces.

#### Microscopic wear pattern on woodworking tools (fig. 13)

The constant impact against wood causes continual micro-breakage all along the edge, which means that it is difficult for extensive micro-polish and edge rounding to develop (fig. 13:A). Indeed, we observed a mixture of recently micro-chipped surfaces with angular grains which did not display either linear or polish wear and punctual spots of only about 4000 to 7000  $\mu\text{m}^2$  where the polish and rounding were actually preserved.

On the very edge, one could see isolated areas of compact-patterned micro-polish visible only at 200/400X. As may be observed in the images, these features were characterised by great brightness and an undulating micro-topography (fig. 13:E). This micro-polish appeared both in the superficial areas of the edge as well as within the internal parts of the chips. A semi-closed irregular-patterned micro-polish, with internal directional striation appeared inside some isolated and short grooves. The edge damage was fundamentally half-moon shaped, although quadrangular and triangular features were also to be seen. Some of them were rounded, with internal linear traces and micro-chipping. The micro-chipping closest to the cutting edge presented fresh fractures and high grain angularity.

With regards to crystal wear, there was often a mixture of altered and fresh crystals. The altered crystals revealed high rounding, a bright aspect, and an undulated micro-polish, with isolated large extractions, reflecting the hardness of the worked material (fig. 13:C). In some cases, it was possible to identify internal striation.

The wear pattern exhibited clear differences between hornfels and eclogite/jadeite. While in hornfels the crystal micro-polish was partial, in the eclogite/jadeite



