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Bones as Tools: Current Methods and Interpretations in Worked Bone Studies

Edited by

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Methods, Means, and Results when Studying European Bone Industries

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Introduction

What are the subjects of study, the methods, criteria and results in technological and use-wear studies? The examination of about ten thousand bone tools, provided by Neolithic and Chalcolithic sites from Bulgaria to France, including those of the Aceramic Neolithic in Cyprus, will be taken into account to answer these questions. This is done in a continuous effort to study new collections with the aim of testing and enlarging our knowledge about these artifacts.

Technology

Technological categorization is the first method to be implemented (see Billamboz 1977; Christidou 2001a; Legrand 2005b; Louwe Kooijmans *et al.* 2001; Murray 1979; Poplin 1974; Sidéra 1993a, 2005; and Stordeur 1974, for example). It proceeds in three principal steps: 1) technical identification (sawing, knapping, grinding etc.), 2) cutting procedures (metapodial divided in two, three or four parts), and 3) characterizing technical methods (fig. 1). Measuring the ratio between the investment in *débitage* and the degree of shaping may be added to make the technical portrait of a given assemblage (Sidéra 2000, 2001; Stordeur-Yédid 1976). The use of microscopy is always necessary to understand which techniques are employed and how traces overlap. This also enables the reconstruction of the manufacturing processes. Technical methods, which are to say, characterized stable manufacturing processes involving different techniques, are most important. Because of the strong morphological and technical homogeneity of Neolithic bone artifacts, technical methods appear to be efficient criteria for integrating bone assemblages into the cultural range (Sidéra 2004, in press). This provides feedback for archaeological interpretation. Questions such as cultural practices, innovation, relationships between different traditions and transfers from one culture to another can thus be addressed with greater accuracy. Secondly, as technology is the link between raw material, morphology, styles and

function, it is a major design system criterion, as Chippendale suggested (1986). This explains the special attention given to technological study.

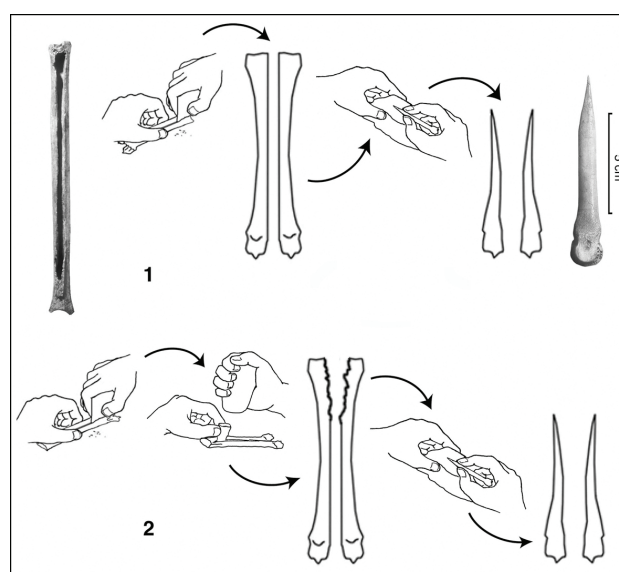


Figure 1: Manufacturing methods for metapodials. 1) Southern France Middle Neolithic (Montbolo) method: both sides are sawed from one extremity of the bone to the other, after which each halves are grinded. Archaeological artifacts from Corbères-les-Cabanès "grotte de Montou" (Pyrénées orientales, France: F. Claustre-CNRS excavations). 2) Aceramic Neolithic of Cyprus method: both sides are partially sawed, then knapped, and then each halves are grinded. Photos by I. Sidéra.

The awl manufactured on a half ruminant metapodial, which preserves the distal epiphysis as a handle, gives a good illustration of the interaction between techniques and methods. It is a very common tool, which spread from the Near Eastern Aceramic Neolithic to the Western European Chalcolithic (see awl in fig. 1). The techniques employed to make it and, as a result, the morphology of this type of awl, have a small range of variation within the chronologies and cultures. There is little or no stylistic variation. Methods are much more characteristic than techniques and morphology in this case. In southern France Middle Neolithic, for example, most awls of this type are sawed on both sides from one extremity to the other (Sidéra in press), whereas in Cypriot

Aceramic Neolithic, they are often partially sawed and then knapped with a chisel and a hammer (fig. 1) (Legrand 2005a). At the end of the Linear Pottery Culture, in the Paris basin, the method of sawing one side and knapping the other was just introduced and it developed to produce the same type (Sidéra 1993a). These methods have been reproduced and their results were compared with the original artifacts.

Experimentation

Experiments are currently targeted on either manufacture or functional questions (Barge 1982; Camps-Fabrer H. *et al.* 1977; Ettos 1985 and 1991; Nandris and Camps-Fabrer 1993; Maigrot 2001; Schibler 2001; Sénépart 1991) or, as Keeley argued, "real time" experimentations (1980). For clarifying initial usage conditions, precise contextual and environmental information such as fauna, vegetation or sources of raw materials need to be taken into account (Campana 1989; Lemoine 1997; Meneses Fernandez 1993; Sidéra 1993a). Bone artifact copies are also needed for use in specified tasks: perforating bark (fig. 2.1), scraping skin to make leather, digging wood (fig. 2.2), weaving a belt (fig. 2.3), etc. Parameters such as the nature of the bone (fresh, dry or heat-treated), hide state (rough or tanned), wood state (fresh or dry) and wood textures and density (tough or soft) can change the results. All of these experiments aim to document; 1) the most frequent archaeological artifacts; 2) the types of tools and materials rarely explored, such as needles, awls and soft vegetal fibers (Legrand 2003, in press); and 3) the greatest variety of material worked, the different kind of tools available to illustrate the largest range of use-wear traces (Peltier 1986; Peltier and Plisson 1986). We have tested 120 tools and objects in such

conditions. In addition, we led some of the experiments in collective program and found that cooperation is necessary for success.

