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Bevel-ended tools on large ungulate ribs during the Bronze Age in northern Italy: Preliminary result of functional and experimental analyses

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A B S T R A C T

Functional analyses and experimental works on animal hard materials artefacts have been sparsely applied in the Italian territory, especially in Bronze Age contexts. Recent researches, carried out on several sets of artefacts coming from sites dated between the Middle and Late Bronze Age in north-eastern Italy, have highlighted a good amount of bevel on large ungulate ribs.

This paper aims at identifying the function of these objects through an experimental work, in order to reproduce the same category of artefacts that have been utilized on different materials and in different ways. The analyses of the archaeological remains and the experimental artefacts were performed at low magnification using a stereomicroscope Leica EC3 S6D with an integrated digital camera. Then, the surface analysis at high magnification was carried out by using a metallographic microscope in reflected and transmitted light (Optika Met: 50×–500×).

The experiments were carried out using the experimental tools on various hard materials, such as wood (fresh and dry) and antler (dry and wet) and elastic ones (fresh and dry skin). During the testing phase, the time of use, the state of the material processed, the gestures employed (direction and quantity) were monitored and recorded. All the archaeological artefacts bear almost similar use-wear patterns. Some of them have fractures and micro-chipped areas on the distal margin that indicate contact with a hard and durable material. The remaining artefacts, however, present edges slightly smoothened and with less evident anomalies. On the upper face, use-wear ends after about 5 mm from the distal edge, while on the lower face it seems to be slightly larger, about 1 cm from the edge. Under the microscope, very dense longitudinally-oriented striations are visible on the distal edge, while in the mesial portion of the artefact, they proceed to become rarer and often oblique. Under high magnification, the analysed surfaces are fairly uniform near the edge and more irregular at farther distances from it. The experimental work has allowed us to hypothesize that some of these artefacts were used for the removal of fresh and dry bark. In fact, experimental use-wear presents macro-and micro-morphologies compatible with the ones detected on the archaeological remains.

1. Introduction

This paper purposes a design for integration of technological studies with functional analyses of animal hard materials from some Bronze Age settlements of western Po Valley (north-eastern Italy). The aim of the project was to investigate the manufacturing and transformation processes of animal hard materials in an area and a chronological period scarcely investigated from this point of view (Bertolini, 2014). The first technological analysis began only at the end of '80s in the last century, and developed in the next decade thanks to the studies of N. Provenzano (1988, 1996–97, 1997, 2001) who investigated animal hard materials artefacts from excavations of Terramare, Emilia region (Middle/Late Bronze Age; northern Italy). These works are fundamental for other studies that from the 21st century slowly developed for other contexts of northern Italy (Aimar and Gregoriani, 2000; Malerba et al., 2006a, 2006b, 2012; Thun Hohenstein and Bertolini, 2010; Zuolo and Thun Hohenstein, 2010; Petrucci et al., 2012; Thun Hohenstein et al., 2012a,b; Cilli et al., 2013; Epifani, 2013; Bertolini, 2014).

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The project, initially devoted to technological analysis of several hard animal materials artefacts (Bertolini, 2014), revealed the opportunity to analyse their function, studying the surfaces at low and high magnification and combining the study of archaeological finds with an experimental activity designed to create a reference use-wear traces collection.

This paper presents the results of a functional study deriving from the investigation on bevel-ended artefacts of large ungulate rib fragments. This category of objects was first studied by Provenzano (1997, 2001) from a technological point of view, investigating on animal hard materials industries of Terramare. This author called these objects "spatulas" for their morphology, characterised by a more or less expanded and thinned end, and a clear detachment between the handle and their active part (Provenzano, 1988). These artefacts have a geographical distribution limited to the central-eastern Po Valley, and a reasonable chronological duration from the Early to the Late Bronze Age (2200–1200 B.C.). Functional and experimental studies on this category of tools have never been performed until today throughout the Italian territory. In agreement with what already suggested by Provenzano (1997, 2001), only a preliminary study conducted on this type of artefacts at Lavagnone settlement (Cilli et al., 2013) assumes that the more plausible functional interpretation is that of "spatulas" or smoothers.

1.1. Cultural context

The Bronze Age in Italy is characterised by a great cultural phenomenon called "Pile-Dwelling–Terramare". In agreement with Cupitò et al. (2012), this is marked by two principal components: pile dwelling and Terramare that blend at a certain point of their history.

The "Pile-Dwelling–Terramare" culture represents an important historical and demographic phenomenon inside the European Bronze Age (Bernabò Brea et al., 1997; Cardarelli, 1997, 2009; De Marinis, 1997, 1999; Cremaschi, 2009; Cupitò et al., 2012), and develops among the regions of the oriental Lombardy, western Veneto and Emilia during about two millenniums, more precisely from the last decade of the third millennium BC to the first half of the twelfth century BC.

The most ancient phase of the Bronze Age (Early Bronze Age, EBA 2200–1650 BC) is distinguished by a settlements concentrated North of the river Po, and particularly near the Garda Lake and the little intra-moraine lakes of the Pre-Alps.

The settlements are all pile-dwellings and their characteristic material culture is almost homogeneous and defined as "culture of Polada" based on ceramics and bronze artefacts (De Marinis, 2009).

In a later EBA phase, conditions of stability and abundance of resources in the settlements led to a great demographic increase. This is quite visible with the colonisation of great part of the Po plain North of the Po river according to the principal fluvial arteries.

This phenomenon can be interpreted as resulting from the expansion of pile-dwelling populations who were looking for environments with physiographic characteristics similar to those of Garda lake (Balista and Leonardi, 2003).

Based on archaeological data, this area shows a net increase in population density, whereas in the South of the Po the residential evidence is very little during this period.

A constant predilection of the marshy areas continues also during the Middle Bronze Age despite the environment typology is often suffering from sudden climatic variations and the increasingly high requirement for wood and craftsmen for pile dwelling construction (Peretto et al., 2004; De Marinis, 2009).

The Middle Bronze Age (MBA I 1650–1550) coincides with the beginning of Terramare cycle. This new settlement typology shows structural elements similar to those of pile dwelling. The typical Terramare structure can be defined as a quadrangular settlement surrounded by an earthwork and a ditch in which the water was canalised from a near river (Cardarelli, 2009). The function of these evidences is both defensive and intended to water redistribution. The appearance of this new settlement typology is interpreted as the beginning of a colonisation process of the Po Plain according to different routes. The idea of a new cultural contribution is based on the ceramic typology that since the most ancient phases is characterised by elements from Polada in North Italy, Grotta Nuova in Central Italy, and other oriental influences.

During the MBA 2 (1550–1450 BC) a great increase in the number of Terramare settlements is observed. The Po plain turns out to be completely colonised, with huge settlements characterised by a certain structural homogeneity. Each Terramare covers an area of about 2 ha and a distance one each other ranging about 1–2 km.

This great demographic increase is the direct consequence of the population expansion during the most ancient Bronze Age phases. From the perspective of material culture, this period is characterised by a strong uniformity both Northern and Southern of the Po river.