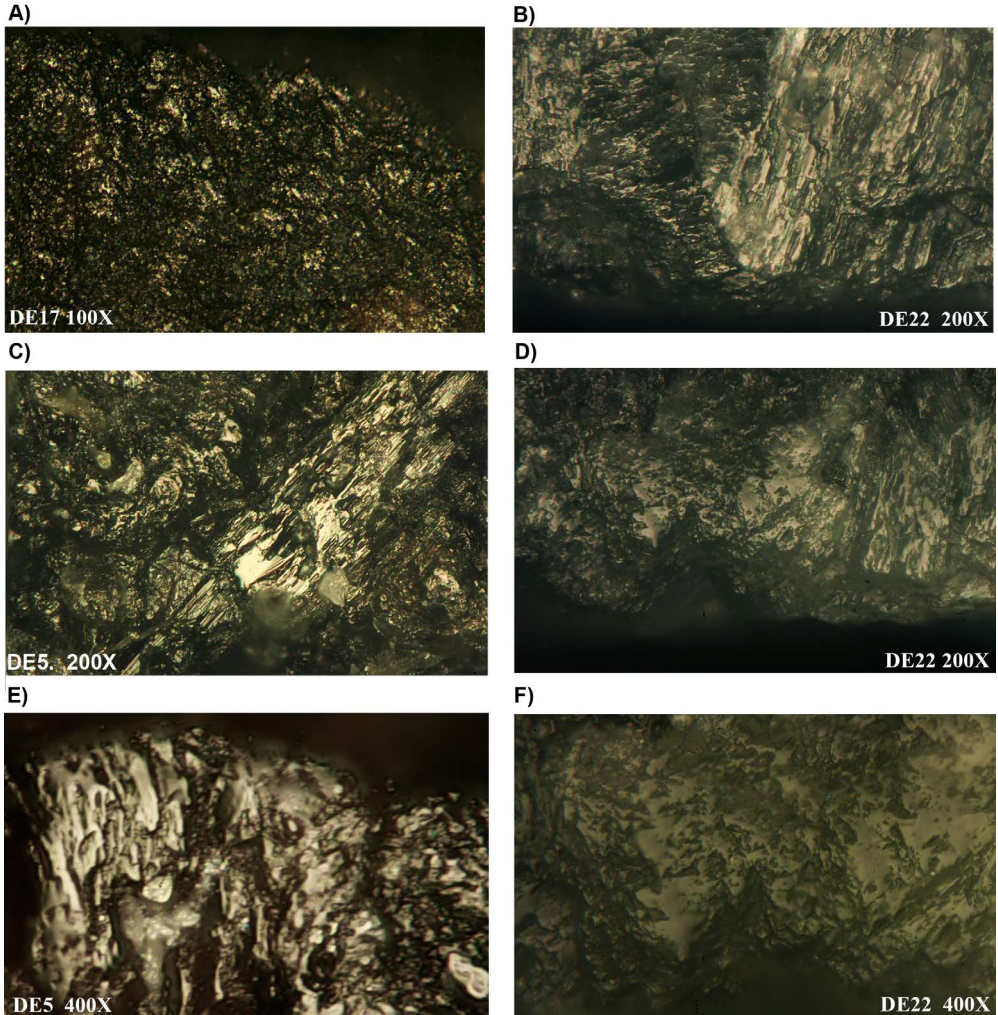


Fig. 13.—Woodworking microscopic wear pattern. A) Hornfels displaying an irregular, semi-open micro-polish. DE17, B) Eclogite crystal covered by a bright, undulating micro-polish. DE22, C) Hornfels with an undulating, bright micro-wear both over a quartz crystal and the rock matrix, D/F) Eclogite with a flat/undulating bright and compact micro-polish. DE22, E) Hornfels crystal covered by a bright, undulating micro-polish. DE5.

rock the main part of the affected crystals appeared completely covered by a very bright and undulating micro-polish (fig. 13:B). Another difference is the fact that, as the eclogite surfaces are harder and more difficult to break, the polish development was more extensive and brighter in these cases (fig. 13:D, fig. 13:F).

Differences between Faces A and B are difficult to establish microscopically in the case of the axes, as the micro-polish was only confined to very small areas.

As for the tools hafted perpendicularly to the edge, there was a tendency whereby a more extensive wear appeared on the contact face and a more closed micro-polish had developed.

Regarding AE30 (debarking burned wood), the contact face (Face A) displayed medium rounding extending 4 mm from the edge, while micro-polish extended somewhat further (5 mm from the edge). This micro-polish was closed to compact, irregular and bright and it included directional indicators. The micro-chipping was continuous, displaying a rounded fracture. Deep striations were present between micro-chippings in a closed-concentrated organisation, oriented perpendicularly to the edge. Closed-loose, oblique to the edge, U-shaped striations were also present. Face B showed less extensive micro-polish development as well as a less compact network pattern without directional indicators. The crystals were fresh, medium and much abraded, with no micro-polishing or extraction/striation, though they were affected by pecked breakage.

As for AE27 and AE33, used to scrape soaked bark, AE33 developed a dull, open to semi-closed, irregular micro-polish, located in small spots in the superficial areas of the micro-topography extending up to 0.3 mm from the edge. On the contact face, this polish had directional indicators and was concentrated midway down the edge, presenting an orientation perpendicular to the edge and a closed-concentrated association. Micro-chipping was accumulated on Face A (displayed continuously, with an abrupt fracture and quadrangular shapes), where there was no rounding nor crystals preserved. Linear traces were also more common on Face A, where deep striations between micro-chippings were formed in a closed-concentrated orientation perpendicular to the edge. The crystals were scarce on Face B, much abraded, presenting pecked breakage and a partial, smooth micro-polish.

On the other hand, AE27, made of eclogite, developed an open irregular micro-polish on Face A, while on Face B it was closed, undulating and shiny, and at 0.3 mm from the edge, it became compact, flat, and appeared in isolated plaques. The crystals were complete and medium-abraded displaying an undulating, bright micro-polish on both faces, with pecked breakage, large straight extractions and striations on Face B. Superficial striation was present on Face A, which was concentrated-separated, perpendicular to the edge and flat-shaped. Micro-chipping was continuous and superimposed in the central areas of Faces A/B, showing an abrupt fracture and oval-shaped, triangular, irregular shapes.

Finally, the use-wear traces on CIS35, made of jadeite and used to hollow out fresh timber, extended up to 3 mm from the edge, and were characterised by an undulating, bright, open to semi-open network pattern located in the superficial parts of the micro-topography. The crystals were fresh, medium and much abraded, revealing a partial, undulating and bright micro-polish and large straight extractions. There were fresh and continuous micro-chippings displaying oval, half-moon and irregular shapes. Scarce deep striations were present between the micro-chippings, displaying a concentrated-closed orientation parallel to the edge and ending in a U-shape. Face B showed less extensive micro-polish development as well as a less compact network pattern without directional indicators.

*Hide processing wear*

## Macroscopic wear pattern (fig. 12)

Hide processing using hornfels tools did not provoke micro-chipping bigger than 0.5 mm in length. These features were very common, practically appearing all along the edge of the non-contact face. The edge rounding is noteworthy (fig. 12:E, fig. 12:F). It appeared chiefly midway down the edge of the artefact and became especially distinct after at least three hours of work. In these cases, the use-wear differences between the bevels were very pronounced: the rounding and the micro-chipping appeared unifacially, concentrated on the bevel that had been in contact with the worked material.