The main problem is to acquire long lasting used artifacts, close to the original, which are often extremely modified by use. Time dimension cannot be measured by wear and this constitutes a major problem. As a solution, ethnographic artifacts can be studied, but as their exact function and duration of use is not often clear, they are not always available.

Functional Approach

Since the 80's, functional analysis based on experimentation is common, serving different goals. A majority of studies deals with the description and characterization of individual tools or bone surface alterations (Aimar *et al.* 1998; Christidou 1999; d'Errico 1991, 1993, 1996; d'Errico and Villa 1997; d'Errico *et al.* 1985, 1995; Ettos 1991; Meneses Fernandez 1993, 1994; Olsen 1989, 2001; Stordeur 1983; Stordeur and Anderson-Gerfaud 1985). Fewer studies tend to undertake whole assemblages with the view of answering historical, anthropological and cultural questions at the same time (Campana 1989; Legrand 2005b; Lemoine 1997; Maigrot 2003; Sidéra 1989). For all these purposes, both low and high power analysis are used. Their efficiency depends either on the development of use-wear or on the functional end shape of the tools and naturally, on the previous questions. The criteria used in the different optical methods for gathering information about the nature of the material worked and about artifacts, their use, and hafting, as well as their respective contribution, complementary and interaction, will be discussed below.



Figure 2: 1) Perforating bark with a bone awl by indirect percussion; 2) digging wood with an antler axe; 3) weaving with a bone awl. 1, 3: Experimentations and photos by A. Legrand. 2: Experimentations and photos by I. Sidéra.

Macro-wear

The low power examination is first executed with the naked eye and with a stereomicroscope at the most common magnification range of 10x to 80x, but sometimes up to 130x. Concepts and analytical criteria have been specifically investigated during the 1980's (Campana 1989; Maigrot 1997 and 2003; Meneses Fernandez 1994; Sidéra 1989, 1993a, 2000; Stordeur 1983, 1989). According to S. A. Semenov (1964), who founded use-wear analysis, the principle consists of marking all deformations occurring on artifacts: "volume alterations" (Sidéra 1993a). The plastic property of bone and its softness, compared to stone, lead to a rapid and characteristic recording of a given work. This involves a proper methodology, which differs significantly from the lithic use-wear analysis process. Different traces such as scratches, new surface aspects (polish or coloration) and flaking appear during the first minutes of the tool's use. Later, smoothing and deformations of the contours occur according to the material worked, its nature and shape, and kinematics. These deformations, which come from either wear, shaping

or sharpening can be deduced, depicted and measured at this scale of magnification. For example, because of their limited and concave active edge, tools like scrapers, which have worked narrow materials such as wood or bone - we know of some ethnographic tools in Papua New Guinea - have been easily identified in the European Neolithic period (fig. 3) (Sidéra 1995). Concavity also marks pottery scrapers (fig. 4), as it modifies the course of some tips (fig. 5).

Functional diagnostic elements such as smooth contour shapes and cutting edge profile are useful when observed at 20x to 80x magnifications (Sidéra in progress) (fig. 6). Let us cite some examples yielded by a Linear Pottery site; Cuiry-lès-Chaudardes in the North of France. Two types of hide scrapers made of bone were identified (Sidéra 1989 and 1993b). There, we dealt with a similar type of tool, with the exception of their bevelled shape (fig. 7). The first one is flat-sided, bevelled, sharp-edged, with numerous short, broad, straight scratches which correspond to frequent resharpening (fig. 7.1). It was used for fleshing hides, which were perhaps laid