The apogee of Terramare appears during the transition between MBA3 and RBA1 (Recent Bronze Age). In this phase, the archaeological evidences of settlements become more substantial indicating a period of great abundance of resources and an increase of trade. The continuous demographic growth leads to the creation of a territorial system with large to small settlements. The mean dimension of the smallest settlements seems to increase when these are satellites of the larger ones with a central economic and political role (Cardarelli, 2009; Cupitò et al., 2012).

The sites of Tombola and Vallette (Western Veneto), and Larda I and II that provide the materials of this study, are well included in this cultural and settlement context. The first two sites are in the most oriental area of Valli Grandi Veronesi, a wide Po plain area located between the rivers Adige, Tartar and Po, characterised by wide marshy zones evolved thanks to the abundance of rivers during the Bronze Age.

The villages have been partially investigated, with a distance between them of about 1 km as the crow flies and, according to the plain population phenomenon during this phase of the Bronze Age, their location follows the north–south axis. The accumulated layers, according to their characteristics and conformation, seems attributable to the disposal of materials derived from anthropic activities inside the settlement. In the explored area, a total of 73 wooden elements has been found in Tombola, and 164 in Vallette including mainly vertical piles and oak timbers orientated according to a north-east/south-west axis. Being a small area, there are no clear elements pertaining the existence of a perimeter around the settlements, and this can represent an obstacle to a correct identification of the settlement typology (pile dwelling or Terramare) and their role (central or satellite) in the territory.

A dendrochronology study was carried out thanks to the abundance of wooden elements in Tombola, obtaining a mean curve of 106 years with the wiggle-matching technique for the radiometric dating with ^{14}C on three samples. The series is positioned between 1520 and 1413 cal BC, with an error of ±15 years (1σ), and characterised by at least two episodes of demolition (piles 8 and 54) dating the first 1425 ± 15 cal BC and the second 1413 ± 15 cal BC (Martinelli, 2005).

Considering the material culture, the sites have numerous affinities with the artefacts of MBA 3 characterising the plains of Emilia, Lombardia and Veneto. The ceramics show distinctive vase shapes evolved respect to those of preceding periods to which the

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association of wide grooves incisions on all the possible spaces of the vase is necessary.

Since the RBA 1, the settlement situation and especially the cultural aspect becomes more complex. If on the one hand the Terramare slowly starts his demise with the disappearance of almost the totality of settlements in the central Po plain, in the western plain a new settlement model appears: the great palisaded settlements. These villages develop near smaller rivers or in marshy areas; with the Final Bronze Age the preferred locations are the principal fluvial arteries, probably as a new social and economic order aimed at exchanges on the long distance (Peretto, 2010).

The sites of Larda I and Larda II belong to this settlement category, located near Gavello (Rovigo). According to the ceramics typology, these villages dated between XIV and XIII sec. B.C.

This hypothesis is supported by aerial photos highlighting an elliptic paleoriver of reduced dimensions, to which a palisaded structure with an external ditch can be associated (Peretto and Salzani, 2004; Mischiatti et al., 2011).

The main evidence is a ditch filled with organic and ceramic elements. Near the ditch some post-holes are observable. From a typological perspective, the ceramic materials are comparable with those of near Larda I settlement, for which a correlation with the sub-Apennine–Adriatic facies was observed, differing from those of Grandi Valli Veronesi (Peretto and Salzani, 2004; Mischiatti et al., 2011).

2. Materials and methods

2.1. Methodology

In order to identify the reduction sequence, the first step was the analysis of archaeological tools intended to locate the manufacturing marks. The finds were analysed using a stereo-microscope at low-power magnification for the identification of technological marks. In this phase, the artefacts were classified basing on morphological and functional characteristics and measured according to the bevel ended tools standards (Camps-Fabrer et al., 1998).

A technological experimentation was later programmed recovering both the raw material for artefacts production (bovine ribs) and the tools for their working: flint blades, a bronze knife, some bronze and bone chisels, limestones and sandstones. According to the microscopic analysis and with the purpose to create a reference collection for working and use-wear discrimination, we attempt to reproduce experimentally the marks similar to the ones observed on the archaeological specimens.

A functional experimentation was subsequently programmed, including the laboratory analysis of archaeological and experimental tools. In order to create the use-wear reference collection, the experimental tools have been tested on different materials. Thanks to the abundance of direct (wooden piles in situ) and indirect evidences (post-holes) in the settlements including wooden elements, ceramics, animal remains and deer antler tools, we decided to focus the functional experimentation on four categories of raw material: hide, bark, antler and clay.

In the last decade, the application of functional analysis on animal hard materials tools has become increasingly common, in virtue of the increase in international publications (LeMoine, 1997; Maigrot, 2005; van Gijn, 2005, 2007; Sidéra and Legrand, 2006; Gates St-Pierre, 2007; Legrand and Sidéra 2007; Christidou, 2008) and PhD thesis (Sidéra 1993; Maigrot, 2003; Griffitts, 2006; Legrand, 2007).

In order to create a reference database these works emphasise the importance of developing experimental programs associated with the systematic observation and surfaces evaluation at different magnification.

Before the microscopical analysis, the experimental tools were washed with distilled water in an Ultrasonic tank.

According to the available literature, in a first phase a use-wear study has been opted using the Low Power Approach (Tringham et al., 1974) through the stereo-microscope Leica SD6 (6×–48×) with EC3 camera, allowing to identify type of tool action and material hardness on which the tool was used (Stordeur-Yedid, 1974; Newcomer, 1977; Julien, 1982; d'Errico et al., 1984; d'Errico and Giacobini, 1985, 1986; Peltier and Plisson, 1986; Campana, 1989; Sidéra, 1989).

In a later time, a metallographic microscope Optika Met 600B at high magnification (50×–500×) has been used (High Power Approach; Keeley, 1980), and the procedure developed by Peltier and Plisson (1986) subsequently supplemented by other authors (Sidéra, 1993; Maigrot, 1997, 2003, 2004; Plisson, 2006; Sidéra and Legrand, 2006). The surfaces have been reproduced using silicon moulds (Provil Novo® Fast Light Set, Heraeus Kulzer) and epoxy resin (Araldite® LY554, Hardener HY956) to obtain replicas of the zones to be analysed.

For a greater punctual detail, a Scanning Electron Microscopy (d'Errico, 1993; d'Errico et al., 1995; Aimar et al., 1998; Christidou, 2001; d'Errico and Backwell 2003) has been used. The description criteria of macro and micro-wears is referring to the available literature (Plisson, 1985; Peltier and Plisson, 1986; Lemoine, 1997; Maigrot, 2005; Sidéra and Legrand, 2006; Legrand, 2007; Legrand and Sidéra, 2007).

2.2. The macro-wear traces

A low-magnitude analysis is necessary for the identification of macro-wear. Main evidences are flaking, rounding, striations, notching, pitting, fractures and polishing.

The detachments consequent to usage create little crushing and removal scars on the distal edge of the pointed or cutting tool, causing a material loss related to the type of raw material, usage time, and applied force. Their distribution, shape and dimension can be variable (Maigrot, 2003). However, the detachments can also be produced by a prolonged wear, making the bone surface more fragile (Legrand, 2007). The flattening can be the first step in the use-wear, due to the bone fibres retraction (Legrand, 2007). The rounding results from a repetitive wear (e.g. Semenov, 1964; Sidéra, 1993; Maigrot, 1997, 2003; Legrand, 2007).

