EDGE-WEAR ANALYSIS IN ARCHAEOLOGY

The current state of research

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ABSTRACT

The analytical method by which macroscopic and above all microscopic traces of wear are studied, in order to reach conclusions about how flint tools were employed, has been applied with varying success in western archaeology since the1960s. Two main approaches can be distinguished, where each approach examines somewhat different wear traces using different microscopic equipment. The scanning electron microscope provides a complement to these. The problems associated with each approach are discussed, and the article concludes with a brief description of examples of how the method has been used in archaeology.

Introduction

The analytical method by which macroscopic and above all microscopic traces are studied in order to reach conclusions about how flint toools were employed, has been applied with varying success in western archaeology since 1964, when the English translation of Sergei Semenov's book "Prehistoric Technology" was published (Semenov 1964). This method was revolutionary in as much as Semenov was able to show that it was possible to reach conclusions about prehistoric tool use by systematically registering striations and microdamage on the tools.

The next major development in the method occurred in 1977, when Lawrence Keeley, in an article published in the journal "Scientific American" (Keeley 1977), claimed he could identify not only *how* but also *on what material* prehistoric tools had been usen. With this advance, archaeologists began to believe that the road to detailed knowledge about prehistoric activities and economy lay open. However, the optimism which characterized advocates of the so-called "Keeley method" in the beginning of the 1980s has subsequently been tempered with a large measure of caution, as more and more microwear analysts have discovered factors which distort any direct relationship between the wear patterns on an artifact and how it was used. In spite of this, however, developments in the method have continued, and microwear analysis is still regarded as a promising means for reaching a better understanding of one of our major categories of archaeological source material: stone tools.

Definitions

The analytical method which is the subject of this article is known by a variety of names. These include edge-wear analysis, use-wear analysis, traceology, and microwear analysis. In general, the method entails the systematic registration of use-damage on stone tools. The magnitude of the damage and the aim of the study dictate what magnification level will be chosen; in this article we will be dealing primarily with damage visible at the microscopic level.

Microwear analysis has primarily two major approaches, each with its own particular advantages and disadvantages (fig 1). In many cases these approaches are used to complement each other.

Approaches to Microwear Analysis

"Low power approach"	*"High power approach"*
* stereomicroscope	* incident light microscope
* magnifications of 10 to 60 x	* magnifications of 100 to 300 x
* examines primarily - mechanical wear such as striations, microflaking, abrasion	* examines primarily - polish - residues - also mechanical wear

Fig 1. Approaches to microwear analysis.

The "low power approach" was that developed by Semenov. This involves the use of a stereomicroscope and 10 to 60 magnifications. Using this approach, the placement and appearance of primarily mechanical wear traces are examined and registered. The direction of striations can often be used to identify the direction of use (fig 2), while the appearance and location of microscarring can be used to identify how the tool was used and on what general category of object material. In addition to Semenov (1964), other examples of this approach are Tringham et al. 1974, Odell (1977), Odell & Odell-Vereecken (1980) and Knutsson (1978).

