Method in Microwear Analysis

Prehistoric Sickles and Other Stone Tools from Arjoune, Syria

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Preface

This work is based on a thesis written as a result of research carried out at the Institute of Archaeology, London, between 1981 and 1984. The research was funded by the Department of Education and Science of Great Britain.

My research dealt with experimental "high-power" microwear analysis. This approach to the functional analysis of stone tools is comparatively new and, in my opinion, a great deal of research still needs to be done. Although I am fully aware of the innovative quality and importance of work by other researchers, I have sometimes found myself in disagreement with them. I expect (and hope) to be disagreed with in turn.

Since the completion of this thesis in 1984 I have considered a number of the problems it addresses in greater detail. Much other work has also been done on this subject. For obvious reasons it has not been possible to take account of that work here.

I would like to thank the following: Dr. Mark H. Newcomer for his expert guidance and his reading, discussion and correction of the manuscript; Peter Parr for providing access to the material and moral support; Christopher Bergman for his generous help with the manufacture of tools and experimentation; Gordon C. Hillman for his practical help and advise on the botanical aspects of this subject; Jonathan Moffett and Peter Duckworth for their help with the computer system; Chris Clayton for his help with some of the geological aspects of this subject; Peter Dorrell for his never-ending good spirits.

I would like to thank the following for their help in various ways: Prof. Ofer Bar-Yosef, Dr. John Bryant, Michael Charles, Susan Colledge, Lorraine Copeland, Joan Crowfoot Payne, John Dumont, Nick Barton and others at the Institute for Quaternary Research, Oxford, Afif Dakermanji, A.S. Gale, Dr. Ian Graham, Phil Harding, Anna Kersten, Dr. M. Kislev, Christopher May, Dr. Robert Miller, Arlene Miller-Rosen, Naomi Nicolas, Dr. Peter Reynolds and staff at Butser Ancient farm, Simon Richardson, Dr. Don Robins, Richard Whitcombe, Christine Wilson, and the Microwear Research Group at the Institute of Archaeology, London.

Most of all I am grateful to my sons, Felix and Ferdy, my mother and John Hope Mason for their patience, encouragement and support.

Part I. Theory and Method of Microwear Analysis

Introduction

At the beginning of my research into microwear analysis in 1980 I did not think that I would have to write a substantial chapter dealing with theory and method: the principles and procedures seemed to have been established over the previous ten to fifteen years.

From the middle of the nineteenth century research into functional analysis of stone tools was carried out through ethnographic analogy or use-wear study with or without experimentation by observation with the naked eye or the magnifying glass.(For a detailed and comprehensive review of research into functional analysis of stone tools the reader is advised to turn to Vaughan (1981, pp. 1-76).) This research was revolutionized in 1964 when the work of Semenov, begun in the 1930s, became available in an English translation. Semenov carried out a comprehensive experimental program and used high power microscopy in order to identify tool function by comparing wear traces (polish, striations and edge damage) on experimental tools with those on prehistoric tools (Semenov, 1964). Keeley (e.g 1976, 1980) developed this method by focussing on one aspect, the polish, to the extent that it seemed possible to identify with considerable accuracy the material on which the ancient tools had been used. A blind test carried out by Keeley and Newcomer (1977) seemed to demonstrate the viability of Keeley's method. Similarly Tringham et al. (1974) carried out a study, focussing on another aspect, the formation of edge damage, and again the viability of that approach was tested by Odell and Odell- Vereecken (1980) with claims of some success. Many microwear analyses have been carried out in recent years, notably the PhD theses of Anderson-Gerfaud (1981), Vaughan (1981) and Moss (1983), all of whom concentrated on Keeley's"High Power Approach"in which polishes were observed. Anderson-Gerfaud (Anderson, 1980, Anderson-Gerfaud, 1981, 1982, 1983) seemed to have solved the riddle of the mechanism of polish formation and also seemed to have found a method (by using scanning electron microscope (SEM) techniques) for identifying the exact worked material by means of residues from worked materials trapped in the polish on the surfaces of used stone tools. Most recently researchers have begun to investigate the possibilities of mechanisation of "High Power"microwear analysis (by computer digitization (Grace et al. , 1986) and by interferometry (Dumont, 1982). This illustrates the confidence with which microwear analysis has come to be regarded.

However, very soon after I began my research I found that there were a considerable number of problems with each of the methods referred to above: the"Low Power"method, i.e. the analysis of tool function by observation of edge damage, the"High Power"method, i.e. the analysis of tool function by observation of polish and striations, and the SEM method, i.e. the analysis of tool function by observation of residues on tool surfaces under the SEM. I also felt that, following a publication which seemed to contain evidence opposed to Anderson-Gerfaud's theory of polish formation (Masson *et al.* , 1981), I had to investigate the mechanism of polish formation, although such an investigation would be limited by the fact that I am not a chemist or geologist.

As a result this account of my work begins with the following topics: the principles of experimentation, the techniques of microscopy and photography, and the different kinds of wear traces and their value to functional analysis. Particular emphasis is placed on to Keeley's method of observation of polish and striations at high magnifications since this has stimulated many areas of discussion; attention is also paid to the theory of polish formation and to the viability of Anderson-Gerfaud's method in identifying worked materials from residues, to cleaning methods, and the effect of soil chemistry on polishes on ancient tools. Also discussed are the difficulties of transferring conclusions about experimental work onto archaeological samples. Finally, accounts of two series of blind tests are given, one designed to test experimental results on the same line as Keeley's and Newcomer's test (Keeley and Newcomer, 1977) and the other to test the efficiency of Keeley's method applied to archaeological tools.

Part I provides the basis on which my work in Part II is conducted.

Chapter 1 - Experimentation

It is now generally accepted by microwear analysts (e.g. Keeley, 1980, pp. 5-7, Anderson-Gerfaud, 1981, Vol.I, p.6-12, Vaughan, 1981, pp. 78-82, Moss, 1983, p.54-56) that an experimental program must not only be carried out before the wear traces on prehistoric tools can be identified, but also that such a program must be designed to be"...relevant a) to the ecological situation and other general conditions of the site and sites from which the study materials originate, b) to the likely worked materials (hide, bone, meat and so on), and c) to the rock types from which the archaeological implements are made"(Keeley, 1980, p. 5). Publications of earlier work in which inappropriate materials were used for experimentation have often been criticised: see for example Keeley's criticism of a paper by Ahler (1971) (Keeley, op. cit., pp.6-7).

Therefore, in order to carry out the appropriate experimentation it is necessary to investigate the environment of the present site of Arjoune and carry out experiments there, using local flint and materials in accordance with the evidence of finds excavated from the site. It is also necessary to investigate the past environmental conditions and resources, and the probable methods of resource exploitation and manufacture. The first task was easily achieved, i.e. the site was visited, local flint was collected and used experimentally on materials suggested by the archaeological evidence. The second task, investigating past conditions, proved more difficult: an analysis of the environmental evidence indicating past conditions and resources is still in progress (see Part II, Chapters 4-5). The last task, to"imitate" methods of resource exploitation and methods of manufacture, was the most difficult, if not an impossible task: the only comprehensive ethnographic studies which could be used as evidence are those available for areas in Palestine (Turkovski, 1969) and in Iran (Wulff, 1966). It is questionable to what extent one can rely on ethnographic evidence from completely different environmental areas and traditions, such as from Australian hunter-gatherers or American Indians, for an analysis concerning the environments and ways of life of Neolithic people from Arjoune in Syria. Keeley (op. cit. p. 6) in fact criticised a paper by Gould et al. (1971) who had examined wood-adzes used by Australian aborigines and suggested that European Mousterian scrapers had been used as wood-adzes, on account of their shape which was similar to that of the Australian tools.

Moss (op. cit., p.55) pointed out that one of the most problematic aspects of experimentation is the way in which stone tools are used, especially by inexperienced experimenters. In fact, opinion seemed to be divided amongst researchers and I found it difficult to decide as to whether experiments should be carried out mechanically with the variables held constant in order to investigate the process of wear trace formation (see Tringham et al. , 1974), or whether it would be better to"imitate"tasks, as far as known. Keeley (1980, p.8) stated:"If we wish to replicate wear traces found on prehistoric implements, then our implements must be used in a human, not a mechanical fashion."Vaughan (1981, pp. 95-96) attempted to combine the human and mechanical approach and stated that"...the controlled, limited version of the aboriginal tasks was conducted with the same materials and motions as would be the case if the researcher were performing it"for real"and not under"laboratory conditions".

As I could not see how Vaughan's combined approach would work out in practice I carried out two series of experiments - the first as mechanical as possible in order to investigate the theory of wear trace formation, the second, in what seemed the manner which was most natural and which would be closest to possible prehistoric usage, such as by using sickle blades mounted in a wooden handle. I will describe such procedures fully in connection with the archaeological tools (see Part II, Chapters 10-17).

Chapter 2 - Microscopy and Photography

Vaughan (1981, pp. 14-15) discussed the early research into functions of stone tools which was essentially conducted with the naked eye or else with a magnifying glass or a hand lens. In his work (1964) Semenov employed a binocular microscope with diagonally reflected external light which he used to view cracks, edge chipping and striations up to 180x magnifications, whereas he used a monocular microscope with perpendicular incident lighting for detailed examination of very small areas at magnifications of 300x to 500x or more (Semenov, 1964, p. 22). Since then microwear researchers have employed a variety of light microscopes: Tringham <u>et al</u>. (1974) and Odell (e.g. Odell and Odell-Vereecken, 1980) used a stereomicroscope with generally lower magnifications to view primarily the edge damage. Keeley (e.g. 1980) who concentrated on polishes viewed at higher magnifications used two microscopes: a stereomicroscope (Wild M 5) and a lab microscope (Wild M 20) with an incident light attachment (ibid, p.12) which he found vastly superior to the stereomicroscope (ibid, p. 13). Vaughan (op. cit. p.81) used only one metallurgical microscope (Wild M 50). Moss (1983, pp.79-80) discussed the fact that researchers such as Keeley, Anderson-Gerfaud, Vaughan and herself used similar microscopes - the Wild M 20 or M 50, the Leitz Metallux 2 or the Olympus Vanox microscope, all with magnifications ranging from about 35x to about 360x (in the case of the Olympus Vanox 50x to 400x), all with incident light and bright field illumination - and that therefore results were comparable.

I used the Olympus Vanox microscope because I had access to one and found it easy to use. However, because of the small distance from the stage to the lens, in cases where prehistoric tools were large, I used the Wild M 20. I did find that using different microscopes, even two microscopes of the same model, altered my perception of wear traces slightly but not to the extent that observations were not comparable. The reason for this optical difference is unclear to me.

Anderson-Gerfaud (Anderson, 1980, Anderson-Gerfaud, 1981, 1982, 1983), followed by other researchers, e.g. Mansur-Franchomme (1983), studied the mechanism of polish formation and residues on used flint surfaces under a scanning electron microscope (models: Siemens and Cameca) mostly at an accelerated voltage of kv 20 and at magnifications of 500x to 10,000x (Anderson-Gerfaud, 1981, Vol.I, p.94).

I too carried out investigations under the scanning electron microscope (model: JEOL), using an accelerated voltage of 25 V and similar magnifications to Anderson-Gerfaud (see Part I, Chapter 7 and Unger-Hamilton, 1984), in order to see whether I could detect residues from the worked materials on the flint surfaces and in order to investigate polish formation. I did not use SEM techniques to investigate surfaces of archaeological tools, as the experimental research suggested it would be unprofitable and time consuming (see Part I, Chapter 7) and as some of the ancient tools would have had to be fragmented in order to be inserted into the SEM chamber.

I photographed all tools with Ilford FP4 film. I found that photographs of the same wear traces could look very different according to the film and printing processes used, and according to the angle of the photographed surface to the microscopic lens. I therefore tried to keep these factors constant.

Chapter 3 - Features Observed in a Microwear Analysis

The following features have in recent years been studied as indicative of tool function, each type of feature requiring a different range of magnifications:

1) Edge damage on tools was studied by Tringham et al. (1974), Odell (e.g 1978, 1981, 1983, Odell and Odell-Vereecken, 1980), Roy (1982) and by other researchers. In this"Low Power"approach magnifications between 10x to 50x were usually used on a light microscope.

2) Polish and striations were first and foremost studied by Semenov (1964) , then by Keeley (1976, 1978, 1980, 1982, 1983, Keeley and Newcomer, 1977, Keeley in Cahen et al. , 1979, 1980), Anderson-Gerfaud (1981, 1982, 1983), Vaughan (1980, 1981, Perles and Vaughan, 1983) and by many other researchers. For this"High Power"approach magnifications of 50x to 400x were usually used on a light microscope.

3) Residues seen under the SEM were studied by Anderson-Gerfaud (Anderson, 1980, Anderson-Gerfaud, 1981, 1982, 1983) and by Mansur-Franchomme (1983). For this approach magnifications of between 500x and 10,000x were used.

I will discuss each of these features and its value in functional analysis in the following chapters. The observations of residues, using SEM techniques, are discussed together with the theory of polish formation, as the viability of the former is linked to the understanding of the latter.

Chapter 4 - Edge Damage

1. Outline of Research.

There has been a heated debate during the past ten years whether edge damage on a stone tool when viewed under relatively low magnifications of up to 50x is indicative of the action with which, and of the material on which a stone implement had been used (Tringham et al. , 1974; Odell and Odell-Vereecken, 1980; Roy, 1982), or whether it is an unreliable indicator and should only be considered a"...useful check on an interpretation already based on the microwear traces..." (Keeley, 1980, p.83), that is, the polish and striations observed under higher magnifications of 50x to 400x (Keeley, ibid; Vaughan, 1981; Moss, 1983).

Several researchers argued that edge damage alone was a reliable indicator of both tool action and worked material. Tringham et al. (1974) referred to edge damage as"microflaking", to be distinguished from "abrasion in the form of striations and polish" (ibid, p.171). They decided to concentrate on this feature of microwear as it was faster and easier to observe than polish and striations, needing less magnification and less sophisticated equipment (ibid, p.175). They used 105 experimental flint tools with various actions - divided into longitudinal (cutting, sawing), transverse (scraping, shaving, planing) and circular (boring) actions - on various materials (including antler, bone, wood, meat and skin) classified according to whether they were considered hard, medium or soft. Tringham et al. found that the location and the direction of microflaking varied according to the action, and that the scar morphology (i.e. size, depth and shape of the scar) varied according to the relative hardness of the worked material. They also pointed out the many variables other than tool action and worked material , such as flint type, edge angle, edge shape, angle of the tool to the worked material, which affect microflaking. They investigated microflaking due to causes other than use, such as microflaking due to intentional retouch, accident or natural causes. They claimed to be able to distinguish this type of flaking from flaking due to use, because of the randomness of location and orientation of the former and, in the instance of intentional retouch, because of the size of the scars. They concluded that microflaking alone, when viewed under magnifications of 10x to 60x, would be evidence of the action with which, and the relative hardness of the material on which, archaeological tools had been used. However, they also concluded that by this method alone one could not go any further and specify the exact movement of the tool or the exact nature of the worked material (e.g. meat or skin).

Odell and Odell-Vereecken (1980) followed Tringham et al.'s basic method which they referred to as the"Low Power Approach". They conducted a blind test comparable to the blind test of the"High Power Approach"(ibid., p.88) conducted by Keeley and Newcomer (1977). Odell-Vereecken used 31 basalt implements in a greater diversity of (8) actions than Tringham et al. on a wide variety of materials which had been subdivided into four categories : hard, medium-hard, medium-soft and soft. Odell analysed the implements using magnifications of 10x to 20x, but also up to 100x in order to view"problem areas". The Odells stated that they referred deliberately to"edge damage" as they felt edge rounding was as indicative of activities such as scraping as was"flaking". Their observations agreed with those of Tringham et al. (perhaps not surprisingly as Odell was one of the "alii"). The results of their blind test seemed encouraging despite the fact that the sample was rather small and such statistical evaluations as a"69.4%"rate of success seemed to me rather misleading. Odell achieved a success rate of 79% in distinguishing the worked area of the tools, of 69.4% in distinguishing the action and of 61.3% in distinguishing the relative hardness of the worked material, although only of 38.7% in distinguishing the precise worked material. The Odells too claimed that edge damage due to other factors than use was distinct, although at the end of the same paper (ibid., p.117) they admitted that Keeley and Newcomer (op., cit., p.35) may have been right in saying that"utilisation damage...cannot usually be distinguished on retouched edges."

Roy (1982) went further than Tringham et al. and Odell and Odell-Vereecken, claiming that by viewing edge damage on unretouched blades and flakes she could not only tell the action but the precise worked material, by fitting the materials into more precise hardness categories. Roy too claimed to be able to differentiate between edge damage due to use and edge damage due to other agencies. She only briefly mentioned the large number of variables involved in edge damage formation and stated, "Il n'est pas question de les enumerer ici" (ibid, p.168) as if they had no particular relevance to her investigation.

Keeley, Vaughan and Moss have separately argued that edge damage alone is not a particularly reliable indicator of either tool action or worked material, and that polish and striations observed at 50x to 400x were far more diagnostic of both: Keeley (1980) referred to"edge damage" (ibid., pp.24-25) but, as opposed to Odell and Odell-Vereecken, did not take edge rounding into account. He noted edge rounding as a"microwear feature"of e.g. hide polish (1977, p.42). He classified individual edge damage scars according to size, shape and depth and counted them individually on each experimental tool. Keeley's findings differed considerably from those of Tringham et al. , Odell and Odell-Vereecken and Roy, in that he could not see any particular pattern of scars according to action and no variability of scar shape and size according to the worked material. He claimed that other variables such as edge angle affected microflaking as much as the action and the

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Vaughan (1981, pp.83-86, pp.106-120) referred to "microchipping"and, like Keeley, did not include edge rounding in his category of"Edge Damage". The results of his attribute analysis of microscarring on 249 tools, made of three different flint types and viewed at magnifications of up to 280x, showed considerable differences to the results of Tringham _et_ _al_. , those of the Odells and those of Roy: scar types and sizes were far more varied in his analysis and he found that sometimes even hard materials did not scar edges at all; (however, this happened with only 6% of his experimental tools (ibid., p.114).) Vaughan also demonstrated the other variables affecting the formation of edge damage, notably the different flint types, and referred to the many causes (other than use) of edge damage. He therefore concluded that microchipping alone was not a precise indicator of the action with which and the material on which a prehistoric tool had been used (ibid., p.115).

Moss (1983, pp.76-79) referred to"edge damage" without taking edge rounding into account. She discussed the differences between the findings of Odell and Odell-Vereecken and of Vaughan in detail and, in my opinion quite rightly, pointed to the following differences as possibly responsible: the different stone they used, the different level of expertise of the experimenters - which was demonstrated by Moss and Newcomer (1981) to cause different frequency of edge damage - and the fact that Vaughan used much higher magnifications. Vaughan himself (op. cit.) listed different sample size as a possible reason. Despite the fact that Moss attempted to relate these different results to controllable factors, she agreed with Vaughan and Keeley that"edge damage due to use is neither very diagnostic of the worked material, nor is it always present"(Moss, op. cit., p.76).

2. Experimental Results

In order to decide whether there is a distinct variation in edge damage according to a particular type of action with which, and a particular material on which, a flint implement had been used, I investigated under the microscope at 50x the edges of 72 of my own experimental tools. They had been knapped from three types of flint: fine-grained Brandon flint, fine-grained Syrian flint and medium-grained frost shattered Syrian flint. I used the tools on hard limestone, dried bone, fresh reeds, dried antler, soaked antler, fresh and seasoned wood, medium fresh hide and fresh meat with longitudinal actions (sawing /

slicing) and with transversal actions (scraping). Most implements were unretouched blades or flakes of varying shape and with varying edge angles, although most scrapers had been retouched with a hammerstone. As opposed to other researchers (Tringham _et al._ , op. cit. ; Brink, 1978) who observed the edge damage on the dorsal aspect of the scrapers, I concentrated on the ventral (the contact) aspect as a) there were no misleading intentional retouch scars on this aspect and b) I wanted to observe the edge rounding which - like Odell and Odell-Vereecken (op. cit., p.90) - I considered as belonging to "edge damage".

I classified individual damage scars according to their terminations into three basic types (modifying the"Ho Ho Classification" (Hayden ed., 1979, pp.133-135) which had distinguished between four types of terminations) : 1) A feather (F) scar is"a flake (scar) which terminates in an edge with a minimal margin"(Crabtree, 1972, p.64); 2) A step (ST) scar is"a flake or flake scar that terminates abruptly in a right angle break"(Crabtree, 1972, p. 93). I could not differentiate at 50x between step and hinge scars which have different terminations when viewed in cross-section (Hayden ed., 1979, p.134) and result from slightly different processes of formation (Lawrence, 1979, p.117). Lawrence too (ibid.) found that these scars were"...similar in appearance and sometimes difficult to distinguish". Tringham _et al._ (op. cit., p.188) did not distinguish between them. 3) Snap (Sn) terminations result from the edge being broken away through"bending initiations". This category incorporates labels such as"break"and "half-moon breakage"(Hayden ed., op. cit.). Unlike Keeley (1980, p.24) I did not count scars individually but observed the predominance of large or small scars, thereby observing a pattern rather than the individual unit.

Table 1 and Plates 1-2 show the results: all scraping tools (regardless of the worked material) showed edge rounding, which was never seen on sawing or slicing tools. Cutting limestone caused a lot of edge damage with large scars, predominantly with step terminations. (However, when limestone was scraped, the scraper edge became abraded rather than flaked.) The number of feather and snap terminations seemed to depend on the angle of contact between the tool and the worked material. Dried bone caused a lot of edge damage with large scars, predominantly with step terminations. The tools which showed no edge damage tended to be of the same medium-grained frost shattered flint from Syria. Fresh reed caused almost as much and the same types and sizes of scars as dried bone, although it caused somehwat less damage than did bone to scraping tools. Dried antler caused somewhat less damage than stone, reed or bone. Soaked antler caused smaller scars, fewer step terminations and altogether less damage than did dried antler. Wood (both fresh and seasoned) caused less damage, smaller scars with fewer step terminations than the harder materials listed above. I did not test the difference between fresh and seasoned wood. Medium fresh hide caused much smaller scars than the above materials, mainly with feather terminations, but also some tiny scars with step terminations. Meat caused the least damage and the smallest scars of the materials listed. The scars had mainly feather terminations, although a few very small step terminations could also be seen.

I saw distinct variations in edge damage according to tool action: longitudinal actions did not result in any noticeable edge rounding but in considerable microflaking which was usually bifacial, although it could be almost unifacial when the tool was held at an acute angle to the worked material. Transverse actions always resulted in considerable edge rounding, but in very little microflaking on the ventral (contact) aspect, as opposed to the dorsal aspect.

My findings agreed with those of Odell and Odell-Vereecken (op. cit. , p.90) who stated that edge rounding was diagnostic of scraping. My findings disagreed with those of Tringham et al. (op. cit., pp.188-189) and with those of the Odells (Odell and Odell-Vereecken, op. cit., pp.98-99, p.109) which had led them to assume that sawing actions almost always caused bifacial, while transversal actions almost always caused unifacial microflaking.

My findings also accorded well with my earlier observations with the naked eye : two similarly shaped and angled flint edges developed a different shape and angle according to whether they were used to saw or scrape limestone. After one minute's use the sawing edge became finely retouched and remained acutely angled, while the scraping edge became invasively retouched and steeply angled, i.e. the sawing edge looked like that of a denticulated blade while the scraping edge looked like that of an intentionally retouched scraper. This experiment had indicated at a macroscopic level that tool action affected the character of the edge damage on that tool.

I also saw distinct variations in edge damage according to the hardness of the worked material. Hard materials such as stone, bone or dry antler nearly always produced most microflaking, the largest scars and the most frequent step fractures. The soft materials , such as fresh hide and meat, produced the least microflaking , the smallest scars and only a few and minute step fractures.

My findings disagreed with those of Keeley (1980, p.83) who reported that the size of scars and the occurrence of particular types of scars were indicative of other variables, e.g. edge angle, as much as of the worked material. My findings also disagreed with those of Tringham et al. (1974, p.191) who stated that soft materials could not produce stepped removals. I could not see any variations in edge damage which might indicate the precise material as was claimed by Roy (1982); materials such as wood or antler occur naturally, or can be treated in such a way that they can vary enormously in hardness. Roy (ibid.) classified plants as medium-soft, but my experimental tools used on reeds , which are surely hard materials, showed edge damage which could not be distinguished from that from bone.

3. Variables

Just as Vaughan (1981, p.114) and Moss (1983, p.76) I found that on some tools edge damage was notably absent or unexpectedly different to that on most of the other tools used with the same actions on the same materials. These exceptions could be related to the following variables:

The edge angle of the tool. The frequency and type of scarring varied according to the acuteness and steepness of the edge angle. I found that steeper edges hardly scarred at all.

The edge shape. I found that absolutely straight edges were hardly damaged at all even when used on hard materials. This agreed with Moss' observations (1983, p.76).

The angle of the edge to the worked material. While all researchers including Tringham et al. agreed about the effect of this variable, the latter insisted that sawing always produced bifacial retouch (1974, p.188). However, my blades when held at an angle of 45° against limestone during sawing became unifacially retouched, while blades with the same edge angles used with the same actions on the same material for the same amount of time, but held at an angle of 90°, developed bifacial retouch.

The flint type. I found that the medium-grained frost shattered Syrian flint was invariably less damaged than were the other two fine-grained flints from Brandon and Syria. This is in accord with the different fracturing properties of different cryptocrystalline stones referred to by other researchers (Tringham, op. cit.,p.178). Vaughan (1981, pp.107-108) in his experiments tested such properties. However, he found that"in the majority of cases (17 out of 21) the factor of lithic raw material was not found to exert a significant influence in causing the differences noted among scarring patterns on the three varieties of flint..."(ibid.). Recent experimental work showed that naturally recrystallised flint (chert) (Bradley and Clayton, 1986) and thermally altered flint (Bradley and Clayton, ibid.; Seitzer-Olaussen, 1983) chipped more easily than unaltered flint.

The condition of the worked material. More and larger scars and more step fractures occurred on the flint edges used on dry antler (Pl.1:g,h), than on those used on antler soaked for three days (Pl.2:a,b). Other researchers have noted the same phenomenon (Odell and Odell-Vereecken, op. cit., p.102). Vaughan (op. cit., p.114) referred to the varying conditions of the worked materials as a possible reason for varying results.

The duration of the action. The longer a tool was used the more edge damage formed. However it seemed that size and type of scarring were not notably affected (Tringham et al., op. cit., p.191).

Contact through pressure or percussion. These different types of contact were discussed by Moss (op. cit., pp.78-79) using flint knapping by pressure flaking and percussion flaking as a model. Moss stated that contact through pressure, such as during drilling, created far smaller flake scars than did contact through percussion, such as when a projectile is fired. I found this to be the case with 15 experimental drillbits which showed very small scars if any, but lots of fine abrasion, while experimental projectiles showed the opposite: very large scars (see Bergman and Newcomer, 1983) and hardly any abrasion.

It seemed to be the general consensus of all researchers mentioned that the variables affecting the formation of edge damage are the following: the action of the tool, the duration of this action, the hardness of the worked material, the moisture content of the worked material, the stone type of the tool, the edge angle, the edge shape, the angle of the tool to the worked material and the kind of contact, i.e. whether it is through pressure or percussion. These variables seem to be the same as those affecting the formation and distribution of polish (see Part I, Chapter 15) although differing in degree or extent; contact through pressure creates only small damage scars but it creates a lot of polish, whereas contact through percussion creates large damage scars , but very little polish.

4. Edge Damage due to Other Factors than Use

Again there seemed to be a consensus amongst researchers that there are many causes for edge damage other than use. They only seemed to disagree about the distinctiveness of such damage. Researchers who used edge damage alone in their microwear analyses claimed to be able to distinguish in most cases between edge damage due to use and that due to other factors (Tringham et al. , op. cit., p.181; Odell and Odell-Vereecken, op. cit., pp.96-97 and 119; Roy, op. cit., p.168) while those who relied mainly on polish and striations claimed they could often not distinguish between use and non-use edge damage (Keeley, op. cit.,p.83; Vaughan, op. cit., pp.116-120; Moss, op. cit., p.76).

Amongst these causes of edge damage are"spontaneous retouch"during manufacture (Newcomer, 1976; Keeley, 1980, pp.25-28) and accidental retouch due to a flint implement falling from a height. In relation to the latter cause I found that"single blow"tools such as notches and blade segments could be created in this way. I could not differentiate between these and intentionally shaped tools, although more intensive research suggested that it might be possible to distinguish between intentional and accidental breaks on blades, even without a microscope (Bergman <u>et</u> <u>al</u>., 1983). Accidental dropping of a tool could also create edge damage indistinguishable from that due to use.

Handling and transport or flint tools could create considerable edge damage according to Vaughan (op. cit. p.86, referring to Hayden and Kamminga, 1973, p.4).

Edge damage due to trampling (Miller, 1982), agricultural activities (Betts, 1977, pp.14-15) and natural agencies such as water-rolling could also be quite regular, at least when viewed with the naked eye, and therefore be confused with intentional retouch and use. My own experiment, leaving 20 flint pieces with varying edge angles inside a perforated plastic basket for five weeks in a fast-running stream, demonstrated the occurrence of often regular retouch, especially where edge angles were acute.

All these potential problems are of course very familiar to researchers who concentrate on the observations of polish and striations alone, as the problems are precisely the same.

5. Conclusions

Because the variables affecting edge damage and polish are the same, and since the agencies imitating edge damage or polish due to use are the same and since it will be argued that polish is largely due to abrasion of the flint surface (see Part I, Chapter 7) it seems to me that edge damage in the form of microflaking, edge rounding, and polish are all largely due to attrition of the tool and are therefore interrelated and should be viewed together. (The process of microflaking is of course governed by the laws of fracture mechanics (e.g. Odell, 1981)). In fact I cannot understand why edge damage and polish were not usually seen together by most researchers, as the location of polish is visible with most types of microscope at magnifications of 50x and edge damage is visible at magnifications of 200x. Not only should edge damage and polish be looked at together but also their quantitative relation to each other should be examined: on this particular point Moss' discussion of different effects of contact due to pressure and percussion was very suggestive. Both she and I found that a tool used with pressure would tend to have less edge damage but more abrasion (i.e. polish) while a tool used with percussion would tend to have larger flake scars, but very little signs of abrasion (i.e. polish). Similarly, where edge damage has occurred the polished edge is removed. Where this is not recognised, the perception of polish distribution and subsequent identification of polish can be completely mistaken. Therefore I conclude that the relation of edge damage to polish is important in microwear analysis.

Chapter 5 - Polish, Striations and Gloss - Outline of Research

Microscopic wear-trace analysis of flint tools was first used in the late 1920s when Curwen (1930) investigated "sickle gloss"on blades under low magnifications of approximately 2x (ibid, pl.1-4). At about the same time Semenov began to develop his experimental approach to wear-trace analysis using higher magnifications of 300x or more (1964, p.22). Semenov defined three different kinds of microwear:"(1) Polishing (small specific pressures with dispersion of minute particles and micro-plastic alterations of the surface), (2) grinding (higher specific pressures with dispersion of more substantial particles), and (3) rasping (large specific pressures with macroscopic destruction of the surface)"(ibid., p.14). Semenov also pointed to striations as a form of microwear (ibid., p.15) usually associated with contact with hard materials or the presence of abrasives during work. He concentrated on the observations of striations as evidence for the"kinematics" of tool use (ibid., p.17).

Keeley stated"To restrict oneself to the kinematic approach leads only to a refinement in typology and not necessarily to any better information about ancient economics" (1974, p.328). Keeley developed his experimental method, also using high power magnifications of 50x to 400x, in which he concentrated not just on the observation of striations as indicators of tool action (and in some cases of the worked material), but mainly on the polish which according to him (1976, p.50 ; 1977, p.37 ; 1980, p.83) is distinct according to the exact material (such as bone, meat or antler) on which a flint tool had been used. Although he admitted a few convergences which may present some difficulties:"Use on meat may not always be distinguishable from use on fresh, wet hide; use on wood may not always be distinguishable from use on soaked antler, unless the microwear polish is well developed; bone and antler saws will sometimes be indistinguishable from one another."He continued,"But these <u>few problems</u> (my emphasis) should hardly effect the overall ability of the microwear analyst correctly and fully to interpret flint implements in functional terms, and there may be other kinds of evidence to help him choose between alternative identifications"(1980, p.83).

Keeley's"High Power Approach"(a term used by Odell and Odell- Vereecken (1980)) was put to the (blind) test by Keeley and Newcomer (1977). Keeley claimed a success rate of "approximately 10 out of 16 correct"(ibid., p.60) in distinguishing the precise worked materials. Holley and Del Bene (1981) asked whether"Keeley's identifications of worked materials were based on recognition of his described "characteristic polishes"or had their basis in a suite of other attributes of wear"(ibid., p.346). Keeley insisted in his reply (1981), as he had earlier, that, "it was the character of the polishes found on the test implements that provided the main basis for the inferences concerning the worked materials"(1977, p.61).

In addition, Keeley thought that the width and the depth of striations can vary according to the worked material itself (1980, p.23).

Keeley seemed to accept Witthoft's theory (Witthoft, 1967) that,"corn"gloss on an implement is a sure sign that the implement was used on grass..."(Keeley, 1980, p.61). On the other hand he reported similar wear-traces from bracken and bamboo (ibid.).

Microwear analysts who largely followed Keeley's method seemed to agree with his statement that most polishes are distinct according to the worked material (Anderson-Gerfaud, 1981, Vol. I, p.35; Vaughan, 1980, p.88 (although he pointed to a systematic overlap of polishes in Vaughan, 1981, p.382); Moss, 1983, p.80) and mostly with the characteristics of the polishes which Keeley described (Keeley, 1980, pp.35-61; Anderson-Gerfaud, 1981, Vol. I, pp.44-63; Vaughan, 1981, pp.127-179; Moss, 1983, pp.83-105) although in some instances variations were observed by different observers. Moss (ibid.) discussed these and also noted that,"interpretation of polish type includes much more than an analysis of one small patch of polish."(ibid, p.80).

Researchers seem to vary in their opinion as to what extent striations indicate the worked material (Vaughan, 1981, p.121; Fedje, 1979; Del Bene, 1979; Mansur, 1981).

Most microwear analysts seem to accept that gloss on flint implements which is visible to the naked eye indicates that grasses or at least plants (Vaughan, 1981, p.156) were worked.

In 1980 Anderson-Gerfaud published her research using SEM techniques. They revealed on the used edges of flint tools objects she believed to be residues from the worked materials which had become embedded in the flint surface during use (Anderson, 1980, p.183; Anderson-Gerfaud, 1981, Vol.I, p.100). Since then microwear analysts have apparently accepted that polish forms as a result not of attrition alone (as Semenov had believed (1964, p.15)), but as a result of the formation of a deposit of amorphous silica in which residues from the worked materials become embedded (Keeley, 1980, p.43 and 1981, p.349; Vaughan, 1981, p.179, Moss, 1983, pp.16-18). Moreover, this finding was important evidence for of the distinctiveness of polish according to worked material when viewed under the light microscope.

In addition Anderson-Gerfaud (Anderson, 1980; Anderson-Gerfaud, 1981, 1982, 1983) and another researcher (Mansur-Franchomme, 1983) attempted to identify such residues on flint surfaces under the SEM in order to find out the exact worked material on which the tools had been used.

Despite their acceptance of Anderson-Gerfaud's hypothesis, an implication of which was that residues from worked materials as well as amorphous silica could be removed by chemical cleaning, most microwear researchers cleaned their experimental and archaeological tools with chemicals such as solutions of sodium hydroxide (NaOH) and hydrochloric acid (HCl) (Keeley, 1980, p.11). However, Anderson-Gerfaud (1981, Vol.I, pp.28-29), Vaughan (1981, p.97) and Moss (1983, p.105) were cautious and to a certain extent restricted their use of chemicals.

In a critical review of microwear in 1974 Keeley had stated ,"It is a matter of controlling against microscopic traces that are <u>not</u> the result of utilization and controlling for the factors that affect utilization traces, such as the raw materials of the artefacts, the manner of use and the material on which the artefacts were used. If these controls are not introduced, then serious and confusing errors can result."(1974, p.327). In the publication of his thesis Keeley discussed the effects of abrasion from wind and water, patination, natural gloss, soil movements and frost contortions (1980, pp.28-35). He investigated such effects in some cases experimentally and found that in some instances they rendered the archaeological tools unusable for microwear analysis by obliterating all traces caused by use. He claimed to be able to distinguish between traces due to such effects and traces due to use:"Most natural processes, then, leave traces which are unlikely to cause much confusion for the microwear analyst, once he is familiar with them and with true microwear features..." (ibid., pp.34-35). Other microwear analysts seemed not quite as confident as Keeley (see Vaughan, 1981, pp.173-179; Moss, 1983, p.81-83).

Polishes due to technological processes had also been experimentally demonstrated and discussed by Keeley (1980, pp.25-28). He concluded that"technological effects, examined with due care, demonstrate many appreciable differences with true microwear..." (ibid., p.28). This statement found general acceptance with the other researchers (Anderson-Gerfaud, 1981, Vol. I, p.40).

Variables possibly involved in polish formation, other than the worked material, include: different flint types from which the tools are made; the tool action and duration of such action; freshness, dryness or hydration of the worked material; the species of the worked material; the shape of the tool and the presence of external abrasives. Some of these variables have been investigated by various researchers: Keeley used several types of flint , including fine-grained flint from Brandon and coarse-grained flint from Denmark, and stated that"in the experiments, the type of flint involved had no effect on the formation or appearance of any of the microwear features."(ibid., p.16). In an earlier publication, however, he did refer to the distribution of wood polish differing according to the texture of the flint surface (1977, p.39). Vaughan, who used three flint types in his experiments, saw a"quantitative", not a"qualitative"difference in polish formation according to the grain size of the flint (1980, p.90 and 1981, pp.129-130 and p.184). Anderson-Gerfaud did see a relation of the amount of"dissolution of the tool edge"to the fineness of the grain structure of the flint (Anderson, 1980, p.190) but did not mention particular sources of raw materials for her experimental tools in her paper, which dealt not only with archaeological flint but also with archaeological quartz implements. However, she mentioned the sources for her experimental implements in her thesis (1981, Vol. I, p.6). Moss stated that the raw material of the ancient tools must be duplicated (1983, p.55).

Different actions seemed to produce at most some differences in the location and extent of the areas of polishes (Keeley, 1977, p.37). Distinct polishes from different actions were rarely mentioned; an exception was the difference between sawing and scraping or planing of materials of anisotropic structure, such as the sawing and scraping or planing of antler which led to"rough"and"smooth"antler polishes respectively (Keeley, 1977, p.44; 1980, p.56). Other researchers agreed with this (Anderson-Gerfaud, 1981, Vol. I, pp.61-62; Vaughan, 1981, p.143).

The effects of different durations of work were hardly discussed by Keeley in any of his publications since he thought that the intensity of polish was an indication of a particular worked material. He did not measure the effect of duration of work when he measured the light reflectivity of his polishes (1980, p.62). Vaughan (1981, pp.133-137) dealt with the time factor and pointed to the similarity of polishes at the beginning of their formation.

All researchers noted some variations in the polishes according to the state of the material, the polishes varying with the freshness or dryness of such materials as bone (Keeley, 1980, p.44), hide (ibid., p.49) or wood (ibid., p.56). However, Keeley for instance did not describe polish from working dry antler as he had found that antler could not be worked efficiently unless fresh or soaked in water (1977, p.44).

Similarly, Keeley only speculated that there is probably no difference in polish according to the species of antler (1980, p.56), although he did refer to quantitative differences in polishes between those from"dense" woods and those from"less dense"woods (ibid., p.36). Vaughan (1981, pp.154-155), Anderson-Gerfaud (1982 and 1983, pp.90-91) , Moss (1983, p.94) and I (Unger-Hamilton, 1983, pp.245-246) noted differences in plant polishes according to species of plant.

Variations in polish according to tool shape seemed to have been overlooked since Keeley (in connection with experiments on antler) stated,"Variations of the edge angle do not, as was the case with use on other materials, result in any recognizable variation in the appearance of the microwear polish or striations." (1980, p.59). Moss, however, (Moss and Newcomer, 1981; Moss, 1983, p.55) did say that the"morphology of the piece, particularly the working edges"should be duplicated experimentally"(1983, p.55).

The effect on polish formation of the addition of abrasives during use was rarely mentioned by researchers. Those who did study such effects found that they were considerable (Vaughan, 1981, pp.163-164; Brink, 1978, pp.88-93 and pp.106-110; Mansur-Franchomme, 1983).

In summary, there seemed to be a general agreement between microwear analysts (although Vaughan and Moss were more cautious than the others) that polishes are distinct according to worked materials, and that neither the effects of natural agencies nor of technological processes, nor the effects of variables other than the worked materials, are sufficiently strong to impede the functional analysis of ancient flint tools.

It seemed to me that this confidence was responsible for the recent publications by microwear analysts who, although arriving at very detailed conclusions (such as that implements had been used to cut meat close to the bone, or that implements had been hafted with bone hafts (Bueller, 1983)), omitted details of experimentation, evidence in the form of comparative photographs, drawings of experimental tools (Bueller, ibid.) or seemingly any specific experimentation at all (Coqueugniot, 1983; Keeley, 1983). Whether such confidence is justified will be subject to investigation in the following chapters.

Chapter 6 - Polish, Striations and Gloss - Aims of the Investigation

As indicated in the outline of research (Part I, Chapter 5) there were in my opinion several important questions which needed to be answered before the"High Power Approach"- the diagnosis of the used area of the tool, the action with which and the material on which a tool had been used, by observation of polish and striations at magnifications of 50x to 400x - could be accepted as viable. The most important questions which emerged were the following:

1) Does polish really vary consistently according to an exact worked material (such as bone, antler or meat) as Keeley (1980, p.83) would have us believe, i.e. does polish vary according to a man-made classification?

In order to investigate this problem I used a fourfold approach :

a) I wanted to find out whether such a variation was likely by looking at the mechanism of polish formation. If polish was due to a lasting deposition of worked material on the tool surface, then a variation in polish according to a precise worked material seemed logical. I also attempted to construct a model of polish formation. In addition I tried to assess the extent to which striations and macroscopic gloss were indicative of an exact worked material. With the results of these investigations in mind I went on to consider three topics: firstly, whether residues found on flint tools , by using SEM tecniques, could be used to identify materials ancient tools had been used on, secondly, to what extent cleaning with chemicals altered polishes and whether such cleaning was necessary, and finally how the chemical composition of the soil could affect polishes on ancient tools.

b) I wanted to find out whether clearcut differences in polishes according to the exact worked materials were discernible in practice by observing my own flint tools. These had been used in controlled experiments on a variety of materials.

c) I wanted to find out which variables other than the worked material affected polish formation. If they were few and of minor importance this would argue in favour of consistent variations of polishes according to an exact worked material.

d) In order to test my experimental results I took part in a series of blind tests. I wanted to investigate whether Keeley's success in determining exact worked materials could be replicated and what precisely the circumstances were under which microwear analyses turned out to be most accurate.

2) The second most important question was whether the"High Power Approach"can be applied with equal certainty to both archaeological and experimental tools, or whether surface alterations on the flint tools due to natural (or other) agencies not only render a good proportion of the excavated flint material unusable for a microwear analysis, but also positively mislead the microwear analyst. This question bears on the problem of sampling. The principal method of tackling this question was a "blind test"in which I analysed microwear polishes on tools excavated from Abu Salabikh before reading the excavation report, in order to find out whether the results of a microwear analysis of ancient tools matched the evidence from the excavation.

Chapter 7 - The Mechanism of Polish Formation

1. Recent Theories

Despite the long history of research into use-wear on flint tools the nature of polish formation is still a matter of debate. Various hypotheses have been put forward, most recently centring on the question whether use-wear polish on flint is primarily due to the formation of a deposit (Witthoft, 1967; Anderson, 1980; Keeley, 1980; Anderson-Gerfaud, 1981, 1982; Plisson, 1983; Bradley and Clayton, in press) or whether it is due to attrition (Curwen, 1930; Kamminga, 1979; Masson et al. , 1981; Meeks et al. , 1982). These hypotheses appeared at first sight irreconcilable.

There were a number of arguments for the hypothesis of an additive use-wear polish on flint. Anderson-Gerfaud (Anderson, 1980; Anderson-Gerfaud, 1981, 1982) observed used edges on experimental flint tools under the light microscope and under the SEM and suggested that under the light microscope the polish looked inflated (1982). Also, under the SEM what she took to be residues from contact materials - such as bone, or phytoliths from siliceous plants - appeared to be sinking into or melting onto the"dissolved"flint surface; these residues were used to identify the contact materials on which the archaeological flint tools had been used. Anderson-Gerfaud also compared objects seen on experimental flint tools, which had been used to cut plants, with photomicrographs of phytoliths (Wynn Parry and Smithson, 1964), and then attempted with the help of different"phytoliths" to identify different plant species cut by archaeological tools. Anderson-Gerfaud (e.g. 1982, pp.152-153) suggested that during the use of a flint tool on plants the silica of the flint surface dissolves and amorphous silica is precipitated, forming a deposit of silica gel around the phytoliths. The proposed cause was a chemical reaction involving a combination of factors: the concentration of silica in water; high temperature; abrasion; a pH over 9; certain plant acids and contact with other silica gels.

Keeley (1980, p.43) found that polish from bone on flint looked altered and"pitted"after treatment with hot hydrochloric acid (HCl), and deduced that the material removed was inorganic as it had not been removed with sodium hydroxide (NaOH). He suggested that it probably consisted of crystals of bone apatite which may have become incorporated in the polish.

Plisson (1983) found that use-wear polishes could be removed by prolonged chemical attack with solutions of sodium hydroxide (NaOH), calcium oxide (CaO) and sodium carbonate (Na_2CO_3). The speed of removal varied according to the contact material and the geological age of the flint.

Bradley and Clayton (1986) in their investigation into the influence of the microstructure of flint on the formation of microwear polish referred to the depositional element of the polish (as envisaged by Anderson-Gerfaud), and the possibility of the redeposition of amorphous silica in the interstices around the lepispheres and quartz grains of the flint.

In contrast, there were also many arguments for the hypothesis that use-wear polish on flint is due attrition. Masson _et_ _al_. (1981) pointed out that while polish formation on flint due to attrition was well documented, additive polish was not, and had yet to be proven. They examined burnt sickle blades from Mureybet using X-Ray Diffraction but could not detect any evidence for a surface layer of amorphous silica and phytoliths in the form of amorphous organic opal (opal-A) and opal-CT, as would be expected. The authors admitted the possibility of a superficial dissolution of the flint surface from attrition, but on too small a scale to be detected by X-Ray Diffraction or to contain phytoliths. They stated that the history of a piece of flint begins with its formation, and not with its use, and that many structures interpreted as use-wear traces may be geological in origin.

Meeks _et_ _al_. (1982) published, as part of their research on plant polish, SEM micrographs showing the sectioned edges of flint tools used to cut plants or polished with diamond paste. They found no trace of a build-up on the polished surface.

Del Bene (1979; Holley and Del Bene, 1981) thought that some polishes (e.g. from plants) are due to deposition while polishes from other materials are due to attrition.

2. Experimental Investigation under the Light Microscope

The apparently irreconcilable views outlined above led me to investigate some of my own experimental and archaeological flint implements under the light microscope at 100x -200x for a preliminary study. I later used SEM techniques for a more detailed investigation.

I decided to test the following suppositions: 1) If polish is due to deposition then a major chemical reaction must take place during its formation. In order to find out whether a major chemical reaction is involved, I tested the effects of heat and pH - both of which are known to affect chemical reactions - on polish formation, by rubbing 12 Brandon flint pieces 200 times against each other with the addition of either cold or hot (boiling) water, or with the addition of acid (10% HCl, pH 4-5) or alkaline (10% NaOH, pH 10-11) solutions. The resulting polishes were too similar to conclude that a major chemical reaction is involved in polish formation.

2) If polish is due to deposition, then the physical structure of the worked material should not affect polish formation noticeably, i.e. polish from contact with antler should be the same regardless of whether flint is rubbed against the surface of the antler, or whether antler, a fibrous material, is cut across or lengthwise. Experiments (Pl.29:a,b) and Blind Test 11-20 (see Part I, Chapter 20) showed that polishes looked very different according to whether flint had been used for rubbing a material or cutting it. This indicated that attrition is the major cause of polish. The variation took place irrespective of whether the worked material was plant or animal, discrediting the hypothesis that polishes from plants are due to deposition while polishes from some other materials are due to attrition (Del Bene, 1979; Holley and Del Bene, 1981).

Two observations led me to believe that polish is perhaps not only due to attrition but also due to a coating of amorphous silica on the flint surface:

1) Experimental blades used to work fresh or hydrated materials, such as wood, plants, bone or antler, showed almost"melted" looking surfaces (e.g. Pl.23:d).

2) Blades with"sickle gloss", especially those excavated from the PPNA levels at Jericho, revealed in some instances a"cracked"looking microscopic polish (Pl.7:h) which remained unaltered despite cleaning in soapy water and White Spirit, which would have removed most organic substances while leaving the flint surface intact.

In summary, I deduced from the preliminary study under the light microscope that polish is foremost the result of attrition although there were also indications of the presence of a coating of amorphous silica on the surfaces of both the experimental and the archaeological tools.

3. Investigation under the SEM

In order to find out whether there was any evidence for residues from worked materials embedded in a thick layer of amorphous silica such as would constitute a depositional polish, I decided to investigate, using SEM techniques, some of my own experimental blades which had been knapped from Brandon flint (see also Unger-Hamilton, 1984). Two blades had been used to cut fresh English grass and bone respectively, each for thirty minutes, while a third blade had been rubbed against another flint blade for ten minutes. The blades had been washed in hot water and detergent. In addition several unused freshly knapped blades were chosen for observation under the SEM. The results were as follows:

Evidence concerning the residues from worked materials:

The residues from the working of bone (as shown by Anderson-Gerfaud (1981, p.150, Pl.22:1, reproduced here as

Pl.3:a) appeared only on the flint blade I had used to saw bone (Pl.3:c,e). They had not sunk into the flint surface, but rested on top of it, and traces of the"partings"between the residues and the flint surface were clearly visible (Pl.3:e).

The"phytoliths"and some other"cellular vegetable matter" shown by Anderson-Gerfaud (1981, p.122, Pl.8:2 (the arrow indicates the area of apparent embedding of the object in silica, the triangle points to either embedded constituents or an area of recrystallised amorphous silica) and Pl.8:1 (the arrow picks out an area of supposed dissolution and recrystallisation of silica), p.140, pl.17:2, reproduced here as Pl.3:b,d and 4:a) to have"melted onto"or"sunk into"the flint surface, appeared not only on flint blades used to cut plants; objects resembling her"phytoliths"were observed on the surface of the flint blade which had had no contact with any plant, but had been used exclusively to polish other flint (Pl.3:f and 4:b). The size of the objects (c. 20-30 microns), the characteristic ridges, and the attachment to the flint surface all looked very similar (Pl.3;b,d,f). In addition the shape and the"twist" of the objects shown in Pl.4:a,b looked identical, although the sizes differed slightly (20 and 15 microns respectively). Similar objects, of a variety of shapes and sizes, were also observed on the surfaces of freshly knapped flint which had had no contact with any other material (Pl.4:c,d). The photograph shown in Pl.4:e shows clearly one such object projecting from an unused flint surface.

The similarity between the objects found on flint which had been in contact only with flint, those found projecting from freshly knapped unused flint surfaces, and those shown as"phytoliths", leads me to suggest that they are not phytoliths from plants melting onto or sinking into the flint surface, but components of the flint itself which project from the flint surface. These objects might be relic grains of skeletal calcite of echinoderms or Inoceramids (A. S. Gale, King's College, London, pers. comm.) or relic organic tissues - such as of dinoflagellates - which have not been fully replaced by silica (Holdaway and Clayton, 1982). The ring of dissolved silica around the objects (arrowed, Pl.3:d) might well be due to the deposition of amorphous silica in the interstices between the flint and the objects. The attachments around the objects (arrowed, Pl.3:b) might be due to a build- up of amorphous silica on the flint surface around the objects. Another possibility, that these objects are due to recent contamination, such as dust particles or pollen, can be excluded on the grounds that dust or pollen would clearly settle on top of the flint surface, rather than sink into it.

Evidence concerning the additive or abrasive nature of polish formation:

The surfaces of the used flint edges (Pl.3:b,d,f) appear to be smoothed and planed, and the"rings"immediately surrounding the objects (arrowed, Pl.3:d) appear to be"melted". This evidence suggests the presence of amorphous silica filling the interstices around the objects and, possibly, a very thin coating of amorphous silica on the general abraded surface of the flint. I have suggested above that the projecting objects on the flint surfaces might be relic grains of unreplaced skeletal calcite or relic organic tissues, and the experiment of one flint being rubbed against another had shown that these objects remain projecting from the polished surface. This leads me to suppose that polish formation involves a strong chemical interaction rather than mechanical abrasion alone. This is because the softer relics of organisms would tend to be worn away before the harder flint surface (unless they were ductile, in which case they might give way and be pushed into the hollows of the flint).

The results of the SEM investigation led me to conclude the following:

The only residues clearly due to use-wear which I have detected on the three blades investigated are deposited on top of the flint surface, and have not sunk into it. It therefore seems unlikely that such residues would be preserved on a flint surface for a long time, or that due to the preservation of the residues, polishes on archaeological flint tools derive their characteristic appearance from a specific worked material such as bone or hide. This fact also leads me to suggest that cleaning with chemicals, such as was carried out by Keeley (1980, p.43) and by Plisson (1983, Plisson and Mauger, 1986) would remove any residues which did remain. In addition, I concluded from the similarity between the objects on unused flint surfaces and the so-called residues from worked materials such as "phytoliths"that - as Masson et al. (1981) had pointed out - the genesis and diagenesis of the flint itself need to be known in order that the researcher can differentiate between residues from the use of flint and organisms incorporated in the flint during its formation (see Part I, Chapter 11).

The fact that the objects remained protruding from the flint after one flint was rubbed against another leads me to conclude that there does seem to be a chemical dissolution of the flint surface as Anderson-Gerfaud (Anderson, 1980; Anderson-Gerfaud, 1981, 1982) had suspected. However, there was no evidence for a layer of amorphous silica thick enough (i.e. on the scale of several microns) to contain residues such as phytoliths from worked materials. A well-formed polish could be produced by a very thin and generally invisible coating of amorphous silica, particularly if infilling interstices on an already abraded surface. Most of this coating would seem to be deposited in the interstices between the flint grains , around the lepispheres of the flint (Bradley and Clayton, 1986) and also in the interstices around the relics of organisms (see above). The thinness of such a layer (detectable on an Angstrom scale only) would explain why neither the analysis by X-Ray Diffraction (Masson *et al.*, 1981) nor the observation under the SEM (Meeks *et al.*, 1982) registered it.

4. Conclusions

It therefore seemed from both the preliminary investigation under the light microscope and the investigation under the SEM that use-wear polish on flint is the result of both abrasion and deposition. Other experiments (Unger-Hamilton, 1983, see Part I, Chapter 16) led me to suggest that among other factors water plays an essential role in the process of polish formation, as others have also suggested (Anderson, 1980, p.181; Gysels and Cahen, 1982).

Two recent publications seem to support my conclusions: Mansur-Franchomme (1983) has investigated the effects of abrasion and humidity on polish formation under the SEM and has found that polish was influenced by both. Anderson and Whitlow (1983), two physicists, have used hydrogen profiling (by means of Ion-Beam Analysis) to study water uptake of flint surfaces. They found that the modification of hydrogen profiles through the working of different materials appeared to be strong evidence in favour of the gel-formation hypothesis. The maximum depth of such a layer (caused by working wet and hard materials) which they mentioned was 0.7 microns (i.e. not on a scale large enough to contain phytoliths, as I stated above). Anderson and Whitlow (ibid., p.471) also thought that the thinness of such a layer of amorphous silica would not have been registered by X-Ray Diffraction analysis as carried out by Masson *et al.* (1981). Although Mansur-Franchomme (op. cit.) and Anderson and Whitlow (op. cit.) seemed to accept Anderson-Gerfaud's identification of residues as phytoliths on flint surfaces, there was in my investigation no evidence for a deposit in which residues from the worked materials are embedded. This means that there seems to be no magical ingredient in the use-wear polish which would make it characteristic of a worked material.

Chapter 8 - A Model of Polish Formation

My investigation of experimental flint tools using SEM techniques led me to conclude that polish was the result of abrasion and a coating of amorphous silica (Unger-Hamilton, 1984). Other observations (Unger- Hamilton, 1983) had shown that water plays an essential role in this process and that it seems instrumental in the formation of amorphous silica (see Part I, Chapter 7).

Observations under the light microscope had likewise shown that the presence of amorphous silica seemed largely dependent on the water content of the worked material. Surfaces of experimental flint tools seemed flattened when very hard materials were worked, while they were only gently polished when softer materials were worked (see Part I, Chapter 14).

I would therefore propose the following model of polish formation:

1) (Fig. 1a) When the worked material is very hard then the tops of the microtopography of the flint are completely flattened.

2) (Fig. 1b) When the worked material is medium hard then only the tops of the microtopography are polished, leading to the pitted or reticular look often mentioned.

3) (Fig. 1c) When the material is soft then the whole surface of the flint, including the depressions, is polished.

The amorphous silica - probably liberated by the humidity in the worked material - collects around the flint grains and around the lepispheres of the flint (Bradley and Clayton, in press) and around the micro-organisms in the flint (see Part I, Chapter 7). It is unknown how such amorphous silica is bonded to the flint surface. Other features, e.g. the horizontal distribution of polishes (related to the extent of contact with the worked material) or characteristics like"bumpyness"in the case of hide polish (probably related to the structure of the material) will lead to a more precise identification of the worked material.

This model of polish formation was tested by applying these criteria in Blind Test 11-20 (see Part I, Chapter 20) with a success rate of approximately 7 out of 10 correct identifications of the worked materials.

Chapter 9 - Striations

1. Formation

Mansur-Franchomme (Mansur, 1981) investigated the formation of striations using SEM techniques. She stated that striations were caused by extraneous sand and dust particles caught in between the surfaces of the flint and the worked material, and also by microflakes removed from the tool during use. She defined three categories for the state of the surface of the flint tool, based on the degree of fluidity at the moment of utilisation. To each category corresponded a special type of striation. These were:"fluid-gel state" striations from working wet or fresh materials such as fresh plants,"intermediate-gel state"striations from working wood and fresh hide, and"solid-gel state"striations from working dry materials, such as dry hide (Mansur, 1981; Mansur- Franchomme, 1983, p.229).

I did not investigate the formation of striations using SEM techniques, as her and my understanding of polish formation seemed to be largely in agreement (see Part I, Chapter 7) and because the following observations by others and myself seemed to support her model of the formation of striations:

When I rubbed flint against quartzite, many striations were visible on the flint, however when I rubbed the same material for the same number of strokes with the addition of water, hardly any striations were visible.

Plisson (1983; Plisson and Mauger, in 1986) demonstrated that previously invisible striations could be"uncovered" by treating the flint surface with chemicals which attack amorphous silica.

2. The Value of Striations to Microwear Analysis

Moss (1983, p.74) discussed striations in Semenov's sense , i.e. as"any kind of linear depressions in the flint surface, which is not a feature of flint itself"(ibid.). She pointed to the fact that for Semenov"...striations were the most important functionally diagnostic features" with which he not only located use-wear on a tool, but also identified the motion during tool use. All microwear analysts seemed to agree that the location of use-wear on a tool and the motion during use can be identified with the help of striations, although Keeley (Keeley and Newcomer, 1977, p.37) had stated cautiously that striations should only be considered to be the result of intentional work when they are accompanied by microwear polishes. In addition, Moss (op.cit., p.74) observed (according to my experiments quite rightly) that there might be sometimes"incidental striations"during work which do"not always conform to the overall expected pattern"(ibid.).

However the extent to which the occurrence and nature of striations indicate the worked material seemed to be open to question. The following factors might be the cause of striations:

Microchipping of the flint itself during use was held to be largely responsible for the formation of striations by all researchers (see Mansur-Franchomme, 1981, 1983; Del Bene, 1979; and Fedje, 1979, who observed the formation of striations on obsidian.)

The accidental presence or deliberate addition of grit during use of a stone tool was also held responsible for the formation of striations by all researchers (see Semenov, 1964, p.15; Fedje, op. cit.; Mansur, 1981; Moss, 1983).

The worked material itself (presumably its structure) caused in some instances characteristic striations according to Keeley (1980, p.23). He described such striations together with the microwear polishes: e.g. broad (approximately 15 micron) and shallow striations on woodworking tools (ibid., p.35), deep and narrow striations on boneworking tools (ibid., p.43), narrow, deep and relatively broad and shallow striations sometimes on hideworking tools (ibid., p.50), very few and very minute striations on tools used on meat (ibid., p.54), rare, narrow, not particularly deep and short striations on antlerworking tools (ibid., p.56) ,"filled in"striations (following Witthoft, 1967) on plantworking tools. Vaughan (1981, p.121) and Moss (1983, p.76) also thought that in some instances striations were specific to a particular worked material, while Mansur had listed the worked material only as an indirect cause of striations (1981).

My own experiments showed the following:

Microchipping as a cause of striations was demonstrated by the fact that in general the quantity of striations on a flint tool related directly to the hardness of the worked material. However there were exceptions (see below).

Abrasion from external agents such as grit and dust (see Korobkova, 1981, p.331), rather than from the presence of silica in the plants (Steensberg, 1943), seemed to be largely the cause of striations in plant polish. Riverine plants, regardless of whether harvested in England or Syria, did not cause any striations on flint surfaces, even when bristling with silica, such as was the case with <u>Equisetum fluviatile</u> (Pl.25:f) - aptly named"The Scouring Rush"- , or when very hard, such as was the case with cane (Pl.24:d). Land plants, such as grass (pl.25:d), when harvested from compact soil held together by a grassy cover, caused few striations, regardless of whether they were fresh or dry. Plants harvested from upturned, but humid and humus-rich (and therefore compacted) soil in England caused more striae (occasionally in great quantity) than did land plants cut from a grass cover (Pl.22:f). (Plenty of striations are likely to occur when plants are cut from upturned loose soils in the Near East.)

The worked material (i.e. its structure) did seem to cause striations; this was most evident when fibrous materials, such as sheep's wool (Pl.14:e) and sinew (Pl.16:b) were cut. In neither case did any edge damage occur and at least the sinew was completely grit-free. However, the polish consisted almost solely of striations, which are perhaps the negative impressions of the fibers. Some materials such as shell and fallow-deer antler caused striations which were consistent and regularly spaced.

It therefore seems to me that striations are not only of value in the location of use-wear and the identification of the motion during use, but that they can also be indicative of the hardness and the humidity of the worked material, the presence of abrasives (which in my opinion is a particularly important indicator for the investigation into plant cultivation), and the structure of the worked material itself.

Striations due to causes other than use, such as manufacture, natural agencies and handling during and after excavation are discussed in Part I, Chapter 18 together with post-depositional polishes.

Chapter 10 - Macroscopic Gloss

1. Formation

Gloss which is visible to the naked eye has often been referred to as"sickle gloss, sickle polish, sickle sheen, corn gloss..." (Diamond, 1979, p.159) indicating that the occurrence of such a gloss was usually associated with the harvesting of plants and especially of grasses (Vaughan, 1981, p.156). The reason for this is that this gloss had been seen primarily on blades whose shape indicated their use as sickle blades, and that experiments (Curwen, 1930, 1935) had shown that while prolonged use of flint on wood and straw caused gloss on the flint surface, prolonged use on bone did not. Researchers therefore concluded that gloss is due to the presence of silica in the plants or due to the presence of silica in other materials such as sand, flinty soil and wood (Curwen, 1937, p.93). Witthoft (1967, p.385) in fact thought that gloss is due to an accumulated layer of fused silica glass and opaline molecules.

My own experiments led me to agree for some time with the conclusion that gloss is entirely due to the presence of silica in the worked material. I had found that cutting plants with a high silica content, such as <u>Equisetum fluviatile</u> (see Iler, 1979, p.742), led to gloss formation much faster than cutting modern cereals (see Iler, 1979, p.744; Hillman, pers.comm.) which are bred for a low silica content: it took 200 s.m. (sawing movements) on <u>Equisetum</u> and 5000 s.m. on modern barley to get gloss on the cutting edge of the blades. I also found that cutting or scraping siliceous materials such as stone, sand or wood led to gloss formation on the flint tool while cutting or scraping materials such as bone, antler or hide, which contain very little silica (generally 2-10% in the ash, see Iler, 1979, p.754) did not. However, I later noticed that rubbing the same materials with flint led to gloss formation according to relative hardness of the worked material, i.e. rubbing bone caused considerable gloss, while rubbing meat did not. The difference between the effects of sawing, scraping and rubbing such anisohydrous materials as bone and antler may have been due to the fact that when such a material is cut or scraped, less of the worked material comes into contact with the flint, and less intensely, than when the harder outer surface is rubbed. This led me to conclude that the hardness of the worked material is important in gloss formation. Phytoliths and other silica bodies are of course very hard.

In order to find out whether it is the hardness of such bodies or the fact that they consist of silica which leads to gloss formation, I cut another highly siliceous, but soft, material, a feather (feathers contain up to 77% silica in the ash (Iler, 1979, p.753)). No gloss formed even after prolonged contact. Conversely, intense gloss developed on the flint tool when copper (which contains at most trace amounts of silica) was drilled.

In addition I had observed that gloss formation was greatly influenced by the moisture content of the worked material (Unger-Hamilton, 1983, see also Chapter 17). I therefore conclude that gloss, like microscopic polish, is the result of abrasion and moisture and that it is simply the macroscopic manifestation of a strongly polished flint surface.

2. The Value of Gloss to Microwear Analysis

The above conclusion, that gloss is the result of abrasion and moisture implies that it is not indicative of a particular worked material, such as grass or plant. However, the distribution of gloss did seem to indicate the worked material: gloss from hard materials , such as stone or bone, looked streaky, while gloss from soft materials, such as plants, looked evenly distributed. In practice, I have never seen any <u>strong</u> and evenly distributed macroscopic gloss on experimental flint tools other than those used on plants.

Chapter 11 - Residues

Vaughan (1981, p.91) stated,"Under certain ideal conditions of preservation, organic residues such as vegetal fibers or amino acids may be left adhering to prehistoric stone tools and can be studied by relatively straight-forward methods of chemical or physical examination."He referred to the publications of Briuer (1976), Broderick (1979) and Shafer and Holloway (1979).

I myself observed under the light microscope inorganic residues, such as from lapis lazuli, on experimental flint drills and possibly on drills excavated from Abu Salabikh. Similar residues had been reported by Tosi and Piperno (1973) on drills excavated from Shahr-i-Sokhta. Such inorganic residues presumably do not need"certain ideal conditions"(Vaughan, op. cit.) such as extreme aridity or humidity for their preservation.

As already outlined in Part I, Chapter 7, Anderson-Gerfaud had observed under the SEM residues from worked materials - such as residues from bone, or phytoliths from siliceous plants - which appeared to be sinking into or melting onto the"dissolved"flint surface (Anderson, 1980; Anderson-Gerfaud, 1981, Vol.I, pp.100-101, 1982). Similar residues (from hide) were observed, also under the SEM, by Mansur-Franchomme (1983). Most microwear analysts seemed to accept that the residues observed were in all cases residues from the worked materials, and that such residues could be used to identify the worked materials on which archaeological tools had been used (Keeley, 1981; Vaughan, 1981, p.91), although Moss (1983, pp.17-18) expressed some reservations.

However , as also outlined in Chapter 7, there were some arguments against the survival of such residues from the worked materials on flint, and I came to the following conclusions:

As Masson et al. (1981) have pointed out, the genesis and diagenesis of the flint itself need to be known in order that the researcher can differentiate between residues from the use of flint and organisms incorporated in the flint during its formation. Provenance and geological age must also be taken into account. As"flint"(or more specifically"chert") has formed in different areas and different sediment types during different geological periods, it naturally shows a great variety of forms and particularly of different quantities and types of organisms. Species and quantities of macro- and micro- organisms may vary even within one flint source. Therefore it is desirable to study unused flint from the relevant sources under the SEM before residues on the experimental or archaeological tools can be identified with certainty.

Masson *et al*. (op. cit.) concluded from their investigations of burnt blades with"silica gloss" that there were no phytoliths on the surfaces of these tools. Their results agree with my findings which suggest that objects resembling supposed phytoliths appear on flint surfaces used only to polish other flint. The possibility that phytoliths might be preserved on a flint surface cannot at present be ruled out. Convincing evidence in the form of SEM micrographs of phytoliths from plants, however, has yet to be presented. (The only SEM micrograph of a phytolith Anderson-Gerfaud seems to have published until now (1983, p.103, pl.1:7b) did not convince me of its similarity to a corresponding "phytolith"on a flint tool (ibid., pl.1:7a)).

Chapter 12 - Cleaning

At the beginning of this microwear analysis it was widely accepted that cleaning with chemicals of experimental and archaeological flint tools must be carried out before examining the tools under the microscope. Keeley (1980, pp.10-11) had cleaned most of his experimental and archaeological tools with detergent, White Spirit, a 10% solution of warm HCl, and a 20-30% solution of NaOH. Anderson-Gerfaud (1981, Vol.I, p.28-29) had followed Keeley's procedure initially, but had substituted H_2O_2 for NaOH, as she was aware of the fact that NaOH attacks silica. She also restricted chemical cleaning to the experimental tools. Vaughan had cleaned his experimental (1981, p.97) and archaeological (ibid., p.235) tools in soapy water, acetone and in some cases in a 15% solution of HCl. Moss (1983, p.105) had initially followed Keeley's method of cleaning with dilute HCl and NaOH, but had later used acetone, and occasionally dilute NaOH , as she discovered that she"found absolutely no difference in the appearance of the wear traces"after comparing chemically cleaned and uncleaned, experimental and archaeological implements.

Chemical cleaning had been carried out in order to remove remnants from the worked materials on experimental tools and also extraneous material which"is often deposited on an implement surface while the implement is buried in the archaeological deposit or during the handling of it after recovery by the archaeologist and the microwear analyst. Such material obscures existing wear traces and may even be liable to misinterpretation as an effect of use"(Keeley, ibid., p.10).

However, as mentioned above in Chapter 7, Keeley (1980. p.43) had found that cleaning with HCl altered bone polish. Vaughan stated that,"Systematic use of the acid (HCl) was avoided because it removed diagnostic residues, such as those from bone/antler, dried beef and stone...; and it destroyed the surface of flints in which there were even minute limestone impurities within the silicate matrix"(1981, p.97). Plisson (1983, Plisson and Mauger, 1986) had found that use-wear polishes could be removed by prolonged chemical attack with solutions of NaOH, CaO and Na_2CO_3, and that the speed of removal varied according to the contact material and the geological age of the flint.

My own observations under the SEM had shown that the only residues clearly due to use-wear which I had detected on the three blades investigated were deposited on top of the flint surface and had not sunk into it (see Part I, Chapter 7). This would make their removal with chemicals, such as reported by Keeley (1980, p.43), Vaughan (1981, p.97), and by Plisson (1983; Mauger and Plisson, 1986) very easy. Keeley (ibid., p.11) had used solutions of HCl which is known to attack the calcium of which the bone residues may consist. He also noted (ibid.) that prolonged immersion of the flint in solutions of NaOH led to patination of the immersed tool, and pointed out (ibid., p.10) that chemical cleaning would remove organic residues surviving on artefacts recovered from environments in which they are preserved, such as dry cave sites (Wylie, 1975).

Plisson (op. cit.) used solutions of NaOH and Na_2CO_3 which (as he was aware) to some extent may attack amorphous silica such as would form a deposit (such a process was demonstrated by Anderson and Whitlow, 1983, p.471) and to a lesser extent may attack the flint grains themselves.

Moss (1983, p.92) mentioned the fact that she did not find a polish"bevel"from bone (such as observed by Vaughan) on her experimental flint implements. This might well be due to the fact that Moss cleaned her experimental tools in dilute NaOH, as in my opinion (see Chapter 14) such a"bevel"is a build-up of amorphous silica.

While the above evidence suggested to me that neither the experimental nor the archaeological tools should be cleaned in chemical solutions the following problems remained:

Obvious extraneous deposits (identified as such by virtue of their appearance, which differed from that of polish) were seen on some of my experimental tools. However they tended to fall off after some time in storage, and, as I discovered when I viewed the flint tools of Blind Test 1-10 before and after immersion in dilute NaOH, their presence or absence did not alter my interpretation of the polishes (see Part I, Chapter 20).

Residues from hafting, such as wax, resin or cellulose adhesive (Uhu), had to be removed in order to look for hafting traces. I initially attempted to remove these with acetone, but soon found that the acetone combined, especially with Uhu, to leave acetone"bloom" on the flint surface. I therefore cleaned hafted tools in White Spirit which removed wax and resin satisfactorily and which does not attack flint (Dr. Don Robins, pers. comm.).

Limestone concretions obscured the edges of a few of the archaeological implements completely. I did clean such tools in a 10% solution of HCl but always noted the exact cleaning procedure in order to treat experimental tools in the same way for comparison.

Grease from handling of the tools was cleaned with soapy water.

I therefore decided to clean the experimental and the archaeological tools only in water and ammonia free detergent, and then, if necessary, in an ultrasonic cleaning tank. In the few instances where chemicals had to be used, i.e. when experimental tools had been hafted, or when archaeological tools were covered with concretions, I always noted the exact cleaning procedure. From the observed (see Blind Tests 1-10, Part I, Chapter 20) and the reported alteration of polishes due to cleaning with chemicals (Keeley, 1980, p.43; Vaughan, 1981, p.97; Plisson, 1983; Plisson and Mauger, 1986) it seems to me that the exact cleaning procedure should always be stated in publications.

Chapter 13 - The Influence of Soil Chemistry on Polishes

Plisson (1983) remarked that his research into the effect of chemicals on polished flint surfaces suggested that the chemical composition of the soil might significantly affect the polish on the flint tools excavated from it. This process was demonstrated by Anderson and Whitlow (1983, pp.471-472) who found that archaeological flints excavated from alkaline environments showed similarly changed amorphous silica layers as did experimental flints which had been rinsed in NaOH. In fact, Anderson-Gerfaud (1981, Vol.I, p.7) stated that she cleaned some of her experimental tools chemically in order to imitate the natural environments from which the tools were excavated. However she did not state what the chemical compositons of these various layers were.

It seems to me that while it would be impossible to analyse the composition of a particular soil layer over the ages (as such compositions change according to such factors as the climate), and while it would be very time-consuming to analyse the chemical composition of the soil in its present state down to every chemical, it is nevertheless advisable to collect soil samples from the site in order to get some idea of its pH which, if very alkaline, would tend to affect amorphous silica.

The analysis of the soil from Arjoune, Trench VI, carried out by means of a B.D.H. Barium Sulphate Test, showed the following pH values: the soil from the pre-occupation layer had a pH of 7.5-8.0; the soil from the occupation layer had a pH of 7.0; the soil of the alluvium above the occupation layer had a pH of 7.0-7.5.

As the occupation layer showed a neutral pH value and as the investigation of the archaeological tools showed that in most instances the amorphous silica coating seemed to be intact - most obviously on the sickle blades - I did not clean my experimental tools in alkaline solutions such as of NaOH.

Chapter 14 - Experimental Polishes

1. Method

Four Hundred and thirty-six implements made of flint from Brandon in Suffolk, Surrey and Potter's Bar, London, in England, of flint and chert from Arjoune in Syria, and from the Dordogne and Pincevent in France, were used to saw, cut, scrape, whittle, plane, bore, drill, pierce, chop, grave and rub the following broad categories of materials: wood, bone, hide, antler, horn, meat, fish, shell, stone, pottery, sand, feather, wool, ivory, copper and plants. Some experimental tools were used hafted. The experimental procedures are described in Part II in relation to the tool classes.

The experimental tools were cleaned in warm water and ammonia-free detergent and often for up to 10 minutes in an ultrasonic cleaning tank in distilled water. No chemicals were used. The tools were observed under the light microscope at magnifications of:

50x - in order to locate the polish, define its extent and look at the edge damage (see Part I, Chapter 4).

100x - in order to look at the directional distribution of the polish and the striations.

200x - in order to look at the character of the polish (i.e. the degree of abrasion of the flint surface, the amount of amorphous silica and the distribution of both) and the depth and the width of striations.

Unless otherwise indicated, the descriptions and the photographs of the polishes are based on magnifications of 200x, with the investigated surface held parallel to the microscope lens. The understanding of polish formation, and therefore its description, is based on observations under the SEM which indicated that polish is formed as the result of abrasion and a very thin coating of amorphous silica (see Part I, Chapter 7, Unger-Hamilton, 1984).

Although I described the polishes from a slightly different viewpoint from that of other researchers, i.e. I described what I thought had happened to the flint surface rather than just the appearance of the altered flint surface, I found that my observations of polishes generally agreed with those of other microwear analysts (Keeley, 1980; Anderson-Gerfaud, 1981; Vaughan, 1981; Moss, 1983).

2. Wood

Fifty-six experiments had been carried out sawing, scraping, whittling, boring, drilling, graving, chopping and rubbing the following kinds of seasoned and fresh wood (in some instances soaked in water for one day): oak, ash, sycamore, birch, cherry and pine.