The rounding morphology of the active part is useful to understand the tool position and the actions during its use, and also to identify the manufacture material (Maigrot, 2003). Some deformations are related to a repeated use and often exacerbated for the cutting edge re-sharpening (Sidéra, 1989, 1993). The study of this particular evidence is very useful for identifying the cutting edge use-wear. Generally, when the tool axis inclination angle on raw material is about 90°, a smoothing of active cutting edge is observable; on the contrary, when the angle is very low, the wear tends to involve the upper part of tool entering into contact with the material (Sidéra, 1989).

Notching, pittings, incisions and fractures are alterations linked to the plastic properties of hard animal materials (Sidéra, 1993; Maigrot, 2003). They are produced by contact with material with a density greater than or equal to the bone and antler (Maigrot, 2003). Their distribution on the surface and their morphometry are suggestive of methods of use, shape and density of material generating these marks (Maigrot, 2003).

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2.3. The micro-wear traces

Polishing and striations are microscopic marks always related to the tool usage. The polishing consists of tool surface modifications subsequent to the repeated contact with material. According to Peltier and Plisson (1986), the so-called micro-polishing is characterised by topography (degree of surface erosion), weft (bright/non bright areas ratio), *texture* and gloss. Other important factors are size (surface subjected to these modifications) and position on the tool. The micro-polishing is specific for the material and sensitive to its state (i.e. fresh or dried) (Maigrot, 2003). Sometimes, it is difficult to distinguish these marks from the natural polishing of taphonomic origin. In addition, the same micro-polishing could be the result of work carried out on very different materials (Peltier and Plisson, 1986; LeMoine, 1997; Maigrot, 1997, 2003).

Finally, the striations from contact with abrasive materials deliberately or accidentally introduced during the manufacturing process phases are interposed between tool active part and raw material. Their organization reveals the direction in which the object was used (d'Errico and Giacobini, 1986; Peltier and Plisson, 1986; Maigrot, 2003).

The striations are classified according to their distribution (50–100×) and morphology (200×; Legrand, 2007). The distribution is classified according to the tool main axis and can be transversal, longitudinal and chaotic (Averbouh, 2000). In addition to the distribution, the arrangement between the various observed striations, defined as parallel, crossed or irregular, is observed.

The morphology evaluation is based on different factors including length (shorter or larger than 1μ; Legrand, 2007); width (narrow, wide, or variable along the striation length); shape (straight, curved, sinuous); depth, as the most difficult factor to describe: deep (when the bottom of striations is inside the bone cortical surface) and shallow (when the striations are only visible on the bone cortical surface); inner characteristics: coarse or smooth (LeMoine, 1997); close V-shaped, open V-shaped.

2.4. Archaeological materials

A total of 11 archaeological tools were analysed and recovered in four different villages. The largest set comes from the Middle Bronze Age site of Vallette in Cerea (Verona, northern Italy), one from the coeval site near Tombola Cerea (Verona, northern Italy), and two artifacts from the Recent Bronze Age sites of Larda I and II (Rovigo, northern Italy) (Fig. 1).

The artefacts assemblage is not particularly abundant if compared to those of Early Bronze Age settlement in Lavagnone (Cilli et al., 2013) and Terramare villages (Provenzano, 2001). This discrepancy is, first of all, ascribable to archaeological issues as the partial sites excavation and the modest dimensions of investigated areas; in the second place, this difference can be also attributable to taphonomic factors, considering that the remains of Larda I and Larda II are in worse conservative conditions compared to those of Tombola and Vallette. In these last sites, the still current marshy and peaty environment conditions allowed an good preservation of artefacts; on the contrary, the loamy deposits in Larda I and Larda II caused more invasive alterations, often leading to clayish concretions, damaging the bone surfaces.

From a morphological point of view, they are fully included in the morphological and typological categories described by Provenzano (1988, 2001), defined as follows:

- Morpho-type 1: spatulas approximately triangular in shape, without distinction or with a mild detachment between handle and expanded end, ending usually straight or slightly curved (Table 1; Fig. 2A–D);
- Morpho-type 2: spatulas elongated with active end, more or less rounded; in some cases a rather clear detachment from the handle is observed (Fig. 2E–H);
- Morpho-type 3: spatulas characterised by a clear detachment between handle and quadrangular expanded portion with straight end (Fig. 2I).

Table 1
Number of bone tools analysed for each sites, and percentage of all the morpho-type categories.

Morpho-type	Site					
	Tombola	Vallette	Larda I	Larda II	Total	%
1		3	1		4	33.3
2		4			4	33
3	1				1	8.3
Undetermined			1	1	2	17
Total	**1**	**7**	**2**	**1**	**11**	**100**

Observing the ratio of total length to width of distal part, a certain heterogeneity in the examined sample is observed, measuring 5–9 cm in length and 2–3 cm in width. This difference in the proportions seems depending on the dimensions of the blank and, probably, also on the type of utilisation to which these tools were assigned.

The anatomical elements employed for the extraction of supports appear to be ribs of large ungulate, probably bovine. The identification of the anatomical element has been quite simple; according to the reduced cortical thickness (about 2–3 mm), and the spongy morphology, the supports could not be other than large ungulate rib fragments.

Generally, all the artefacts are in good condition; 5 are only partially preserved, with fractures involving the mesial, and proximal part. Some of these marks (NR 3) are probably due to indirect percussion with a soft or hard percussor. The fractures are primarily transversal and with characteristics compatible with an instrument flexion. Most of the artefacts side edges are characterised by a regular wear, often evanescent, which could correspond to the instrument manipulation or, very probably, to the tools handling. These marks are particularly evident in the finds that show a slightly curved or straight distal portion, and where the detachment between distal and meso-proximal part is less clear; on the contrary, for the findings showing a strongly curved and asymmetric distal part, an intrusive wear on most of the surface is observed.

Among the different tools with more or less developed smoothing, the use-wear of the active part shows quite different characteristics. The tools with a straight distal part or a symmetrical curvature have a rounded and generally quite thin edge. In some cases, small removal scars are visible; other show major shattering with rounded edges, indicating that the tool was also used after the damage had occurred. The artefacts with an asymmetrical distal portion show an edge thinning in one of the lateral border and, generally, a relevant thickness in the distal part. Only one tool shows a marked use-wear of the lateral side.