In the case of the adze made of eclogite and used to process a fresh hide, no micro-chipping formed even after 2 hours of work and the rounding was only visible in a few spots (fig. 12:D). Here, the grain cohesion keeps playing a very important role, as the tools that display a more cohesive pattern will develop less rounding and fewer linear traces than those made of coarse and soft materials.

Regarding the hides processed with abrasives, the results were quite different from the ones above. In the case of the artefacts where ochre was used, we observed a higher degree of rounding in all the experimental artefacts. The ochre and animal particles formed a new levelled surface that smoothed the technological one. This process of levelling appeared combined with isolated micro-chipping no wider than 2-3 mm. In the tools that had worked with ash as an abrasive, the bevel rounding reached 2 mm from the edge, and appeared jointly with a bright micro-polish along the working bevel, which eliminated the previous technological surface. The micro-chipping features appeared unifacially and were never bigger than 1 mm. Only on AE15 did this micro-chipping occur combined with short linear traces (1 mm long).

As for the dry hide working tools, the aforementioned features observed on tools used to work fresh hide also occurred here, this time, however, they were even more accentuated. The tool used to process dry hide with ochre developed a new rounded edge extending 3 mm from the old edge, completely smooth, while the dry hide processing tool with ash as an abrasive generated an intense rounding extending 2 mm from the edge, covered by short and non-polished grooves perpendicular to the edge. And finally, Adze 39, used to work a soaked hide developed a high degree of rounding extending 3 mm from the edge, crossed by concentrated-connected linear traces and a bright polish.

## Microscopic wear pattern on hide processing tools (fig. 14)

In the hornfels tools that worked without abrasive particles, a high degree of rounding in some of the edge areas can be observed after three hours of work (fig. 14:E, fig. 14:A). An irregular micro-polish with semi-open network appears covering