The resulting polishes were quite varied. In general the microtopography of the flint was gently polished, leading to the"domed"look (Keeley, 1980, p.35) often described as characteristic of wood polishes. The undulating, brilliant look of the flint surface is probably caused by the amount of amorphous silica which I believe is due to the amorphisation of the flint surface. The brilliance and amount of"liquid" looking polish varied with the moisture content of the wood (Pl.8:e,g). Some woods, like sycamore, also caused a greater degree of amorphisation of the flint surface than did others. Cutting pine produced only little polish on the tool surface. The likely reason for this was the fact that the flint became covered in pine resin. Contact with bark caused rougher looking polish than did contact with heartwood. The distribution of wood polish was generally wide, presumably because wood is a yielding material. It depended on the action with which the tool was used, i.e. when wood was scraped, a continuous line of polish, a kind of "bevel", probably of amorphous silica, was found at the scraping edge (Pl.9:a). Such a"bevel"was not found on wood saws. The distribution of wood polish is generally described as "reticular"(Moss, 1983, p.91). However, I found the "reticularity"or the degree of horizontal linkage of the polish varied with the hardness of the wood, the grain size of the flint, and with the pressure applied and drilling led to completely linked smooth polish with few striations at the drill tip (Pl.12:a), while boring led to an incompletely linked polish with striations at the borer tip (Pl.11:a). Striations were not common on woodworking tools. This agreed with Moss' experimental results (1983, p.91) and disagreed with those of Keeley (1980, p.35) who found a distinctive broad shallow type of striation on his woodworking tools. However, I found that striations apparently filled with amorphous silica (Mansur, 1981) were the most common types of striations from woodworking.

Similarity to other polishes:

In Blind Test 1-10 I consistently mistook wood polish for (reindeer) antler polish. The same had happened to other microwear analysts (e.g. Keeley, in Keeley and Newcomer, 1977, p.55). I feel that the following could have been the reasons for this mistake: 1) I was not familiar with reindeer antler polish at the time. 2) Newcomer, who carried out the experiments for these blind tests, had used the scraper at an angle of 90 degrees , while I had used my own at angles of c. 45 degrees , and therefore the distribution of polish on the test scraper had been slightly unusual for me.

I also found a similarity between fresh wood and reed polishes (Pl.13:c and 23:d). However, reed polishes were always distinct because of the complete absence of striations on them. Leather, when soaked in water for one day, caused a polish virtually identical to wood polish

(Pl.29:c and 9:a). The"bevel", or apparent build-up of amorphous silica found on some woodworking tools could be confused with such bevels on tools used on soaked antler and fresh or cooked bone (Pl.9:a,g,h).

3. Bone

Fifty-five experiments were carried out sawing, scraping, whittling, boring, drilling, graving, chopping, rubbing bone (long bones, shoulder blades and ribs) of the following animals: cattle, pig, sheep, deer and chicken. The bones were worked fresh, dried, roasted and cooked.

Like Newcomer (1974) I found that soaking bone in water did not make bone working easier, and therefore I did not soak bone after my initial experiments.

Bone polish in general was isolated, as bone is an unyielding material.

When a flint had been used on dried bone, the polish looked "pitted", probably because bone, which is hard, had flattened the very tops of the microtopography of the flint only, leaving the depressions in the flint surface unpolished. Very little amorphous silica was seen, which is probably why the polish looked matt (Pl.15:c).

However, when fresh or cooked bones were worked, the flint surface looked more brilliant, probably due to the presence of amorphous silica which often collected as a "bevel"(Vaughan, 1981, p.141) on the tool edges (Pl.9:h and 11:e). (But note the"bevel"from dry bone on Pl.19:a). The fact that Moss (1983, p.92) had not detected such a bevel on her experimental tools (although she had seen it on prehistoric tools) could well be due to the fact that she had cleaned her experimental tools in dilute NaOH which can attack amorphous silica (see Part I, Chapter 12). Keeley (1980, p.43) discovered that after cleaning his boneworking tools in solutions of HCl, the polishes looked pitted, and he suggested that the removed elements had been bone apatite which had become embedded in the polish. (This is discussed in Part I, Chapters 7 and 12 : I had found bone residues adhering to, but not embedded in the flint). If such residues merely adhere to the flint (albeit for a long time - 6 months - as was shown in my experiments) it follows that such residues might eventually fall off and that bone polishes will look"pitted", as Keeley had described, even when HCl is not used to clean boneworking tools.

The distribution of bone polish varied according to the action; as Vaughan (op. cit., p.168) had observed, polish bevels only resulted from transverse actions, while a"smooth-pitted" polish (ibid, p.135) resulted from sawing bone.

I only observed one instance where a difference in polish might have been due to a difference in species of animal: sawing the long bones of (roast) chicken always caused wide bands of bright polish (Pl.29:f) not seen on flint used to saw bones from other animals.

Striations tended to be deep and narrow. They were often seen on polishes from sawing bone, but not from working bone with transverse actions, such as scraping, although polish bevels on such scraping edges tended to look lined (Pl.9:h, see also Pl.11:e).

Similarity to other polishes:

As Vaughan (1981, p.135) pointed out, polishes from sawing of bone and antler could be virtually indistinguishable. I also found that bevels of bone polish could look like bevels from wood or antler scraping or graving.

4. Hide

Twenty experiments had been carried out scraping, cutting, piercing, drilling and rubbing dry and fresh deer hide. Also, two experimental tools used by Bergman on hide with the addition of ochre were examined. Some experiments were carried out scraping pig skin, dry and soaked in water for one hour.

In general hide is fairly yielding, and working it led to the gentle polishing of the flint surface which gives it the"bumpy","matt" look (Keeley, 1980, p.49) often described (Pl.10:g and 14:g). There were great variations according to the state of the hide: dry hide - less yielding than fresh - caused the"pitted"(Keeley, ibid.) look by only polishing the tops of the microtopography of the flint. Fresh hide - more yielding, and therefore polishing the flint depressions as well as the tops - caused the"bumpy" (Keeley, ibid.) polish with some amorphous silica, I believe, making the polish look somewhat brighter than dry hide polish.

Dry leather caused very little polish, because it was dry and also softer than dry hide . However, leather soaked in water caused a very brilliant, fluid looking polish, totally different to the other polishes from hide. This polish resembles wood polish (Pl.29:c).

Hide scraped with the addition of ochre led to far greater abrasion of the scraping edge (Pl.10:e).

There were no differences in polishes according to different actions, except when dry hide was rubbed. The polish was not typically"pitted"looking, as one would have expected from dry hide.

Not enough experiments were carried out to investigate the effect of hides from different species of animals. Kamminga (1978, p.137) mentioned that marsupial skins caused wear-traces which were different to those reported from skins of other animals.

Striations seemed rare when hide was cut, but lots of diffuse shallow linear features (Keeley, ibid., p.50) could be seen on hide scrapers.

Similarity to other polishes:

Anderson-Gerfaud (1981, Vol.I, p.53) combined hide and meat polishes, while Vaughan (1981, p.160) combined fresh hide and meat polishes. However, I agree with Keeley (op. cit.) and with Moss (1983, p.86) that the two are fairly distinct. Like Moss (ibid.) I found a similarity between the reticular distribution of dry hide polish and that of wood (or in my case dry reed). I also would have mistaken the polish from soaked leather for fresh sycamore polish. I did confuse hide and antler polishes at times.

5. Antler

Twenty-five experiments had been carried out sawing, scraping, boring, drilling, graving and rubbing red deer, reindeer and fallow deer antler, dry and soaked for three days in water. Unfortunately the faunal evidence, for red deer at Arjoune, was only completed a week before this thesis. I carried out two experiments with red deer antler and the resulting wear-traces were similar to those from fallow deer antler.

In general, the distribution of soaked antler polishes from both species was quite wide and reticular, very much like that of wood polish, probably because both wood and soaked antler were in my experiments similarly yielding.

Contrary to Keeley's assumption (1980, p.56) the polish from reindeer antler and from fallow deer antler looked somewhat different: contact with fallow deer antler caused the flint surface to be quite flattened, and in all cases widely spaced fine striations were visible (Pl.9:g) while reindeer antler which is perhaps less dense, did not flatten the flint surface considerably, but caused a"domed"look (Vaughan, 1981, p.144), especially when antler had been scraped or planed, and striations were not always seen (however, see Pl.11:c).

The polishes from dry antler (Pl.15:h) of either species looked matt and reticular like dry bone polish, while the polishes from soaked antler of either species invariably became more linked, bright and more undulating, probably because the antler had become more yielding and more silica had become amorphous due to the increase of moisture in the antler.

There were some variations in polishes according to tool action: as all researchers had found (Keeley, op. cit.

,p.56; Vaughan, 1981, p. 145; Moss, 1983, p.87) sawing reindeer antler caused a"rough and pitted"(Keeley, op. cit., p.56) polish. (I did not find such pitting, possibly because I had not cleaned my tools in chemicals such as HCl.) I did notice a lot of striations on antler sawing tools, especially on those used to saw fallow deer (Pl.15:g). Transverse actions, such as scraping or planing antler, tended to cause polish"bevels"on the used flint edges. Rubbing caused an altogether different polish which could be identified on Blind Test tool 12 by virtue of its streaky distribution and a somewhat flattened flint surface with some amorphous silica.

Similarity to other polishes:

I found (as had Keeley, 1977, p.55; Vaughan, 1981, p.144) that "smooth antler"polish from transverse actions on antler could be confused with wood polish (Pl.9:g and 8:e). I found (as had Vaughan, 1981, p.135) that polish from antler sawing could look indistinguishable from that of bone sawing, and also that the bevels of polish from scraping antler and bone could look similar (Pl.9:g and h) (Vaughan, op. cit., p.145). Although Keeley appeared to doubt this (op. cit., p.56), I thought that undeveloped antler polish could look like dry hide polish. Pressure flaking with antler caused a polish which could be confused with undeveloped hide or antler use-wear polish (Pl.6:f).

6. Horn

Four experiments were carried out sawing, scraping, graving and boring cow horn soaked in water for five hours.

Although the flint edges were blunt, very little polish developed. Only a few areas of relatively flat polish could be seen, together with a few short tracks (Pl.16:d). This polish would be impossible to detect on archaeological tools with post-depositional surface modifications (a term first used by Holmes, 1986).

Similarity to other polishes:

The polish from scraping horn could be confused with weak hide or antler polish.

7. Meat

Eleven experiments were carried out cutting meat (cooked and uncooked), beef, pork, chicken and lamb, and scraping meat off deer hide. In addition, projectiles (points and transverse arrowheads) and barbs which Bergman, and Newcomer, had shot into meat were examined. Meat cutting tools used by Miller were also examined.

Polish from the contact with all meat, regardless of animal species or whether cooked or fresh, looked similar:

the flint surfaces were only gently polished, some fine striations and very little amorphous silica were present (Pl.14:a). This observation seemed to agree with those made by other researchers (Keeley, 1980, pp.53-54; Moss, 1983, p.93; Vaughan, 1981, pp.160-162).

Variations in polishes appeared to depend on whether bones or tendons were cut as well as meat (Pl.14:c), or whether a wooden cutting board had been touched by the tool: bones and tendons (Pl.16:a) seemed to cause some bright striations, while touching the wooden board left isolated patches of wood polish at the tool edge.

Scraping meat off hide caused meat polish on the aspect of the flint blade which had had contact with the meat, while hide polish could be seen on the other side.

Most of the arrowheads shot into a deer carcass showed what Moss (1983, p.95) had called"microscopic linear impact traces (MLIT)"(Pl.20:e,g). She found (as did I) that in most cases the target could not be determined from such traces. Apart from these traces found along the impact axis, I noted that linear polish and striations were also located at other angles on projectiles than those of the impact. Such traces presumably originated when the projectile was deflected inside the carcass, e.g. by bone, or else when it was pulled out of the target.

Similarity to other polishes:

As Vaughan had pointed out (1981, p.162), meat polish is weak and could be disguised by general post-depositional traces (which he referred to as"soil sheen"). On coarse-grained flint I sometimes could not detect meat polish at all. Vaughan (ibid., p.161) and Anderson-Gerfaud (1981, Vol.I, p.53) could not find any difference between fresh hide and meat polish. However, I agree with Moss (op. cit., p.93) that on experimental tools the two polishes looked quite different.

8. Fish

Five experiments were carried out gutting, cutting and scaling bream, gurnet and trout.

When fish was gutted, hardly any polish was visible; when fish was cut, the resulting polish consisted of bright line at the flint edge, the flint microtopography looked quite flattened, and some fine striations were visible. When fish was scaled, in some cases a very distinct pattern of polish developed. It consisted of wide polish streaks running obliquely from the flint edge, presumably where the fish scales had come into contact with the flint (Pl.15:e and 29:d). A similar pattern of"cross-hatching"had been reported by Moss (1983, p.105). However, in some instances, when flint was coarse-grained or in Blind Test 1-10 (although the fish scaled had hard scales), no such pattern could be seen.

Similarity to other polishes:

I could not find any similar polishes to either the polish from cutting fish, nor to the polish from scaling fish. However, the frequent absence of the streaky polish pattern from fish scaling indicates caution, and one should not conclude from its absence that fish was not the worked material.

9. Shell

Twelve experiments were carried out cutting, scraping, drilling, boring , incising and rubbing cardium, scallop shell and ormar shell.

The resulting polishes looked similar, regardless of shell variety and tool action: shell polish affected only isolated areas of the flint surface. The high points of the flint microtopography were quite flattened, more so than from contact with bone, less so than from contact with stone.

Characteristic and always present were parallel bundles of fine, narrowly spaced striations (Pl.9:e).

This polish looked exactly like that shown by Moss (1983, p. 104, pl. 6:8a) and by Yerkes (1983).

Similarity to other polishes:

I found shell polish very characteristic on account of its narrowly spaced striations, although it could possibly be confused with stone, bone or antler polishes, if these caused similarly spaced striations.

10. Stone

Fourty-one experiments were carried out cutting, scraping, polishing, graving, drilling the following varieties of stone: limestone, quartzite, schist, metamorphic rock, lapis lazuli, malachite and flint. In addition, traces from the manufacture of tools with quartzite or limestone hammers were observed.

The general polishes consisted of a complete flattening of the tool surface resulting in very bright, wide streaks of polish and bundles of striations (Pl.9:c, 12:e, 7:e), see also Moss (1983, p. 103, pl. 6:8c). Some amorphous silica was visible, probably causing the hammerstone"smears" shown by Keeley (1980, Pl.8) (Pl.6:a,b).

The polishes did not show any particular variance according to tool action, only according to stone type: the polish looked more diffuse (i.e. the tool surface was finely scratched rather than completely flattened) from contact with softer stones, such as limestone or malachite.

Drilling both lapis lazuli and malachite left residues from these materials on the tools even after cleaning.

Similarity to other polishes:

Polishes from soft stones, such as malachite, could be confused with polish from sand and pottery, probably due to the sand-like consistency of the soft stones. In one instance (Blind Test 1-10) the traces from scraping stone left on a scraper made of medium to coarse-grained French flint were confused by me with antler polish. This might have been due to the fact that at the time I was not familiar with stone scrapers, nor with wear traces on that particular flint. Hammerstone traces were usually distinct. However, they might well be the dominant type of wear trace on such tools as scrapers, thus potentially misleading, especially to the inexperienced microwear analyst.

11. Pottery

Eight experiments were carried out cutting, boring, graving and drilling pot sherds from Arjoune, Trench VI and from Abu Salabikh. Only the tops of the flint microtopography were flattened and the polish looked bright, but diffuse and finely scratched, with lots of striations (Pl.11:g). Residues from the pottery could still be seen adhering to the flint surface after cleaning.

Similarity to other polishes:

I found the polish indistinguishable from sand polish (Pl.7:a), and therefore potentially indistinguishable from natural sand polishes, except for the residues from the pottery (Pl.11:g). Sand did not seem to leave such residues. The polish also looked similar to polishes from soft stone.

12. Sand

Six experiments were carried out to show wear traces from sand: flint was rubbed against sand, drill bits were used on various materials: copper, shell and lapis lazuli, with the addition of sand, and sand together with water. In addition, a projectile shot into earth by Newcomer was examined.

Sand polish from all these activities (except drilling) looked similar: the surfaces of the flint tools were diffusely polished with scratches and lots of fine striations running in the direction of use (Pl.7:a).

Drilling with the addition of sand however caused an even (but not smooth) polish without any visible striations which totally obliterated the wear traces from the worked material itself. A similar phenomenon was described by Vaughan (1981, p.163).

Drilling with the addition of sand and water also obliterated the traces from the worked materials, but caused a different polish from that of drilling with the addition of sand alone: when water was added, the wear traces consisted of a completely smooth tool tip with a concentric ring pattern (Pl.29:g). A similar phenomenon had been reported by Gwinnet and Gorelick (1979) who had examined drill casts - made by wooden drills with the addition of sand - under the SEM.

Similarity to other polishes:

In Blind Test 1-10 I confused polish on a projectile point shot into earth with bone polish, on account of the striations. As pointed out above, sand polish can be confused with polish from working both soft stone and pottery. Striations in sand polish due to natural agencies would presumably be randomly orientated; however, this too is an area for potential mistakes.

13. Feather

One experiment cutting the quill of a pigeon feather left a thin, indistinct, band of polish along the edge (Pl.15:f).

14. Wool

One experiment was carried out cutting wool from a Shetland sheep. The sheep's wool might be different to that of the ancient Near Eastern sheep, as the ancient breeds had long, coarse hair with a downy undercoat, unlike the thick-fleeced breeds of today (Broudy, 1979). It is unlikely that the ancient breeds who moulted (Ryder, 1983) were shorn with flints, but the spun fibers may have been cut.

The wear traces consisted of a brilliant line of polish just on the edge of the flint blade, together with lots of fine striations in the cutting direction (Pl.14:e).

This polish looked similar to sinew polish (Pl.16:b).

15. Hippopotamus"Ivory"

One experiment was carried out drilling hippopotamus tooth.

The resulting polish was very distinct: it had flattened the flint tip gently while very small pits remained visible (Pl.29:h). I did not see any similarity between this polish and any other polishes.

16. Copper

In two experiments copper was drilled.

The resulting polish (Pl.29:e) was very distinct: the drill tip was completely and evenly flattened. Some copper residues were seen adhering to the tool surface.

I did not see any similarity between this and other polishes.

17. Plant

One Hundred and eighty-seven experimental flint edges were used to cut cereal and non-cereal plant species. (The complete list of these plants is given in Part II, Chapter 17.4 .) The plants were cut in some instances both fresh and dried. Reeds were also scraped and cane was scraped and bored. In two experiments root vegetables (carrots) were cut.

Most plants caused macroscopic gloss as soon as polish was visible under the microscope, with the exception of occasions when very coarse grained flint blades had been used. On these gloss was visible somewhat later than microscopic polish. (For a detailed account of the variables involved in the formation of plant polish see Part I, Chapter 16 .)

In general, contact with plants caused a gentle polishing of the flint surface which left the tops of the flint microtopography rounded. The polishes looked buoyant, probably due to the amorphous silica liberated by the moisture from the plants (see Pl.22-25).

Contact with fresh plants caused a greater amount brilliant polish, developing at a much faster rate, than did contact with dried plants (Pl.23:c,e).

There were considerable variations in polish formation according to plant species (see Table 2). This agreed with observations of Anderson-Gerfaud (1983). Hard-stemmed plants such as reeds and einkorn caused a reticular polish due to the fact that the unyielding stems could only polish the very tops of the flint microtopography (Pl.23:c and Pl.22:a). However, cane, perhaps because it was very hard, polished the entire flint edge (Pl.24:c), while very soft plants,such as bulrushes, horsetails and grass, also polished the entire flint surface (Pl.23:a, 25:e,c). Thick-stemmed plants, such as reeds and bulrushes caused flint surfaces to be widely and relatively evenly polished (Pl.23:c,a), while thin-stemmed plants, such as grass, caused only a narrow band of polish on the very edge of the flint (Pl.25:c). Stems of medium width, such as the stems of cereals and of cane (as cane stems, although thick, are hollow), caused both a concentrated band of polish on the very edge of the flint and some weaker polish away from the edge (Pl.22:a,c,e,g, Pl.24:c).

Polishes from plants in their wild and domesticated form had a similar distribution (Pl.22:b,h).

The occurrence of striations, comet-shaped pits (Witthoft, 1967; Diamond, 1979) and of micro-pitting looking like the effect of sandblasting, seemed related not to the structure of the plant, but to the presence of loose soil during harvest (see Part I, Chapter 9). Korobkova was the first to suggest that striations in plant polishes are due to abrasion from the soil rather than from silica in the plants (1981, p.331).

In my experiments, striations were absent in polishes from cutting plants growing in water (in England as well as in Syria), such as reeds, bulrushes or horsetails (Pl.23:c,a, 25:e). A few striations were usually present on blades used to cut plants growing on a grassy soilcover (Pl.22:a), while many more striations were present on polishes from plants cut at the base from upturned soil in England (Pl.22:e,f). Plenty of striations are likely to occur when plants are cut from upturned loose soil in the Near East.

Scraping reeds (Pl.23:g,h) and scraping and boring cane caused essentially the same polishes as did cutting these plants.

One water plant species, Sparganium ramosum , cut both in England and in Syria, caused very unusual wear traces in the form of a cracked looking deposit (or polish?) (Pl.24:e,f) which not even twelve hours immersion in White Spirit , known to be a powerful organic solvent , could remove. Very little is known about this plant, and according to Dr. John Bryant, Reader in Plant Physiology at Univ. College, Cardiff, (pers. comm.) there may be some plant waxes which do not dissolve in White Spirit.

The polish from cutting carrots for approximately 15 minutes (Pl.16:c) was indistinct. No macroscopic gloss was visible on the flint blades.

Similarity to other polishes:

The divisions between plant polishes were by no means clear cut. A large sample of archaeological flint tools would need to be examined before attempts can be made to identify different plant polishes.

Reed polish could be similar to fresh wood polish, but it is almost never striated, and the gloss from reeds tends to be much stronger. However, dry plant polishes could well be confused with wood polishes.

The presence of strong macroscopic gloss makes most plant polishes easily distinguishable. Other materials which caused gloss caused polishes which looked different to plant polishes.

18. Hafting and Prehension Traces

Hafting traces in the form of polish and striations, have often been reported, an example being the traces Anderson-Gerfaud saw as hafting traces on Mousterian implements (1981, Vol.I, p.41). Keeley identified the raw material from which alleged hafting traces originated, i.e. of the haft itself (1982, figs.1 and 2). Cahen and Gysels (1983, p.44) reported hafting evidence in the form of hide and bone or antler polish on unused areas of Neolithic tools from Blicquy. Bueller (1983, pp.114-124) defined on almost all the Natufian tools which he had studied microscopically the exact material of the hafts. In none of these examples did the authors report any hafting experiments nor did they refer to any possible post-depositional surface modifications (see Holmes, in press) of the ancient flint tools they had studied.

Plisson performed 20 hafting experiments (1981) and found that traces were so isolated that on ancient tools they could be confused with post-depositional traces. Only when ochre had been mixed with the hafting agent and the tool loose had been loose in the haft were hafting traces present. Moss (Moss and Newcomer, 1981; Moss, 1983, pp.101-102) also found that traces from firmly fixed hafts were rare and minimal. Odell (1978, p.42) observed that friction in a loose haft also caused not only polish, but also diagnostic edge damage. However, as Keeley himself stated (1979, p.681) a properly hafted tool should not be loose, and in my opinion would be immediately rehafted because of its reduced efficiency.

Some authors (Semenov, 1964, p.115 ; M.-C. Cauvin, 1973) referred to the distribution of polish on the flint, and to a"sharp demarcation between the polished and mat surfaces..."(Semenov, op. cit.) as evidence for hafting.

Prehension traces (i.e. traces from holding an implement) were reported in the form of edge damage (Odell and Odell-Vereecken, 1981) or in the form of polish and striations (Semenov, op. cit., pp.14 and 107; Keeley, 1982, p.807; Vaughan, 1981, pp.164-165).

My own experiments showed that I could not detect any hafting traces on end scrapers securely hafted with resin, wax and sinew, nor on those simply wedged into a wooden haft. Nor were any such traces visible - with the exception of a few striations across the bulb of one tool - on 15 drills used for up to 10 minutes to drill very hard materials, such as stone or copper. The drills had been hafted not only with resin, wax and sinew, but also with the addition of ochre in some cases. Neither could I detect any hafting traces on ancient drills which on account of their small size and concentrically polished tips must have been used in a haft. Had there been any minute traces, such as described by Moss in connection with firmly secured hafts, they would have been obliterated by the postdepositional traces found all over these tools.

On the tools of Blind Test 1-10 all manner of traces were observed on the areas which were obviously not used. However, there was no consistency in the nature of these traces according to whether they had been used hafted or handheld. This indicated to me (as Moss had observed in connection with traces from refitting (op. cit., p.102) that it might be fruitless to attempt to isolate prehension traces on ancient tools.

I did find that the distribution of the use-wear polish could indicate hafting; for example, on a blade used in Blind Test 1-10 to cut meat, polish formed a completely straight line along the entire edge of the tool. This indicated to me (correctly) that the tool had been hafted. I found the same phenomenon, and in some cases a sharp demarcation between polished and unpolished areas on experimental sickle blades which I had used hafted.

However, I do agree with Moss (ibid., p.102) that"... hafting wear traces are inconsistent..."and I found it therefore hard to believe (in the absence of any evidence) that the researchers quoted at the beginning of this section could not only tell whether tools had been hafted, but also the precise material from which the haft had been made. I also agree with Moss (ibid.) that other"more consistent factors"should be looked for as evidence for hafting, such as the tool shape and/or the frequency of resharpening of a tool, and finally the recovery of the hafts themselves, although - as Moss herself realised - wooden hafts would rarely be preserved.

19. Conclusions

I found that in practice experimental polishes differed according to hardness, width, structure and water content of the worked material, and that therefore it is likely that such differences can be recognised. However, I also found that quite often such attributes on one worked material could be similar to those on a totally different worked material, and that therefore polishes from two very different materials could look alike.

On the whole, my observations agreed with those of the other researchers. Where they did not, the differences could be explained - at least in theory.

Chapter 15 - The Variables Affecting the Development and the Appearance of Polish - Outline

Despite the fact that microwear analysts had noticed the effects of variables other than the worked material on the rate of development and appearance of polish (Anderson, 1980, p.181; Vaughan, 1981, p.100; Moss, 1983, p.55) there had been no systematic series of experiments aimed at discovering which variables are involved and to what extent they are involved in polish formation. The only exceptions had been Vaughan, who had experimented with three different flint types (op. cit., pp.127-132) and Gysels and Cahen (1982) who had investigated the effect of hydration on a variety of materials. However, both these investigations came to my attention after I had conducted most of the experiments described in this chapter.

I ran a preliminary controlled series of experiments concentrating on plants as a worked material, in order to investigate how the rate and the appearance of polish were affected by the following variables: plant species; the water content of the plant; the point at which the stem was cut; the time of year of harvest; the number of stems cut with one movement; the source of flint; the force applied by different workers; the resistance or hardness of the stems; the effect of different environments on the same plant species.

Other variables which were not tested at the time were kept as constant as possible: the direction of the cutting movements; the dimensions, shape and angle of the edge of the blades; the temperature, humidity and windforce during the experimental work.

After this preliminary investigation concentrating on plants, I carried out further series of experiments in order to:

- see whether the same variables affected polish formation due to contact with materials other than plants. This I did in view of the fact that Del Bene (1979; Holley and Del Bene, 1981) had argued that materials such as plants caused additive polishes, while other materials caused abrasional polishes.

- investigate more fully some variables, and demonstrate their effect with the help of measurements of light sensitivity.

- test some variables which had not yet been tested in the preliminary experiments.

Chapter 16 - The Preliminary Series of Experiments with Plants

1. Method

The blades were struck with an antler hammer, caught by hand, and examined under the microscope before use. Most blades were made of vitreous-looking black flint from Brandon, others of opaque-looking grey flint from Potter's Bar in London, others of coarse- and very coarse-grained flint from Arjoune in Syria. Sixty-six experimental blades were used between May 1982 and May 1983 in South England, Wales and Syria. The following plant species were cut fresh and dried, in some instances at intervals of four to six weeks: reed (Phragmites communis Trin.), bulrush (Schoenoplectus lacustris L. (Palla), grass (several species including the Sweet Vernal Grass (Anthoxanthum odoratum L.)), einkorn (Triticum monococcum L. emend. Lam.) and domesticated barley (Hordeum disticum L. emend. Lam.). The non-cereal species were classified according to Clapham et al. (1962) and the cereal species according to Schiemann (1948).

The blades were used unretouched and unhafted to cut across the plant stems which were bundled in one hand. At all times a sawing motion was used at right angles across the plant stem. One s.m. equals one movement forward and one backward. The sawing movements were counted and the blades examined every 100 s.m. for appearance of gloss by gently wiping the surface of the flint with distilled water and letting it dry naturally. As the investigation of the ancient"sickle"blades had shown that gloss and plant polish nearly always corresponded (with the exception of very coarse-grained flint, see below), it was assumed that whatever caused gloss also caused polish. Therefore the first appearance of gloss was taken as a fixed point at which to compare the polish on the blades. The following may serve as an example: it took 100 s.m. through fresh reeds in July to cause the beginning of gloss and polish on Brandon flint, and 2000 s.m. (also in July) through fresh einkorn to cause the same, therefore 100 s.m. in the case of reeds, and 2000 s.m. in the case of einkorn were taken as one unit of development, and the polishes were compared as representing an equal stage of development.

The method of storage, cleaning and investigation of the tools was the same as that of all the tools (see Part II, Chapter 9).

2. Results

The plant species seemed to affect the rate of development of polish: it took approximately 50-100 s.m. through reeds, 2000 s.m. through bulrushes, 600 s.m. through grass, 2000 s.m. through einkorn, and 4000 s.m. through domesticated barley, before gloss and polish could be seen.

There were also considerable differences in the appearance of polish, especially when the cutting edges of the flint tools were compared at 200x; in particular the degree of smoothness varied. Grass caused the smoothest polish, followed by bulrushes, barley, reeds and einkorn which caused the most reticular polish (Pl.25:c, 23:a, 22:c, 23:c, 22:h). The distribution varied. The polishes from reeds and einkorn were more evenly distributed over the flint surface than those from the other plants, which were concentrated on the edge. After continued experimental work the differences seemed to increase, the grass polish becoming increasingly smooth, while reed polish remained quite reticular though showing a continuous edge, while einkorn polish, despite developing some reflective ridges, retained a discontinuous edge.

The water content of the plant seemed to affect the rate of development of the polish: it took 2000 s.m. on reeds stored for one month, 3000 s.m. on reeds stored for two months, 6000 s.m. on bulrushes stored for one month, 1200 s.m. on grass stored for one month, and 8000 s.m. on einkorn stored for four days, before gloss and polish could be seen. In the case of reeds this increased the number of s.m.s necessary for gloss and polish twenty times after one month and thirty times after two months, while in the case of bulrushes it increased three times after one month, in the case of grass twice after one month, and in the case of einkorn four times after only four days. The polishes also looked different from those caused by fresh plants: whereas polishes from fresh plants looked buoyant and smooth, those from the same plant species dried looked relatively flat and less smooth. Hardly any increase in polish seemed to take place after subsequent use. It was impossible to distinguish between polishes from different species of dried plants. Striations were seen only once, on dried reed polish.

It did not seem to make any difference to either rate of development or appearance of polish whether reeds were cut at the base or at higher points of the stem. This variable was not tested on other plants.

The time of year of harvest seemed to affect the rate of polish formation but not its appearance. Experiments were carried out harvesting reeds at intervals of six weeks and in May the polish was very strong, in July it was weaker, in September only faint at 100 s.m., and in November 200 s.m. were needed to form gloss and polish. This variation seemed related to the water content of the plant.

The number of stems cut with one movement (i.e. a single stem or a bundle of five stems) did not affect the rate of polish formation or appearance (18 experiments with reeds only).

The source of flint affected the rate of polish formation and although polish appeared on Brandon flint after 2000 s.m. through einkorn, it did not on the slightly coarser-grained Potter's Bar flint. However, after prolonged use (9000 s.m.) on grass the Potter's Bar flint showed the same amount of polish as the Brandon flint. Brandon blades used to cut reeds in November developed polish and gloss after 200 s.m.. However, coarse-grained flint and very coarse-grained Syrian flints used on the same reeds developed gloss only after 2500 s.m. and 5000 s.m. respectively. Microscopic polish had developed earlier than gloss, but had been difficult to spot as it looked unconnected, affecting only a few high points of the flint microtopography only. It therefore seemed that the appearance of polish was influenced by the topography of the flint surface; even on the fine-grained flints polish is most clearly evident along the ridges of feather fractures.

The force applied by different workers did not seem to make any difference to polish formation (18 experiments with reeds only).

The resistance or hardness of the stem was only superficially judged. It did not bear any relation to the rate of polish formation. The stems are listed in order of hardness and are compared to the approximate amount of s.m. needed for the appearance of gloss and polish: einkorn (hardest) 2000 s.m., reeds 50-100 s.m., barley 4000 s.m., bulrushes 2000 s.m., grass 600 s.m.. However, there seemed to be a relation to the appearance of polish and the sequence of plants graded according to their hardness corresponds to the sequence graded according to roughness (reticularity) of polish.

Different environments did not seem to affect polish formation and plants of the same species (reeds, and another plant, Sparganium ramosum , which was not used in the other experiments) caused similar rates of development and identical wear traces, regardless of whether they were harvested in England, Wales or Syria.

3. Conclusions

The rate of polish formation seems to be governed most importantly by the plant species, by the water content and by the type of flint from which the tool was made.

The appearance of plant polish seems governed by the plant species, perhaps because of the varying hardness and width of the stems, by the water content of the plant and by the topography of the flint surface.

The rate of polish development and its appearance do not seem noticeably influenced by the point at which the stem is cut, by the number of stems cut at a time, by the strength of the worker or by different environmental conditions.

The absence of gloss visible to the naked eye on coarse grained flint does not necessarily mean that plant polish will not be visible under the microscope on the same flint.

It seems that water from the plant (and/or substances contained in it) acts as a medium for polish formation. This conclusion is based on the fact that drying the plants causes a drastic reduction in the rate of polish formation. This reduction cannot simply be explained by loss of suppleness of plant tissue and therefore less contact with the flint surface, as was suggested by Masson _et_ _al_. (1981). This is evident from the fact that the reduction in the rate of polish formation was four times in einkorn after only four days of storage but during this time the stems had lost hardly any suppleness.

Chapter 17 - Variables of Polish Formation - Further Experiments

1. Flint

As the preliminary investigation had shown that both the rate of development and the appearance of plant polish were affected by the flint types I wanted to see whether the same variables applied when materials other than plants were worked, in order to find out how important it is to use experimental replicas made of the same raw material as the archaeological tools. Other researchers had reported widely differing results: Keeley (1980, p.16) found that different flint types did not cause different polishes, while Vaughan (1981, pp.131-132) from his experiments with three flint types of varying grain sizes concluded that polish formation was similar in rate of development and appearance, although somewhat slower and less connected- looking on flint of larger grain size, and that therefore different flint types would not pose any problem for the microwear analyst. Holmes (1986) demonstrated the differing rates of development of English chalk flint and of Egyptian limestone chert in paired experiments, but also concluded that polishes on the two stone types looked similar, when well developed. Moss (1983, p.55) simply stated that the raw material of the tool had to be replicated.

Experiments

I used five flint types: Brandon, Syrian"Type A", Syrian"Type B", Syrian"Type C", and Syrian"Type D". Of the Syrian flints two types had been found on the surface of the site of Arjoune, while two types had been knapped from cores excavated from Trench V. They ranged from fine to very coarse-grained. Ten experiments were conducted on bone and wood, and comparisons were made after each flint had been used for the same number of strokes.

Differentiation between flint types was made according to the following criteria: grain size, surface texture, opaqueness and colour. Of these attributes grain size and surface texture turned out to be interrelated and - except for inclusions - they were found to be consistent throughout each flint piece. Opaqueness was found to be unrelated to grain size/surface texture and not consistent throughout each piece. Colour was found to be unrelated to grain size/surface texture. The last two attributes were therefore disregarded.

I thought it simplest to define grain size/surface texture in relation to the focus under magnifications of 200x to 50x, as the depth of field increases with decreasing magnifications. Therefore flint easily focussed at 200x (Brandon and Syrian"Type D") was defined as fine-grained; flint easily focussed at 100x (Syrian "Type C") as medium-grained; flint easily focussed at 50x (Syrian"Type

A") as coarse-grained; and flint which can hardly be focussed at 50x (Syrian"Type B") as very coarse-grained (Pl.5:a,c,e,g).

Results

The results from the experiments sawing bone up to 800 s.m. and scraping wood up to 3200 s.m. (Pl.5:b,d,f,h) showed the following:

The rate of polish development seemed at first slower on the coarse grained flints. However, closer inspection revealed that the polish in its initial stages was very difficult to detect on coarse-grained flint, as the uneven texture of such flint led to only isolated areas of polish. Light sensitivity measurements of polishes on coarse-grained flints (Fig.2) showed that the rate of polish development was much slower on these. This was found with all materials worked, regardless of whether they were plants, wood or bone.

The appearance of polish was found to differ according to the flint type: the relative fineness or coarseness of the flint was nearly always found to correspond to the degree of linking of the polish. The exception was the medium-grained Syrian"Type C"which was patinated: polish on this flint was at least as developed and connected than the polish from equivalent use on the finer-grained Brandon flint. The other exception was the fine-grained Syrian"Type D" which developed very unconnected polish. This was probably due to its very irregular edge, again a consequence of patination.

Conclusions

The evidence from my experiments with different flint types supported Vaughan's conclusions (1981, pp.130-132) that both the rate of development and the appearance of polish vary with the grain size of the flint. However I did find exceptions to this rule, when flint was patinated. Seitzer Olaussen (1983) and Bradley and Clayton (1986) also reported different rates of polish development on thermally altered and recrystallised flint. I would therefore agree with Moss (1983, p.55) that the raw material of the archaeological tools should be replicated, in my opinion at least until such time that the microwear analyst is familiar with the polishes on the flint from his site.

The flint grain size proved to be an important variable in both the development of polishes from contact with plants, and of that from contact with other materials, such as bone. I therefore saw no evidence in favour of the hypothesis that polish from plants and wood is depositional while polish from other materials is attritional (Del Bene, 1979; Holley and Del Bene, 1981).

As had been the case with plants, the faint gloss visible on woodworking implements made of fine-grained flint was not seen on coarse-grained implements used on the same wood for the same number of strokes, although wood polish was visible at a microscopic level.

2. Duration of Work

While most researchers reported that at the very beginning of their development polishes from different worked materials could look indistinguishable, only Vaughan investigated the effect of time on polish formation more fully. He found three developmental stages:"generic weak polish"(1981, p.133 and pp.137-138), then"smooth-pitted polish"(ibid., pp.135 and 139), followed by fully developed polish. Although he referred to the initial"generic weak polish"as"dull"(ibid., p.138), he did not discuss a change in polish reflectivity related to the duration of work, but only as the first amongst the various attributes by which"micropolishes induced by certain classes of worked materials may be distinguished in most instances..."(ibid., p.129). Anderson-Gerfaud had made a similar statement (1981, Vol.I, p.35).

In fact, reflectivity, brightness, or (the term I prefer) intensity of polish, was generally seen as indicating primarily the worked material. Keeley (1980) used the term"brightness"in his description of polishes of precise worked materials, e.g. he described wood polish as"very bright"(ibid., p.35) and dry hide polish as"dull"(ibid.,p.49). He did not seem to see brightness of polish as related to the duration of work: he left out the time factor as a variable in his"Light Reflectivity Measurements"of polishes (ibid., p.62). Moss (1983, p.80), however, found that such attribution of a distinct polish intensity to a precise worked material only hindered her identification of polishes.

Intensity of polish was also seen as an indicator of the water content of the worked material (Anderson, 1980, p.181; Gysels and Cahen, 1982; Unger-Hamilton, 1983). Gysels and Cahen (op. cit., p.224), in their paper (which appeared after I had begun my experimental work) did refer to a variation of polish intensity related to the duration of work.

Observations

I wanted to find out to what extent the intensity of the polish was influenced by the duration of work:

Fifteen experimental tools of different grain size were used to work plants, wood and bone, and were examined before use and at regular intervals during use. The intensity of the polishes was measured using the exposure meter attached to the microscope.

Measurements were taken at 50x (this measurement would reflect primarily the distribution of the polish); at 100x (this measurement would reflect both the distribution and the intensity of the polish); and at 200x (this measurement would reflect primarily the intensity of the polish). A mean from measurements on three areas of the polish was calculated for each intensity value. The aperture of the microscope was held open and constant during this series of observations. Care was taken:

- to measure only even surfaces parallel to the lens, as a flint surface held at an angle to the lens is less reflective.I therefore measured only the ventral aspects of the flint implements;

- to ensure that the background was not measured as well as the flint surface;

- to ensure that the flint surfaces measured were of even colour and opaqueness;

- to avoid polish due to agencies other than use;

- to use similarly shaped tool edges in order to avoid uneven distribution of polish.

The measurements of the exposure needed (TIME) were plotted against the number of strokes (WORK). Absolute measurements of polish intensity cannot be made, but intensity could be measured by comparison with grades of white to black on a film test strip (P. Dorrell, pers. comm.).

Results

(See Fig.2:a-f)

The duration of work affected the intensity of the polishes from all worked materials (see plant and wood polishes).

The relative fineness and coarseness of the flint affected the intensity of the polish. In all cases the measurements of polishes on fine-grained Brandon flint produced steeper curves than did those of polishes on coarse-grained Syrian flints"Type A"and"Type B". The curves of the latter show hardly any deflection (compared to those of the polishes on fine-grained flint) although they become a little steeper at 200x. This probably reflects the fact that polish on coarse- grained flint was less connected compared to that on fine- grained flint. The medium-grained patinated "Type C"flint had a polish the intensity of which was similar to that on the fine-grained Brandon flint. The fine-grained patinated flint"Type D" showed an increase in polish intensity later than did the fine-grained Brandon flint, and then very suddenly.

The contact materials affected the intensity of the polishes to some extent on the few measurements made.

The amount of moisture in the worked material led to a great variation in the intensity of all the polishes measured.

Conclusions

Variations in polish intensities were caused by all factors: the duration of work, the flint grain size, the worked material and the moisture of the worked material.

The question of whether one could work out the duration of work from measurements of polish intensity on ancient flint tools depends on the certainty with which one could know the other variables affecting the intensity of the polish. These variables include the precise worked material, the moisture content of this material, the flint grain size,as well as also other factors, such as the brightness of the unused flint surface (the presence of post-depositional polish would obstruct this measurement) and the edge damage and possible resharpening, either of which would cause the removal of polished surfaces. Intensity of polish alone is therefore not a good indicator of the duration of use. Gysels and Cahen (op. cit., p.224)arrived at a similar conclusion.

3. Tool Action

Although he never discussed this variable in polish formation systematically, Keeley mentioned that polishes from sawing antler were"rough" while polishes from scraping/planing/graving antler were"smooth"(1980, p.56). Anderson-Gerfaud (1981, Vol.I, pp.61-62) agreed and stated that this difference was probably due to the anisotropic structure of antler. Vaughan (1981, p.135) pointed out that polishes from sawing solid materials such as bone, antler, wood and reeds never developed past the "smooth-pitted"stage (obviously he used this term differently from Keeley who had called the polish from sawing antler "rough and pitted") and that they looked often indistinguishable from each other. Vaughan thought that the cause of this lay either in the anisotropic structure of these materials, or else in the"dispersal of contact forces over a wider area in a sawing action than is the case with transverse motions and grooving, where a small part of the edge is submitted to more intense, sustained contact than the rest of the used area"(ibid.). Vaughan (ibid., pp.167-170) discussed the formation of polishes according to"Types of Actions in Intentional Use"(ibid., p.167). He described how the distribution of polishes varied according to tool action. Although he never explicitly stated it, he seemed to refer mostly to variations in the distribution of polishes when viewed under low magnifications, i.e. the entire polish location was observed and the distribution of polish on edge damage scars. In one instance only (apart from the"smooth-pitted polish"referred to above) did Vaughan seem to refer to a variation in polish according to tool action, when the polish was viewed under high magnification: this was a polish"bevel"which he could only find on tools which had been used with transverse actions. Moss (1983, p.3) wisely headed a section on experimental polishes "The wear-traces of certain uses and worked materials". She appeared to be largely in agreement with the other researchers (as discussed above) and in addition referred to specific wear-traces, which she called microscopic linear impact traces (MLIT) (ibid., p.95), on projectile points and barbs.

My own experiments showed similar variations in polishes from longitudinal (cutting/sawing) actions and transversal (scraping/planing/graving) actions on anisotropic materials such as bone and antler (although not as much on wood and reeds as Vaughan (op. cit., p.135) had reported.)

In addition, Blind Test 11-20 (see Part I, Chapter 20) in which tools had been rubbed against antler, wood, bone, hide and fern, illustrated the importance of tool action as a variable most clearly: the resulting polishes were completely different from those of tool actions such as sawing or scraping, and a whole new series of experiments rubbing various materials had to be carried out, before polish identification could be attempted. The cause of this difference was probably the fact that the structure of the material influences the polish considerably , as Anderson-Gerfaud (1981, Vol.I, pp.61-62) and Vaughan, (1981, p.135) had pointed out.

I also found that drilling (mechanically) and boring (by hand) the same plank of wood for the same amount of time, with tools made of the same raw material, caused different polishes. Drilling caused the formation of a completely smooth polish with very few striations on the tip of the tool, while boring caused only isolated polish-areas with lots of striations on the tip of the borer. The difference was probably caused by several factors (discussed below) such as different pressure during work, different real duration of work (i.e. the number of rotations)and a slightly different angle of the tool to the worked material.

In summary, I agree with Moss (1983, p.55) that"the motion or a set of motions, of the tool in use"should be repeated as closely as possible, and therefore one should not compare polish on an experimental flint edge used to cut antler with polish on an archaeological tool, which because of its shape and retouch is classified as a scraper. It follows that the exact action with which an experimental tool had been used should be indicated in microwear reports.

4. Tool Shape

Keeley did not think that variations of the edge angle resulted in any recognisable variation in the appearance of polish (1980, p.59). Most microwear analysts did not pay too much attention to this variable, and in recent publications any indication of the shape of the experimental tool has been omitted (Keeley, 1983; Bueller, 1983). The notable exception was Moss who stated that the"morphology of the piece, particularly the working edge"(1983, p.55) should be duplicated.

In my own experiments I found that the edge angle influenced the distribution of the polish, and so a thin-tipped borer penetrated deeper into the worked material than a broad-tipped borer and therefore the polish had a wider distribution. I also found that the edge shape (when viewed in section) affected polish distribution. Polish tended to form primarily on the higher part of an uneven edge. I therefore found myself agreeing with Moss that the shape of tool edges should be duplicated as far as possible.

5. Pressure

Although this variable when tested in connection with reed cutting (see Part I, Chapter 16 , Unger-Hamilton, 1983) did not seem to be important, the opposite was true in other experiments: for instance, it was found that rubbing materials, using different amounts of pressure (while all the other variables were the same) produced different amounts of polish on the flint implements.

6. Tool Angle

The effect of this variable was illustrated when I used a scraper on wood at an angle of 90 degrees to the worked material and the resulting polish was confined to the very edge of the tool. On the other hand I had used scrapers on wood at an angle of approximately 45 degrees and the resulting polishes extended considerably over the ventral surface of the scrapers. While we cannot know at which angle ancient tools were held, we must nevertheless be aware that different angles of the tool to the worked material can lead to slightly different polish distributions.

7. Moisture Content

Most microwear analysts mentioned that polishes varied according to the moisture content of the worked materials, such as bone (Keeley, 1980, p.44), hide (ibid., p.49), wood (ibid., p.36; Anderson, 1980, p.181) and antler (Vaughan, 1981, pp.145-146). However, only a few systematic experimental investigations into the effect of the moisture content of the worked material on polish formation have been carried out to date: Gysels and Cahen (1982) studied polishes from a variety of materials, such as clay, both dry and moist; Mansur-Franchomme (1983) studied the effect of moisture on dry hide under the SEM; while I carried out a study on plant polishes (Unger-Hamilton, 1983).

My experiments (see Part I, Chapter 16 for details) with fresh and dried plants, cut in some instances at different times of the year, showed that the rate of polish development and the appearance of polish varied considerably according to the moisture content of the plants.

I observed the same phenomenon with practically all materials (such as fresh and dry bone, fresh and dry hide, soaked and dry leather, fresh and dry wood) (e.g. Pl.23:d,f, Pl.8:e,g).

In some instances (e.g. from use on soaked leather) polishes looked totally different to those from use on the same dry material and looked much more like polishes from use on other soaked or fresh materials (in this instance wood).

It follows that we should pay more attention to this variable. For instance, the time during which antler was soaked for experimental use should be stated in publications.

8. Species

Keeley stated that there is probably no difference in polish according to the exact species of antler (1980, p.56) as different species of other worked materials such as hide, wood, bone had not led to variations in polishes. However, Keeley did refer to quantitative differences in polishes according to whether "dense wood"or"less dense wood"(ibid., p.36) had been cut. Vaughan (1981, pp.154-155), Anderson-Gerfaud (1983), and I (Unger-Hamilton, see Part I, Chapter 16) had found that plant polishes varied according to the species of the plants cut. In addition I had observed slight differences in the appearance of polishes from reindeer and fallow deer antler , and wood (see Part I, Chapter 14). Such variations appeared to be related to slight variations in the structure and the density of the worked materials.

It therefore seems to me that the exact species of the worked material should be used in experiments if possible, and that it should be reported in publications, even if only a few categories, such as plants or antler, cause specific variations in polishes.

9. Abrasives

Brink, in his microwear study of scrapers, found that when external abrasives had been added during the scraping of bone (1978, pp.81-82 and 88-93) and of dry hide (ibid., pp.97-98 and 106-110)that the rounding process of the flint surface occurred much more rapidly than when abrasives had not been added. The same phenomenon was demonstrated by Mansur-Franchomme (1983) in her study using SEM techniques. Vaughan (1981, pp.163-4) devoted a section in his thesis to the"Influence of Grit on Polish Characteristics"which he found to be considerable: "A substantial amount of grit will act to replace existing polishes with grit polish, or it will completely dominate the polish formation to leave only its own characteristics..."(ibid., p.163).

My own experiments drilling various materials, such as stone, with or without the addition of abrasives, such as sand, or sand and water together (Unger-Hamilton et al. , 1987) (Pl.29:g), led me to agree wholeheartedly with Vaughan's statement.

10. Conclusions

The results from the investigation into the variables involved in polish formation proved that a great many variables other than the worked material are involved. This implied that a great range of controlled experiments should ideally be carried out before a microwear analysis is attempted. However, it would be impossible to test every combination of variables, for reasons of time and the limitations of human visual memory. This in turn means that the researcher should investigate and construct experimental programmes for one tool group at a time, or ideally that several researchers cooperate and establish large reference collections of experimental tools. It also implies that variables should be reported in detail in publications dealing with microwear analyses.

Chapter 18 - Polish and Striations due to Factors Other than Use

All scholars agreed that polish and striations, as well as edge damage (see Part I, Chapter 4), could form on flint surfaces which had not been used at all. Wear traces could form during the manufacture of a flint tool, could be produced by natural agencies and by trampling, handling and processing by archaeologists.

1. Manufacture

Such traces have been discussed and demonstrated by Keeley (1980, pp.25-28) in his section on"technological effects". He stated that"these traces can happen during the removal of a flake from a core, when a flake strikes the ground, or, especially, when an implement is being retouched. They are important...because they can resemble "true"microwear and need to be distinguished from it"(ibid, p.25). Keeley observed the effects of various experimental manufacturing processes, e.g. hard hammer knapping (ibid., pl.7-8), "spontaneous retouch"(ibid, pl.9) during knapping (Newcomer, 1976), retouch with hard hammer (stone) and soft hammer (antler), and found that the resulting edge damage could be confused with edge damage due to use, but that this was not the case with polish and striations. He stated that the latter (e.g."smears"(ibid., pl.8) from hard hammer retouch and"abrasion"from spontaneous retouch) were unlikely to be confused with polish and striations due to use (ibid., p.28). Vaughan discussed polish and striations from retouch with stone, antler, bone and wood (1981, pp.170-172). He thought that traces from soft hammer retouch would be too weak to be recognised on ancient tools"given the problem of soil sheen or grit polish on prehistoric flints" (ibid., p.172). He had only detected a few instances of traces attributable to hard hammer retouch on the Lower Magdalenian tools from Cassegros he had studied (ibid., p.172), as had Moss (1983, p.104) on her tools from the French Final Paleolithic from Pincevent and Pont d'Ambon.

My own experiments indicated that all manner of polish and striations resulted from knapping and hard hammer (quartzite, see Pl.6:c, and limestone, see Pl.6:a) retouch and soft hammer (antler) retouch and pressure flaking with an antler tine (Pl.6:f). Such traces conformed to the use-wear traces from the corresponding materials outlined in Part I, Chapter 14.

As was the case with use-wear traces, the traces from manufacture tended to be more developed on fine grained flint than on coarse grained flint (see Part I, Chapter 17).

I agree with the other researchers inasmuch as I found that traces from manufacture were usually distinguishable from those due to use, on account of the former's alignment with observable retouch scars, and on account of the fact that they occurred in isolation, compared to the use-wear polishes, which tended to cover the entire surface of the working edge of the flint tool. However, I did find traces from manufacture potentially indistinguishable with those from use when the retouch was considerable, when the retouch was carried out with a material which may have been worked, or when the retouch was on the same alignment as the tool to the worked material during use, i.e. on scrapers or drills.

I also found that snapping tools, such as blades, could leave a thin line of polish with striations running in the direction of the snapping, i.e. along the tools long axis (Pl.6:e). Such traces could be misinterpreted as the result of scraping.

It follows that the microwear analyst has to familiarize himself with all manner of manufacturing traces in order to avoid misinterpretations.

2. Natural Agencies

Keeley discussed the effects of various natural agencies on surfaces of used flint implements, such as the effects of patination, abrasion by water-borne sediments, abrasion by wind-borne sediments and soil movements (1980, pp.28-35).

He based his observations mainly on the effects of patination on his own experimental flints which he had patinated by immersion into a 30% solution of NaOH. (Despite his knowledge that NaOH patinates flint, he used similar solutions of NaOH to clean his flint tools (ibid., p.11); this is discussed in Part I, Chapter 12). He also referred to the findings of other researchers, for example Semenov (1964, p.11), and to the detailed research by Rottlander (1975). Keeley found that patination effects such as pitting and a granular appearance, were not likely to be confused with use-wear traces. He also found that severe patination rendered implements"unusable for microwear analysis" (op. cit., p.29).

Keeley also discussed the effects of water- and wind-borne abrasion and of soil-movements on the basis of other researchers' results (Shackley, 1974; Stapert, 1976) and on the basis of his own observations of excavated flint implements. He investigated the effects of trampling experimentally (this has recently also been investigated by Holmes, in press). Keeley concluded that such traces in the form of abrasion, percussion craters, striations, and in the case of soil movements,"white scratches", would be easily distinguished because of their random and widespread distribution over the tool surfaces (Keeley, op. cit., pp.34-35, pl.11-17). He did point out, however, that Stapert had been"somewhat pessimistic on some points concerning potential confusions between natural traces and microwear..."(ibid., p.35).

Vaughan (1981, pp.173-179) described the effects from contact with soil and grit on his experimental flints leading to"smooth-type grit polish",(in his opinion potentially similar to certain weak use-wear polishes, if striations are absent), and"rough-type grit or soil polish"(the"glossy patina"of other researchers) from such agencies as water-rolling. This type of polish was according to him unmistakable, but rendered archaeological implements useless for microwear analysis. He stated that"the same general soil sheen is present in lesser degrees on every archaeological flint that has resided in a sedimentary or aqueous matrix" (ibid., p.174). He also thought that such polishes could be distinguished from true microwear due to use on account of the widespread distribution of the former. However, he listed some cases (meat and hide polishes) which could look like weak soil sheen. He also pointed to the fact that natural agencies can remove polish (ibid., p.176). He quite rightly deplored the fact that the implications of such damage had been almost completely neglected in microwear publications (ibid.).

Vaughan therefore adopted Anderson-Gerfaud's system (1981, Vol.II, p.69) which reflected"the degree of certitude in the determination of the worked material from prehistoric microwear polishes" (Vaughan, op. cit., p.177) . Vaughan's identifications ranged from"definitely or very highly probable","most likely"to"unspecified...materials" (ibid., p.177) or"too abraded"(ibid., p.178; see also Vaughan's Table 35).

Moss (1983, pp.81-83) agreed with Keeley inasmuch as she stated that if"...natural phenomena do not conform to microwear patterns they can confidently be ascribed to some other causal factor than human use"(ibid., p.81). She agreed with Vaughan that"all archaeological collections have some sort of soil sheen"(ibid.). She mostly discussed one particular phenomenon which she called"bright spots" which may be due to friction (see Shepherd, 1972) or other, unknown agencies (see Vaughan, op. cit., p.365; Stapert, 1976, p.38).

I too observed all the natural traces discussed above (apart from the"white scratches") on my archaeological tools from Arjoune (Pl.7:b,d,f).

Although microwear analysts had agreed that most post-depositional traces, on account of their random distribution over the flint surfaces, are distinguishable from use-wear polishes, and although this seemed to be the case on most of my archaeological pieces, I conducted my own series of experiments, designed to test the effects of burning, and of water and/or sand action on flint.

Experiments

An experiment was carried out in which pieces of Brandon and Syrian flint had been thrown into a wood fire and left overnight in the cooling fire. The resulting "wear"traces included complete greying of the flint, and cracks visible under the microscope (Pl.7:g). The same phenomena were observed on several flint implements from Arjoune. Also experiments were carried out rubbing flint against sand and stone, with and without water. The polishes varied according to the contact material (Pl.7:a,c,e).

An experiment was carried out in which a perforated plastic basket containing 20 flint pieces (fine-grained flint from Brandon, fine- to coarse-grained flint pieces from Syria, and burnt flint) was left in a fast-running stream in Wales for five weeks in the spring 1984. A considerable amount of sediment had collected at the bottom of the basket by the time it was retrieved. The resulting wear traces were surprisingly very few and very weak. A few isolated, random striations and a few polish spots resembling the"bright spots"discussed by Moss (op. cit.,pp.81-83) were confined to the fine grained flint pieces. This experiment was perhaps too short in duration to judge whether the flints from Arjoune had been water-rolled or not.

Removal of Use-Wear Polish

Far more disturbing than the positive traces left by natural agencies on flint surfaces, was the phenomenon first mentioned by Vaughan (see above) and by Gysels and Cahen (1982) that polishes on archaeological flint implements never looked as well developed as those on the experimental tools. Also worrying was the publication by Plisson of his experimental work (1983, Plisson and Mauger, 1986) which showed that polishes can be removed by various alkaline chemicals. Similar effects on experimental flint implements, from rinsing these with solutions of NaOH, and effects of alkaline environments on ancient flint implements, were reported by Anderson and Whitlow (1983). (See also Part I, Chapter 13.)

In Plisson's experiments the rate of removal of polishes varied according to the worked material. Hide polishes survived longer than other polishes, and it is therefore somewhat disturbing that on both the sites which Vaughan (1981) and Moss (1983) analysed, hide working tools were reported to be in the majority . The reason for Plisson's result is probably not the fact (as he believed (op. cit.)) that the chemical compositions of the polishes vary with the worked material, but that alkaline chemicals such as NaOH attack amorphous silica and to a lesser extent the flint grains; and therefore that the more amorphous silica is present, the faster the polish seems to disappear.

Like Gysels and Cahen (1982) I had found that polishes on archaeological flints rarely looked exactly like the experimental polishes, and it seemed to me that sometimes the amorphous silica had disappeared. However, the distribution of the polish (in the form of flattening of the flint surfaces) remained in most cases visible.

3. Polish and Striations from Post-excavational Procedures

In addition to traces from natural agencies one has to take into account wear traces from archaeological procedures:

Stone polish can occur from bagging flints together in one bag; metal polish can occur from trowelling and sieving; striations can occur from cleaning with brushes and polish can be produced by touching the tools with a pencil during drawing. Such traces are rarely referred to in microwear reports.

I did find such traces, but they tended to be isolated and random (as in the case of polish from bagging tools together) or they could be detected with the naked eye (as in the cases of contact with pencil). It is however conceivable that brushing a flint edge along that edge might cause striations which could be mistaken for striations due to use.

If a microwear analysis is intended for a site which is in the process of being excavated, then the microwear analyst can ensure that most of such traces can be avoided, by insisting that the tools he wants to analyse are not sieved, not cleaned with brushes and that they are wrapped separately, and that care is exercised during drawing.

4. Conclusions

On account of the problems discussed above, I believe that archaeological implements would only rarely show intact use-wear polishes. This means that a lot of archaeological implements cannot be assigned to a particular worked material. This in turn means that a statistical evaluation of particular functions in relation to particular areas of a site (i.e. a distribution analysis) is impossible.

Chapter 19 - Sampling

Moss (1983, pp.106-107) discussed the problems related to sampling for the microwear analyst. As we are dealing with a very slow method involving experimentation and scanning implements at high magnifications we are dealing nearly always with sub-samples of the samples excavated by archaeologists. Moss stated,"We can either sample in accordance with the patterning of a particular site or we can choose a site in accordance with particular microwear questions"(ibid., p.106). She listed five categories of investigation: technological efficiency; spatial variability; a straightforward description of a total assemblage (such as carried out by Vaughan on the Magdalenian O assemblage at Cassegros, possible because of the relatively small number of flints excavated); temporal changes; and the"affirmation of some experimental phenomena"(ibid.).

I had chosen the site of Arjoune because it had been excavated recently by excavators known to me (so their methods could be checked) because all the excavated lithic material had been kept, because the entire assemblage was theoretically available for study, because it was possible for me to get to the site in order to find the flint sources and use the local flint experimentally, and because environmental evidence was available as an independent check on the microwear analysis. As the assemblage from Arjoune comprised 16,351 flints (see Part II, Chapter 6), possibly from two slightly different periods (Trenches I-V and VII, and Trench VI) it was impossible to look at all of the flints, and I decided to sample with the following topics in mind:

- One particular tool class, the sickle blades;

- The use of other tool types at Arjoune;

- The comparison of classifications based on microwear analysis with those based on morphological typology;

- The use of the lithic raw material.

- The significance of burnt flint at the site.

I examined the following tools under the microscope: all the available lustered blades from Trenches V (40) and VI (38), as well as 88 lustered blades from other sites and periods ; all the tools from Trench VI (241), all the tools drawn by Copeland (in prep.) and a selection of tools from Trenches I-IV (27) and VII (47), and a selection of tools from Trench V (77). (These counts do not include the lustered blades.)

In order to investigate the significance of burnt flint at Arjoune I examined (macroscopically) all the lithic material from Trench VI (1,477 pieces). The total number of tools from Arjoune examined under the microscope was 470. I could only come to an opinion about 180 tools (including all the sickle blades (78) examined)

Originally I had intended a far more ambitious program involving the microwear analysis of all the flint from several loci of Trenches V and VI, in order to be able to chart the horizontal distribution of polishes according to worked material. It was hoped that this would illustrate possible activity areas on the site. In the event it was not possible to carry out this task; for a variety of reasons (see Conclusions: Theory and Method of Microwear) the identifications of worked materials were only rarely precise and therefore a statistical analysis of polishes on all flint proved impossible; in addition the drawn flints from Trench V had disappeared and I was unable to examine the most distinctive tools from the most productive trench.

Chapter 20 - The Blind Tests

A few blind tests (involving the use of experimental tools by one researcher, and the identification of the wear-traces on such tools by another researcher) had been carried out. Newcomer (Keeley and Newcomer, 1977) had used fifteen unretouched flakes and simple tools made of Brandon flint in a variety of tasks, on a variety of materials. Keeley identified 14 out 16 used areas, 12 out of 16 tool movements and 10 out of 16 materials correctly. (For a similar blind test see Gendel and Pirnay (1982, pp.251-265).) Holley and Del Bene (1981) criticised the methodology of Keeley and Newcomer's blind test. They applied more stringent criteria in defining the success rate of Keeley's identification of worked materials and thought that instead of"approximately 10 out of 16", Keeley had only identified 8 out of 16 worked materials correctly (ibid., p.341). Keeley (in the same volume, 1981, p.351) replied that"Holley and Del Bene show an obvious bias toward counting errors". Holley and Del Bene (op.cit.) also claimed that Keeley had based his interpretation not only on polish identification, but on the perceived resistance of the worked material (ibid., p.342), a claim which Keeley vigorously denied (1981, p.350). As I discussed in Part I, Chapters 7, it seems that the resistance of the worked material (i.e. the abrasion) influences the appearance of polishes, and I therefore believe that Holley and Del Bene were wrong in stating that identification of this attribute invalidated Keeley's method, and that Keeley was wrong in claiming that he did not take resistance of the worked materials into account.

Odell and Odell-Vereecken (1980) accepted Keeley's method as viable after Keeley and Newcomer's blind test; however, they decided to design a blind test to test their own Low Power Approach. Odell-Vereecken used thirty one basalt implements on a wide range of activities and materials, and Odell's results were as follows: 79.4% correct location, 69% correct tool action, 61.3% correct relative hardness of the worked material and only 38.7% correct worked material (ibid., p.116). Despite the last (expected) low percentage, their results seemed to be similar to those of Keeley and Newcomer's blind test of the more laborious and costly High Power Approach. Keeley criticised this test which in his opinion was not quite"blind" as the researchers were married to one another, and also pointed out that the Odells had counted"as correct, guesses on implements on which the used portion had been misidentified"(1981, p.351).

Vaughan's"Reliability Test"(1981, pp.102-5) was in my opinion even less"blind"than that conducted by the Odells. Vaughan had used thirty two implements himself, subjected them to all manner of accidental and natural processes, and subsequently believed that four months later (when he examined the wear-traces) he had forgotten how he had used the tools. He identified the function of 23 out of 32 tools correctly (ibid., p.103).

In my own research I took part in a series of experimental blind test which were not completed at the time this thesis was examined but which has in the meantime been published (Newcomer et al. , 1986), and also in a microwear-analysis of ancient tools which I carried out before looking at other evidence from the site (Unger-Hamilton et al. , 1987).

The following were the results:

Blind tests 1-10 (see Table 3): a variety of tools, made of Seine flint, were used by Newcomer in a variety of actions. The tools were examined, cleaned in a solution of NaOH and reexamined. The chemical cleaning appeared to remove some polish. Nevertheless, my polish identifications remained the same. My results were as follows: 7 out of 10 correct location, 6 out of 10 correct tool action and 2 out of 10 correct worked material.

I attribute the poor results concerning the identification of the worked material to several factors: polishes are not always distinct according to the worked material (see Part I, Chapter 14); a large number of variables had been involved; I had not experimented with the flint type nor with all the tool types Newcomer had used; instead of using my own interpretation of polishes from the point of view of what happens to the flint surface and deciding simply whether the worked material was hard or soft and dry or moist, I followed the usual interpretative technique of looking at the appearance of polish. I was thus forced into identifying exact materials rather than categories of materials to begin with.

Blind test 11-20 (see Table 4): Newcomer used ten Brandon flint flakes to rub against various materials, which turned out to be paired, for ten minutes each. The edges of the flakes had been removed with a copper pressure flaker, in order to eliminate edge damage as a possible indicator. I identified approximately 7 out of 1o worked materials correctly. This positive result was in my opinion due to the fact that the number of variables was limited, that I had carried out all the relevant experimentation (with the exception of fern; however I did identify this polish correctly as plant polish), and that I had used my own technique of observation leading me to first identify categories of materials (hard-soft, dry-moist) and only then the worked materials. The visible gloss was also helpful for correct identification.

Blind test 21-30 (see Table 5): Newcomer used ten Brandon flint blades to cut various materials for ten minutes. We knew that the materials had been the same as those in blind test 11-20. There was very little edge damage, and the microscopic polishes looked mostly indistinguishable. My results were as follows: from observation of the edge damage and gloss with the naked eye I identified 3 out of 10 materials correctly, by microscopic examination only 2 out of 10 materials.

A blind test related to prehistoric conditions was carried out by us (Unger-Hamilton et al. , 1987) through an experimental microwear analysis of fifteen drills from Abu Salabikh, which we carried out before we looked up the published details about the site (Crowfoot Payne, 1980). Bergman had made copies of the drills and we carried out a wide range of experiments (23) drilling and in some instances boring wood, pottery, lapis lazuli, malachite, hippopotamus "ivory", bone, copper, two kinds of shell, hide, with and without the addition of abrasives and/or water. I concentrated on the identification of polish and striations only, as the edge damage was negligible in all cases, except where the tips had broken off. Only the wear-traces on 3 out of 15 drills from Abu Salabikh could be identified with certainty; the others were either severely damaged, or else covered with a weak polish, probably due to natural agencies. I thought that two drills had been used to drill shell and one drill had been used to drill something with the addition of sand and water. In the latter case the drilled material was probably stone with a hardness grade of less than 7 on the MOH scale, as drilling with abrasives proved ineffective with harder stone (see also Hodges, 1976, p.107). We were encouraged to see, when we looked at the site report, that drills had been found together with shell beads, and lumps and beads of carnelian and lapis (both stones with a hardness grade of less than 7 on the MOH scale).

Conclusions

The results of the blind tests suggested that the High Power Approach to microwear analysis can be relied on to identify both the used area of a tool and the tool action with some certainty.

The identification of the worked material is more problematic. It seems that the greater the number of variables (especially when their effect is not tested), the less chance there is of identifying the worked material correctly.

My own approach, first defining the categories of worked materials (from the flattening of the flint surface and the amount of amorphous silica on the tool), and only subsequently guessing the worked material (from the distribution of the polish), may be more helpful than the attempt to identify the worked material immediately from the appearance of the polish.

Wear-traces from uses involving intense pressure, such as from drilling or rubbing, were more developed than those from uses involving less intense pressure, such as cutting. This suggests that worked materials are less likely to be be identified through a microwear analysis of cutting implements than through a microwear analysis of drilling or scraping implements.

It seems that worked materials can be identified on ancient tools, provided they were used intensely and the number of variables involved is small. However, even under those conditions, experimentation has to be wide-ranging.

Conclusions - Theory and Method of Microwear Analysis

As a result of the foregoing examination of the theory and method of microwear analysis I came to the conclusion that both the Low Power Approach and the High Power Approach are affected by the same variables and the same problems. These approaches need to be used together as the principal elements of each - edge damage and polish - should be viewed in relation to one another.

Polish appears to consist of an abraded flint surface, together with a thin coating of amorphous silica. The factors involved in the formation of polish, striations and gloss seem to be the same, that is to say abrasion and the moisture content of the worked material.

Examination under the SEM seems to suggest that residues from worked materials adhered to the flint but did not become embedded in the flint, and that micro- and macro-organisms incorporated in the flint during its formation could be mistaken for residues.

The examination under the SEM led me to conclude that cleaning with chemicals, especially alkaline solutions, should be avoided.

The High Power Approach was found to be of varying usefulness. It can be used to identify the working edge of a tool and the tool action. However the identification of the worked material was fraught with problems: materials, when worked for a short time, left hardly any wear-traces and several materials left only ill-defined traces, even when worked for a long time. Some tool actions led to more strongly developed polishes than did others. Polishes did not mysteriously conform to precise worked materials, by virtue of a magical ingredient, such as residues from the worked materials. Polishes seemed to be affected by the hardness, the moisture content and the structure of the worked material. This means that totally different materials can cause virtually identical polishes, and also that the same materials can cause polishes distinct from each other.

The number of variables involved in polish formation was found to be considerable. This means that experimentation has to be well controlled and wide-ranging, and that researchers should concentrate on a few tool classes only. This was also borne out by the results of the blind tests. The effect of some variables, such as the flint type, was found to be considerable.

Many traces due to agencies other than use can affect excavated flint implements. This fact, and other factors like coarse-grained flint, could render many implements unusable for microwear analysis. This has direct implications on sampling; it might be impossible to carry out a site distribution analysis.

An isolated blind test is unsatisfactory, and to produce results, a sequence of blind tests needs to be conducted; only in this way can different methods be developed and assessed.

Part II. Sickle Blades and Other Tools from Arjoune

Introduction

Part I, the investigation into the theory and method of microwear analysis, suggested that the used areas of tools and the action with which tools had been used could be identified with some degree of certainty. Among the many variables however, the worked material could only be identified under certain circumstances and with far less certainty than had previously been assumed. This meant that in Part II I could only come to an opinion about a relatively small selection of tools from the site I had chosen, namely the 5th millennium BC site of Arjoune in Syria.

In Part II, I describe the site of Arjoune, its setting, environmental evidence and its artefacts. I investigate the condition of the prehistoric flint tools and the source of the flint. (Although the chipped stone tools at Arjoune were made of both limestone chert and chalk flint, I refer to both as"flint"for the sake of simplicity.) I briefly outline the method of investigation which is based on Part I. I discuss previous research, my own experiments and selected ancient tools according to tool type. I devote a large chapter to lustered"sickle blades"as the tool type which interested me most, and compare the wear-traces on lustered blades from Arjoune with those from other periods and sites, namely from Natufian Mugharet El Kebara (hereinafter referred to as Kebara) and Mugharet El Wad (hereinafter referred to as El Wad), and from the Pre-Pottery Neolithic (hereinafter referred to as PPN) A to the Early Bronze Age (hereinafter referred to as EB) at Tell es-Sultan (hereinafter referred to as Jericho). The wear-traces on lustered blades are also compared with botanical evidence where available. I investigate the occurrence and significance of burnt flint implements at Arjoune. Finally I report my conclusions as regards the site of Arjoune and reassess the usefulness of microwear analysis in archaeology.

Chapter 1 - Arjoune and its Environment

The physical setting of Arjoune has been described by Dorrell (in prep.). The site is situated north of the Beqaa Valley in the middle of the funnel-shaped divergence of the Lebanon and the Anti-Lebanon ranges (Fig.3,4). Just north of Arjoune, the Lebanon range is interrupted by the Homs-Tripoli Gap which runs east to west. The site lies on a low terrace, formed of alluvium and eroded bedrock with outcrops of underlying conglomerate, on the eastern edge of the floodplain of the Orontes river. The Orontes aquifer is fed by rainfall in the Lebanon mountains and is therefore largely independent of seasonal variations in local rainfall. Near Arjoune, the river forms a series of active meanders down towards the Lake of Homs.

The present-day annual rainfall of 400-600 mm is confined to the period between November and mid-April (about 50 rain days per annum). Summer drought is almost total, but westerlies give rise to morning mist and dew. Temperatures are more variable and, as far as cultivation is concerned, less important than rainfall. Mean monthly maximum temperatures range from 20 C degrees in January to 38 C degrees in August, both extremes tempered by westerly winds (Dorrell, ibid.).

At present the economy in this fertile region is based on agriculture, farming mainly New World crops such as maize and livestock such as sheep, goats, cattle and horses. Dorrell (ibid.) reported that water-meadows on the flood plains still support a closed cover of grasses and herbs, despite intensive grazing. I found many marshy plants such as reeds and canes, and many species of fish, frogs and birds in and around the Orontes.

There seemed to be no evidence for a major climatic shift since 6000 BC (the evidence from pollen cores (e.g. Niklevski and Van Zeist, 1970) is discussed by Dorrell, ibid.). The country around Arjoune was probably forest-steppe during the Chalcolithic and easily cleared for cultivation. the flood plain may well have had dense riverine vegetation and gallery forest and was probably an area rich in game, fish and wild tree crops. Dorrell pointed out that so far no settlement of this period had been found west of the Orontes and that it was unclear whether the flood plain of the river had been crossable in the wet season. He thought that in the past the attractions of this site probably included its position on the Beqaa routes northwards.

Chapter 2 - The Excavations

The final excavation report has not yet been published, but the present author has seen the final manuscript, and the following summary is based on this.

The site of Arjoune, encompassing several small natural mounds, follows the edge of a meander cusp and covers an area of approximately 400 x 200 meters (Fig.5,6). Surface scatters on all the mounds consisted predominantly of sherds and lithics of the Late Neolithic/ Chalcolithic period, together with some Hellenistic sherds.

The highest Mound A (approximately 5 m in height) was investigated in one sounding and three small probes (Trenches I-IV) in 1978 (Marfoe et al. , 1981). On the larger Mound B Trench V and Trench VII were excavated in 1979 and 1982 respectively. In addition Trench VI was excavated in 1981 (Fig.6). The trenches were excavated in squares of 1 x 1, 1 x 2 or 2 x 2 meters. Some of the excavated soil was dry-sieved. All the lithic material was curated.

According to the excavators (Parr et al. , in prep.) several areas of the excavation revealed what were probably the lower portions of semi-subterranean dwellings or"activity areas", roughly circular in shape and sunk up to a meter or so into the natural rock. The sunken areas were filled with occupation deposits. Faint traces of horizontal surfaces in the deposits were noted, but there is no clear evidence that these were real living floors. The excavators found the absence of structures puzzling and thought it possible that permanent structures may have been destroyed by erosion.

The accelerated carbon dates were obtained from bone and grain samples. "Arjoune V and VII are believed to be shortterm occupations, which are of effectively the same age, c. 6600 BP. Arjoune VI clearly represents later occupation." (Gowlett et al., 1987). In fact the dates obtained from Arjoune VI appear to be about one thousand years later than those from the other trenches.

Chapter 3 - The Botanical Evidence

Moffett (in prep.) carried out a small-scale program of sampling for charred botanical remains. The staple crops represented at Arjoune were einkorn, emmer, two-row hulled barley and lentils. The wheats were fully domesticated. Free-threshing wheat was found in Trench V, but not in Trench VI. This may have been an artefact of sampling according to Moffett. The same may have been the case with the scarcity of barley in Trench VI as opposed to Trench V. Lentils were probably the cultivated form, although the possibility that wild lentils (as well as wild cereals) had been collected could not be ruled out. Other food plants included the horsebean and grapes, pips of which were found to be concentrated in locus 115.3 in Trench V. These could have been an early cultivated type, or else may have been collected from vines growing wild in the Orontes Valley. In addition seeds from various fruit trees were recovered: hawthorn, pistacio, plum or cherry, sweet almond and fig. Fruit from these trees was probably collected from trees growing on the mountain slopes of the Lebanon and Anti-Lebanon.

Chapter 4 - The Faunal Analysis

Grigson (in prep.) has shown that domestic ungulates (goats, sheep, pigs and cattle) made up 96.4% of the faunal assemblage and dogs 0.5%. The wild animals represented were hare, cat, gazelle, red deer (shed antler of red deer was found in Trench VI), bird, tortoise and crab. It was not possible to say whether the equid bones were of onager or donkey, nor whether they were from wild or domesticated animals.