A metallographic analysis revealed a correlation among distal edges morphology, meso-proximal portion, and type of marks. In general, the artefacts with curved and asymmetric distal part are characteristically comparable with the experimental modifications described for the ceramic manufacture (Martineau and Maigrot, 2000; Buc, 2011; Maigrot, 2003). Whereas, the spatulas with straight or curved distal part (Morpho-type 2 and 3) and with a more or less clear detachment of the meso-proximal part, show a certain variability among the recorded marks. In effect, the use-

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Fig. 1. Site locations in northeastern Italy: 1 – Vallette (Cerea, Verona). 2 – Tombola (Cerea, Verona). 3 – Larda I (Gavello, Rovigo). 4 – Larda II (Gavello, Rovigo).

wear is generally evanescent and bi-facial, with a tight compact weft and hard coalescence. The striations, visible only at high magnification, are often longitudinal or oblique and rarely intersecting. They show small dimensions and, in most cases, are very thin. In some cases, curvilinear parallel striations are visible, almost similar to small scraping. According to the literature, a certain affinity with the experimental marks recorded during the skin processing and the hard plant material has been observed (Maigrot, 2005; van Gijn 2005; Buc, 2011).

An experimental verification has been necessary to effectively understand which raw material has been processed (exclusively one or more materials), and verify the marks attributable to the contact with the ceramic material.

3. Experimental tools

3.1. *Manufacture of experimental tools*

In order to detect the manufacture marks identifying the reduction sequence and enable their discrimination from those attributable to the use, before starting the experimental tools production, a study of archaeological find surfaces has been performed.

Almost all the findings (8 out of 11) show marked and parallel striations located on the upper and lower surface of tool distal end. According to morphology, repetitive actions and comparison with the experimental use-wear collection, their attribution to an abrasion action for shaping or re-sharpening of tool active part was sufficiently simple (Fig. 3). This action produces a mainly rectilinear bevel-shaped distal end.

Other marks were found on the sides of meso-proximal sector, characterised by a clear detachment between distal and meso-proximal area. These showed scraping marks due to edges production.

Some findings showed fractures transverse to the major axis, resulting from flexions and attributable to action type and pressure exerted by handling or prehension.

After the identification of these evidences, the experimentation started using fresh bovine ribs as raw material. Cattle since this is the only large size animal identified from the skeletal point of view in all the settlements. The deer has been excluded since the antlers are generally associated with scarce fragments of limb bones.

In order to verify the type of tools used for the production of these objects, the reduction sequence was carried out using both stone and bronze tools (Fig. 4). The employment of these tools is due to the discovery of both bronze and flint artefacts in Tombola and Vallette settlements, and a use-wear analysis for discrimination of the related marks on the surfaces was necessary.

We removed the rib cartilaginous distal end with and hard percussor. The caudal edge was scraped in order to expose the spongy bone. This step was performed with both a lithic blade and a bronze knife in order to record the differences in the marks on the scraped surface. The scraping phase was tested using two opposite motions (from top to bottom and from bottom to top) leading to record the use-wear differences on the bone surfaces. The flint tool

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Fig. 2. Archaeological bone tools analysis. A–D: Morpho-type 1. E–H: Morpho-type 2. I: Morpho-type 3. L–M: Undetermined Morpho-type (scale bar: 1 cm).

acts leaving evident chatter-marks and striations that superimpose to the others cancelling the preceding action on the surface. The bronze blade leaves more frequent, not much profound and visible chatter-marks, suggesting a more scarce ability to penetrate the bone and a better slipping capacity. The striations left by the tool are thinner, rarely have different widths, and the surface is polished.

The use of metal tools seems to be confirmed by stereo-microscopical analysis of the lateral edges of archaeological and

Fig. 3. Experimental reduction sequence using bronze tools. A: Cattle rib. B–C: Scraping on rib caudal margin with a bronze knife. D: Indirect percussion using a bronze chisel to obtain an useful bone support. E: After few blows, support production designed to tool manufacture.

experimental tools. Moreover, metal marks observable on one or both sides are very interesting, indicating a specific tendency to manufacture the meso-proximal portions with a width less than the distal part (Fig. 5). This occurs only with tools having a wider active edge. On the lateral edge of the tools the very evanescent chatter-marks result from scraping of a metal knife.

Subsequently, an indirect percussion on the exposed spongy bone with a cutting tool formed a flake morphologically similar to those observed in the archaeological sample. However we cannot exclude that a blank may be obtained by rib bipartition and subsequently worked.

The shaping sequence seems to be characterised by use of abrasive stones, probably quartzite or sandstone, to make cutting the active edges, adopting a movement predominantly transverse to the major tool axis. The experimental striations are stereomicroscopically long, straight, wide width, and coarse, consistent to what observed in the archaeological sample (Newcomer, 1974; Campana, 1989; Provenzano, 1996–97, 2001). The metallographic microscopy (50×–100×) shows internal micro-striations typical of materials containing angle grains, such as sandstone and quartzite (LeMoine, 1997; Averbouh and Provenzano, 1998–1999; Legrand, 2007).

A total amount of 18 tools have been manufactured to test on different raw materials. All were photographed prior to use and at the end of the experimentation (Fig. 6A). Duration of the activity, angle of use, direction of gestures, presence or absence of handling, and technique have been taken into consideration.

3.2. Use of experimental tools

3.2.1. Scraping fresh, dry and re-hydrated hide

Four experimental tools were used for the removal of fresh hide fat, one for the re-hydrated and one for the dry hide (Table 2). Two rabbit and a hare fresh hides, and a chamois dry hide were employed for the experimentations. We decided to provide the tools with a deer antler handle (Fig 7B), on the basis of the fractures deriving from flexions observed on the archaeological sample, and in that the morphology of the object itself does not allow to obtain a strong grip during the operation without the aid of a handle. After stretching out the hide, the tools were used with longitudinal and repetitive movement in order to scrape away the fat in the inner part of the hide. The angle of attack could vary between 20° and 30°. All the tools were observed every 15 min of use to analyse the use-wear degree. Silicone replicas were prepared. In order to observe macro and micro-modifications, the experiment was prolonged over 60 min for two objects. Generally, all the tools were effective in various activities. In general, a greater resistance of the active part in the hide scratching has been observed, so that even after 60 min the tools could still be used. On the contrary, for dry or re-hydrated hide, a tool edge re-shaping was necessary after about 10 min.

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Table 2
Experimental database.

ID	Bone raw material	Handle	Worked material	State	Motion	Duration
E23	*B. taurus* rib	y	Antler	Soaked	carving	5′
E24	*B. taurus* rib	y	Antler	Soaked	carving	5′
E4	*B. taurus* rib	y	Bark	Green	peeling	47′
E22	*B. taurus* rib	y	Bark	Fresh	scraping	10′
E5	*B. taurus* rib	y	Bark	Fresh	carving	10′
E6	*B. taurus* rib	y	Bark	Fresh	carving	10′
E26	*B. taurus* rib	y	Bark	Fresh	scraping	15′
E25	*B. taurus* rib	n	Clay	Wet	smoothing	60′
E9	*B. taurus* rib	n	Clay	Wet	smoothing	35′
E10	*B. taurus* rib	n	Clay with inclusions	Wet	smoothing	60′
E11	*B. taurus* rib	n	Clay with inclusions	Dry	polishing	70′
E7	*B. taurus* rib	y	Hide	Re-hydrated	scraping	10′
E8	*B. taurus* rib	y	Hide	Dry	scraping	15′
E1	*B. taurus* rib	y	Hide	Fresh	scraping	35′
E21	*B. taurus* rib	y	Hide	Fresh	scraping	35′
E2	*B. taurus* rib	y	Hide	Fresh	scraping	65′
E3	*B. taurus* rib	y	Hide	Fresh	scraping	35′
E20	*B. taurus* rib	n	Bark	Dry	scraping	10′

3.2.2. Removing green, fresh and dry bark

One experimental tool was employed for the removal of the green bark from the oak branches. With the purpose of keeping intact the bark, the actions mainly performed were its incision and removal. The angle of attack was initially placed at 90°, and subsequently modified between 0° and 20° during the removing. Two instruments were handled, and the remaining were directly hafted in the meso-proximal portion.