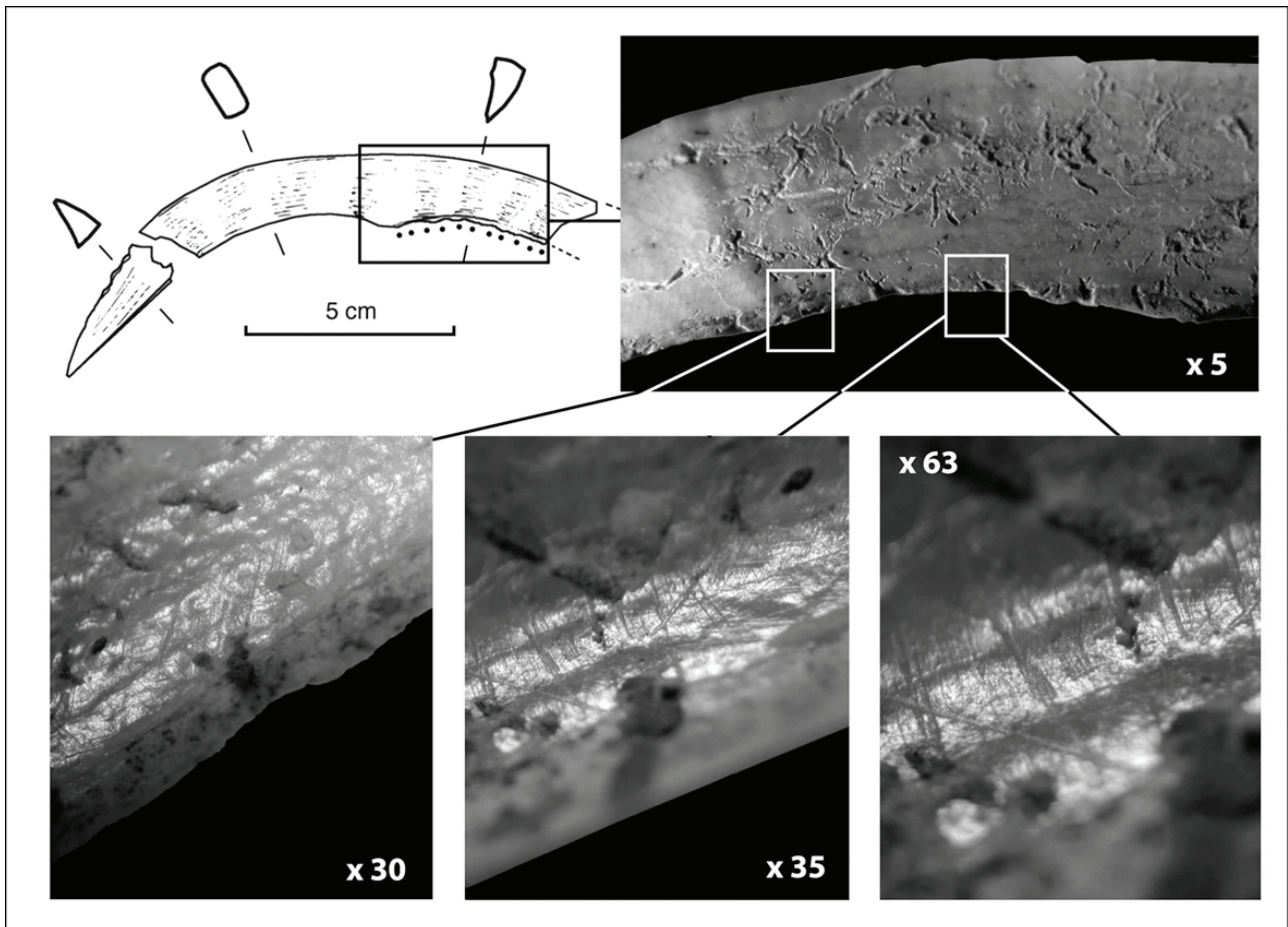


Figure 3: Archaeological pig tusk scraper from Mareuil-les-Meaux (Seine-et-Marne, France: R. Cottiaux–INRAP excavations). Progressive enlargement of the end part of the tool. At naked eye and at 5x magnifications, see the concave and notched appearance of the active edge. From 35x to 63x magnifications, numerous and developed crossed and perpendicular striations and a micro-smoothing appear on the edge. Drawing and photos by I. Sidéra.

down on a block of wood (fig. 7.A). The second type is a convex-sided, bevelled tool, which was highly smoothed and lightly polished, with thin, long and curved scratches (fig. 7.4). It was used with a pendulum movement during a later step of the work, probably to soften the hide stretched on a frame (fig. 7.B). In both cases, the bevelled forms result not only from use but also from shaping and resharpening, whilst respecting the original shape (fig. 7.1).

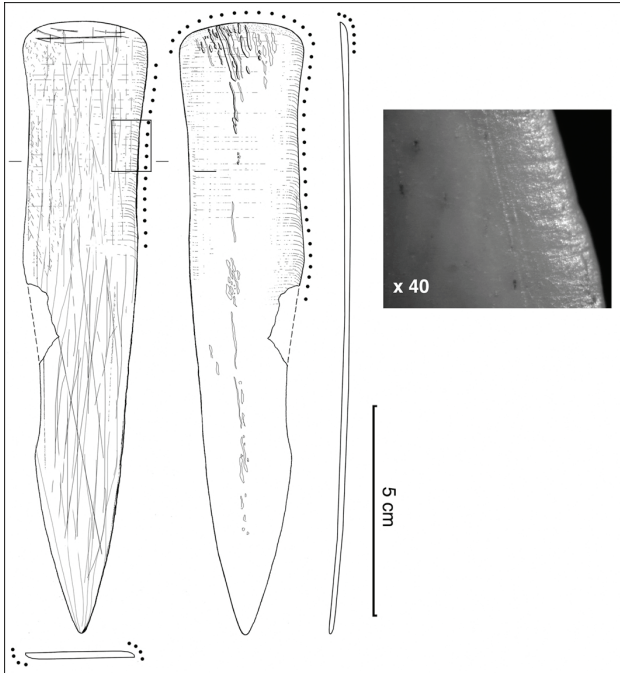


Figure 4: Archaeological bone pottery scraper from Corbères-les-Cabanes "grotte de Montou" (Pyrénées orientales, France: F. Claustre-CNRS excavations). At 40x magnifications numerous, broad, long and straight striations appear perpendicularly to the edge. Drawing and photos by I. Sidéra.

All these interactions between manufacture, use and resharpening are complex and need to be understood to achieve a functional interpretation. Thus, the restoration of the wear process, by means of a *chaîne d'usure* based on the valuation of the degree of use of a number of artifacts of the same type, allows us to understand the use mode of the artifact (Sidéra 1993a, 2002) (fig. 8). The contour deformations are often accompanied by other volume alterations like different types of smoothing, chipping, crushing and surface alterations such as polish and striations (fig. 9). Finally, surface and volume deformations ought not to be separated. Let us return to the examples of the wood and pottery scrapers to illustrate this point. The main difference between them are the notches and chips visible along the edge for the wood or bone scraper, and the long, numerous and parallel striations which cross perpendicularly the edge of the pottery scraper (fig. 3 and 4).

The handling mode, important for defining the artifact

use mode, has to be investigated as well. Different types were distinguished, involving specific traces localized on either the bottom or the entire length of the tool (fig. 10). We noticed that the proportion of the archaeological hafted artifacts is quite stable, about 20% in all European Neolithic cultures. Only the types of artifacts differ. Antler tine picks and hide skin scrapers were mainly hafted in the Early Neolithic of Northern France (Linear Pottery Culture). This was due to functional constraints for pick antlers, used to dig soil, and economical factors for hide working which represented an important investment for this culture. Later, in the Middle Neolithic *Chasséen* and *Michelsberg*, as woodworking increases and diversifies, a real variety of hafted instruments appears (fig. 11). Hafts are mainly tenons, directly fastened on the tools, and previously perforated (fig. 11.1, 11.2, 11.4, 11.6, 11.7). Riveting also comes into view at the beginning of the Middle Neolithic *Cerny* (Sidéra 2000, 2001: fig. 3.7 to 3.9) (fig. 11.3).