About 60% of the domestic ungulates were sheep and goats, with goats outnumbering sheep by about 6:4. In both species females outnumbered males, more of the males having been slaughtered when young. The survivorship curves together with the sexing analyses suggested the sheep and goats from Trenches V and VII were kept primarily for meat, whereas those from Trench VI indicated a herding strategy with an emphasis on milk. This suggested to Grigson that Trench VI was perhaps later in time than Trenches V and VII. Pig bones constituted 20% of the domestic ungulate assemblage. Ageing data showed that about a third of the pigs were killed in their first year and about a half in their second. It was suggested that most males were killed in their first year, while more females were kept until adulthood, presumably for breeding. Ageing data, and the hypothesis that these pigs, like wild pigs, gave birth once a year in March, suggested that most of the pigs at Arjoune were killed in the summer. This indicated either a deliberate culling policy or seasonal occupation or both; the marshy flood plain of Arjoune in the summer might be an ideal area in which to herd pigs, while in the winter the pigs were perhaps driven to a drier area.

Cattle bones constituted the remaining 20% of the domestic ungulate assemblage. The few ageing and sexing data for cattle suggested a generalised herding policy allowing for meat and breeding.

Chapter 5 - Non-Flint Artefacts

Finds from Arjoune consisted of pot sherds, dated to the 5th millennium BC including Amuq Dark Faced Burnished and related wares and some painted wares including probably imported Halaf ware (Marfoe _et al_. , 1981; Parr _et al_. , in prep.). Many stone objects were found. These included heavy stone equipment, such as basalt querns, and also grindstones, bowls, rubbers and hammerstones, limestone bowls and plaques, stone maceheads, engraved and pierced pendants and engraved pebble figurines. Clay objects included spindle whorls or weights, baked clay figurines with incised features, and a large quantity of unperforated clay disks. Objects carved of bone included awls and a tiered carving. A shell pendant was also found. No metal objects were recovered.

Chapter 6 - The Flint

Copeland (1981; in prep.), who is publishing the typology of the flint, stated that a total of 16,351 flint pieces was recovered from the site of Arjoune. In 1978 541 pieces were excavated mainly from disturbed contexts, Trenches I and III on mound A (Marfoe et al. , 1981). Here, only Phase I in Trench I was an undisturbed Neolithic/Chalcolithic deposit, with just 88 flint pieces, comprising 3 tools and 85 pieces of debitage. The rest of the flint, from disturbed or later contexts was dated to the same period and consisted of 98 tools and 355 pieces of debitage (unretouched flakes or cores). In 1979 12,248 flint pieces were excavated from Trench V, and 2 were collected from mounds B and C. Of these, 1,004 were classified as tools, 8,769 as debitage and 2,465 pieces as non-artefactual. The excavation in 1981 of Trench VI yielded 1,477 flint pieces, comprising 241 tools, 1,236 pieces of debitage and 383 non-artefactual pieces. In 1982 excavation of Trench VII yielded 102 tools and 1,710 pieces of debitage. In addition 37 flint artefacts were recovered from Sounding 1, 16 from Sounding 3, 117 from Sounding 4, 13 from Sounding 5 and 88 from Sounding Mound C. These were included by Copeland in the lists of the lithic artefacts from Trench VII and soundings.

The tool total included fragments of non-flint artefacts, presumed to have been used for milling or flint knapping, and obsidian. Very large or intact stone tools, such as mortars, were not included (Copeland, in prep.).

The Tables 7-10 (taken from Copeland's report, ibid.) show the exact breakdown of the flint assemblages into tool types, debitage and non-artefacts. The tool types included axes, chisels, picks, arrowheads, choppers, sickle elements (lustered and unlustered), retouched bladelets, microliths, end-scrapers, straight-ended scrapers, flake-scrapers (including fan-scrapers), core-scrapers, steep-scrapers, racloirs (side-scrapers) , raclettes (small scrapers on thin blanks), burins, borers (or piercers or drills), denticulates, notched pieces, backed blades, knives, composites, abruptly retouched pieces, pieces with nibbled retouch, bifacially retouched pieces, pieces with inverse/alternate retouch, truncations and various non-flint artefacts, such as hammerstones, anvils and obsidian implements. (Non-flint artefacts were not included in my study.)

According to Copeland (ibid.) the lithic assemblages from the various Arjoune trenches resemble each other fairly closely in raw materials, debitage techniques and tool types. Nevertheless, there were differences in detail between assemblages from Trenches I-IV,V and VII as against those from Trench VI. There were also differences from trench to trench in the proportions and presence and absence of certain types. Byblos and Amuq points were apparently represented by only a few fragments in Trench V and one surface find on Mound B. In contrast, transverse arrowheads formed 1.67% of the assemblage of Trench VI. Byblos points began in a simple form in the PPN and virtually disappeared with the advent of the Chalcolithic while transverse arrowheads occurred on Late Neolithic/Early Chalcolithic sites in the Near East, dated to 5000 - 4000 BC (Copeland, ibid., after Bar-Yosef, 1981, fig.4). They related to the 4th millennium BC in Sinai sites (Copeland, ibid., after Bar-Yosef, 1981, p.561). From the arrowhead typology Copeland suggested a date of between 5000 and 4000 BC for the Arjoune trenches. Other features pointed out by Copeland (ibid.) included the scarcity of axes at Arjoune, duplicated at other inland Neolithic sites, in comparison to the great number of axes on coastal Neolithic sites, such as Ras Shamra or Byblos, near forested mountains. Axes from Trenches I-IV and VII resembled those from Ard Tlaili and sites northwards to the Amuq, while the adze from Trench VI looked similar to a type characteristic of the Chalcolithic at southern sites. Sickle elements were more abundant in Trench VI (25.1%) and Trench VII (22.5%) than in Trench V where they only constituted 14.9% of the tools. This suggested to Copeland that special activities were carried out in the area of Trench V. Equally the presence of many and varied non-flint stone tools in the area of Trench V led Copeland to wonder about the significance of such a concentration: were these implements involved in processing vegetable, mineral or animal matter, or did they represent"tools to make tools"? There were traces of the same heavy tool kit at Trenches I-IV and VII, but it was virtually absent from Trench VI. Obsidian was absent in Trenches VI and VII and rare in Trench V (0.9%) compared to the small Trench I-IV samples where it constituted 9% of the tools.

Chapter 7 - The Raw Material (Flint)

The raw material used to make the ancient tools at Arjoune was very heterogeneous and comprised a variety of types of flint (and chert) of varying colour, as well as limestone and some obsidian. Most of the tools were relatively small and of irregular shape, which would make their use often difficult. They were often made from coarse and/or variegated flint which must have been difficult to knap (see below). However, a few tools were made of good quality flint, the nodules of which had been quite large.

We (Parr, Dorrell and I) discovered two sources of flint in the vicinity of Arjoune, both of them secondary. The first, a gravel deposit containing flint, chert, limestone, schistose and quartzite, was found in a dried out river-bed, the Wadi Rabiy'ah, approximately one hour's walk from Arjoune (Fig.4). The colour and variegation of the flint and chert matched the raw material from the excavation exactly. The primary sources of these gravels are in the Lebanese mountains, unfortunately inaccessible at the moment. It is probably from there that the finer larger nodules of flint derived. Secondly, some outcrops of flint were found at Arjoune itself. However, most flint pebbles were found to be either frost-shattered or compressed into a conglomerate and therefore impossible to knap. Similar nodules (probably rejects) had been found in the excavated trenches.

Most of the variegated (probably frost-shattered) flint and most of the conglomerate proved impossible to knap as it splintered. In some instances the flint nodules had to be shattered with a metal hammer, as the fracture lines were interrupted by variegation. Similarly some apparently recrystallised flint (Syrian A and B, see Part I, Chapter 17, Pl.5:e-h) was difficult to knap as it was very dry and broke easily. Some apparently frost-shattered dark-purple flint was quite easy to knap. So was dark-brown fine-grained flint (Syrian D, see Part I, Chapter 17.1) which however only occurred in very small pebbles. Fine-grained brown and orange striped flint (Syrian C, ibid., Pl.5:c,d) was easiest to work. Usually a limestone hammer was used which worked well at first but soon became very abraded. A heavier, harder stone, such as quartzite, would have been better. An antler hammer was rarely used. The tools produced were even smaller than those of the excavation. This may partly be due to the inferior quality of the present day flint in comparison to the ancient flint, or else to my inferior knapping skills.

I came to the following conclusions about the raw material used at Arjoune:

Most of the raw material was obtained from a source approximately one hour's walk from the site, with possible exceptions being the fine-grained large nodules from which the high-quality tools were made (e.g. the tabular scrapers), and the obsidian (which has not been analysed).

The great typological variation and limitation in size of the archaeological lithic material from Arjoune can be explained by the poor quality of the raw material. Tool manufacture must have been a difficult business, and from that point of view the site was badly located, compared with sites in the Jebel Abiad in the Syrian Desert for instance, where seams of superb flint abound.

Chapter 8 - Preservation of the Excavated Flint

When viewed with the naked eye, the flint from Arjoune looked"often mint-fresh"(Copeland, 1981, p.9). Only a few pieces were slightly patinated (i.e. white or shiny) and a good number of pieces looked heated or burnt (Copeland., ibid). However when viewed under the microscope it became apparent that more post-depositional surface modifications (Holmes, 1986; Part I, Chapter 18, Pl.7:b,d,f) had taken place than expected. There were many pieces - only slightly shiny to the naked eye - which turned out to have a polish consistent with patination. When I knapped a flake from one such shiny core, it turned out that the fresh break was not glossy, and therefore the surface modification had taken place after deposition on the site. Some pieces made on what seemed to be black or grey flint turned out to be burnt, judging by the cracks seen under the microscope (Pl.6:h). Experimental flint pieces which I had left in a fire overnight developed the same colour, consistency and cracks as those pieces excavated from Arjoune (Pl.6:g). Random striations and polish covering all areas of the tool, including those areas which had most likely not been used, were found on many tools to a differing extent. Such traces could well have originated from possible annual flooding of the site by the Orontes, or perhaps a lake may have formed here (Dorrell, pers.comm.). Although experiments leaving modern Arjoune flint in a fast-running stream for a month, had shown that hardly any traces resulted from this (see Part I, Chapter 18), the duration of the experiment was perhaps far too short to be comparable. The soil itself may have left traces: Grigson's bone element analysis (in prep.) showed that fragile bones had probably been destroyed. According to her this may have been due to a number of reasons, among them physical effects such as temperature changes. As far as the effects of soil chemistry are concerned it is interesting that she reported evidence of a neutralisation of the calcareous environment by humic acid. The barium sulphate analysis I had carried out gave a neutral value (pH 7) for the occupation levels from Arjoune (Part I, Chapter 13).

Polish (probably partially consisting of amorphous silica, see Part I, Chapter 7) may have been removed in some cases, although examination of the sickle blades suggested that the polishes on most of these were relatively intact.

A third and fourth possibility for the occurrence of post-depositional surface modifications may have been the fact that tools had been sieved, and that they had not been bagged individually, but had been transported and stored for a few years, and so had rubbed against each other.

I therefore had to leave many tools out of the examination.

Chapter 9 - The Method

The method used in the microwear analysis of the tools from Arjoune and of the sickle blades from Kebara, El Wad and Jericho is based on the conclusions of Part I.

As far as possible copies were made of the ancient tools or at least of the edges which had most likely been used. The raw material for the copies was mostly flint from Arjoune, but I had also used other flint of various grain sizes. These included fine-grained black flint from Brandon, medium-grained grey flint from Potter's Bar, fine-grained black-grey flint from Surrey and various types of flint (fine- to coarse-grained) from France . As the flint collected from Arjoune was of mediocre quality and small, larger tools had to be made of other flint.

Both hard hammers (of quartzite and limestone) and soft hammers (made of antler) were used to retouch the blanks which were kept individually in plastic bags. The tools were, whenever possible, examined under the microscope before use. A few tools were also examined and photographed before and after retouch.

A wide range of experiments (436) was carried out in two separate series. The first, well controlled, was designed to identify the variables involved in polish formation (Part I, Chapters 16 and 17); the second, less controlled, was designed to simulate, as far as it is known, prehistoric activity. As far as possible the materials used were chosen according to whether they were found on the site and whether they may have been worked by the prehistoric peoples at Arjoune. Several species of wood (seasoned and fresh and in one instance soaked in water), bone from various parts and species of animals (fresh, cooked and dried), hide from various species of animals (fresh, dried, tanned and soaked), antler from various species (dry and soaked), soaked cow horn, cooked and raw meat, fresh and dried sinew, several species of fish, several species of shell, several varieties of stone, pottery, sand, feather, sheep's wool, hippopotamus "ivory", copper and several species of plants (wild and cultivated, fresh and dried), were worked. The wear-traces from these are described in Part I, Chapter 14. As the microwear investigation had shown that the hydration and in some instances the exact species of the worked material could create differences in polishes I always noted the condition and the species of the worked material. Actions included: sawing and cutting, scraping, whittling, planing, boring, drilling (mechanically), piercing, chopping, graving and rubbing. As different actions could cause differences in polishes the tool action was noted. The experiments are described in detail together with the tool types from Arjoune (see also Appendix). I found the information derived from the experimentation itself extremely valuable.

The experimental (as well as the archaeological) tools were washed in water and detergent (usually ammonia-free). In addition, the archaeological tools were immersed for up to 10 minutes in an ultrasonic cleaning tank. Chemicals were not used (Part I, Chapter 12) as a rule. However in a few instances a 10% solution of hydrochloric acid (HCl) was used to remove concretions from flint edges. As chemicals could (and did) alter polishes I noted any treatment with HCl. Experimental blades when hafted in sickles with a resin and wax mixture, were immersed in white spirit for up to twenty-four hours in order to remove the hafting agent completely. After cleaning, the tools were bagged individually in plastic bags.

All the pieces from Trench VI which were classified by Copeland as tools were examined under the microscope, as well as many tools from Trench V, all the drawn tools from Trenches I-IV and VII and a selection of other tools from Trench VII. Unfortunately the drawn tools from Trench V were not available for study. Altogether 470 tools from Arjoune were examined under the microscope, as well as 25 lustered blades from Kebara and El Wad and 63 from Jericho. However, in only some cases (180) could an opinion be formed about the tools from Arjoune. This was presumably because of the slowness with which coarse-grained flint (often used for Arjoune tools) develops polishes and also because of post-depositional traces found to a greater or lesser extent on all the tools from the site. As a result a site distribution analysis could not be carried out.

Observation of experimental polishes and the results of the blind tests had demonstrated that the worked materials could only sometimes be identified with some certainty (see Conclusions: Theory and Method of Microwear Analysis). I therefore did not always attempt to identify the worked material.

I did not attempt to identify hafting traces (Part I, Chapter 14.18), but tried to deduce hafting from the distribution of polish on what seemed to be the used edge, and also from the retouch or shape of an implement.

Edge damage is described at magnifications of 50x, and polish and striations at 200x. Photographs are shown at 200x, unless otherwise stated. The drawings are at a 1:1 scale, unless otherwise indicated. A few tools were outlined from drawings by Copeland. This is indicated by"(L.C.)"next to the figures.

The edge angles of scrapers were measured with a protractor (Fig.8:c).

I have not attempted to give a comprehensive survey of previous research into functional analysis of certain tool types, as full surveys of the previous literature have been given by Vaughan (1981) and Moss (1983).

Chapter 10 - Scrapers

(Pl.8-10, Fig.10-15)

Flakes or blades with a retouched working edge, usually at one end, which is often rounded, but sometimes straight or denticulated, are usually referred to as"scrapers". Most scrapers are clearly tools though"scraper retouch" can also occur accidentally (Newcomer, 1976).

1. Previous Research

Scrapers have received attention by functional analysts since the 19th century (Moss, pp.38-43). The abundance of scrapers in Magdalenian and Neolithic times led some researchers to believe that they were multi-purpose tools used as scrapers, saws, chisels or burins (Pfeiffer, 1912, p.132). Recently Gould et al. (1971) from ethnographic evidence inferred that Mousterian"La Quina"scrapers may have been used as wood adzes. Microscopic wear-traces suggested that scrapers from Mureybet had been used as wood choppers (Coqueugniot, 1983) and that a few scrapers from Ringkloster had been used as burins (Juel Jensen, 1981). Semenov (1964, p.87) on the other hand believed that all the end-scrapers he had examined were used to scrape or soften hide.

An important feature in the functional analysis of scrapers proved to be the angle of the working edge. Wilmsen (1968) introduced a hypothetical correlation between edge angle and function: for instance a relatively acute angle of 46-55 degrees was in his opinion optimal for hide scraping, a steeper edge of 66-75 degrees optimal for hide softening and wood and bone scraping. Ethnographic studies (Gould et al. , 1971; Hayden, 1979, p.124) and experimental (low power) microwear studies (Broadbent and Knutssen, 1975) confirmed Wilmsen's edge angle hypothesis. The edge-angle seemed to be a good indicator of scraper use, but there were some problems: the lack of a uniform measuring technique (Hayden, 1979a, p.211) led to different measurements when two researchers measured the same tools. According to Wilmsen (1968) the edge angle might have been considerably increased by resharpening retouch. However, Broadbent and Knutssen (1975) reported from their experiments that not only did the edge angle increase with each resharpening by as much as 10 degrees, but also that with the increased edge angle, resharpening by pressure-flaking became very difficult.

Another feature observed in the functional analysis of scrapers was the sharpness or bluntness of the working edge. This feature provided the distinction between hide scraping and hide softening implements for Semenov (1964, p.87). Rounding (in plan) of the working edge was an important feature of hide scrapers for Nissen and Dittemore (1974) as otherwise the hide might have been lacerated. Kamminga (1978, p.137), however, found that this was not so when he scraped marsupial skins.

Hafting too was debated. Semenov (ibid.) thought that wear-traces concentrated on one part of the working edge constituted proof of handapplied pressure and thus believed that almost all except the smallest scrapers had been used unhafted. Most other researchers reported that hide scrapers were only efficient when used hafted (Broadbent and Knutssen, 1975, p.116).

Microscopic studies concentrating on the worked material included low-power studies, notably the excellent study by Brink (1978), carried out on various materials in various conditions at up to 50x. Brink investigated flaking, rounding, polish and striations on used experimental scrapers. He found only polish and rounding to be consistently influenced by the worked material (ibid., p.117). However as regards the other two features, he had observed flaking on the dorsal, i.e. retouched, aspect only (see Part I, Chapter 4), and he had counted linear abrasion marks not as striations, but as rounding (op. cit., p.117) and therefore did not find any striations. He noted the considerable differences in wear-traces according to the condition of the worked material (ibid., pp.118-119). The recognition of the fact that wear-traces from hide working can differ considerably from each other was in my opinion important. Such divergences (apart from fresh hide - dry hide) were rarely mentioned with the notable exception of Kamminga (1978, p.137) who reported that wear-traces from working marsupial skins looked different to those from other animals.

High-power studies of scrapers included those by Keeley (1979), Vaughan (1981), Plisson (1981), Gendel (1982), Juel Jensen (1981), Moss (1983), Coqueugniot (1983). Hide, wood, bone and antler were inferred as the worked materials. Problems such as absence of wear-traces due to resharpening or short duration of use, mentioned in connection with low power studies (Hayden, 1979a, p.207) presumably affect high power studies. In this context Plisson may have been a little hasty when he classified the majority of scrapers (69 out of 95) from La Tourasse as unused (1981).

2. Experiments

Fifty-eight experimental scrapers were made of several types of flint (see Part II, Chapter 9), using both hard hammer and in some instances an antler pressure flaker in order to produce acute edge angles. The sizes of the scrapers ranged from very small (2.3 x 3.0 cm) to large (7.2 x 7.0 cm). In order to copy the variety of scrapers from Arjoune (see Tables 7-10), flake-scrapers, end-scrapers, side-scrapers and small scrapers were made. Three of the scrapers were used inserted longitudinally in a wooden haft, held either with wooden wedges and dental floss, or else with resin, wax and sinew. The following materials were scraped: fresh and seasoned wood (oak, ash, sycamore, cherry), bone (long bones and ribs, cooked, raw and dried, from cow, pig and lamb), hide (tanned pig's hide, dry and soaked, fresh red and roe deer hide, and the hairy sides of the latter hides, soaked for three days), antler (reindeer and fallow deer, dry and soaked for three days), soaked horn, ormar shell, limestone, fresh cane and reeds.

It was always much easier to scrape wood which was fresh or water soaked rather than seasoned. Relatively steep-angled (70-90 degrees) scrapers could be used. Edges used to scrape fresh or soaked wood could still be used after 1200 strokes, while edges used on seasoned wood became blunted after 600 strokes. (Broadbent and Knutssen (1975) reported exhaustion of their quartz scrapers after fewer strokes). As with bone and hide, a hafted scraper was far more efficient and easier used than an unhafted scraper. Hafting with resin, wax and sinew proved more efficient than wedging; the wedges became loose and the dental floss broked quickly.

Scraping cooked and dried bone was easier than scraping fresh uncooked bone. Relatively steep-angled scrapers could be used, but had to be held at an angle of approximately 80 degrees to the bone to be effective. Edges used on uncooked fresh bone became dull after 1000 strokes, while edges on dried or cooked bone could be used much longer. Brink had experienced similar difficulties when working clean bone (1978, p.79).

Bergman and I scraped a red deer hide taken from an adult animal killed one week before the experiment. The hide had been left in a refrigerator and was slightly dry with some meat and fat left on it. Water was used to soften the skin. (For ethnographic accounts of hide preparation see Nissen and Dittemore, 1974, pp.67-8; Wulff, 1966, pp.230-232 .) Scrapers used in the fleshing process had to have an acute angle (c.45 degrees) and most importantly an overhang (Fig.8:c) with which to grip the hide. Steep scrapers without an overhang simply did not work at all even when held at a steep angle to the hide. Hafting made a visible difference. A hafted scraper was not only easier to use but scraped a much wider area much cleaner, even when used by a an inexperienced worker like myself, compared to the unhafted scraper used for the same time by an experienced worker like Bergman. It took us two hours to flesh the hide. The acutely angled scrapers were still usable after 84 minutes of scraping. According to Bergman (pers. comm.) who had scraped a hide with the addition of ochre, ochre did not make hide scraping more efficient. Moss and I used scrapers to dehair a fresh roe deer hide after letting the hide soak in water for three days. The hair came off quite easily although longer soaking would have been better. I had tried to dehair a red deer hide with only a few minutes soaking and no hairs came off at all.

Antler was much easier scraped when soaked for several days in water than when dry. Scraper edges used on dry antler became dull after 1000 strokes, while those used on soaked antler could be used for two hours (c.3000 strokes). Acutely angled scrapers cut better than steeply angled scrapers.

Only soaked horn was scraped. It was an easy task, but in my experiment the horn flaked off.

When concretions were scraped off shell, the scraper edges became blunt after 2 minutes (c.50 strokes). Steep scrapers could not be used for this task.

Hard limestone was easily scraped. Edges were not dull after 10 minutes (c.200 strokes) scraping.

Acutely angled scraper edges used to cut shell and limestone worked well and remained largely undamaged (as opposed to unretouched blades used for this task): a large ormar shell (1.5 cm thick) was cut through in 5 minutes.

Fresh cane and reeds were scraped easily and the scrapers were not blunt after 2000 strokes.

The different kinds of flint I had used seemed to work equally well.

3. Results

Unused retouched scrapers showed traces in the form of stone polish, or faint antler polish in the case of pressure-flaking, with striations running in the direction of the retouch on the ventral aspect of the scrapers. Although such traces were isolated rather than continuous on the edge, they might well be (and were, see Part I, chapter 20) confused with use-wear. This suggested that use of ancient scrapers could only be ascertained if the use-wear polish on them was well developed.

Wood scraping left a continuous smooth line of polish, brilliant probably due to the amount of amorphous silica present (Part I, Chapter 14, Pl.8:g). Seasoned wood caused less polish than did fresh wood scraped for the same time (Pl.8:e and g). There was hardly any micro-chipping on the ventral aspects of the scrapers. However, while well developed wood polish was fairly easy to identify, there were areas of confusion: on coarse-grained large flake-scrapers the use was distributed over a long edge and therefore hardly any identifiable polish could be seen even after one hour's use. The same happened with a small scraper of the same raw material which had been used to plane wood for 10 minutes. In one instance wood polish on a scraper had a distribution similar to hide polish, in another it was similar to bone polish. Wood polishes also looked slightly different according to species: scraping sycamore led to a very fluid looking polish (Pl.8:g). When bark was scraped the resulting polish (flat with short striations) looked like limestone polish (Pl.9:a).

Scraping dry bone caused the flattened dry bone polish with narrow deep striations (see Part I, Chapter 14). The scraper edge became not rounded (in profile) like that of hide scrapers, but looked very jagged due to the intense microflaking of the edge (Pl.1:d). Fresh uncooked and cooked bone also caused some edge damage (although not as much as dry bone) and a distinctive striated polish"bevel"(Pl.9:h). Sometimes this bevel was only seen on a small projecting area of the scraper edge and the only other wear-traces were a generally bright polished area. The same was the case with a scraper which Miller had used to scrape meat from bone.

Scraping pig hide (dried and tanned) resulted in a polish distribution similar to the"pitted"look usually associated with dry hide polish (Part I, Chapter 14). Scraping fresh hide and dehairing hide led to a rounded edge with"bumpy"polish and short striations. Very little microflaking could be discerned (Pl.2:f). Hide polishes could differ very much according to flint type: sometimes on a fine-grained flint-scraper (used by Bergman for 30 minutes) a lot of polish was seen, while on a medium-grained scraper used by me very little polish was discernible even after 84 minutes' use (Pl.10:g). I found this worrying in view of the fact that even less polish might be visible on ancient tools, and that such sparse polish could be confused with other weak polishes, including those from manufacture. One reason for this variation might be that polishes could vary according to the surface on which the hide is scraped. The scraper used with ochre showed a polish similar to hide polish with a few more striations (Pl.10:e,g).

Scraping dry antler left a few ill-defined traces (see Part I, Chapter 14). The polish on my scrapers looked like the beginning of wood polish but somewhat duller, that is, with probably less amorphous silica. Scraping soaked antler left a polish which could be confused with wood polish (cf. Pl.9:g and 8:e). The edge was also rounded and short striations were visible. There was little microflaking (Pl.2:b).

Scraping soaked horn left only ill-defined traces (Part I, Chapter 14).

Scraping concretions off shell left a generally abraded surface with fine striations (ibid.).

Scraping limestone caused considerable abrasion of the edge, microflaking and flattened stone polish with short flat striations (ibid.) (Pl.1:b, 9:c).

Sawing shell with a scraper caused shell polish (ibid), that is bright patches of polish with parallel groups of striations (Pl.9:e).

Sawing limestone with a scraper caused thin striations on small patches of polish.

Scraping cane caused a fluid looking polish without any striations and with hardly any edge damage.

Scraping reeds caused the domed reed polish (Part I, Chapter 14, Pl.23:g,h) with no striations, but some edge damage.

One scraper was used on bone, then on wood. The resulting wear-traces looked like a mixture of bone and wood polish.

In all cases speed of polish formation varied with the flint type (see Part I, Chapter 17, Pl.5). Macroscopic gloss was strongest on the plant scrapers and was visible on some wood scrapers. However, I suspect that any hard material when worked long enough would cause gloss (see Part I, Chapter 10). Macroscopic rounding was always visible when a scraper had been used for a long time, say one hour. However, with some scrapers such long use was not possible. On very hard materials, such as stone, scrapers became rounded faster than when used on soft materials.

For hafting traces (or rather the lack of them) see Part I, Chapter 14.18).

4. Scrapers from Arjoune

The scrapers discussed below measured from small (1.8 x 1.9 cm) to large (8.3 x 6.8 cm). One reason for this variation in size may have been the scarcity of suitable raw material (see Part II, Chapter 9). Despite the small sample size I tried to investigate the relation between size (as well as type and edge angle) and worked material. For types, numbers and percentages see Tables 7-10 .

Trenches I-IV

Of the two drawn scrapers (one"end-scraper"(Copeland, 1981, Fig.11:6, here Fig.14:a) and one"truncated blade-section (or ?scraper)" (ibid., Fig.11:16, here Fig.14:b) the former was patinated, the latter a surface find. I therefore left both these scrapers out of the discussion although they both showed wear-traces compatible with their use as scrapers.

Trench V

104.2 - A retouched backed flake (4.5 x 3.4 cm) with a straight regularly retouched edge forming an angle of c. 45 degrees (Fig.14:c) , without an overhang, seemed to have been used as a side-scraper. This was indicated by the directions of striations and polish. It was impossible to identify a worked material as the flint was coarse-grained, and the polish too weak.

114.2 - A small blade (3.6 x 1.6 cm) with end-scraper retouch forming a steep angle of c.80 degrees, but with a slight overhang due to the natural curve of the blade (Fig.12:b), had been used as a scraper, possibly on stone, although use on tree bark could not be ruled out (Pl.9:b). Thinning flakes on the dorsal proximal end suggested hafting.

210.1 - A hinged flake (4.5 x 3.2 cm) with steep scraper retouch on one lateral and on the distal edge (with an angle of c.75 degrees) had a less steep retouch on the other lateral edge (Fig.14:d). Apparently the more acutely angled edge had been used to scrape, possibly on wood.

220.1 - A tabular scraper fragment (5.5 x 4.0 cm) with scraper retouch forming an angle of c. 75 degrees opposite the break (Fig.11:b), had patches of gloss on a projection of the scraper edge. The lack of edge rounding and the polish suggested wood as the worked material. Unfortunately the patch of polish was very small and the rest of the tool was covered with a general polish, which suggested that the patch might be due to some post-depositional surface modification (Pl.8:h).

Trench VI

Surface - A"circular flake-scraper or fan-scraper"(Copeland, in prep., Fig.19:3) (6.3 x 5.2 cm) had a slight overhang and one edge area more acutely angled (c. 50 degrees) than the remaining retouched edge (Fig.11:a). Unfortunately the scraper was covered with a general polish, probably due to natural agencies, and there was extensive microflaking on the ventral aspect. Nevertheless the lack of rounding of the edge and the distribution of polish on the most acute part of the retouched edge suggested that wood had been scraped (Pl.8:d).

500.1 - A large"circular flake-scraper, with butt thinned, or fan-scraper"(Copeland, in prep., Fig.19:1) (8.3 x 6.8 cm) had retouch all around (Fig.15:a). One side was more acutely angled (c.45 degrees) than the other. Heavy flaking on the ventral aspect which was concentrated on the acutely angled edge suggested either resharpening retouch of the ventral surface or else that this edge had been reused as a chopper (cf. Coqueugniot, 1983) or adze (cf. Gould et al. , 1971). However, as the entire ventral aspect was covered with general gloss and polish it was impossible to identify the worked material. Thinning flakes had been removed from the proximal end on both aspects suggesting that the tool had been used in a haft.

500.1 - A flake-scraper fragment (4.9 x 4.1 cm) had a rounded retouched edge which indicated that it had originally been an end-scraper (Fig.13:h). The retouched edge had an angle of c. 50 degrees and the flake's natural curve gave it an overhang ideal for gripping pliable materials. The polish and relative lack of edge damage visible near the break looked exactly like the wear-traces from experimental hide working (Pl.10:h). Several thinning flakes had been detached from the proximal dorsal end, suggesting that the scraper had been hafted.

702.3B - A side-scraper (5.0 x 3.1 cm) had been made on a fractured blank (fig.15:b). The scraper-edge looked fresh and formed an angle of c. 55 degrees. No microflaking could be seen, but a weak polish blended into the general polish found all over the tool. Striations indicated that the tool had been used as a scraper, but I could not identify the worked material. The distal ventral end had been thinned, suggesting that the tool had been hafted.

703.3B - A fragment of a flake-scraper (5.0 x 4.6 cm) had been retouched to form a very acute edge angle (c.30 degrees) (Fig.12:e). Heavy flaking was visible on the ventral aspect. Domed polish on the ventral aspect, running perpendicular to the edge, suggested that wood had been scraped. However, there were also groups of thin deep striations running parallel to the edge on both aspects, particularly on the dorsal aspect. This suggested that the scraper had been reused to cut something hard, perhaps stone or shell (Pl.9:f). As the breaks opposite the scraper edge formed a tang, the tool may have been hafted.

800.1 - A small flake-scraper (3.8 x 3.0 cm) made of translucent flint, had been retouched on both sides and both ends. One lateral edge, obviously not the working edge, was very steeply retouched, while the other lateral and the distal edges had angles of c. 60 degrees and no overhang (Fig.10:e). No rounding could be seen and the polish looked like wood polish (Pl.8:f). The retouch on the"inactive"edge, too sharp on the dorsal aspect to be comfortably held by hand, suggested that the scraper had been hafted.

801.3 - A large"composite denticulate with racloir"(Copeland, in prep., Fig.19:4) (6.6 x 4.1 cm) with pronounced overhang and an edge angle, at its most acute c. 45 degrees (Fig.13:f), had an edge rounded both in profile and in plan and little edge damage. The polish (Pl.10:f) looked identical to experimental hide polish. Thinning flakes on the dorsal surface at the proximal end and on one lateral edge indicated that the scraper had been hafted.

900.1 - A small"lustered fragment, possibly a reused end-scraper"(Copeland, in prep., Fig.18:16) (2.6 x 1.9 cm) had been made out of a lustered truncated blade, apparently a sickle blade. The edge (angle c. 70 degrees) had a slight overhang (Fig.15:c) and very little polish which looked like experimental hide polish. This suggested that it had been used on hide, although the possibility that it had been retouched with antler and left unused cannot be ruled out, as the beginning of hide and antler polishes looked similar. The fact that a notch had been made into the lateral edge near the distal end suggested that the converted scraper had been meant to be used inside a haft.

Trench VII

1000.1 - A"thumbnail scraper"(Copeland, in prep., Fig.23:12) (1.9 x 1.8 cm) seemed on closer inspection to have been retouched not only on the dorsal but also on the ventral aspect (Fig.15:d). This would make its use as a scraper unlikely. No use-wear polish could be seen.

1000.1 - A"composite scraper and 'epine' borer"(Copeland, in prep., Fig.23:11) (4.3 x 3.2 cm) had very steep retouch (c. 90 degrees) forming a very jagged edge (Fig.13:b). Polish indicated that it had been used as Copeland suggested: the polish on the scraping edge was too general to identify the worked material. However, the steepness of the scraper edge together with the striated rotatory polish of the projection classified as a borer (Pl.10:b) suggested that a hard material was scraped and bored, possibly bone. There was no indication that the tool had been used hafted.

1005.3 - A small"straight-ended end-scraper"(Copeland, in prep., Fig.23:8) (2.6 x 2.4 cm) had similarly steep retouch (c. 80 degrees) as the scraper discussed immediately above (Fig.13:d). Striations indicated that perhaps bone (Pl.10:d) had been scraped, although they could also have been due to retouch. There was no indication of hafting.

1008.3 - A fragment of a large flake-scraper (7.0 x 3.8 cm) (Fig.10:c), with an edge retouched to form an angle of c. 45-50 degrees, had no overhang nor noticeable edge rounding or edge damage. The polish (Pl.8:b) looked exactly like experimental wood polish. The break opposite the used edge had probably followed a natural line in the stone and could therefore not be regarded as evidence of hafting.

Mound C (Sounding)- An"end-scraper"(Copeland, in prep., Fig.24:8) (3.6 x 2.1 cm) had a very abraded steep (c. 85 degrees) scraper-edge (Fig.12:d) and showed a polish (Pl.9:d) like experimental stone polish. As only the end was abraded it seemed likely that it had been used on stone. The fact that the end was visibly abraded suggested that the stone polish was not due to retouch.

5. Conclusions

The scrapers from Arjoune seemed to have been used on hide, wood and possibly bone and stone. In many instances identification of the material was uncertain, however.

Although the sample was too small to come to any definite conclusions, there were indications that size of scraper was linked to a particular worked material: large scrapers had apparently been used on wood and hide, materials with very extensive surfaces, while small scrapers had been used on bone and stone (as well as on wood and hide, perhaps because large flint blanks were at a premium).

Given the small size of the sample there were some indications that scraper type was linked to a worked material: round tabular scrapers seemed to have been used on wood, end-scrapers seemed to have been used on hide, while straight-sided scrapers with slightly denticulated edges had apparently been used on bone.

Edge angle and overhang seemed to be important: the scrapers with the steepest edges had been used to scrape hard materials. The scrapers with overhang seemed to have been used on softer materials such as hide and indeed my experiments had shown that the overhang of the working edge is essential for hide scraping. However, I tried to avoid being influenced by this in polish identification.

Many tools had been reused: one scraper had been made out of a sickle blade, other scrapers had apparently been reused as saws, choppers or adzes. One tool was used to scrape and bore, probably the same material.

Hafting could only be deduced from circumstantial evidence, such as thinning of the butt, and in one instance by lack of comfortable accommodating retouch. The smaller tools, including one composite, did not show any indications that they had been hafted.

The sample was too small to indicate differences between individual trenches.

Chapter 11 - Perforators (Borers, Piercers, Drills)

(Pl.11-12, Fig.16-18)

Any pointed flint piece could be used as a perforator, that is to pierce, bore or drill a hole. (By"boring"I mean hand-use, by"drilling"mechanical use). Usually a flint piece is classified as a perforator if it has a retouched point on its central axis and a more or less circular cross- section.

1. Previous Research

Semenov (1964, pp.74-83) examined perforated shell and stone objects from the Upper Paleolithic and the Neolithic. He illustrated (ibid., fig.25) various methods of boring by hand, drilling with a stone drill inserted in a dowel and rotated between the palms of the hand, and a bow-drill which was accepted as present at least by Neolithic times (ibid.); Cauvin (1968, p.163) stated that bow-drills at Neolithic Byblos were"prâtiquement prouvée"). Unfortunately the wear-traces drawn in Semenov's publication (fig.25) looked identical, regardless of whether they originated from hand-boring or bow-drilling. I did not find this in practice (see below).

Low power studies of perforators included that by Tosi and Piperno (1973) who found residues from lapis lazuli embedded in perforators made from microlithic blades and burin-spalls at Tepe Hissar and Shahr-i-Sokhta.

High-power microwear analysis of Paleo-Indian drills (Yerkes, 1983) revealed drilling of shell, bone, wood and stone, probably with a bow-drill, judging from the regularity of the striations (ibid., p.511). A few drills had been used as gravers rather than borers (ibid.). Our own microwear analysis of 15 drills from Abu Salabikh (Unger-Hamilton <u>et</u> <u>al</u>. , 1987) is reported in some detail in Part I, Chapter 20. The drilled materials were apparently shell, and a material, probably stone, which had been drilled with the addition of abrasives. The wear-traces were consistent with mechanical drilling. Gwinnet and Gorelick (1979) in their SEM study of ancient drilling methods reported concentric patterns similar to those observed by us on the Abu Salabikh drills. Such concentric patterns were according to Gwinnet and Gorelick (ibid., p.20) characteristic of the addition of sand as an abrasive, as had been the case with our experiments. Keeley (1983) investigated a few <u>mèches</u> <u>de</u> <u>forêts</u> from Neolithic Abu Hureyra and found that some - the broken specimens - had been used to drill wood, possibly with a pump- or bow-drill, while others - the complete specimen - had been used to enlarge the holes. However, no comparable experiments were reported nor were any photomicrographs shown as evidence for this early Neolithic example of"joinery" (Keeley, ibid.).

2. Experiments

Twenty piercers and borers and 32 hafted drills ranging from very large to very small had been made of various types of flint (see Part II, Chapter 9). They were used to perforate wood (fresh and seasoned), bone (cooked, uncooked and dried), antler (soaked and dried), hide, soaked horn, pottery from Arjoune, various types of stone, various types of shell, and cane. Some piercers were also used to groove wood, bone, pottery and stone. Bergman and I had used a bow-drill to drill the above materials, and also lapis lazuli, copper, malachite and hippopotamus"ivory" which had not been found at Arjoune. Lapis lazuli and copper were drilled, and stone and wood were bored with the addition of abrasives, including sand on its own, and sand and water. In addition a"leather awl"used by Miller, and a piercer used to groove soaked antler by Newcomer were examined.

Grooving with piercers proved an easy task. For instance the tip of a piercer was still intact after 30 minutes when a fresh deer metatarsal was grooved in order to make a bone awl after the method illustrated by Poplin (1974, Figs.7-11).

Five holes were pierced into a relatively fresh hide which had been moistened with water. This was difficult: the hide stretched over the piercer tip which the retouch had somewhat blunted. It would have been better either to pierce dry hide or else use a much sharper tip.

Boring holes in fresh wood was, not surprisingly, easier than in seasoned wood. For wood a relatively broad tip could be used. Tips were still intact after boring for 15 minutes. It took 10 minutes to make a biconical hole through a wooden plank of 3 cm thickness, and half that time to make a similar hole through fresh wood.

Bone could also be bored, even when dried, but the tip was easily crushed or broken.

Boring soaked antler was easy: eight holes were drilled through the flat tip of a reindeer antler in 10 minutes.

Horn could be perforated, but the inner casing was very hard.

Limestone was much easier perforated than quartzite, on which the tip broke immediately.

It took 5 minutes to bore a biconical hole through a pot sherd.

Two holes were bored through a shell of 0.2 cm thickness in 5 minutes with a large bec. However, the tip was so blunted that a third hole could not be made.

Five holes were bored into cane. The tip broke after the third hole.

Boring wood and limestone with the addition of sand did not make the tasks easier: it was laborious to feed the sand into the hole.

Bergman and I (Unger-Hamilton _et al_. , 1987) used a bow-drill made by Bergman on all the materials listed above, which were fastened to a bead-board , usually with bitumen. The drills were hafted in wooden dowels with resin and sinew, and in some instances with wooden splints and sinew. The bow-drill was easy to handle and very hard materials could be drilled quickly. Most of the flint tips remained intact. Mechanical drilling was always more effective and easier than boring by hand. It took for instance 12 minutes to make one hole into lapis and 10 minutes to make three holes in hippopotamus"ivory"(see Unger-Hamilton _et al_. , ibid.). Drilling with sand and water was somewhat easier than with sand alone as the abrasive stayed in place. The addition of abrasives did not seem greatly to increase efficiency of the drilling process, except perhaps when soft stone was drilled (see Hodges , 1976, p.107). Bergman found that large drills were difficult to haft and use, and that a great amount of heat was generated during the drilling of wood with a _mèche de forêt_.

It seemed that, when used to perforate, coarse-grained flint broke more easily than fine-grained flint.

3. Results

Polishes and striations from grooving and rotary movements could be differentiated by their different distribution. In the former case polish and striations were confined to the contact aspect and ran along the longitudinal axis of the tool tip; in the latter case they were found on the sides of the tool tip as well, and were perpendicularly oriented to the tool's long axis. The edge damage distribution was also similar but - as with the polish and striations - could be difficult to isolate from retouch traces.

Hide piercing left little in the way of wear-traces, except a slight polish at the tool tip.

Boring and mechanical drilling could be differentiated. Boring often involved considerable edge damage but little polish and slightly random striations (Pl.11:a), while drilling caused hardly any edge damage (apart from complete breaking of the tips), but strong polish, often with rotational striations (Pl.12:c, 29:g). Gloss was rarely seen on borer tips (the exception being wood borers), while it was seen on drill tips used to drill hard materials like stone, malachite or copper, or wood. It was in some instances impossible to identify the worked materials on the piercers and borers, as the areas used were so small. A complicating fact was the retouch leaving its own wear-traces perpendicular to the tip axis, although they were minimal in the case of the antler hammer (Pl.6:f). Often the tips of hand-held perforators used on hard materials had broken.

There were some distinct polishes on hand-held perforators, e.g. from wood (Part I, Chapter 14, Pl.11:a), stone (ibid.) and pottery (ibid.). However, a large number of striations, probably from the flint particles, were seen on all borers, regardless of the worked material. This made it impossible to differentiate shell from bone polish, although bone sometimes - but by no means always - caused the characteristic bevel (ibid.). Antler could look like wood polish, while hide and horn left only weak traces which on ancient tools could be mistaken for post-depositional traces. Macroscopically, tool tips were found to be relatively intact when hide or wood had been perforated; they were splintered when bone was worked, and abraded by limestone and shell.

Mechanical drilling left stronger traces which (with the exception of pottery and malachite polishes) looked distinct according to the worked materials (Pl.12;a,c, 29:e,h). They matched the general descriptions of polishes (Part I, Chapter 14). Of the polishes only briefly mentioned there, malachite polish looked like that from pottery, presumably as the materials are of similar consistency, copper polish looked unmistakably smooth and flat (Pl.29:e), and hippopotamus "ivory"caused a corrugated polish with lots of tiny pits (Pl.29:h).

Drilling with abrasives left distinct wear-traces which were always dominant regardless of the worked material; drilling with sand alone left a roughly abraded surface, while drilling with sand and water left a concentric ring pattern (Pl.29:g).

In all cases,the more yielding the material and the steeper angled the tool tip, the more penetration of the material was achieved, and the more invasive were the wear-traces down thè tool tip. Obviously, thickness of the material was also important: a drill would penetrate much deeper into a wooden plank of 5 cm thickness than into one of 1 cm thickness.

4. Borers, Piercers, Drills from Arjoune

See Tables 7-10 for numbers and percentages of borers, piercers and drills

Trenches I-IV

Two of the drawn perforators, a"drill-bit"(Copeland, 1981, Fig.11:1) and a"borer"(ibid., Fig.11:2) , although surface finds, had what seemed to be well preserved wear-traces. The drill-bit (Fig.16:i), with what looked like a broken and subsequently abraded tip, had clear rotary traces, like those from stone drilling, down to a few mm from the tip. This suggested that the tool had been used to drill stone (Pl.12:h). The "borer"(Fig.18:a) had a slightly abraded intact tip with little edge damage, and polish and rotary traces indicating that it may have been used as a wood drill.

Trench V

I could only find two perforators which were not either burnt or had broken tips, or else no identifiable wear-traces.

313.2 - A tool made on a truncated blade had an intact tip (Fig.18:b). Judging from the striations and polish, it had probably been used as a wood drill.

403.2 - A tool with a flattened tip (Fig.17:e) may have been used to drill wood, although use on stone could not be ruled out (Pl.12:f).

Trench VI

500.1 - A"borer 'bec' type on retouched flake"(Copeland, in prep., Fig.20:2, here Fig.16:e) had clear wear-traces on the"bec" indicating that it had been used as a borer. The microscopic bevel (Pl.11:f) at the tip was more typical of wood than of bone boring, as was the tip which was quite intact. The shape of the tool suggested that it had been used by hand.

700.1 - A large"borer, drill-bit type"(Copeland, ibid., Fig.20:1, here Fig.17:d) had a very abraded tip and wear-traces consistent with use in a fast rotary drill, probably to drill stone, although wood could be a possibility (Pl.12:g). Bergman reported (pers.comm.) that a copy of this tool could only be hafted with great difficulty.

700.1 - A borer with an intact tip (Fig.16:b) had very little polish and few striations consistent with wood boring (Pl.11:b). The irregularity of the proximal end suggested that the tool had not been hafted.

701.3B - A long thin"borer, drill-bit type"(Copeland, ibid., Fig.21:3, here Fig.17:b), often referred to as a <u>mèche de forêt</u> , had an intact tip and wear-traces consistent with the drilling of wood in a fast rotary drill (Pl.12:b,d). The fact that the wear-traces affected the tip down to 4.2 cm was surprising as Bergman (pers.comm.) found that he could not drill wood very deeply with a copy of this tool.

703.3B - A small"borer, piercer type"(Copeland, ibid., Fig.20:3, here Fig.18:c) had a somewhat abraded tip, little edge damage and very weak polish which could be hide polish. Striations indicated that the tool had been used to pierce as well as bore.

800.2 - A short projection on a truncated blade (Fig.16:d) appeared to have been used to incise wood or antler, judging from the polish (Pl.11:d) and relative lack of edge damage.

900.1 - A small perforator with an intact tip (Fig.18:d) had probably been used on wood, judging by the domed polish. The strong development of the polish and the small size of the tool suggested that it had been used in a haft.

Trench VII

1000.1 - A"borer, piercer type"(Copeland, in prep., Fig.23:13, here Fig.16:g) had apparently been used as a borer. Brown earthy-looking inclusions and diffuse polish at the tip suggested that pottery may have been bored, although post-depositional traces could not be ruled out (Pl.11:h).

1000.1 - A small borer (Fig.18:e) had traces similar to the borers discussed immediately above and may also have been used to perforate pottery.

5. Conclusions

It seems that of the few perforators with relatively clear wear-traces most had been used on wood. This may however be due to the fact that hard materials, such as stone, shell or bone tend to lead to tip breakage, while relatively soft materials, such as hide, leave very weak traces. It is also possible that antler polish could have been mistaken for weak wood polish, but as no worked antler had been found on the site at Arjoune, though unworked antler was found, this was unlikely. Other materials apparently perforated were stone, pottery and perhaps hide.

It seems that there is clear evidence for the use of drills, in a mechanical drill, possibly a bow-drill. Copeland (in prep.) had suspected as much. The drilled materials had apparently been wood and stone. It seems that at least at Arjoune the <u>mèche de forêt</u> had been a wood drill as its name suggested.

There was no evidence for the use of abrasives.

Hafting had to be inferred from the wear-traces on the tool tips and the shape of the haft.

Finds from the site at Arjoune, such as a perforated macehead, suggested the use of thick drills. However Bergman reported difficulties with such thick drills (see above, Section 2). Further experimentation is needed. It is possible that hollow drills (Semenov, 1964), perhaps of cane, may have been used. Other perforated objects included a shell pendant.

Chapter 12 - Retouched Blades, Bladelets and Flakes

A - Blades, Bladelets and Flakes with Lateral Retouch

(Pl.13-15, 16:a-d, Fig.19-24:a-d, 25-27:a-h)

A flake is any element which is struck off a core. A blade is a flake with parallel edges and ridges. A bladelet is similarly proportioned and is less than 1.2 cm wide (Tixier, 1974). Only implements with retouch on one or both lateral edges are discussed, as these are most likely to have been used. Lateral retouch, which may be shallow, semi-abrupt or abrupt, may either provide backing of the tool, that is, the hafted or hand-held edge, or else it could be the working edge. Blades or flakes with snapped ends are discussed separately in Chapter 12 B.

1. Previous Research

There has been a debate whether steeply retouched edges, usually thought to be backs of blades, may have been used as rasps or whether one would cut oneself on the sharp edge (see Moss, 1983 ,pp.43-46). In my opinion it is possible that the sharp edge was inserted in a haft. Retouch could be created accidentally, e.g. during knapping (Newcomer, 1976) or else during use (Part I, Chapter 4). Various uses could be envisaged for blades and flakes: Moss (1983, pp.43-46) discussed research in which such tools had been classified as scrapers, kinves, saws, and in the case of bladelets as barbs and projectile points. Wilmsen's hypothetical relation of angle of the working edge to function suggested certain optimal edge angles for scrapers (see Part II, Chapter 10), acute angles (26-35 degrees) for cutting tools of soft materials, and wider angles (46-55 degrees) for the cutting of harder materials, and he apparently accepted Semenov's optimal angle (35-40 degrees) for whittling knives. Such edge angles were largely confirmed by the ethnographic evidence (Gould _et_ _al_. , 1971).

Semenov stressed the importance of meat knives (1964, pp.101-113) for hunting activities, but Frison's experiments (1979) and Gould _et_ _al_.'_s_ ethnographic observations (1971) suggested that sharp flint flakes need only be used during butchering to cut the skin and ligaments of the animal. Stone choppers, bone tools, wooden wedges and logs could be used to butcher the carcass.

According to Gould _et_ _al_. (ibid.) aborigines used small flake knives in circumcision rituals and larger flake knives for a variety of tasks including domestic ones.

Retouch of the cutting edge varied: Gould _et_ _al_. (ibid.) reported that flake knives used for day-to-day activities were mostly discarded after a few uses, and not resharpened. Escalon de Fonton (1979) resharpened blades by denticulation during wood working experiments, and after further work the denticulated edge became straightened by the breaking of the teeth. I found that denticulation did not make a blade sharper but always prolonged the life of the blade considerably (see Part II, Chapter 17).

A number of microwear studies have been carried out on blades and flakes. The results of the low-power studies, concentrating on edge damage are discussed in Part I, Chapter 4. High-power studies included those by Vaughan (1981, e.g. table 50), Bueller (1983), and Moss (1983) who reported that at Pincevent blades had been used to butcher and cut meat, cut and bore hide, and that obliquely truncated blades had been used to groove bone (p.132). Moss (ibid., pp.43-46) referred to the hafting of bladelets, and I have examined wear-traces on blades from Kebara and El Wad, shaped exactly like the sickle blades from the same sites, but with wear-traces from materials other than plant.

Backed bladelets had probably been used as barbs and projectile points (Moss, 1983, p.115; Barton and Bergman, 1982). Real examples of such use, i.e. complete Egyptian pre-dynastic and dynastic arrows, were shown by Clark _et_ _al_. (1974).

The difficulty in assigning wear-traces on cutting tools to a specific worked material has been discussed in Part I, Chapter 20. I believe that this is mostly due to the fact that the hardness and surface texture of the material cut is largely unknown to the microwear-analyst, and also that a long time is required for polishes to develop on such implements, except with some worked materials such as wood or some plant species.

2. Experiments

Ninety-one unretouched and denticulated blades and flakes had been used on wood, bone, hide, antler, horn, meat, fish, stone, pottery, feather, wool, shell and root vegetables.(For experiments on siliceous plants see Part II, Chapter 17). The tools had been used to cut, saw, whittle ,scale (fish) and to groove (hard materials). I used all the tools unhafted, but also studied wear-traces on blades and bladelets which had been used by Newcomer, inserted parallel in groups of three in hafts, to cut meat and wood.

In addition I examined flakes and blades used by Miller to cut meat and scale fish, and several backed bladelets used by Bergman as arrowheads and barbs.

Experiments sawing wood showed that it was almost impossible to make any deep incisions into seasoned wood. Fresh wood could be incised down to a few mm deep, but blades had to be denticulated after 10 minute's use. When denticulated, they became blunt after 45 minute's use on fresh wood. The denticulated edge broke easily and great care had to be taken during sawing. Only thin twigs could be cut through. The ease with which bone was sawn depended apparently not so much on whether bone was cooked, dried or fresh, but on the type of bone and animal: thin chicken leg bones could be sawn with ease, while cow leg bones or the epiphysis of a roe deer metatarsal could hardly be cut at all. On most bones cuts could only be made to a few mm deep. Blades were blunt after 1000 sm, and the teeth of denticulated blades snapped off.

With antler the ease of sawing depended on whether the antler was soaked or not. Soaked antler could easily be sawn (although the deepest cut I could achieve without the blade breaking was only 2 cm), while dry antler was almost impossible to cut; edges were worn out after 500 sm. A retouched cutting edge worked better than an unretouched one.

Hide cutting was easy, especially when the hide was dry. However an unretouched blade was blunted after 5 minutes. Horn soaked for four hours was also quite easily cut although it would have been better to soak the horn longer as the inner casing was hard.

To cut meat one needed a very acutely angled blade and ideally a long blade, or else several blades hafted together. Other tasks (all easy) carried out were cutting fat off hide, tendon off bone, and cutting through dried sinew. Several kinds of fish were gutted and trimmed.

Limestone was incised with a blade: a scraper edge had been more efficient for this task (Part II, Chapter 10). The same was the case with shell: two fine incisions , each 3 cm long, were made with a flake in 5 minutes. However, after that the edge was blunt, and a thin scraper or burin edge proved better at cutting through the shell.

Sheep's wool was cut with an unretouched flake. However, this was a very laborious task and the flake was not sharp enough. Ryder (1983) stated that woolly sheep were only bred when wool shears could be used. From my experiments I would agree with Ryder.

Altogether for cutting it was best to use very acutely angled blades with edges straight both in section and in profile. Soft materials were easiest cut with unretouched edges, medium-hard materials with denticulated edges , very hard materials with edges with scraper retouch. Whittling wood and scaling fish also had to be done with acutely angled blades. Grooving fine incisions into hard materials was easy, but edges broke quickly.

3. Results

Wood sawing (e.g. after 2000 sm) left macroscopic gloss, relatively little and rounded edge damage, and the continuous, bright wood polish, either gently domed or very fluid looking (Part I, Chapter 14, Pl.13:c). Very thin edges broke away completely, thus leaving hardly any polish even after 30 minute's use. In this case striations were not in sawing direction, but rather in the direction of the microflaking. On coarse-grained flint very little and isolated polish with striations could be seen, although because of its continuity, the polish looked like wood polish.

Bone polish could vary considerably: uncooked and fresh bone left a general bright area of polish with a few striations, while dry bone could leave little polish (Pl.15:c), but in some instances striations. Stepped microflaking was the most characteristic feature of bone sawing (Pl.1:c). Chicken bones seemed to lead invariably to a special polish with inflated looking polish streaks (Pl.29:f).

Polishes from the cutting of hide (Pl.14:g), meat (Pl.14:a,c) and carrots (Pl.16:c) looked very similar to each other: in each case a general bright area of polish with some streaks was visible. Similarly vague traces were generated by cutting dry sinew (Pl.16:b), cutting fat from hide, tendon from bone (Pl.16:a), and feather (Pl.15:f). None of these wear-traces could be detected on coarse-grained flint and none would in my opinion be distinguishable on excavated tools with soil sheen.

Sawing dry antler generated some isolated areas of flat polish (Pl.15:h) with striations, which could look like wood polish. Similarly soaked reindeer, red deer and fallow deer antler caused a continuous inflated-looking polish (Pl.15:g) akin to that of wood. However, gloss was never as obvious as that caused by contact with wood. Fallow deer antler seemed to cause regular shallow striations not seen (by me) on blades used to saw reindeer antler.

Cutting fish left a somewhat flatter and brighter band of polish than did meat. Nevertheless, I doubt whether these polishes could be detected on ancient tools.

Wool left a narrow band of polish (Pl.14:e) with fine striations and lots of small edge damage scars.

Limestone left the flat polish (Pl.15:a) with diffuse flat striations.

Shell left bright patches of polish (Pl.9:e) with groups of striations.

Whittling wood (and soaked antler) left very rounded edge damage and invasive polish on the contact aspect, wood polish in the former case, domed and striated polish in the latter case. Seasoned wood left very little flat polish at the edge. Sawing and whittling wood with the same edge left vague traces of buoyant polish apparently spread in both directions of use (Pl.13:e).

Fish scaling left in some instances a pattern of bright bands of polish (Pl.15:e,29:d) running diagonally to the edge, presumably where the scales had touched (cf. Semenov, 1964, p.107). Unfortunately this happened only with some fish, like gurnet, and not with bream.

Bladelets used as arrowheads and barbs were often severely shattered and damaged (see"Previous Research"in Part II, Chapter 15). Wear traces tended to consist of striations running in various directions (Pl.20:g), presumably depending on how the bladelets had hit the carcass, been deflected in it and been removed from it. Bladelets shot into sand by Newcomer had very bright specks of sand polish and jagged edge damage (see Part II, Chapter 15).

Grooving caused specific polishes, but the used area was so small that it could be missed on ancient blades, or held to be affected by post-depositional traces.

Altogether, the fact that wear-traces on blades used to cut meat, fat, sinew, hide, horn, carrots, and to a certain extent wool and fish, were very weak or non-existent made me very pessimistic about the detection of such traces on ancient blades. Blades used to cut hard materials, such as dry antler, bone or shell, were subject to a lot of breakage, and again this meant that worked materials could not be identified on ancient blades. Antler and wood polishes on blades looked sometimes similar while bone polishes showed tremendous internal variability. In fact the blind tests (Part I, Chapter 20) had demonstrated to me that when blades are used for only 10 minutes, the chances of identifying the worked material seemed higher by examining the blades with the naked eye than by microscopic examination of weak or virtually indistinguishable wear-traces.

No blades were examined for hafting traces, but polishes were very evenly distributed along the edge on hafted blades (used by Newcomer) and such a distribution might suggest that a blade had been hafted.

Blades, Bladelets and Flakes with Lateral Retouch from Arjoune

See Tables 7-10 for numbers and percentages of retouched blades, bladelets and flakes at Arjoune. The tools discussed below had been classified (by me) as unlustered after the initial macroscopic examination. In some instances closer inspection revealed a weak lustre. (Lustered"sickle blades"are discussed in Part II, Chapter 17 .)

Trenches I-IV

The wear-traces on only two unlustered blades could be identified although the fact that they were surface finds lessened the degree of certainty. On a"?sickle blade (no sheen)"(Copeland, 1981, Fig.10:10, here Fig.19:d) from Arjoune I Surface showed a few spots of wood or possibly reed polish (Pl.13:d). The lack of gloss may have been due to the considerable resharpening retouch. A"crescent-shaped backed ?sickle-blade (no sheen)"(ibid., Fig.10:12, here Fig.25:a) also from Arjoune I Surface showed stone polish and striations in the cutting direction.

Trench V

Baulk 101-401 - A retouched bladelet (Fig.25:b) was burnt, an important observation in view of the fact that only small tools which had probably been hafted had been heavily burnt (see PartII, Chapter 18).

102.2 - A small truncated blade (Fig.25:c) looked like a sickle-element, but wear-traces consisted of a weak band of polish suggesting that hide or meat had been cut.

104.2 - A small truncated backed blade (Fig.25:d) with regular rounded edge damage at the cutting edge showed polish consistent with wood sawing, or perhaps the beginning of plant polish.

104.3 - A large irregular blade with shallow backing retouch (Fig.25:e) had a cutting edge which on closer inspection revealed a weak gloss. The wear-traces on this edge were consistent with wood sawing. Antler as a sawn material was considered unlikely (see Part II, Chapter 11).

200.0 - A crescentic-backed blade (Fig.25:f) with a series of small notches confined to the middle sharp edge had been apparently used with a transverse movement, probably to whittle wood. Perhaps the notches had been made to sharpen a very fine point.

Baulk 201-210 - A crescentic backed blade (Fig.22:b) shaped like a sickle blade revealed rounded edge damage and a quantity of fine striations parallel to the cutting edge, on a weak polish. Perhaps pottery or else a fibrous material had been cut (Pl.14:f).

201.2 - A large blade (Fig.20:b) snapped at one end, with the distal part shaped like a tang, and the proximal part backed like a crescent, had a finely denticulated cutting edge. The rounded edge damage and the polish were consistent with wood cutting/sawing (Pl.13:f). The presence of the tang suggested that the blade had been used hafted, although polish and retouch of the cutting edge was found down to the very end.

202.2 - A very small unretouched bladelet snapped at the distal end (Fig.25:h) had striated weak wear-traces (rather like MLIT, see Part I, Chapter 14) along its long axis, and also general polish on its dorsal ridges. It may have been used as a projectile or possibly the traces might be post-depositional.

202.2 - A very small backed bladelet (Fig.25:g) was completely covered with polish. The shape suggested that it may have been used as a barb.

211.2 - A large flake (Fig.26:a) with a tang and an inversely retouched cutting edge had apparently been used as a wood saw.

Trench VI

Baulk 600-700.3 - A naturally curved (in plan) truncated blade (Fig.26:b) with a serrated edge on the distal part had been used as a saw on medium-hard material, judging by the orientation of the striations and from the polish. However, the flint was too coarse to be more precise.

Baulk 600-700.3 - A denticulated blade (of very coarse flint) with a thinned back (Fig.26:c), truncated or snapped at both ends, had no polish on the denticulated edge, but the stepped edge damage and the polish on the acutely angled edge could be consistent with bone sawing.

Baulk 600-700.3 - A long, naturally backed blade (Fig.21:b) showed rounded edge damage, and a thin band of polish with striations parallel to the cutting edge. It may have been used on a soft material, such as meat (Pl.14:b), although short use on wood could not be ruled out.

Baulk 700-800.3 - A"backed truncated blade-segment with 'hook'" (Copeland, in prep., Fig.18:15, here Fig.26:d) had small patches of polish on the 'hook', similar to that from seasoned wood, with striations parallel to the tool's long axis. The lack of edge damage on the hook together with the polish suggested that wood had been incised.

700.1 - A backed truncated element (Fig.20:c) with semi-abrupt retouch on the cutting edge did not have much polish, presumably because of resharpening. It had probably been used as a wood saw (Pl.13:h).

700.1 - A small truncated element (Fig.22:c) shaped like a sickle-element had a notch on the cortex side which had wear-traces, perhaps from use. It had a wide band of weak polish on the opposite edge, part of which had broken away. This polish may have been due to the cutting of a soft material, perhaps hide or meat (Pl.14:h).

701.3A - The tip of a backed knife (Fig.20:d) had probably broken accidentally, as its shape was very similar to a complete knife found in 801.3 (see below). From the rounded edge damage, the domed polish on both aspects, the slight macroscopic gloss and the direction of the striations it appeared that the knife had been used to whittle wood (Pl.13:g).

701.3B - A backed (Fig.23:d) flake with a heavily retouched cutting edge had been used to cut a hard material, perhaps bone (Pl.15:d).

702.3B - A crescentic backed bladelet (Fig.27:a) with a regularly notched-looking retouch had, judging from its polish and deep striations, been used to saw a hard material.

703.3B - A"blade fragment with nibbled retouch"(Copeland, in prep., Fig.21:7, here Fig.19:b) had a weak gloss along its straight edge, and had apparently been used to saw wood (Pl.13:b).

801.3 - A long backed knife (Fig.27:b) with a snapped distal end had an acutely angled lateral edge with rounded edge damage, slight gloss and polish on both aspects, though more invasive on the ventral aspect. Striations and polish suggested that this had been a wood-whittling knife like the similarly shaped tool from 701.3A (see above).

801.3 - A small truncated blade (Fig.27:c) with a denticulated edge had a weak domed polish which could suggest wood sawing.

803.3 - A"backed knife"(Copeland, in prep., Fig.20:8, here Fig.21:d) had very little edge damage and only general polish along the cutting edge, and had perhaps been used to slice meat or hide (Pl.14:d).

Trench VII

1001.3 - A crescentic"backed knife"(Copeland, in prep., Fig.23:6, here Fig.27:d) had little edge damage, some domed polish on the ventral aspect, some flat polish with fine striations on the dorsal aspect, and may have been used to saw a medium-hard material.

1002.3 - A backed truncated bladelet (Fig.27:e) had fine striations on a very thin band of polish and may have been used to cut a fibrous material, such as hair or wool.

1007.2 - A blade (Fig.27:f) with an unretouched fresh-looking edge and a finely denticulated edge showed a few edge damage scars and a domed polish on the denticulated edge. It was probably a wood saw.

1007.3 - A crescentic backed blade (Fig.27:g) with a retouched cutting edge had deep striations and isolated flat polish, and had probably been used on a hard material, perhaps stone.

1007.3 - The tip of a bladelet (Fig.27:h) had been burnt.

Mound C (Sounding) - A naturally backed (Fig.23:b) flake had considerable edge damage and a quantity of deep striations, indicating that shell or stone had been sawn (Pl.15:b).

5. Conclusions

The identification of worked materials from wear-traces on blades and flakes had, as expected (Part I, Chapter 20, and above) proved tentative or impossible. Most of the blades on which it did seem possible to identify wear-traces showed evidence of wood sawing or whittling. The fact that only wood working (and plant working, see Part II, Chapter 17) could be identified, may be due to the fact that traces from softer materials are too weak to be recognised, while edges (with the wear-traces) tend to break away when hard materials are cut.

There was evidence that soft materials (perhaps hide, meat, horn or feather) and fibrous material (perhaps wool) had been cut with truncated elements shaped like sickle-elements. There was also evidence for cutting harder materials (perhaps pottery, stone, bone or shell), but it was impossible to identify the exact worked material.

The hafting of tools like wood-saws and blades used on soft materials could only be deduced indirectly from the shapes of the blades. It appeared that most hafted elements had been inserted either into a straight or a curved handle, judging from the shape of the backing. A few "tanged"tools may have been hafted at the end.

A lot of the materials sawn or whittled at Arjoune had probably been perishable materials, such as meat or wood. However there was evidence, in the form of pebble figurines, incised limestone plaques, shell amulets, bone objects and pottery disks, that these materials could have been sawn or incised with blades or flakes.

The evidence for the use of bladelets as barbs or arrowheads was mainly based on the shape of the bladelets and cannot be seen as certain.

B - Snapped Blades

(Pl.16:e-h, Fig.24:e-g, Fig.27:i)

1. Previous Research

Bergman et al. (1983) reported certain features indicating that blades had been deliberately snapped, presumably in order to increase the number of right-angled working edges and also to create particularly strong edges. The microwear examination (ibid.) suggested that the breaks on blades from Hengistbury Head had been used to work bone. Beyries and Inizan (1982) reported that truncated blades from the Capsian had been used to scrape wood and bone.

2. Experiments and Results

Experiments showed that the mere act of breaking a blade could leave a microscopic polish along the break which could be confused with a scraping polish on account of the very fine striations running perpendicularly to the edge.

The breaks were best used to scrape and polishes looked exactly like those on scrapers (Part II, Chapter 10).

3. Snapped Blades from Arjoune

Only 3 snapped blades were examined.

Trench V

102.4 - A snapped blade (Fig.24:g) had a lateral unretouched edge which showed clear striations perpendicular to the edge, suggesting that a hard material had been cut. The snapped end had a bright line of general polish along the edge, with random striations (Pl.16:f). Such traces did not suggest that the snapped end had been used.

103.3 - The break on an unretouched blade (Fig.27:i) showed polish and striations, the direction of which suggested that the snapped end may have been used to scrape. The denticulated lateral edge had some general polish suggesting that it had been used.

Trench VI

900.1 - The ventral edge of a break (on a blade (Fig.24:e) with an irregularly retouched lateral edge) showed the only traces possibly due to use on this implement. Rounded polish and striations running perpendicular to the edge suggested that the break had been used to scrape wood (Pl.16:h). The tip at the break may have been used.

4. Conclusion

The end of two snapped blades (out of three examined) may have been used as scrapers, in one instance possibly of wood.

Chapter 13 - Notches and Denticulates

(Pl.17-18, Fig.28-32)

Introduction

A notch is a flake or blade with a"notch"made by one or several blows from the dorsal or ventral aspect. A denticulate consists of several such notches on the same edge. Relatively fine denticulation can occur simply as retouch to resharpen or strengthen a cutting edge and is discussed in Part II, Chapters 12 and 17. The division between denticulates and denticulated retouch is arbitrary and purely based on size of the notching.

Notches, unless present to facilitate hafting (Cauvin, 1968, p.170) or handling (Semenov, 1964, p.108), were generally thought to have been"concave scrapers"(Cauvin, op.cit.) used to shave or whittle relatively hard materials of small diameter, particularly wood. Semenov (1964, p.113) suggested that"concave blades" might have been used to make shafts, axe- and adze-handles, poles, stakes etc.

High-power microwear studies showed the following uses: Cahen and Gysels (1983) reported that notches had been used to cut wood. Bueller (1983), without presenting any evidence or taking post-depositional wear-traces into account, reported that notches from El Wad had been used to cut tendons from bone.

Very little has been written about the functional analysis of denticulates. Denticulates may of course be simply notches which had been used consecutively. On the other hand a denticulate may be a tool on which all the notches were used at the same time: Moss (1983, p.72) reported that a denticulate worked better than an end-scraper in her experiment dehairing hide. Cahen and Gysels (1983, Fig.4:1-2) illustrated denticulates which had apparently been used to scrape or plane wood and Bueller (1983) reported similar uses.

The fact that notches and denticulates can be produced accidentally is discussed in Part I, Chapter 4. Notches (13 - A) and Denticulates (13 - B) are discussed separately as they may have been used in different ways.

A - Notches

(Pl.17, Fig.28, 29:a-b, 31:a-d)

1. Experiments

Nine experimental notches (single- and multiple-blow) were retouched with a small hammerstone. The notches were used to shave seasoned and fresh wood, dry and fresh wood, soaked antler and limestone, and to cut dried sinew. In addition several accidental notches were produced by dropping flakes into a hard floor, and a notch used by Miller to plane wood was examined.

Notches were most efficient (more so than scrapers) when materials such as wood, bone or stone had a diameter somewhat smaller than that of the notch. Nevertheless, the edge of a notch used to shave a fresh birch twig was exhausted after 1000 sm, and those used on bone and stone earlier than that. I found it much more difficult to cut sinew with a notch than with a flake.

2. Results

Wear-traces from the quarzite-hammer retouch were absent on one notch and present on another where they consisted of the typical"stone smears"on the edge, in direction of the blow. Similar traces were observed in some instances on accidental notches.

Shaving wood caused rounded and little edge damage, a faint, continuous line of polish on the very edge of the notch, and a quantity of fine, deep striations (Pl.17:c). Shaving bone caused some edge damage and general"bone"polish (Pl.17:e) (see Part I, Chapter 14).

Shaving antler caused weak antler polish (see Part I, Chapter 14) with fine striations.

Shaving limestone caused general polish with fine striations in the direction of use and an abraded edge (Pl.17:g).

Cutting sinew left very little edge damage, some isolated polish and superficial striations.

I found the wear-traces on notches difficult to identify. However, the nature of these tools would suggest that their use was limited to wood, bone, antler or stone.

3. Notches from Arjoune

See Tables 7-10 for numbers and percentages of notches at Arjoune. All notches were made from the ventral aspect, unless otherwise stated.

Trenches I-IV

Trench I, 103.10 - A"notched blade"(Copeland, 1981, Fig.11:4, here Fig.28:a) with a small single-blow notch may have been used as a notch. The only wear-traces on the implement, in the form of thin striations perpendicular to the notch, looked like those from stone (Pl.17:a). They may have been due to use or else due to accidental or deliberate retouch.

Trench V

202.3 - A flake with a multiple-blow notch (Fig.28:b) which gave rise to a projection had apparently not been used as a notch, but the projection seems to have been used as a perforator, perhaps on antler and hide (Pl.17:b).

??5.2 - A flake with a multiple notch (Fig.28:c) had been used on wood, judging by the fine striations on the very edge (Pl.17:d).

Trench VI

Baulk 600-700.3 - A flake with a single-blow notch on the lateral edge, which had been made from the dorsal aspect, had a concavely truncated distal end, and thus two projections on either side of the distal end (Fig.31:a). One of these projections, opposite the notched side, was slightly hooked. The small lateral notch and the tip next to it did not have any wear-traces, while the truncated end (especially near the hooked point) had continuous polish, looking like wood polish. It therefore seemed that the truncated end had been used, perhaps to scrape wood, as the notch was too steeply angled for shaving.

701.3B - A backed blade, truncated at one end and snapped at the other, had been burnt. The small single-blow notch (Fig.31:b) looked unused. The tool had probably been used as a cutting blade, and the notch was accidental.

702.3B - A broken blade with a single-blow notch made from the dorsal aspect (Fig.31:c) had a"stone smear"on the ventral aspect of the notch which may mean that the notch had been produced accidentally.

801.3 - A long blade, truncated at the distal end with semi-abrupt retouch and with a multiple irregular notch at the distal end (Fig.28:e) showed little edge damage at the notch, and a polish (Pl.17:f) which looked like bone polish. I could not tell whether the lateral retouched edges had been used.

Trench VII

1000.1 - A blade with a multiple-blow notch (Fig.31:d) had been used as a notch, judging by the rounding of the edge of the notch. However the flint was slightly patinated and it was impossible to identify the worked material.

1011.2 - A flake with a single notch (Fig.29:b) had a concave truncated distal end thus forming a point. It seemed that the notch and the tip (with little edge damage and continuous polish) had been used on wood, as had perhaps the concave truncation, although the polish (Pl.17:h) there may have been from retouch. Altogether it is likely that this tool had been used as a borer, with the wood touching the notch and the truncation.

4. Conclusions

Only a few notches had wear-traces which could be identified with some degree of certainty. Notches appeared to have been used to scrape (or shave) wood, bone and possibly perforate wood.

It seemed that single-blow notches, especially when small and hit from the dorsal aspect, were accidental.

Some notches appeared to have been made to provide a tip to perforate materials.

B - Denticulates

(Pl.18, Fig.29:c-e, 30, 31:e-g, 32)

1. Experiments

Four denticulates were retouched with a hammerstone and used to scrape fresh and dry wood, dehair hide and comb sheep's wool.

I found that denticulates were not efficient when used to scrape wood. Moss (1983, p.72) reported that denticulates worked best when she dehaired a hide. However, in an experiment which she and I carried out together we found that on a fine roe deer hide (soaked for several days in water) denticulates only scraped away thin lines of hair and were in constant danger of tearing the hide. Wool was combed easily.

2. Results

The wear-traces from accidental denticulates and retouch were the same as those on notches and are discussed above.

The wear-traces from scraping a large plank of oak wood affected mostly the projections and the edges of the notches with a weak continuous line of polish on the very edge (Pl.18:a), with broad striations running in the direction of use.

Few wear-traces could be seen on the denticulate used to dehair hide for 7 minutes on a stone-surface. Only one flake had broken off each projection of the tool. The polish (Pl.18:e) looked similar to stone polish and was confined to the tips of the projections.

The wear traces from combing wool consisted of very fine striations.

3. Denticulates from Arjoune

See Tables 7-10 for numbers and percentages of denticulates.

Trench V

101.1 - A retouched flake with two notches on one side and a pointed end (Fig.30:d) had clear stone polish on the projections only. The points may have been used to incise stone (Pl.18:h).

101.1 - A flake with two notches (largely cortex) (Fig.31:e) had little edge damage, continuous polish on the upper notch, and may have been used as a notch rather than a denticulate. It seemed to have been used to scrape or plane wood. The lower notch also had weak traces, possibly due to the same use.

103.3 - A flake with two notches on one side and one notch on the other (Fig.29:c) had little edge damage, but a continuous line of polish (like experimental wood polish) around the two notches on one side. The tip had similarly little edge damage and similar polish, and looked as if it had been used to incise wood (Pl.18:b). The implement could easily be held in such a way as to make incising easy.

213.3 - A burnt blade-fragment with three small notches on one lateral edge (Fig.29:e) had very fine striations perpendicular to the notches and the projections. There was hardly any edge damage. The wear-traces indicated that this implement may have been used to comb a fibrous material (Pl.18:c, cf. Pl.14:e). On the other hand the notches as well as the wear-traces may have been due to natural agencies, as the implement was burnt.