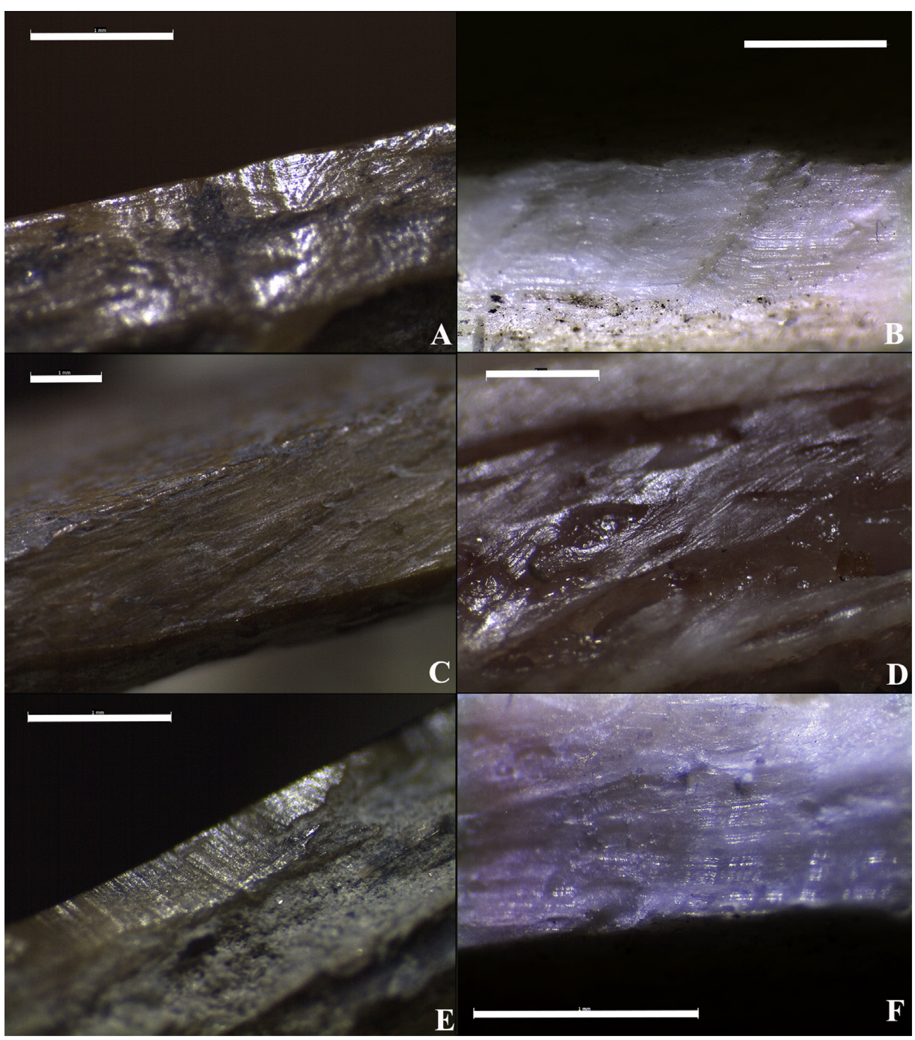

Fig. 4. Archaeological (left) and experimental (right) manufacturing marks. A–B: Large sized chatter-marks by a metal knife on the tool lateral edge. C–D: Striation on the tool lateral edge by scraping. E–F: Small sized chatter-marks on lateral edge for tool mesial-proximal end manufacture.

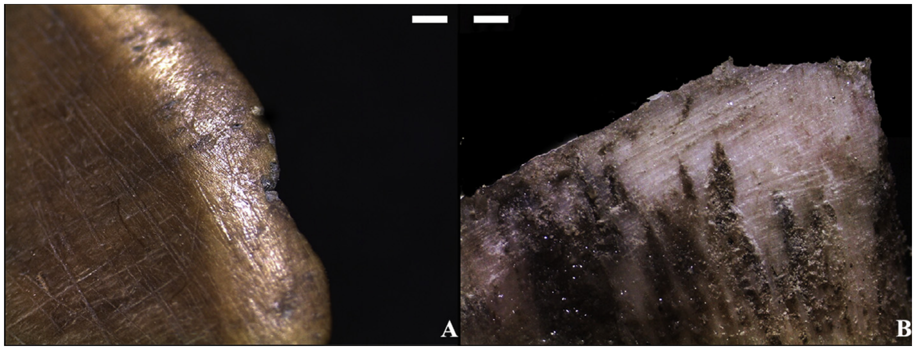

Fig. 5. Archaeological (A) and experimental (B) macro-striations resulting from the distal end manufacture with a coarse stone.

Four instruments were used to remove the fresh bark by means of indirect or direct percussion, using a soft (wood) and a hard percussor (pebble, 3 kg approx).

Finally, other two tools have been used for the dry bark removal by means of indirect o direct percussion (Table 2).

3.2.3. *Working soaked antler*

To complete the reference experimental collection, we decided to use two tools for the antler processing soaked in water for 24 h. Even in this case, the experimental tools were handled and used for indirect percussion with hard percussor. The angle of

Fig. 6. Some experimental tools (A). Different hafting systems used for experimental activities (B–D).