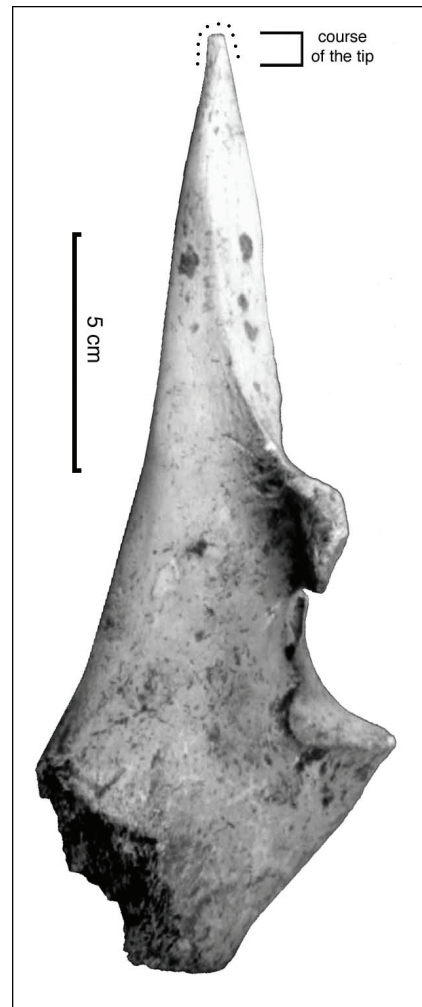


Figure 5: Archaeological perforating tool from Cuiry-lès-Chaudardes (Aisne, France, ERA 12 excavations). Deformation of the awl tip due to use and resharpening and materializing the course of the tip. Photos by I. Sidéra.

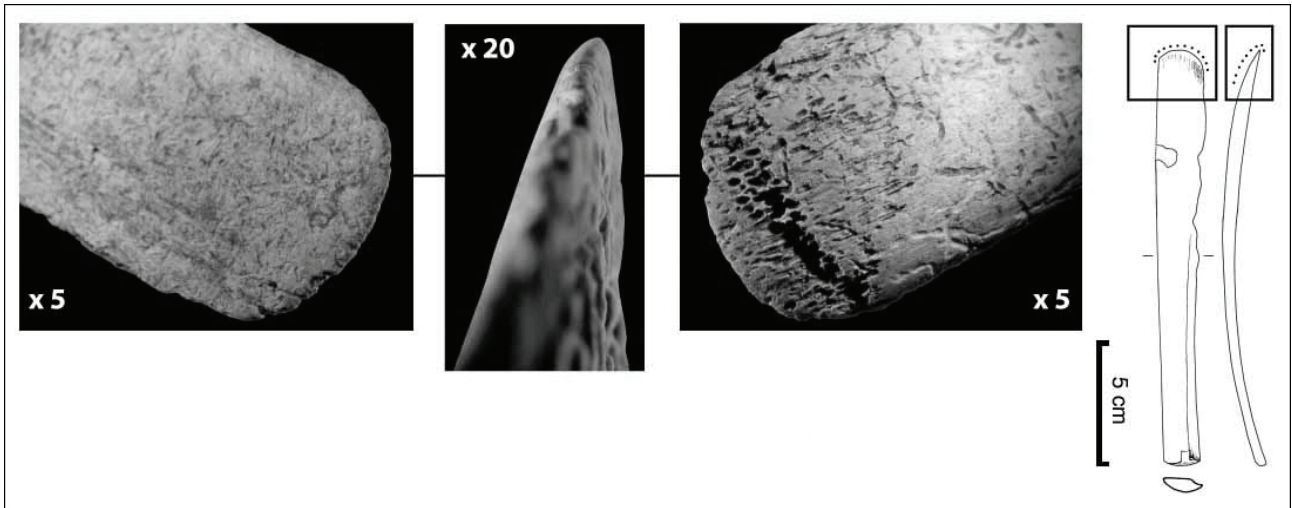


Figure 6: Archaeological flesher, up and low sides and profile. See the shape profile characterized by a symmetric smoothed micro-bevel and a sharpened extremity. Drawing and photos by I. Sidéra.