Trench VI

500.1 - A denticulated flake (Fig.30:a) had been used to scrape wood or hide, judging from the continuous polish and the relative lack of edge damage. The polish (Pl.18:d) was found on the notches and on the projections. The flint was too coarse to permit a more precise reconstruction of this tool's use.

700.1 - A denticulated flake (Fig.31:f) had been used to scrape wood or hide. It showed the same wear-traces as the tool discussed immediately above.

800.1 - A denticulated flake (Fig.31:g) with a point seemed to have been used to scrape and bore wood.

804.3 - A denticulated flake (Fig.32:a) with a point seemed to have been used to scrape hide. The point was crystalline, and I could not tell whether it had been used.

900.1 - A cortex blade (Fig.32:b) with two notches on one side was patinated. The larger notch seemed to have been used but it was impossible to say on what material.

Trench VII

Sounding 4 - A naturally backed flake (Fig.32:c) with one multiple and several small single-blow notches had been used, judging from the rounded polish on the projections. However, it was not clear whether the denticulated edge had been used with a transversal or longitudinal movement, as the striations ran in both directions.

1001.3 - A denticulated cortex-flake (Fig.32:d) had stone polish, but also rounded continuous polish on its edge, and had probably been used as a scraper, perhaps on wood or hide.

1002.3 - A"denticulate on a cortex-flake"(Copeland, in prep., Fig.23:7, here Fig.30:e) had stone polish all over the edge. It may have been a stone scraper, but the possibility that it had been a core could not be ruled out (Pl.18:g).

4. Conclusions

It seems that denticulates had been used as multi-purpose tools in a variety of ways: as notches to shave or scrape wood; as scrapers perhaps on wood, hide and stone; as"combs"of fibrous materials; as perforators, perhaps of wood; as gravers, perhaps of wood and stone.

In one instance a"denticulate"may have been a core.

Chapter 14 - Burins

(Pl.19, Fig.33-34)

A burin (see Newcomer, 1972, for a typology of burins), sometimes also referred to as"graver"(Crowfoot Payne, 1983), is a flake or blade from which a burin-spall has been removed by burin-blow technique (see Newcomer, 1972, p.26). In this way six working edges can be created (Moss, 1983, p.47). As only one blow is required for the creation of a burin, it can be easily created accidentally (Moss, ibid. ; Barton and Bergman, 1982). In two cases implements with edges looking like burin-edges were in fact blades with two snapped intersecting edges. I called these implements"pseudo-burins".

1. Previous Research

Newcomer (1972, Appendix 3) discussed the following uses (some more, some less likely, but all possible) of burins: to groove hard organic materials, as scrapers, as boring or drilling tools (cf. Semenov, 1964, pp.66 and 98-99), as stone-engraving tools, truncations on burins as scraping edges, burins as cores and the burin-blow technique as a way of tipping arrowheads. Newcomer (1981) also made a stone bowl, using (amongst other tools) a burin. In some cases it appeared that the burin-spall, the"by-product" of the burin-blow technique, was in fact the tool: this was the case at Tepe Hissar (Tosi and Piperno, 1973) where burin spalls had been used as drills.

Low power studies of burins include that by Seitzer (1978); from her attribute analysis she found no statistically significant relation between function (as indicated by edge wear) and various burin types. Seitzer (ibid.) quoted Bordes who had stated that after 15 minutes cutting reindeer antler with a burin, he noted little microwear, and, what was worse (for microwear analysts), that he would have resharpened the burin normally beforehand. However, no magnifications were given in this context.

High-power microwear studies of burins suggested that they had been used to work reeds or wood (Moss, 1983a), or to groove or bore hard organic materials (Keeley, in: Audouze et al. , 1981, p.139). Moss (1983, pp.116-117) reported that burins from Pincevent had been used for bone or antler work, involving the burin edges and facets, and also for hide scraping, piercing and cutting, although not necessarily involving the burin edges. In addition, she mentioned wear-traces, from butchering, woodworking and other activities, on burins from the same site. Other high-power analyses of burins included those by Cahen and Gysels (1983) and Bueller (1983).

2. Experiments

Twenty-one burins had been retouched with hard hammers and antler hammers, and the burin-edges (see Fig.8:b) were used to groove fresh and seasoned wood, fresh and dry bone, soaked fallow deer and reindeer antler, soaked horn, pottery from Arjoune, limestone and shell. Two burin-facets (see Fig.8:b) were used to cut rough-outs from a shell 1.2. cm thick, and a burin-edge was used to perforate bone. In addition I scraped bone with a burin-edge, and examined a burin used by Newcomer to scrape wood and a burin used by Grace to scrape reindeer antler.

The burins were usually used to groove with a pulling movement of the upper edge. (The lower edge could not be used as the upper edge invariably got in the way .) Pushing was only possible when the worked material was fairly soft. Most materials could be grooved easily, although antler had to be soaked for several days. Burin-edges used on fresh or soaked wood were blunt after one hour, while those used on dry bone were blunt after 10 minutes. Very hard materials such as limestone and horn (because of its inner casing) caused the edge to slip rather than to cut deeply. Fine and/or deep grooves in bone, shell or stone had to be made with piercers (Part II, Chapter 11), flakes (Part II, Chapter 12) or narrow-angled scrapers (Part II, Chapter 10).

Burin-facets used to cut shell worked very well and were blunt after 10 minutes.

In contrast to others (Newcomer, pers.comm.) I found boring with burin edges almost impossible.

3. Results

Grooving wood left little edge damage and the typical wood polish (Pl.19:g), in some cases with faint macroscopic gloss. Grooving fresh and dried bone left diffuse bone polish, often with the characteristic striated"bevel"(see Part I, Chapter 14, Pl.19:a). Fresh bone caused little edge damage, dried bone severe edge damage. Grooving soaked reindeer antler left only isolated domed polish areas, as the flint used had been coarse-grained. Grooving fallow-deer antler caused a diffuse continuous polish with some edge damage and regularly spaced striations, which I found to be typical of fallow-deer antler (cf. Pl.11:c). When used for a considerable time, reindeer antler polish did look like the"snowbank"Keeley (1980) described. In this case antler polish looked similar to wood polish. Less developed antler polish however, could look like bone polish, although the edge looked less jagged. Grooving horn left weak flattened polish, while grooving pottery left diffuse polish with inclusions (from the pottery) and shallow striations. Grooving limestone left an abraded tip and typical limestone polish (see Part I, Chapter 14, Pl.19:c), while incising and cutting shell left typical shell polish (ibid., Pl.19:e).

Scraping bone, wood and soaked antler with the burin-facet left wear-traces like those on scrapers (see Part II, Chapter 10), with less edge damage, presumably because the edge angles were steeper.

Boring bone left a general striated polish.

On the whole I found that the area used could be identified, but that the worked materials presented problems: antler polish could look similar to bone or wood, depending probably on the duration of work; shell and stone left traces which looked similar depending on the angle of the flint to the microscope lens. The polish from grooving horn and from perforating bone looked too weak to be distinguished on ancient tools.

4. Burins from Arjoune

See Tables 7-10 for numbers and percentages of burins.

Trench I

Surface - A"single-blow burin"(Copeland, 1981, Fig.11:11, here Fig.34:a) had severe edge damage, together with a buoyant polish and striations at its burin-edge. Weak polish was also found on the burin-facet, and on both aspects bordering the burin-facet. It seemed that the tool had been used to incise sideways. The material could not be determined.

Trench V

212.3 - A burin (Fig.33:h) had apparently been used to cut or split plants with the edge on which the burin-facet had been made. This edge had macroscopic gloss, and plant polish (Pl.19:h) looking like that from dried reeds (Pl.23:f). The burin-facet had a weak line of polish along the ventral aspect, indicating that it had been used for the same purpose.

Trench VI

700.1 - A"composite burin with scraper"(Copeland, in prep., Fig.21:4, here Fig.33:b) made on a patinated blank, had a polish"bevel" with striations on its burin-edge. This suggested that bone may have been grooved (Pl.19:b). The scraping edge looked used, but as the tool was patinated it was impossible to identify the worked material. Heavy edge damage suggested bone scraping.

701.3A - A pseudo-burin on a broken blank (Fig.33:f) was generally covered with stone and sand polish, but had at its dorsal and ventral burin-edges bright patches of polish with deep striations, rather like experimental shell polish

(Pl.19:f). This suggested that this tool may have been used to incise or cut shell.

703.3B - A pseudo-burin (Fig.34:b) on a broken blade had a broad burin-edge, with lots of edge damage, buoyant polish and striations which suggested that it had been used (sideways) to incise rather than groove a hard material. The polished area was too small to be more precise. Some weak polish was seen on the retouched lateral edge opposite the burin facet. However, it remained unclear whether this edge had been used or not.

703.3B - A narrow burin-edge (Fig.33:c) had very little buoyant polish with thin deep striations. The edge was abraded rather then chipped which suggested that limestone may have been incised (Pl.19:d). The edge opposite the burin-facet had some irregular retouch, but was probably unused.

800.1 - A burin (fig.34:c) had a crushed burin-edge with very little polish. Striations indicated that it had been used to incise a hard material, judging by the polish and edge damage shell or bone.

Trench VII

Mound C (Sounding) - A"dihedral burin"(Copeland, in prep., Fig.24:10, here Fig.34:d) had some rounded polish and inclusions which suggested that the incised material may have been pottery.

1001.2 - A single-blow burin (Fig.34:e) on a broken, retouched bladelet had apparently not been used, judging by the absence of any definite wear-traces. It is possible that the burin-spall came off accidentally, or else that it had been detached for easier hafting.

5. Conclusions

Only very few burins with reasonably definite wear-traces could be found. Of these most had apparently been used to incise (and in one instance perhaps to cut) relatively hard materials, perhaps bone, shell or limestone. Such materials were found to be incised on the site. One burin seemed to have been used to split reeds.

The burin-break on a small bladelet may have been accidental, unless it served as a tang.

Two implements were broken blades which appeared to have been used as burins.

Chapter 15 - Arrowheads and Barbs

(Pl.20, Fig.35)

A few transverse arrowheads were excavated at Arjoune. Previous research (see below) suggested that variously shaped points and bladelets could have been used as arrowheads and barbs.

1. Previous Research

Clark _et_ _al_. (1974) investigated Late Predynastic and Dynastic Egyptian archery equipment. Arrows were hafted in fletched reed-shafts with hardwood foreshafts, and in dynastic times barbs were added. The stone arrowheads were transversely mounted lunates or naturally backed pieces, but other materials like bone, ivory or wood, were made into points, and some were probably coated with vegetable poison; even bones from a catfish spine were used as arrow tips. Arrowheads were probably hafted with beeswax and resin, (whereas arrowheads at Tell Hadidi in Syria had been hafted with gypsum (Miller, 1983). Clark _et_ _al_. (op.cit.) reported that some transversely mounted stone arrowheads and barbs were hafted loosely and obviously designed to disengage from the haft, in order to cause severe wounding. Normally such arrowheads were firmly mounted (ibid.). The earliest Egyptian bow - depicted on Predynastic rock drawings - was the self-bow. It was similar to those still found in parts of Africa today (ibid).

Experimental archery was carried out by Bergman and others with copies of points from Hengistbury Head (Barton and Bergman, 1982) and from Upper Paleolithic levels at Ksar Akil (Bergman and Newcomer, 1983). The fracture patterns on the points, flute-like, burin-like and transversal bending fractures (op. cit.) were also observed on many of the archaeological points the authors had studied, but sometimes no breakage occurred (Barton and Bergman, 1982).

The effectiveness of small transverse arrowheads, thought of by Woolley as bird-hunting arrows, was proved on large game (Miller _et_ _al_., 1982). These researchers suggested the use of vegetable poison, perhaps on wooden arrow tips (similar to the tips described by Clark _et_ _al_., 1974), since only a few arrowheads had been excavated from the site their paper referred to, namely the Halafian site of Shams ed Din, a site rich in wild fauna (Uerpmann, 1982).

Low-power microwear investigations included those by Ahlers (1971) who reported that Paleo-Indian projectiles had been used not only as such, but also as scrapers and whittling tools, and a short paper by Odell (1978).

High-power microwear analyses dealing with projectiles included two recent studies: Anderson-Gerfaud (1983) reported that wear-traces and residual hafting agents suggested that some lunates and triangles from the Mesolithic and Natufian levels at Mureybet and at Abu Hureyra had been shot as arrowheads and barbs into animal tissue. Moss (1983) reported that she could only find MLIT on 30% of her experimentally shot projectiles (ibid., p.95). She stated (wisely in my opinion) that the precise target could usually not be determined (ibid.), e.g. on Azilian points from Pont d'Ambon (p.147) and on tanged points from Abu Hureyra (1983a).

2. Experiments

Several projectiles with arrowheads (3 of them transverse) and barbs had been fired by Bergman and Barton at a red deer carcass which had been defrosted. The self-bow was a copy, but in yew, of the Mesolithic Holmegaard bow and drew 40 lbs at 26 inches (see also Barton and Bergman, 1982). The unfletched arrows (79.5 cm long) had been made of Port Orford Cedar wood, and the arrowheads (made of Brandon flint with a hammer stone and an antler pressure-flaker) had been fastened with wax and sinew, covered by resin, in a notch cut at the tip of the arrow. Several pairs of barbs were inserted at the sides of the arrow. The shooting distance was 4 meters. The transverse arrowheads were very efficient: one arrowhead went right through the chest cavity of the deer, completely intact. Only the resin had cracked. Another penetrated the carcass, got lodged in the spine and could not be retrieved. It is hoped that the arrowhead will be retrieved during future osteological analysis. The third transverse arrowhead shattered on impact on the right leg of the carcass.

In addition, several pointed arrowheads and barbs shot once into meat and bone, and others shot into dry sand, and one shot seven times into wet sand (all by Newcomer) will be examined.

3. Results

The most characteristic wear-traces on transverse arrowheads which had been fired were the edge damage; this consisted of heavy (macroscopic) chipping of the cutting edge. Bergman (pers. comm.) who had additionally shot 7 transverse flint and obsidian arrowheads with a self-bow drawing 40 lbs in weight, reported similar breakage, and also that spalls were removed along the retouched edge.

Microscopic traces were very random: MLIT could sometimes be seen in the direction of the shot, mostly on the arrowhead ridges (Pl.20:e,g). However, striations could also be seen in different directions, probably originating when the arrowhead was deflected inside the carcass or pulled out from the carcass. Edge damage on transverse arrowheads was rounded (Pl.20:a). A general polish with fine striations could be seen on tips of pointed arrowheads even when these had broken, but on ancient tools such polish might be confused with post-depositional polish.

Arrowheads shot into wet sand were covered with slightly buoyant looking polish flecks. The strength of this polish was probably related to the fact that the projectile had been shot seven times. Such polish, covering almost the entire active part of the tool, could be mistaken for soil sheen. An Azilian point, shot into dry sand, had jagged edge damage on part of the lateral edge, and very bright polish flecks characteristic of sand or metal.

Barbs (Part II, Chapter 12) were either shattered or survived intact. No particular traces could be identified on barbs, except some general polish covering most of the implement (Pl.20:c).

Hafting traces were not studied.

4. Arrowheads from Arjoune

For numbers and percentages see Tables 7-10.

Trench I

Surface - A"fragment of a pressure-flaked arrowhead"drawn by Copeland inside the outline of an Amuq Point from Janoudiye (1981, Fig.10:1, here Fig.35:g) had some striations in the direction of shooting on its dorsal ridge. However, as it was a surface find there was lots of random stone polish all over both aspects (Pl.20:h). Also, according to Copeland's reconstruction, I was examining the hafted end.

Trench VI

700.2 - A burnt"transverse arrowhead"(Copeland, in prep., Fig.18:1, here Fig.35:d) with both aspects of the distal edge slightly chipped (Pl.20:d) had polish and deep striations on its dorsal ridge. Unfortunately the entire tool was somewhat polished, probably due to the burning, but it may have been shot.

701.3B - A burnt"transverse arrowhead"(ibid., Fig.18:2, here Fig.35:b) had similar wear-traces (Pl.20:b,f) to the arrowhead discussed immediately above. There was rounded edge damage on the distal end and lots of general polish and striations, as well as some rounding and striations parallel to the axis of the implement at the distal end. It had probably been shot.

803.3 - an"atypical transverse arrowhead"(Copeland, ibid., Fig.18:4, here Fig.35:f) showed wear-traces similar to those on the above arrowheads.

No arrowheads had been recovered from Trench VII and those from Trench V were not available for study.

5. Conclusions

Little can be said about the few arrowheads discussed except that they could have been used efficiently to hunt large game. Two transverse arrowheads from Trench VI seem to have been used.

All the arrowheads appeared to have been found relatively closely together and two were burnt.

Chapter 16 - Axes, Adzes and Choppers

(Pl.21, Fig.36-38)

Axes are defined by their shape. The difference between axes and adzes is in the method of their use: axes are hafted with their working edges parallel to the haft, while adzes are hafted transversely to the haft. Choppers are usually pebbles or cobbles with bifacially retouched edges.

1. Previous Research

Semenov (1964) stated that he could differentiate between axes and adzes from the distribution of striations, which were stronger on the front face (away from the handle) in the case of an adze, while they were found in similar quantity on both faces in the case of an axe (p.125). He thought that axes were always connected with wood working, although use of axes on other materials like ivory or bone was not ruled out. Adzes were according to him also wood-working tools, and he stated that adzes used as hoes, i.e. to dig the ground, could not be reused as wood-working tools, although the reverse was possible (ibid.). Gould *et al*. (1971) cited instances of stone hand-axes used as digging tools by aborigines, but reported that such tools were almost always used to chop wood (p.156-157). Flakes used as adzes had edge angles between 40 and 89 degrees. A hafted adze was used in a sitting position and drawn towards the worker, to make a spear-thrower for instance. The adze was resharpened some 20 times and the tool sometimes reversed in the haft. It took the aborigines about eight hours and 30 minutes to make a spear-thrower with a stone-adze, compared to four to five hours with metal tools. Adzes were also used for other purposes (ibid.) , e.g. to engrave sacred boards.

Microwear studies on axes and adzes included that by Keeley (1983a) who found that wear-traces on stone tools from PPNA Jericho indicated that they had been used as wood-adzes (p.759 and pl.33). Coqueugniot (1983) examined wear-traces on flake-adzes from Mureybet under low-power magnifications. He found that the adzes had been used to chop and also to plane wood. According to him, some scrapers from the same context had been used in the same way.

Ground stone hatchets from PPNB Bouqras had, according to Roodenberg (1983), been used in various ways: as felling axes, wedges, chisels, and adzes. Hafting arrangements as axes and adzes were shown (ibid., Figs.3 and 4) after reconstructions by Mellaart and Cauvin.

2. Experiments

Four axes and choppers were used experimentally to chop wood and bone. In addition five hafted tranchet axes (one used by Bergman to chop wood, the other four used by Harding to chop hazel wood with up to 1500 blows) were examined. Unfortunately, no hoeing experiments were carried out.

3. Results

The wear-traces consisted of fairly isolated polish areas and striations running parallel to the direction of use, on both aspects of the working edges of the choppers and axes. Wood left little edge damage and domed wood polish with striations (Pl.21:c,e), while bone left a lot of edge damage and isolated flat polish (Pl.21:a).

4. Axes, Adzes and Choppers from Arjoune

For numbers and percentages see Tables 7-10.

Trenches I-IV

Surface - An"axe (with polish on upper part...made on a chert pebble"(Copeland, 1981, Fig.10:3, here Fig.36:b) had regular retouch on one aspect of its sharp edge. Microscopic examination revealed a domed polish, perhaps from wood, and invasive stone polish (Pl.21:b), probably from polishing and retouch, although of course post-depositional damage was possible. Wear-traces were found over both aspects. This tool's shape suggested that it had been hafted.

Trench V

222.2 - A large chopper (Fig.37:b) made on a flake seemed to have deliberate (regular) retouch on the dorsal aspect, and edge damage on the ventral aspect. Domed polish and striations on both aspects of the working edge suggested that it had been used as a wood chopper (Pl.21:d). The shape suggested that it had not been hafted.

Trench VI

Surface - A"chipped axe or adze with damaged bit"(Copeland, in prep., Fig.21:5, here Fig.38:a) showed domed polish and striations on both ends, suggesting that perhaps both ends had been used. The polish was in each case quite invasive. This fact, together with the nature of the polish (Pl.21:f), suggested that wood had been worked. Striations ran both perpendicular and parallel to the long axis of the tool, thus indicating two directions of impact. Wear-traces were found on both aspects, suggesting it was an axe rather than an adze.

Trench VII

Sounding I - A"small chopper or axe-roughout"(Copeland, in prep., Fig.24:9, here Fig.37:c) had some polish (Pl.21:g) on the projections of the cutting edge, which may have been wood or stone polish, but was probably wood considering the lack of crushing of the edge. Judging by the shape it may have been hafted.

Sounding 4 - A chopper (Fig.38:b) on a flake similar to the chopper from Trench V had rounded edge damage on both aspects and domed polish (Pl.21:h) with striations perpendicular to the cutting edge. This suggested that the tool had been used as a wood chopper.

5. Conclusion

Unfortunately only a few axes and choppers could be studied as most of such tools had been made of limestone, rather than of flint or chert. The tools examined appeared to have been used to chop wood. But the fact that no hoeing experiments were carried out and that most of the archaeological tools were surface finds made the conclusions uncertain.

Chapter 17 - Blades with Gloss from Arjoune and Other Sites in the Levant.

Introduction

A significant number of blades or bladelets with gloss or lustre along one or both edges were found on sites in Palestine and Syria from the Epi-Paleolithic ,dating from approximately 18,000 to 15,000 BC onwards (Bar-Yosef, 1970, p.9). These pieces became more numerous and larger in size in the course of the Neolithic, that is, approximately from about the beginning of the 8th millennium BC (see the Carbon 14 dates in Mellaart, 1975, pp.283-288). These blades are commonly referred to as"sickle blades" and have sometimes been regarded as evidence for cereal-gathering, if not plant cultivation among otherwise pre-agricultural peoples (Neuville, 1934, p.18).

Similarly the mention of"sickle blades"in the context of Neolithic and later sites has become almost synonymous with"agriculture", and where"sickle blades"have been absent, this has been seen as an enigma: were there no cereals to harvest? If there were cereals, how were they harvested?

These last two questions are indicative of two fallacies often encountered when dealing with"sickle blades"and harvesting. The first fallacy is that gloss (often called"sickle gloss", "silica gloss"or"corn gloss", see Part I, Chapter 10) equals gloss from grasses (Wilke et al. , p.205), especially from wild or domesticated cereals. The fact is that a considerable, varying amount of silica the hardness of which seems to cause the gloss (see Part I , Chapter 10) is present in all green plants. Not only grasses, such as cereals, but also other plants, such as reeds and rushes, have siliceous stems; these were common in the Levant and had their uses in daily life. They all produce gloss when rubbed against a flint surface for a length of time.

In fact, as demonstrated in Part I, Chapter 10, gloss on flint is caused by contact with plants and with other hard materials.

Conversely, there is the question whether similarly shaped blades without gloss are definitely not"sickle blades". Some archaeologists, e.g. Otte (1976) in his study of Neolithic tools from Apamea in Syria, counted blades without gloss as"sickle blades". However, in Part I, Chapter 16 it was shown that only on coarse-grained flint did gloss appear later than did microscopic polish. Such blades without gloss could of course have been unused.

The second fallacy rests on the assumption that cereals - wild or domesticated - are always harvested by cutting. In fact there are other methods still used today in some parts of the world, including harvesting by beating or by uprooting. Examples exist for all three methods:

- Harvest of cereals by cutting with non-metallic sickle blades: in Africa domesticated wheat and barley, amongst others, are still harvested with flint and bone sickle blades (Whitcombe, pers.comm.). Even wild cereals with their brittle rachis have been cut quite successfully (Harlan, 1967). Wild cereals were cut not long ago in Mongolia (Maurizio, 1927, p.136).

- Harvest by beating is often referred to (Maurizio, ibid.) though it is an inefficient method because of the grain lost (ibid.).

- Harvest by uprooting was practiced in Palestine (Dalman, 1928, Vol.I, Part 2, p.551) and more recently in Syria (Van Zeist and Bakker-Heeres, 1979, p.166). It is seen by Hillman (pers. comm.) as the easiest method, especially when wild cereals are harvested; reeds and rushes on the other hand have to be cut because of their horizontal rhizomes which are almost impossible to pull out.

Nevertheless several arguments favour the possibility that cereals were cut, even with stone sickle blades:

- The present day use of metal sickles and scythes points to non-metallic precursors.

- There are plenty of present day instances of the use of stone sickles on cereals.

- There are disadvantages to uprooting cereals: soil from the roots would get mixed into the grain or straw. Perhaps worse, erosion of the soil would be severe if the roots were pulled from the already upturned soil, especially in areas such as Arjoune where winds from the Mediterranean prevail forcefully all day and all year around.

It seems that all three methods of harvesting have their advantages and disadvantages, and any could have been practiced at a site in the Levant. The absence of sickle blades is therefore not proof of a non-agricultural economy, and, as outlined above, the presence of sickle blades is not necessarily proof of an agricultural economy.

I therefore wanted to study the blades with gloss and some blades without gloss classified as"sickle blades" (Copeland, 1981, p.11, and in prep.) in detail, in order to find out whether they had been used as parts of sickles to harvest cultivated cereals. The results of my experimental work (see Part I, Chapters 14 and 15) had shown that only contact with plants or wood led to an evenly distributed gloss on flint cutting-blades, and that most different plant species left different wear-traces on the blades (Table 2, Pl.22-25). Nevertheless, the interpretation of different wear-traces from different plant species and/or varieties proved quite problematic (see Part II, Chapter 17.4). I therefore decided to compare the wear-traces on the Arjoune blades with those on blades with gloss from other periods and environments, and to compare the results of the wear-trace analyses with the botanical evidence available for the relevant sites or at least the relevant areas. For this comparison I chose 25 Epi-Paleolithic lustered bladelets and blades from Kebara published by Turville-Petre (1932) and from El Wad published by Garrod and Bate (1937). Both these sites were discovered in the coastal lowland of Palestine a region which according to Vita-Finzi and Higgs (1970, p.16) was largely unsuited to the growing of cereals. I also chose 63 lustered blades from the PPNA, PPNB, Pottery Neolithic A (hereinafter referred to as PNA) and the EB levels in area F at Jericho which were published by Crowfoot Payne (1983).

2. Previous Research

Experimental investigation of blades with gloss.

"Sickle blades"with gloss have fascinated archaeologists from the beginning of research into functional analysis. Spurrell (1892) tried to reproduce gloss which he had noted on"early sickles"experimentally and found that it was only produced by cutting"ripe straw" (ibid., pp.57-58). Vayson (1919) in his study of sickles from Europe and Africa demonstrated that gloss was also produced by other materials, such as wood. Curwen (1930) demonstrated experimentally that wood and corn caused somewhat different patterns of gloss. He also raised the question whether one type of flint polishes as easily as another, and whether gloss always occurs when plants are cut (ibid., pp.184-186). In a paper published in response to Neuville's assertion that gloss was caused by hard usage, Curwen stated that it was safe to assume that diffuse gloss was caused by"corn or other siliceous grasses" (Curwen, 1935, p.65) and that"one may assume that it is generally agreed that the discovery of the remains of a sickle in an ancient deposit is evidence that its owner knew how to grow corn"(ibid., p.62). This interpretation of gloss seemed to have induced archaeologists to regard lustered"sickle blades"as evidence for cereal-gathering if not cereal-cultivation.

In recent years however, it has been demonstrated by several researchers that gloss is not only caused by corn or grass (as well as by other siliceous materials (Curwen, 1937, p.93)) and by rubbing hard material (see Part I, Chapter 10) but by all green plants which have so far been harvested experimentally, like reeds (Vaughan, 1981, pp.149-154), bamboo (Keeley, 1980, p.61), sedges, rushes, reedmaces and other plants (Anderson-Gerfaud, 1983, p.89), bulrushes (Unger- Hamilton, 1983), cane, horsetails, stipa, weeds (see Part I, Chapter 14). The exceptions were poppies which may not have been cut long enough for gloss to develop.

Studies have been carried out on the microscopic polishes which were produced by different plant species (Anderson- Gerfaud, 1983; Unger-Hamilton, 1983; Perles and Vaughan, 1983).

Studies have also been carried out on microscopic polishes on lustered flint implements other than"sickle blades", e.g. on burins and tanged points from Tell Abu Hureyra (Moss, 1983a).

Experimental efficiency studies

In 1943 Steensberg published his results of various experiments harvesting barley and oats with European Stone, Bronze and Iron Age sickles: most efficient was a Viking scythe, least efficient were a crescentic flint sickle with a serrated straight edge and a copy of the Stenild sickle, a flint flake mounted perpendicular to the handle. The latter sickle was efficient in cutting weeds and thistles rather than corn (Steensberg, 1943, pp.23-25). Steensberg noted that pronounced serration of flint cutting edges was unsuitable for cutting corn as the straws slipped between the coarse teeth (ibid., pp.25-26).

Korobkova (1981) studied and compared the evolution of harvesting tools from the earliest agricultural complexes in Central Asia, Kazakhstan, the Caucasus, the Ukraine and Moldavia. Copies of the tools were made and used to harvest various cereals, beans, reeds and grasses. Korobkova pointed to the differences (mainly in the number of striations) between wear-traces from cultivated cereals, wild cereals, grasses and reeds (ibid., pp.331-334). She also examined the relative efficiency of the different implements (ibid., p.343, Fig.8) and the approximate plot size cut with each type of sickle.

Helmer (1983) reconstituted various types of prehistoric sickles from Europe, Africa and the Near East on the basis of observations made by J. and M.-C. Cauvin; he classified these implements into straight and curved sickles, with parallel and oblique hafting arrangement and with single and multiple retouched and unretouched elements. Helmer used these sickles experimentally on cereals, though by his own admission for a short time only. He came to various conclusions: for example, on sickles with parallel hafted blades, it was the retouch and not the number of blades which made the sickle efficient for cutting ripe cereals, while on obliquely hafted sickles it was the number of blades which made the sickle efficient. He also stated that steeply angled sickles were better for reaping while straight sickles were better for cutting. He found the overall efficiency of variously shaped sickle mounts to be similar.

Typology

Amongst the innumerable typological studies of"sickle blades" I would like to mention the study of the lustered blades from the Byblos Neolithique Ancien, Neolithique Moyen and Neolithique Recent by J. Cauvin (1968, pp.70-73, pp.100-105, pp.128-133). Cauvin in his"Analyse Fonctionelle"(ibid.) attempted to calculate the number and length of sickles from the number of one-ended truncated elements (ibid., p.72). He tried to reconstruct the sickle mounts from the shapes of the sickle elements and from the angle of their truncations. He mentioned the fact that in his experiments coarsely denticulated blades had proved inefficient in cutting cereals, but rather effective for cutting reeds. The early habitations at Byblos were thought to have been covered with plant material (ibid., p.73) and in fact coarsely denticulated blades were found in great numbers in the Neolithique Ancien, but not in the later levels. Recently M.-C. Cauvin (1983) based her study of sickle blades from the Near East on typology and a few microwear analyses. She came to the conclusions that the earliest sickle had been used to cut plants other than cereals.

Hafting

Studies of hafts, hafting materials and hafting arrangements of blades include M.-C. Cauvin's study of sickle blades from Tell Aswad (Cauvin, 1973). From the location of the bitumen used as a hafting agent, as well as gloss and retouch, she deduced the hafting arrangement of the blades.

Korobkova mentioned that harvesting implements, the hafts and hafting arrangements of which she had studied, had in some instances been hafted with bitumen (Korobkova, 1981, p.328) or resinous vegetable matter (ibid., p.330).

Camps-Fabrer and Courtin in their paper"Essaie d'approche technologique des faucilles prehistoriques dans le bassin Mediterraneen" (1982) gave a comprehensive survey of excavated early sickles and sickle fragments and in addition made suggestions about hafting methods.

3. Plants

In this section I list the plants which were common in the Syro-Palestinian region and which in my opinion were most likely to have been useful to prehistoric peoples there. The list is based on botanical, archaeological and ethnographic evidence. For reasons of time and place I could not harvest all of these plants myself and have therefore concentrated only on those plants which according to available ethnographic evidence and common sense are harvested by cutting. This is problematic: flax, for instance, is universally uprooted but in the Gezer Calendar, dated to the 10th century BC, the Hebrew word `zd which is translated as"to cut" (Donner and Roellig, 1964, p.181) is used in connection with flax. (It is possible that not flax, but its variety, linseed is referred to (Hillman, pers.comm.).) An even greater problem is presented by the fact that there may have been many plant species which may have died out or may not be deemed important anymore. Some plants like papyrus are nowadays nearly extinct in the Near East, while others, for instance the opium poppy, could only be harvested by risking imprisonment or worse. I could only harvest plant varieties which are closely related to these plants. The plant species and varieties I have listed and harvested are therefore quite likely to be incomplete. This fact has been taken into account in the interpretation of the results (see below).

Wild Cereals

Wild barley (Hordeum spontaneum C. Koch) had a wide distribution (Helbaek, 1960, p.112). Nowadays it is still found in abundance in the Near East, both in primary and in disturbed habitats. It is relatively tolerant of drought and heat, but not of cold, and is not commonly found at altitudes of over 1500 meters above sea-level (Harlan and Zohary, 1966, p.1076).

Wild einkorn wheat (Triticum boeoticum Boiss. emend. Schiem.) is found nowadays mainly in the Zagros-Taurus arc, an area from which it is thought to have spread to the Levant. It is far more resistant to cold than barley and can grow at heights of 2000 meters above sea-level. It is found in both primary and disturbed habitats.

Wild emmer wheat (Triticum dicoccoides) is also found in various regions of the Near East. Two races exist, one in Iran, Iraq and the USSR, the other in the Jordan Valley. Wild emmer wheat is very exacting and only grows in a primary, i.e. undisturbed habitat, on slopes such as the limestone and basaltic slopes of the Eastern Galilee (Harlan and Zohary, 1966).

All three species have been exploited as food plants, as is indicated by carbonised grain samples from Epi-Paleolithic village sites. Wild einkorn was found at Tell Abu Hureyra (Hillman, 1975) and at Mureybet (Van Zeist, 1970) where present day stands of wild einkorn are separated from the site by a distance of 100 to 150 km. This distance was one of the facts which suggested to Moore (1982) that cereals, though morphologically still wild, had been cultivated at Epi-Paleolithic (or Mesolithic) Tell Abu Hureyra. However, Van Zeist and Woldring (1980, p.124) pointed out that the distribution of wild cereals might well have been different in the past. The Natufian sites in Palestine lie within the presentday distribution zone of wild barley, and most within the present distribution zone of wild emmer wheat. The equipment found on these sites, such as sickle blades and hafts, grinding stones and mortars suggested to Harlan (unpublished manuscript) an economy oriented towards harvest of wild cereals.

Harvesting of wild cereals is probably most efficiently carried out by beating because these wild varieties have a brittle rachis which enables the plants to disperse their seeds. However, researchers have convincingly argued that harvest by beating would not lead to the tough rachis of the domesticated variety of the species, and in fact select against it (Wilke _et al_. , 1972). It therefore follows that at some stage before the Neolithic cereals were cut with blades or else uprooted. Nowadays wild grain often harvested by beating, both by non-agricultural and by agricultural peoples who use sickles on their domesticated crops. However, there are exceptions, such as the Mongolian tribes who cut cereals (Maurizio, 1927, p.136). It is also likely that wild grain is cut when the stems are to be used for such purposes as making mats, bedding or perhaps as animal fodder, and under humid conditions which would be adverse to seed dispersal (Hillman, pers.comm.).

Domesticated Cereals

Domesticated barley (_Hordeum vulgare_ L.) includes several varieties. The earliest variety was the two-row hulled barley with a tough rachis which was very similar to the wild variety (Harlan and Zohary, 1966, p.1076). Further genetic change led to six-row hulled barley, four-row lax-eared barley and to the naked barley, the first two forms carrying more seeds, the latter easier to process.

Domesticated einkorn wheat (_Triticum monococcum_ L.) also resembles its wild progenitor very closely. The tough rachis is the most conspicuous difference between the wild and the domesticated varieties (Harlan and Zohary, 1966, p.1076).

Domesticated emmer wheat (_Triticum dicoccum_) too is very similar to its wild form. It is a glume wheat and arduous processing is required to free the edible part of the grain from the glume. Further genetic change into free-threshing wheat (_T.aestivum T.durum_) ensured that the glume would fall free upon threshing (Harlan, unpublished manuscript).

Domesticated spelt (_Triticum spelta_ L.) was not found in the Neolithic in the Near East. The earliest finds of spelt are from 2nd millennium BC sites in Europe. Helbaek (1960, p.105) referred to the possibility that spelt might have existed earlier since carbonised spelt seeds look very similar to those of emmer wheat.

Three of the four species (spelt being the exception) have been used as food plants in the Near East from the beginning of the 8th millennium onwards. Einkorn is likely to have been domesticated in the Northern Levant and Turkey and emmer further south in the Upper Jordan Valley (Harlan and Zohary, 1966), while barley could have been domesticated anywhere in the Near East. Helbaek argued that barley, which grows as a weed and which is far more ubiquitous than wheat, may have been domesticated accidentally together with wheat (Helbaek, 1960, p.112). Harlan and Zohary (1966) pointed out that the domestication of plants is not likely to have occurred where wild cereals grew, but in adjacent areas.

The archaeological record in the Levant shows the following: at Tell Aswad (Van Zeist and Bakker-Heeres, 1979) domesticated emmer wheat and einkorn wheat were found from the earliest phase IA dated to around 7800 BC. At Tell Abu Hureyra (Hillman, 1975) domesticated emmer and einkorn wheat, six-row hulled barley and naked barley were found in the Neolithic levels. At Jericho domesticated emmer and einkorn wheat and barley were found in the PPNA levels (Hopf, 1983, p. 609). At Tell Ramad domesticated emmer and einkorn wheat and barley were also found in the Neolithic levels (Van Zeist and Bottema, 1966).

Van Zeist and Bakker-Heeres (1979, p.168) concluded from their investigation of plant remains from Tell Aswad that agriculture was well established by the beginning of the 8th millennium BC in the Aswad area which did not seem to have been particularly suited to agriculture. They also concluded (ibid.) that possible exploitation of surface water for agricultural purposes could suggest that plant culivation may have begun as early as the 9th millennium.

According to Zohary (1969, p.60) the early farmers, for instance at Beidha (Helbaek, 1966) practiced both collection and cultivation. The fact that two varieties of barley, one with a brittle and the other with a tough rachis, had been found at Beidha did not necessarily mean in Zohary's opinion that domestication began at precisely that point in time. Harlan (unpublished manuscript) stated that some domesticated cereals might have been subsequently abandoned by early farmers.

Several ethnographic studies have been carried out in the Near East, by Dalman in Palestine at the beginning of this century, by Turkovski in the Judean Hills in 1943-1947, by Sweet at Tell Toqaan in Northern Syria in the 1950s and by Wulff in Iran in the 1960s. A variety of harvesting practices were reported and most of these were probably not very different to those in prehistoric times. In general cereals were harvested when ripe, but in some instances (when growing too high or when needed as animal fodder) Palestinian barley (and rarely wheat) was cut when still green (Dalman, Vol.II, pp.349-350). At Tell Toqaan green wheat was used to prepare a special dish (Sweet, 1960, p.78). The usual annual harvest took place in May-June while the summer crops in Iran were harvested in September (Wulff, 1966, p.271). In Iran, barley was uprooted, while wheat was mostly cut with sickles (Wulff, 1966, p.272). The same was true at Tell Toqaan in Syria (Sweet, op. cit., p.70), though barley was also sometimes cut there, when the"grain was thick"(ibid.). In the Judean Hills most crops were uprooted, although in the mountainous areas sickles were used to cut grain (Turkovski, 1969). Dalman reported that short barley was uprooted (1933, Vol.III, pp.34-35) while high barley and wheat were almost always cut (ibid., p.37).

In both Syria and Iran, cereals were cut as close to the ground as possible (Sweet, op. cit., p.71, Wulff, op. cit.). In Palestine however, long culms were were cut higher up (Dalman, op. cit., p.37), leaving 20 to 30 cm high stubble for the animals to graze. Dalman also pointed to the biblical evidence for the cutting of the cereal heads from the culms (op. cit, p.42).

The sickles varied according to both region and plant. Wulff reported two kinds of sickles, a large hooked grain-cutting sickle and a smaller, almost straight grass-cutting sickle, tooth-edged in some regions, straight-edged and hardened with hornmeal in other regions (op. cit., p.272). Turkovski (op. cit.) reported two types of cutting implements, a serrated curved knife, mainly used to cut branches such as vines, and a large curved sickle, mainly used to reap corn, but also used on other plants such as herbs and grasses. Dalman (1933, Vol. III, pl.1B) showed and described several harvesting implements, including a blunt curved sickle used to uproot cereals and weeds (ibid., p.19), a straighter sharp sickle (ibid., pp.20-21) used to cut cereals, although smaller versions were used to cut grasses in some areas. These sickles were sometimes tooth-edged, sometimes not, as in Iran this depended on the region; in some cases then the teeth are stylistic and not functional. In addition, Dalman reported two types of sickles, both curved, toothed and untoothed, which were commonly used to prune fruit trees and vines (ibid., p.23).

The practices following the harvest were fairly similar in all countries. The crops were tied into sheaves, dried and taken to the threshing floor, where they were threshed by beating, animal hooves or threshing sledges. Threshing sledges are of special interest to a study of flint tools as the undersides of the wooden boards were studded with flints (Crawford, 1935). However, the earliest references for such implements stem from biblical times (Wulff, 1966, p.275) and microscopic study of threshing flints from Cyprus revealed distinctive wear-traces so far not seen on the prehistoric implements I have studied. The grain was winnowed with forks. The chaff was used as temper in bricks and pise (Wulff, 1966, pp.108-109) and in oil-seed presses (ibid., p.297); the straw was used to make baskets, mats and as animal fodder (e.g. Turkovski, 1969). The grain was sieved to separate it from the husks (e.g. Sweet, 1960, p.72). The grain was then taken to the mill or quern. The earliest rotary millstones so far discovered come from the second millennium BC in Palestine (Wulff, op. cit., p.277). However, querns were found on much earlier sites, e.g. at Jericho from the Proto-Neolithic onwards (Dorrell, 1983, p.488).

Different cereals were used for different purposes, and in the Judean Hills (Turkovski, op. cit.) wheat was used to make bread while barley was only used for human consumption in case of food shortage.

Other Plants

Wild grasses proliferate in the Syro-Palestinian region and were in recent times cut with sickles (Dalman, 1932, Vol.II, p.349-350). They were probably used in prehistoric times as food for humans and animals and in the manufacture of household articles such as mats and baskets, such as depicted in Iraq and Egypt in the 5th millennium BC (Wulff, 1966, pp.219-222). Several species have been found on early sites in the Levant, including Bromus and Setaria (Van Zeist, 1970) at Mureybet and Bromus, Lolium and Phalaris at Tell Aswad (Van Zeist and Bakker-Heeres, 1979). The last-named researchers also pointed out that wild grasses (and several leguminous seeds) may have been collected intentionally at Tell Aswad (Van Zeist and Bakker-Heeres, 1979, p.166).

Weeds are all plants which compete with crops and include such plants as grasses or poppies. In order to allow growth of the crops, weeds have to be eliminated from the fields. This was often done by uprooting (Dalman, 1932, Vol.II, p.324) but also with the help of knives, hoes or spades (Dalman, ibid.; Wulff, 1966, p.271). Dalman (ibid., pp.328-329) listed ancient references to weed management including the cutting of thistles with sickles. Several genera, including Polygonum sp., Rumex sp. and Chenopodium sp. (which I cut experimentally), have been found at Tell Aswad (Van Zeist and Bakker-Heeres, 1979, p.162), Tell Abu Hureyra (Hillman, 1975) and Mureybet (Van Zeist, 1970). Boraginaceous seeds, such as Arnebia decumbens, Buglossoides tennuiflora and B.arvensis have been recovered from many early Near Eastern sites, such as Tell Abu Hureyra (Hillman, pers.comm.). It is not clear whether the seeds were carried there accidentally as weeds, or whether they had been deliberately gathered for the sake of the red dye which their roots yield. However, in the latter case they would have been uprooted (Hillman, pers.comm.).

Several species of Stipa including Stipa holosericea have a wide distribution including Mongolia (S.gigantia) and Palestine. Seeds of this tall tussocked steppe grass were abundant in the Mesolithic levels at Tell Abu Hureyra, but rare in the Neolithic levels. According to Hillman (1975), Stipa is very sensitive to overgrazing. Like the reed, Stipa could be used for a number of purposes, such as constructing shelters (Hillman, pers.comm.). The stems can be pulled from the basal node, cut or else uprooted. The presence of Stipa in the Judean uplands suggested to Sauer (1958, pp.187-189) that the serrated blades from Jericho may have cut plants used in crafts and building rather than as food plants.

Scirpus maritimus is found in coastal areas and on river banks. Seeds of this plant have been found at many sites, such as at Tell Abu Hureyra (Hillman, 1975, p.71). It is unlikely that the stems were used to make basketry or mats as stems have sharp siliceous edges, but the seeds which are edible can be rubbed out by hand (Hillman, pers.comm.).

Equisetum fluviatile , a species of horsetail, is found in shallow rivers. The high silica content of horsetails makes them ideal for polishing and scouring. I found it easier to cut E.fluviatile than to uproot it.

Reeds (Phragmites communis emend. Lam.) proliferate in all the marshy regions and riverbanks of the Near East and their distribution has probably not changed much since prehistoric times. Reeds are found near all the sites I am dealing with: Kebara and El Wad in the coastal lowland of Palestine, Jericho in the Jordan Valley and Arjoune in the Orontes Valley. Hillman identified stem fragments of reeds at Tell Abu Hureyra (Hillman, 1975, p.71). Vita-Finzi and Higgs (1970, pp.21-22) thought that it had probably been reeds rather than cereals which had been cut at Kebara and El Wad (see below, Section 8). Mat impressions have been reported from various sites, such as the Aceramic Neolithic at Jericho (Crowfoot, 1982). Reeds were still important recently in everyday life; they were made into mats, baskets (Wulff, 1966 ,pp.219-222)and trays for oilseeds in oil-presses (ibid., p.297). In recent years cane and bamboo were used for relatively heavy-duty thatching (Wulff, ibid., p.107) as well as roof mats, blinds and curtains (Wulff, ibid., pp.219-222) and also as beater combs in weaving (ibid., p.195). However, as bamboo is not indigenous in the Near East, it is likely that large reeds or stipa were used instead. Reeds could also have been used as arrowshafts (Clark et al. , 1974). Reeds (see Wulff, ibid., p.107) must be cut on account of their horizontal rhizomes. Curved knives were used in Iran to split and trim reeds and cane used for matweaving, basketry and comb making (Wulff, 1966, p.107 and 221).

Rushes v.bulrushes (Juncus spp.) v. (Cyperaceae) , including Schoenoplectus lacustris L. (Palla) and Scirpus cf. tabernaemontanii , are normally found on riverbanks but, because of their over-exploitation by man, are now rare in the Near East, rather like Cyperus papyrus , the papyrus plant. Scirpus cf. tabernaemontanii seeds were found at Tell Abu Hureyra (Hillman, 1975, p.71). Rushes were probably used in the past in the same way as recently, for thatching (Wulff, 1966, p.107), mats, brooms, baskets (ibid., pp.219-222) and oilseed trays (ibid., p.297) rather like the harder reed. Like reeds, bulrushes have horizontal rhizomes and must be cut.

Sparganium ramosum grows near presentday Arjoune on the banks of the Orontes River. Its soft broad leaves may have been used for basketry and other articles rather like reeds or rushes. It too has to be cut.

Certain species of Cyperus sp. are indigenous in Palestine and a high proportion of seeds found at Tell Aswad (Van-Zeist and Bakker-Heeres, 1979) were of this genus. Although mainly mentioned in Egyptian references, the variety of Cyperus papyrus was found by Dalman in Northern Palestine (Dalman, 1937, Vol.V, p.22). According to evidence from Egypt, the Bible and accounts by Pliny (see Dalman, ibid., p.31), papyrus (which grows to 3-4 meter height), was used in Egypt to make virtually everything from ships, sails, blankets, and ropes to garments. The fact that parchment was developed when Egypt cut off papyrus supplies to the Greeks indicates that papyrus was not a common plant in neighbouring countries (Ferguson, 1973, p.100).

A few varieties of cane (Saccarum sp.) are indigenous in the Near East. Two varieties are found growing at present day Arjoune and are still used to make roofing mats. In the past S.spontaneum had a wide distribution in the Near East (Taeckholm and Drar, 1941, Vol.I, p.489). In Egypt cane was used to make mats. Culms were found in 5th Dynasty tombs (ibid, p.490).

Legumes, such as vetch, wild and cultivated, (Vicia ervilia , the Bitter Vetch, Vicia sativa , the Common Vetch, Vicia faba , the Horse Bean), have been found in many early levels of Near Estern sites, for example, Vicia ervilia at Tell Mureybet (Van Zeist, 1970) and at Mesolithic Tell Abu Hureyra (Hillman, 1975) and Vicia faba at Neolithic Tell Abu Hureyra (ibid.). Vetch is still harvested by uprooting, for example at Tell Toqaan in Syria where it is used as animal fodder (Sweet, 1960, p.70).

Wild lentils (Lens orientalis) were found at Mesolithic sites, for example at Tell Abu Hureyra (Hillman, 1975, p.71), and cultivated lentils (Lens culinaris) and/or chickpeas (Cicer arietinum) at Neolithic sites (for example at Tell Abu Hureyra (ibid.), Tell Aswad (Van Zeist and Bakker-Heeres, 1979), Tell Mureybet (Van Zeist, 1970) and at Jericho (Hopf, 1983, p.609)). Pulses apparently became a staple in Syro-palestine. As far as I am aware pulses are always harvested by uprooting (Dalman, 1937, Vol.III, p.34; Turkovski, 1969).

Varieties of both wild flax (several species, including Linum bienne) and domesticated flax (Linum usitatissimum) grew in Palestine when Dalman carried out his survey at the beginning of this century. The domesticated form was found on many Neolithic sites in the Near East. From its likely ocurrence at Ramad, Van Zeist and Bakker- Heeres (1975, p.218) concluded that cultivation of flax must have started in the second half of the 7th millennium BC if not earlier. Domesticated flax grows to a height of 1 meter. It needs humidity or irrigated land (Dalman, 1937, Vol.V, p.19). The stems contain fibers used for weaving (ibid.) and used as wicks for oil-lamps (ibid., p.28), while the seeds yield linseed oil (ibid., p.19). Dalman referred to G. Crowfoot's observation of flax harvest in Egypt: flax was uprooted, combed and left in water for fifteen days. It was then dried and left for two years and subsequently beaten with wooden mallets and combed again to extract the fibers (ibid., p.20). According to Egyptian pictorial references (ibid., p.29) and biblical references (ibid., p.26), flax was uprooted as it is nowadays (E. Crowfoot, pers.comm.). However, the Gezer Calendar used the word `zd, which is related to the Hebrew word for knife, in connection with flax (Donner and Roellig, 1964, p.181).

Sesame (Sesamum indicum) is cultivated for its seeds and the oil contained in the seeds."The oil, the seeds and even the leaves have been ascribed several medicinal and other desirable properties." (Simmonds, 1976, p.231). Archaeological evidence indicates that sesame was cultivated in Palestine and Syria as early as 3000 BC (ibid., p.232). However, no wild species of sesame have been found in the Near East according to Simmonds; he considered Africa as a possible region where sesame originated (ibid., p.232).

Other oil plants include hemp (Cannabis sativa) and the opium poppy (Papaver somniferam var. globrum), all of which are found in the Near East today. The seeds of the sesame are also used in baking, and the hemp and the opium poppy have much publicised narcotic qualities. However none of these plants have been found on Syro-palestinian sites until a date much later than the periods I am dealing with. Dalman (1937, Vol.V, p.30) thought that hemp was imported from the Hellenistic world, as he could not find any biblical references. Nevertheless, opium had been important in Egypt at an early date and was probably traded in the poppy-shaped"base ring"jugs in the Late Bronze Age (Merillees, 1962). My own experiments harvesting two poppy species (see below, Section 4) suggested that they were difficult to cut, but easily uprooted. The seedheads were easily snapped off by hand. My own feeling therefore is that poppies were not harvested with flint blades.

Vines and Fruit trees

The vine (Vitis) grew wild along Levantine river valleys. Remains of the wild and the cultivated vine were found from Neolithic times onward on Near Eastern sites, e.g. at Tell Abu Hureyra (Hillman, 1975). Grape pips recovered from the 5th millennium BC site at Arjoune may have come from the wild or the cultivated vine (Moffat, in prep.) The fruit of the vine may have been eaten as raisins (Helbaek, 1958), or drunk as juice, or may perhaps even have been fermented as wine. Special knives and sickles, both serrated and unserrated, were used in Palestine to trim vines (Dalman, 1937, Vol.III, p.23) and fruit trees, such as hawthorn (*Crataegus sp.*), pistacio (*Pistacio sp.*), plum or cherry (*Prunus sp.*), fig (*Ficus sp.*) and sweet almond (*Amygdalus dulcis*) listed by Moffat (in prep.) as occurring in the 5th millennium BC site at Arjoune.

4. Experiments

One Hundred and eighty-four sickle blades, unretouched or with fine or coarse denticulations, 11 straight sickles and 7 curved sickles with both unretouched or finely or coarsely denticulated blades were used to cut the following plant species,which in some instances were both fresh and dried:

Cereal species:

Wild barley (*Hordeum spontaneum* C. Koch)(not shown, see below), domesticated einkorn wheat (*Triticum monococcum* L.) (Pl.22:g,h), domesticated barley (*Hordeum disticum* L. emend. Lam.) (Pl.22:c,d), domesticated emmer wheat (*Triticum dicoccum* L.) (Pl.22:e,f), domesticated spelt (*Triticum spelta* L.) (not shown).

Non-cereal species:

Grass (several species including the Sweet Vernal Grass (*Anthoxanthum odoratum* L.)) (Pl.25:c,d), weeds (several species, including *Polygonum convulvulus* , *Chenopodium album* , *Rumex crispus* , *Seline alba* , *Potentella arvensis* , *Mentha arvensis* , *Sonchus arvensis*, all of which grow in temperate climates but some of which grow in the Near East (Pl.25:g,h)), a tussocked steppe grass (*Stipa gigantia*) (Pl.25:a,b), horsetail (*Equisetum fluviatile*) (Pl.25:e,f), reed (*Phragmites communis* Trin.) (Pl.23:2-h), bulrush (*Schoenoplectus lacustris* L. (Palla)) (Pl.23:a,b), *Sparganium ramosum* (Pl.24:e,f), *Cyperus longus* (Pl.24:a,b), cane (*Saccarum sp.*) (Pl.24:c,d), field poppy (*Papaver rhoeas*), oriental poppy (*Papaver orientale*) (Pl.24:g,h) and various species of wood including wood of the cherry tree (*Prunus sp.*) (Pl.26:g).

The experiments were carried out between May 1981 and June 1984 in England, Wales and Syria. In Syria non-cereal species were harvested on the banks of the Orontes River near Arjoune, while cereal species were harvested at the International Centre for Agricultural Research into Dry Areas (I.C.A.R.D.A.) in Aleppo. Wild barley was harvested by Miller-Rosen in Jersualem. In addition Hillman allowed me to examine a sickle he had used to cut einkorn, mostly wild (Pl.22:a,b), in Wales, while Harding allowed me to examine a sickle which he had used to harvest domesticated wheat and barley in England. Bar-Yosef and Kislev kindly sent me sickle blades which they had used to cut wild and domesticated barley. In addition I examined 4 threshing flints which had been used in Cyprus.

The Sickles

A variety of sickle hafts, mostly fragmented, have been recovered from Mesolithic and Neolithic sites in the Near East (see the comprehensive survey by Camps-Fabrer and Courtin, 1982). Sickle hafts were made of various materials, such as bone, wood, antler, clay and horn, and were either rectilinear or curved in shape. While sickle hafts have been recovered from Palestine, e.g. from Kebara and El Wad (ibid.), no remnants of such hafts have so far been found in Syria as far as I know. This indicates that sickle hafts in Syria may have been made of wood. Circumstantial evidence for sickle hafts comes from Byblos, where Cauvin (1968, pp.70-73, pp.100-105, pp.128-133) calculated the size, shape and length of composite sickles from the number and shapes of sickle elements, and postulated a change from rectilinear sickles in the Neolithique Ancien to both rectilinear and curved sickles in the Neolithique Recent. A similar case for the coexistence of two types of sickles is made for the sickles at Arjoune (see below, Section 7). I therefore used two types of sickles in my own experiments:

- A rectilinear sickle (Fig.7:a) 50 cm long (made of cherry wood after a sickle found in the Fayum in Egypt, see Camps-Fabrer and Courtin, 1982, fig.5) in which 8-10 blades were hafted parallel to the sickle edge.

- A curved sickle (Fig.7:b), 22 cm long (made of red deer antler by Newcomer after a sickle excavated at Hacilar, see M.-C. Cauvin, 1983, fig.5:8), in which 4-5 blades were hafted parallel to the sickle edge.

The hafting agent I had used in the first 4 experiments was Uhu, a commercial cellulose adhesive, but it proved to be not very strong and the blades fell out quickly. Another problem was the impossibility of removing the adhesive with acetone without leaving an"acetone bloom"which obscured the wear-traces on the flint surfaces. The hafting agent used in all the subsequent experiments was resin mixed with wax in a proportion of approximately 4:1. This mixture set quickly and was very strong: the blades were firmly hafted. The resin and wax could be removed easily by immersion in white spirit without altering the wear-traces on the flint.

The Work

All harvesting implements were used between approximately 5 minutes (200 strokes) and four hours (15,000 strokes), mostly with both unidirectional and bidirectional cutting movements.

The non-cereal species were cut all through the year and in some instances after storage. They were usually cut at the base of the stem. Fresh and seasoned wood was sawn. The cereal species were usually cut when ripe, although domesticated barley was in one instance cut green, three weeks before harvest was due. Sometimes cereals were cut away from the field and after storage. Cereals were harvested in June in the Near East and in August- September in England and Wales. They were usually cut at the base of the culm.

The non-cereal species were harvested singly or in bundles. No other plants were cut at the same time. The upturned soils in which cereals are sown are also the habitat of weeds. The proportion of weeds to cereal stalks ranged between less than 5 to 20% (see Table 6). I rarely cut any weeds together with the cereals, although I cut weeds separately in order to examine the wear-traces from these (see Part I, Chapter 14, Pl.25:g,h ,Table 2). When wild barley was harvested in Jerusalem, wild oats were cut as well (Miller-Rosen, pers.comm.); however, no wear-traces could be discerned on these blades (see Section 4). No weed counts were given for the experiments by staff at I.C.A.R.D.A. at Aleppo.

Efficiency

When non-cereal species were harvested, single unhafted blades could be used with ease, provided they were quite large and had backing retouch. The most efficient composite sickle for plants growing in dense stands, such as reeds and bulrushes, was the short curved sickle which was best used to reap rather than to cut or saw. Unretouched flint edges always cut best. However, on wooden branches or hard stemmed plants such as reeds, unretouched edges became damaged within seconds of use while denticulated flint edges did not. No plot sizes were calculated. Only thin branches of wood could be efficiently sawn with flint blades. Poppies were much easier uprooted than cut.

When cereal species were cut, single unhafted blades could be used, but composite sickles were far more efficient. As stands were not as dense as those of the marsh plants, the long rectilinear sickle could be easily used and proved more efficient than the short curved sickle.The former was best used for cutting, not for reaping. Again, unretouched flint edges were the sharpest, but wore out too quickly. Coarsely denticulated blades could not be used, as the culms got caught in the denticulations and were pulled out. For similar reasons blades had to touch end to end in the haft,at least in my experiments. Finely denticulated blades were the most efficient and lasted longest. This principle is still recognised today: modern combine harvesters have finely denticulated steel blades.

At I.C.A.R.D.A. two rectilinear wooden sickles, hafted with flint elements with finely denticulated cutting edges, were used by a sixteen year old girl, an experienced farm worker. She harvested two rows of domesticated barley and three rows of domesticated wheat, by holding bundles of culms from two rows of the same crop together. Each row was 70 cm long and the rows stood 25 cm apart.

Harvesting barley with the flint sickle took her 23 minutes, while harvesting the same sized plot with a modern metal sickle took her 12 minutes. Harvesting wheat with the flint sickle took her 14 minutes, while harvesting the same sized plot with a modern sickle took her 11 minutes. She declared that the flint sickle was "acceptable".

At Butser Hill it took me three hours to cut 105 square meters of domesticated einkorn, one hour and 30 minutes to cut 35 square meters of domesticated emmer and one hour to cut 45 square meters of domesticated spelt with rectilinear flint sickles (see Table 6 for stem counts). The work took longer than expected as it was raining heavily at the time.

All of the flint sickles could have been used longer than they were, although a few blades fell out and had to be reset.

Korobkova (1981, p.340) listed the efficiency of the models of prehistoric sickles her experienced team had used: the most efficient, a gently curved sickle of the Late Tripolye type with sawtooth flaking on the edge, had an average productivity of 1.1 square meter per minute. If we calculate that the worker at I.C.A.R.D.A. would have to harvest 8 rows of 70 meters instead of 2 rows of 70 meters (which stood 25 cm apart) in order to harvest 70 square meters, then it would have taken her approximately 92 minutes to harvest 70 square meters of barley and 56 minutes to harvest 70 square meters of wheat, a mean of just under 1 square meter per minute. I therefore conclude that the rectilinear wooden sickle in which several finely denticulated flint elements had been inserted parallel to the haft was quite efficient.

Hafting was very much a matter of experience: blades fell out if they were not hafted in a straight line with their ends touching. The proportions of resin to wax also proved important: when too much wax was added, the blades - especially when used in a warm climate - became covered with wax and no wear-traces could be seen. This happened with the experiment cutting wild barley in Jerusalem. It also led to a loosening of the blades and it is therefore unlikely that it is the cause of the absence of gloss on ancient blades otherwise shaped like sickle blades. When too little wax was added, especially in a cold climate, the resin became too brittle and broke away.

Results

The wear-traces resulting from working different plant species are shown on Table 2, Plates 22-25, and Fig.39, 40:a,c,e,f.

The edge damage (see Part I, Chapter 4) on the blades depended on the hardness of the plant stems and to some extent on other variables such as the moisture content of the plant and on the type of flint from which the blade was made. Soft-stemmed plants like bulrushes left hardly any damage, while hard-stemmed plants like reeds and wood left considerable damage.

Polishes (see Part I , Chapters 14 and 17) differed in their horizontal and vertical distribution according to plant species,and in their brilliance mostly according to the moisture content of the plant. They also differed to some extent according to certain variables such as the flint (see Part I , Chapters 15 and 16).

Striations (see Part I , Chapter 9) were only seen on polishes from contact with plants growing on land, and most were seen on polishes from contact with cultivated plants harvested from upturned soil (Pl.22:c-h). It is most likely that polishes from plants cultivated in dry loess soils would be the most striated (see Korobkova's experiments in Moldavia and Odessa Oblast (1981, p.331). Some striations were also seen on wood polishes (see Part I, Chapter 14).

A"sandblasting"effect was also only observed on polishes from plants harvested from upturned soil (Pl.22:e,f).

Macroscopic Gloss (see Part I , Chapter 10) nearly always began at the same time as microscopic polish but when coarse-grained flint was used gloss appeared much later than microscopic polish. As with the polishes, the rate of gloss development varied according to plant species, and moisture content of the plant, as well as other variables, such as the flint type. Thus the beginning of gloss on Brandon flint was visible when fresh reeds had been cut for 200 s.m. and when fresh barley had been cut for 4000 s.m.. The only plants which so far have not caused any gloss were the two poppy species which up to 1500 s.m. produced only very finely streaked polish.

No different rates of development could be detected between gloss and polishes from plants harvested in England and Wales and those harvested in the Near East.

No hafting traces could be discerned. Hafting was indicated by the regularity of polish distribution along the cutting edge and by the fact that polish stopped abruptly at the ends of the blade and did not affect the ends themselves. A sharp demarcation between polished and unpolished flint (where the haft had covered the blade) was not visible on my experimental blades.

Problems

I discovered many problems related to a microwear analysis dealing with sickle blades which may be discussed in three sections:

Problems related to the plants:

- Plants may have died out or may have been overlooked. Some plants which are commonly uprooted may have been cut in the past. Prehistoric plants may have differed slightly in their morphology and physiological balance, with broader or narrower stems or with slightly different silica content from today. This may have been the case with the domesticated cereals which are nowadays bred to be silica-free. Silica and moisture content of plants may vary from area to area and wear-traces may differ slightly accordingly, but this did not seem to be the case in my experiments with reeds, barley and Sparganium ramosum. Silica and moisture content do vary according to the time of year and the weather, and we are not certain at what time of the year cereals were harvested and what the weather was like. Cereals may well have been harvested when unripe, and stored. However, I did harvest plants at varying times of the year, in order to familiarize myself with varying wear-traces.

Problems related to the work:

- I could not do the experimental harvesting of cereals myself in the Near East. The blades used at I.C.A.R.D.A. were not available for me to examine. The blades used at Jerusalem had no wear-traces on them because the wax had run.

Problems related to the results:

- In my experiments the polishes from different plant species (see Part I, Chapters 14, 15, Table 2, Pl.22-25) varied slightly according to species. However, as pointed out in Part I, Chapters 15 and 16, if worked materials have similar properties, polishes can look similar. This was found to be the case with the polishes from reeds and Stipa gigantia (see Table 2, Pl.23:c,d and Pl.25:a,b). As also pointed out in Part I, Chapters 15 and 16, there are many variables other than the species which can affect polish formation. It is therefore possible that polishes from the same plant species can differ slightly. Polishes from dry plants (Pl.23:e,f) were indistinguishable from each other, and could also be confused with the beginning of wood polishes. They were very weak and chances are that they would not be discernible on ancient tools. Sometimes wear-traces showed a combination of features which was not consistent with those of the wear-traces observed on the experimental blades: e.g. there were wear-traces most of whose features suggested use on rushes (see Table 2),but there were also many striations which would indicate plants growing in upturned soil. Here several possibilities occurred to me: a) several plant species may have been cut with the same sickle; b) an unknown plant species may have been cut; c) conditions such as soil type or presence of weeds may have been different; d) slight changes in the plant morphology may have occurred; e) post-depositional damage may have occurred. In such cases I classified the polish as "plant"polish. The presence of striations could indicate that plants had been cultivated. Equally, however, some plants, such as barley, occur wild in disturbed soils, such as screes. Striations are therefore not an infallible indicator of cultivation. Conversely the lack of striations on polishes, otherwise thought to originate from contact with cereals, could indicate that plants had been cut some distance from the soil, perhaps halfway up the stem, or else that the soils had not been loose, perhaps because of a damp spell or because digging sticks were used which do not produce complete upturning of the soil.

Consideration of these problems led me to conclude that many ancient blades have to be examined in order to avoid misinterpretation of wear-traces, and that results of the microwear analyses should be compared with the extant plant remains from the sites, in order to see whether the results correspond.

5. Blades with Gloss from Arjoune

Aims

(Pl.26:b,d,f,h, Fig.40:b,d,f,h, 41)

All the excavated lustered blades (38) from Trench VI and all the available (40 out of 60) lustered blades excavated from Trench V were examined with the naked eye and under the light microscope. A few of the unlustered blades from both trenches, classified by Copeland (1981, p.11, and in prep.) as sickle blades on account of their shape, were examined for comparison.

In this microwear analysis I concentrated on the assemblage from Trench VI as all the flint implements were available for study and for this reason I discuss Trench VI before Trench V.

I had several main aims:

- I wanted to investigate whether the blades had been used hafted. Apart from affecting the estimation of tool efficiency (Korobkova, 1981) this factor has also implications for the interpretation of the nature of the site: a concentration of sickle elements might indicate that the site is an undisturbed living site (see Part II, Chapter 2.)

- As no sickle hafts have been excavated from this site or, as far as I am aware, from any Neolithic to Chalcolithic Syrian site, I wanted to try and reconstruct the shapes of sickles, the hafting arrangement and the movements used, using features such as the shape of the blades and the polish distribution.

- I wanted to find out at what stage and why the cutting edge of a blade was retouched.

- I wanted to investigate whether the blades had been used exclusively on cultivated cereals and whether plants had been cut fresh or dried.

- I wanted to investigate the unlustered blades microscopically in order to see whether they had been used on plants or not.

- I wanted to find out whether the blades had been worn out and to calculate the minimum duration of use from the edge damage and the amount of polish. However, as ancient cereals were probably more siliceous than they are now (see Section 4, Problems), the time could not be estimated very accurately.

Results from this investigation which relate to general questions about the nature of the site and the flint assemblage, such as the spatial distribution of the burnt blades and a comparison of the microwear with the typological analysis will be discussed in the relevant general chapters.

Results : Hafting

The blades were measured (see Fig.8:c). Relatively short, straight blades of uniform width and thickness would, I believe, have been used hafted. (The thickness of a blades is effectively increased by its curvature, when viewed in profile, and this was taken into account in the measurement of the thickness.) "Truncation", accompanied by retouch and/or likely intentional breaks at the distal and/or proximal ends of the blades indicated to me that the blades had been intentionally shortened to be used as sickle elements. Hinge fractures were counted as intentional breaks, as the thus shortened blade had been chosen to be used. Another feature which indicated to me that the blades had been used hafted was a uniform orientation of microscopic striations.

Trench VI

Out of of 38 lustered tools, 35 were blades and 3 were bladelets (less than 1.2 cm wide).

The length of the blades varied from 1.5 cm to 6.7 cm. Twenty out of 38 blades were between 2.0 cm and 4.0 cm and 13 blades were between 4.0 and 5.9 cm long. Only 2 out of 38 blades were shorter than 2.0 cm and only 3 were longer than 6.0 cm. All the blades, with the exception of 1, were either truncated or snapped at one or both ends. The width of the blades ranged from 0.9 to 2.6 cm. Twenty nine blades were between 1.5 and 2.0 cm, and 6 blades were between 2.1 and 2.6 cm wide. The gap between the widest bladelet (1.0 cm) and the narrowest blade (1.5 cm) suggested to me a different use for the bladelets. The effective thickness ranged from 0.2 to 1.2 cm. The majority of the blades (34) were between 0.3 and 0.9 cm thick. The thinnest (0.2 cm) was one of the bladelets, and the 3 thickest blades (1.0 to 1.2 cm) were all over 4 cm long. The curvature of the profile was minimal (less than 0.1 cm) in 32 of the blades. Four blades had a curvature of 0.1 cm to a third of their thickness, only 2 blades had a strong curvature of a third of their thickness or more.

The measurements of the blades from Trench VI suggested some standardisation of length, width and thickness. All except 4 blades had been intentionally shortened and of these 4, 3 had broken after use (and therefore may have been intentionally shortened before accidental breakage). Most blades were straight in profile and usually rectilinear in plan with straight truncations. Two blades had slightly curved backs, 3 blades were slightly narrower at the proximal end and 3 blades had pointed ends indicating their use as end pieces. Only 2 blades were exceptionally shaped in that they had tangs, one of these being the unbroken blade referred to above. Three bladelets may have been used separately from the rest.

The microscopic examination showed that 34 blades had uniformly oriented striations parallel to the cutting edges (Pl.26:b,d).

Trench V

It is likely that of the 40 tools examined all had been blades before being shortened by truncation or snapping. One blade had neither been truncated nor snapped. Six blades were probably broken after use. There was only 1 bladelet. One sickle blade had been made into a scraper (see Part II, Chapter 10).

The length of the blades ranged from 1.6 to 6.2 cm., but 25 out of the 40 blades were between 2.0 and 4.0 cm long. Eight blades were between 1.6 and 1.9 cm, 6 blades were between 4.0 and 6.0 cm and only 1 blade was over 6.0 cm long. Four of the 6 pieces which were probably fragments of tools were between 1.6 and 1.9 cm long. This could decrease the shortest group to only 4 tools, the other 2 fragments being 2.1 and 3.1. cm long. The width of the blades ranged from 1.1 to 2.5 cm. Twenty-four blades were between 1.5 and 2.0 cm wide, while 11 blades were between 1.1 and 1.4 cm and 5 blades were between 2.1 and 2.5 cm wide. The thickness of the blades ranged from 0.3 to 1.4 cm. Thirty-seven blades were 0.3 to 0.9 cm thick, only 3 of the blades being exceptionally thick. The curvature (in profile) of most blades was negligible. Only 3 blades had a curvature of between 0.1 cm and a third of their thickness and 4 blades had a curvature of over a third of their thickness.

The measurements of blades from Trench V suggested a standardisation of length, width and thickness. Excluding the fragments, most blades were intentionally shortened and of rectangular shape. There were, however, also 6 slightly pointed pieces, probably end pieces, and also 3 curved, 1 triangular and 3 trapezoidal elements. Most blades had uniformly oriented striations running parallel to the cutting edge and therefore most blades appeared to be sickle elements, probably hafted in both straight and curved sickles, although a few, like a bladelet with perpendicular striations and a tanged blade, may have been individually used.

Comparison

Apart from the more variable shapes of the segments in Trench V, the differences between the tools of the two trenches were slight: the blades from Trench VI tended to be slightly longer and wider, but not thicker than those from Trench V. There was a gap between bladelets and blades from Trench VI which was not observed in Trench V.

Sickle Shape, Hafting Arrangement and Movements during Use.

The shapes of the sickles and the hafting arrangement were inferred from the shape of the blades (usually determined by backing retouch), the angle of the truncations or breaks at the ends, from the distribution of polish and gloss over the dorsal and ventral aspects of the blades, and from the direction of the microscopic striations. Movement during use was reconstructed from the orientation of the striations.

Trench VI

The shapes of most of the 38 blades were rectangular, although some were pointed, and two blades had slightly curved backs. The angle of the truncation to the back was usually 90 degrees, the exceptions being the 2 blades with tangs.

The distribution of polish and gloss varied; on 3 blades retouch had obliterated the polish almost completely and the distribution had to be classified as unknown. Sixteen blades had a straight and narrow band of polish along the cutting edge,which terminated abruptly at the ends. This indicated that when used the blades had been inserted in a straight or gently curving haft. Eight blades had a wide distribution of polish; 1 blade with unusual striations and with polish extending over the ends had probably been hand held. Two blades (one with a tang, Pl.26:f) with unusually oriented striations and with polish which stopped before the proximal end were probably hafted at one end. The other 5 blades, with a wide distribution of polish but uniformly oriented striations, might have protruded from the haft, or alternatively the wide polish distribution could indicate that thick-stemmed plants were been cut. This latter possibility is less likely since the polish on these blades looked like the experimental cereal polish found on most of the blades. Eight blades with slightly curved polish and 3 blades with diagonally distributed polish were probably used while inserted in a curved haft. All of these blades were straight in profile and therefore the uneven distribution of the polish was not due to a curved profile. All the blades had microscopic striations parallel to the cutting edge which indicated that the hafting had been parallel and that the sickles had been used with cutting or sawing rather than with reaping movements.

Trench V

Most of the 40 blades were rectangular with truncations approximately 90 degrees to the cutting edges, one of these had a tang, 6 blades were straight but slightly pointed, 3 blades were curved, 1 was triangular, and 3 were trapezoidal.

The distribution of polish and gloss varied; on 8 blades the distribution could not be classified because of considerable edge damage. Eighteen blades had a straight line of polish just along the very cutting edge, indicating that most had been hafted in a straight sickle. The exception was a bladelet with perpendicular striations. Five blades had a wide polish distribution. Two of these blades had a polish which terminated abruptly halfway down the blade, indicating that the blades had been hafted at one end. One of these was triangular and very thick. Four blades had a curved polish distribution, 2 of these were curved in profile and the polish distribution could be due to this fact rather than the shape of the sickle. Three blades had a diagonal distribution of polish. Altogether 5 blades, 2 with the curved polish and 3 with the diagonal polish, had probably been inserted in a curved haft.

Comparison

The results of the investigation were similar for the blades from Trench VI and Trench V in that most elements had probably been hafted in straight or only slightly curved handles, possibly made of wood. Both antler and bone were preserved on the site and it is therefore unlikely that sickles made of these materials had not been discovered. Some elements had probably been hafted in curved sickles, especially those from Trench V which were backed to be curved or trapezoidal. The size of the blades (Fig.40-41) suggested different sized straight, or else pointed sickle handles. However, given the poor quality of the flint (see Part II, Chapter 7) found near the site, the different sizes of elements may reflect necessity rather than choice. The sickles seemed to have been used with cutting or sawing rather than reaping movements. A few other plant cutting blades had probably been used hand held and some had probably been hafted at one end. The results from the different trenches only differed in as much as the blades from Trench V were slightly less standardised in shape.

Retouch

I was interested to discover whether retouch had been intentional, and if intentional, whether it was done before use, perhaps in order to cut specific plants, or whether it was done during or after use, in order to resharpen the blade. The investigation assumed that intentional retouch is regular and occurs before and during use, and that unintentional retouch is irregular and occurs mostly during and after use. With intentional retouch, the amount of microscopic polish would equal the polish on the other aspects of the blade, while with unintentional retouch, the amount of microscopic polish on the scars , if not absent, would be considerably less than the polish on the other aspects of the blade.

Retouch proved a very difficult aspect to investigate, since there was no sharp division between regular and irregular retouch on the blades from Arjoune, and since it was difficult to see microscopic polish inside the retouch scars because of the oblique angle of the scars to the microscope lens. It was also difficult to decide whether a smaller amount of polish found on the scars, compared to the polish on the ventral and dorsal aspects, was due to the scars forming during rather than before work, or whether this was due to the oblique angle of the scars to the worked material.

The microscopic examination was therefore carried out before the independent examination of the retouch with the naked eye in order to avoid bias. The results were then compared.