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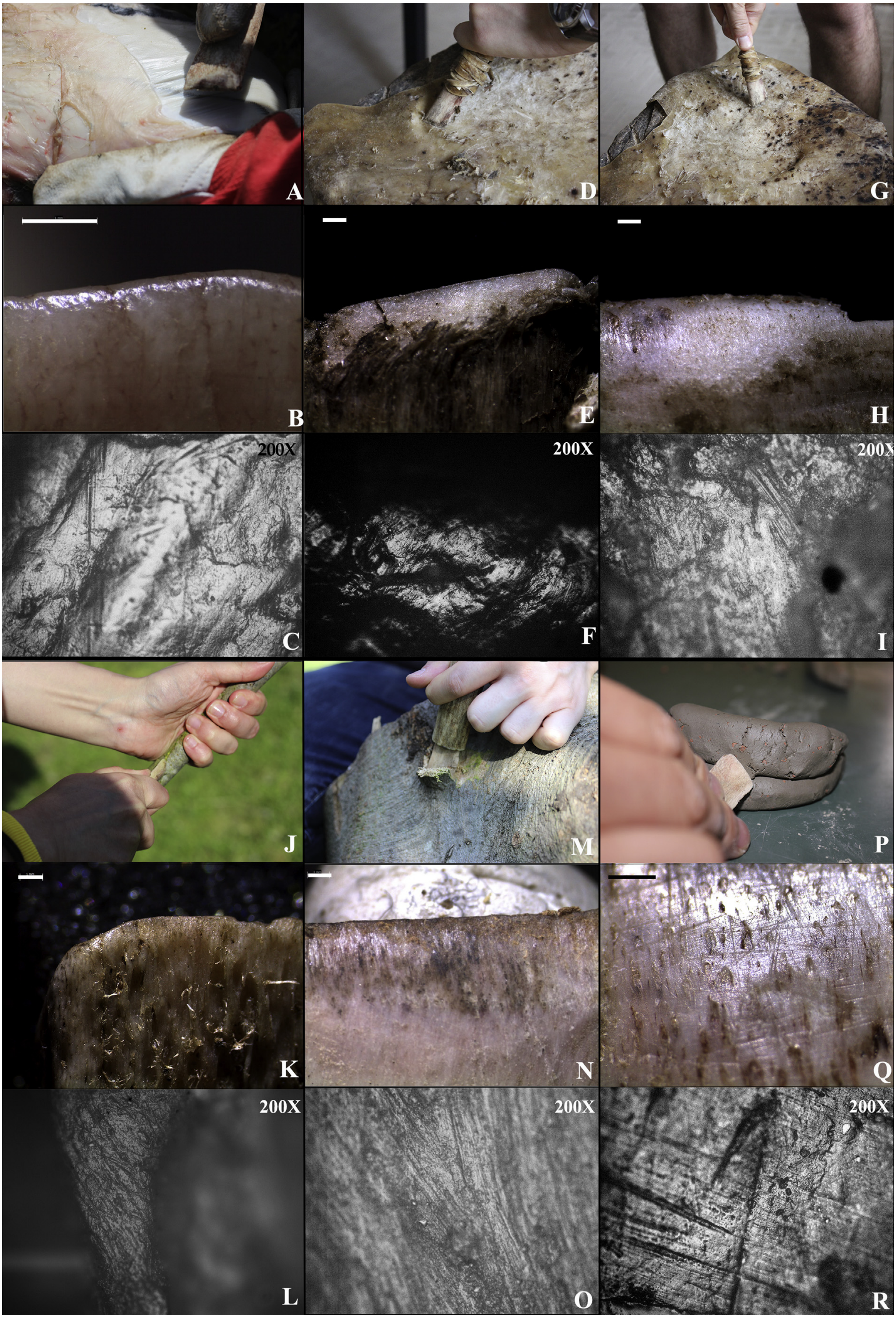
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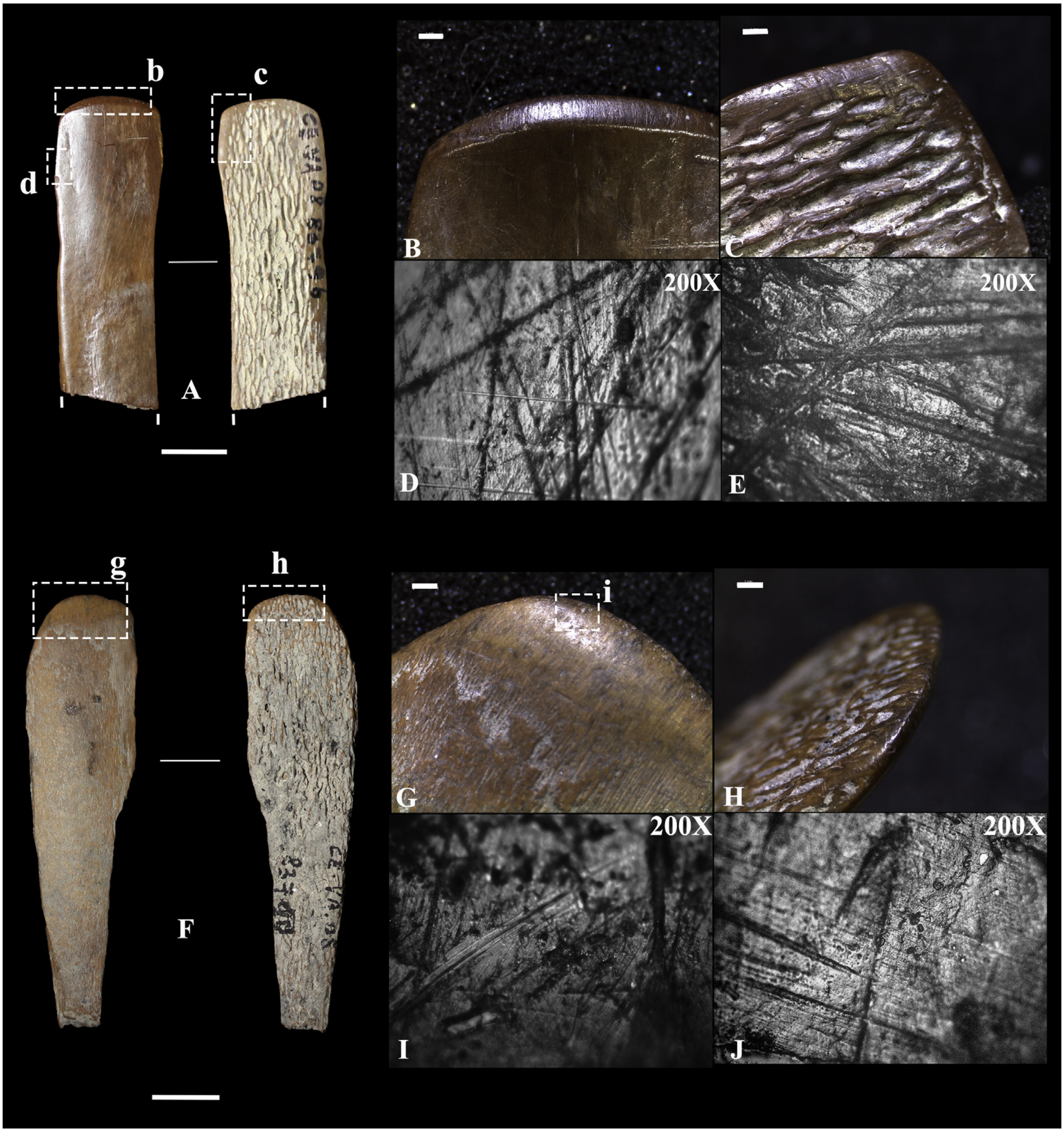

Fig. 8. Archaeological tools probably used for wet clay smoothing (A–J). A–E: Morpho-type 1 (A); details of upper and lower distal end surface (B–C). Bifacial polishing. Cross striations on archaeological tool with different widths and lengths (D). Same striations also present on experimental tool (E). F–J: Morpho-type 2 (F); details of use-wear on upper and lower distal end surface (G–H). Cross striations on archaeological tool with different widths and lengths (I). Same striations also evident on experimental tool (J) (Bar scales: 1 cm; bar scales on stereomicroscope images: 1 mm).

action results variable: in effect, the tool was initially placed between approximately 90° and 45°, and subsequently arranged according to an angle below 45°. The tools were ineffective in this operation, with an evident damage of the active part after a few minutes of use.