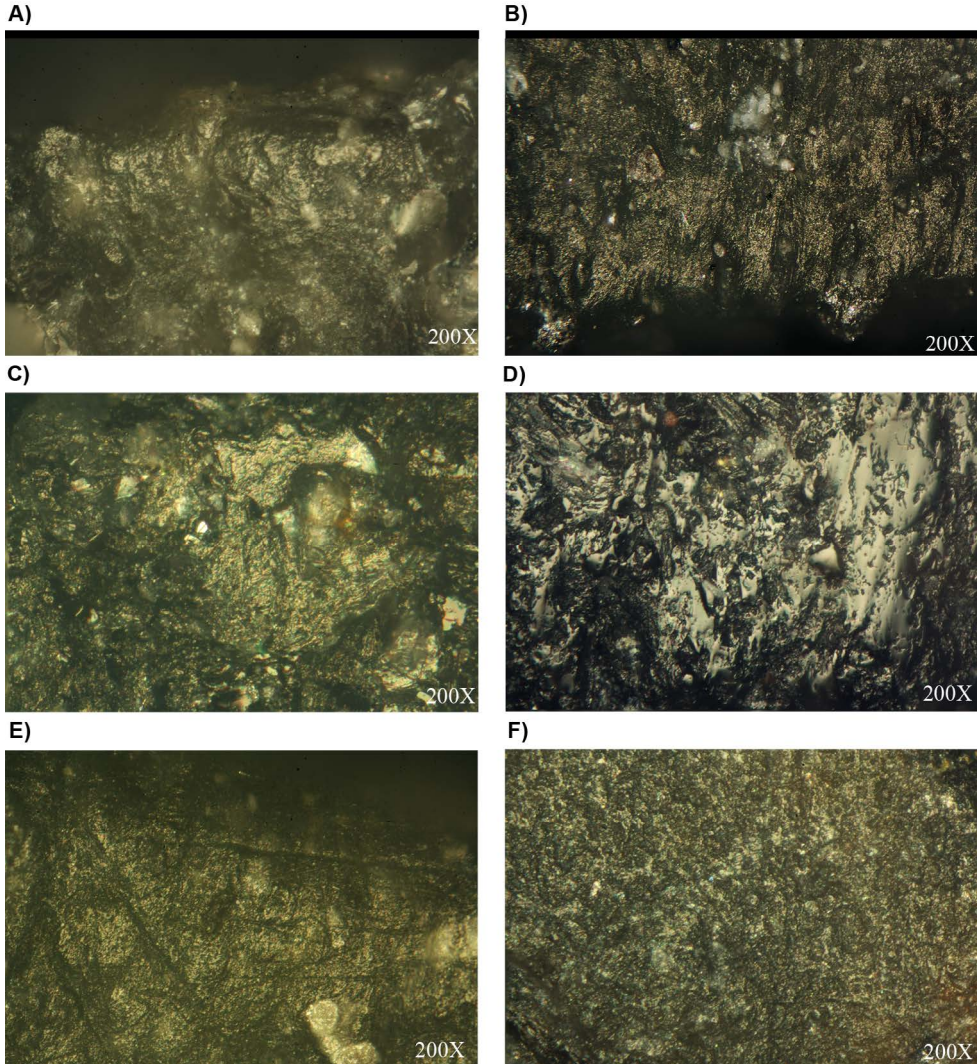


Fig. 14.—Hide processing microscopic wear pattern. A) Fresh hide semi-closed and irregular micro-polish and rounding. AE8, B) Fresh hide with ash as abrasive closed and irregular micro-polish with directional indicators and rounding. AE15, C) Fresh hide crystal displaying corrosion and irregular micro-polish. AE12, D) Fresh hide with ash as abrasive compact, flat/undulating micro-polish with directional indicators. DE20, E) Fresh hide irregular, semi-closed micro-polish covered by randomly oriented linear traces. AE11, F) Fresh hide open and irregular micro-polish. DE18.

the rounded edge features. It never extends further than 2-3 mm from the edge, and becomes semi-closed in the superficial parts of the topography.

Linear traces are widely developed, although they never extend beyond the limit of 2 mm from the edge. They can be short polished striations or non-polished

striations superimposed on the irregular micro-polish previously described. Although in some cases they appear parallel to each other and perpendicular to the edge, they are quite frequently randomly distributed (fig. 14:E). Regarding crystal wear, there is a clear process of abrasion that progressively eliminates the crystals emerged during the manufacturing process (fig. 14:C). Nevertheless, the crystals that emerge after micro-chipping has taken place often appear with evident traces of corrosion which we have only identified in this kind of wear. Micro-chipping generally appears on the non-contact faces as isolated and rounded features of irregular shape.

The wear pattern again exhibits clear differences between hornfels and eclogite. As happens in woodworking, while in hornfels tools the crystal micro-polish is quite a diagnostic feature, in the eclogite rock it is not useful. Actually, our only experimental tool made of eclogite shows no significant wear damage after working hide without abrasive particles for 90 minutes.

Regarding the micro-wear developed on the artefacts that worked with ash as an abrasive, it appears closed patterned with a very extensive bright and undulating polish. The polish micro-topography is smooth and rounded (fig. 14:D). The crystal wear looks similar to the micro-polish developed on the matrix: extensive, close-patterned, very bright, smooth and rounded. The described features are very similar to those developed during fresh woodworking. Nevertheless, we have identified different criteria that allow one worked material to be distinguished from the other. In the first place, the kinematics of work on wood could never allow the formation of such an extensive and compact micro-polish pattern, because of the continual grain extraction that eliminates the polished surfaces permanently. On the other hand, the linear traces that appear overlapping the matrix perpendicularly to the edge can only indicate a scraping movement on a soft but abrasive material that reaches both the lower and the upper parts of the topography (fig. 14:B). Finally, the micro-polished surface appears abraded and crossed by numerous striations perpendicular/oblique to the working edge.

When ochre is used as an abrasive, a second surface is developed, which is very similar to the technological one, although it is more rounded. We can see scratches, grooves and a weak superficial micro-polish like the features described in the technological wear. The main difference is that the weak polish identified on hornfels technological surfaces appears more closed and irregular after working with ochre.

As for the dry hide working tools, the features observed on them resembled those identified on tools used on fresh hides, though they are even more accentuated. On tool AE24, used to work dry hide with ochre, an open, dull and irregular micro-polish has developed, without directional indicators or striation on the non-contact face. Micro-chipping is absent on the contact face and very scarce on the opposite bevel, whereas the crystals are completely abraded.

Regarding AE25, which has worked a dry hide with ash as an abrasive, presents a closed and semi-closed patterned micro-polish extending 4 mm from the edge. It displays an irregular, bright micro-topography with directional indicators. The crystals are generally abraded but in those cases where there is a medium conservation, what can be observed is a complete, smooth and bright micro-polish covering the

crystals. Pecked breakage is also visible. These features are more extensive on the contact face, where, in addition, isolated deep striations perpendicular to the edge are formed.