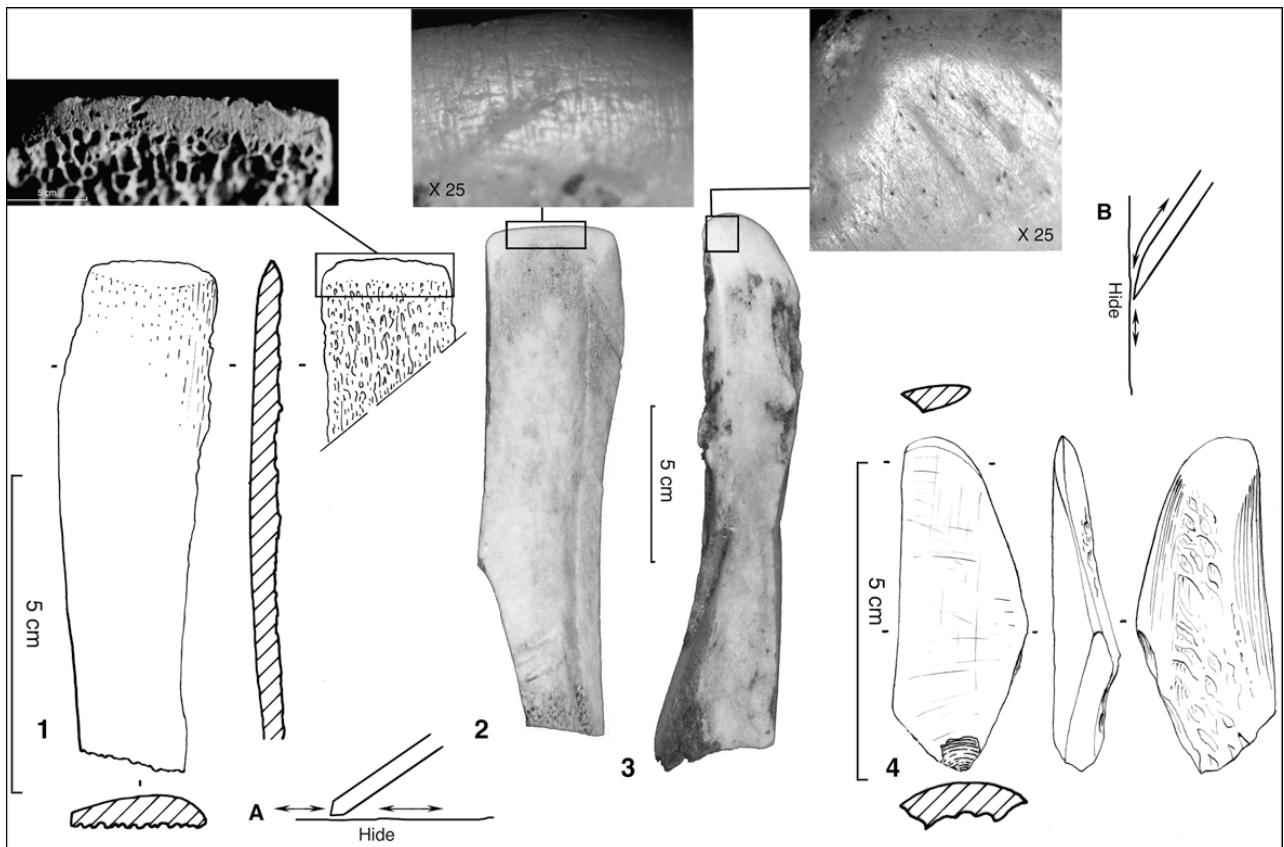


Figure 7: Archaeological and experimental hide scrapers. 1) Archaeological ribbon flesher type 1, flat-sided bevel with sharp-edged and numerous striations due to resharpening from Cuiiry-lès-Chaudardes (Aisne, France, ERA 12 excavations; 2) experimental and used replica of the flesher with short, broad and straight striations on the active end; 3) experimental and used replica of the convex-sided bevel with thin, long and curved striations on the active end; 4) Archaeological long bone softener type 2, convex-sided bevel from Cuiiry-lès-Chaudardes (Aisne, France, ERA 12 excavations archaeological. A) Flesher use mode. B) softener use mode. Photos and experimentation by I. Sidéra. Drawings by G. Deraprahamian.

Low power examination is not always efficient for functional interpretation. The case of awls is the most significant. The macroscopic features observed on their active end show a slight difference from one awl to another and thus do not reveal the nature of the

material worked and the tool action. It must be remembered that low power examination is most efficient on well-worn artifacts, which display a tangible volume deformation and well-developed traces.

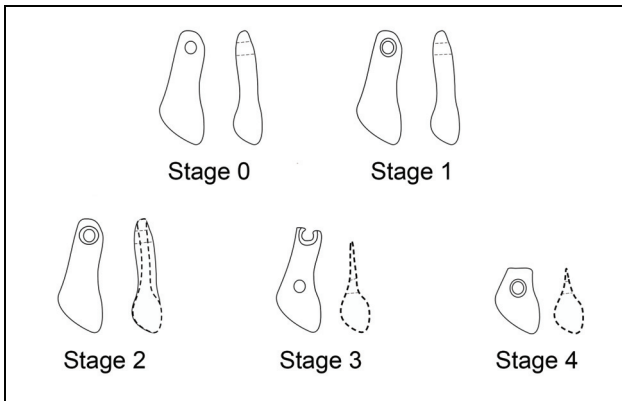


Figure 8: Chaîne d'usure realized on a series of archaeological perforated deer canines from Val-de-Reuil (Eure, France). From Sidéra 2002, figure 10 p. 224.

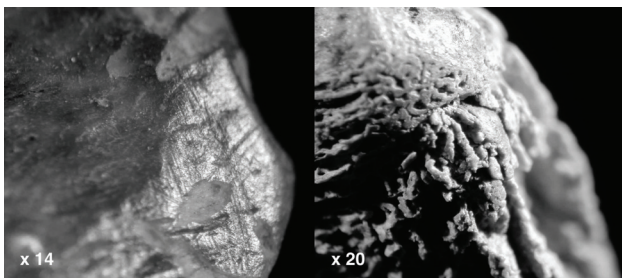


Figure 9: Different macro-wear on cutting edges from Drama (Bulgaria, Pr Lichardus, Sarreebruck University excavations). 1) chipping, smoothing, polishing and striations; 2) crushing with separation of bone fibers. Photos by I. Sidéra.