3.2.4. Smoothing wet and dry clay

The last experimental manufacturing was addressed to smoothing and polishing of ceramics. A fine clay was used, to which fired ceramic fragments (*chamotte*), vegetable fragments and sand were gradually added in order to observe how this material can alter the surface of tools with different types and states of

Fig. 7. Experimental collection. A–C: Fresh hide scraping (A); tool distal end with a rounded edge (B); detail of longitudinal and parallel fine striations (C). D–F: Rehydrated hide scraping (D); irregular and rounded cutting edge (E); detail of fine and parallel striations on distal end (F). G–I: Dry hide scraping (G); more shiny, curved and regular tool distal end (H); detail of surface large striations (I). J–L: Green bark peeling (J); rounded and very shiny cutting edge (K); detail of irregular surface with some small and long parallel striations (L). M–O: Fresh bark removal (M); rounded and irregular distal end from impact with hard material; many longitudinal striations are already visible at low magnification (N); detail of many chaotic parallel striations resulting from tool sliding (O). P–R: Wet clay smoothing (P); many crossed striations on tool upper surface with different lengths and widths (Q); detail of some surface striations at 200× (R). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

components. Thanks to the easily manageable tools, a handle was not indispensable.

The action was almost always held using the upper face of tool, performing different types of not always linear movements.

4. Results

4.1. Scraping fresh, dry and re-hydrated hide

From a macroscopic point of view, the action carried out on the hide in several states produced quite similar modifications (Fig. 7A–I). The tool active edge tends to become round after a few minutes, while the distal lateral edges show a more or less developed curvature depending on how the force is applied, angle of attack, direction of movement. The real use-wear involves the first 5 mm of distal edge of tool lower face, while in the upper face is evanescent.

The micro-topography tends to be uniform among all the tools, with a weft generally tending to be tightened or compact in artefacts used on dry and re-hydrated hide. The micro-reliefs show rounded shapes.

The tools used on fresh hide show a bright surface distinguished by a granular texture. A rather variable frequency of striations was observed, generally small and very thin. In the majority of cases, they are iso-oriented in the sense of the adopted movement that is longitudinal in this case, and mostly localised on lower face and front edge of the tool active part.

When the wet hide is processed, the surface appearance is more brilliant and smooth. Small superficial detachments often with polishing are visible, and small depressions form, uniformly integrating with the shiny surface (Fig. 7A–C).

When the tools are used on dry hide, the stereomicroscopy shows an uniform surface erosion altered by scratches and flaking, so that the bone surface seems unaltered (Fig 7E).

Concerning the processing of re-hydrated and dry hide, a greater number of striations showing different width was observed. In effect, wide striations are also observed, often rough. In some areas, more pronounced striations arranged in parallel bundles and similar to scrapes were observed, perhaps caused by hide debris inserting between the tool and the raw material (Fig. 7D–I).

4.2. Removing green, fresh and dry bark

The surface of tools used for removal of green bark is characterised by smooth and glossy active part (Fig. 7J–L). From the macroscopic point of view, edge notches appear mild, and the use-wear tends to affect most parts of the active edge used in cutting and removal. The coalescence of the upper surface is hard and flat (Fig. 7L). On the upper surface, a 100× magnitude shows often rough and transversal striations. The polishing is characterised by a flat appearance and uniform weft. The frontal edge is rounded, with a sufficiently heterogeneous weft. There are few wide and deep striations, oriented according to the incision axis.

The use-wear linked to the fresh bark removal develops after a few minutes of use, and covers a quite limited tool surface, both from the upper and the lower face (Fig. 7M–O). Since this is hard and sufficiently abrasive material, the surfaces observed at high magnification shows a certain homogeneity and flattening of the reliefs (Fig. 7O). The striations are very dense, often showing a sinuous and transversal morphology, deriving from the bark curls passage and the lateral tool sliding.

The dry bark removal of shows characteristics very similar to those seen in the previous experimentation. However, the striations appear having a greater incidence on the surfaces, as greater is the number of fractures created on the active edge, indicating exactly a greater hardness of raw material.

Another important factor is the scrapings on the mesial part, realised during the rubbing of the raised bark on the tool surface. In this case also, high magnifications show dense longitudinal striations and a greater amount of curvilinear striations. Using a soft percussor, the tool penetration was limited and reason for its breakage after a few blows.

4.3. Working soaked antler

As for the use-wears previously seen, these appear to be little invasive and localised in the first 4 mm of the distal margin. A greater number of macro and micro-fractures due to the impact with the hardest material, and their subsequent rounding, are observed. The surface tends to be more heterogeneous with often curvilinear striations, very similar to those found for the wood experimentation.

4.4. Smoothing wet and dry clay

The use-wear resulting from polishing wet clay has slowly developed, as to be barely visible after about 15 min. On the lower edge of the distal margin, the use-wear is practically absent. The high magnification showed a rather heterogeneous surface with irregular micro-reliefs and more raised smoothed, flatted and highly reflective areas (Fig. 7P–R).

The striations are often deep, straight, grouped, crossed and rough deep end. Size and distance among striations change depending on the type of clay and components.

On the contrary, the dry clay smoothing leads to a greater surface homogeneity, with chaotic and different thickness striations over the entire surface (Fig. 7Q). In this case, the use-wear has developed more quickly.

5. Discussion

According to what was already highlighted by several studies (Semenov, 1964; Peltier and Plisson, 1986; Maigrot, 2003; Legrand, 2007; van Gijn, 2007; Buc, 2011) the experimental tools analysis revealed that each material and activity is associated with specific marks of use. The characteristics assemblage considered for the analysis showed to be more or less useful for the identification of marks detected on archaeological finds (Table 3). In particular, the polishing location, its main characteristics (coalescence, weft, degree of reflectance) in association with the morphology and distribution of striations, are the most important variables for the identification of the raw material with which the tool is entered contact. However, at the same time they may mislead the analysis as they are easily influenced by post-depositional processes and manipulation to which the archaeological remains are often exposed once recovered (Peltier and Plisson, 1986; Maigrot, 2003).

Table 3
Results of bone tools micro-wear analysis: contact material relative to motion.

Contact material	Motion			
	Peeling	Smoothing	Polishing	Undet.
Hide				
Wood	2			
Clay		5	1	
Hard material?	2			
Undetermined				1
Total	**4**	**5**	**1**	**1**

Functional experimentation has clearly shown that this typological tool category may have been used for different activities (Table 4).

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Table 4
Results of bone tools micro-wear analysis: contact material relative to morpho-type.

Contact material	Morpho-type			
	1	2	3	Undet.
Hide				
Wood		2		
Clay	4	1	1	
Hard material?				2
Undetermined		1		
Total	**4**	**4**	**1**	**2**

The dry and wet hide processing has changed a limited area of the tool distal portion, with a greater extension on the lower face. From a macroscopic point of view, the change of the distal edge profile is most evident. In effect, the lower face tends to no longer be flat, but to tilt due to the inclination angle at which the tool comes into contact with the raw material surface. This is not observed for the archaeological assemblage tools that generally have a flat lower face, while the distal edge viewed from the upper face tends to have a more or less accentuated angle.