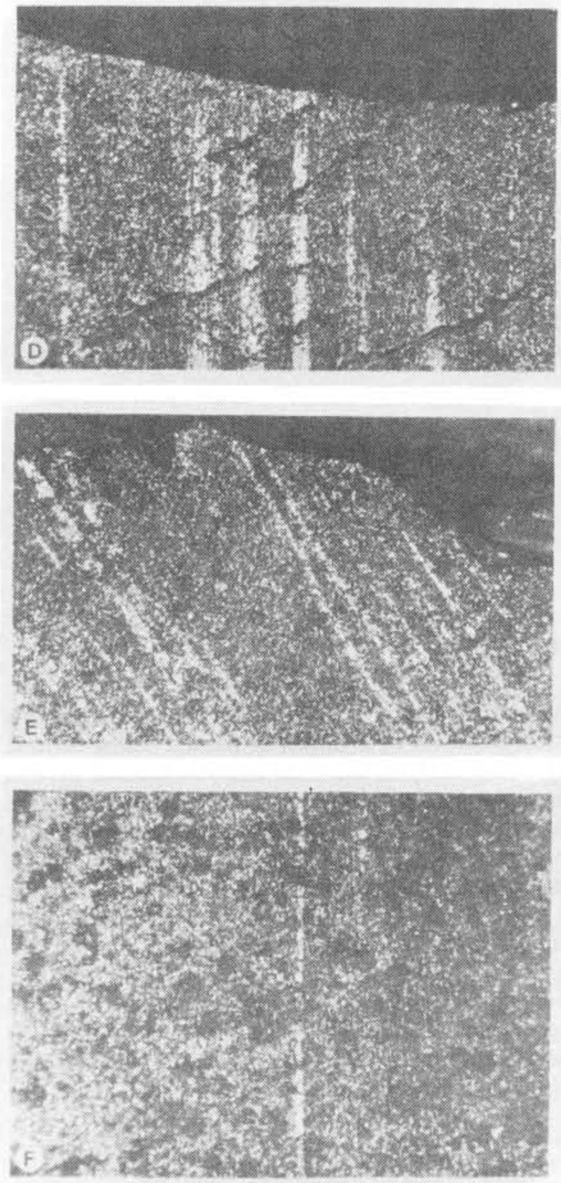

Fig 2. Striations and breakage patterns on lithic projectile points. From Fischer et al. 1974, fig 29.

In the "high power approach", as developed by Keeley, an incident-light microscop is used with magnifications of 100 to 300. Keeley claimed that material specific polishes arise when certain stone materials come into contact with other materials (Keeley 1980). The processes which cause this are still not fully understood (e.g. Unger-Hamilton 1984). The high-power approach also looks for striations to understand direction of motion, and in many cases it has been possible to identify residues on tool edges using this method (e.g. Shafer & Holloway 1979).

As a complement to the above approaches, the scanning electron microscope can be used to look more closely at specific aspects of usewear. Since polish identification relies on reflection of light, the SEM has not proved particularly helpful for polish identification (fig 3). It has been used with success in penetrating the causes of structural damage such as striations and microscarring (fig 4). Thanks to good depth of field and high quality of focus, the SEM has been particularly useful when examining and identifying residues on tool edges (fig 5)(Anderson 1980, Anderson-Gerfaud 1986, Hurcombe 1986).

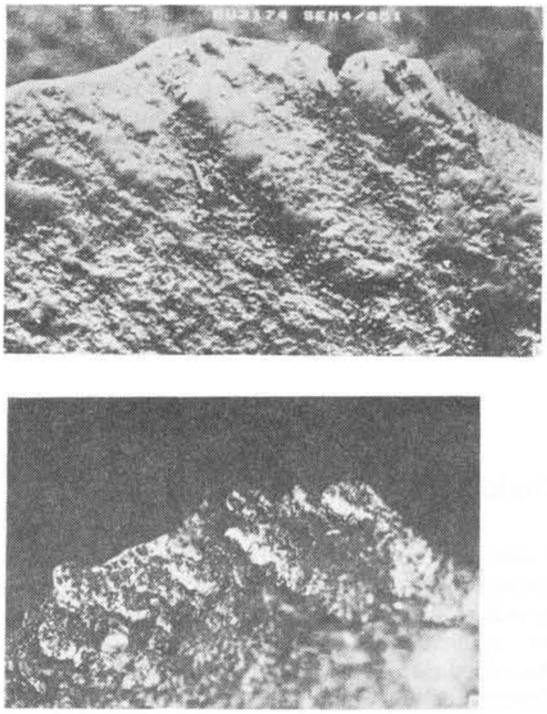

Fig 3. Photomicrographs of the same area of antler polish. a) SEM microhgraph, b) oblique incident light micrograph. From Cook & Dumont 1987, fig 7.2.

Fig 4. SEM photograph of replica surface of mechanically ruptured edges on a quartz flake. Scale: 70 my. From Knutsson 1988a, fig 67.