Adze 39, used to work a soaked hide, has developed a high degree of rounding, with a compact, undulating and bright micro-polish which does not extend further than 6 mm from the edge. The micro-polish displays micro-holes and striations appearing pecked in some points. The crystals appear in all degrees of abrasion, presenting completely polished surfaces, with flat/undulating and shiny micro-topographies and no signs of corrosion. No micro-chipping has been identified, while deep striations ending in a U-shape have been observed inside and between the micro-chipping in a concentrated-closed and parallel association. All these features are less pronounced on Face B, the non-contact face.

## CONCLUSIONS AND ARCHAEOLOGICAL APPLICATIONS

As a whole, the results obtained from the experimental programme to date have been positive. Criteria have been formulated that make it possible to distinguish between technological wear resulting from woodworking, butchering, hoeing and hide processing activities, as these generate a very distinctive wear pattern which can be identified both macroscopically and microscopically.

These criteria have been tested and successfully implemented in the course of the use-wear analysis of the polished and bevelled metamorphic artefacts from two of the most important Neolithic sites of the North East of the Iberian Peninsula: “Bòbila Madurell – Can Gambús 1-2” (Masclans *et al.*, 2016) and Feixa del Moro (Masclans and Remolins, in press). What the analysis of the experimental artefacts has successfully confirmed is a reliable methodology that has made it possible to determine the economic processes carried out with these artefacts in archaeological contexts. This methodology can thus be considered a useful tool that will surely shed new light on a multitude of artefacts whose economic and symbolic use has, until now, remained unknown.

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## BIBLIOGRAPHY

- ADAMS, J. (2014): "Ground stone use-wear analysis: a review of terminology and experimental methods", *Journal of Archaeological Science* 48, pp. 129-138.
- ADAMS, J., DELGADO, S., DE BREUIL, L., HAMON, C., PLISSON, H. and RISCH, R. (2009): "Functional analysis of macro-lithic artefacts: a focus on working surfaces", *L'utilisation préhistorique de matières premières lithiques alternatives*, (Sternke, F., Eigeland, L. and Costa, L.J. eds.), British Archaeological Reports. International Series 1939, Oxford, pp. 43-66.
- AMICO, C. (2005): "Neolithic 'greenstone' axe blades from northwestern Italy across Europe: a first petrographic comparison", *Archaeometry* 47:2, pp. 235-252.
- BEST, E. (1912): *The Stone Implements of the Maori*, Dominion Museum Bulletin 4, Wellington.
- BINNEMAN, J. and DEACON, J. (1986): "Experimental Determination of Use Wear on Stone Adzes from Boomplaas Cave, South Africa", *Journal of Archaeological Science* 13, pp. 219-228.
- BOAS, F. (1909): "The Kwakiutl of Vancouver Island", *The Jesup North Pacific Expedition* (Boas, F., ed.), Memoir of the American Museum of Natural History New York 5:II, J. Brill, Leiden, pp. 301-522 and Plates XXXVII-LII.
- BOSCH, A., PALOMO, A., PIQUÉ, R. and TARRÚS, J. (2006): "Les fulles de pedra polida de les aixes", *Els Objectes de fusta del Poblats neolític de la Draga. Excavacions de 1995-2005* (Bosch, A., Chinchilla, J. and Tarrús, J., eds.), Monografies del CASC 6, Museu d'Arqueologia de Catalunya-CASC, Girona, pp. 133-138.
- BURET, C. (1984): *L'industrie de la pierre polie du Néolithique moyen et récent à Auvergnier, canton de Neuchâtel (Suisse)*, Unpublished PhD thesis, Université de Paris X, Paris.
- BURTON, J.E. (1984a): *Axe makers of the Wahgi: pre-colonial industrialists of the Papua New Guinea highlands*, Unpublished PhD thesis, Australian National University, Canberra. URL: <http://hdl.handle.net/1885/49431>
- BURTON, J.E. (1984b): "Quarrying in a Tribal Society", *World Archaeology* 16:2, pp. 234-247.
- CARNEIRO, R.L. (1974): "On the Use of the Stone Axe by the Amahuaca Indians of Eastern Peru", *Ethnologische Zeitschrift Zurich* 1, pp. 107-122.
- CARNEIRO, R.L. (1979): "Tree Felling with the Stone Axe", *Ethnoarchaeology* (Kramer, C., ed.), Columbia University Press, New York, pp. 21-58.
- CASTRO DORADO, A. (1988): *Petrografía básica. Texturas, clasificación y nomenclatura de rocas*, Editorial Paraninfo, Madrid.
- CLEMENTE CONTE, I. (1997): *Los instrumentos líticos de Túnel VII: una aproximación etnoarqueológica*, Treballs d'etnoarqueologia 2, Consejo Superior de Investigaciones Científicas, Madrid.
- CLOP, X. (2004): "La gestión de los recursos minerales durante la prehistoria reciente en el noreste de la Península Ibérica", *Cypsela* 15, pp. 171-186.
- COLES, J. M. and ORME, B. J. (1985): "Prehistoric Woodworking from the Somerset Levels:1", *Somerset Levels Papers* 9, pp. 19-43.
- DAVIS, V. and EDMONDS, M. (2011): *Stone axe studies III*, Oxbow Books, Oxford.
- DEBREUIL, L. and SAVAGE, D. (2014): "Ground stones: a synthesis of the use-wear approach", *Journal of Archaeological Science* 48, pp. 139-153.
- DECHELETTE, J. (1908/1987): *Manuel d'Archéologie Préhistorique, Celtique, et Gallo-romaine*, Librairie Alphonse Picard et fils, Paris.
- DELGADO, S. (2008): *Prácticas económicas y gestión social de recursos (macro)líticos en la prehistoria reciente (III – I milenios AC) del Mediterráneo occidental*, Unpublished PhD thesis, Universitat Autònoma de Barcelona, Barcelona.
- DETEV, P. (1960): "Essai d'établir une distinction entre les haches et les ciseaux, les herminettes, les houes et les socs de l'époque neolithique", *Annuaire du Musée National Archéologique du Plovdiv* 4, pp. 61-74.
- DICKSON, F.P. (1981): *Australian Stone Hatchets: A Study in Design and Dynamics*, Academic Press, Sydney.