Trench VI

The microscopic examination indicated that 18 blades had been retouched before use, 9 blades had been retouched during and after use and 11 blades had been retouched either before, during or after use.

The macroscopic examination revealed that 23 blades had regular retouch. Of these, 5 blades were definitely denticulated and 2 seemed to have been heavily retouched, that is, probably resharpened. Six blades had irregular, probably unintentional retouch and retouch on 9 blades could not be classified.

The fact that all 5 tools classified as denticulated were also classified under the microscope as retouched before use, and that the 2 resharpened tools were thought to have been retouched during and after use, and that most tools classified as retouched before use were also thought to have been intentionally retouched (16 out of 18) seemed to indicate that this approach was quite productive.

Trench V

The microscopic investigation suggested that 19 blades had been retouched before use, that 10 blades had been retouched during and after use, and that 11 blades had been retouched before, during and after use.

The macroscopic investigation indicated that 24 blades had been intentionally retouched. Of these, 5 blades had been denticulated and 2 had probably been resharpened. Eight blades had irregular and therefore probably unintentional retouch, while on 8 blades retouch could not be classified.

Most of the tools classified under the microscope as retouched before use were also identified as intentionally retouched (17 out of 19). All the blades classified as denticulated were thought to have been retouched before use as well.

Retouch and Plants

There seemed to be a continuum from finely retouched to denticulated blades, and it was therefore difficult to examine the relation between denticulation and plants cut. The denticulated blades from Trench VI showed the common"sickle polish"(see below) which was probably caused by cultivated grain. In only one case did the polish look like experimental reed or <u>Stipa</u> polish. Three of the 5 denticulated blades from Trench V showed unusual polishes which looked like experimental reed or <u>Stipa</u> and wood polishes. Conversely, however, uncommon polishes were also seen on the common finely retouched blades.

Blades classified as unretouched from both Trenches showed polishes probably due to the harvesting of cultivated cereals, as well as to the harvesting of other plants. Blades with inverse retouch which were only found in Trench VI also showed both"sickle polish" and other plant polishes (see below).

In summary, it seemed that blades had not been retouched with certain plants in mind, but a few blades which had been denticulated were probably used to cut reeds or Stipa and wood.

Plants

Polishes from different plant species were found to be slightly different (see Part 1, Chapters 14, 15, Table 2 and Plates 22-25), but differences were not always clearcut (see above, Section 4). I therefore concentrated on distinguishing polishes which resembled experimental polishes made by cutting cultivated cereals from polishes made by processing other plants. The fact that the Arjoune material was made of different flint types has been taken into account, but no consistent correlation was found between a particular flint type and the identification of a particular plant species.

Trench VI

Of the 38 blades excavated from Trench VI, 31 showed the"sickle polish"(Table 2 and Pl.26:a-d)with many striations and"comet-shaped pits", and many showed numerous tiny holes which are perhaps due to sand grains hitting the flint. This polish was probably due to contact with cultivated cereals which had been cut at the base from upturned loose soils. The remaining 7 blades had widely distributed unstriated polishes which could have been from contact with reeds or Stipa (Pl.26:e,f). However, in all these instances the blades were either made of coarse-grained flint on which polish distribution can be quite different (see Part I, Chapter 17) or else they were burnt (Pl.6:h) or patinated. Both burning and patination can affect the appearance of the polish (see Part I, Chapter 18). However, all the blades with polishes other than the common"sickle polish"had features which made them slightly different from the rest of the blades: 2 blades were exceptionally small, 1 blade was especially thick and had a regularly notched edge, 1 was unusually strongly denticulated, while 1 was exceptionally long, broad and thin, 1 blade had a tang, and one bladelet was double-edged. It is therefore possible that these blades, although clearly parts of sickles, may also have been used on plants other than cereals. No relation could be seen between curved blades or polishes and plant species cut. An unshortened blade which, on account of its thickness, widely distributed polish and random striations, I had classified as probably hand-held, showed the common"sickle polish"which indicated that it had been used on cereals but hand-held.

Trench V

Twenty-two out of 40 blades showed the common"sickle polish"with striations (Table 2, Pl.26:a-d) which indicated that cereals had been cut at the base from upturned soil. In general, however, polishes were somewhat less striated than the polishes on the blades from Trench VI. Of the remaining 18 blades, 8 were burnt (Pl.6:h) or patinated, 6 had polishes which could have been from cereals or other plants, 3 had polishes which looked like experimental reed or Stipa polishes (Pl.26:e-f), while 1 blade showed wood polish (Pl.26:h).

All the lustered blades from both trenches seemed to have been used on fresh plants (cf.Pl.23:e,f).

"Sickle Blades"Without Gloss

Only 2 of the unlustered blades from Trench VI classified as"sickle blades"proved to have microscopic plant polish on them. They were both very coarse-grained. It was impossible to assign this polish to a particular plant as the distribution of the polish - governed to a certain extent by the flint - was very isolated and difficult to assess.

Duration of Use

Most blades from both trenches looked well-used and heavily polished. I cut green barley for approximately four hours and ripe einkorn for approximately three hours and in both cases the blades were quite undamaged and not very polished. It seems to me that most of the blades from Arjoune must have been used at least 3 times as long, i.e. for about 12 hours, if the ancient plants and the plants I cut had similar properties.

Conclusions

Several observations may be made following this investigation of the blades with gloss from Arjoune:

Most of the lustered blades appeared to have been used as sickle elements, while some blades appeared to have been used individually, either hafted at one end or else hand-held. The latter had probably been used to cut other plants such as reeds or Stipa and wood. Stipa is, however, commonly harvested by uprooting rather than by cutting (Hillman, pers. comm.). I could not see any concentration of sickle blades or indeed of any particular feature, such as size or polish according to the layout of the site.

The distribution of gloss and the different sizes and shapes of blades from both trenches suggested to me that both straight and curved sickles may have been used and that these may well have been made in large and small sizes.

There seemed to be no relation between the sickle shape and the plant species cut. As no sickle hafts have been found on the site it is likely that they were made of wood.

Retouch was carried out before use, possibly, as experiments suggest, to prolong the life of the blades rather than to increase sharpness, and the blades were also retouched during use, probably to resharpen the edges. Retouch ranged from fine to coarse denticulation and seems to have been random rather than matching any particular plant. However, the one instance of wood polish was found on a coarse denticulate, as were some of the polishes which looked like experimental polishes from hardstemmed plants, such as reeds or Stipa.

The plants the blades had been used on seemed to have been fresh and were in my opinion cultivated cereals, possibly reeds or Stipa , and in one case wood. However,it must be admitted that I found the allocation of polishes difficult as plant polishes seem to form a continuum, and one can easily be confused with another. There may well have been plants which I did not harvest experimentally. Comparison with the botanical evidence therefore seemed very important. Analysis of the botanical remains (see Part II, Chapter 3) showed that the staple food crops represented at Arjoune were einkorn, emmer, two-row hulled barley and lentils. The wheats were fully domesticated. Free-threshing wheat seemed to be present at Arjoune V, but whether its absence at Arjoune VI was real or apparent was according to Moffett (in prep.) uncertain. A similar artefact of sampling may have been the relative scarcity of barley in Trench VI. The lentils were probably the cultivated species. Evidence for other food plants included grape pips in large numbers from Trench V, seeds from the horse bean and remains from various fruit tress, such as hawthorn, pistacio, plum or cherry, sweet almond and fig. According to Moffett such fruit was most likely collected from trees growing on the slopes of the Lebanon and Anti-Lebanon.

This list matches my evidence fairly well: the microwear analysis pointed to the harvest of cultivated cereals. In one instance wood polish could indicate that vines or fruit trees had been pruned, although it might have been any wood which had been cut. Neither lentils nor horse beans are harvested by cutting, as far as I am aware. Reeds and Stipa are absent from the botanical analysis. This could indicate that my identification was wrong or else that these plants were not preserved in the botanical record. Certainly reeds proliferate nowadays near Arjoune.

I could only find two unlustered"sickle blades"from Trench VI which showed microscopic polishes which I would attribute to plants. Both had been made of coarse-grained flint. This suggested to me that the other unlustered blades, although of similar shape and with edge damage and microscopic polish, had been used on other materials.

All of the blades from Trench VI and many of the blades from Trench V appeared to be worn out. On the evidence of experimentation with modern cultivated cereals I would estimate that they had been used for about six to twelve hours. As the site was not completely excavated and there was no apparent concentration of sickle blades, it would be futile to attempt to calculate the length of the sickles and the plot size harvested by each.

There were a few differences between the blades of Trench VI and Trench V: the blades from Trench VI were slightly longer and more uniformely shaped. The"sickle polishes", i.e. probable cereal polishes, from Trench VI looked to me generally more heavily striated than those on blades from Trench V. This may have been coincidence. Alternatively, it may be that the blades from Trench V had been used to cut cereals higher up the culms. Could this have been related to the higher percentage of barley recovered from Trench V? It is unlikely that the less striated blades had been used to cut wild cereals, although - on account of the poor preservation of the botanical remains - the possibility of wild emmer at Arjoune was not ruled out (Moffett, in prep.).

6. Polishes on Natufian Blades with Gloss

(Pl.27, Fig.42)

Sickles have been found from the Natufian levels from such sites as Kebara and El Wad (Camps-Fabrer and Courtin, 1982) in the Mt. Carmel region. At Kebara fifteen bone sickle hafts had were excavated, two of them complete, 38 cm and 28 cm long. At El Wad thirteen sickle fragments had were found, some of them of antler. One sickle haft was more convex than the others. The overall shape, truncation type, distribution of gloss and polish and orientation of striations on the bladelets and blades from Kebara and El Wad which I examined all indicated to me that the blades had been hafted in sickles.

It has been the subject of long debate what plants these Natufian sickles were used on: some scholars (e.g. Neuville, 1934) thought that they had been used on cultivated cereals, others (Harlan, unpublished manuscript) thought that they indicated a trend towards the exploitation of cereals, while others (Vita-Finzi and Higgs, 1970) thought that most of the territory of these sites in coastal Palestine was not suitable for grain growing (ibid., p.16) and that therefore the sickles from these sites had perhaps been used on reeds and grasses (ibid., p.22). However, according to the map published by Vita-Finzi and Higgs (1970, p.9, Fig.I), Kebara and El Wad lie very close to the Mt.Carmel slopes (10 and 2 km respectively), and Bar-Yosef (1970, p.29) listed these two sites as belonging to a mountainous area. This suggested to me that the sites were well within reach of wild cereals.

I examined twenty-five lustered bladelets including some blades from the Natufian level B and the mixed level A from Kebara, which was according to the excavators Early Bronze Age to Recent Arab (Turville Petre, 1932), and from the Natufian level B2 and the Late Natufian (Khiamian) level B1 at El Wad (Garrod and Bate, 1937, Vol.1, pl.IX and p.34, pl.VIII and p.31.) The bladelets are part of the collection of the Institute of Archaeology, London. The length of the bladelets ranged between 2.5 and 5.2 cm, their width between 0.8 and 2.2 cm and their thickness between 0.3 and 0.6 cm. All the bladelets were straight in profile. Most bladelets had been truncated and/or broken at one or both ends, and had been backed with bifacial ("Helwan") retouch. The 3 bladelets from the mixed level A at Kebara were included as they looked identical in shape and retouch to the other Natufian bladelets and blades. Most bladelets were rectangular, with 2 exceptions which were curved. Nine bladelets had denticulated cutting edges, 2 bladelets had cutting edges with inverse retouch, while the others were probably not retouched before use.

The state of polish preservation varied from apparently complete to poor. In the case of poor preservation this may be attributed to post-depositional changes, probably natural, and also to the fact that the blades had been stored unprotected for a long time. In some instances the polish distribution was obscured by varnish applied by the excavators. The flint ranged from fine-grained to medium-grained.

Examination of the polishes (Pl.27) and comparison with the experimental polishes (Pl.22-25) showed the following:

The 5 bladelets from the Natufian levels at El Wad B2 all had unstriated widely distributed polishes which looked like my experimental reed or Stipa polishes.

Of the 5 Late Natufian bladelets from El Wad B1, 4 showed polishes which looked like experimental cereal polishes (Pl.27:b,d). Striations on 3 of these suggested that loose soil had got caught between the bladelets and the plants during the harvest. This could indicate either that cereals had been cultivated or that wild cereals had been harvested from scree. The only Late Natufian bladelets which were denticulated showed polish which looked like experimental reed or Stipa polish.

The 12 Natufian bladelets and blades from Kebara B showed a mixture of polishes: 5 denticulated bladelets (of which one may have been simply heavily damaged) showed polishes like experimental reed or Stipa polish (Pl.27:e,g), 6 showed polishes like cereal or perhaps grass polishes (Pl.27:f,h), 3 of these without striations, 2 with a few striations and one with many striations, again indicating the presence of loose soil. One of these was either intentionally denticulated or showed very strong edge damage.

Of the 3 bladelets from the mixed level A at Kebara, 1 blade showed cereal polish with a few striations only and the 2 bladelets showed reed or Stipa polishes, although 1 of these could have been unstriated cereal polish.

Conclusions from this investigation had to be tentative, given the small number of blades. I could not and did not set out to investigate the problem of the beginning of agriculture. However, results of the microwear analysis did suggest that some of the Natufian sickle blades at Kebara and some of the Late Natufian sickle blades at El Wad had been used to harvest cereals, which were either wild and growing in loose soil, or else cultivated. These blades were mostly undenticulated. The results also suggested that all the Natufian blades from El Wad B2 had been used to harvest reed or stipa, although the latter is more likely to have been harvested by pulling (Hillman, pers. comm.).

There was no published botanical evidence available from these sites and very little botanical evidence from the Natufian in Palestine. At the neighbouring site of Nahal Oren 3 seeds of T.dicoccum (domesticated wheat) and 1 seed of H.spontaneum (wild barley) had been recovered from an undisturbed Kebaran , that is, pre-Natufian deposit (Noy et al. , 1973, pp.92-93). The finds from the Natufian at Nahal Oren were 5 seeds of Vicia sp. , 6 seeds of Viciae , 1 of Vitis sp. , 4 of Graminae and 9 other seeds (ibid.). Because they thought that this region was not particularly suited for agriculture Vita-Finzi and Higgs (1970, p.21) thought that grain was probably gathered not there, but at upland sites, like Raqefet and Hayonim. But the same could be said of the area around Tell Aswad where domesticated cereals had been found from the beginning of the site in the early 8th millennium (Van Zeist and Bakker-Heeres, 1979).

Thus the results of the microwear analysis agree with the botanical evidence, inasmuch as domesticated cereal grains had been found in the vicinity, albeit from an earlier deposit. However, the results of the microwear analysis did not support the opinion of Vita-Finzi and Higgs based on their site catchment analysis. The results were compatible with the opinion of Harlan (unpublished manuscript) who suggested that Natufian sickle blades could be seen as an indicator of an economic shift towards cereal exploitation and finally cultivation."Sickle blades" (more than 1000) were the most numerous of the flint implements from Kebara B (Turville-Petre, 1932, pp.271-272), and at El Wad 630"sickle blades"had been found in B2 and 394 had been found in B1 (Garrod and Bate, 1937, Vol.I, p.34 and 31). Therefore a potentially large number of Natufian lustered blades could be examined, but my comparatively small sample can not be expected to indicate whether the striated cereal polish is made by cultivated grain or whether it is the result of contact with plants growing in loose soils and therefore undiagnostic. The examination of a large number of Natufian blades, however, might bring us closer to an answer to the question when cereals were first cultivated.

7. Polishes on Blades with Gloss from Jericho PPNA to EB.

(Pl.28, Fig.43-44)

It is sometimes debated whether a change in tool type constitutes an adaptation to different requirements, such as different materials to be worked or is rather a change in fashion, due to the arrival of new people or to the desire for novelty among an established people. Another reason for such a change might be a technological advance.

Changes in the typology of Palestinian"sickle blades"have raised this question. At Jericho (area F) (Crowfoot-Payne, 1983) blades from the Aceramic Neolithic A (PPNA): Sultanian (ibid., pp.649-651) were of various sizes and often irregularly shaped. They had mostly unretouched cutting edges, but quite a lot were backed.

Lustered blades from the Aceramic Neolithic B (PPNB): Tahunian (ibid., pp.683-686) tended to be uniformly long and regular. They were mostly unbacked and had inverse, alternating or bifacial retouch which gave the blades a finely denticulated cutting edge. However, there were also other forms like broken or truncated blades which resembled sickle elements, plus a variety of retouched and unretouched blades.

The small lustered blades from the Pottery Neolithic A: Yarmukian (ibid., pp.708-710) had coarsely denticulated cutting edges, some of which had been produced by bifacial retouch, others by pressure flaking on most or all of the surfaces of the blades. Some elements with straight ends and finely denticulated cutting edges had been completely pressure flaked.

The Pottery Neolithic B: Ghassulian (ibid., p.716) blades had been made with direct retouch and very fine denticulations, but as they had not been found in area F, they were not examined.

One of the hallmarks of the Proto-Urban and Early Bronze Age (ibid., p.718) is the Canaanean blade which is trapezoidal in section and has a faceted butt. Canaanean blades were either unretouched or backed with fine direct retouch.

I examined 63 lustered blades from area F, including 19 blades from the PPNA, 33 blades from the PPNB, 6 blades from the PNA and 5 blades from an EB disturbed deposit which contained Canaanean blades.

The total numbers of excavated blades from area F were given by Crowfoot-Payne as 46 from the PPNA, 146 from the PPNB, 11 from the PNA and 3 from the EB.

The blades had been made from a variety of flint ranging from the very fine-grained flint typical of the PPNB at Jericho to the coarse-grained flint used for the Canaanean blades.

I investigated the relation of flint type to polish identification in order to see whether identifications of worked materials were perhaps influenced by the grain-size of the flint.

Results

The investigation of the PPNA blades showed that polishes were varied: on 4 blades polishes looked similar to experimental cereal polishes and were mostly unstriated. Only 1 of these polishes showed the amount of striations associated with the harvest of cereals from loose soil (Pl.28:e). Polishes on 3 blades looked identical to reed or Stipa polishes (Pl.28:a), while polishes on a further 7 blades looked similar to experimental reed or Stipa polishes. Polishes on 5 blades looked similar to experimental bulrush polishes (Pl.28:c). Polish on 1 blade looked like experimental grass polish. The number of polishes listed here is higher than the actual number of blades investigated because alternative interpretations were made, e.g. one blade might have a polish which looked either like reed or like bulrush polish. Polishes on 2 blades were too damaged to be classified (Pl.7:h). Polish on 1 unlustered blade was not plant polish. Striations, where present, were always oriented parallel to the cutting edges of the blades. This could indicate that the blades had been hafted (see Crowfoot-Payne, ibid., p.651).

Polishes on the lustered blades from the PPNB (ibid., pp.683-686) were less varied: 25 of the 33 blades had polishes which looked exactly like the experimental cereal polishes (Pl.28:b,d,f). All were somewhat striated and 16 of these were heavily striated, 4 blades having polishes which looked similar to experimental cereal polishes. Polishes on 3 blades looked like experimental reed or Stipa polishes, while polishes on 3 blades looked similar to experimental bulrush polishes. Polish on 1 blade looked like experimental grass polish. On a few blades the identification was uncertain because of post-depositional damage and 1 unlustered blade did not have microscopic plant polish. All the long blades with finely denticulated cutting edges (Crowfoot Payne's types 2A and B, ibid.) produced by inverse, alternating and bifacial retouch had"sickle"polish which was slightly to heavily striated (Pl.28:b,d,f). It is possible that the alternating retouch had been carried out in order to straighten the cutting edge, while perhaps the bifacial retouch represented a second sharpening of the blades. All were heavily lustered and had probably been used for a long time. Striations always ran uniformly parallel to the cutting edge, supporting the argument that the blades had been hafted (Crowfoot Payne, ibid., p.686).

The investigation of a few blades from the PNA (ibid., pp.708-710) showed that the pressure flaked straight-ended blades which were probably sickle elements had polishes which seemed to be deteriorating. Judging from the few complete patches of polish, the distribution looked like that of experimental cereal polish. The coarsely denticulated blades had polishes which looked like experimental reed or Stipa polishes (Pl.28:g), although a few striations were present. It would seem that these blades had probably been used to cut plants with thick and hard stems, as the relatively thin stems of cereals would have been caught in the coarse denticulations and simply pulled out. The gloss on these blades was too strong for the polish to be classified as wood polish. In general, polish identification was made difficult by the fact that the blades had been pressure flaked which meant that I could not assess the polish distribution. Striations ran uniformly parallel to the cutting edges of the blades. I could not tell whether the large denticulate had been hafted, but the pressure flaked straight-ended blades were probably used as sickle elements as they were too small to be held by hand.

The Canaanean blades from the EB (ibid., p.718) had striated cereal polishes (Pl.28:h). Striations which ran uniformly parallel to the cutting edges and the presence of little or no backing retouch suggested to me that they had been used hafted.

The comparison of the flint types with polish identification showed that there was no relationship between the two.

Conclusions

There was a variety of polishes on the blades from the PPNA which were similar to experimental polishes from cereals cut with or without the presence of loose soil, grass, reeds and/or Stipa and bulrushes. (Stipa is most commonly harvested by pulling (Hillman, pers. comm.). In some cases the identification was doubtful because of polish disintegration, other post-depositional damage or because polishes did not fit into distinct categories. This could mean that plants harvested with these blades had not been harvested experimentally or that plants or conditions were slightly different to those today. Alternatively this could mean that several plant species had been harvested with the same blades. It is of interest, however, that the striated cereal polish suggesting the presence of loose soil during harvest, and therefore harvest of cultivated cereals, was rarely found in the PPNA, while it was the most common polish in the PPNB and in the later periods. This change from mainly unstriated polishes in the PPNA to the striated polishes in the PPNB, could mean several things, for example, that in the PPNA most of the cereals cut were wild, or else that cultivated cereals were collected by hand or cut high up the culm. It might also mean that in the PPNA cereals may have been planted with the help of digging sticks, thus leaving the ground fairly intact, while in the PPNB the soil was completely turned over (digging stick weights were apparently not found before the PPNB (Dorrell, 1983, p.489). A third and very likely possibility is that this reflects the rarity of domesticated cereal grains (einkorn, emmer and barley) found in the PPNA levels at Jericho (Hopf, 1983, p.609), particularly as independent evidence, such as the proportional decrease of pestles and increase of stone vessels from the PPNA to the PPNB led Dorrell (op. cit., p.527) to come to similar conclusions. He thought that the stone equipment of the PPNA suggested the processing of husked or brittle rachis cereals, while that of the PPNB suggested the processing of naked-grain cereals and tough rachis varieties. The microwear investigation did not contradict the idea that the blades had been hafted.

In the PPNB the majority of polishes looked like heavily striated experimental cereal polishes. Such polishes were found on each of the finely denticulated sickle blades. In some instances unretouched PPNB blades also showed the striated cereal polish. As all the finely denticulated blades were very lustered it was assumed that the retouch was carried out in order to prolong the life of the blades. The microwear investigation supported the assumption that the PPNB blades had been used hafted. Some other polishes suggested to me that a variety of plants, possibly reeds, Stipa or bulrushes, had been cut in the PPNB. Evidence for the use of such plants was found through the basketry and matting recovered from both the PPNA and the PPNB (Crowfoot, 1982). The botanical evidence (Hopf, op.cit., p.609) showed a great increase of finds of domesticated cereal grains from the PPNA to the PPNB.

In the Pottery Neolithic A the smaller pressure flaked straight-ended blades had probably been used as sickle elements to cut cereals, while the coarsely denticulated blades, on account of the distribution of their polishes and from my own experimental evidence, had probably been used to cut reeds or Stipa. Similar blades had been excavated from Pottery Neolithic sites along the bank of the River Yarmuk. The buildings there were huts and houses, the roofing of the former probably made of"branches, leaves and straw"(Stekelis, 1973, p.39); it is therefore quite possible that such coarsely denticulated blades had been used to cut material like reeds. The Yarmukian sites were, however, also agricultural and one would have to examine the sickle blades in order to to see whether they were used on cultivated cereals or not. Interestingly, Hopf (op.cit., p.578) pointed to the small number of seeds and the complete absence of charcoal from the PN at Jericho which she thought supported Kenyon's conclusions that plant growing had been of secondary importance in the PN.

The Canaanean blades which derive from a period when, according to Kenyon (Hopf, op.cit.) people were farmers again, were probably used to cut cultivated cereals, judging from their striated polishes.

The results suggested that typological differences can occur according to the materials cut: examination of the irregular blades of the PPNA suggested a stage of experimentation during which many plants were cut; these plants included cereals, though these may not always have been cultivated. Examination of the PPNB blades suggested an increase in standardisation and specialisation with fine denticulation. It seems that all the finely denticulated blades had been used to harvest cultivated cereals. They constituted over 75% of the total of the lustered blades from the PPNB (Crowfoot Payne, 1983, p.683). In the PNA large denticulates were probably used to cut reeds or Stipa while pressure flaked standardised blades were most likely used to cut domesticated cereals. Canaanean blades from the Proto-Urban to the EB were probably used to harvest domesticated cereals. The botanical evidence did not contradict the evidence from the microwear investigation.

8. Conclusions

The comparison of wear-traces on the lustered blades from the 5th millennium site at Arjoune, with those from the Natufian levels at Kebara and El Wad and those from the PPNA to the EB levels at Jericho led me to the following conclusions:

The identification of plant polishes using high-power optical microscopy was by no means always certain and often the polishes formed a continuum. This indicated to me that the sample of blades should always be large when investigating aspects of plant husbandry. The results of the microwear analysis did not contradict the botanical and other independent evidence, which in order to avoid bias was studied after the microwear analysis had been carried out, and sites from which domesticated cereal grains had been recovered also yielded blades with striated cereal polishes. The increase in domesticated cereal grains from the PPNA to the PPNB at Jericho and the change in proportions of stone vessels and pestles was matched by a considerable increase in blades with striated cereal polishes. From this evidence I conclude that the microscopic examination of polishes on lustered blades is a viable approach to the investigation of aspects of plant husbandry. Nevertheless, given the different explanations that are possible for some features of wear-traces, it is desirable to study the wear-traces at the same time as the botanical evidence.

It was very interesting to note that a few of the bladelets from the Natufian levels at Kebara and El Wad had striated cereal polishes which tally with the harvest of cereals from upturned soil. It may be that both the presence and absence of striations in plant polishes was due to factors other than the cultivation or the gathering of plants and it seems to me that many more blades need to be examined from this period before any statements concerning the beginning of agriculture can be made. But if a large number of Natufian blades with striated polishes is discovered, then this would perhaps indicate early soil-tillage and thus cultivation of cereals. In other words, striations in plant polishes could provide crucial evidence for early agriculture.

The investigation of plant polishes indicated that some typological features were correlated with the harvesting of different plants, and the finely denticulated blades from the PPNB always showed the striated polish which suggests the harvest of cultivated cereals. Coarsely denticulated blades at the same site, both from the PPNA and from the PNA seemed to have been used to cut hard-stemmed plants such as reeds or Stipa. The evidence in both these cases corresponded to the knowledge gained from my experimental work, namely that coarsely denticulated blades were most efficient in cutting reeds, while finely denticulated blades were most efficient in cutting cereals. At Arjoune, however, denticulated blades showed cereal as well as some other plant polishes, which looked like experimental reed, Stipa, grass and wood polishes. (Although Stipa is most easily harvested by pulling (Hillman, pers. comm.). This suggested that typological features need not necessarily correspond to different worked plant species.

Most of the unlustered blades from all sites which I had picked out as"sickle blades" on account of their shape, had apparently not been used on plants, but on other unidentified materials. However, judging by the microscopic polish on them, some unlustered blades made of coarse-grained flint had been used to cut plants. It follows that microscopic examination would help to differentiate unlustered sickle blades from blades used on other materials.

Chapter 18 - Burnt Flint Implements from Arjoune

Copeland (1981, in prep.) had noticed a number of burnt implements at Arjoune. My own examination of the tools revealed that some implements showed traces of heavy burning in the form of microscopic cracks and/or blackening of the flint, such as seen on experimental pieces left in a fire overnight (see Part I, Chapter 19, Pl.6:g,h). These tools (from all trenches) were invariably very small implements which had probably been hafted, such as arrowheads, sickle blades, unlustered bladelets, and drills. A subsequent examination of all the flint from Trench VI, tools, fragments, debitage and"rubbish", revealed that, apart from such tools as described above, only small fragments and pieces of"rubbish"were burnt. The fact that only the smallest, probably hafted tools were burnt, suggested to me that the tools may have been burnt when they were taken out of their hafts and dropped into a fire, which is necessary to melt the hafting agent. Another possibility might be that these tools were used near hearths (Newcomer, pers.comm.).

A horizontal distribution plot of the burnt flint pieces from Trench VI (Fig.9) revealed no significant concentration. Unfortunately the flint had not been plotted precisely during excavation. Also, experiments by Bergman had shown that flint can be heated at 350 degrees centigrade without any visible alterations, except greasy looking flake scars from flaking after burning. It is therefore possible that concentrations of burnt flint did exist but were overlooked.

Chapter 19 - Comparison of Typology and Microwear Analysis

Comparison of the results of the typological and the microwear analysis of the flint tools was not always possible. Often the tools which had been drawn by Copeland were not suitable for microwear analysis (see Part II, Chapter 9), and those which were suitable for microwear analysis were often not drawn. This meant, for example, that only 1 notch, 1 denticulate and 3 burins could be compared. Only the clearest types of tools were selected by me for microwear analysis,and probably had been selected by Copeland for her drawings. It is also true that I based some of my conclusions such as those concerning hafting on macroscopic observations, that is, on the same kind as had been used by Copeland.

It is therefore not surprising that no major discrepancies between typology and microwear analysis were found. Only 2 divergences occurred in the scraper analysis (of 7 scrapers compared): a "thumbnail scraper"(Copeland) had probably not been used as a scraper, while a"denticulate racloir"was probably an end-scraper. Of the perforators (7 compared) a"borer" had probably been used as a drill. One"denticulate on a cortex-flake"may have been a core. Out of 3 compared axes/adzes one had apparently been used as an axe, but it might have been used as an adze to begin with.

The major divergence was that some - but not all - of the unlustered blades, classified by Copeland as"sickle-blades" on account of their shape, had been used on materials other than plants (see Part II, Chapter 17).

Conclusions

1.A - Flint Tools at Arjoune

My research led me to reach the following conclusions about the flint tools at the site of Arjoune (Part II, Chapters 1-6):

The raw materials (Part II,Chapter 7) of which most of the tools had been made at prehistoric Arjoune were found one hour`s walk from the site in a gravel terrace on the banks of the Wadi 'Rabiy'ah. The material consisted mainly of small pebbles and was often of poor quality. Similar, probably frost shattered cores have been excavated from several trenches. The material to make the few large chipped stone tools from Arjoune, such as tabular scrapers, had probably been collected directly from the chalk and limestone of the slopes of the Lebanon whence the gravels originated.

The preservation of the ancient flint implements (Part II, Chapter 8) was found to be variable. Most edges looked in"mint fresh" condition. However when examined under the microscope all the implements showed post-depositional surface modifications to a varying extent, and many were of coarse-grained flint or chert. These factors made a microwear analysis difficult. Another limiting factor was the great quantity of experiments which had to be carried out for each type of implement (see Part I, Chapters 10-17). Therefore only relatively few (470) undamaged tools, made of the finer-grained stone, were selected according to tool type (Part II, Chapter 9). I could only come to an opinion about the use of some 180 of the tools from Arjoune.

The microscopic study at 50x to 200x of the tools showed evidence of the following uses:

Acutely angled end-scrapers (Part II, Chapter 10) with an"overhang"of the working edge, had apparently been used to scrape hides, while steeper angled, often tabular scrapers, had been used on wood. Large scrapers seemed to have been used on both these materials, but not on stone or bone. The latter as well as the former materials had apparently been scraped with smaller scrapers. Many of the scrapers had thinned butts suggesting that they had been inserted in a haft; experiments had shown that this increased the efficiency of the tools, as well as the ease of working.

Perforators (Part II, Chapter 11) seemed to have been used as borers (of wood and pottery) and as piercers (of hide). There was clear evidence of fast, i.e. mechanical drilling, possibly with a bow-drill. A long thin <u>meche de foret</u> had been used to drill wood, while a drill had been used to perforate stone, perhaps such an object as the large macehead recovered from the site.

Retouched blades and flakes (Part II, Chapter 12) of various shapes and sizes appeared to have been used as wood-whittling knives, as wood-saws, and as cutters of various soft (perhaps hide or meat) or hard (perhaps bone, shell and stone) materials. Unfortunately the precise material (with the exception of wood) could not be identified on this type of tool. Judging from the backing and the truncations of many blades, such as the wood-saws, and the blades which had been used on soft materials, they had been used in hafts, rather like the sickle-blades (see below). A few very small bladelets could possibly have been used as barbs. In one instance the truncation on a blade had apparently been used to scrape wood.

Each notch (Part II, Chapter 13A) seemed to have been used in a different way. Some notches appeared to have been used to shave wood, another to shave bone. On several the projections appeared to have been used as perforators. Small single-blow notches made from the dorsal aspect appeared to be accidental.

Denticulates (Part II, Chapter 13B) showed a great variety of wear-traces. They appeared to have been used as scrapers (of wood and hide) and as individual notches (to shave wood). In some instances the projections only appeared to have been used to perforate (wood) or incise (stone).

Burins (Part II, Chapter 14) had apparently been used to incise hard materials (shell, limestone or bone). One burin had been used to split plant material, perhaps reeds.

The few excavated transverse arrowheads (Part II, Chapter 15) seemed to have been shot.

Axes and choppers (Part II, Chapter 16) had apparently been used to chop wood.

Lustered "sickle blades" (Part II, Chapter 17) had indeed been used to harvest plants, apparently mostly cultivated cereals. Experimentation and comparison with wear-traces on 88 sickle-blades from Epi-Paleolithic Kebara and El Wad and from PPNA to EB Jericho, as well as with botanical evidence, suggested that certain wear-traces were indicative of soil-tillage. A significant increase of such wear-traces (in the form of a great quantity of striations) was found from the PPNA to the PPNB at Jericho. A few blades with a considerable number of striations were found from the Epi-Paleolithic sites. At Arjoune most sickle-blades had been truncated and inserted end-to-end in straight and/or curvilinear hafts. Comparison with experimental results showed that the efficiency of my"models"of the Arjoune sickles was about three-quarters of the efficiency of a modern metal-sickle. A few blades, some of which had probably been hafted like knives, appeared to have been used to cut non-cereal plants, such as reeds.

Unlustered blades, classified as"sickle blades"on account of their shape, fell into two categories: those made of coarse flint or chert often revealed microscopic plant polish and had been used as sickle-blades. The macroscopic lustre simply did not show because of the coarseness of the flint. Unlustered blades made of fine-grained flint often revealed different polishes (Part II, Chapter 12) and seemed to have been used to cut wood or other materials (see above).

The study of the ancient tools confirmed that good quality raw material had been at a premium at Arjoune: tools had been reused, e.g. scrapers as saws and choppers or adzes, a sickle-blade as a scraper. There were several composite tools, and many tools had been used or resharpened to"exhaustion". This lack of suitable raw material also seemed to be responsible for the often unorthodox shapes of the tools.

Quite a few of the tools were of a greyish colour and revealed microscopic cracks consistent with burning (Part II, Chapter 18). Such traces were seen on experimental flint pieces which had been burnt in a woodfire for some hours. It was interesting to note that the only obviously burnt tools were the smallest tools which had probably been used hafted: a number of sickle-blades, bladelets, drills and arrowheads were burnt, as well as a few fragments and pieces which I found when I examined all the flint pieces excavated from Trench VI for signs of burning. This suggested that the tools may have been burnt when they had been taken out of their hafts.

Comparison of the typology and the microwear analysis (Part II, Chapter 19) revealed no major discrepancies. This was perhaps not surprising, as only the clearest types of tools had been selected by me for the microwear analysis, and presumably by Copeland, the typologist, for her drawings. Also I had based some of my conclusions on macroscopic observations, i.e. on the same criteria as the typologist. The only"surprise"was that some - but not all - of the unlustered backed truncated blades classified by Copeland as"sickle-blades"had been used on materials other than plant.

1.B - The Site of Arjoune

It seemed clear to me that the site of Arjoune had not been chosen for access to good quality flint.

Many of the examined tools had been used to exhaustion, however many had not. This fact, together with the scarcity of good flint, suggested that the site, a series of pits sunk into bedrock, was not a series of rubbish pits.

Burning of the flint implements seemed to be due to rehafting rather than to a general conflagration of the site.

The horizontal distribution plot of burnt flint from Trench VI did not reveal any significant concentrations. However, if the material was in situ, then it is likely that a retooling area had been in close proximity.

The large amount of debitage and the reject cores suggested that flint tools had been made at the site.

From the evidence of the wear-traces on the tools and in some instances the objects probably made with the tools, as well as the botanical and the faunal remains, the following tasks could be reconstituted: harvesting domesticated crops and non-crop plants, drilling wood and stone, engraving stone, bone and shell, scraping wood, hide, stone and bone, chopping wood, perhaps felling trees, and shooting, presumably game.

2. - The Benefits of High-Power Microwear Analysis

It will be clear that one purpose of adopting this method, namely to define possible activity areas through a distribution analysis of implements according to worked materials, was not achieved. This was for the following reasons:

- most tools did not have any definite wear-traces.

- It has been demonstrated (Part I, Chapter 20) that on some tools, e.g. cutting implements used on materials other than plant or wood, wear-traces could not be identified with certainty. This could also not be done on tools which had not been used for some time, nor on tools of coarse flint which had been used for some time (Part I, Chapter 17). Polishes from the same materials could look different since many variables affected polishes. On the other hand, polishes from different materials could look indistinguishable (Part I, Chapter 14).

- Post-depositional surface modifications were present on all tools to a varying degree (Part II, Chapter 8).

- No meaningful sampling process could be devised. Even if sampling had been carried out according to edge damage, one would have excluded tools used on soft materials.

- A high-power microwear analysis of all the flint tools and debitage from several squares would have taken an enormous amount of time, even if wear-traces could be identified on all the implements.

It could be argued that the results of this microwear analysis were often negative because I had had only three years in which to gain experience and to complete my work, and/or perhaps that the flint from the site was unsuitable, either because of its quality or because of post-depositional surface modifications. However, I would argue that the blind tests were conducted at the end of the three years and that the results were not markedly different from those of other researchers with longer experience. The flint from Arjoune, although often coarse-grained, did develop wear-traces as rapidly as English or French flint or chert of corresponding grain-size, and looked in better condition than flint from many other sites which I examined. The site of Arjoune, in prehistoric terms very recent, did not undergo the enormous climatic and environmental changes found in those sites which existed during or before the last glaciation. I therefore feel that my results are relevant to high-power microwear analysis in general.

However valuable supplementary information about the site was derived from the high-power microwear analysis and this method could therefore be useful for this purpose. It also seemed a very good method of investigating individual tool types, especially when the used edge and action of a tool could be identified with some certainty, and when use-wear polishes were strongly developed. Comprehensive experimentation in which many variables were taken into account did seem to produce results which matched other lines of evidence. This was especially the case with the analysis of drills (Part I, Chapter 20) and of sickle blades (Part II, Chapter 17). Furthermore, it appeared that through examination of certain wear-traces (striations) on assemblages of Epi-Paleolithic sickle-blades a major archaeological problem, namely the beginning of plant cultivation, could be solved (Part II, Chapter 17.10).

In general, therefore, high-power microwear analysis can be of considerable value to the archaeologist, provided its present limits are clearly recognised and it is not taken to be the panacea for all problems concerning prehistoric sites. I feel that the major contribution of this thesis was to call attention to such limits (see Conclusions: Theory and Method of Microwear): polishes do not mysteriously conform to precise worked materials, and a great number of variables is involved in polish formation. Other limiting factors are that polishes are affected not only by natural agencies but equally by cleaning with chemicals, and that residues supposedly from worked materials appeared to be constituents of the flint itself. I therefore feel that this thesis has taken microwear analysis a step towards a realistic assessment of what it can and cannot do. The results of my work demonstrate that microwear analysis requires a great deal more painstaken and scientifically controlled research and that it needs to be subjected to far more stringent controls, be it blind tests, be it "objective" comparison (by means of computer scans (Grace _et al._, 1986)) of polishes. The results of my work also indicate that far more documentation than has been the rule is required in publications dealing with this subject, and that a site distribution analysis involving a large number of tools is simply not practicable at this stage. Equally it appears that, as with other specialists such as archaeobotanists, a great deal of training is required before a microwear analyst can make a valuable contribution to archaeology. I hope it is also clear that such a contribution is of value, and with future developments, possibly, of great value.

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Appendix - List of Experiments

The items are listed in the following order: the tool, the stone type of the tool, the movement of the tool, the condition of the material, the material, the number of strokes or the time of use, the experimenter.

The following abbreviations are used for the stone type: (B)-Brandon flint, (PB)-Potter's Bar flint, (S)-Surrey flint, (Syr)-Syrian flint from Arjoune, (Syr A,B,C,D)-refers to different types of flint from Arjoune (see Part I, Chapter 17), (F)-French chert, (E)-Egyptian chert, (L)-Lebanese chert.

All blades were used to cut, unless otherwise indicated. Scrapers, borers, drills etc. were used with the movement indicated by the tool's name, unless otherwise indicated. Drills were used in a bow-drill made by Christopher Bergman.

All materials were fresh, unless otherwise indicated.

The duration of work is measured in sawing motions (s.m.) or single strokes (str.), or else in hours and minutes (mins.). "To...s.m." means that the tools were examined at various stages during work.

The experiments were carried out by me, unless otherwise indicated. The experimenters made their own tools. The following abbreviations are used for the experimenters: CB-Christopher Bergman, MHN-Dr.Mark Newcomer, GCH-Gordon Hillman, PH-Philip Harding, PD-Peter Dorrell, PP-Peter Parr, RM-Robert Miller, EHM-Dr.Emily Moss, JHM-John Hope Mason, CM-Christopher May, RUH-Romana Unger-Hamilton.

Experiments during which I was not present, are only listed if the wear-traces resulting from them are discussed in the text or illustrated. Experiments carried out for the blind tests are not listed.

Experiments with plants involved the testing of a great number of variables, and the information as regards these experiments is slightly different. Single blades were used, unless otherwise stated. Plants were cut at varying heights of the stem, unless otherwise stated. Two additional items are the month and year of the experiment (expressed in numbers), and the place; this was in Great Britain, unless otherwise indicated.

Wood

1/1-5 - 5 blades, (B, Syr A-D), used to scrape, beech, to 3200 str. each.

2 - blade (B), dried, oak, 800 s.m..

3 - blade (B), used to whittle, beech, 600 str.

4 - blade (Syr A), used to whittle, beech, 600 str..

5 - blade (Syr B), used to whittle, beech, 600 str..

6 - scraper (PB), dried, oak, 1200 s.m..

7 - borer (Syr), dried, wood, 10 mins., PD.

8 - burin (PB), used to groove, dried, wood, 20 mins., PD.

9 - blade (Syr), oak (with bark), 2000 s.m..

10 - blade (L), oak, 15 mins..

11 - blade (Syr), used to whittle, oak, 20 mins..

12 - burin (Syr), used to groove, oak, 20 mins..

13 - scraper (Syr), dried, oak, 1000 str..

14 - scraper (PB), dried, oak, 1000 str..

15 - scraper (Syr), dried, sycamore (with bark), 600 s.m..

16/1-2 - scraper (Syr), sycamore, 1 - distal edge of tool, 600 str., 2 - lateral edge, 1200 str..

17/1-2 - blade (B), sycamore, 1- lateral edge, 1000 s.m., 2 - other lateral edge, used to whittle, 1000 str..

18 - burin (S), used to groove , dried and soaked in water for 12 hours, ash, 1 hour.

19 - denticulate (S), used to scrape, ash (with bark), 30 mins..

20 - scraper (PB), ash, 1 hour.

21 - denticulated blade (S), ash, 30 mins..

22 - blade (S), used to shave and saw, birch, 30 mins..

23 - scraper (Syr), first cooked cow bone, then birch wood, 500 s.m. each.

24 - notch (Syr), used to scrape, birch (with bark), 1000 s.m..

25 - burin (Syr), used to groove, birch, 1000 s.m..

26 - pick (Syr), used to chop, oak, 30 mins..

27 - scraper (Syr), oak, 15 mins..

28 - borer (Syr), oak, 15 mins..

29 - scraper (Syr), oak, 15 mins..

30 - borer (Syr), oak, 15 mins..

31 - burin (Syr), used to groove, oak, 15 mins..

32 - pick (Syr), oak (with bark), 15 mins..

33 - drill (B), dried, ash, 20 mins., CB.

34 - drill (B), dried, ash, 17 mins., CB.

35 - blade (Syr), denticulated after 10 mins.'use, dried oak, 1 hour.

36/1-2 - 2 piercers (B), dried, ash, 10 mins., CB.

37 - scraper (Syr), cherry (with bark), 30 mins..

38 - flake (B), used to plane, dried, pine, 10 mins., RM.

39 - flake (F), used to plane, wood, 10 mins., RM.

40 - notch (PB), used to shave, wood, 10 mins., RM.

41 - blade (B), used to whittle, dried, cherry, 10 mins..

42 - notch (B), used to cut, dried, cherry, 5 mins..

43 - scraper (B), dried, cherry, 10 mins..

44 - borer (B), dried, cherry, 3 mins..

45 - denticulate (B), used to scrape, dried, cherry (with bark), 3 mins..

46 - blade with hook (B), used to incise, oak, 10 mins..

47/1-2 - 2 blades (B), used to saw and whittle, oak, 10 mins. each.

48 - borer (B), oak, 10 mins..

49 - blade (B), dried, wood, 30 mins.

50 - drill (B), dried wood, 22 mins., CB.

51 - tranchet axe (B), used to chop, hazel, 1500 str., PH.

Bone

1 - blade (B), dried, cow, 30 mins., CB.

2 - blade (B), cooked and dried, chicken leg, 200 sm..

3/1-5 - 5 blades (B) (Syr A-D), cooked, chicken leg, to 800 s.m. each.

4/1-5 - 5 blades (B) (Syr A-D), used to scrape, cooked, chicken leg, to 400 str. each.

5 - hafted scraper (Syr), dried, cow shoulder blade, 1 hour.

6 - scraper (Syr), dried, cow shoulder blade, 5 mins..

7 - flake (Syr), used to incise, dried, cow shoulder blade, 500 s.m..

8 - flake (Syr), used to bore, dried, cow shoulder blade, 5 mins..

9 - blade (Syr), cooked, pork rib, 800 s.m..

10 - scraper (Syr), cooked, pork rib, 800 str..

11/1-2 - 2 flakes, 1 - used to cut, 2 - used to scrape, cooked, pork rib, 800 s.m. each.

12 - scraper (Syr), cooked, pork rib, 1000 str..

13 - scraper (Syr), cow shin, 2000 str..

14 - denticulated blade, cow shin, 1000 s.m..

15/1-3 - scraper (PB), cooked, pork rib, 1-2 - 2 tool-edges with different angles, 1000 str. each, 3 - 200 str..

16 - scraper (Syr), lamb shin (with meat), 1000 str..

17 - scraper (B), cooked, cow shin, 1000 str..

18 - denticulated blade (S), cooked, cow shin, 1000 s.m..

19 - borer (S), used to groove, cooked, cow shin, 15 mins..

20 - denticulated blade (S), cooked and dried, cow shin, 1000 s.m..

21 - scraper (Syr), cooked, cow shin, 1000 str..

22 - scraper (Syr), cooked, cow shin, 1000 str..

23 - scraper (Syr), cooked, cow shin, 500 str..

24 - pick (Syr), dried, cow shin, 10 mins..

25 - notch (Syr), used to scrape, dried, cow shin, 500 str..

26 - burin (Syr), used to groove, dried, cow shin, 10 mins..

27 - burin (Syr), used to groove, dried, cow shin, 10 mins..

28 - blade (Syr), cooked, chicken leg, 1000 s.m..

29 - drill (Syr), dried, cow shin, 12 mins., CB.

30 - drill (F), dried, cow shoulder blade, 14 mins., CB.

31 - drill (B), dried, cow rib, 10 mins., CB.

32 - drill (B), bone, 10 mins., CB.

33 - blade (PB), boiled, bone, 3 mins., RM.

34 - flake (PB), used to scrape, meat from bone, time unknown, RM.

35 - flake (PB), used to cut into bone for marrow, time unknown, RM.

36 - blade (PB), boiled in detergent, bone, 10 mins., RM.

37 - notch (B), used to whittle, dried, cow shin, 5 mins..

38 - flake (Syr), used to groove, dried, cow shin, 5 mins..

39 - borer (Syr), used to groove, dried, cow shin, 5 mins..

40 - flake (Syr), used to bore, cooked, beef rib, 5 mins..

41 - burin (B), used to groove, deer foot, 30 mins..

42 - piercer (B), used to groove, deer foot, 30 mins..

43 - axe (Syr), used to chop, dried, cow shin, 10 mins..

44 - notch (B), used to shave, deer foot, 15 mins..

45 - blade (B), cooked, chicken leg, 10 mins..

Hide

1 - scraper (Syr), tanned, pig, 1000 str..

2 - scraper (Syr), tanned and soaked in water, pig, 1000 str..

3 - hafted scraper (F), deer, 2 hours, CB.

4 - scraper (Syr), deer, 32 mins., CB.

5 - hafted scraper (Syr), deer, 84 mins..

6 - scraper (B), deer, 5 mins..

7 - scraper (Syr), deer, 52 mins..

8 - flake (Syr), used to cut, meat, fat and connective tissue from deer hide, 10 mins. (See below, Meat 14.)

9 - drill (B), tanned, fallow-deer, 35 holes, CB.

10 - drill (B), cow, 32 seconds, CB.

11 - drill (B), tanned, deer, 200 holes, CB.

12 - scraper (F), deer (with ochre), 30 mins., CB.

13 - borer (F), leather, 5 mins., RM.

14 - scraper (B), used to dehair, defrosted, deer, 5 mins..

15 - scraper (Syr), defrosted, deer, 5 mins..

16 - blade (B), defrosted, deer, 5 mins..

17 - piercer (B), defrosted, deer, 5 holes.

18 - blade (Syr), used to pierce, defrosted, deer, 20 holes.

19 - denticulate (Syr), used to scrape, soaked for three days, roe-deer, 7 mins., with EHM.

20 - scraper (Syr), soaked for three days, roe-deer, 7 mins., with EHM.

Antler

1/1-3 - burins (PB) (Syr A,B), used to groove, soaked for 7 days, red deer, 500 s.m. each.

2 - 2 blades (PB), dried, reindeer, 500 s.m. each.

3/1-2 - 2 blades (Syr), dried, reindeer, 1 - 500 s.m., 2 - 1000 s.m..

4/1-2 - scraper (Syr), soaked for 3 days, reindeer, 1 - one edge 1000 s.m., 2 - another edge 2000 s.m..

5 - burin (Syr), used to groove, soaked for three days, reindeer, to 1200 s.m..

6 - borer (Syr), soaked for 3 days, reindeer, 8 holes.

7 - blade (Syr), soaked for 3 days, reindeer, 10 mins..

8 - burin (Syr), used to groove, soaked for 3 days, reindeer, 10 mins..

9 - borer (Syr), used to groove, soaked for 3 days, reindeer, 10 mins..

10 - drill (B), soaked, fallow deer, 14 mins., CB.

11 - drill (B), soaked, fallow deer, 10 mins., CB.

12 - borer (Syr), soaked for 3 days, fallow deer, 30 mins..

13 - scraper (Syr), soaked for 3 days, fallow deer, 2 hours.

14 - denticulated blade (Syr), soaked for 3 days, fallow deer, 15 mins..

15 - burin (Syr), used to groove, soaked for 3 days, fallow deer, 30 mins..

16 - blade (B), used to whittle, soaked for 1 day, fallow deer, 3 mins..

17 - burin (Syr), used to groove, soaked for 1 day, fallow deer, 100 str..

18 - denticulated blade (Syr), soaked for 1 day, fallow deer, 3 mins..

19 - notch (Syr), used to whittle, soaked for 7 days, fallow-deer, 15 mins..

20 - scraper (Syr), dried, red deer, 1000 s.m..

Horn

1 - blade (Syr), soaked for 4 hours, cow, 1200 s.m..

2 - scraper (Syr), soaked for 4 hours, cow, 1200 str..

3 - burin (Syr), used to groove, soaked for 4 hours, cow, 20 str..

4 - flake (Syr), used to incise, soaked, 5 mins..

Meat

1 - denticulated blade (B), pork, 400 s.m..

2 - blade (S), beef, 5 mins..

3 - blade (B), cooked, lamb and pork (with bone), 5 mins..

4 - flake (F), used to cut meat from bone, 10 mins., RM.

5 - flake (PB), used to cut, chicken (with bone), 15 mins, RM

6 - blade (PB), cooked, beef, 5 mins., RM.

7 - blade (PB), cooked, beef, time unknown, RM.

8 - blade (PB), pork, 5 mins., RM.

9 - blade (Syr), dried, sinew, 5 mins..

10 - notch (Syr), used to cut, dried, sinew, 5 mins..

11/1-4 - 4 blades (B), tendon from deer bone, 5 mins. each.

12 - several arrowheads, including 3 transverse arrowheads (B), hafted with resin, wax and sinew in fletched and barbed arrows, each used to shoot once at distance of 4 meters, defrosted, deer carcass, CB.

13 - Point (B), hafted in a barbed arrow, used to shoot once, meat and bone, MHN.

14 - flake (Syr), used to cut, meat, fat and connective tissue from deer hide, 10 mins. (see above Hide 8).

Fish

1 - blade (B), used to gut and scale, gurnet, 20 mins..

2/1-2 - 2 blades (Syr A,B), used to scale, bream, 5 mins. each.

3 - blade (Syr), used to gut and scale, trout, 20 mins..

4 - flake (PB), used to scale, fish, 10 mins., RM.

Shell

1 - drill (B), scallop, 12 mins., CB.

2 - drill (B), scallop, 7 mins., CB.

3 - drill (B), cardium, 7 mins., CB.

4 - burin (Syr), used to incise, ormar, 5 mins..

5 - scraper (Syr), used to saw, ormar, 5 mins..

6 - scraper (Syr), concretions from ormar shell, 5 mins..

7 - borer (B), ormar, 5 mins..

8 - burin (B), used to cut, ormar, 10 mins..

9 - scraper (B), used to saw, ormar, 10 mins..

10 - scraper (B), concretions from ormar shell, 5 mins..

Stone

1/1-8 - 8 flakes (B), used to rub against, 1 - flint (B) without water, 2 - flint (B) with cold water, 3 - flint (B) with hot (100 C degrees) water, 4 - flint (B) with detergent, 5 - flint (B) with vinegar, 6 - quartzite, 7 - flint (B) without water, 8 - flint (B) with cold water, 200 s.m. each.

2 - burin (Syr), used to groove, limestone, 20 mins., PD.

3 - flake (Syr), used to groove, limestone, 7 mins..

4 - flake (Syr), used to polish, quartzite, 10 mins..

5 - borer (Syr), used to incise, quartzite, 10 mins.

6/1-6 - 6 flakes (B), used to rub against flint (B), 1 - with 10% NaOH, 2 - with 30% H H O , 3 - with hot water, 4 - with cold water, 5 - with 10% HCl, 6 - with oil, 100 s.m. each.

7 - drill (B), metamorphic rock, 1 hole, CB.

8 - drill (B), lapis lazuli, 12 mins., CB.

9 - drill (B), laps lazuli, 19 mins., CB.

10 - drill (B), lapis lazuli (with sand and water), 36 mins., CB.

11 - drill (B), malachite, 5 mins..

12 - drill (B), lapis lazuli (with sand and water), 15 mins..

13 - drill (B), lapis lazuli (with sand), 10 mins., CB.

14 - drill (PB), malachite, 7 mins., CB.

15 - flake (Syr), used to incise, limestone, 5 mins..

16 - burin (B), used to groove, limestone, 10 mins..

17 - blade (B), limestone, 10 mins..

18 - scraper (Syr), limestone, 10 mins..

19 - blade (B), limestone, 10 mins..

20 - scraper (B), used to saw, limestone, 10 mins..

21 - notch (B), used to scrape, limestone, 5 mins..

22 - blade (Syr), used to scrape, limestone, 10 mins..

23 - borer (B), limestone, 10 mins..

24 - borer (B), limestone (with sand), 10 mins..

25 - blade (Syr), used to scrape, limestone, 1 min..

26 - blade (Syr), limestone, 1 min..

27/1-2 - 2 blades (Syr), limestone, 15 s.m. each.

28 - borer (B), limestone, 15 mins., CB.

Pottery

1 - burin (Syr), used to groove, sherd from ARJ V 111.3, 5 mins..

2 - flake (Syr), used to groove, sherd from ARJ V 111.3, 5 mins..

3 - borer (Syr), sherd from ARJ V 111.3, 5 mins..

4 - flake (Syr), used to incise, sherd from ARJ V 111.3, 5 mins..

5 - burin (Syr), used to groove, sherd from ARJ V 111.3, 10 mins., PD.

6/1-3 - 3 drills (B), various sherds from Abu Salabikh, several holes, CB.

Sand

1 - 2 flakes (B), used to rub together with English soil, 5 mins..

2 - 4 threshing flints from Cyprus (ethnographic items in the collection of the Institute of Archaeology, London).

3 - 20 flint pieces (B) (Syr A-D), some burnt, left in a perforated basket in a fast-running stream for 5 weeks.

Feather

1 - blade (B), quill of pigeon feather, 400 s.m..

Wool

1 - blade (Syr), Shetland sheep, 15 mins..

2 - denticulate (Syr), Shetland sheep, 5 mins..

Ivory

1 - drill (B), hippopotamus tooth, 10 mins., CB.

Copper

1 - drill (B), copper, 7 mins..

2 - drill (F), copper (with sand and water), 7 mins..

Plant

1 - curved sickle, 4 blades (B), reed (cut at the base of the stem), 100 s.m., 5-82, GCH.

2 - straight sickle, 8 blades (B) (F) (obsidian), grass, to 5 hours, 1 min., MHN.

3 - straight sickle, 7 blades (B), grass (cut at the base of the stem), to 500 s.m., 7-82.

4 - curved sickle, 3 blades (B), grass (cut at the base of the stem), to 500 s.m., 7-82.

5 - straight sickle, 10 blades (PB) (E), grass (cut at the base of the stem), to 10,000 s.m., 7-82.

6 - curved sickle, 4 blades (PB) (B), *Sparganium ramosum* (at the base of the stem), 500 s.m., 7-82.

7 - (S), dried (1 month), reed, 3000 s.m., 8-82.

8 - (B), domestic barley, 7620 s.m., 7-82.

9 - curved sickle, 4 blades (L) (B) (PB), reeds, to 6000 s.m., 7-82.

10 - 2 blades (B), domestic einkorn, to 4000 s.m., 9-82.

11 - 3 blades (B) (L) (PB), domestic einkorn, to 4000 s.m., 9-82.

12 - (B), dried (4 days), domestic einkorn, to 8000 s.m., 9-82.

13 - (B), dried (12 days), to 6000 s.m., 9-82.

14 - (B), dried (10 weeks), reed, to 6000 s.m., 9-82.

15 - (S), bulrush, to 6000 s.m., 8-82, 8-83.

16/1-7 - 7 blades (B), 1-3 - grass, to 1200 s.m., 4-7 - dried (1 month), grass, to 2400 s.m., 9-82. 17/1-11 - 11 blades (B), reed (cut at the base of the stem), 1 to 5 stems, to 500 s.m., 9-82, JHM, CM and RUH.

18/1-7 - 7 blades (B), reed, 1 to 5 stems, to 1600 s.m., JHM, CM and RUH.

19 - (B), reed, to 2000 s.m., 11-82.

20 - (Syr A), reed, 2500 s.m., 11-82.

21 - (Syr B), reed, 5000 s.m., 11-82.

22 - 2 blades (B), reed, 300 s.m. each, 11-82.

23 - (B), used to scrape, reed, 500 str., 11-82.

24/1-2 - 2 blades (B), reed (cut at the base of the stem), 1 - 100 s.m., 2 - 300 s.m., 2-83, JHM.

25 - straight sickle, 5 blades (B) (coarse-grained English flint), wheat with barley and some weeds (cut at the base of the stem), 9 hours, PH.

26 - curved sickle, 6 blades (Syr), reed (cut at the base of the stem), 1800 s.m., 4-83, Arjoune/Syria, PD, PP, RUH.

27 - straight sickle, 8 blades (Syr) (PB), reed (mainly cut at the base of the stem), 1200 s.m., 4-83, Arjoune/Syria, PD, PP, RUH.

28 - denticulated blade (B), reed, 2000 s.m., 4-83, Arjoune/Syria, PD, PP, RUH.

29 - straight sickle, 8 blades (Syr), domesticated wheat and barley (cut at the base of the stem), 6-83, Aleppo, Syria, staff at I.C.A.R.D.A.

30 - curved sickle, 7 blades (Syr), Sparganium ramosum (cut mainly at the base of the stem), 1200 s.m., 4-83, Arjoune/Syria.

31/1-3 - 3 blades (Syr), cane, 1 - used to saw, 2000 s.m., 2 - used to scrape, 2000 str., 3 - used to bore, 5 holes, 4-83, Arjoune/Syria.

32 - curved sickle, 8 blades (E) (B), grass (cut at the base of the stem), 6-83.

33 - (S), bulrush (cut at the base of the stem), 1000 s.m., 8-82.

34 - straight sickle, 9 blades (Syr), wild barley (with wild oat, cut at the base of the stem), 2950 str., 6-83, Jerusalem, A. Miller-Rosen.

35/1-2 - 2 blades (B), horsetail, 1 - 200 s.m., 2 - 600 s.m., 7-83.

36 - (Syr), domesticated barley, 10,500 s.m., 8-83.

37 - (Syr), domesticated barley, 100 s.m., 8-83.

38 - (Syr), reed, 7000 s.m., 8-83.

39 - truncation (Syr), used to cut, reed, 3000 s.m., 8-83.

40 - straight sickle, 7 blades (B), wild einkorn and 10% domesticated einkorn (cut at the base of the stem), c.2000 str., GCH.

41 - straight sickle, 9 blades (Syr) (B), domesticated wheat (cut at the base of the stem), to 2 hours, 30 mins., 8-83, 8-84, PD, RUH.

42 - straight sickle, 9 blades (Syr) (B), domesticated spelt (cut at the base of the stem), 9-83.

43 - straight sickle, 9 blades (Syr), domesticated einkorn (cut at the base of the stem), 3 hours, 9-83.

44 - (S) crop weeds, 2000 s.m., 9-83.

45 - (B), Cyperus longus , 2000 s.m., 8-84.

46 - (B), Stipa gigantia , 3000 s.m., 8-84.

47 - (B), poppy (Papaver rhoea), 2000 s.m., 8-84.

48 - (B), poppy (Papaver orientale), 2000 s.m., 8-84.

Root Vegetable

1 - blade (B), carrot, 200 s.m..

2 - blade (B), carrot, 1000 s.m.

Table 1 - Edge Damage
The number of tools (total of 72) is shown in brackets.
F=feather scar, St=Step scar, Sn=Snap scar (see Part I, Chapter 4).

Material	Sawing/Slicing	Scraping
Limestone (4)	(Pl.1:a), mainly St,some F (when held at angle of 45 degrees),lots Sn (when held at angle of 90 degrees (2)	(Pl.1:b), edge rounding, some St,F (2)

Limestone caused a lot of edge damage with large scars, mostly St. The number of F and Sn seemed to depend on the contact angle. Scraping caused abrasion rather than flaking.

Dried bone (18)	(Pl.1:c), mainly St,some F,Sn (5), almost none (1)	(Pl.1:d), edge rounding (12), of these F and St (10), no scars (2)

Dried bone caused a lot of edge damage with large scars, mostly St. The implements which showed no damage were of the same coarse-grained frost-shattered flint.

Fresh reed (11)	(Pl.1:e), mainly St, some F, Sn (10)	(Pl.1:f) edge rounding, St and F (1)

Fresh reed caused almost as much and the same types and sizes of scars as did bone.

Dried antler (4)	(Pl.1:g) mainly St, some F, Sn (3)	(Pl.1:h), edge rounding, some St, F (1)

Dried antler caused somewhat less damage than the above materials.

Soaked Antler (3 days) (3)	(Pl.2:a) mainly Sn,St (2)	(Pl.2:b) edge rounding, a few F and St (1)

Soaked antler caused smaller scars, less St and less damage than did dried antler.

Wood (fresh and dried) (18)	(Pl.2:c), F,St,Sn in similar proportions (11)	(Pl.2:d) edge rounding, mainly F, but few (7)

Wood caused less and smaller scars than did harder materials. St were rare. I did not test the difference between fresh and dried wood.

Hide (10)	(Pl.2:e), a few small St, mainly F (2)	(Pl.2:f), edge rounding, a few F (8)

Hide caused mainly F and smaller scars than did the above materials. I did not test the difference between fresh and dried hide.

Meat (4)	(Pl.2:g), mainly F, but a few and very small St (4)	

Meat caused the least damage and the smallest scars of the materials listed. However, a few very small St could be seen.

Table 2 - Plant Polishes
(see Pl.22-25)

HD=horizontal distribution of polish, DD=depth distribution of polish; ST=striations, CSP=comet-shaped pits, H=small holes in the polish like the effect of sand-blasting, O=other attributes.
conc.=polish concentrated at edge but quite invasive
med.=medium

Plant	HD	DD	ST	CSP	H	O
Wild einkorn	conc.	med.	few	few	few	-
Dom. einkorn	conc.-wide	med.	many	many	many	-
Dom.wheat	conc.	med.	many	many	many	-
Dom.barley	conc.	med.	many	many	many	-
Grass	narrow	deep	few	few	-	-
Weeds	narrow	wear-traces too weak				
Stipa	wide	high	-	-	-	-
Horsetail	very conc.	deep	-	-	-	-
Reed	wide	high	-	-	-	-
Bulrush	wide	deep	-	few	-	-
Sparganium	wide	cracked polish				
Cyperus	narrow	med.	-	-	-	
Cane	very conc.	deep	-	corrugated effect		
Poppy	thin steaks of polish only, no gloss					

Table 3 - Blind Tests 1-10
The items are listed in the following order: tool type, used area, action, worked material.
MHN=experiment by Dr. Mark H. Newcomer
RUH=identification by Romana Unger-Hamilton

Tool	MHN	RUH
1	Scraper, ventral distal edge, scraping, wood.	scraper,vent.dist.edge, scraping, antler.
2	Drill, proximal tip, drilling, shell.	drill, distal tip, drilling, bone.
3	Piercer, distal tip, grooving, antler.	reamer, distal tip boring, antler.
4	Scraper, ventral distal edge, scraping, stone.	scraper, ventral distal edge, scraping, antler.
5	Burin, both burin edge, scraping, bone.	burin, both burin edges, graving, antler.
6	Retouched point, fired, sand.	backed blade, distal edge, sawing, bone.
7	Scraper, unused.	scraper, scraping, hide.
8	Backed bladelet, unretouched edge, cutting, meat.	backed bladelet, unret. edge,cutting, meat.
9	Blade, right edge, cutting and scaling fish.	blade, right edge, cutting, antler.
10	Burin, ventral facet, scraping, wood.	burin, ventral facet, scraping, antler.

Table 4 - Blind Tests 11-30
The ventral aspect of each flake was rubbed against a material for 10 minutes.

Tool	MHN	RUH
11	Dry hide	hard+dry, dry hide
12	Soaked antler	med.hard+not dry,soaked antler
13	Wood	soft,meat or fresh hide (touched something hard)
14	Soaked antler	hard+not dry, soaked antler or fresh bone
15	Fern	med.soft+med.dry, wood
16	Dry hide	soft, meat or unused
17	Wood	med.hard, not dry, wood or dry reed
18	Fresh bone	hard+not dry, fresh bone
19	Fern	med.hard, not dry, reed or wood
20	Fresh bone	med.hard-hard, not dry, fresh bone

Table 5 - Blind Tests 21-30

Each implement was used by Newcomer to saw a material for 10 minutes. It was known in advance that the materials were the same as those in the Blind Tests 11-20.

Tool	MHN	RUH (microscopic)	RUH (macroscopic)
21	Antler	hard+fresh, bone	med.-hard,antler,wood
22	Wood	soft, hide	soft, fern
23	Fern	med.-hard, not dry, antler	med.-hard, hide
24	Bone	med.-hard+fresh, fern	hard, bone or antler
25	Hide	soft, hide	med.-hard,wood,antler
26	Fern	edge damage:bone	hard, bone
27	Antler	hard+fresh, wood	med.-hard, wood
28	Hide	med.-hard+fresh, fern	med.-hard, hide
29	Bone	med.-hard+fresh, antler	soft, fern
30	Wood	med.-hard+fresh, wood	wood

Table 6 - Experimental Harvest - Proportions of Cereals, Grass and Weeds

The counts were carried out in 1983 by staff at Butser Ancient Farm, Field IV, at the trial plots which I harvested with flint sickle blades. Each sample consisted of a 3 meter run along one row of crops.

Einkorn

stalks 409 and 372
grass nil and nil
weeds 22 and 37

Emmer

stalks 370 and 382
grass 2 and nil
weeds 28 and 50

Spelt
stalks 200 and 197
grass 5 and nil
weeds 33 and 30

Einkorn

stalks 407 and 372
grass nil and nil
weeds 13 and 40

Spelt

stalks 102 and 122
grass 2 and 1
weeds 20 and 17

Table 7 - The Lithic Artefacts from Arjoune, Trenches I-IV, Mounds B and C (Surface)
(after Copeland, in prep.)

Type	Number
Arrowhead	1
Axe, pick, chisel	1
Sickle elements	16
End-scrapers	2
Flake-scrapers	13
Side-scrapers	3
Burins	3
Borers, drills	4
Denticulates, notches	1
Backed knives	2
Divers retouched pieces	9
Non-flint tools	9
Obsidian pieces	9
Truncations	1
Tool total	98
Debitage	
Cores: Prismatic	3
Discoid	7
Double	1
Other	5
Knapping products	16
Unretouched flakes and blades	162
" cortex-flakes	30
" fragments and debris	131
Debitage total	355
Artefact total	453

The above list does not include the 88 lithic artefacts recovered from Trench I, Phase I which Copeland listed in a separate table. Phase I was apparently the only undisturbed prehistoric phase found in Trenches I-IV. Of the 88 artefacts only 3 were classified as tools.

Table 8 - Lithic Artefacts from Arjoune, Trench V
(after Copeland, in prep.)

Type	Number	%
Axes, chisels, picks	7	0.69
Arrowhead fragments	3	0.29
Choppers	55	5.47
Sickle-elements: lustred unretouched	18	1.79
" " backed and truncated	74	7.36
" " truncated	29	2.88
" " crescentic backed	4	0.39
Retouched bladelets, microliths	16	1.59
End-scrapers	24	2.38
Straight-ended scrapers	11	1.09
Flake-scrapers	38	3.78
Core-scrapers, steep-scrapers	31	3.08
Racloirs	33	3.28
Raclettes	19	1.89
Burins	42	4.17
Borers, piercers, drills	45	4.47
Denticulates	108	10.74
Notched pieces	103	10.24
Backed blades, knives	3	0.29
Composites	32	3.18
Naturally-backed knives	27	2.68
Abruptly retouched pieces	29	2.88
Pieces with nibbled retouch	90	8.95
Bifacially retouched pieces	5	0.49
Pieces with inverse/alternate retouch	9	0.89
Hammerstones	36	3.58
Anvils	24	2.38
Obsidian pieces	7	0.69
Other non-flint artefact fragments	78	7.76
Truncations	-	-
Tool total	1,004	99.45%

Debitage		
Cores:	Prismatic	300
	Discoid	46
	Polyhedric/amorphous	60
	Double-ended	71
	Minute	105
	Fragmentary	51
	Rough-outs	38
Knapping products:	Tablets and spalls	56
	Crested blades/flakes	102
	Core refreshment pieces	75
Unretouched	flakes	607
	blades	134
	bladelets	184
	cortex-flakes	552
	part-cortex flakes	1,269
	preparation flakes	2,122
	fragments, debris	2,997
	Debitage total	8,769

Artefact total	9,773
Non-artefacts	2,465
Total examined	12,248

Table 9 - Lithic Artefacts from Arjoune, Trench VI
(after Copeland, in prep.)

Type		Number	%
Axes		1	0.41
Arrowheads		4	1.65
Choppers		1	0.41
Sickle elements:	lustred unretouched	6	2.48
	backed, 2 truncations	14	5.80
	backed, 1 or no trunc.	30	12.44
	truncated	10	4.14
	crescentic backed		
Retouched bladelets, microliths		4	1.65
End-scrapers		2	0.82
Straight-ended scrapers		1	0.41
Flake-scrapers, fan-scrapers		9	3.73
Core-scrapers, steep-scrapers		2	0.82
Racloirs		4	1.65
Raclettes		5	2.07
Burins		7	2.90
Borers, piercers, drills		16	6.63
Denticulates		7	2.90
Notched pieces		15	6.22
Backed blades, knives		3	1.24
Composites of above (scrapers to knives)		10	4.14
Naturally-backed knives		6	2.48
Miscellaneous retouched pieces:	abruptly retouched	8	3.31
	nibbled retouch;'utilised'	57	23.65
	bifacial retouch	1	0.41
	inverse/alternative ret.	13	5.39
Hammers, anvils		1	0.41
Obsidian			
Other non-flint artefacts		2	0.82
Truncations (not sickles)		2	0.82
	Tool total	241	99.80%

Debitage		Number
Cores:	Prismatic	27
	Discoid/flat	9
	Polyhedric/amorphous	8
	Double-ended	5
	Minute	11
	Fragmentary	23
	Rough-outs	5
Knapping products:	tablets and spalls	3
	crested blades and flakes	6
	core-refreshment flakes	15
Unretouched	flakes	117
	blades	174
	bladelets	21
	cortex-flakes	70
	part-cortex flakes	109
	preparation flakes	280
	fragments, debris	353

Debitage total	1,236
Artefact total	1,477
Non-artefacts	383

Table 10 - Lithic Artefacts from Arjoune, Trench VII (after Copeland, in prep.)