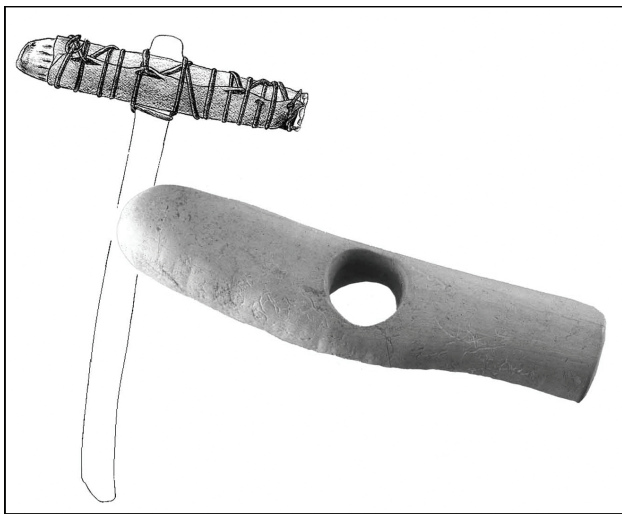


Figure 10: Hafting reconstructions and traces. Archaeological mattock from Boury-en-Vexin (Oise, France, R. Martinez-INRAP excavations) with "festons" all along the tool. These traces are due to the hafting apparatus, probably an envelope made of bark or hide, fastened around the tool with thongs, made to protect the mattock from breaking. The friction of the envelope has produced the feston, whose development is perhaps due to the inentional deep initial shaping traces. At the same time these traces reflect the long duration of this tool. Photos by I. Sidéra. Drawing by D. Thébault.

Micro-wear

High power examination is part of a complementary

and continuous chain of analysis. It uses the most common reflexion microscope with magnifications of 100x and 200x as lithic use-wear analysis specialists do, or SEM microscopy sometimes combined with residue analysis (see for example Aimar *et al.* 1998; Christidou 1999, 2001b; d'Errico *et al.* 1995; Legrand 2003, 2005b; Lemoine 1997; Olsen 2001; Peltier 1986; Stordeur and Anderson-Gerfaud 1985). Our equipment includes a reflexion microscope (Nikon Eclipses ME600) connected to a computer to acquire images via digital cameras (KS300 software and Axiocam, Zeiss) (fig. 12).

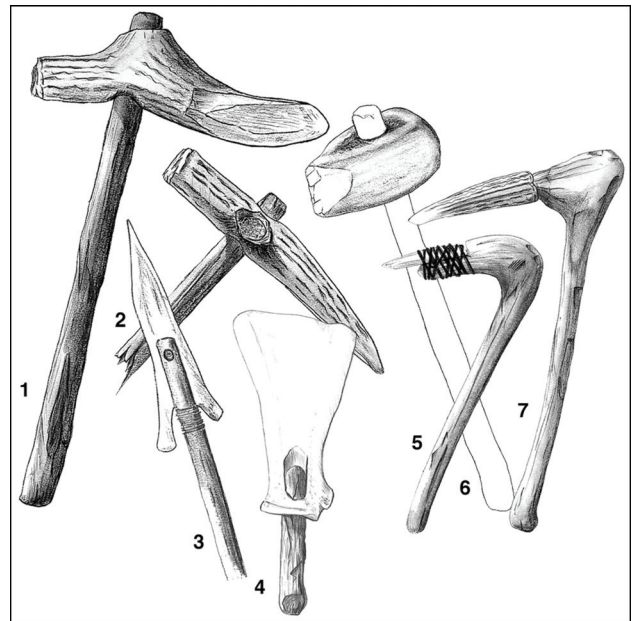


Figure 11: Reconstructions of different kinds of tool hafting. 1, 2, 4, 6 and 7) Hafts are mainly tenons directly fixed in perforated axes or scrapers; 3) haft is fixed by riveting; 5) the adze is attached to the haft. Drawing by D. Thébault.



Figure 12: High power equipment with image processing. Photo by I. Sidéra.

We will illustrate the significance of high power analysis through the examination of two experimental awls, both replicas of artifacts coming from the Khirokitia bone assemblage (Aceramic Neolithic, 7th millennium B.C cal., Cyprus) (Legrand 2005b;

Stordeur 1984). One awl was used to perforate fresh sheep hide (tool number 1), the other to perforate wet bark (tool number 2). Use-times were respectively 65 and 10 minutes. In both cases, indirect percussion was used. Microscopic descriptions are largely inspired by the terminology employed by R. Christidou (1999). Other criteria such as use wear were also considered (Legrand 2005b, in press; Sidéra and Legrand 2006).

When observed with the naked eye and at 15x magnifications, both awls exhibit the same smoothing

and polishing of the tip and the same use-development in three zones (fig. 13-1 and 14-1). The first zone is the tip area. It is characterized by the absence of manufacturing traces down to 2 mm from the tip of tool number 1 and approximately 7 mm from the tip of tool number 2. Numerous use-striations, which cross the polished surface, become clearly visible with a 32x magnification (fig. 13-2 and 14-2). They are longitudinal, quite long and parallel to the long axis of the awl. Some micro-pits are also observed. 2) Further down from the tip, use characteristics are the same as the ones described