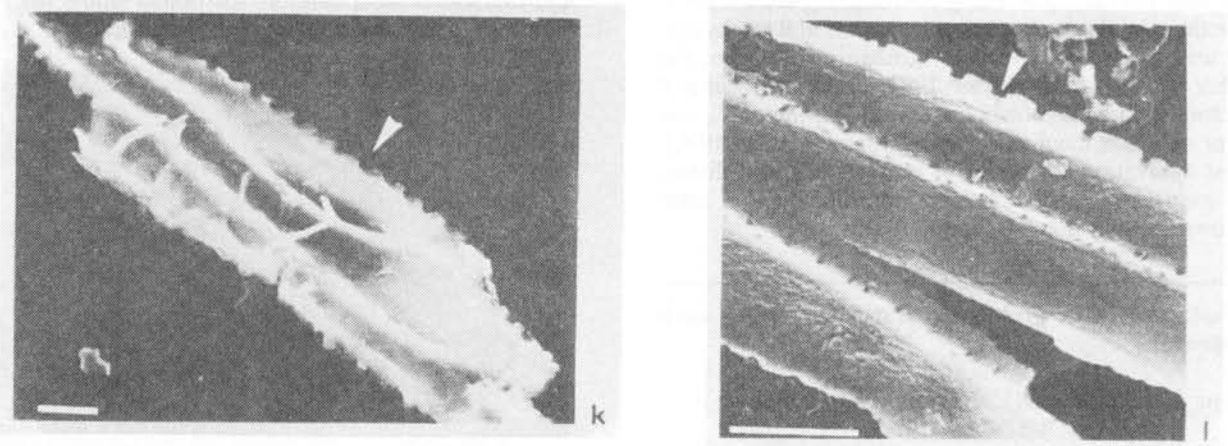

Fig 5 SEM micrographs of residues. k) Plant residue (Gramineae family) on the edge of a Middle Bronze Age flint "sickle" from Denmark. l) Reference specimen of a stem fragment of a Gramineae. Scale = 10 microns. From Anderson-Gerfaud 1986, Plate 19.

In order to relate the damage seen on prehistoric tools to their probable use, a knowledge of the physical laws which govern for example the formation and appearance of microwear (Odell 1981), as well as a reference material consisting of carefully controlled experiments, are necessary. Because of the fact that the causes of use-polish on stone tools are still poorly known, the only way to be able to relate polish to use is through the medium of comparison with an experimental reference collection. Such a collection must be specific for the archaeological situation one wishes to study. The experimental reference collection must correspond to the archaeological material in at least the following characteristics:

1. tool raw material
2. material worked
3. manner of use
4. duration of use
5. absence or presence of grit during use (Brink 1978)
6. post depositional factors (see below)

What information can be gained from each approach?

In most analysis, best results are reached when both of the two approaches described above are used, since each yields somewhat different sorts of information (fig 6). Because of the low magnifications required in the low power approach, it is particularly suitable for the initial sorting of the material to be studied. For the same reason, this approach is to be preferred when searching for the contact edge(s) on the artifact under study. The low power approach can usually be used to identify tasks ("cutting", "scraping" etc.) and even to identify category of object material (e.g. "hard", "soft", "elastic", etc.).

According to its advocates the main advantage of the high power approach over the low power approach is that it is possible to identify object material with greater precision using the high power method. Thus identifications of the type "hard wood", "bone/antler" or "dry hide" are often seen. The high power approach can also be used to identify the used portion of an artifact, although due to the small area visible in the microscope it is hardly realistic to try to scan entire surfaces of artifacts using only this approach. Since polish development is apparently related to duration of use (see below), it has sometimes been claimed that it should prove possible to use the high power approach to make statements about how long a particular artifact has been in use.

What Information Can Be Gained?

"Low power approach"	*"High power approach"*
• identification of the used edge • identification of how the tool was used ("cutting", "sawing", etc.) • identification of general category of worked material ("very hard", "hard", "soft", etc.)	• identification of the used edge • more exact identification of worked material ("hard wood", "dry hide", "antler", etc.)

Fig 6. What information can be gained from each approach?

What are the problems associated with each? (fig 7)

One of the major problems connected with both methods is finding a means of objectively registering and classifying use-wear. Various methods have been tried for registering low power observations, including a) counting the number of different types of microflakes per unit of edge (e.g. Olausson 1983b), b) classifying types of damage patterns according to a nominal system (e.g. Seitzer 1978), or c) using linear measurements of edge-wear categories (e.g. White 1969). In most cases, however, results are reported by microphotographs and descriptions, sometimes accompanied by drawings, of typical examples of the wear patterns one is describing (e.g. Odell 1981).

Because the rules governing microflaking are the same whether the flaking is caused by intentional retouch or by use, it can be difficult to distinguish one from the other (Odell 1981, Moss 1983). Post depositional factors such as cryoturbation, wind washing, etc., can alter or erase mechanical wear traces (Stapert 1976). Post excavation treatment of artifacts can also distort or even remove striations or microflaking - a term known as "bag wear" (Gero 1978).

What are the problems associated with each approach?

"Low power approach"	*"High power approach"*
* lacks objectivity	* lacks objectivity
* difficult to distinguish use damage from chipping due to other causes: - manufacture - trampling - post excavation handling - "bag wear"	* time-consuming * polish formation and appearance is *not* material specific (see fig 10)
* reworking of tool edge can remove edge damage	
* use identification is not exact	

Fig 7. What are the problems associated with each approach?