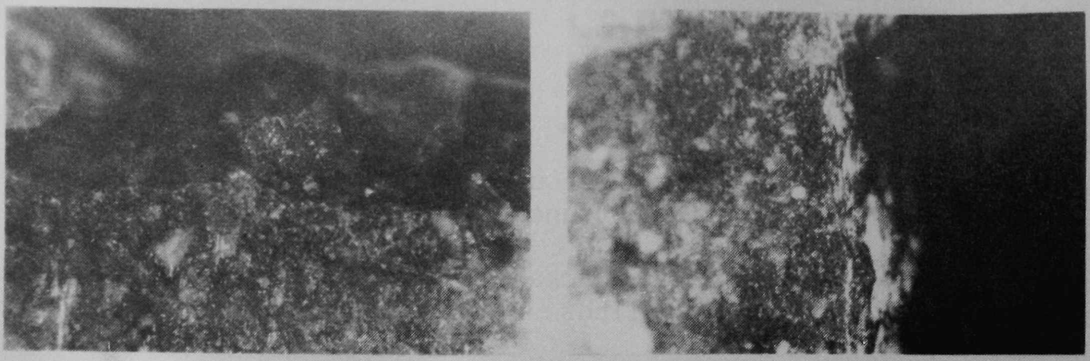
Type		Number	%
Axes, chisels, picks		1	0.98
Arrowheads			
Choppers		4	3.92
Sickle elements:	lustred, unretouched	2	1.96
	backed and truncated	15	14.70
	truncated	2	1.96
	crescentic backed	4	3.92
Retouched bladelets, microliths		4	3.92
End-scrapers			
Straight-ended scrapers		1	0.98
Flake-scrapers		6	5.88
Core-scrapers, steep-scrapers		1	0.98
Racloirs		5	4.90
Raclettes			
Burins		4	3.92
Borers, piercers, drills		5	4.90
Denticulates		3	2.94
Notched pieces		4	3.92
Backed knives		1	0.98
Composites		2	1.96
Naturally-backed knives			
Abruptly retouched pieces		8	7.84
Pieces with nibbled retouch		14	13.72
Pieces with bifacial retouch		1	0.98
Pieces with inverse/alternate retouch		6	5.88
Hammerstones		2	1.96
Anvils			
Obsidian pieces			
Other non-flint artefacts		1	0.98
Truncations		6	5.88
	Tool total	102	99.96%

Debitage

Cores:	Prismatic	14		
	Discoid	6		
	Polyhedric/amorphous	11		
	Double-ended	11		
	Minute	35		
	Fragmentary	19		
	Rough-outs	2		
Knapping Products:	tablets, spalls	9		
	crested blades/flakes	10		
	core-refreshment pieces	12		
Unretouched	flakes	105		
	blades	44		
	bladelets	56		
	cortex flakes	71		
	part-cortex flakes	209		
	preparation flakes	594		
Fragments, debris		502		
	Debitage total	1,710	Artifact total	1,812

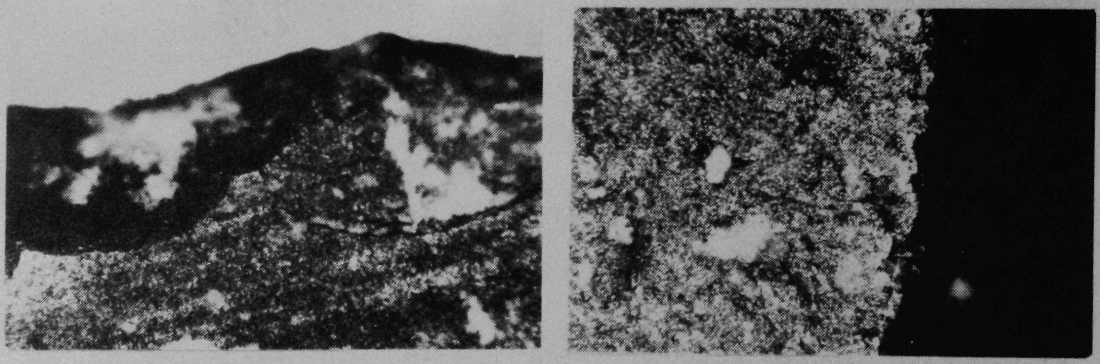
Plate 1 - Edge Damage

cutting scraping



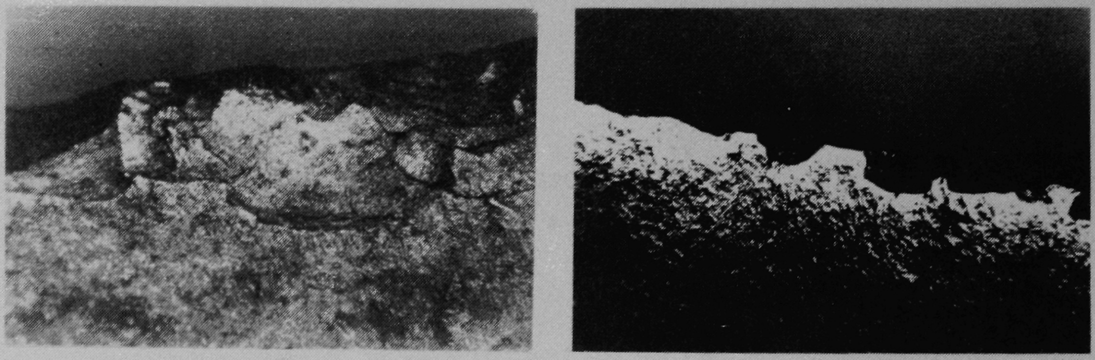
a-Stone 17

b-Stone 18



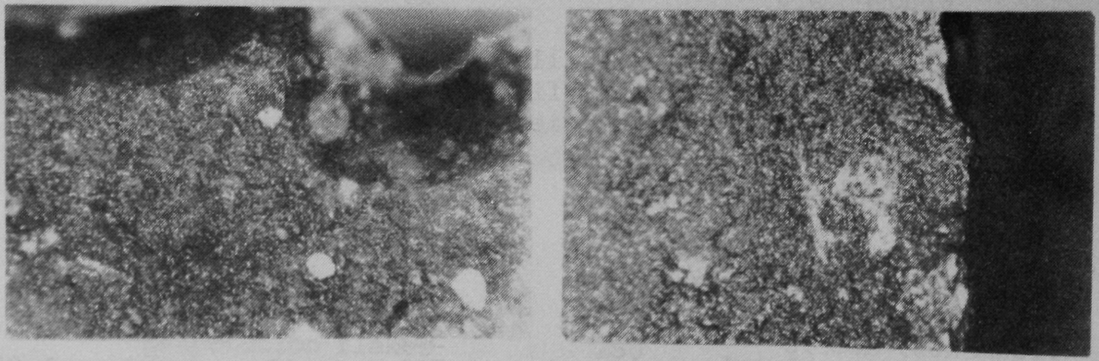
c-Bone 1, dried

d-Bone 5, dried



e-Plant 26, reed

f-Plant 23, reed



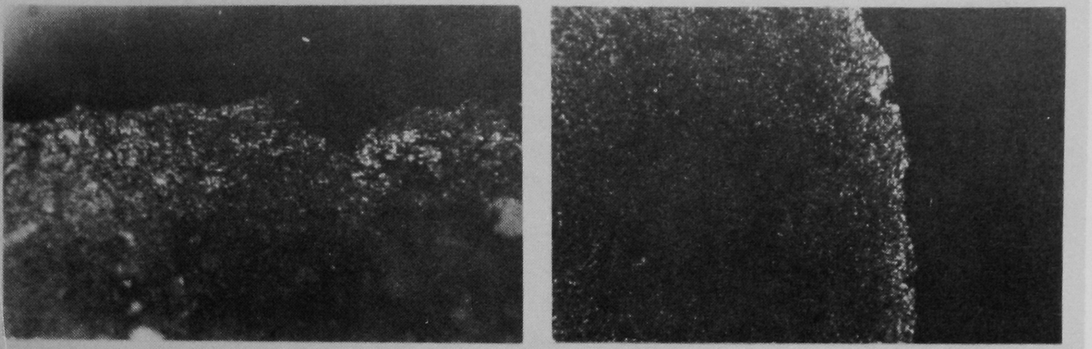
g-Antler 18, dried

h-Antler 20, dried

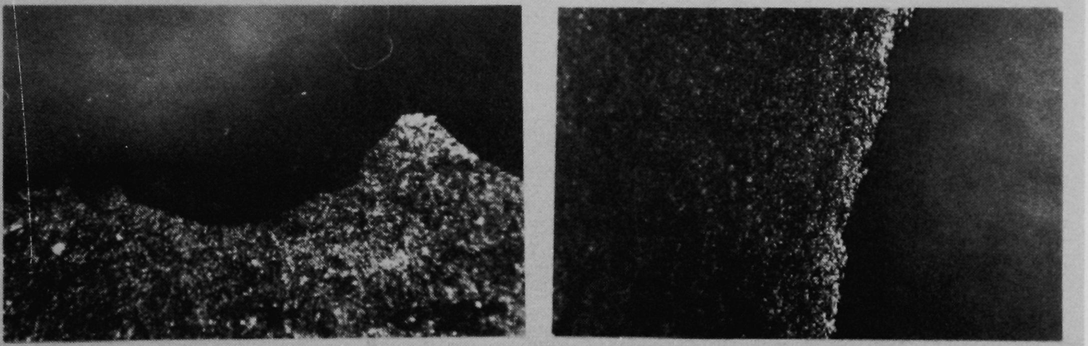
all experiments, 50x

Plate 2 - Edge Damage

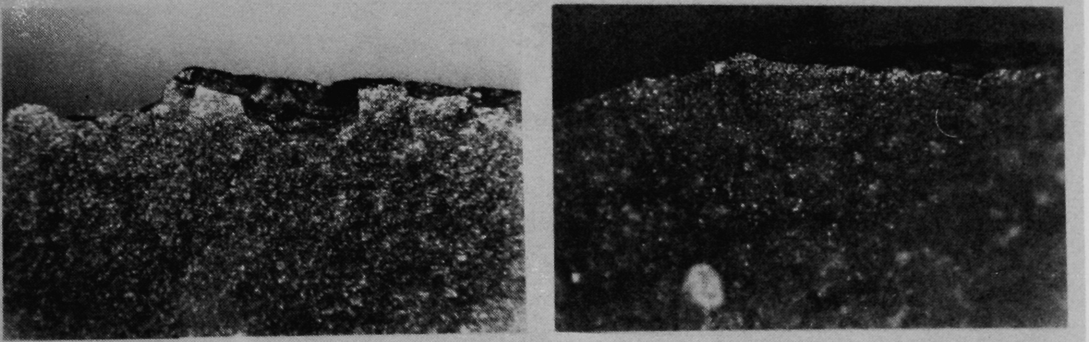
cutting scraping



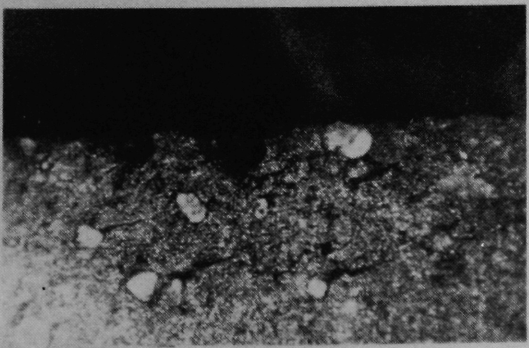
a-Antler 14, soaked b-Antler 13, soaked



c-Wood 2, dried d-Wood 6, dried



e-Hide 16 f-Hide 5

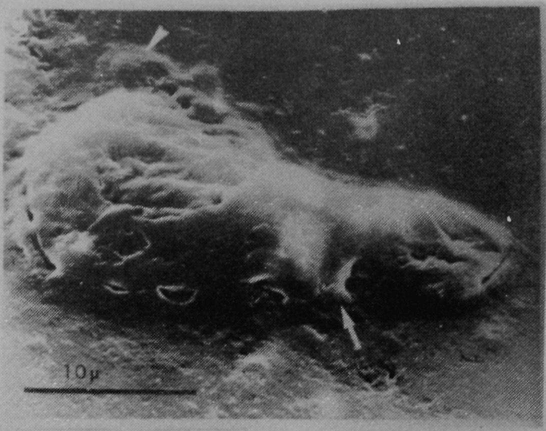


g-Meat 14

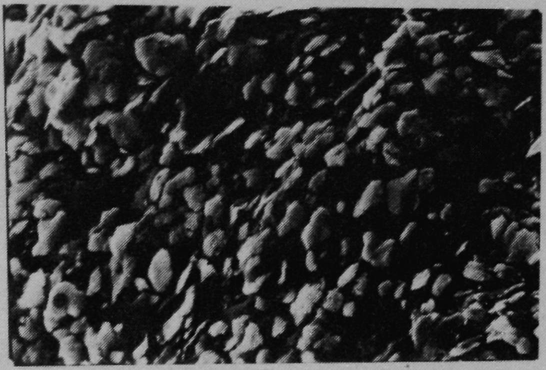
all experiments, 50x

Plate 3 - Residues (SEM)

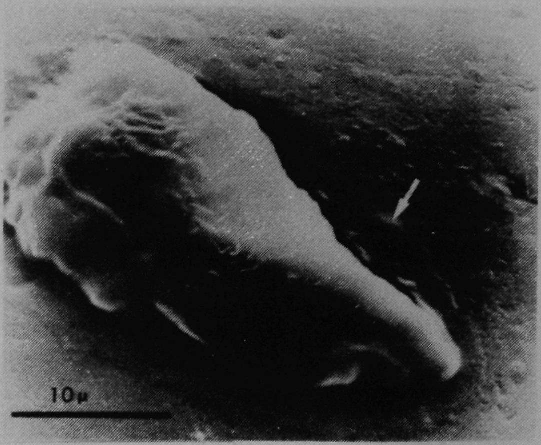
a-bone residues
(Anderson-Gerfaud, 1981), 4000x



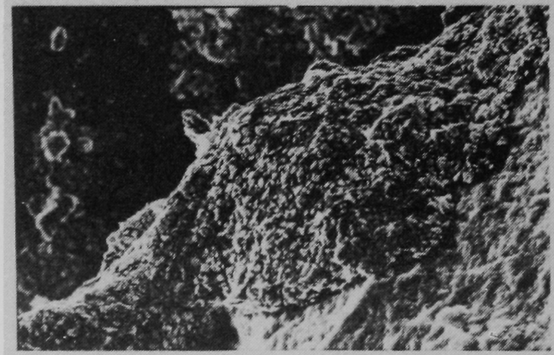
b-"phytolith"
(Anderson-Gerfaud, 1981), 5000x



c-experimental bone residues,
4000x, accelerated voltage 25V



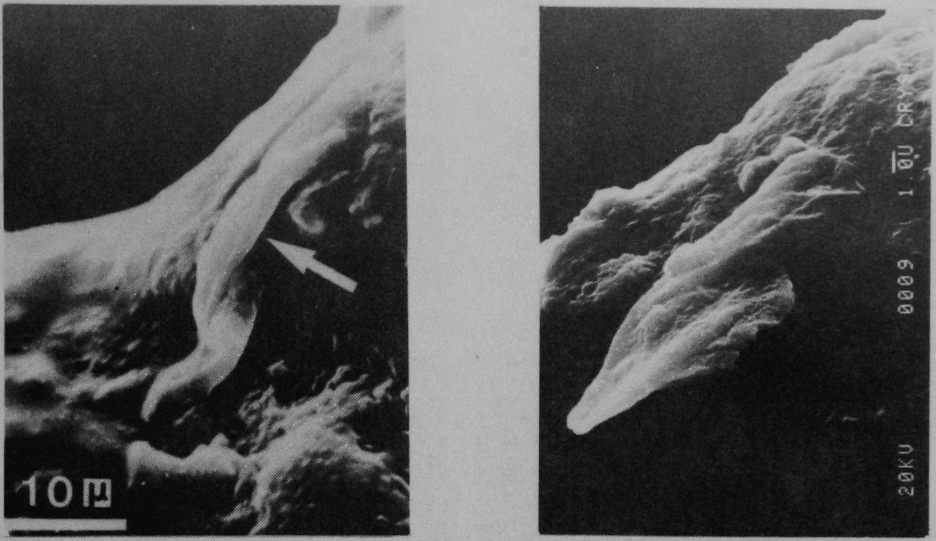
d-"phytolith"
(Anderson-Gerfaud, 1981), 4400x



e-lower power view of 2-c, 1000x

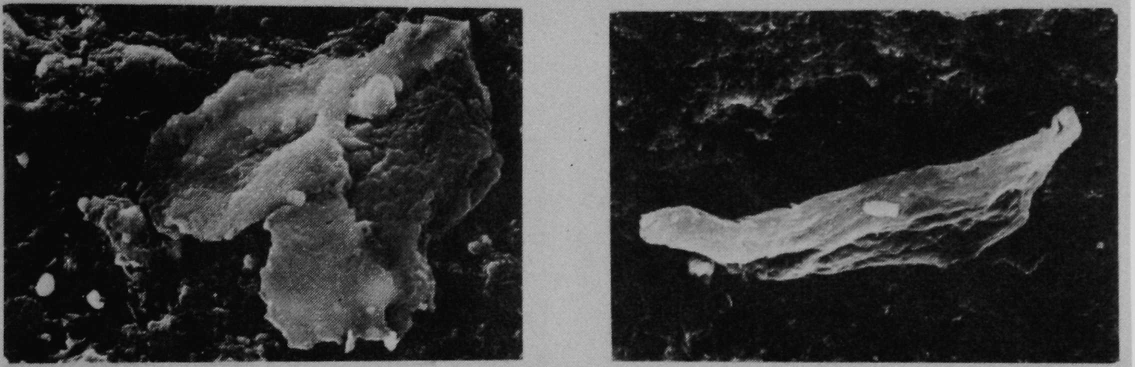
f-object on flint blade used
only to polish other flint, 4400x

Plate 4 - Residues (SEM)



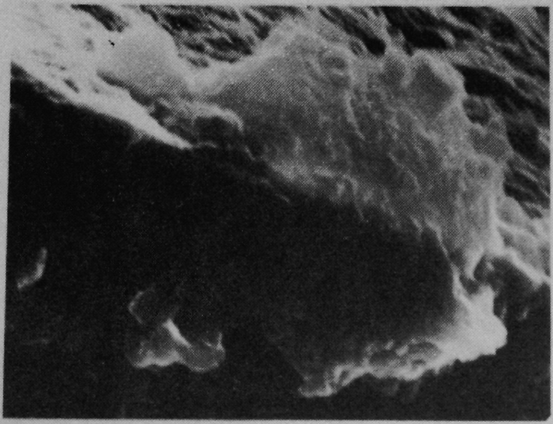
a-"cellular vegetable matter" (Anderson-Gerfaud, 1981), 1800x

b-object on flint blade used only to polish other flint 5400x



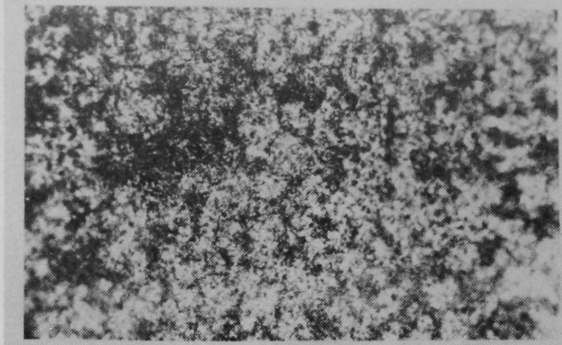
c-similar object on unused flint blade, 6000x

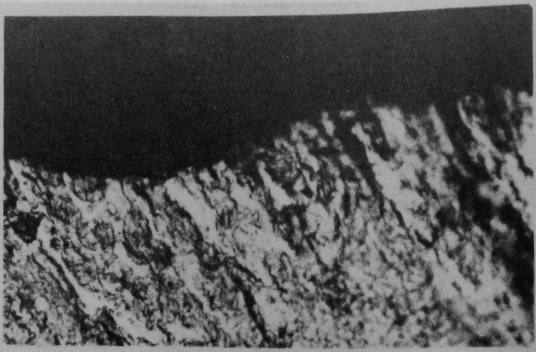
d-similar object on unused flint blade, 5400x

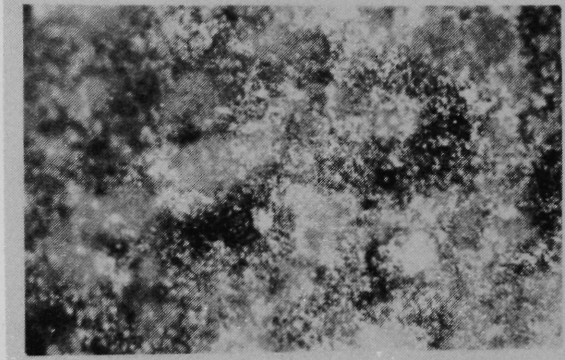


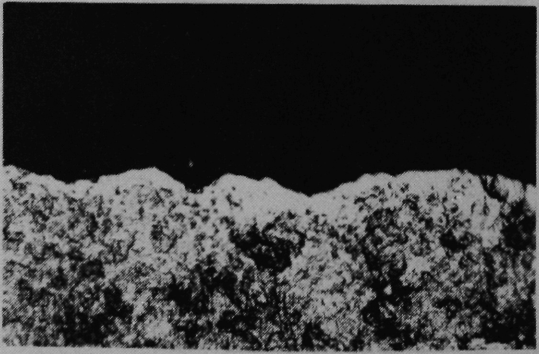
e-object protruding from the surface of an unused flint blade, 6000x

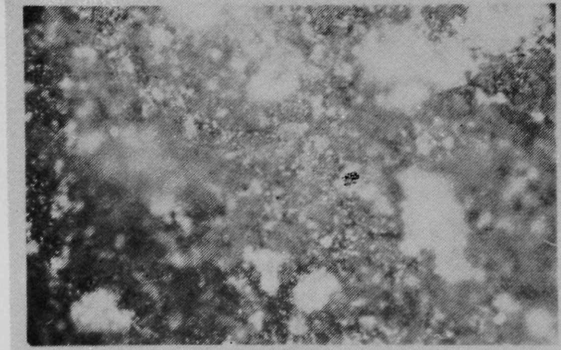
Plate 5 - Variables: Flint

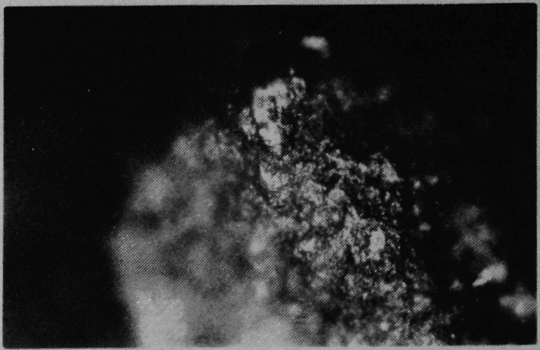

a-Wood 1/1, Brandon, unused

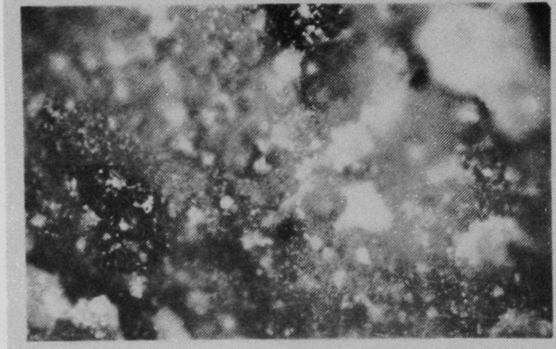

b-Wood 1/1, Brandon, 1400 s.m.


c-Wood 1/2, Syr.C, unused


d-Wood 1/2, Syr.C, 1400 s.m.


e-Wood 1/4, Syr.A, unused

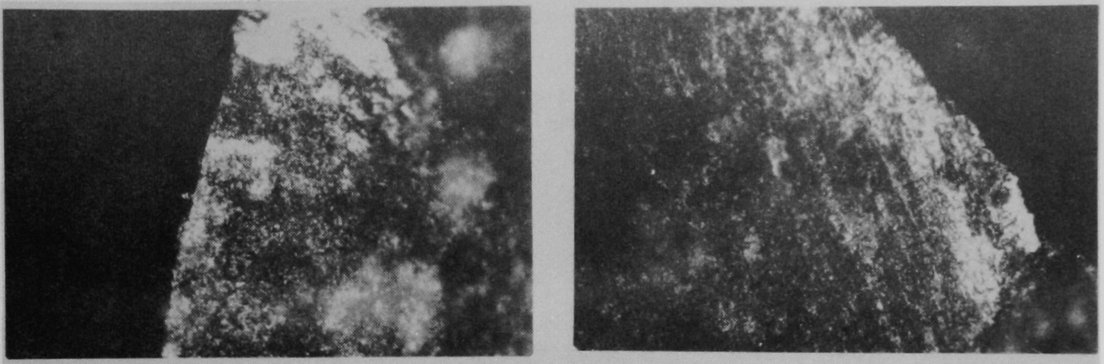

f-Wood 1/4, Syr.A, 1400 s.m.


g-Wood 1/5, Syr.B, unused


h-Wood 1/5, Syr.B, 1400 s.m.

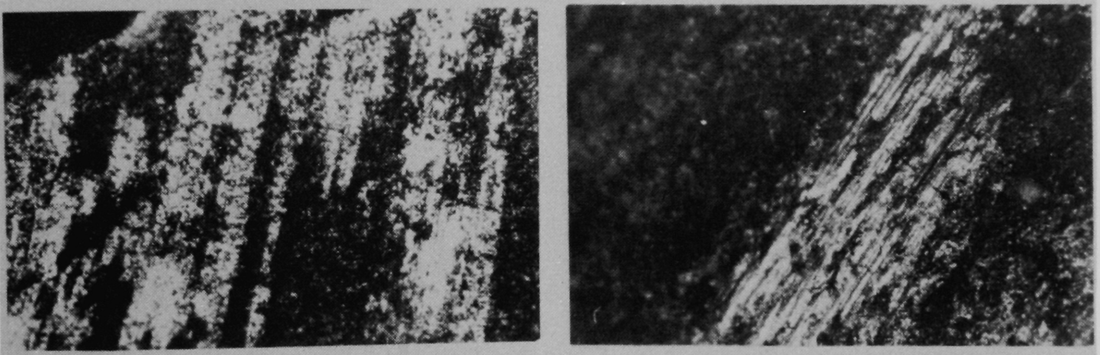
all experimental

Plate 6 - Manufacturing Traces and Burning



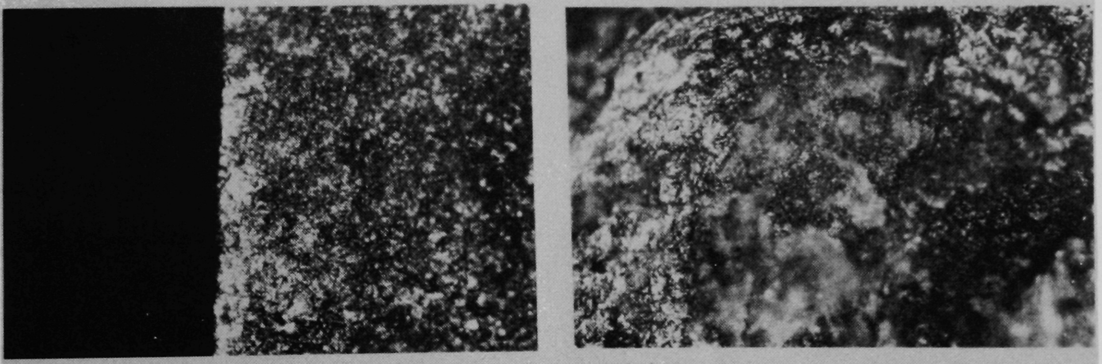
a-exp. limestone retouch, 100x

b-ARJ 702.3B, notch, 100x



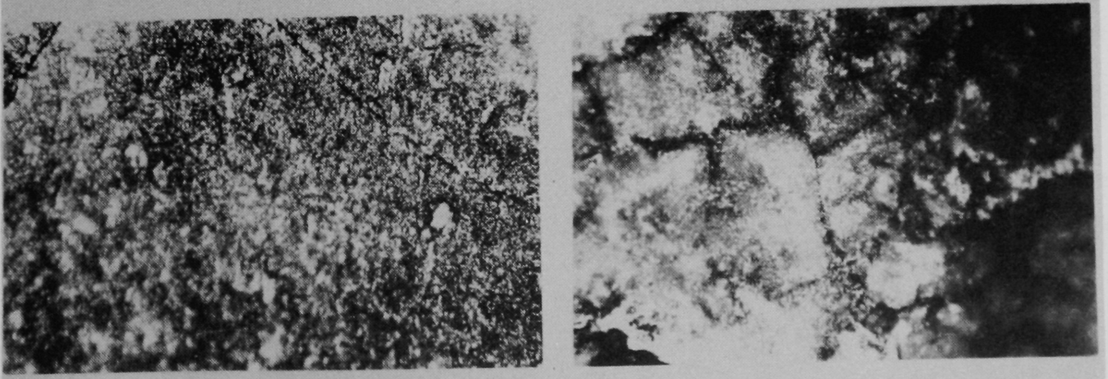
c-exp. quartzite retouch, 100x

d-ARJ 210.1, flake, 100x



e-exp. snapped blade, 200x

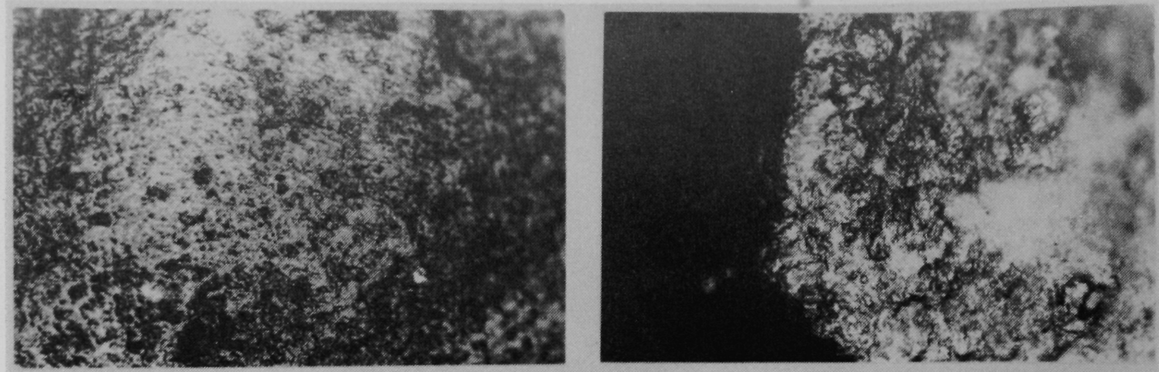
f-exp. antler retouch, 200x



g-exp. burnt flake, 100x

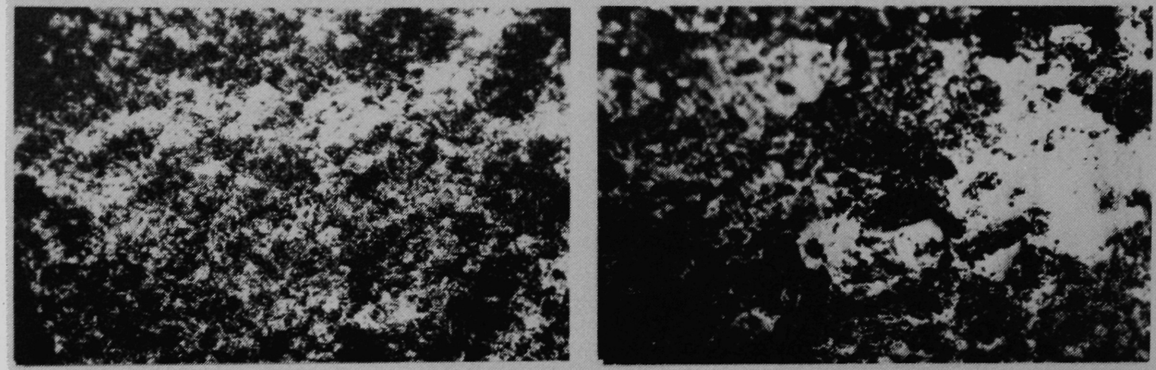
h-ARJ 221.10-232.4, 100x

Plate 7 - Natural Traces



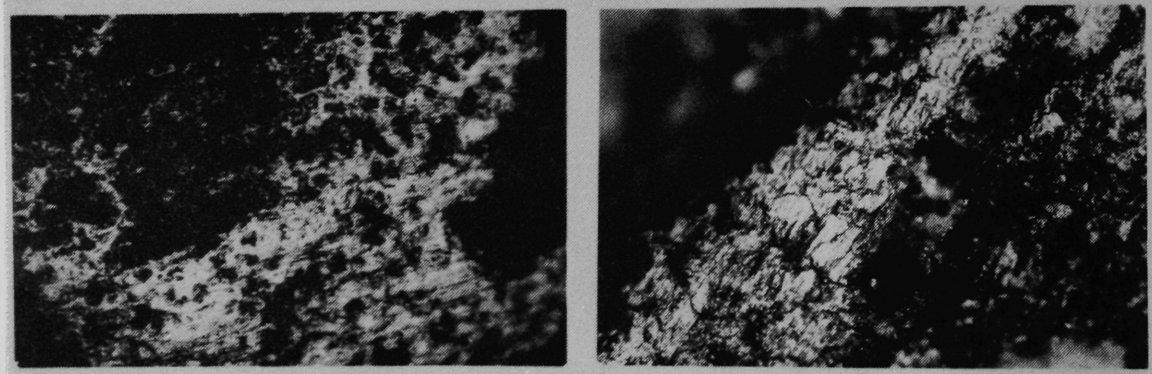
a-exp. Sand 1, 200x

b-ARJ 803.3, blade, 200x



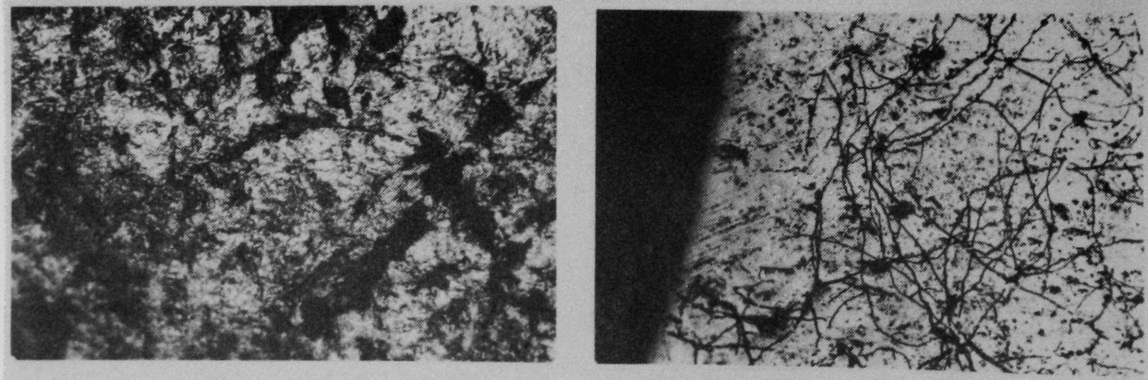
c-exp. Stone 1/8, + water, 100x

d-ARJ V, flake, 100x



e-exp. Stone 1/6, 200x

f-ARJ 701.3A, 200x

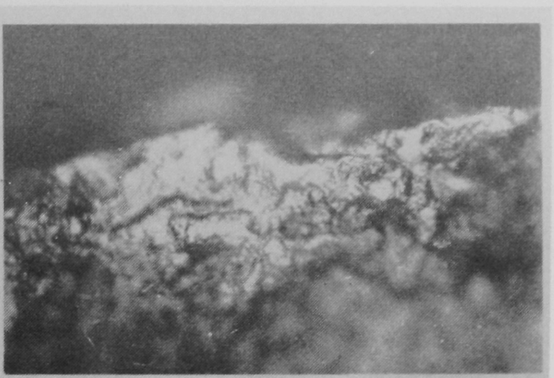


g-exp. Syr.D, unused, 100x

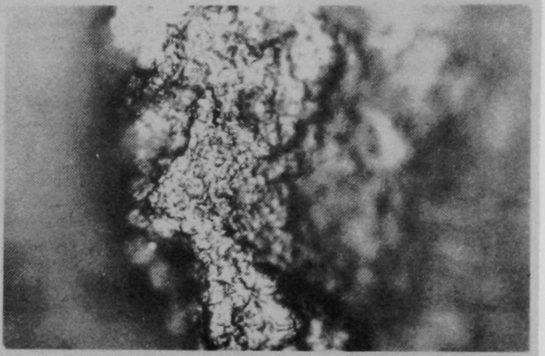
h-JPF 112.4, blade, 100x

Plate 8 - Scrapers

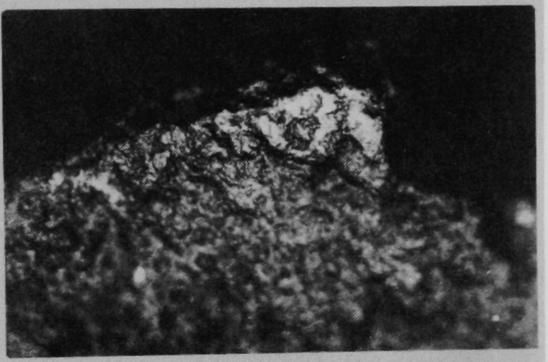

a-exp. Wood 1/4

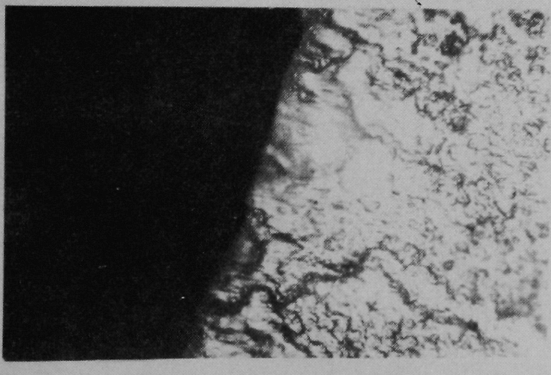

b-ARJ 1008.3


c-exp. Wood 1/5


d-ARJ VI, Surface


e-exp. Wood 15, dried sycamore


f-ARJ 800.1


g-exp. wood 16/1, sycamore

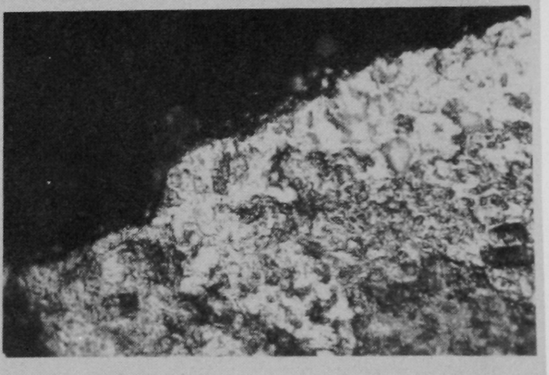
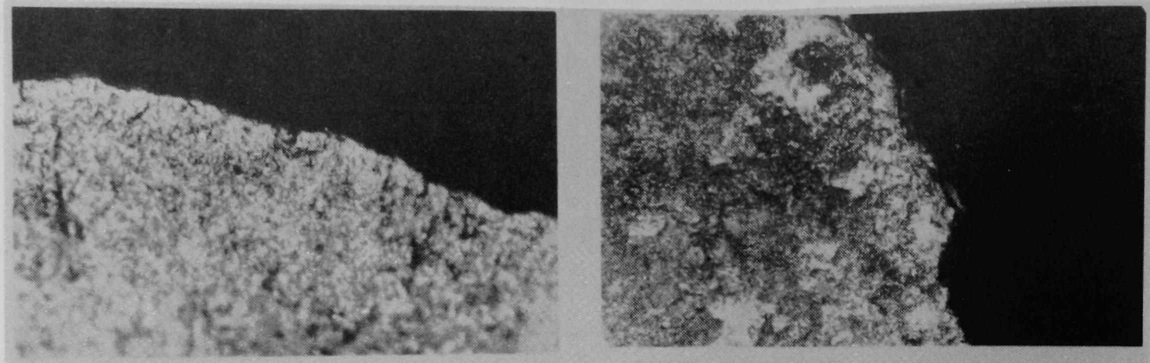
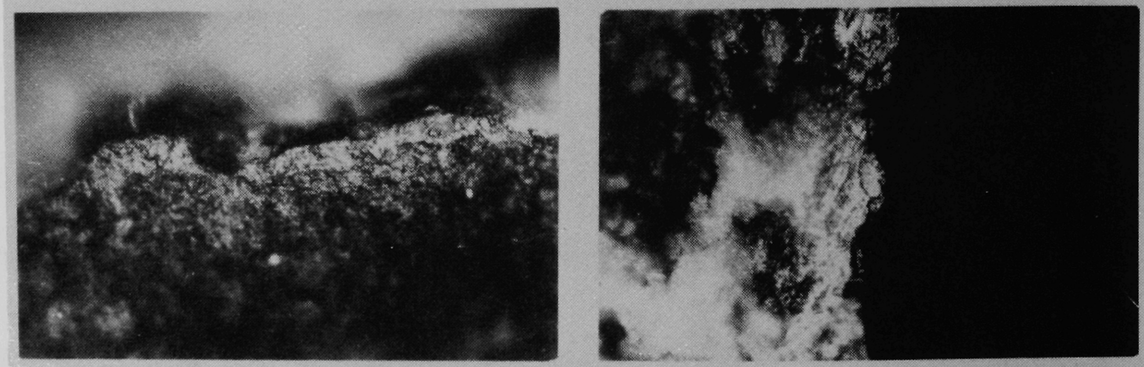