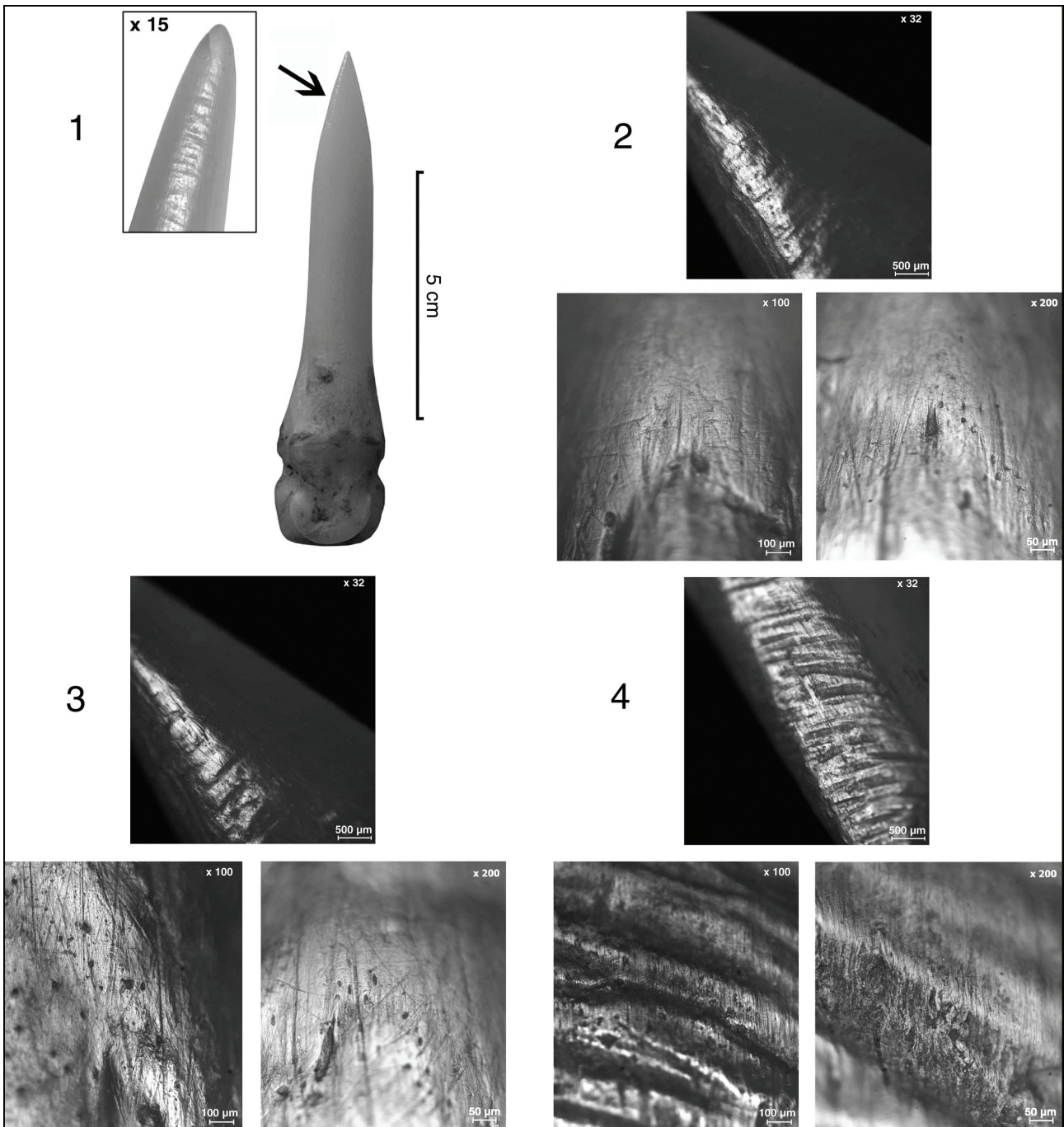


Figure 13: Macroscopical and microscopical features on experimental awl (number 1) created by fresh hide working. 1) whole awl and enlargement of the tip. 2) First zone of use on the tip. 3) Second zone. 4) Third zone of use. Experimentations and photos by A. Legrand.

above, except for the presence of smoothed manufacturing traces perpendicular to the long axis of the awl (fig. 13-3 and 14-3). On the third zone, the intensity of smoothing and polishing decreases as one gets closer to the limit of the use, which is located at 40 mm from the tip on tool 1 and 19 mm from the tip on tool 2. Wear affects only high points of the surface, and rough-bottomed manufacturing traces are clearly visible (fig. 13-4 and 14-4).

This wear development is still clear at high magnifications but differences in use-wear patterns appear between both awls. At 100x magnification, the

examination of the tip of tool number 1 shows an irregular topography due to the variety in dimension and direction of the depressions, striations, micro-pits and craters. At 200x magnification, the high points are smoothed and varnished with a domed profile (fig. 13-2). Numerous fine (1 µm), short or long, superficial and continuous striations are observed. Other striations are broad (3 µm), long, deep and continuous. Their bottom end is rough but more or less unaffected by polish. In both cases, striations show smoothed edges. Some circular rough-bottomed craters (from 9µm to 27µm in diameter) are also observed. These can be similar to the broad