- DUFF, R. (1970): *Stone Adzes of Southeast Asia: An Illustrated Typology*, Canterbury Museum Bulletin 3, Canterbury Museum Trust Board, Christchurch.
- ELBURG, R., HEIN, W., PROBST, A. and WALTER, P. (2015): "Field trials in Neolithic woodworking. (Re)Learning to use Early Neolithic stone adzes", *Archaeology and Crafts. Experiences and Experiments on traditional Skills and Handicrafts in Archaeological Open-Air Museums in Europe* (Kelm, R., ed.), Albersdorfer Forschungen zur Archäologie und Umweltgeschichte 5, AÖZA gGmbH and Husum Druck- und Verlagsgesellschaft, Husum, pp. 62-77.
- EMMONS, G.T. (1923): *Jade in British Columbia and Alaska, and its Use by the Natives*, Indian Notes and Monographs 35, Heye Foundation, New York.
- FABREGAS VALCARCE, R. (1992): "Ensayo de tala con un hacha de piedra pulida", *Trabajos de Prehistoria* 49, pp. 337-345.
- FONTANALS- COLLA, M., EULÀLIA SUBIRÀ, M., DÍAZ-ZORITA BONILLA, M., DUBOSCQ, S. and GIBAJA, J.F. (2015): "Investigating palaeodietary and social differences between two differentiated sectors of a Neolithic community, La Bòbila Madurell-Can Gambús (north-east Iberian Peninsula)", *Journal of Archaeological Science* 3, pp. 160-170.
- GIBAJA, J. F., MAJÓ, T., CHAMBON, P., RUÍZ, J. and SUBIRÀ, E. (2010): "Prácticas funerarias durante el Neolítico. Los enterramientos infantiles en el noreste de la Península Ibérica", *Complutum* 21:2, pp. 47-68.
- GODELIER, M. and GARANGER, J. (1973): "Outils de Pierre, Outils d'Acier Chez les Baruya de Nouvelle-Guinée", *L'Homme* 13, pp. 187-220.
- GONZALEZ URQUIJO, J.E. and IBÁÑEZ, J.J. (1994): *Metodología del análisis funcional de instrumentos tallados en sílex*, Cuadernos de Arqueología de Deusto 14, Bilbao.
- HAMPTON, O.W. (1999): *Culture of Stone. Sacred and Profane Uses of Stone among the Dani*, Texas A & M University Press, College Station.
- HEIDER, K.G. (1970): *The Dugum Dani*, Aldine Publishing Company, Chicago.
- IBÁÑEZ, J.J. and GONZÁLEZ URQUIJO, J. (2013): "La función de los útiles en el yacimiento de Tell Halula (8.700-7500 BP) Valle del Éufrates, Siria", *Tell Halula: un poblado de los primeros agricultores en el valle del Éufrates. Memoria científica –Tomo I* (Molist Montaña, M., coord.), Ministerio de Educación, Cultura y Deporte, Madrid, pp. 356-385.
- JORGENSEN, S., LERCHE, G., TROELS-SMITH, J. and STEENSBERG, A. (1985): *Tree-felling, with original Neolithic flint-axes in Draved wood: report on the experiments in 1952-54*, National Museum of Denmark, Copenhagen.
- LAFUENTE, B., DOWNS, R.T., YANG, H. and STONE, N. (2015): "The power of databases: the RRUFF project", *Highlights in Mineralogical Crystallography* (Armbruster, T. and Danisi, R. M., eds.), W. De Gruyter, Berlin, pp. 1-30.
- LAMMERS-KEIJSERS, Y. M. J. (2008): *Tracing traces from present to past: a functional analysis of pre-Columbian shell and stone artefacts from Anse à la Gourde and Morel, Guadeloupe, FWI*, Archaeological Studies Leiden University 15, Leiden University Press, Leiden.
- LEROY-GOURHAN, A. (1988): *Evolución y técnica*, Taurus, Madrid.
- LEWIS, R., TSORAKI, C., BROUGHTON, J., CRIPPS, J.C., AFODUN, S.A., SLATTER, T. and ROUBOS, V. (2011): "Abrasive and impact wear of stone used to manufacture axes in Neolithic Greece", *Wear*, 271:9, pp. 2549-2560.
- LUNARDI, A. (2008): "Experimental testing with polished green stone axes and adzes: technology and use", *"Prehistoric Technology" 40 Years Later Functional Studies and the Russian Legacy* (Longo, L. and Skakun, N., eds.), British Archaeological Reports. International Series 1783, Oxford, pp. 369-373.
- MASCLANS, A. and REMOLINS, G. (in press): "La gestió de les eines de pedra polida de Juberri (St. Julià de Llòria, Andorra)", *Les Valls d'Andorra durant el Neolític: Un encreuament de camins al centre dels Pirineus* (Remolins, G. y Gibaja, J. F., eds.), Col·lecció de monografies del MAC, Andorra.
- MASCLANS, A., PALOMO, A., GIBAJA, J.F., REMOLINS, G. and GÓMEZ-GRAS, D. (2016): "Use-wear analysis of Neolithic polished axes and adzes: The site of "Bòbila Madurell-Can Gambús-1-2 (Northeast Iberian Peninsula)",