Another problem particular to the low power approach is that mechanical use damage is usually located at the working edge. Such damage will therefore be the first to disappear if the tool edge is resharpened. Since polish is usually more invasive, this is not as much of a disadvantage in the high power approach (Cook & Dumont 1987).

Finally, a problem common to both methods is that as yet no one has succeeded in demonstrating exact agreement between a particular and discrete damage pattern on an archaeological artifact and a single, well-defined use. In fact, we seem no nearer to this goal than we were ten years ago (Seitzer 1978:57).

Attempts to test the objectivity of the method have been made by subjecting it to "blind tests" on a number of occasions. In such exercises, experimentally manufactured tools whose exact use are known are presented to a number of edge-wear analysts for identification. Rates of correct identification of the object material can vary from 26% to 82% (Keeley & Newcomer et al. 1986; Unrath et al. 1986; Moss 1987; Bamforth 1988). Even the low power approach has been subjected to blind tests (Odell & Odell-Vereecken 1980). Two edge-wear analysts do not necessarily *see* the same wear pattern the same way; and what is more they may *interpret* the same pattern differently.

At least two methods for objectifying high power observations can be mentioned: *interferometry* and *texture* analysis. Interferometry has been applied to polish identification studies by Dumont (1987)(fig 8). This method enables one to measure very small topographical differences on a surface. However the method cannot be used where topographical variation is too great, such as on unused flint. For this reason the method is most suitable for polish study, where differences in surface topography are small.

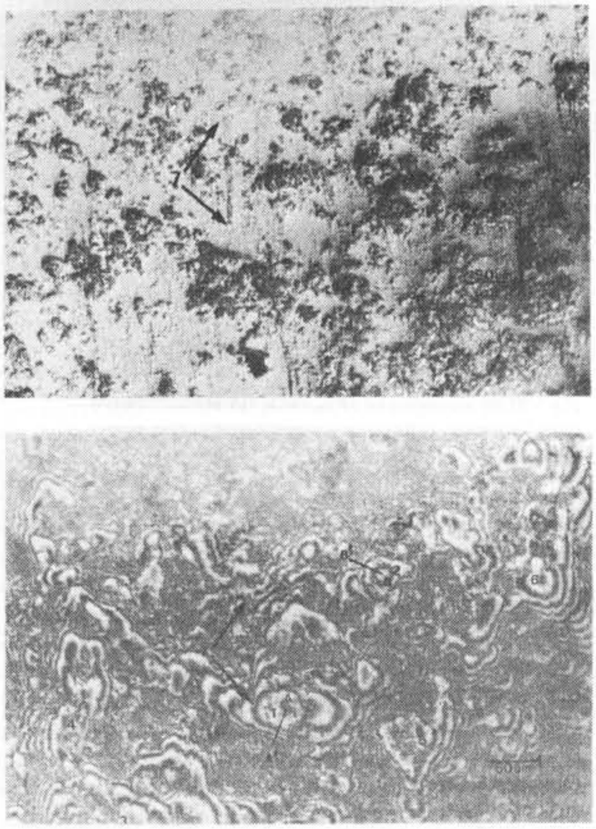

Fig 8. a) The interference pattern produced by the wood polish shown in b) From Dumont 1987, fig 12.1.

Grace et al. (1985), Newcomer et al. (1988) have been working with a method known as texture analysis. This technique was developed for analysing surface topography from photographs of for instance cloud structure or moon landscape. The method sees textures as differences between grey tones in a black-and-white picture. A microphotograph of the surface one wishes to study is digitalised in a scanning digitiser. These values are then converted to grey level scores, which can be statistically manipulated. In this way it is possible to note statistically significant similarities and differences between polish surfaces (fig 9).

Another disadvantage with the high power approach is that it is time-consuming. Because of the method's lack of objectivity and because it is virtually impossible to successfully reproduce polish photographically, the method must be learned directly from another microanalyst. Months of work at the microscope are usually required before the student is prepared to use the method independently (Knutsson & Karlsson 1983:33). Another aspect of this problem is the fact that it is necessary to build up a reference collection for the archaeological material one intends to study. This too is a time-consuming process. Finally, it takes longer to analyze each object using the high power approach, due to the high magnifications which mean that only a tiny portion of the artifact is visible in the microscope at any one time. Shea (1987:45) has estimated that it takes an average of 7.6 minutes to analyze a tool using the low power approach, while 20 to 30 minutes is required for the high power approach.