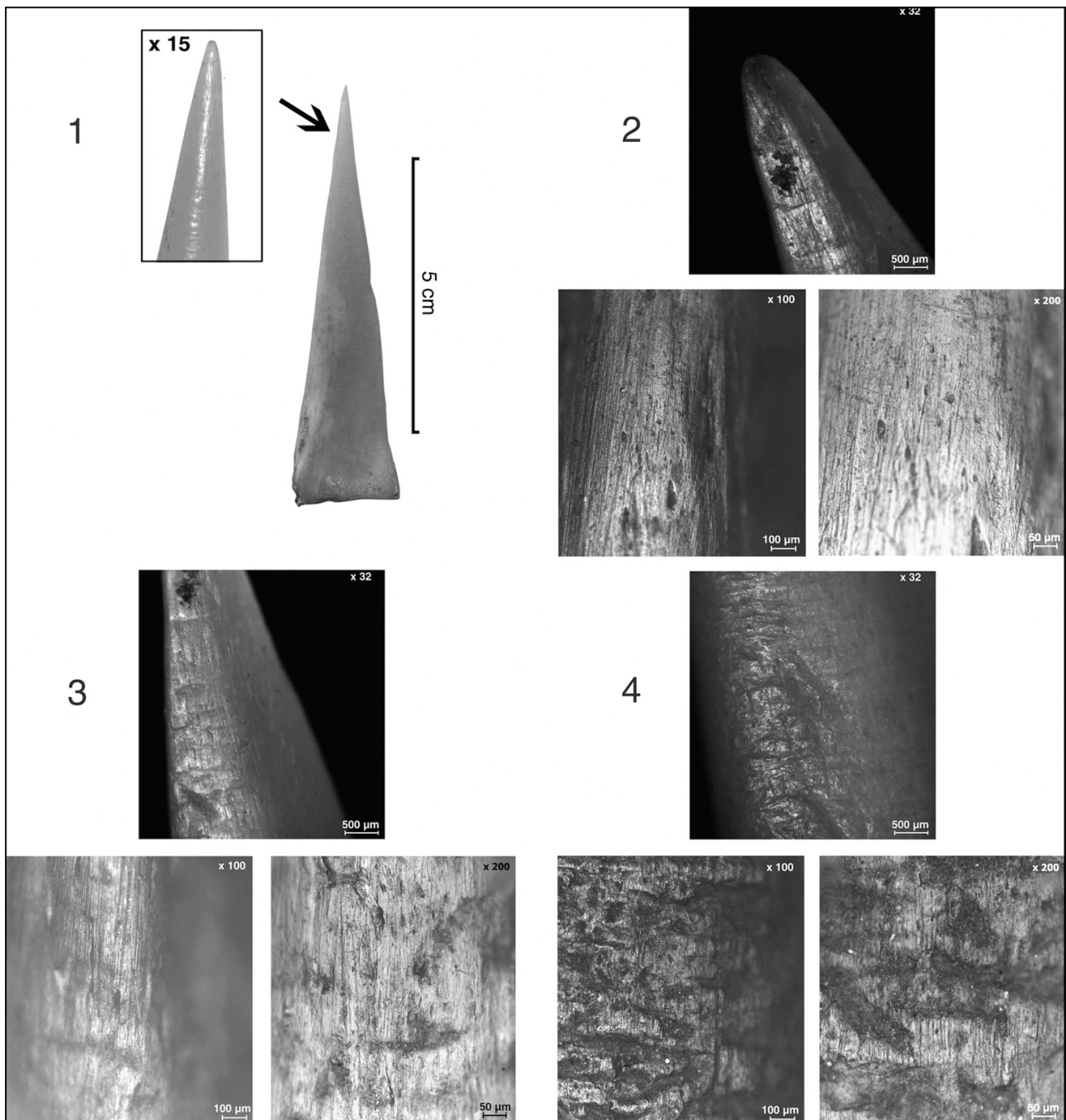


Figure 14: Macroscope and microscopical features on experimental awl (number 2) created by fresh bark working. 1) whole awl and enlargement of the tip. 2) First zone of use on the tib. 3) Second zone. 4) Third zone of use. Experiments and photos by A. Lørand.

striations, more or less polished with smoothed edges. All these depressions, which cross the high points, give them a certain grainy aspect.

Further from the tip, the micro-wear features are quite similar to those observed on the tip area (fig. 13-3). Use-striations, micro-pits and craters can affect the highest smoothed manufacturing striations. Craters are more numerous than in the first zone.

In the last zone, rough-bottomed manufacture striations are very evident. They cannot be confused with those resulting from use due to their width and depth. The high points are smoothed and are still crossed by numerous longitudinal use-striations (fig. 13-4). However, craters have disappeared.

At 100x magnification, the tip of tool number 2 shows a regular topography due to a flat, bright and grainy surface covered by a dense network of unidirectional striations. At 200x magnifications, these are relatively fine (1 µm), long, superficial and continuous (fig. 14-2). Only few transverse, superficial and fine striations are present. Frequent micro-pits and craters with various dimensions (from 9µm to 34µm) are observed. The smaller craters are partially affected by the polish, but all have smoothed edges.

Further down from the tip, where manufacturing striations appear, the surface is marked by the same micro use-wear (fig. 14-3). However, rough-bottomed craters with smoothed edges seem to be more numerous than in the tip area.

Then, in the last worn zone, the topography appears irregular because of deep, large and rough-bottomed manufacture striations and depressions, which cover the major part of the surface (fig. 14-4). The same longitudinal use-striations cross the highest points, which are quite smoothed and varnished.

Here, clearly, high power analysis enables us to characterize use-wear. Differences between the two awls, despite the difficulty in distinguishing macro use-wear, appear in the aspect of topography and of the high points, the morphology, the dimensions and direction of the striations as well as in the nature and number of the non-linear depressions (micro-pits and craters). It must be remembered that original surface textures have an influence on the formation and the distribution of the wear (see for example Cristiani and Alhaique 2005; Christidou 1999, 2004; Christidou and Legrand 2005). This must be taken into account to have a better understanding of the micro use-wear process and this should lead us to undertake new researches in the field of tribology.

Conclusion

Dealing with numerous criteria and a variety of investigations, the functional approach needs cooperation between scholars. Wear analysis is based on a sum of analytical criteria which lead progressively to the identification of the function of the bone tools. We now try to collaborate on a continuous magnification chain of examination, based on experiments. Understanding interactions between macro- and micro wear analysis will bring, we hope, in the future, a use-wear analysis model, which will enable us to identify the majority of bone artifact functions. Macro-wear analysis deals mainly with "volume deformations" and, thus, with well-used artifacts involving use-wear processes. High power analysis is necessary if "volume deformation" is lightly developed. As a result, surfaces must be enlarged for observing polish and striations details. This is particularly true for tools such as awls, needles, hooks, spoons, etc. which are worn by friction. Sometimes chemical analysis can help to identify a tools function. Computer use is valuable for this purpose and has changed our way of working. It permits us to quantify micro-phenomena and create image banks. This will involve more frequent contact between researchers than in the past and will be of great benefit to technological and use-wear research.

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