- Quaternary International* 427:B, pp. 158-174.  
DOI: 10.1016/j.quaint.2015.12.064
- MORRIS, E.H. (1939): *Archaeological Studies in the La Plata District, Southwestern Colorado and Northwestern New Mexico. With appendix: Technology of La Plata Pottery*, Carnegie Institution of Washington publication 519, The Carnegie Institution of Washington, Washington.
- MORTILLET, G. de (1903/1983): *Le préhistorique: antiquité de l'homme*, Reinwald, Paris.
- NILLES, J. (1942): "Digging-Sticks, Spades, Hoes, Axes, and Adzes of the Kuman People in the Bismarck Mountains of East-Central New Guinea", *Anthropos* 37/40, pp. 205-212.
- MUÑOZ, A., (1965): *La cultura neolítica catalana de los "sepulcros de fosa"*, Publicaciones eventuales 9, Instituto de Arqueología y Prehistoria, Universidad de Barcelona, Barcelona.
- OLAUSSON, D. S. (1982-1983): "Flint and ground-stone axes in the Scanian Neolithic. An evaluation of raw materials based on experiment", *Scripta Minora* 2, pp. 7-66.
- PALOMO, A., PIQUÉ, R., TERRADAS, X., LÓPEZ, O., CLEMENTE, I. and GIBAJA, J. F. (2013): "Woodworking technology in the Early Neolithic site of La Draga (Banyoles, Spain)", *Regards croisés sur les outils liés au travail des végétaux. An interdisciplinary focus on plant-working tools* (Anderson, P. C., Cheval, C. and Durand, A., dirs.), Actes des XXXIII<sup>e</sup> Rencontres Internationales d'Archéologie et d'Histoire d'Antibes, Éditions APDCA, Antibes, pp. 383-396.
- PAWLIK, A. (2007): "Analysis of two polished adzes from Ille Cave at El Nido", *Hukay. Journal for Archaeological Research in Asia and the Pacific* 10, pp. 38-59.
- PETREQUIN, P. and PETREQUIN, A.M. (1993): *Écologie d'un outil: la hache de pierre en Irian Jaya (Indonésie)*, CRA Monographies 12, CNRS éditions, Paris.
- PÉTREQUIN, P., SHERIDAN, A., CASSEN, S., ERRERA, M., GAUTHIER, E. KLASSEN, L., MAIX, N., PAILLER, Y., PÉTREQUIN, A.M. and ROSSY, M. (2011): *Eclogite or Jadeitite: The Two Colours Involved in the Transfer of Alpine Axeheads in Western Europe*, *Stone Axe Studies III* (Davis, V. and Edmonds, M., eds.), Oxbow Books, Oxford, pp. 55-83.
- PETREQUIN, P., CASSEN, S., ERRERA, M., KLASSEN, L., SHERIDAN, A. and PETREQUIN, A. M. (dirs.) (2012): *JADE. Grandes haches alpines du Néolithique européen. Ve au IV<sup>e</sup> millénaires av. J.-C.*, Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain, Besançon.
- POND, A.W. (1930): *Primitive Methods of Working Stone Based on the Experiments of Havor F. Skavlem*, The Logan Museum and Beloit College, Beloit.
- PYŻEWICZ, K., (2013): "Analiza traseologiczna materiałów krzemianych", *Koszyce, stanowisko 3. Przemoc i ritual u schyłku neolitu*, (Przybyła, M. M., Szczepanek, A. and Włodarczyk, P.), *Ocalone dziedzictwo archeologiczne* 4, Kraków-Pękowice, pp.179-200.
- RICQ-DE BOUARD, M. (1996): *Pérogaphie et sociétés néolithiques en France méditerranéenne. L'outillage en pierre polie*, CRA Monographies 16, CNRS éditions, Paris.
- RENFREW, C. (1973): *Monuments, mobilization and Social organization in Neolithic Wessex, The explanation of culture change: models in Prehistory* (Renfrew, C., ed.), Duckworth, London, pp. 539-558.
- ROODENBERG, J. J. (1982): "Traces d'utilisation sur les haches polies de Bouqras (Syrie)", *Traces d'utilisation sur les outils en pierres néolithiques du Proche Orient* (Cauvin, M.C. ed.), Travaux de la Maison de l'Orient, 5, Lyon, pp. 177-185.
- SEMENOV, S.A. (1981): *Tecnología prehistórica (Estudio de las herramientas y objetos antiguos a través de las huellas de uso)*, Editorial Akal, Madrid.
- SONNENFELD, J. (1962): "Interpreting the function of primitive implements", *American Antiquity* 28:1, pp. 56-65.
- SEENSBURG, A. (1980): *New Guinea Gardens. A study of Husbandry with parallels in prehistoric Europe*, Academic Press, London.
- STORDEUR, D. (1987): "Manches et emmanchements préhistoriques: quelques propositions préliminaires", *Le main et l'outil. Manches et emmanchements préhistoriques. Table Ronde C.N.R.S. tenue à Lyon du 26 au 29 novembre 1984* (Stordeur, D., dir.), Travaux de la Maison de l'Orient 15, Lyon, pp. 12-34.