The most serious problem for the high power approach, however, is the discovery of various factors which mean that polishes cannot be regarded as being directly material specific (fig 10). These factors are: tool raw material, duration of use, and post depositional surface modification.

Keeley himself was cautious about claiming that polish formation on one raw material could be used to infer use on tools made of other lithic materials (Keeley 1980:169).

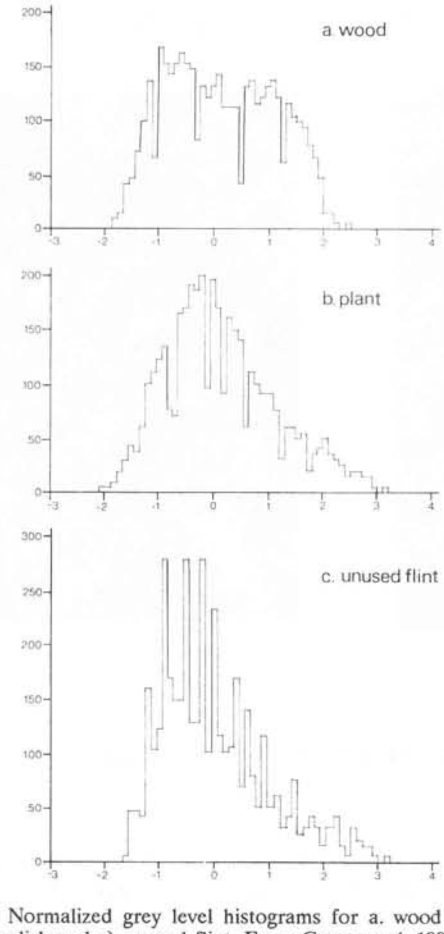

Fig 9. Normalized grey level histograms for a. wood polish, b) plant polish and c) unused flint. From Grace et al. 1987, fig 8.7.

As more research is done with other lithic materials, it has become clear that raw material characteristics can affect the formation and appearance of polish. For this reason, it is important that experimental tool raw material exactly correspond to the raw material of which the archaeological artifacts are made. In addition, different raw materials react differently to post depositional processes, which also affect polish appearance (see below). Finally, polish, being light reflective, can be difficult to see on transparent or semi-transparent materials such as quartz and obsidian (Sussman 1985). It has also become evident that polish intensity is related to duration of use. Poorly developed polishes from a tool in the early stages of use can therefore be difficult to identify (Shea 1987, Hurcombe 1988). Berry and Bamforth have noted (1989:46) that if used long enough under the right conditions, all cryptocrystalline tools will pass through stages of light to heavy polish. In addition, polish from use on softer materials does not form as quickly as polish from use on harder materials (Knutsson 1988b:45-46). Therefore, identifications of use on soft materials will probably be underrepresented in relation to identifications of use on hard materials in any archaeological collection. For this reason, it is dangerous to make statements about the relative importance of identified tasks in a collection.

High Power Approach

Factors (other than material worked) which *also* influence polish appearance:

* tool raw material
* duration of tool use
* chemical and mechanical post depositional surface modification
* treatment for microscopic examination
* magnification

Fig 10. Factors which disturb the correlation between use and wear.

Several papers given at the Tübingen use-wear conference in 1985 presented results which had serious repercussions for the high power approach (Owen & Unrath 1986). Several researchers there noted the effects of chemical and mechanical post depositional surface modification (PDSM) on polish appearance. In a subsequent paper published in 1988, Plisson and Mauger reported the results of a series of experiments to test these processes. They found that acidic solutions did not alter polish. However, basic solutions such as NaCl or NaH_2 could alter or even erase polish. What was worse, they found that calcium oxide can remove polish without changing the surface of the flint and without producing any noticeable patina (Plisson & Mauger 1988). Thus, one runs the risk of identifying as unused a tool which in fact has been used and then subject to chemical weathering.

Whereas chemical post deposition processes can have a highly negative effect on the search for polishes, they can instead have a positive effect on mechanical damage, at least on certain raw materials. Kjel Knutson has called this "the quartz paradox". He notes that post depositonal surface alteration can actually *facilitate* the identification of the used edge and method of use on quartz, because it enhances the mechanical features by etching (Knutsson 1988a:122) (fig 11).