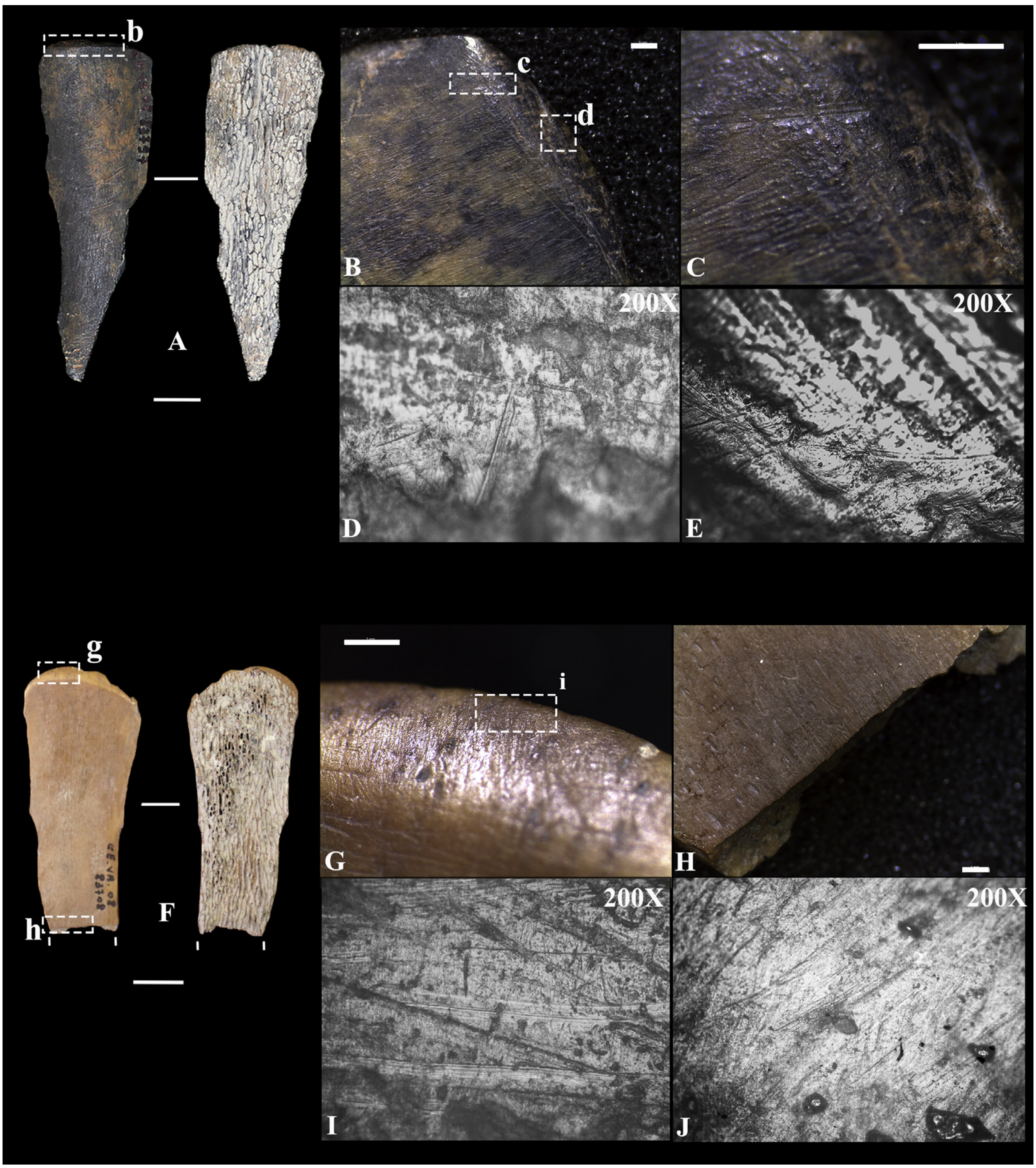

Fig. 9. Archaeological tools probably used for fresh bark removal (A–J). A–E: Morpho-type 2 (A); details of upper distal end surface (B–C). Large striations on upper surface (C). Flat reliefs and compact weft with chaotic striations (D). Experimental tools surface showing reliefs and compact weft, striations often arranged in parallel stripes. F–J: Morpho-type 2 (F); details of macro-striation on upper distal end (G). Hinge fracture on tool mesial-proximal sector (H). Some scraping marks on archeological (I) and experimental (J) tools probably derived from contact with bark (Bar scales: 1 cm; bar scales on stereomicroscope images: 1 mm).

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From the perspective of the micro-wear, in the archaeological tools the main characteristics observed in experimental tools used in this activity and according to the images by other authors in similar experiments are not found (Lemoine, 1997; Maigrot, 2003; Griffitts, 2006; Legrand, 2007).

By contrast, the macro and micro-wear recorded during the fresh bark removal were observed on two tools (Fig. 8). The use-wear is double sided, most evanescent with gentle micro-polishing; the cutting-edge thread shows a multifaceted smoothing with shattered margin (Fig. 8A and F). In general, all the tools used for this activity have an active straight margin. Only a find shows an asymmetrical active margin curvature perhaps caused by an advanced degree of use-wear (Fig. 8F).

The striations of different size are generally iso-oriented and longitudinal (Fig. 8D–E); in some cases curvilinear striations appear, also recorded during the experimental activity and originated from the lateral tool slipping during the indirect percussion (Fig. 8I–J). A tool shows re-sharpening marks, making difficult the use-wear evaluation. The presence of fractures deriving from flexion in at least two artefacts supports the hypothesis that these tools had to be handled and used for indirect percussion with a soft percussor (Fig. 8H). The same type of fracture has been obtained during the experimental activity employing a handled tool for indirect percussion with a soft percussor.

The smoothing and polishing activities leave specific wears, mainly localised on one tool face with crossed striations of very different size (Fig. 9). A 55% of artefacts shows marks fully comparable with the ceramic manufacturing (Martineau and Maigrot, 2000; Maigrot, 2003; Buc, 2011). The tools identified for this activity show almost always a curved distal end with a strong asymmetry (Fig 9F). In some cases, more facets with different inclination may develop thanks to the contact with fresh clay. The striations are chaotic, often large and rough (Fig. 9D–E).

Two tools may probably have been used for ceramic polishing before firing (Fig. 9F–J). They show very polished surfaces also experimentally observed, and striations compatible with the clay manufacturing.

6. Conclusion

The study on this category of tools supported not only the evaluation of their efficiency concerning their main use, but also the evaluation and testing the possibility they could be used for other activities. The creation of a database to collect the experimental use-wear traces was fundamental for this research. Despite the sample of analysed artefacts is relatively modest, this study has undoubtedly highlighted the intrinsic relationship among the morphology of tools, especially with regard to the distal part and the type of use to which they were intended for. The tools with a wider active edge seem to be correlated to the wood decortication, particularly if fresh. Whereas, the smaller tools seem to be used in the dry and moist ceramic manufacture.

In conclusion, the future possibility to analyse more spatulas deriving from other chronological contexts of the Bronze Age could support in further investigations on functional hypotheses, until now deduced with the experimental support.

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