- STOUT, D. (2002): "Skill and cognition in stone tool production. An ethnographic Case Study from Irian Jaya", *Current Anthropology* 45:3, pp. 693-722.
- THIRAULT, E. (2001): "Eric Thirault (2001) - Production, diffusion et usage des haches néolithiques dans les Alpes occidentales et le bassin du Rhone", *Bulletin de la Société Préhistorique française* 98:4, pp. 740-742.
- TOWNSEND, W. (1969): Stone and Steel Tool Use in New Guinea Society, *Etnology* 8, pp. 199-205.
- TURNER, M. T. (2000): *The Function, Design and Distribution of New Zealand Adzes*, Unpublished PhD thesis, University of Auckland, Auckland.
- WALTER, P., RENGERT, E., WULF, H. and WERNER SCHARFF, S. (2013): "Ergersheimer Experimente zur bandkeramischen Fällund Holzbearbeitungstechnik", *Plattform19/20*, pp. 89-94.
- WENTINK, K., VAN GIJN, A. and FONTIJN, D. (2011): "Changing contexts, changing meanings: Flint axes in Middle and late Neolithic communities in the northern Netherlands", *Stone Axe Studies III* (Davis, V. and Edmonds, M. eds.), Oxford Books, Oxford, pp. 399- 408.
- WYSS, R. (1994) *Steinzeitliche Bauern auf der Suche nach neuen Lebensformen. Egolzwil 3 und die Egolzwiler Kultur. Die Funde*, Schweizerisches Landesmuseum, Zürich.
- YERKES, R. W. and BARKAI, R. (2013): "Tree-Felling, Woodworking, and Changing Perceptions of the Landscape during the Neolithic and Chalcolithic Periods in the Southern Levant Source", *Current Anthropology* 54:2, pp. 222-231.