There are also mechanical post depositional processes at work which can alter or obliterate use polish or microwear on archaeological artifacts. In a series of experiments designed to reproduce such processes in the laboratory, Levi Sala found that mechanical processes can create, obliterate or alter any of the wear types commonly registered, including polish, striations, and edge damage (Levi Sala 1986)(fig 12).

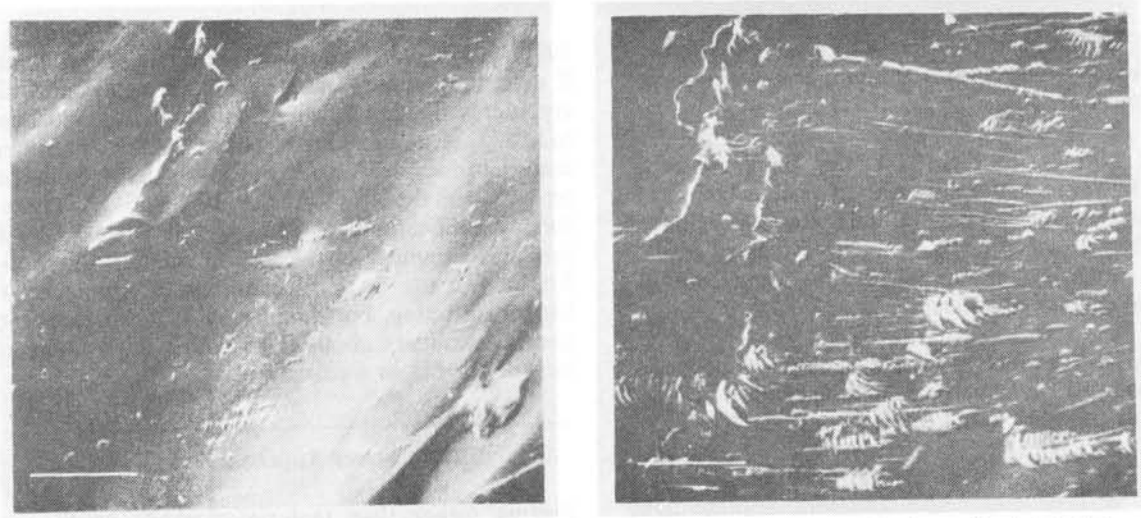

Fig 11. Replica surface of quartz flake used to scrape fresh elk bone for 15 minutes. a) before and b) after etching in NH_4HF_2 for 10 minutes. From Knutsson 1988b, fig 83.

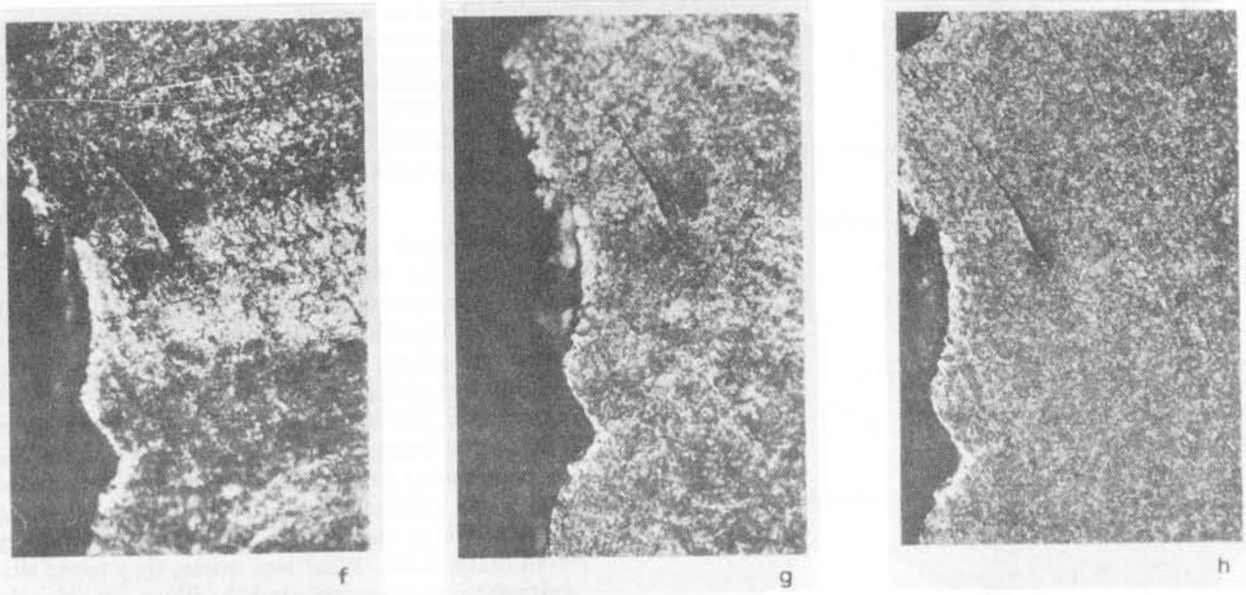

Fig 12. A tool used to whittle reeds for 10 minutes. f) before shaking. g) after shaking for 10 minutes. h) same after 47 hours of shaking. Polish has been almost totally obliterated. From Levi Sala 1986, Plate 27.

The PDSM problem has serious consequences for both the high power and the low power approaches. First of all, it means that we cannot assume that there is a direct link between damage/polish seen on experimental tools and that seen on archaeological examples. Rather, extensive work is required to establish the effects of possible PDSM every time an edge-wear study is to be carried out. Secondly, we must realize that we cannot use the absence of a certain polish type in an assemblage to argue that the activity the polish type represents did not occur there. Third, PDSM can change the appearance of polishes and can therefore result in misinterpretation of object material (e.g. van Gijn 1986). PDSM means that it is not defensible to rely solely on high power studies of polish when carrying out a functional study. All possible criteria must be included in such an analysis:
mechanical wear, polish, morphological characteristics, raw material, etc. In practice, most researchers in fact have recognized this, and analysis carried out today register both observations at the macroscopic level and those visible at various magnifications (e.g. Newcomerr et al. 1988; Grace 1989).

Yet another difficulty tied to the high power approach is the discovery that cleaning procedures used prior to examination under the microscope can also alter polish appearance. Various cleaning techniques are used, including detergent, ultrasound, NaOH and HCL. Moss (1986) showed in a series of convincing micrographs how variations in cleaning techniques can change polish appearance. She also noted here that different levels of magnification also influence the polish picture and may influence identification of use (fig 13).

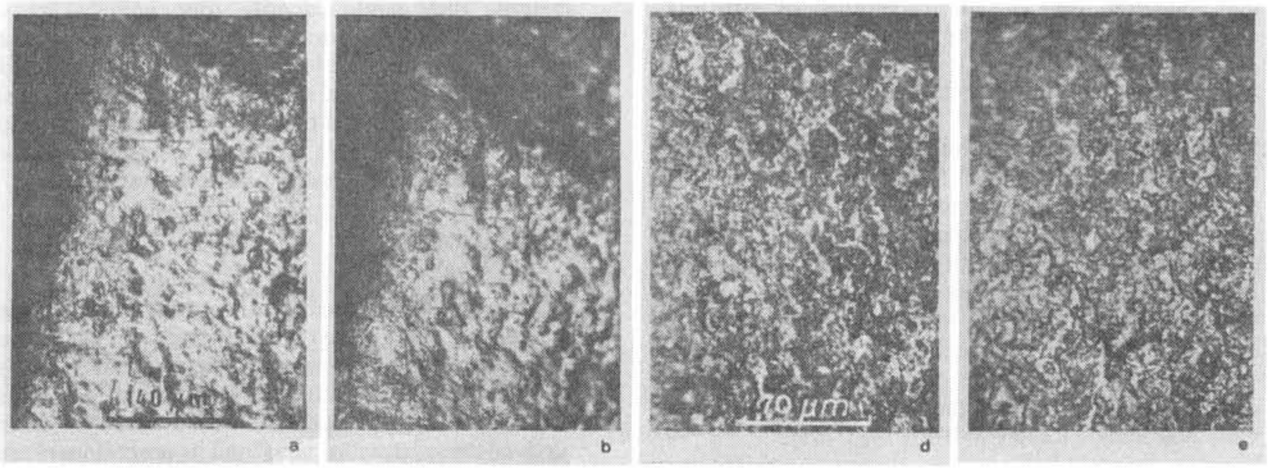

Fig 13. A tool exhibiting wood polish. a) the ventral edge after cleaning in aceton. b) The same place after 5 minutes in a 15% NaOH solution. d) The same wood polish. e) the wood polish after 1 hour in 33% solution of HNO_3. From Moss 1986, Plate 22.

Applications in archaeology

What sorts of questions is it possible to answer with the help of microwear analysis? As is probably true of any method which is fairly young, much of what is written today about microwear analysis deals with ways to improve the method. In addition, however, there are many examples of ways in which the method has been used to answer questions of archaeological interest. Several of these examples will be discussed below.

1. *Tool use - practical or symbolic function.*

This sort of study represents the most elementary level of microwear analysis. The aim here is simply to identify damage which only arises through practical use, in order to determine if certain types of artifacts were not practically used but rather had symbolic or prestige value. A microscope may not be necessary for such an analysis, which can include studies of tool breakage or wear visible with the naked eye (e.g. Olausson 1983a).

Another common application of microwear analysis at an elementary level has as its goal an appendix listing the functions it has been possible to identify in the collection examined. This sort of application is reminiscent of lists of osteological identifications. The time and effort spent are poorly invested if the results are not integrated into the rest of the analysis.

2. *Information from debitage.*

When one considers that debitage is often numerically and volumetrically the largest part of our stone age collections, and that the sharpest possible edge is found on a simple unretouched flake, it becomes clear that microwear analysis is a promising means of gaining information from debitage. Knutsson used both the low power and the high power approaches in his exa-mination of debitage from flint and quartz units at the Bjurselet site in northern Sweden (Knutsson 1988a). The microwear analysis contributed information about which flakes were chosen for use, and about the general kinds of functions which went on here.

3. *Does form follow function?*

This is a common problem which can suitably be addressed through edge wear analysis. Many examples of such studies can be found. For instance, in a high power analysis of the morphological category "scrapers" from the middle neolithic Funnel Beaker Culture site of Sarup, Jeppesen found that 97% of the tools classified as scrapers had been used as scrapers (Jeppesen 1984). H. Knutsson used a high power approach to examine a tool category called "flake axes". She found that this morphologically homogeneous category encompassed several functional categories (Knutsson, H 1982).

4. *Site activity analysis.*

Microwear analysis can be used to identify artifact use and thereby the activities carried out at a site (Odell 1977). When the assemblage is a large one, time constraints may be a problem and make sampling necessary. Here of course one must avoid the trap of assuming that an apparent absence of evidence for certain activities means they were not carried out at the site. In addition to the causes cited above for wear patterns being absent or altered, there are the possibilities of tool curation and resharpening to be considered here.

Another fairly common application of microwear analysis is identifying the location of possible activity areas at a site. Here the locations of tools, whose function has been identified through microwear analysis, are plotted on plans together with debitage and other remains. Madsen and Juel Jensen (1982) used this approach in a study of an Early Neolithic settlement site at Mosegården, Denmark. They attempted to demonstrate different activity areas by plotting features, soil coloration, artifact distribution, and function for certain categories of artifacts examined by the high power method.

5. *Evolution of human activities.*

Keeley and Toth (1981) analysed 54 artifacts from Koobi Fora, a site with 1.5 million year old lithic artifacts. They found evidence for meat cutting, plant working, and wood working. They conclude "We should, therefore, be able to document the successive appearance of activities, such as animal butchery, wood working, hide preparation, bone- and antler-working, throughout the entire Palaeolithic. Such investigations will enable archaeologists to discuss with greater certainty crucial aspects of the behavioral repertoire of early hominids" (Keeley & Toth 1981:465).

6. *Behavioral archaeology.*

Microwear analysis can also shed light on problems such as retooling, tool curation, life cycle and tool lifetime. For instance, Cahen et al. (1979) used microwear analysis and refitting in their investigation of Meer, a preboreal site in Belgium. No visible structural remains were evident here, but 16,000 flint artifacts and flakes were found. By means of a combination of refitting and high power microwear analysis, they could identify four activity areas. Through this combination of refitting and microwear analysis it was possible to follow the life cycles of six flint nodules found on the site, and their products. The authors concluded that the occupation had been brief and that the tools had been manufactured for specific uses and discarded on the site after use.

Conclusions

Like many other analytical methods, microwear analysis has experienced a development in which the initial stage of uncritical enthusiasm is followed by doubts, as more and more methodological problems arise. However the method would seem to have survived these "growing pains" and its practitioners are moving towards a more realistic appreciation of what the method can and cannot accomplish. We can only hope that research in the area continues to strive for a greater understanding of those factors which influence the damage patterns we see on our prehistoric lithic artifacts. When employed with discretion and rigor, microwear analysis should enable us to make concrete statements about artifact function and thus, to assist in the understanding of prehistoric process.

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