h-ARJ 220.1

Plate 9 - Scrapers



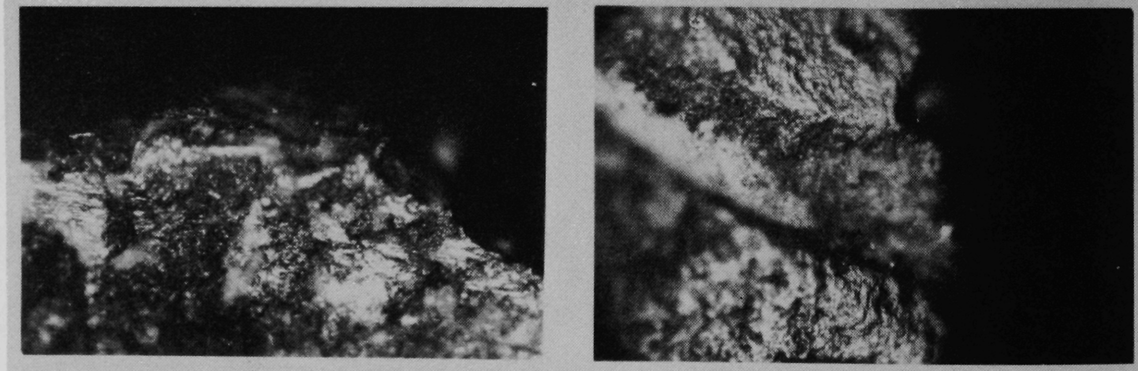
a-exp. Wood 37, + bark

b-ARJ 114.2



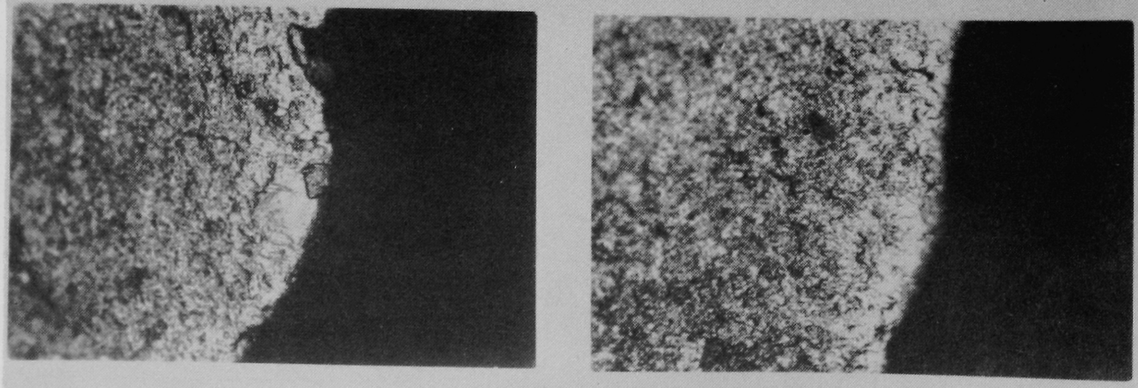
c-exp. Stone 25

d-ARJ Mound C



e-exp. Shell 5, sawing

f-ARJ 703.3B



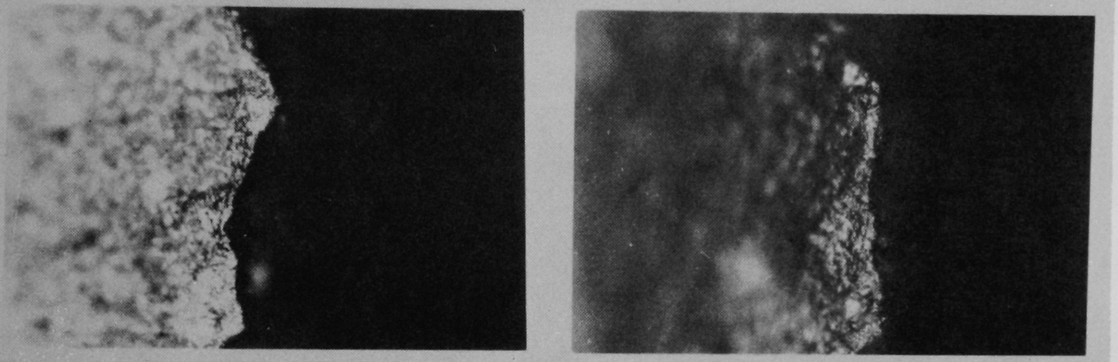
g-exp. Antler 13, soaked

h-exp. Bone 13

Plate 10 - Scrapers

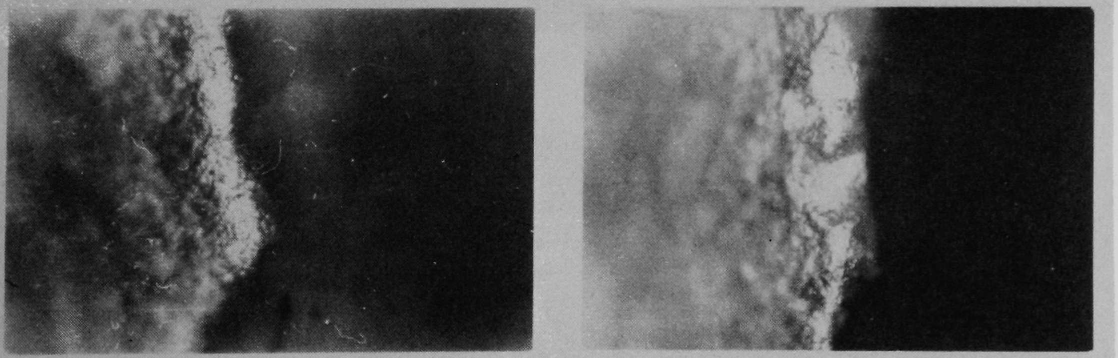
a-exp. Bone 16

b-ARJ 1000.1



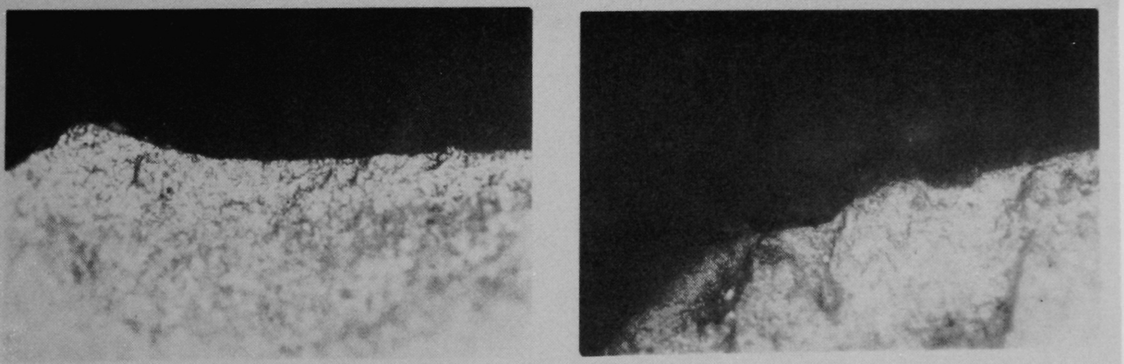
c-exp. Bone 22, cooked

d-ARJ 1005.3



e-exp. Hide 12, + ochre

f-ARJ 801.3

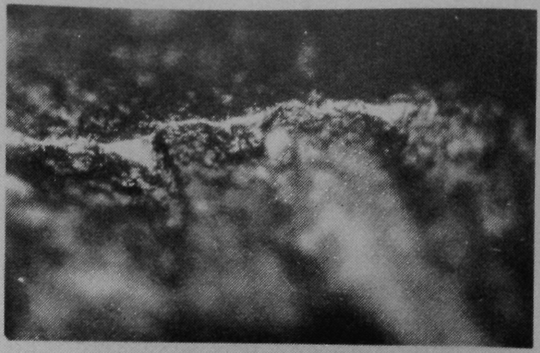


g-exp. Hide 5

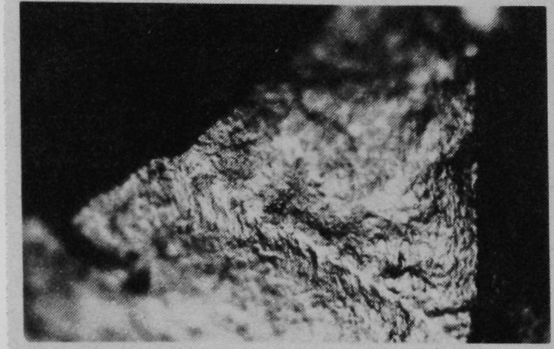
h-ARJ 500.1

Plate 11 - Perforators

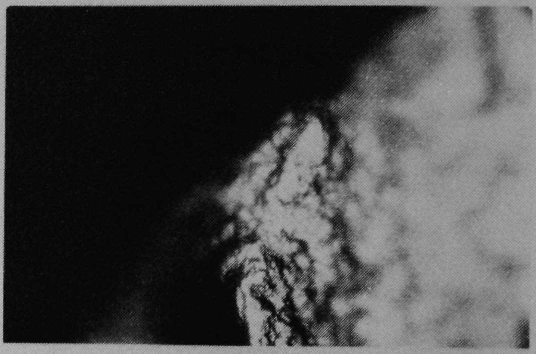
a-exp. Wood 7, boring



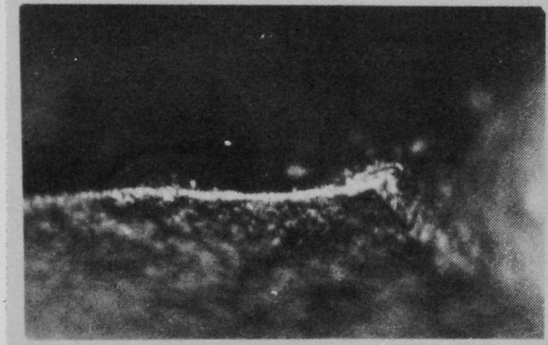
b-ARJ 700.1



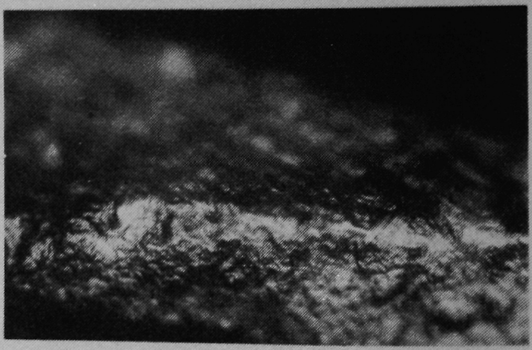
c-exp. Antler 9, boring



d-ARJ 800.2

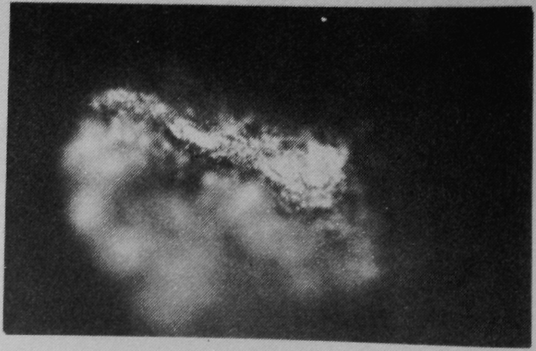


e-exp. Bone 42, grooving



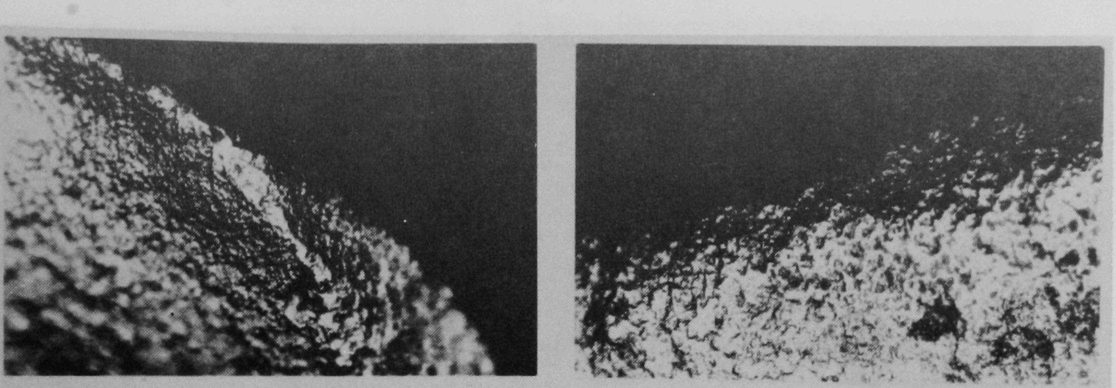
f-ARJ 500.1

g-exp. Pottery 5/1, drilling



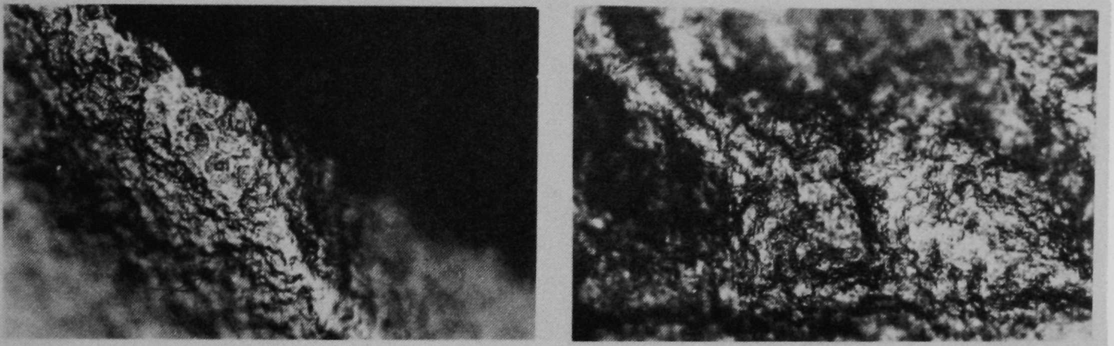
h-ARJ 1000.1

Plate 12 - Perforators



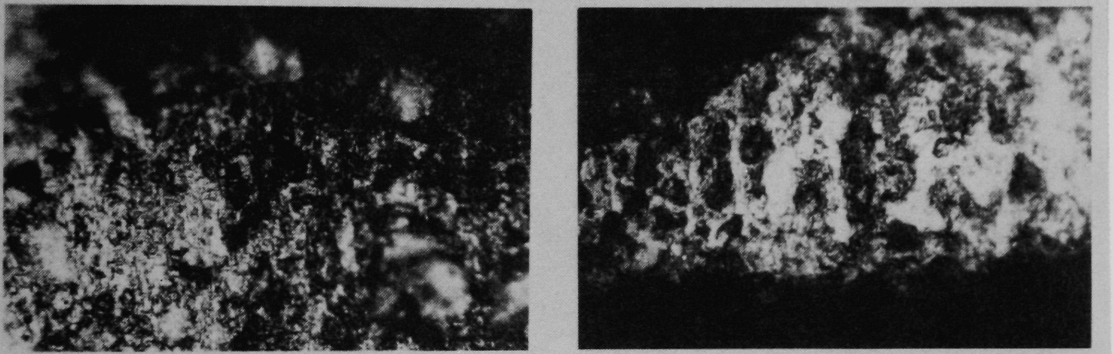
a-exp. Wood 50, drilling, 100x

b-ARJ 701.3B, 100x



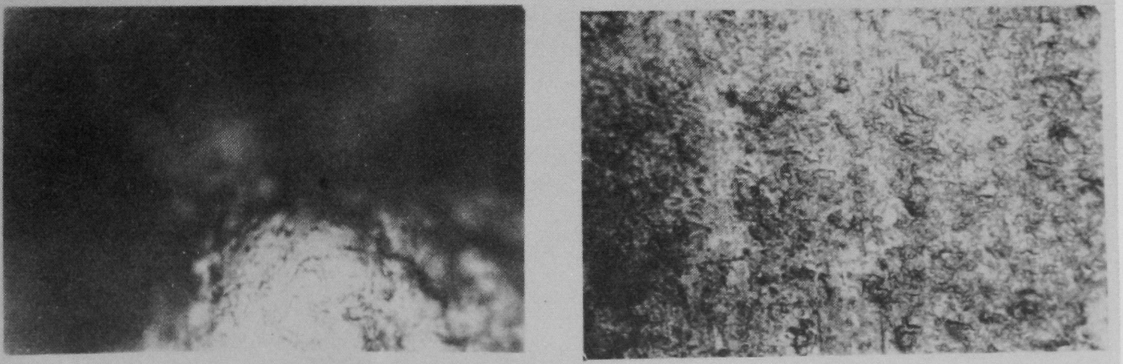
c-exp. Wood 50, drilling, 200x

d-ARJ 701.3B, 200x



e-exp. Stone 28, boring

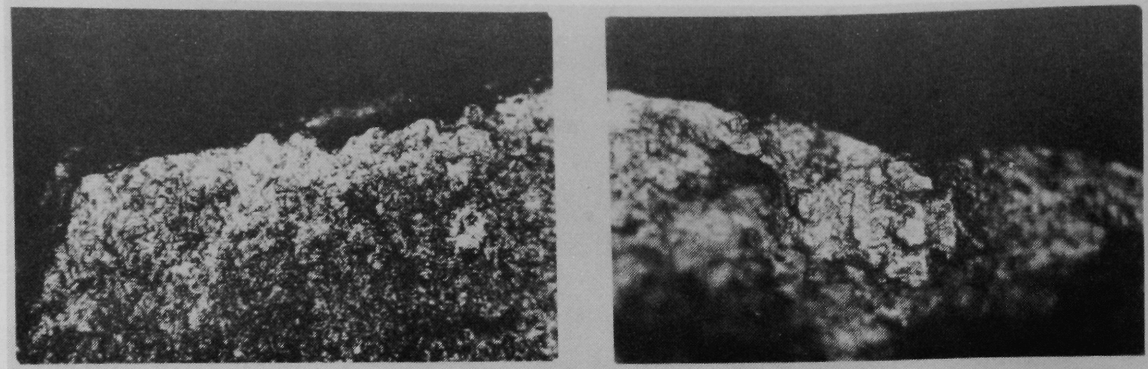
f-ARJ 403.2



g-ARJ 700.1

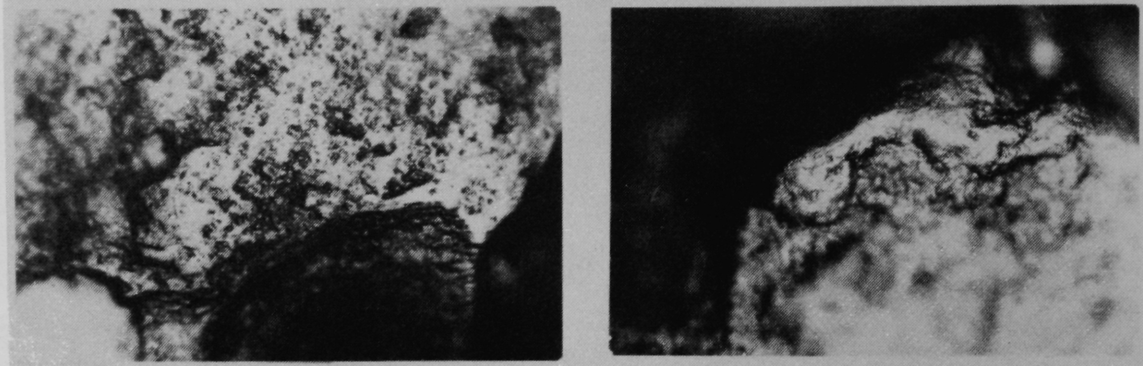
h-ARJ I-IV, Surface

Plate 13 - Blades, Bladelets, Flakes



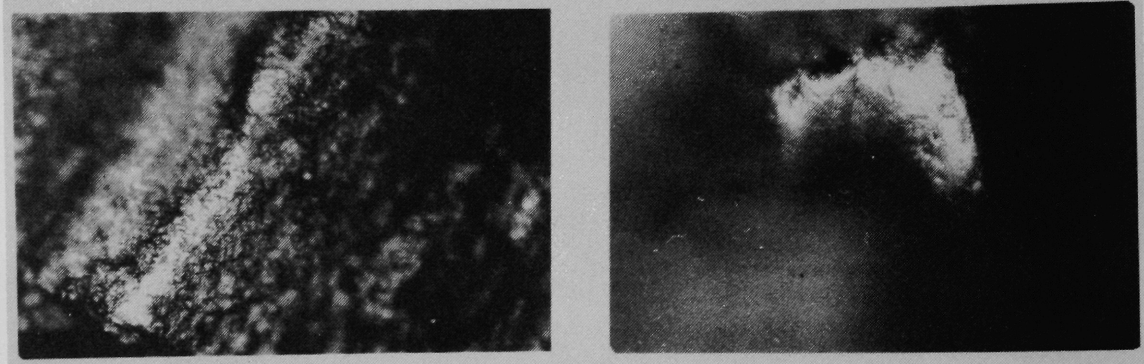
a-exp. Wood 21

b-ARJ 703.3B



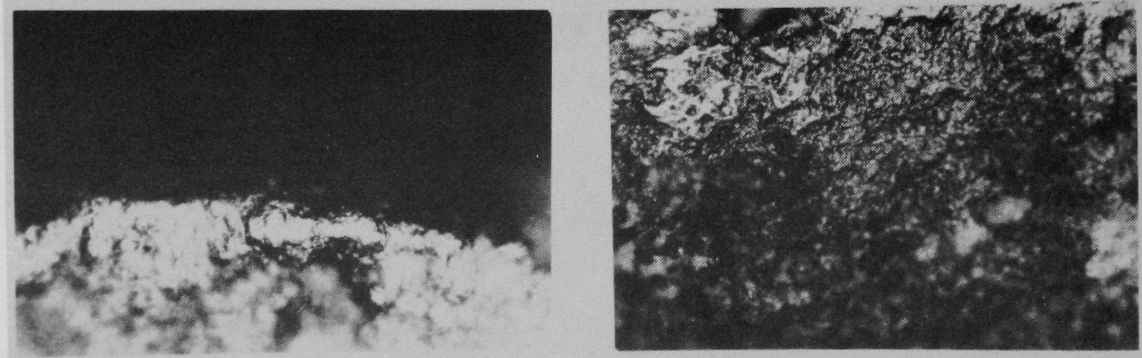
c-exp. Wood 35

d-ARJ I-IV, Surface



e-exp. Wood 47, whittling

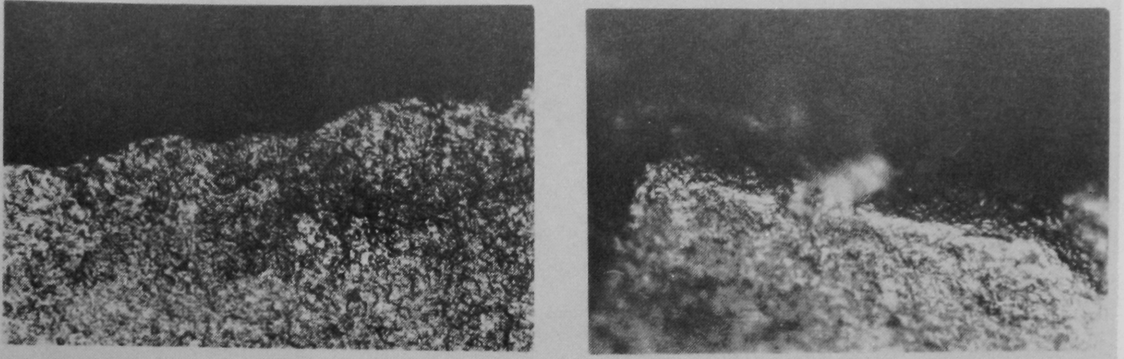
f-ARJ 201.2



g-ARJ 701.3A

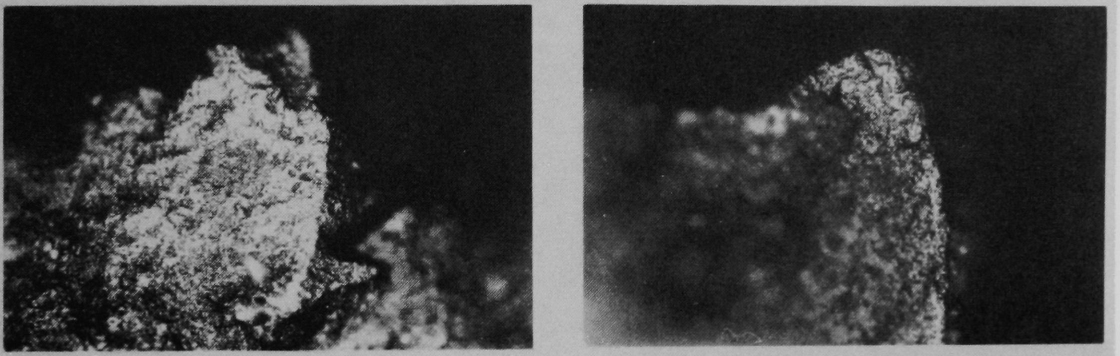
h-ARJ 700.1

Plate 14 - Blades, Bladelets and Flakes



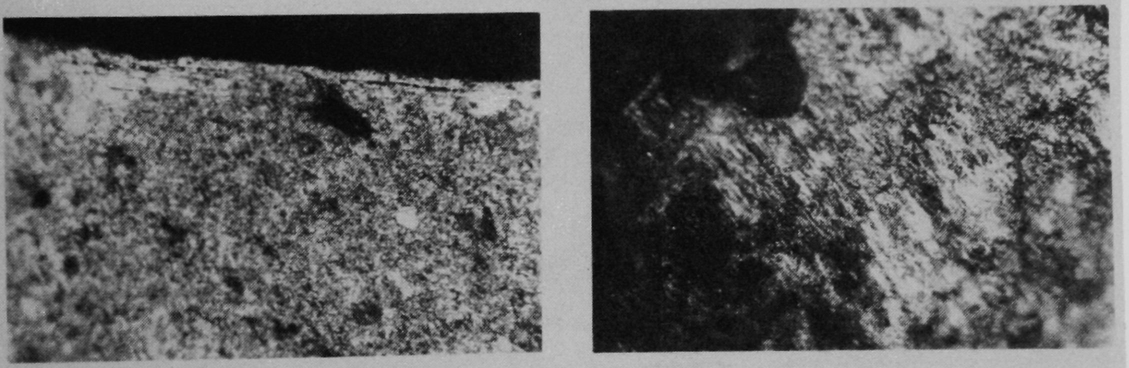
a-exp. Meat 3

b-ARJ, Baulk 600-700.3



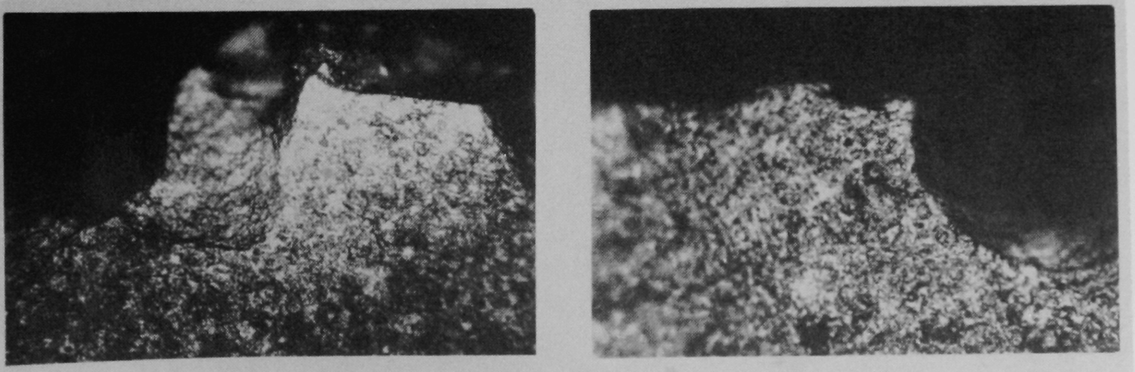
c-exp. Meat 4, + bone

d-ARJ 803.3



e-exp. Wool 1

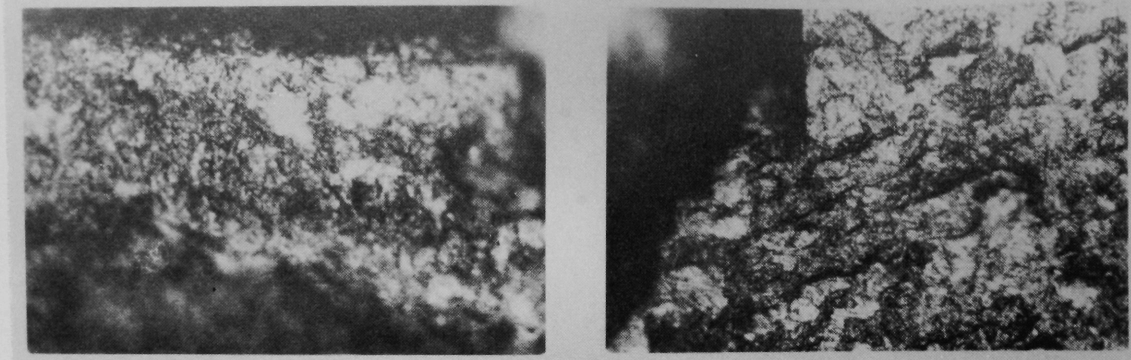
f-ARJ, Baulk 201-210



g-exp. Hide 16

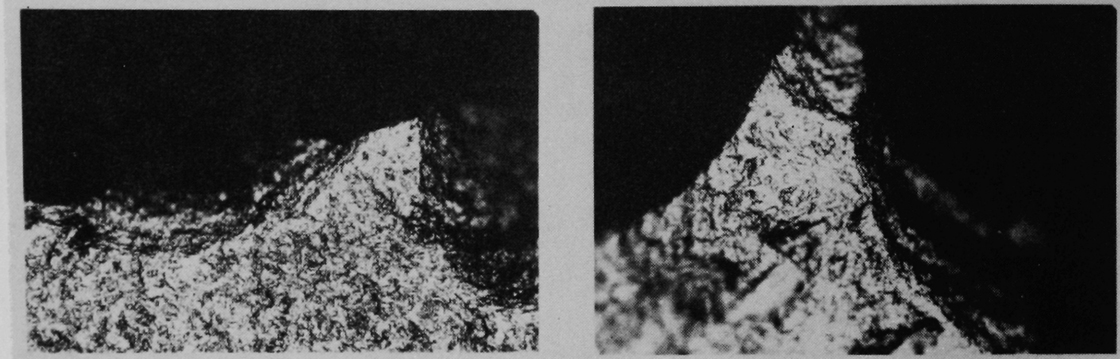
h-ARJ 700.1

Plate 15 - Blades, Bladelets and Flakes



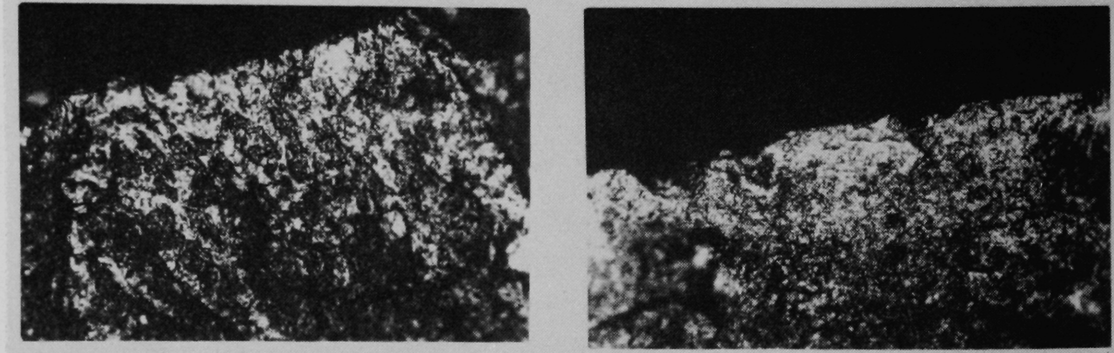
a-exp. Stone 22

b-ARJ Mound C



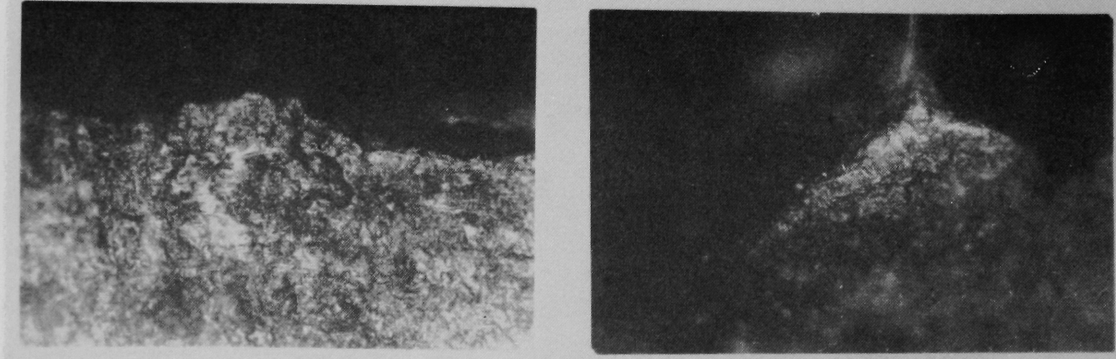
c-exp. Bone 20

d-ARJ 701.3B



e-exp. Fish 1, + scaling

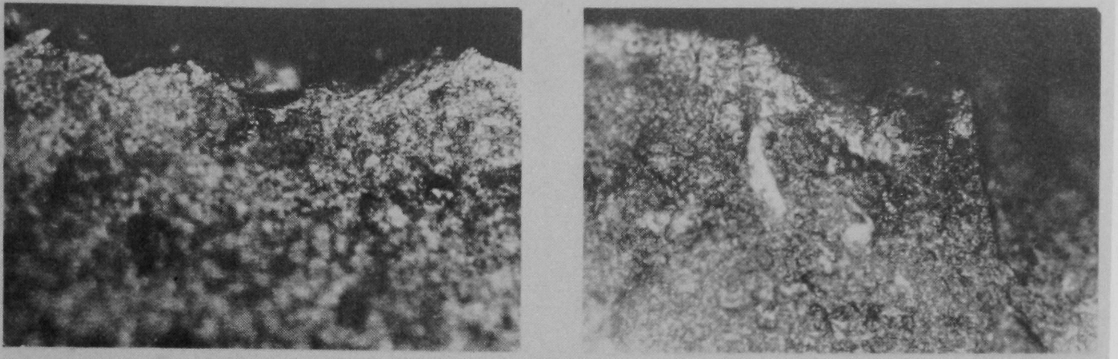
f-exp. Feather 1



g-exp. Antler 18, soaked

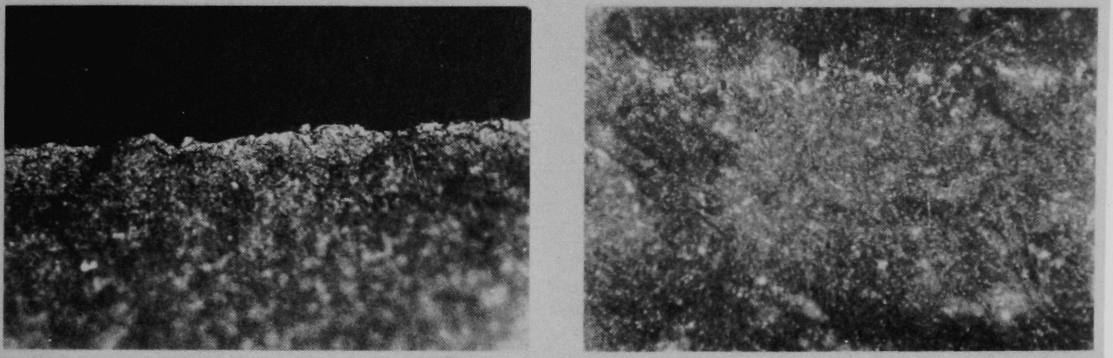
h-exp. Antler 3/1, dried

Plate 16 - Blades and Snapped Blades



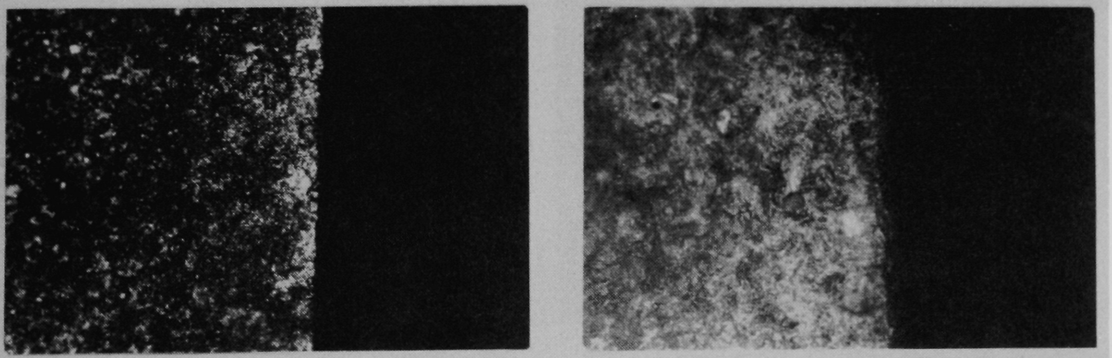
a-exp. Meat 11/1, tendon

b-exp. Meat 9, dried sinew



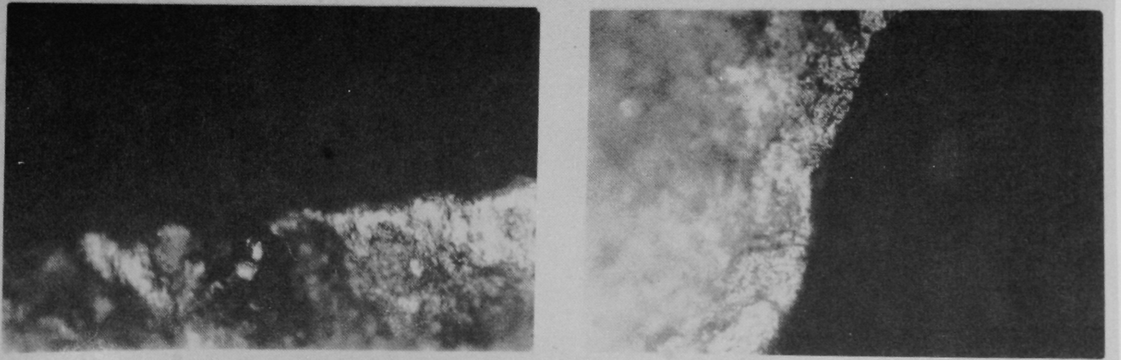
c-exp. Vegetable 1, carrot

d-exp. Horn 1



e-exp. broken blade

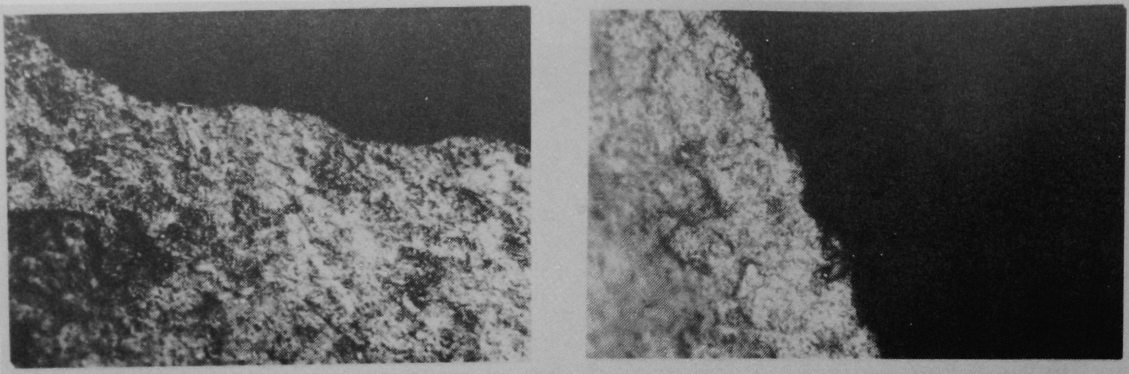
f-ARJ 102.4, break



g-exp. Wood 1/5 scraping

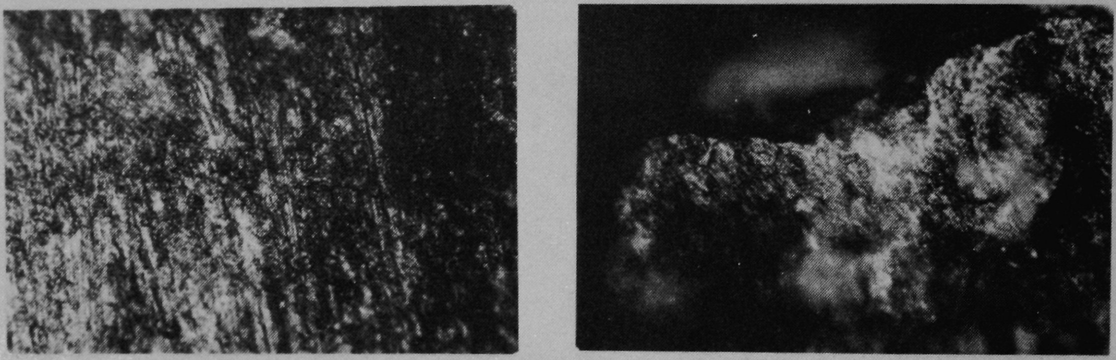
h-ARJ 900.1

Plate 17 - Notches



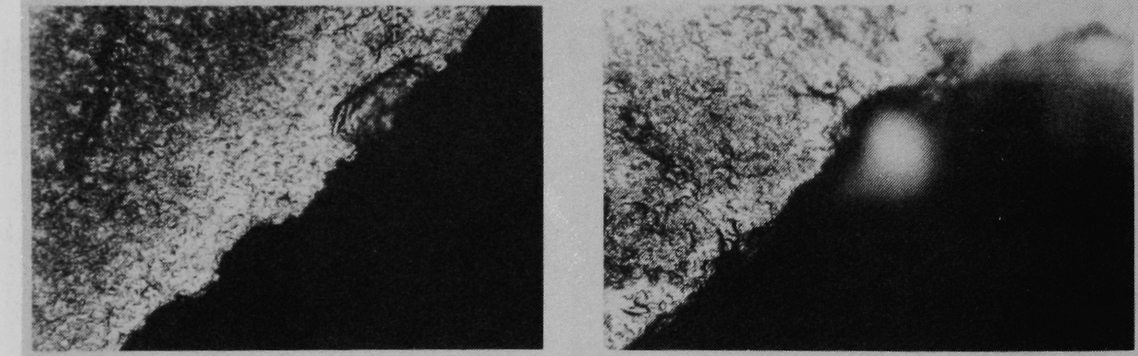
a-ARJ 103.10

b-ARJ 202.3



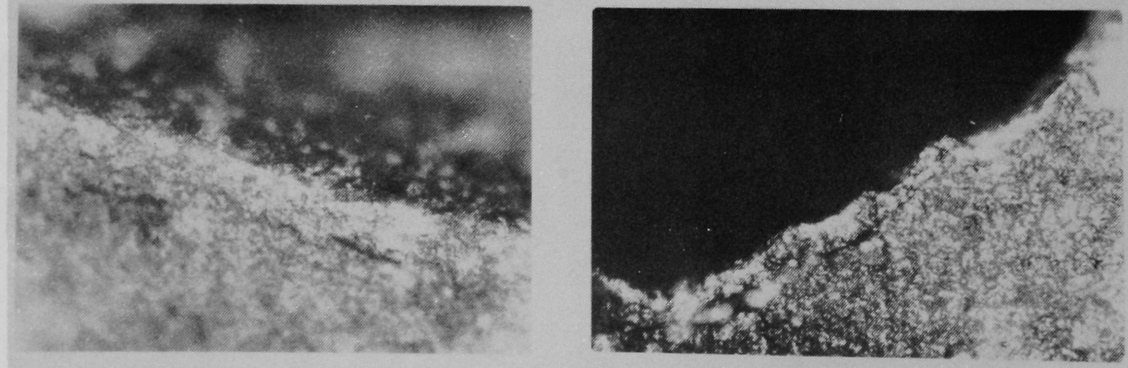
c-exp. Wood 40, shaving

d-ARJ ??5.2



e-exp. Bone 44, shaving

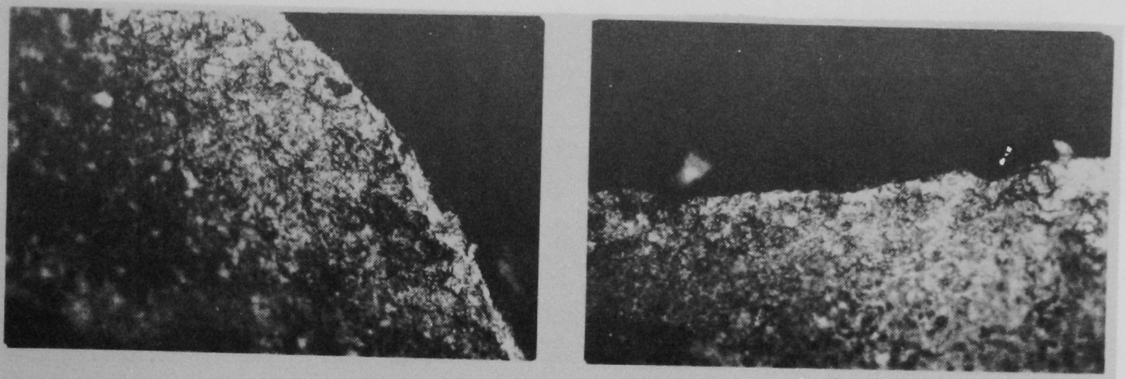
f-ARJ 801.3



g-exp. Stone 21, scraping

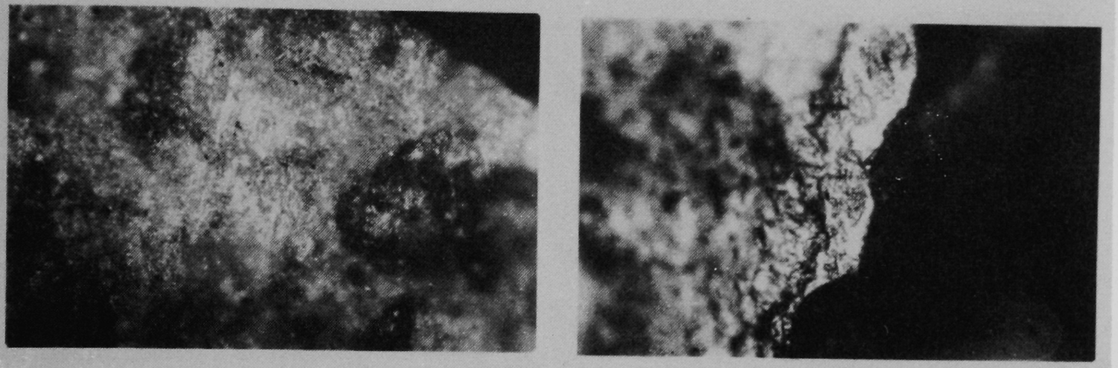
h-ARJ 1011.2

Plate 18 - Denticulates



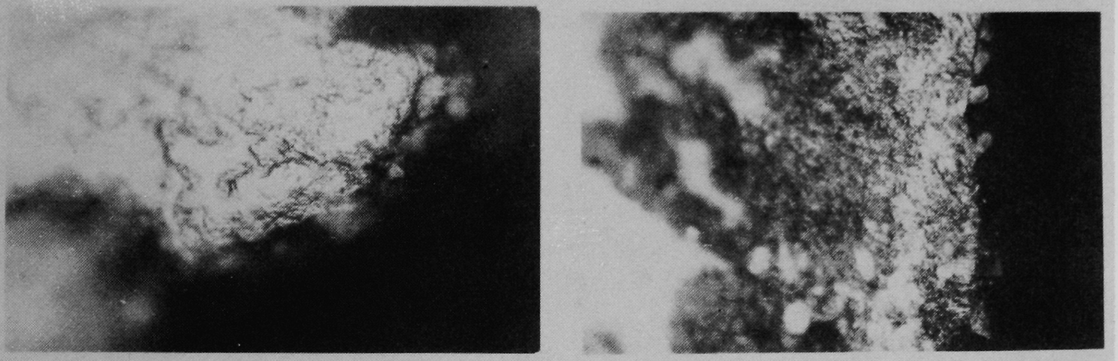
a-exp. Wood 45, scraping

b-ARJ 103.3



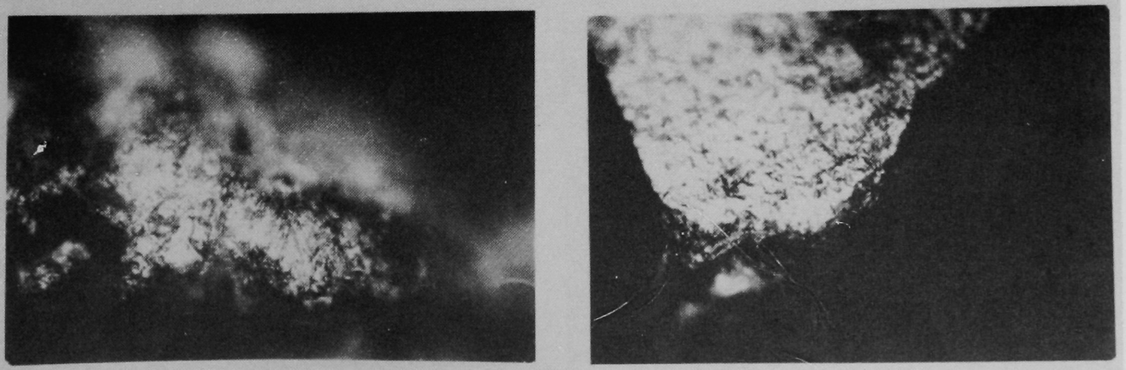
c-ARJ 213.3

d-ARJ 500.1



e-exp. Hide 19, scraping

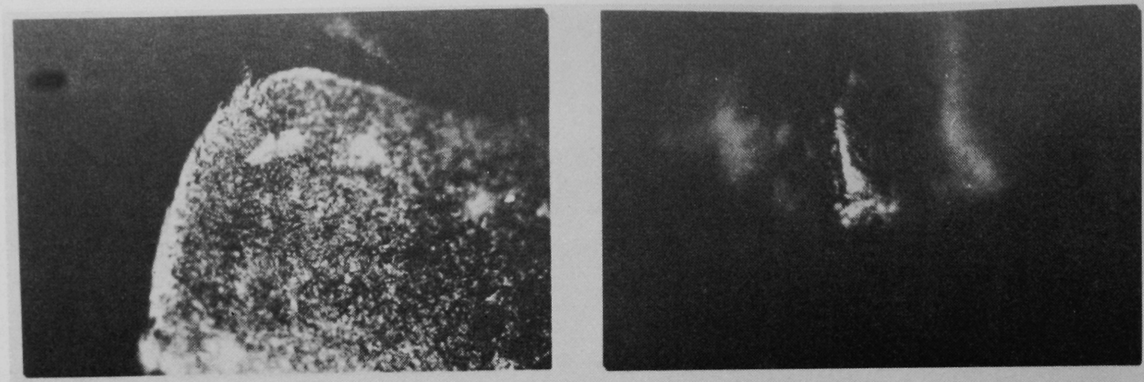
f-exp. Stone 16, grooving



g-ARJ 1002.3

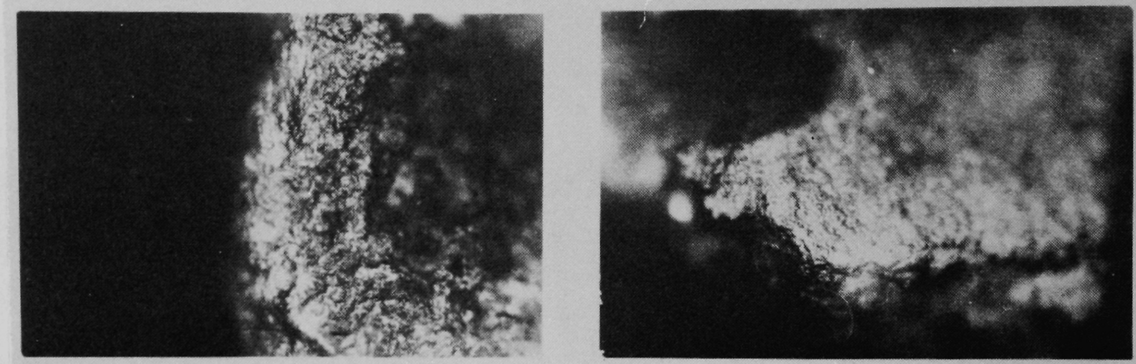
h-ARJ 101.1

Plate 19 - Burins



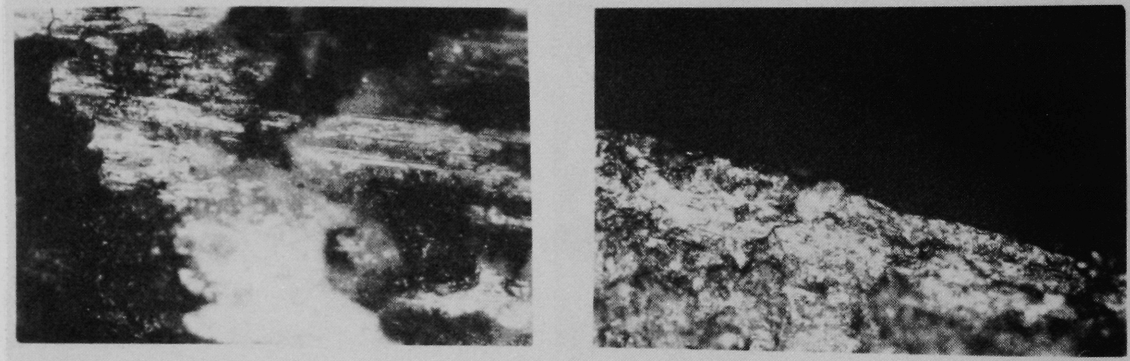
a-exp. Bone 27, grooving

b-ARJ 700.1



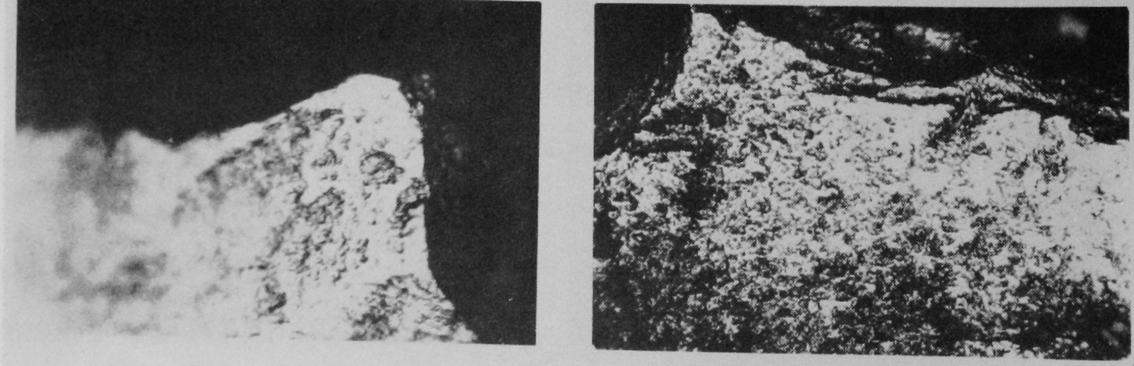
c-exp. Stone 2, grooving

d-ARJ 703.3B



e-exp. Shell 4, incising

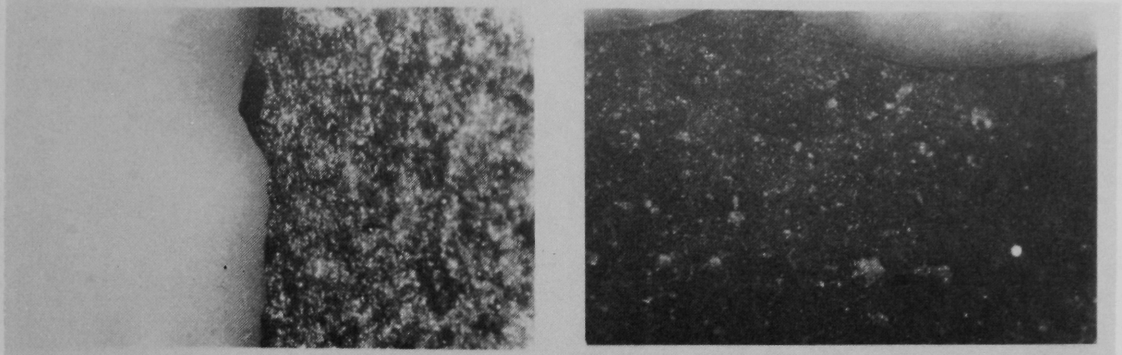
f-ARJ 701.3A



g-exp. Wood 8, grooving

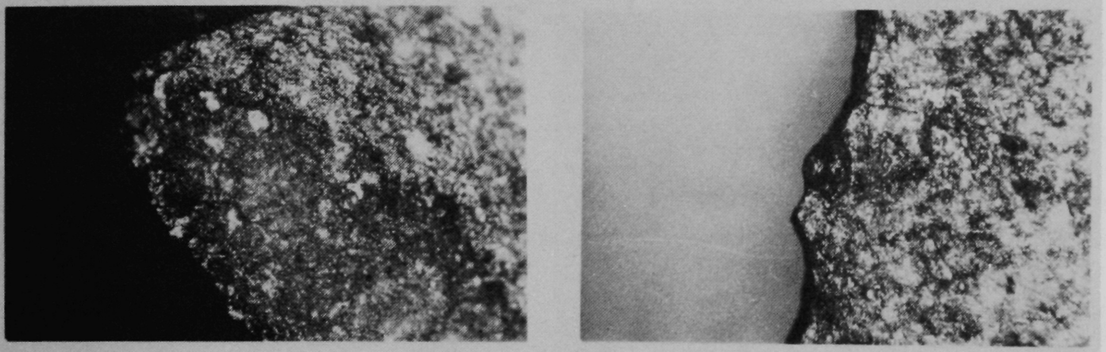
h-ARJ 212.3

Plate 20 - Projectiles



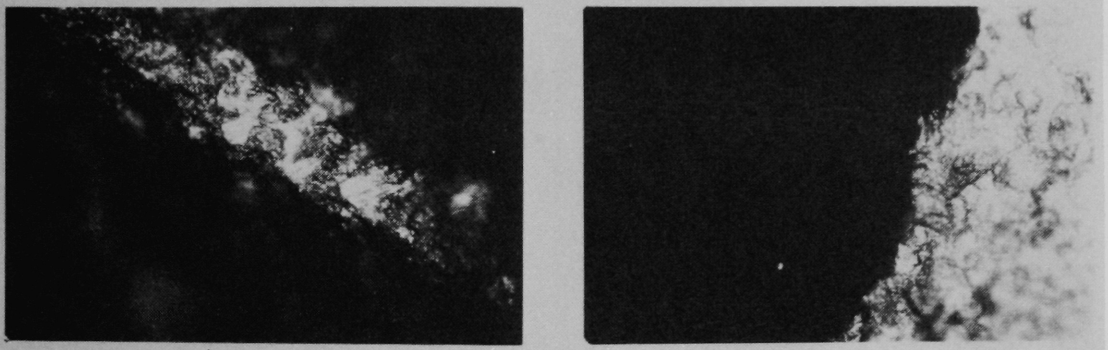
a-exp. Meat 12, arrowhead, 50x

b-ARJ 701.3B, 50x



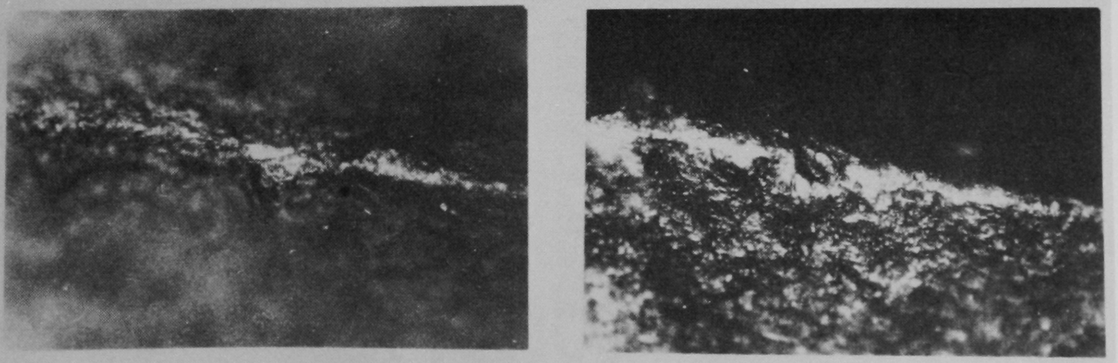
c-exp. Meat 12, barb, 100x

d-ARJ 700.2, 50x



e-exp. Meat 12, 200x

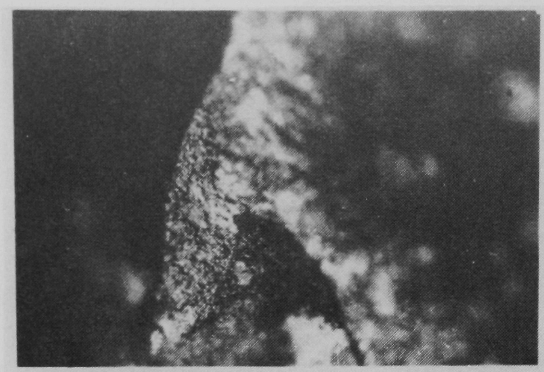
f-ARJ 701.3B, 200x



g-exp. Meat 13, arrowhead, 200x

h-ARJ I, Surface, 200x

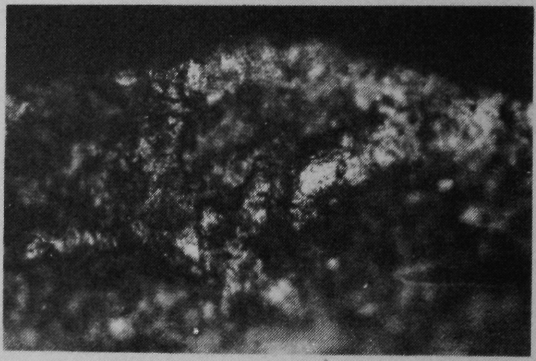
Plate 21 - Axes, Adzes and Choppers



a-exp. Bone 43

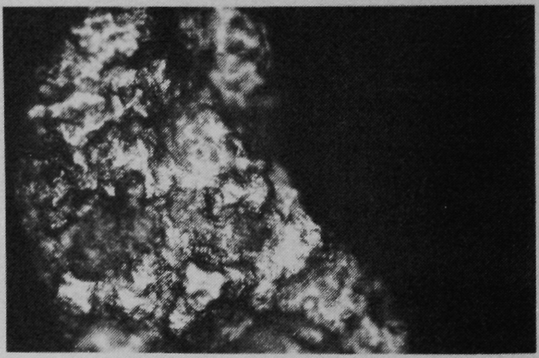
b-ARJ I-IV, Surface

c-exp. Wood 26

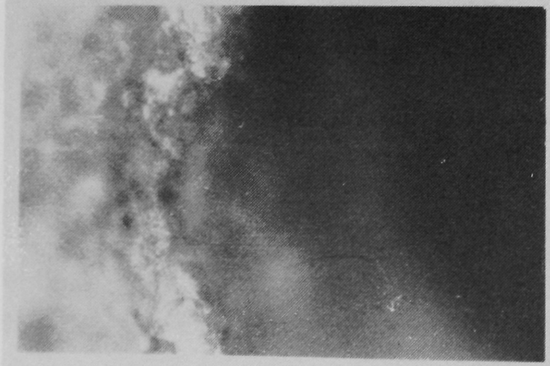


d-ARJ 222.2

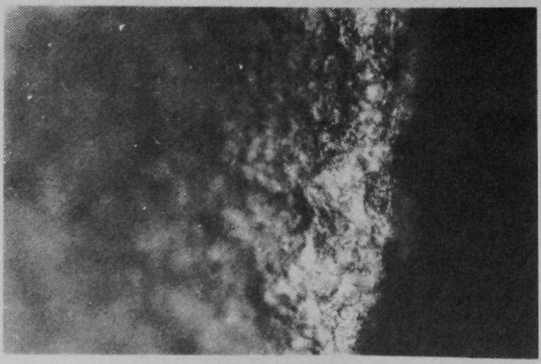
e-exp. Wood 51



f-ARJ VI, Surface

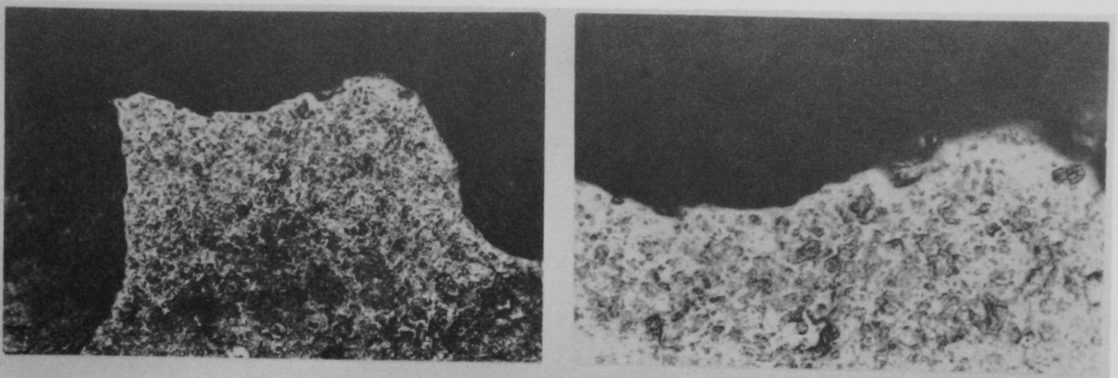


g-ARJ VII, Sounding 1



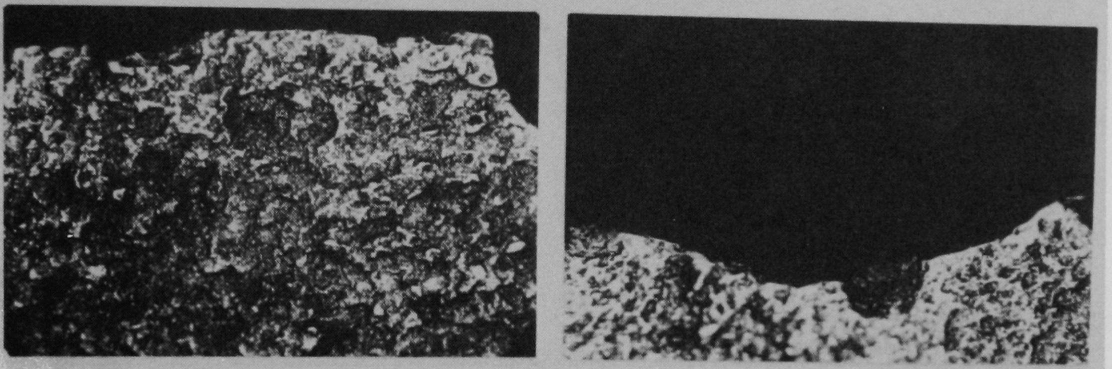
h-ARJ VII, Sounding 4

Plate 22 - Experiments: Plants



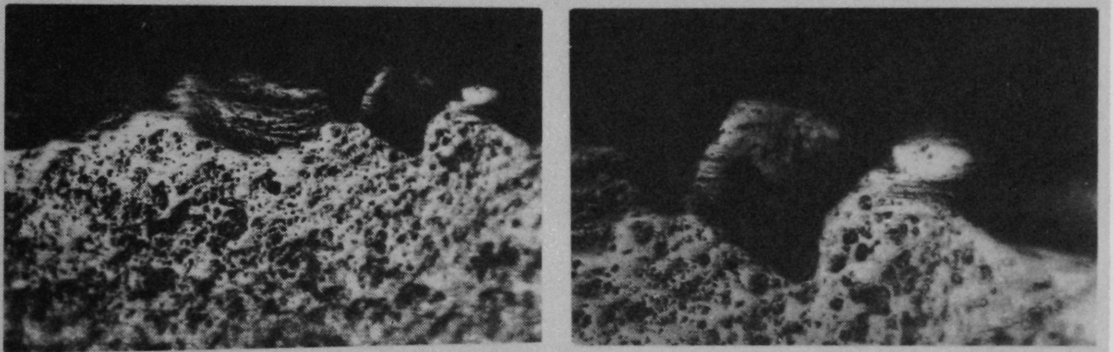
a-Plant 40, wild einkorn, 100x

b-Plant 40, 200x



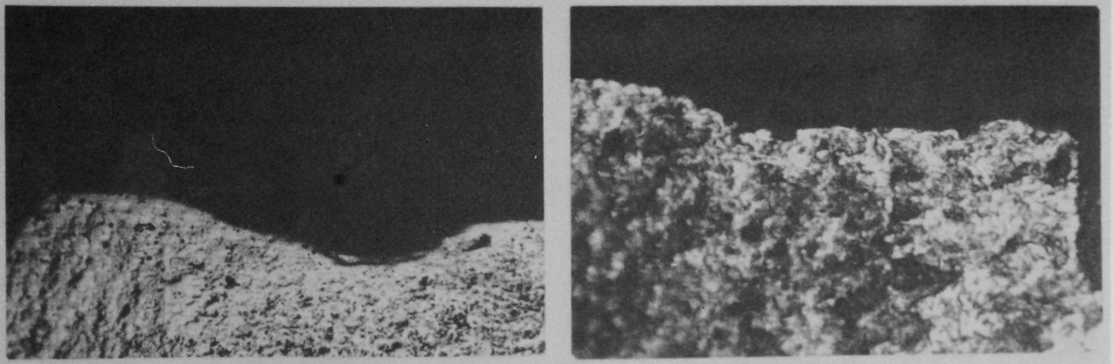
c-Plant 36, dom. barley, 100x

d-Plant 36, 200x



e-Plant 41, dom.wheat, 100x

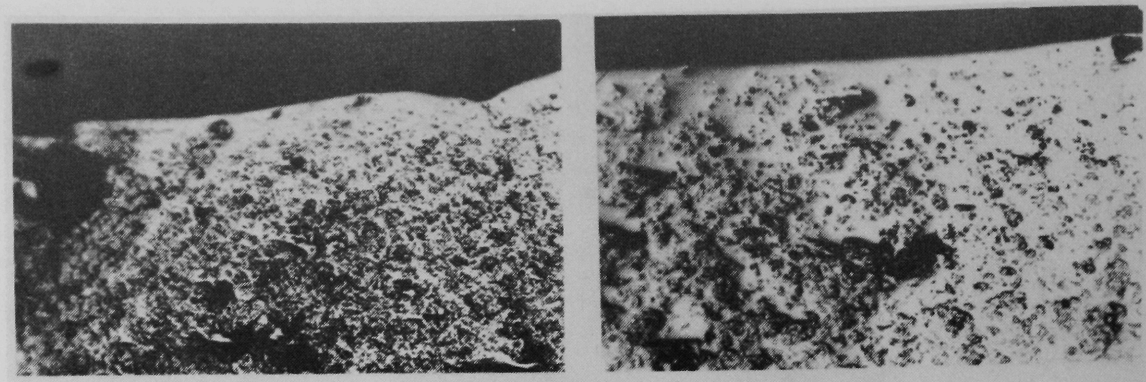
f-Plant 41, 200x



g-Plant 43, dom. einkorn, 100x

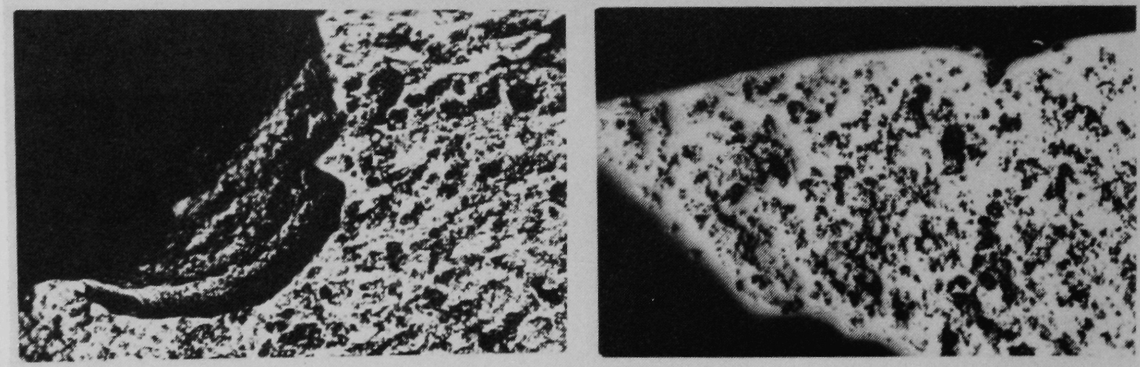
h-Plant 43, 100x

Plate 23 - Experiments: Plants



a-Plant 15, bulrush, 100x

b-Plant 15, 200x

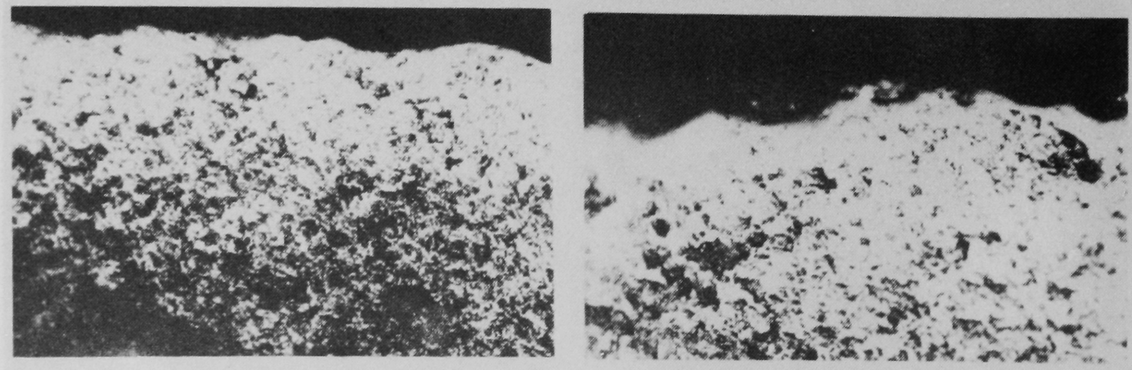


c-Plant 28, reed, 100x

d-Plant 28, 200x

e-Plant 14, dried reed, 100x

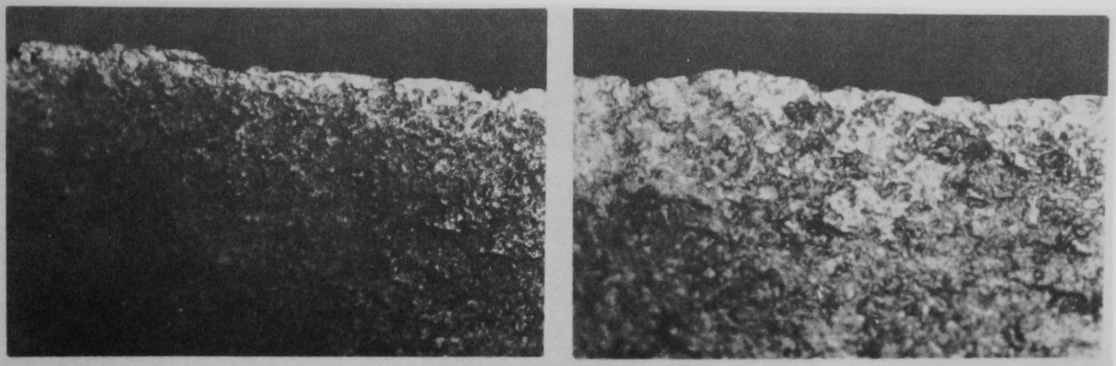
f-Plant 14, 200x



g-Plant 23, reed scraping, 100x

h-Plant 23, 200x

Plate 24 - Experiments: Plants

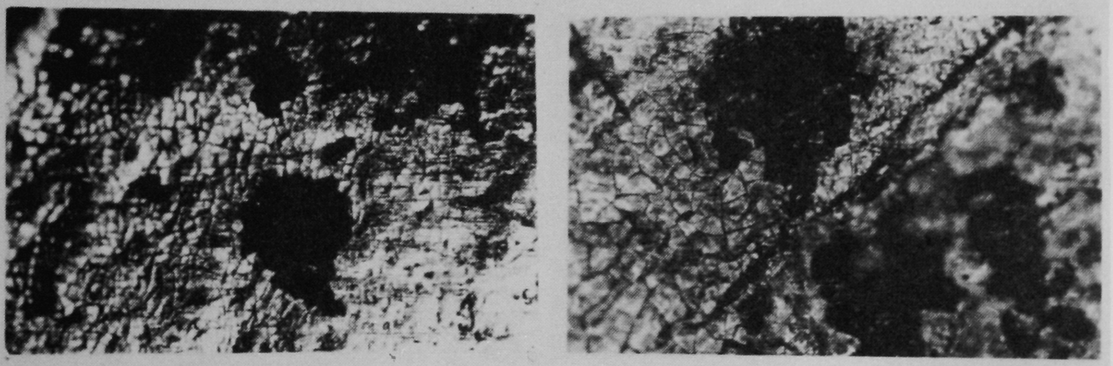


a-Plant 45, Cyperus , 100x

b-Plant 45, 200x

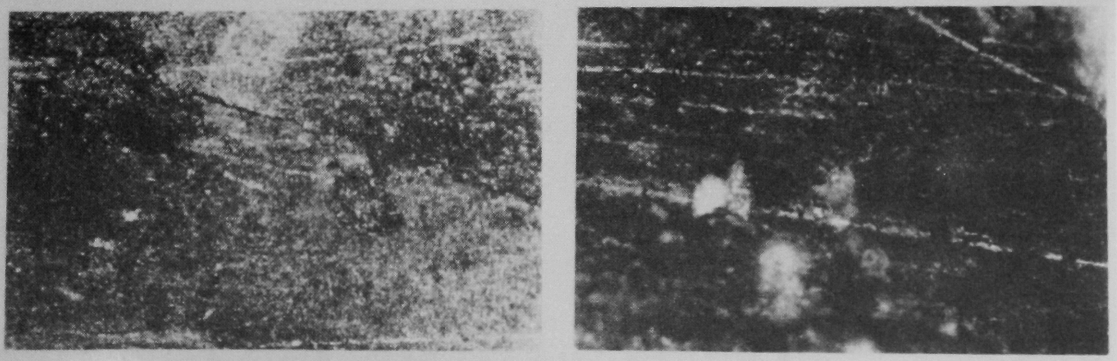
c-Plant 31/1, cane, 100x

d-Plant 31/1, 200x



e-Plant 30, Sparganium , 100x

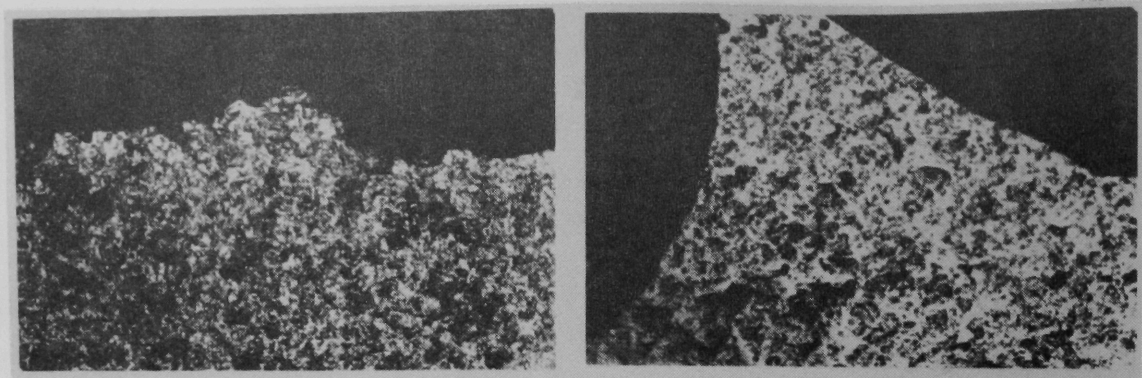
f-Plant 30, 200x



g-Plant 48, poppy, 100x

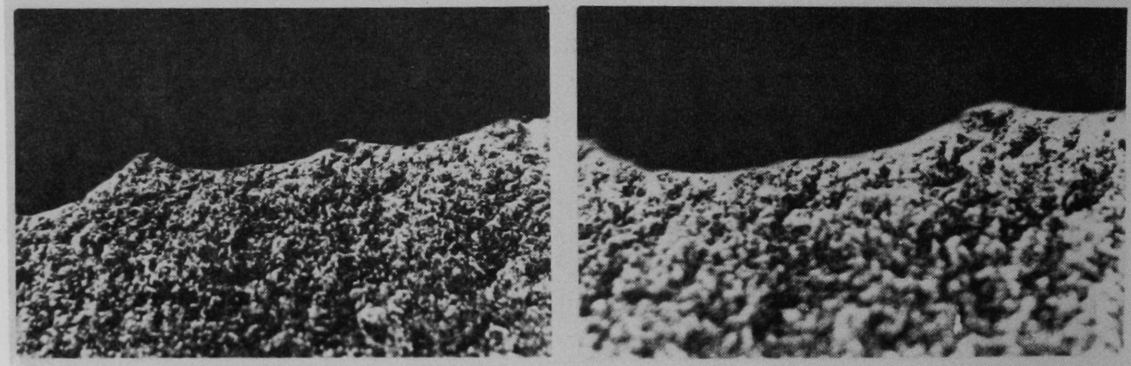
h-Plant 48, 200x

Plate 25 - Experiments: Plants



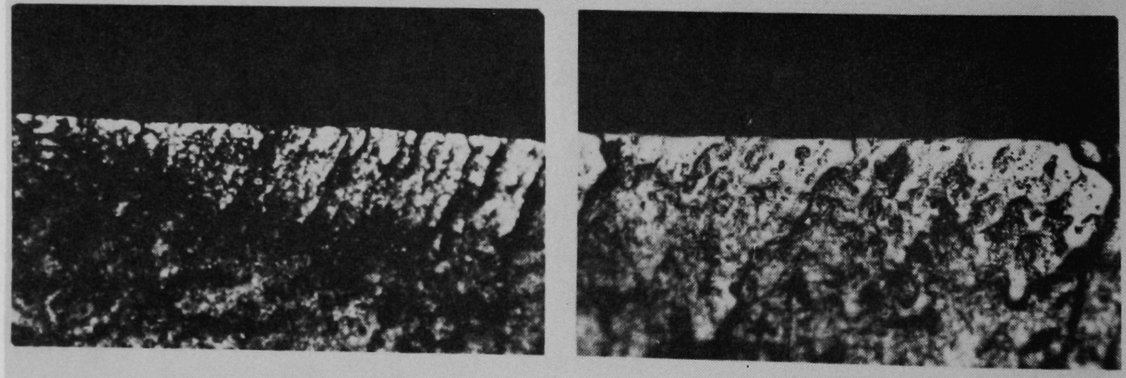
a-Plant 46, Stipa 100x

b-Plant 46, 200x



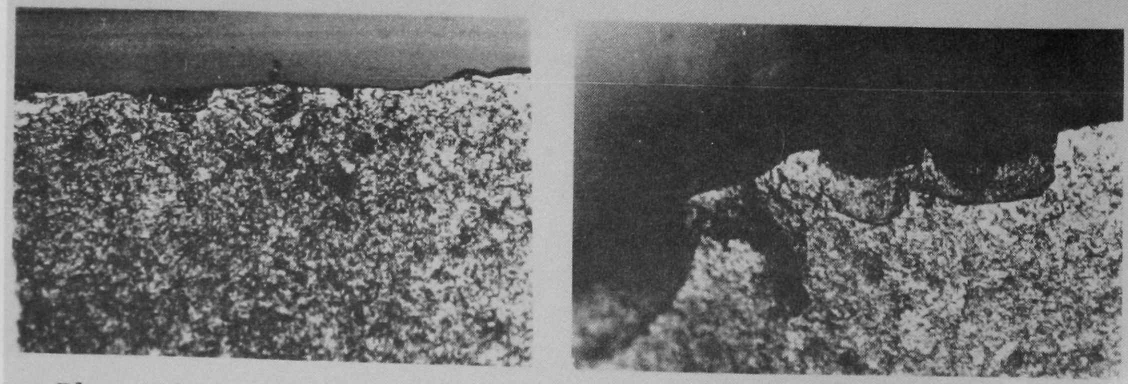
c-Plant 2, grass, 100x

d-Plant 2, 200x



e-Plant 35/2, horsetail, 100x

f-Plant 35/2, 200x



g-Plant 44, weeds, 100x

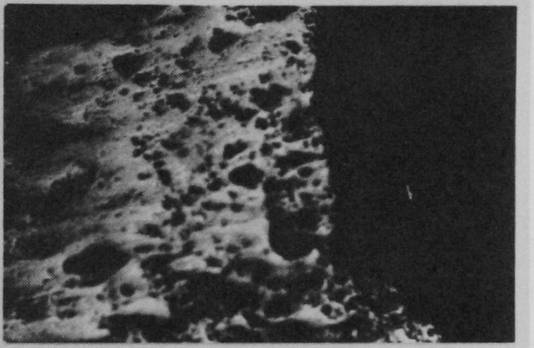
h-Plant 44, 200x

Plate 26 - Arjoune: Plants

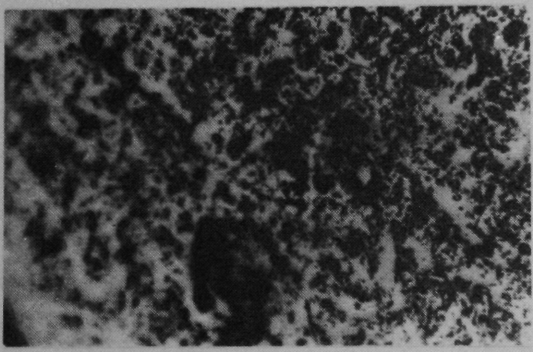
a-exp. Plant 41, dom. wheat

b-ARJ 700.2

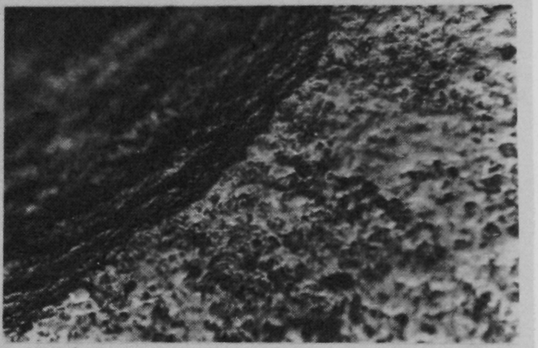
c-exp. Plant 8, dom. barley



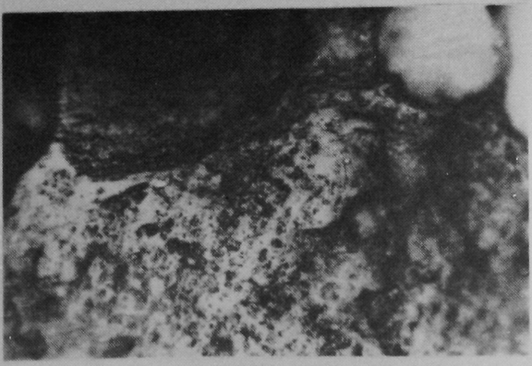
d-ARJ 500.2



e-exp. Plant 28, reed



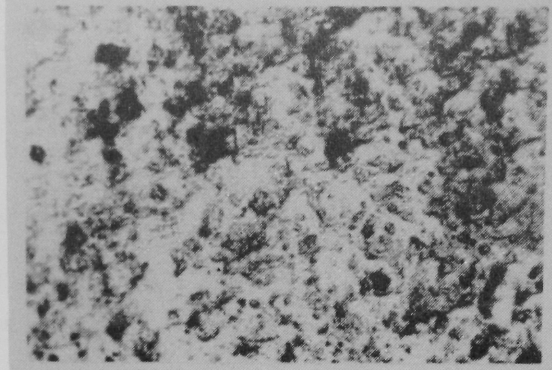
f-ARJ 900.1



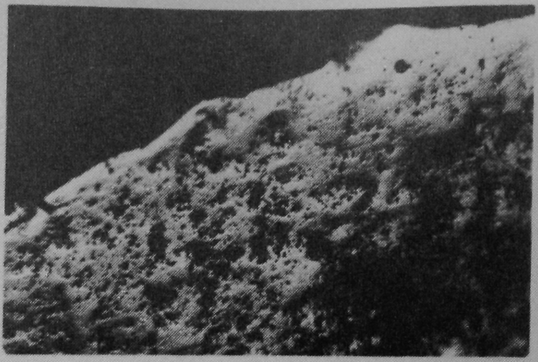
g-exp. Wood 35

h-ARJ 216.1

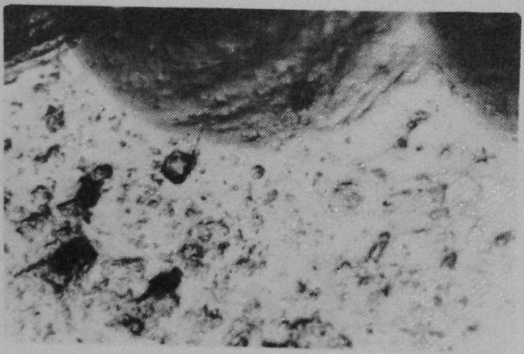
Plate 27 - Kebara and El Wad: Plants



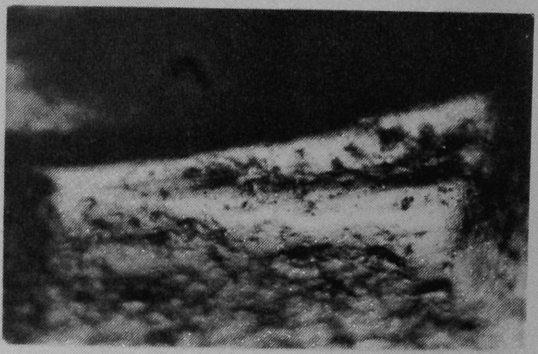
a-WB2, 50/4739, Natufian, 100x



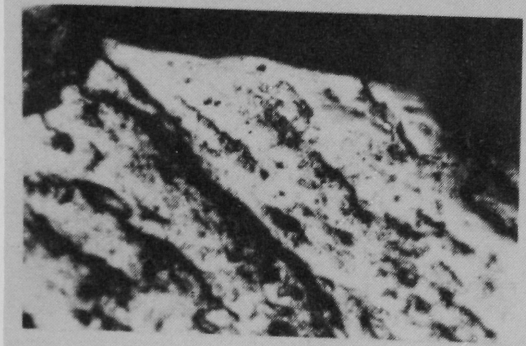
b-WB1, 50/4740, Late Nat., 100x



c-as above (a), 200x



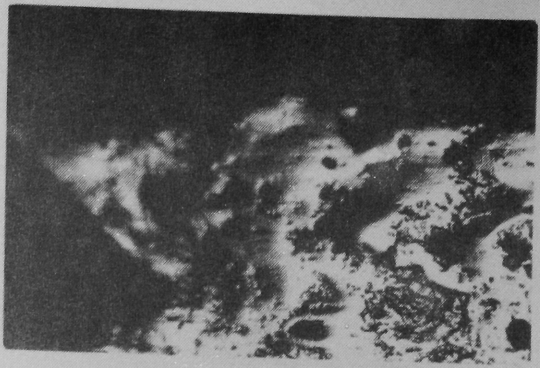
d-as above (b), 200x



e-KB 58/1995, Natufian, 100x

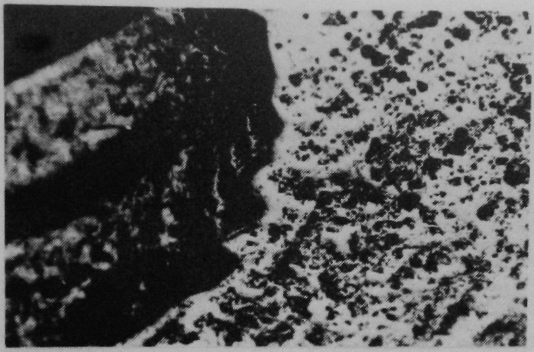
f-KB 58/2010, Natufian, 100x

g-KB 58/2007, Natufian, 200x

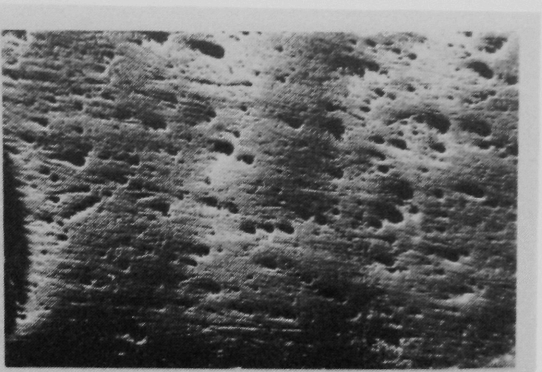


h-KB 58/1976, Natufian, 200x

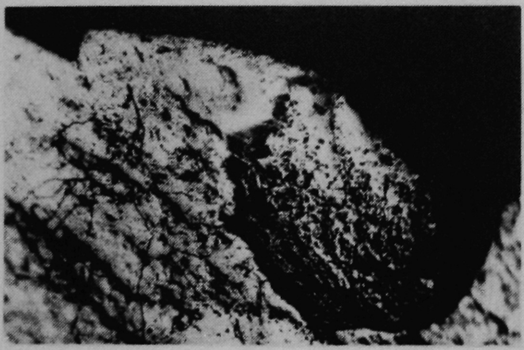
Plate 28 - Jericho: Plants



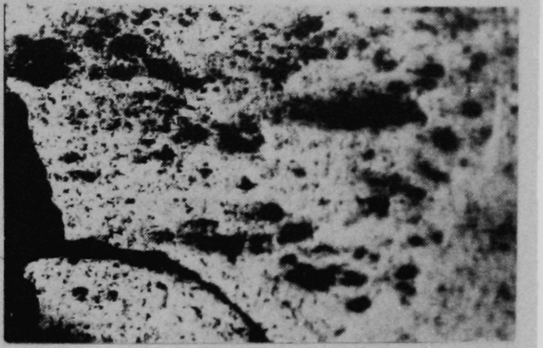
a-JPF PPNA SSiv 300.25, 100x



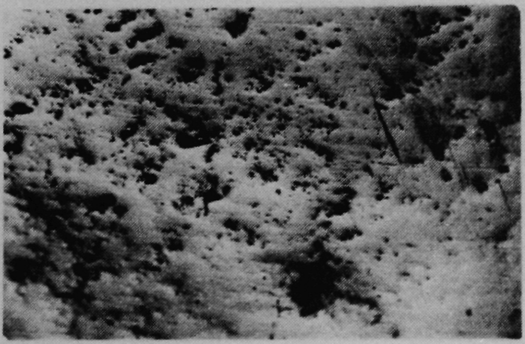
b-JPF PPNB X 8.12A, 100x



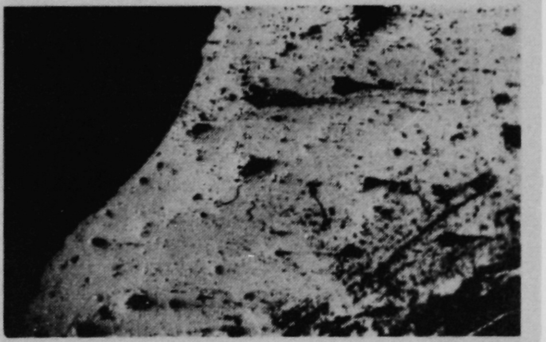
c-JPF PPNA SSii 300.27, 100x



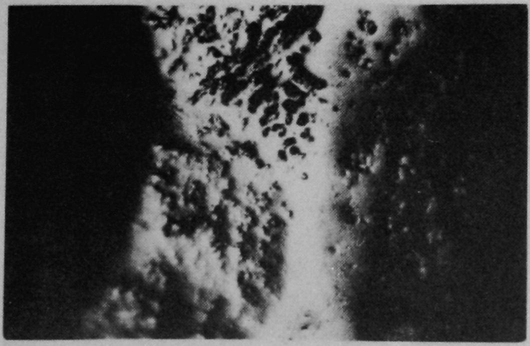
d-JPF PPNB X 100.1, 100x



e-JPF PPNA PPii 300.15, 100x



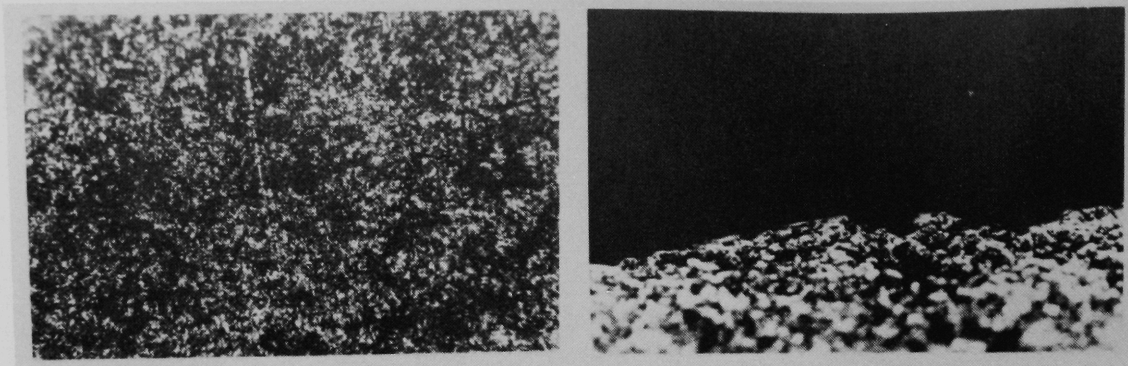
f-JPF PPNB X 8.12a, 100x



g-JPF PN J 101.5, 100x

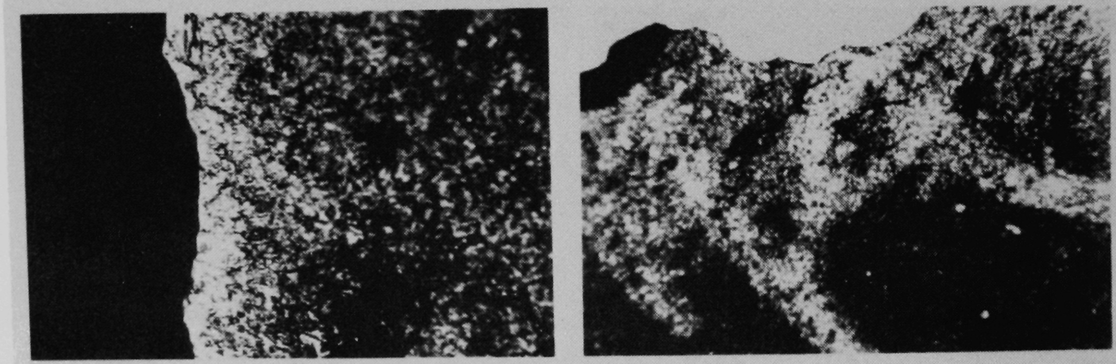
h-JPF EB D 1.5, 100x

Plate 29 - Miscellaneous



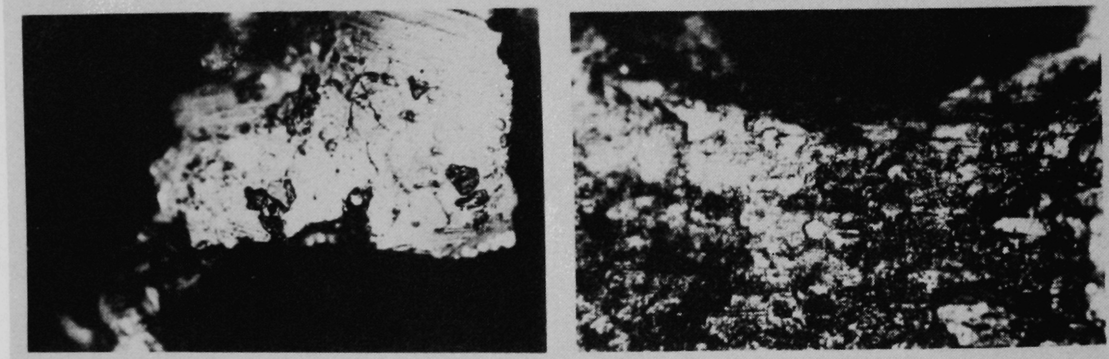
a-exp. rubbing reeds, 10 mins.

b-exp. cutting reeds, 10 mins.



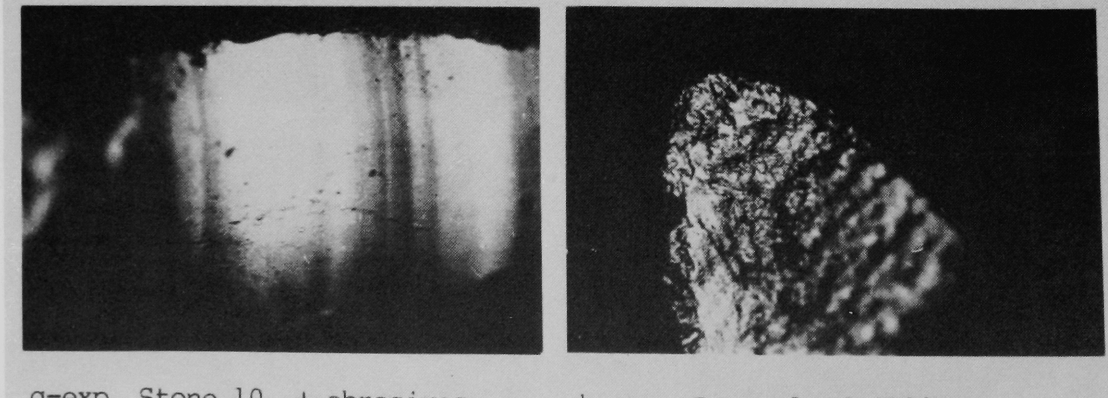
c-exp. Hide 2, soaked leather

d-exp. Fish 1, scaling, 50x



e-exp. Copper 1, drilling

f-exp. Bone 45, chicken

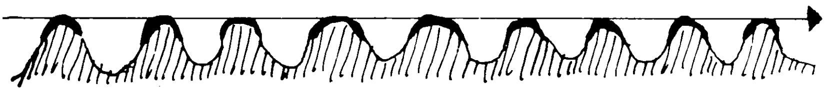


g-exp. Stone 10, + abrasives

h-exp. Ivory 1, drilling

Figure 1 - Model of Polish Formation (schematical, enlarged about 1000x)

a - very hard worked material



b - medium-hard worked material

c - soft worked material

Legend:

------ original flint surface

▬ polished area

▨ remaining flint surface

→ direction of use

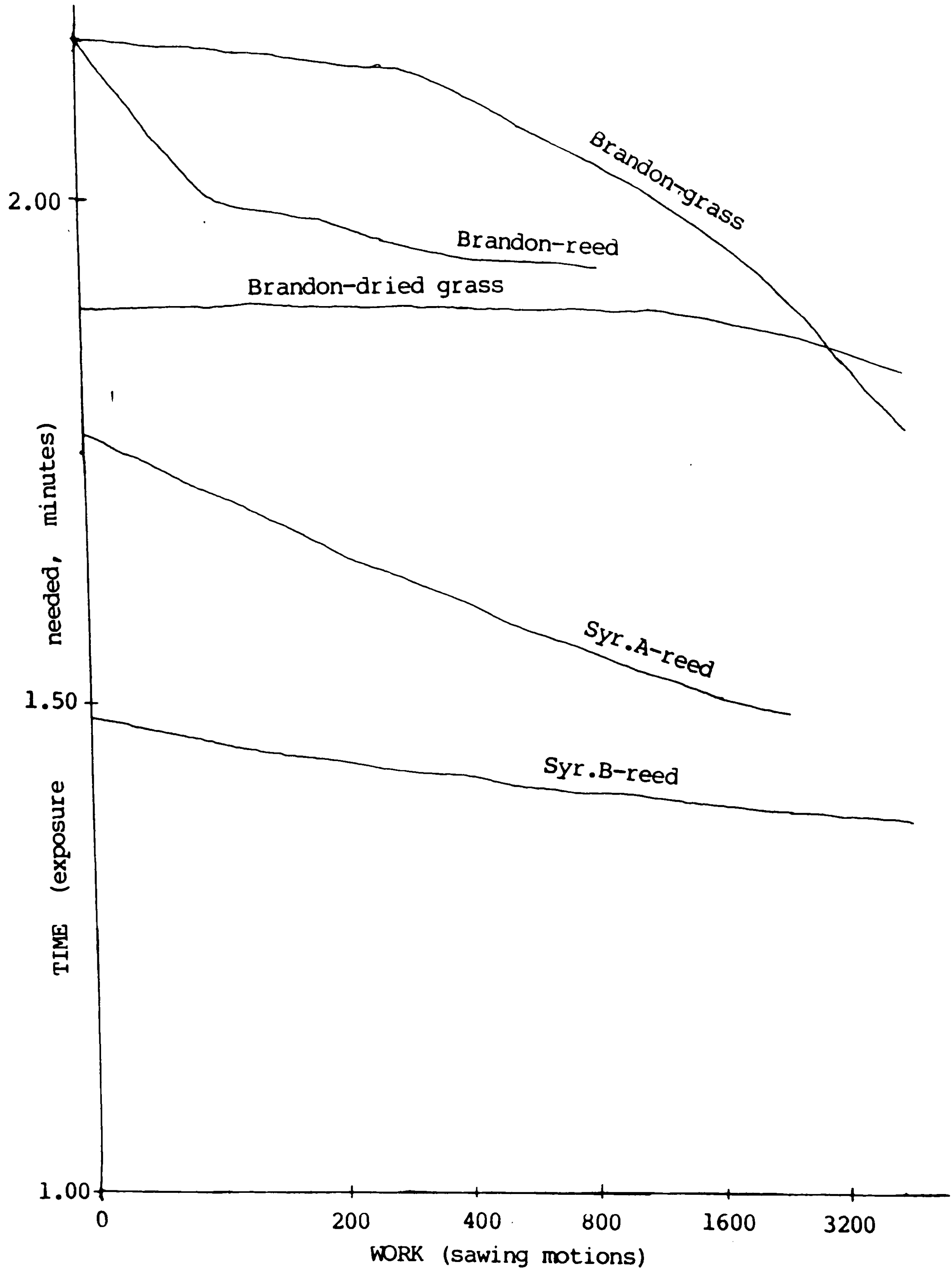


Figure 2:a - Polish Intensity, Plant, Cutting, 50x

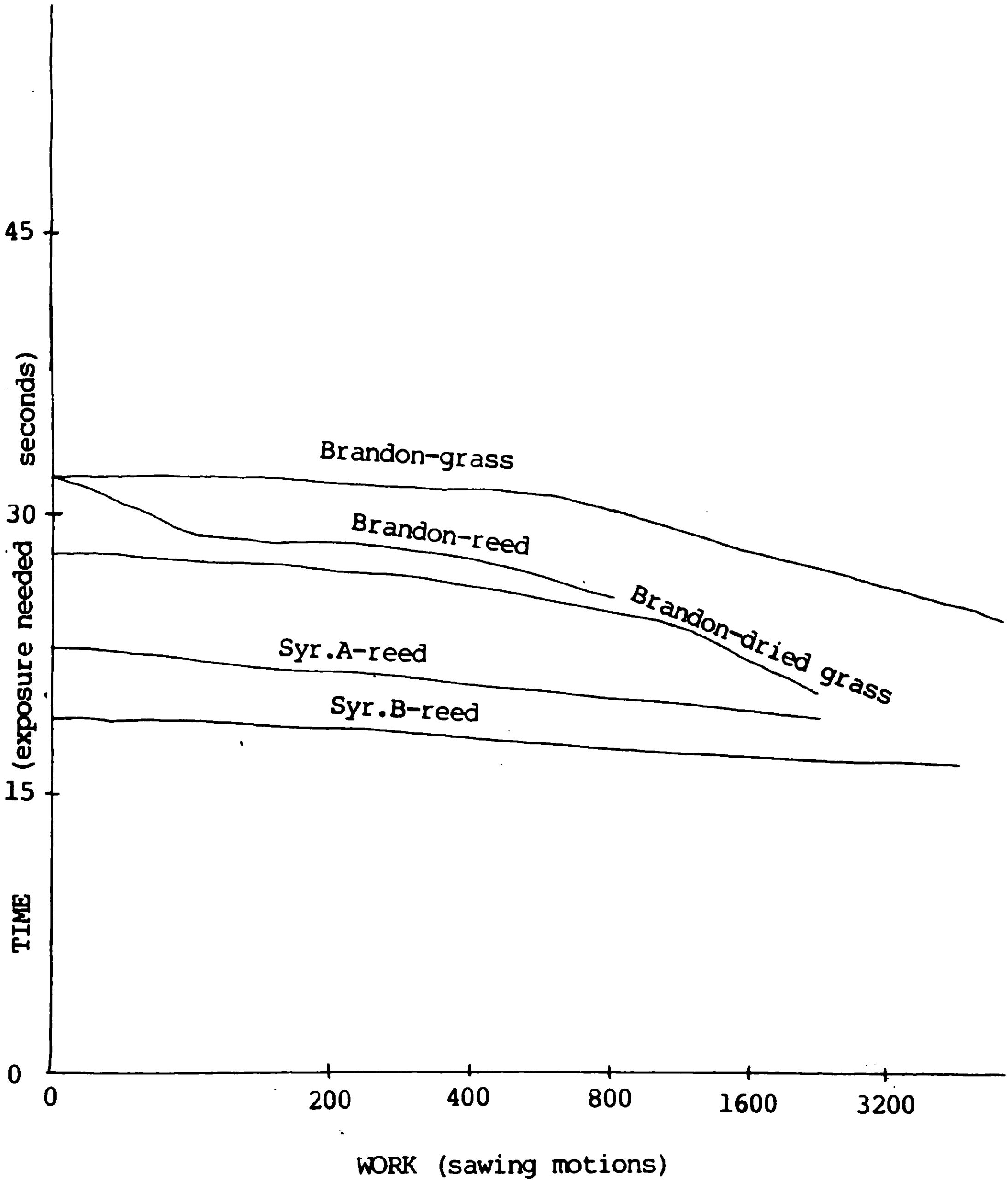


Figure 2:b - Polish Intensity, Plant, Cutting, 100x

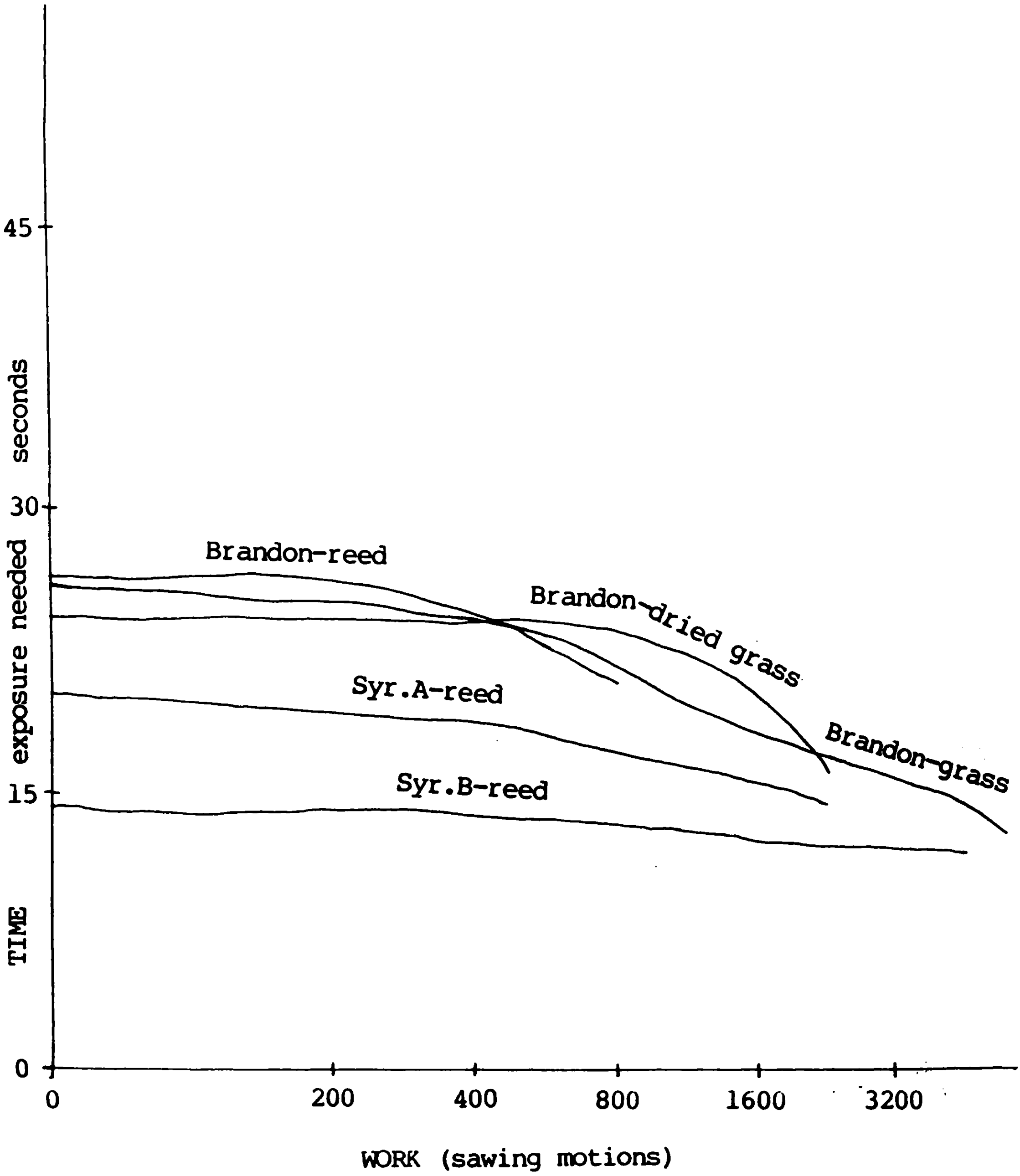


Figure 2:c - Polish Intensity, Plant, Cutting, 200x

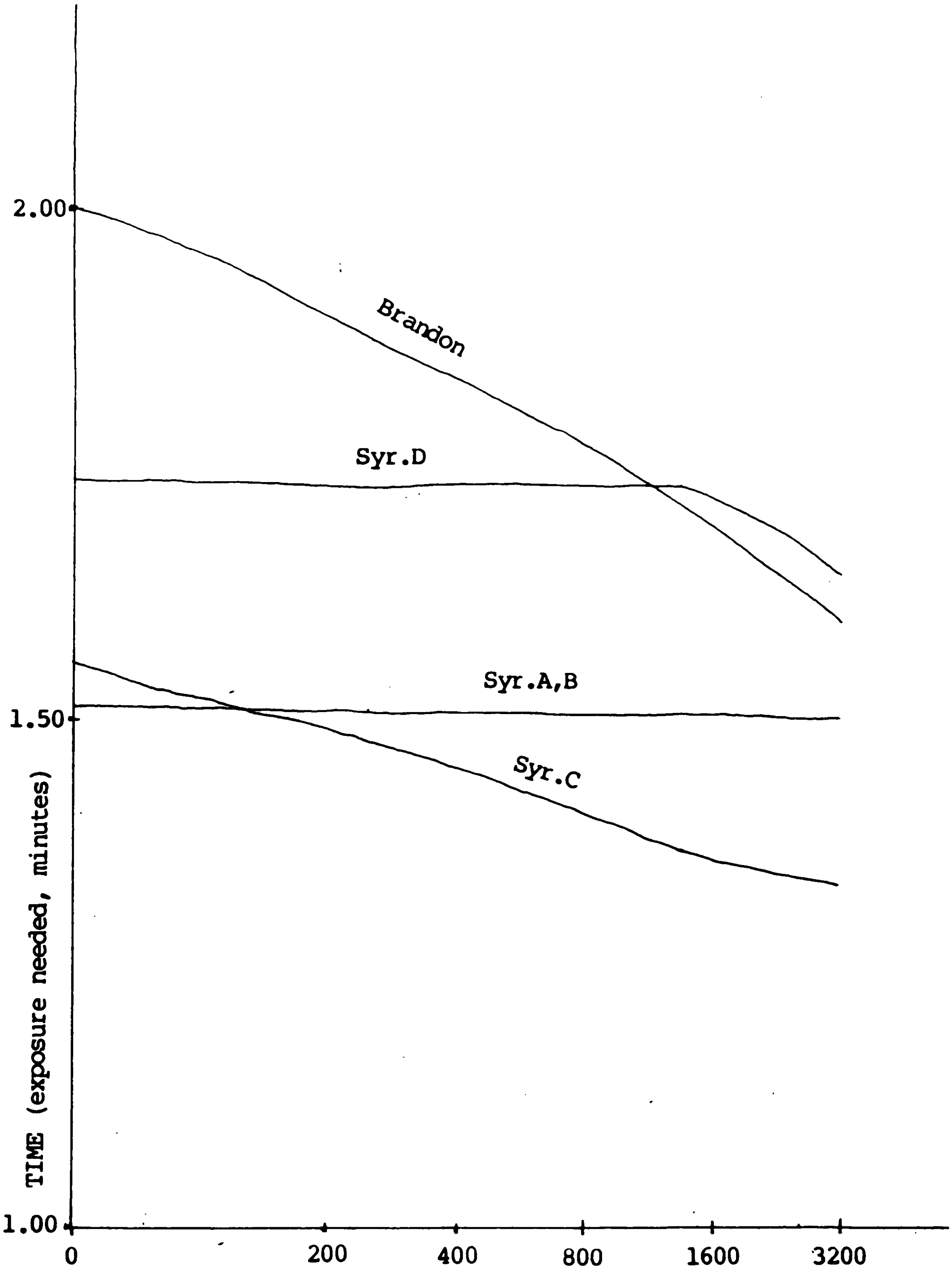


Figure 2:d - Polish Intensity, Wood, Scraping, 50x

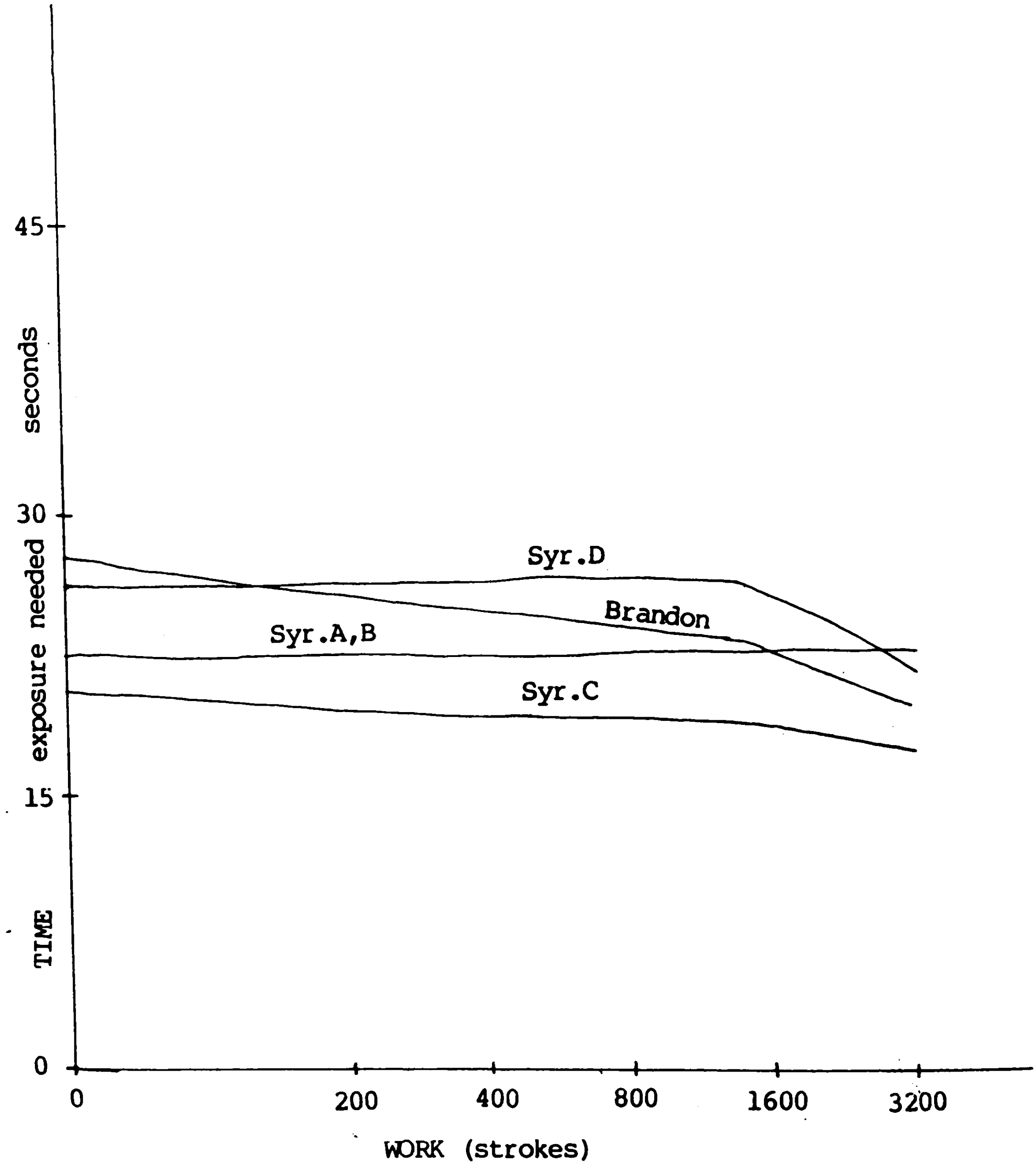


Figure 2:e - Polish Intensity, Wood, Scraping, 100x

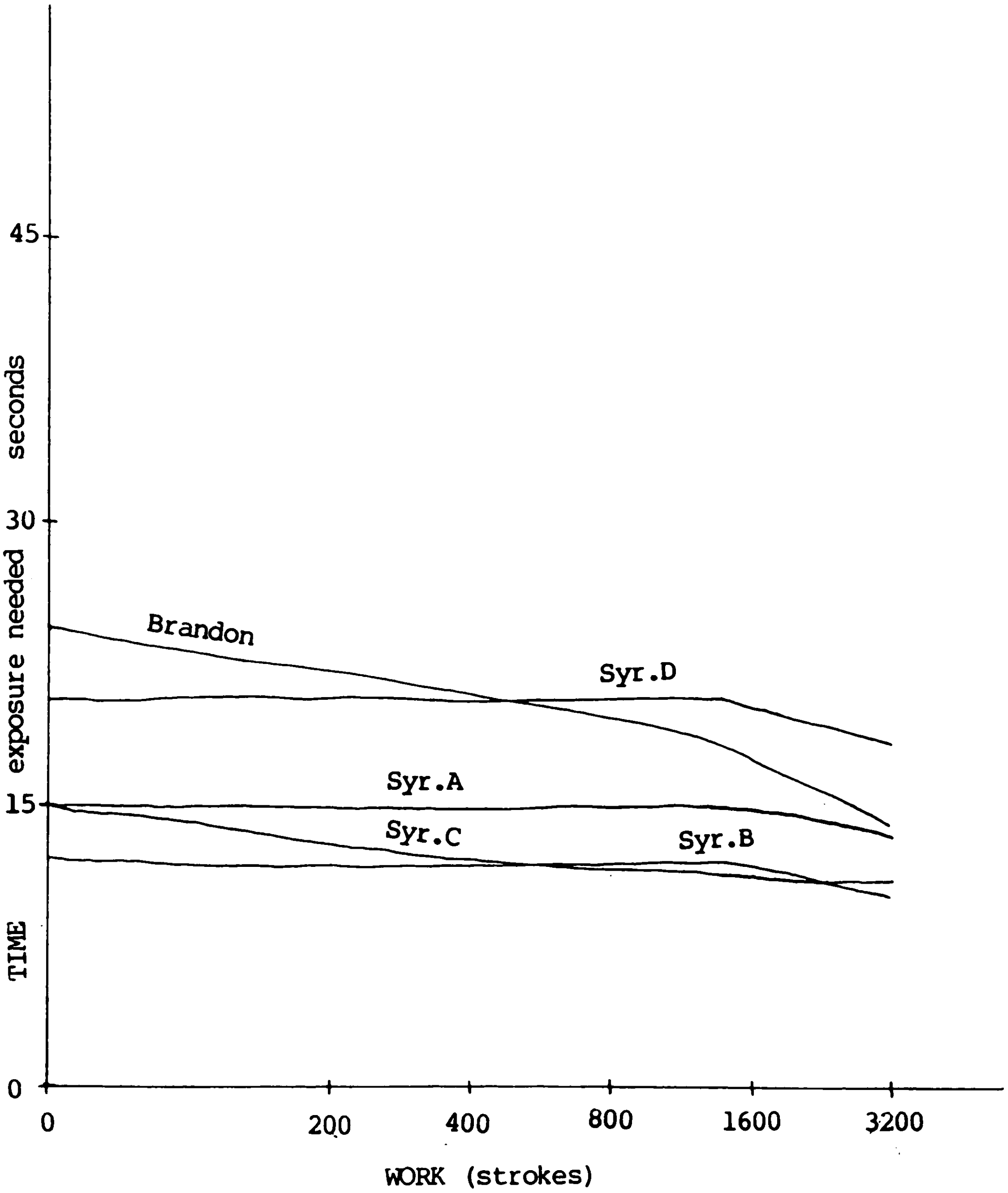


Figure 2:f - Polish Intensity - Wood, Scraping, 200x

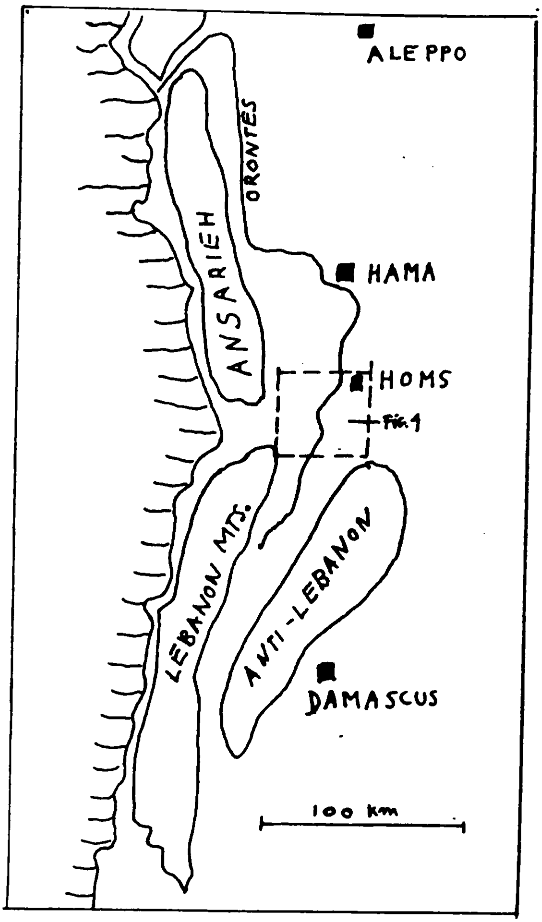


Figure 3 - Map of Syria

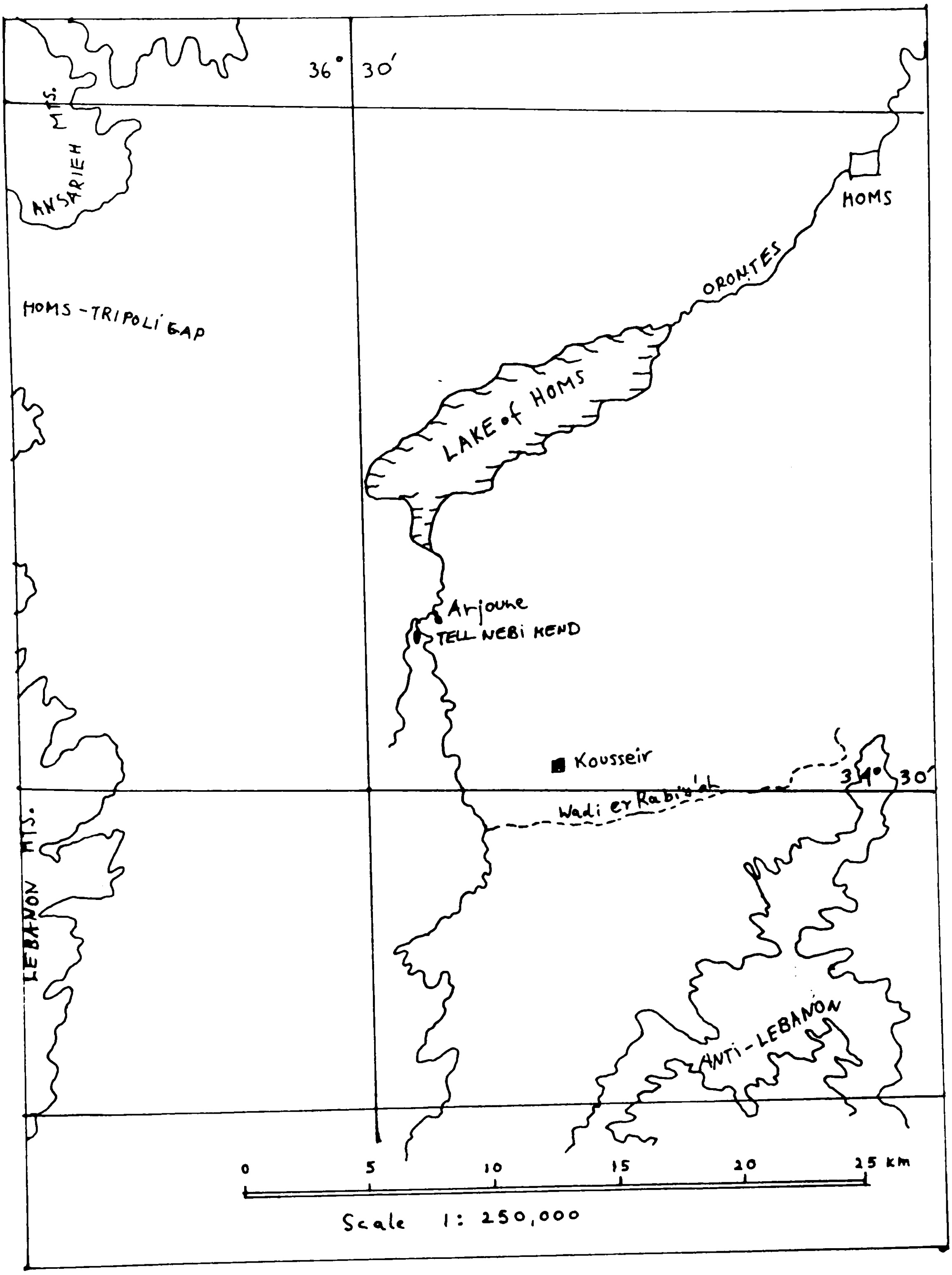


Figure 4 - The Region of Arjoune

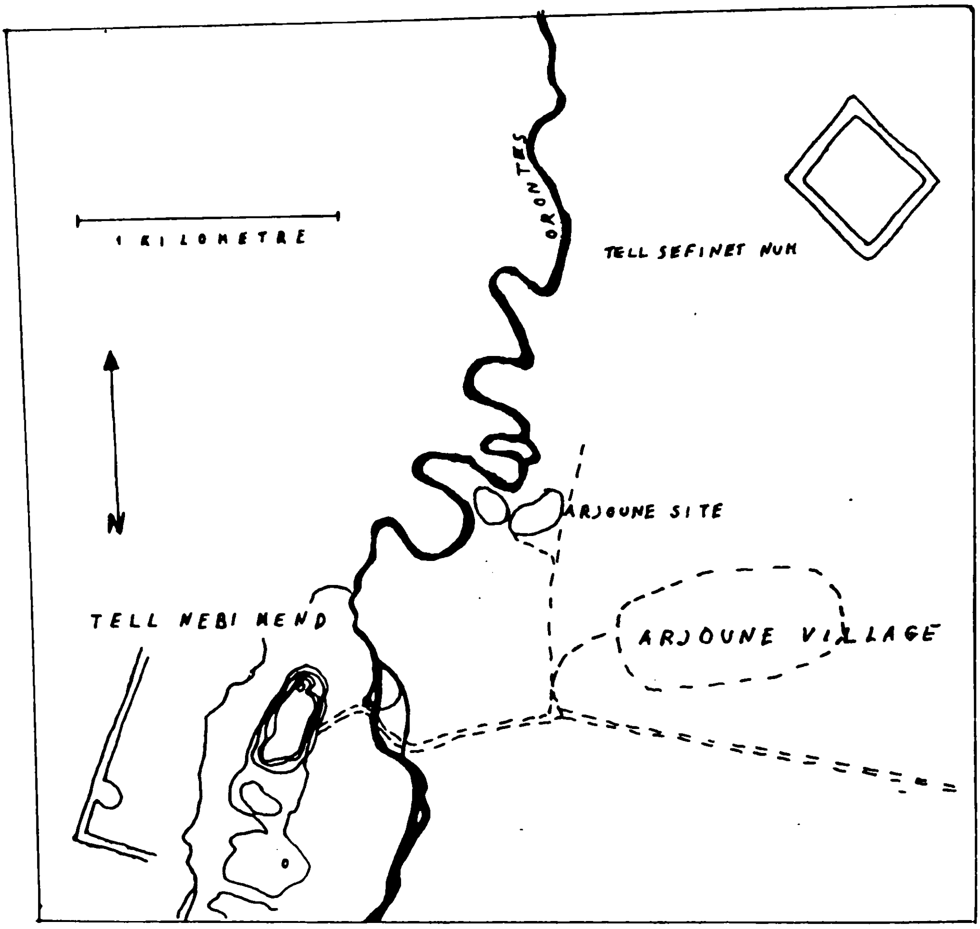
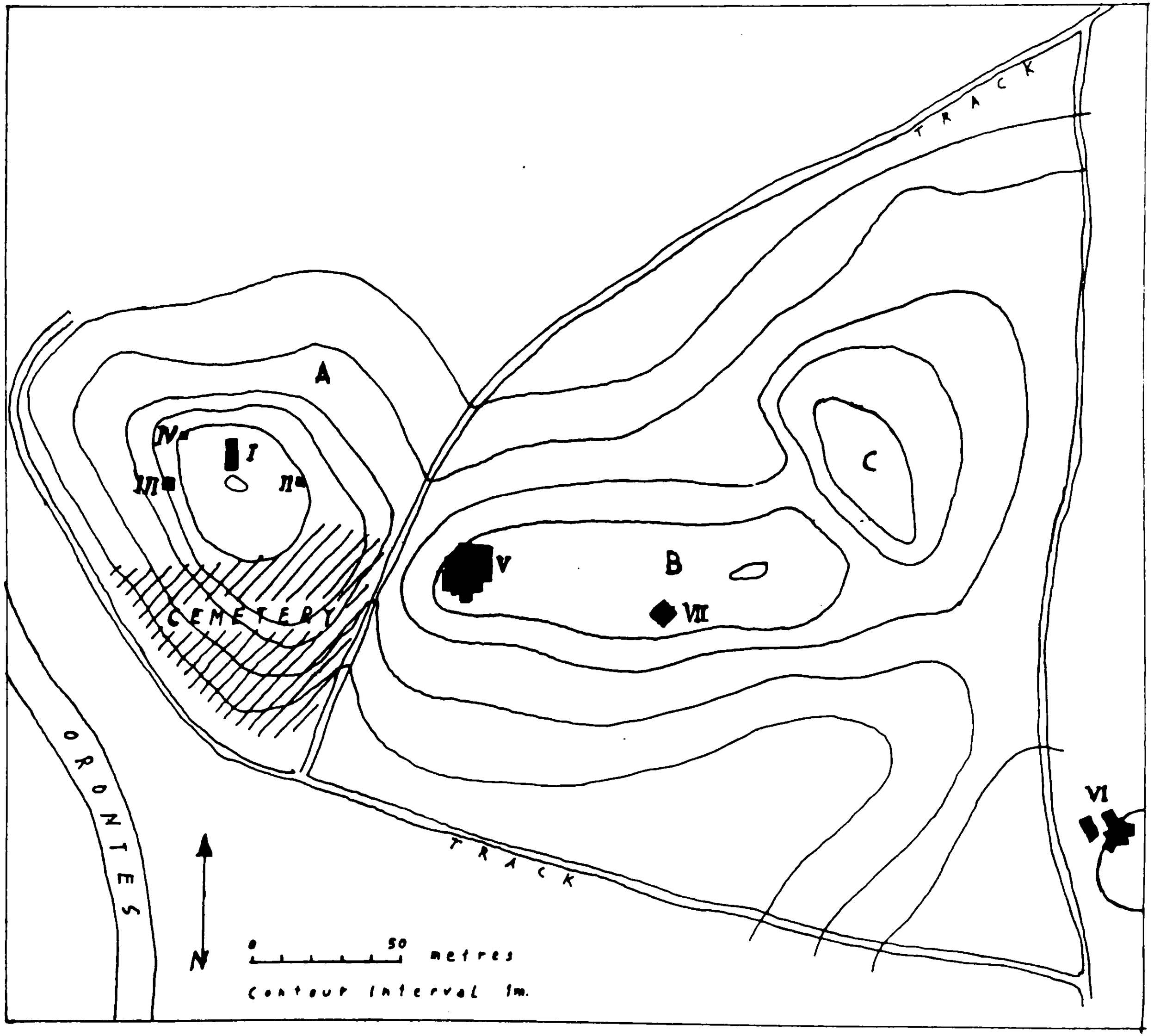


Figure 5 - Location of Arjoune

(after Marfoe <u>et</u> <u>al</u>. , 1981, Fig.1)

Figure 6 - Plan of the Site of Arjoune (showing Mounds A B, and C Trenches I-VII)



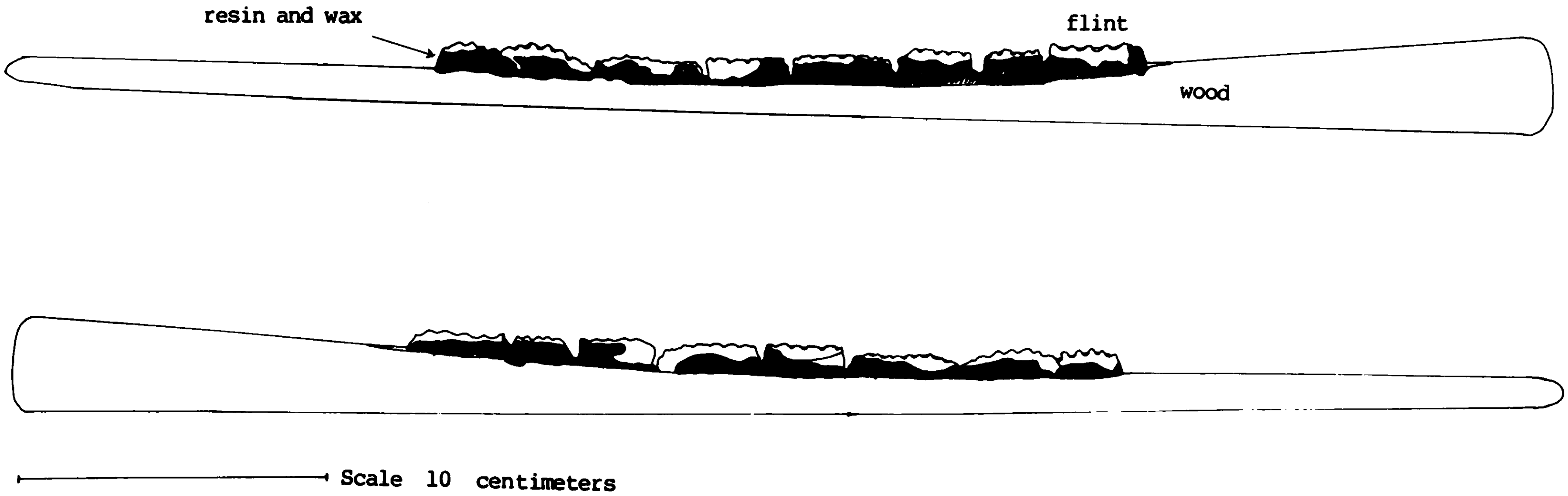


Figure 7 - Experimental Sickles a - Rectilinear Sickle

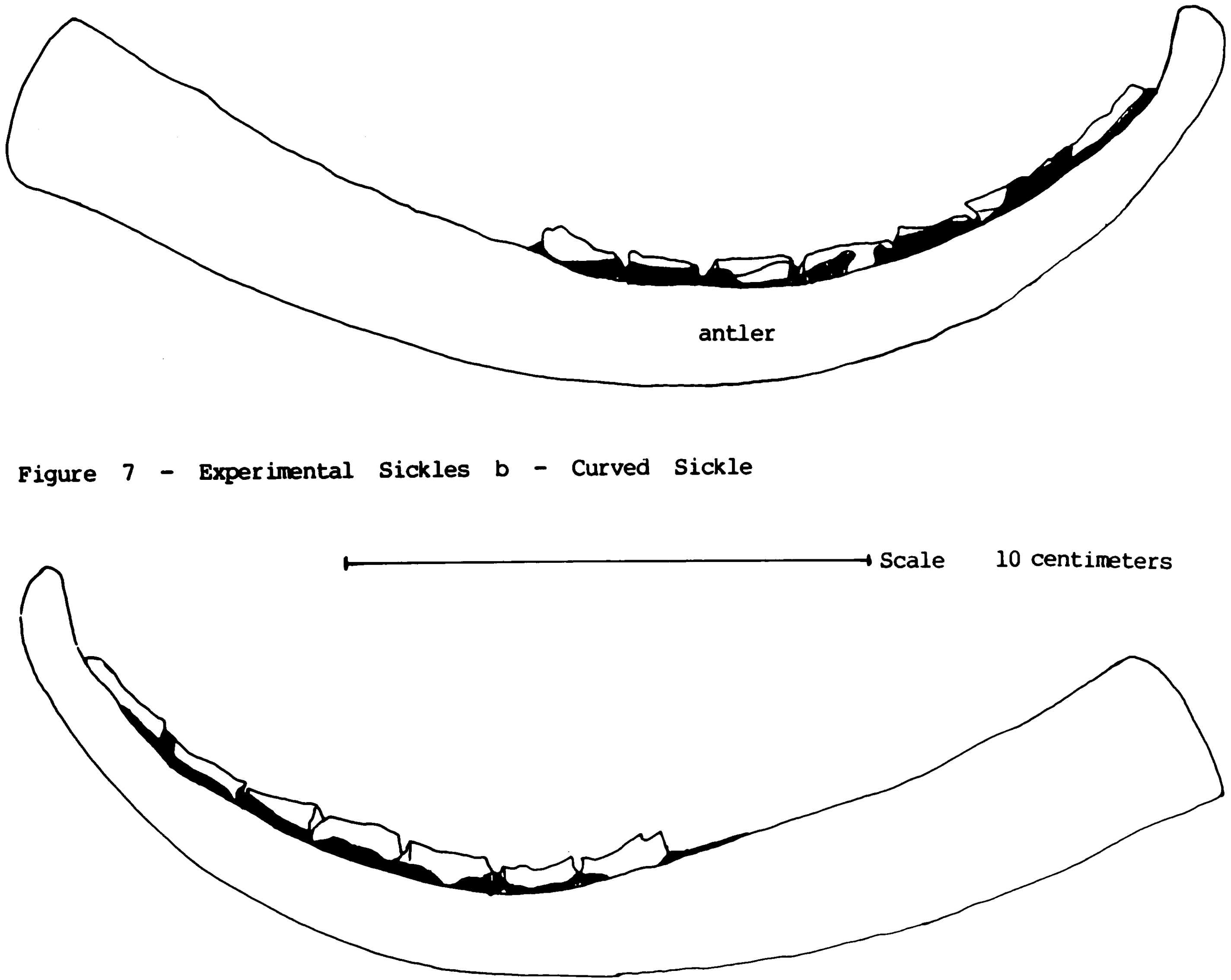
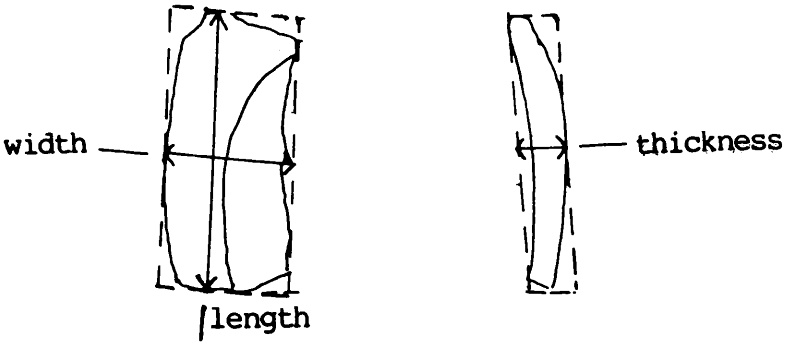
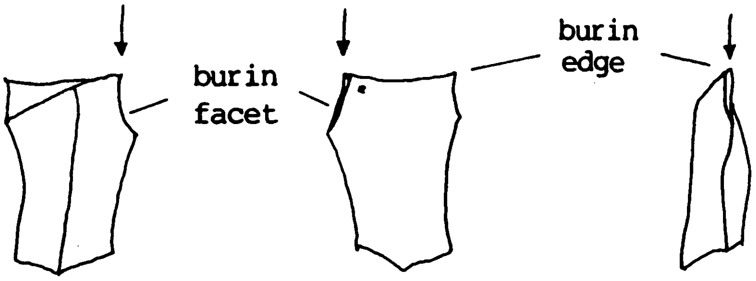


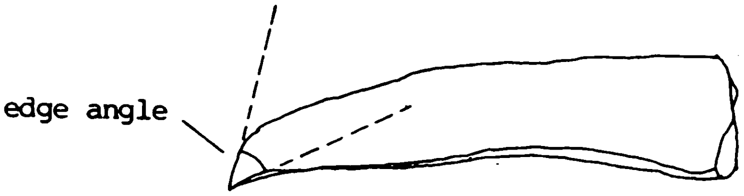
Figure 7 - Experimental Sickles b - Curved Sickle



a - Measurement of Sickle Blades

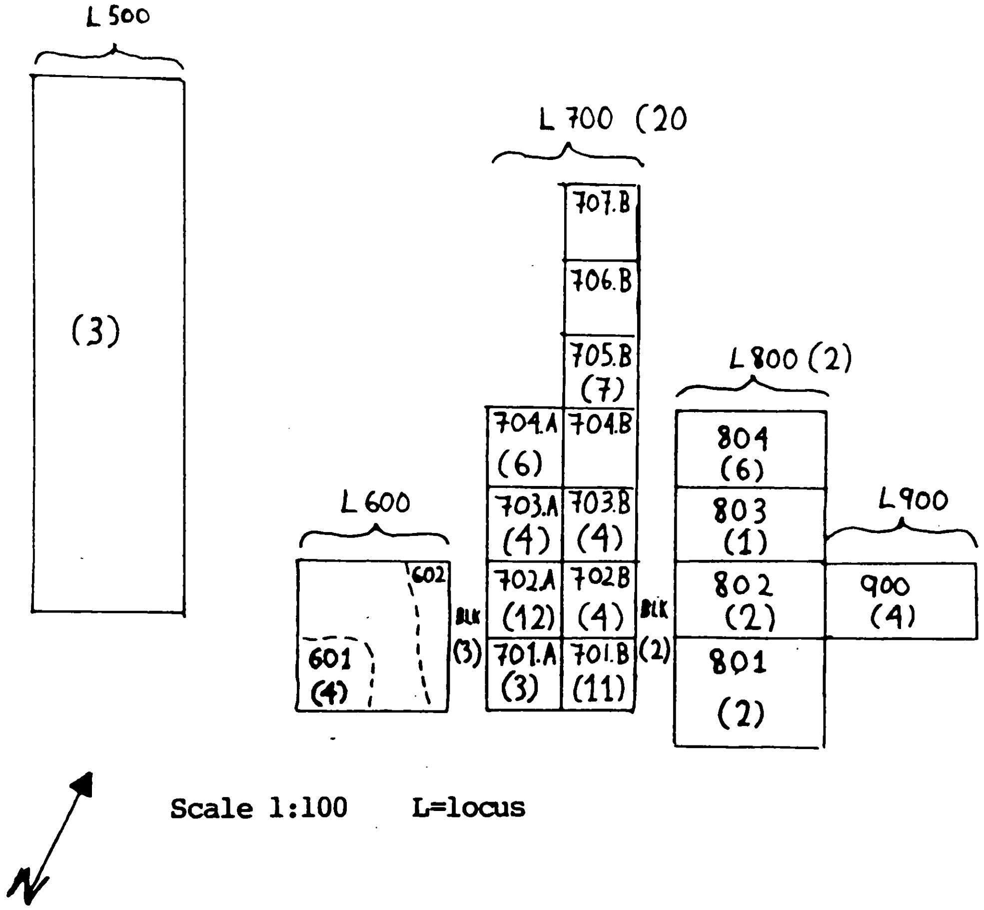


b - Burin Terminology



c - Measurement of Scraper Edge Angle

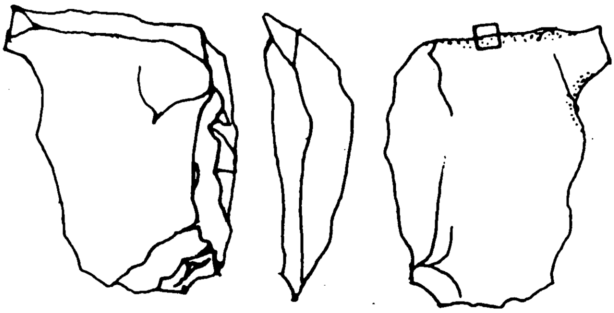
Figure 8 - Tool Measurements and Terminology



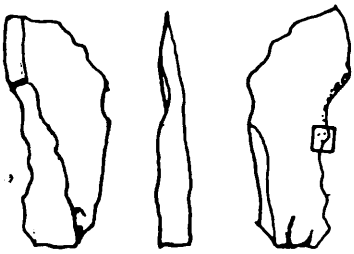
Scale 1:100 L=locus

The number of burnt flint pieces in each locus is indicated in brackets.

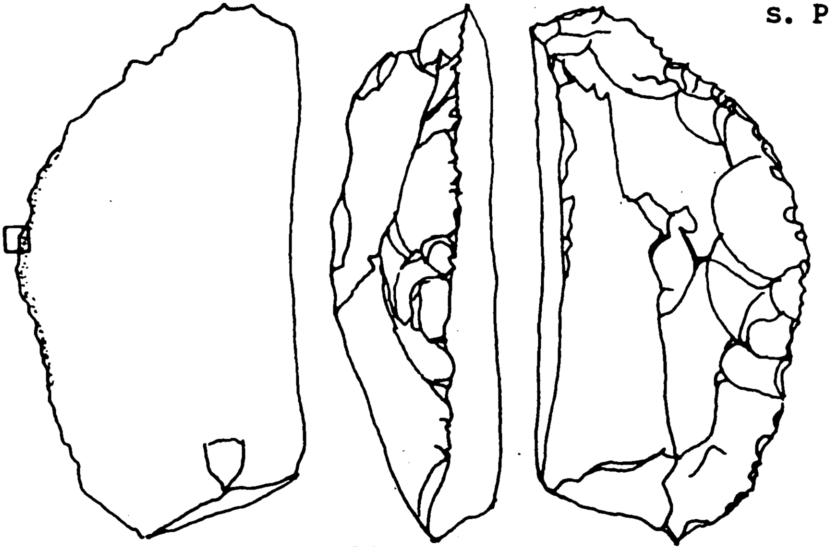
Figure 9 - Distribution of Burnt Flint: Trench VI



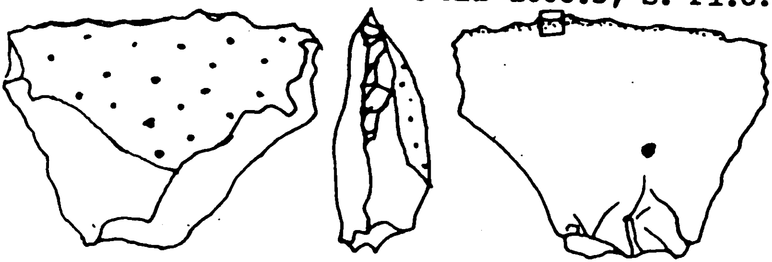
a-exp. Wood 1/4, see (s.) Pl.8:a



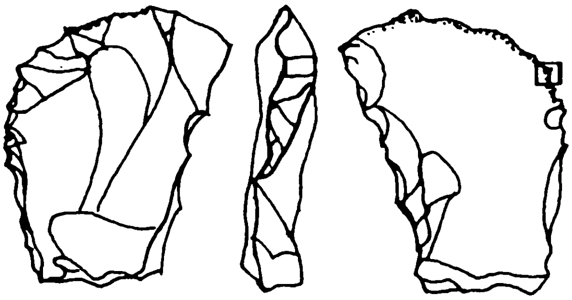
b-exp. Wood 1/5,
s. Pl.8:c



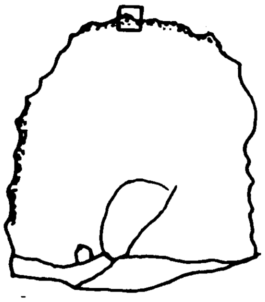
c-ARJ 1008.3, s. Pl.8:b



d-exp. Wood 15, s. Pl.8:e

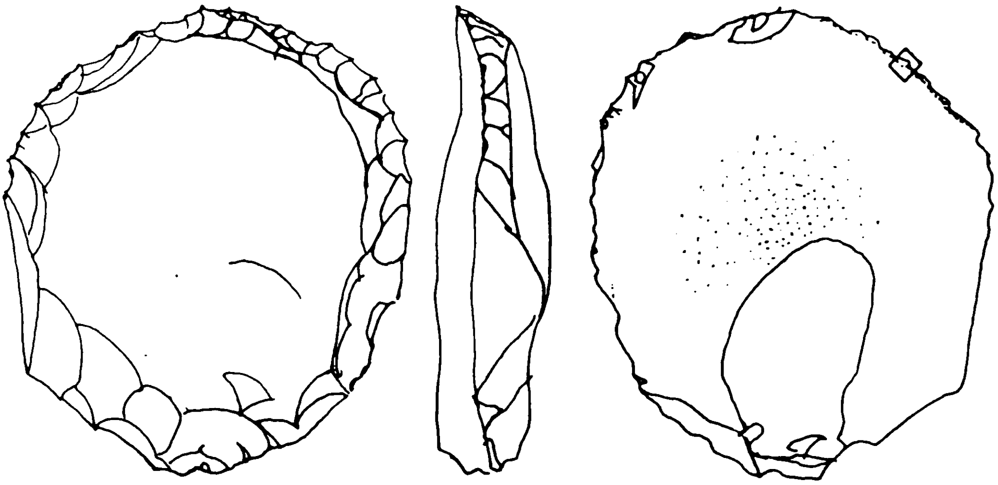


e-ARJ 800.1, s. Pl.8:f

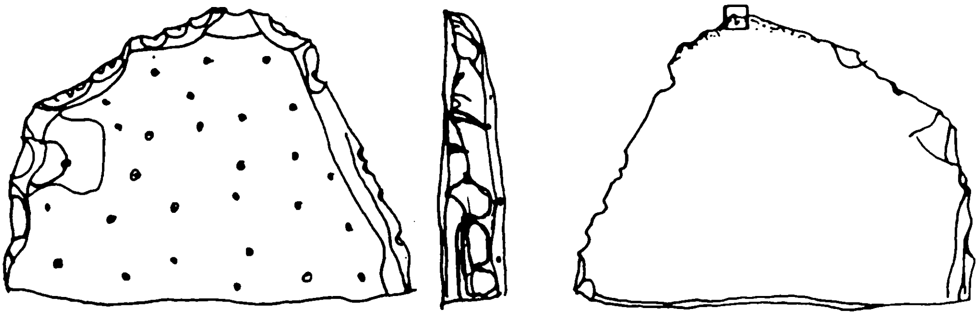


f-exp. Wood 16/1,
s. Pl.8:g

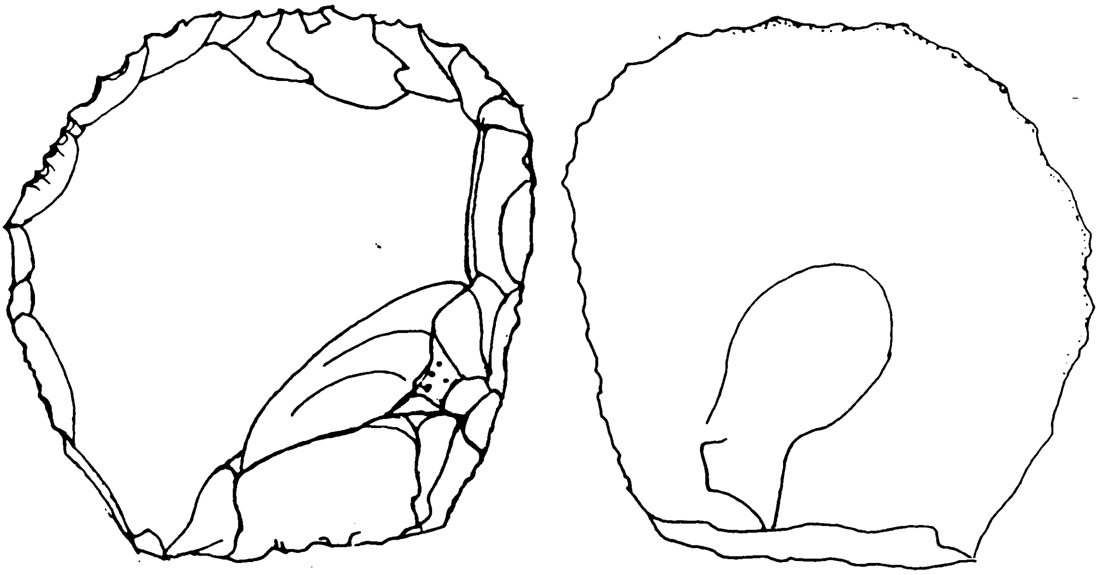
Figure 10 - Scrapers



a-ARJ VI, Surface, s. Pl.8:d

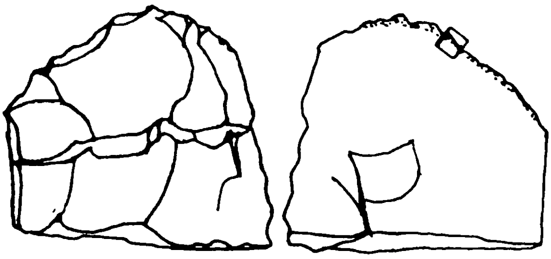


b-ARJ 220.1, s. Pl.8:h

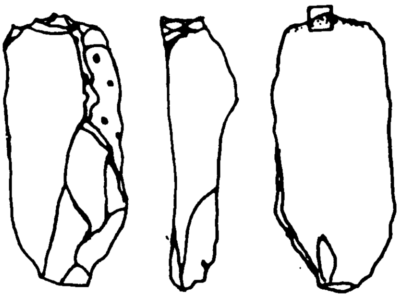


c-exp. Wood 20, no photograph

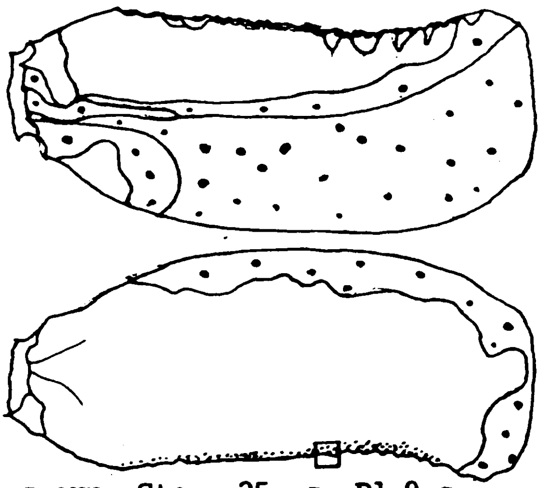
Figure 11 - Scrapers



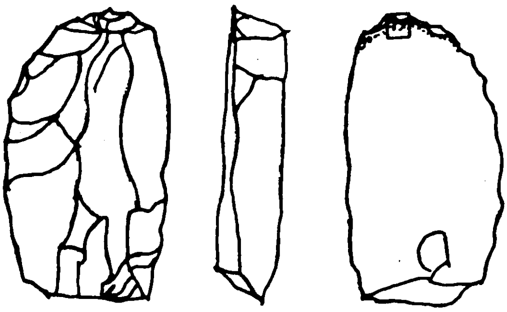
a-exp. Wood 37, s. Pl.9:a



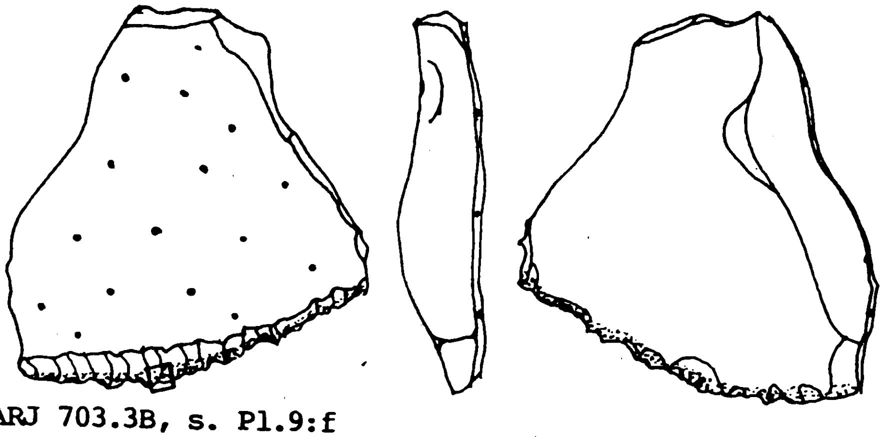
b-ARJ 114.2, s. Pl.9:b



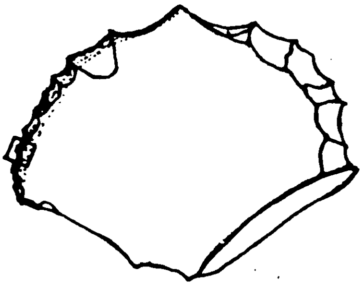
c-exp. Stone 25, s. Pl.9:c



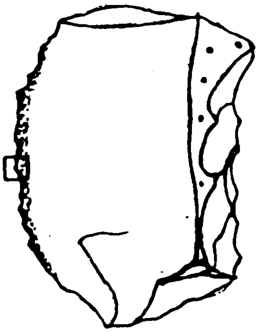
d-ARJ VII Mound C, s. Pl.9:d



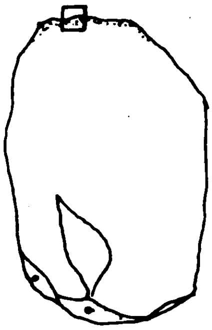
e-ARJ 703.3B, s. Pl.9:f



f-exp. Shell 5, s. Pl.9:e

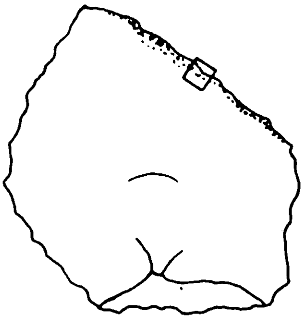


g-exp. Antler 13,
s. Pl.9:g

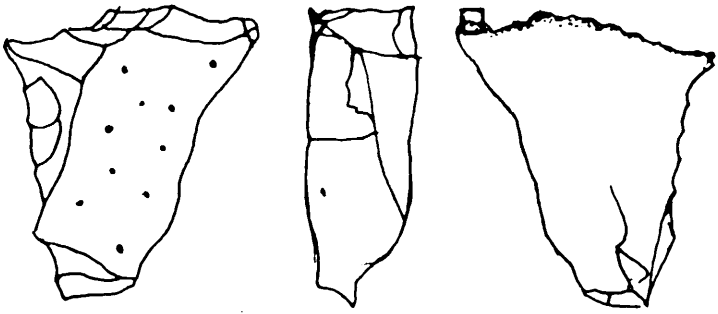


h-exp. Bone 13,
s. Pl.9:h

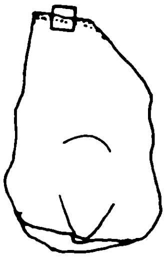
Figure 12 - Scrapers



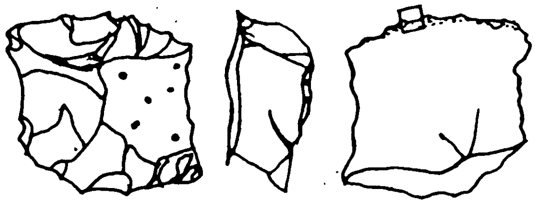
a–exp. Bone 16, s. Pl.10:a



b–ARJ 1000.1, s. Pl.10:b

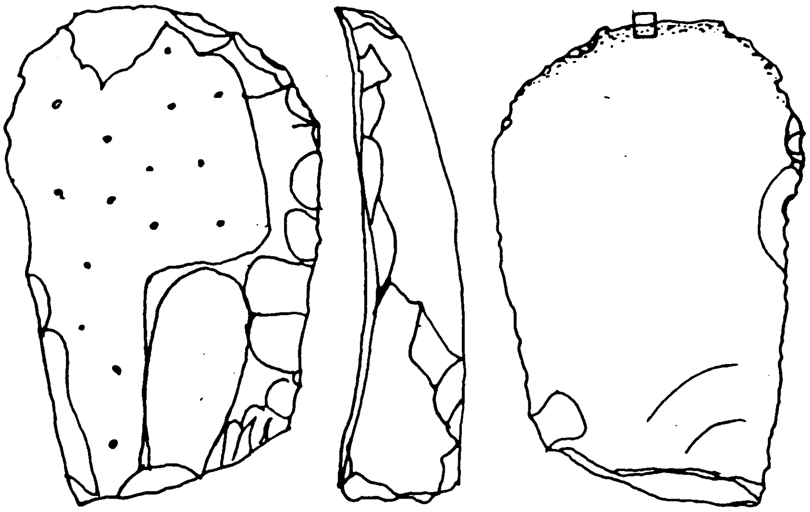


c–exp. Bone 22, s. Pl.10:c

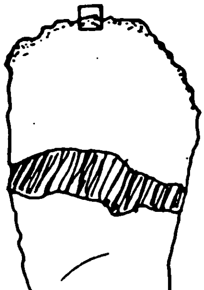


d–ARJ 1005.3, s. Pl.10:d

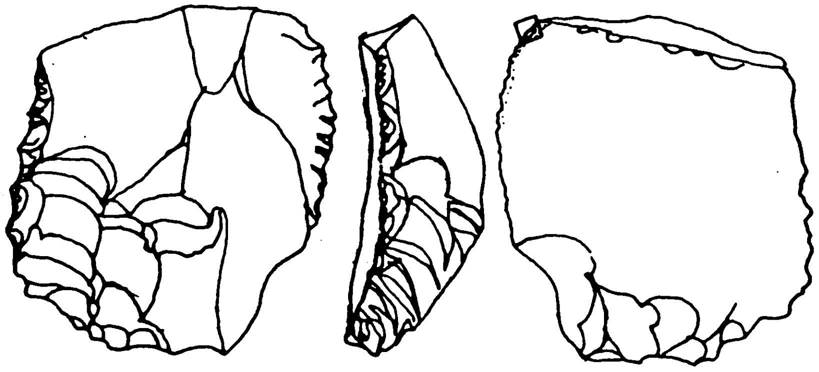
e–exp. Hide 5, s. Pl.10:g



f–ARJ 801.3, s. Pl.10:f

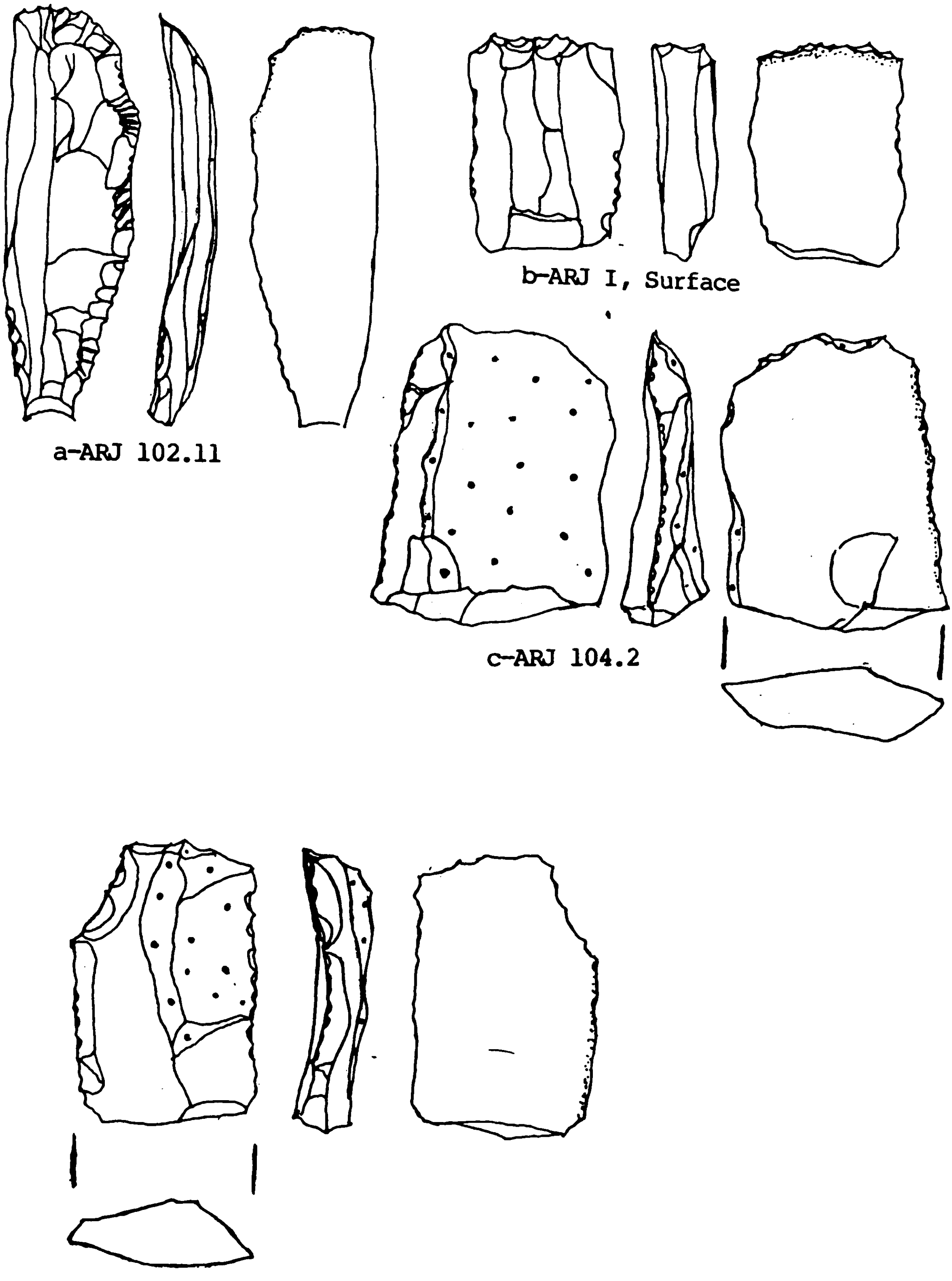


g–exp. Hide 12, s. Pl.10:e



h–ARJ 500.1, s. Pl.10:h

Figure 13 – Scrapers



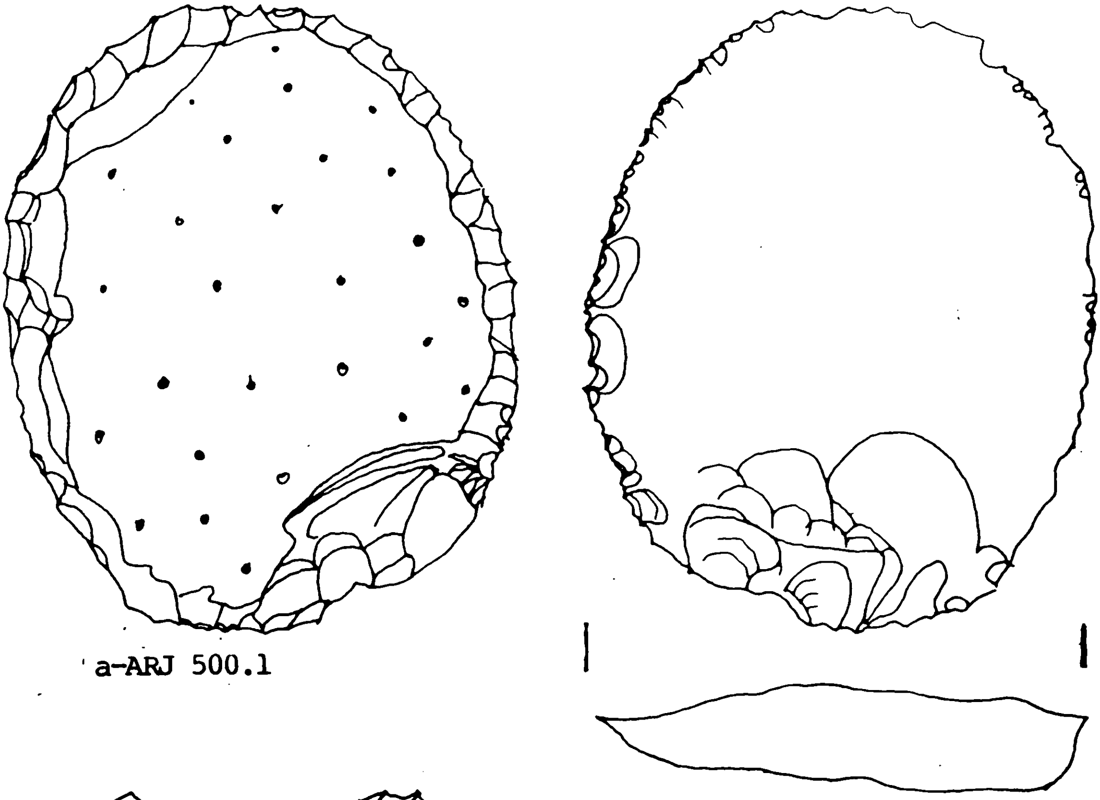
a-ARJ 102.11

b-ARJ I, Surface

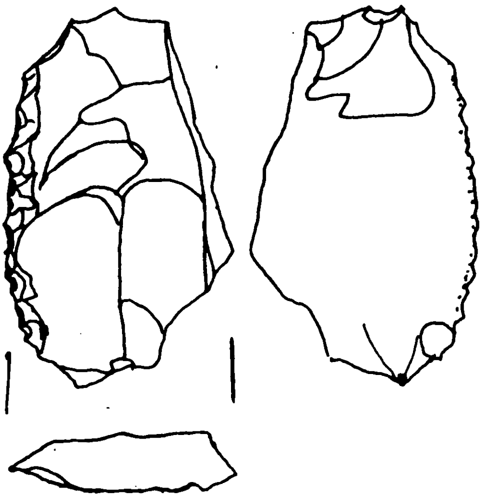
c-ARJ 104.2

d-ARJ 210.1

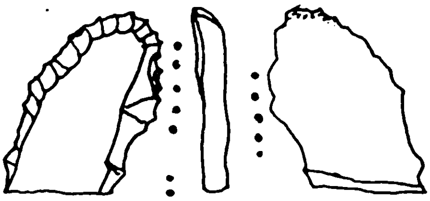
Figure 14 - Scrapers



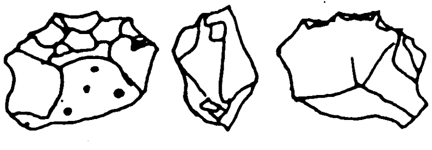
a-ARJ 500.1



b-ARJ 702.3B

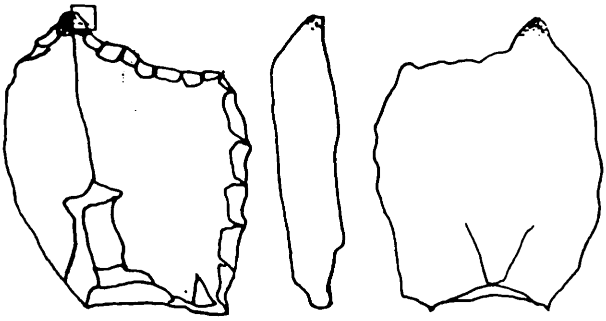


c-ARJ 900.1

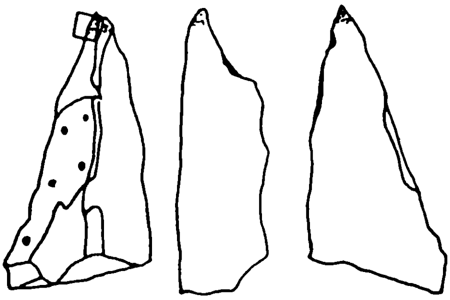


d-ARJ 1000.1

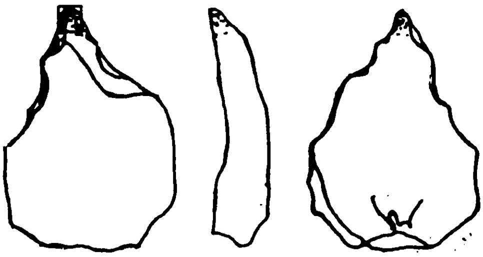
Figure 15 - Scrapers



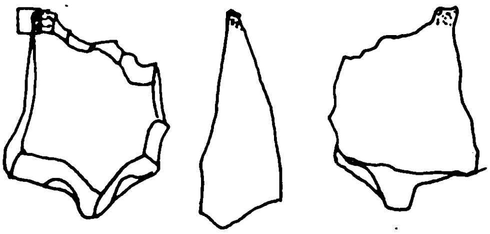
a-exp. Wood 7, s. Pl.11:a



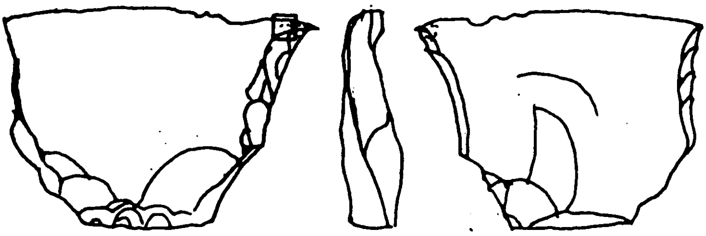
b-ARJ 700.1, s. Pl.11:b



c-exp. Antler 19, s. Pl.11:c

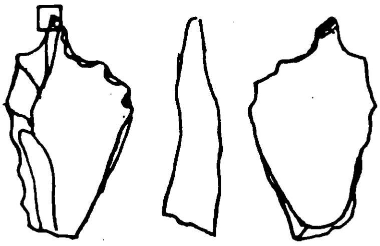


d-ARJ 800.2, s. Pl.11:d



e-ARJ 500.1, s. Pl.11:f

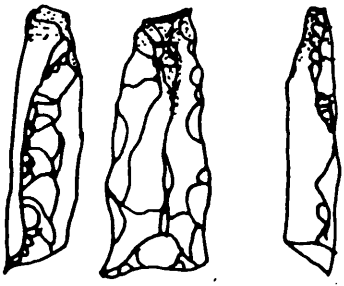
f-exp. Bone 42, s. Pl.11:e



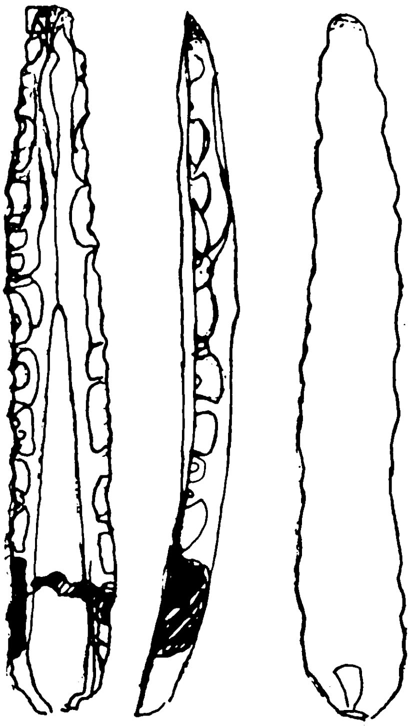
g-ARJ 1000.1, s. Pl.11:h

h-exp. Pottery 6/1, s. Pl.11:g

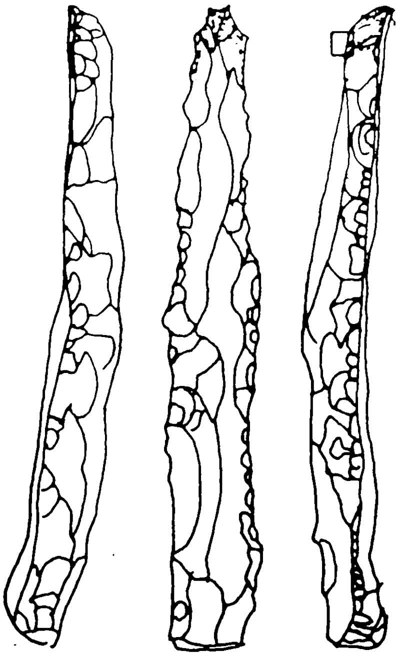
Figure 16 - Perforators



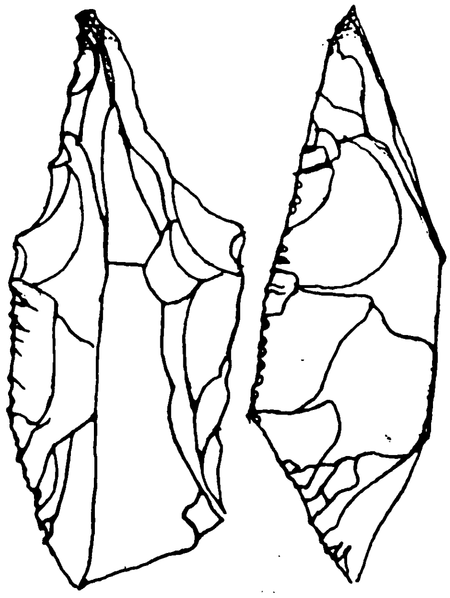
i-ARJ I-IV, Surface, (L.C.), s. Pl.12:h



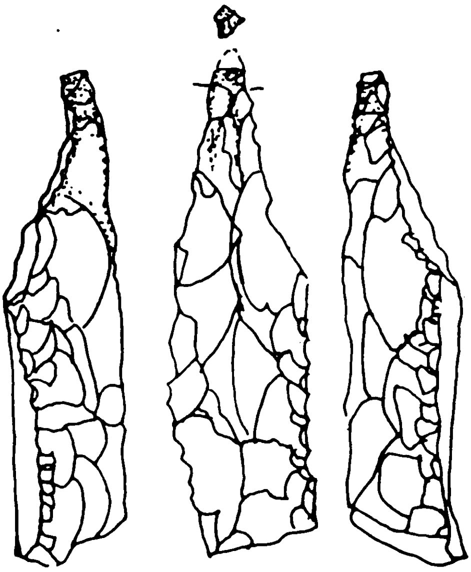
a-exp. Wood 50, s. Pl.12:a,c



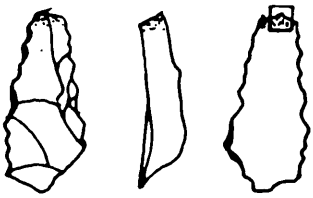
b-ARJ 701.3B, (L.C.), s. Pl.12:b,d



c-exp. Stone 28, s. Pl.12:e

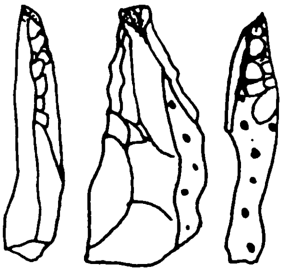


d-ARJ 700.1, (L.C.), s. Pl.12:g

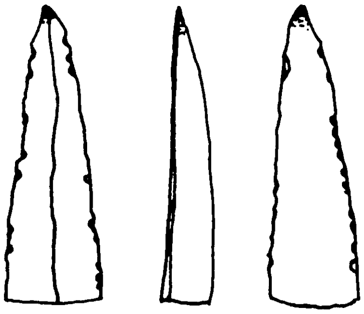


e-ARJ 403.2, s. Pl.12:f

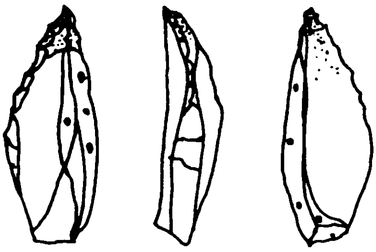
Figure 17 - Perforators



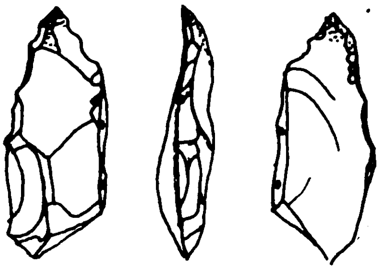
a-ARJ I, Surface, (L.C.)



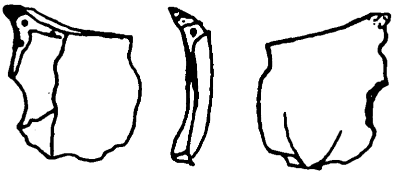
b-ARJ 313.2



c-ARJ 703.3B

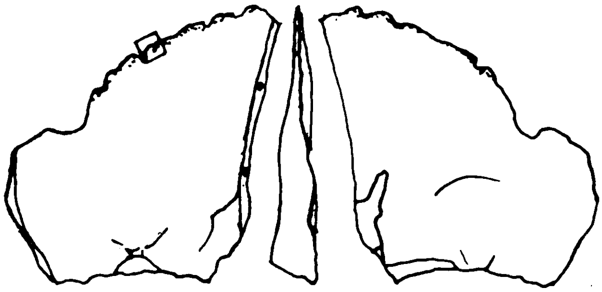


d-ARJ 900.1

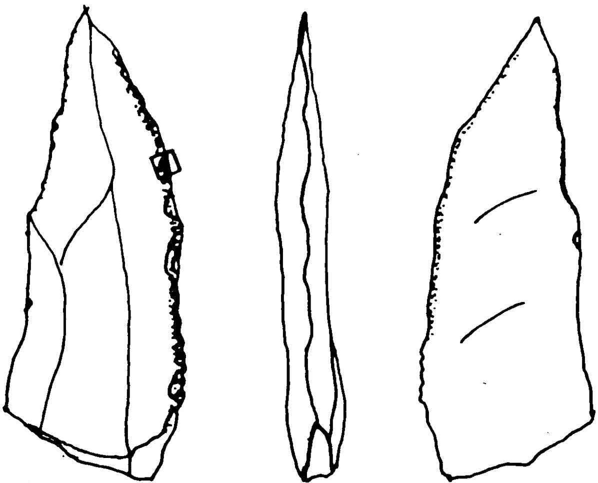


e-ARJ 1000.1

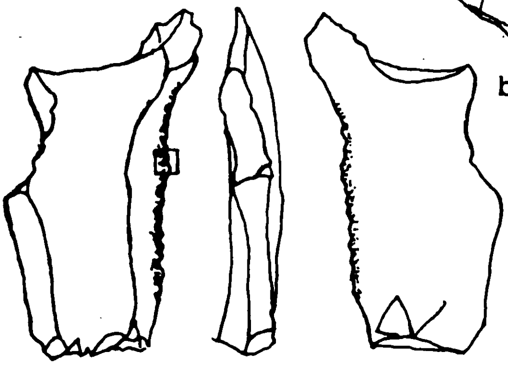
Figure 18 - Perforators



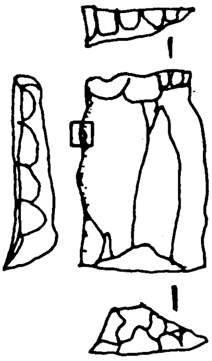
a-exp. Wood 21, s. Pl.13:a



b-ARJ 703.3B, s. Pl.13:b



c-exp. Wood 35, s. Pl.13:c



d-ARJ I-IV, Surface, s. Pl.13:d

Figure 19 - Blades, Bladelets and Flakes

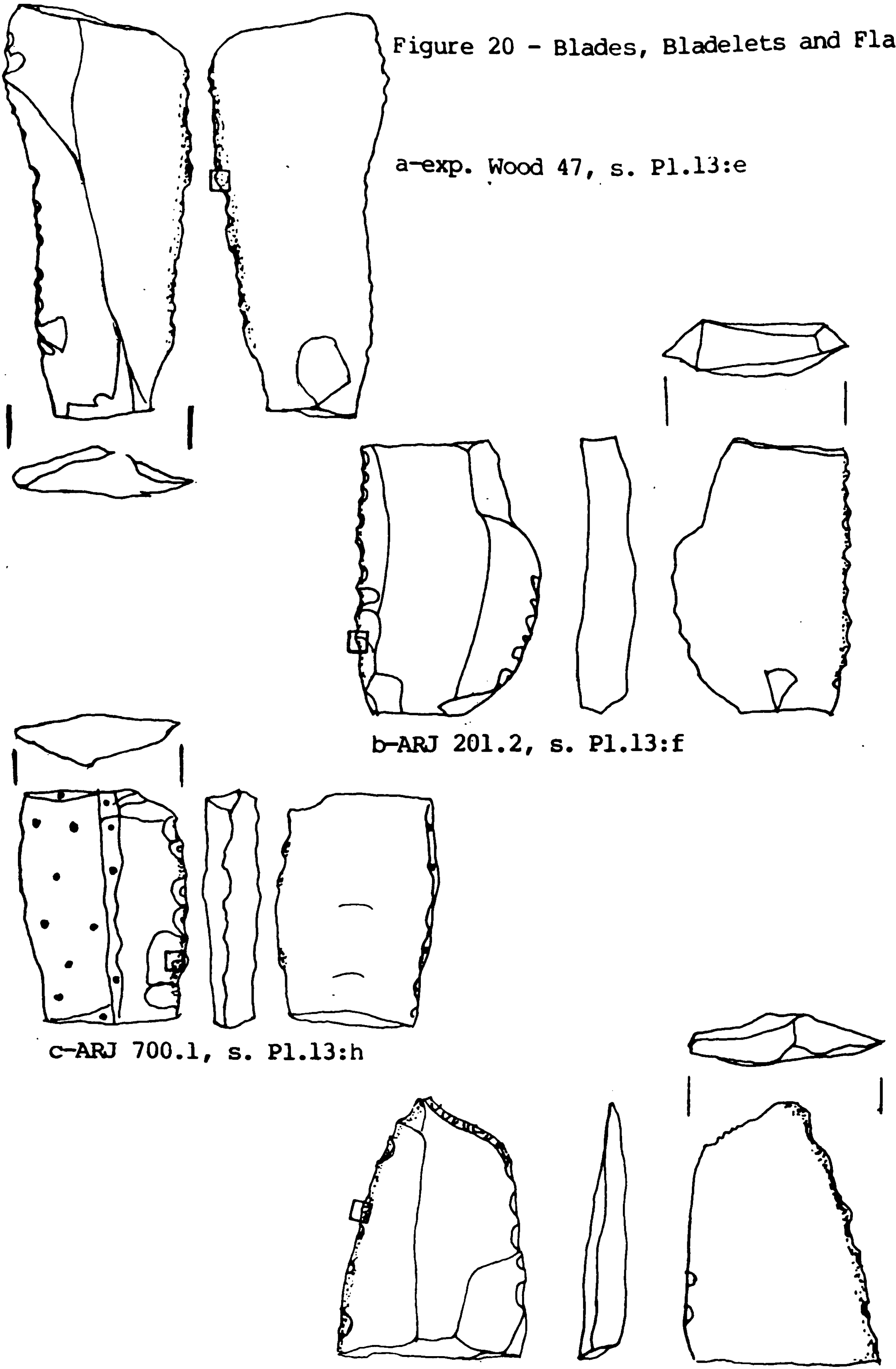


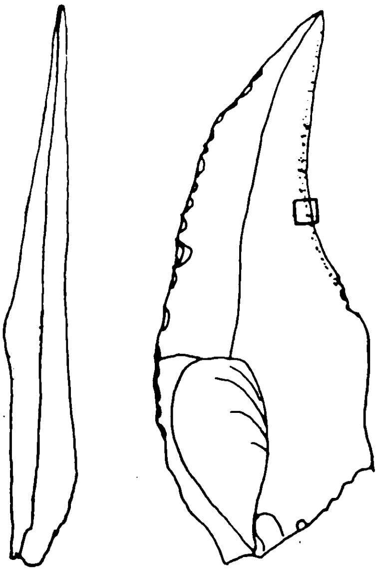
Figure 20 - Blades, Bladelets and Flakes

a-exp. Wood 47, s. Pl.13:e

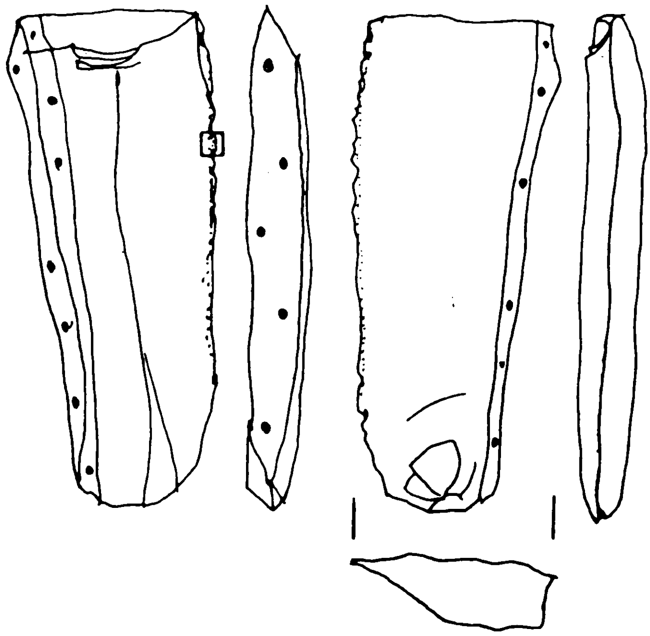
b-ARJ 201.2, s. Pl.13:f

c-ARJ 700.1, s. Pl.13:h

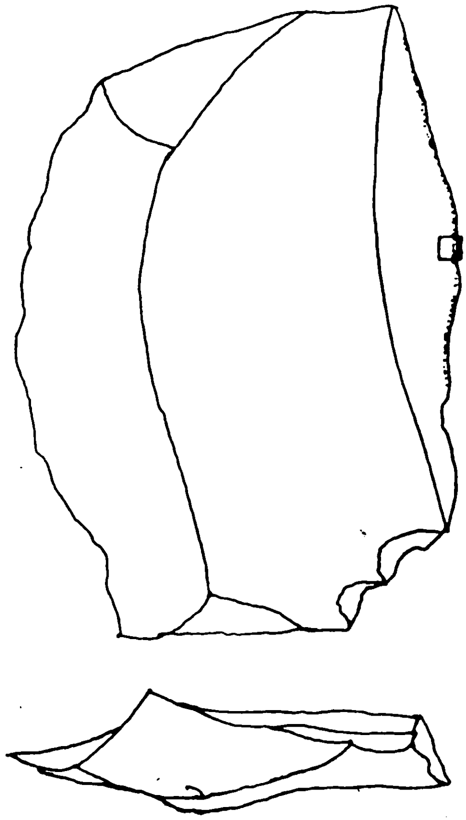
d-ARJ 701.3A, s. Pl.13:g



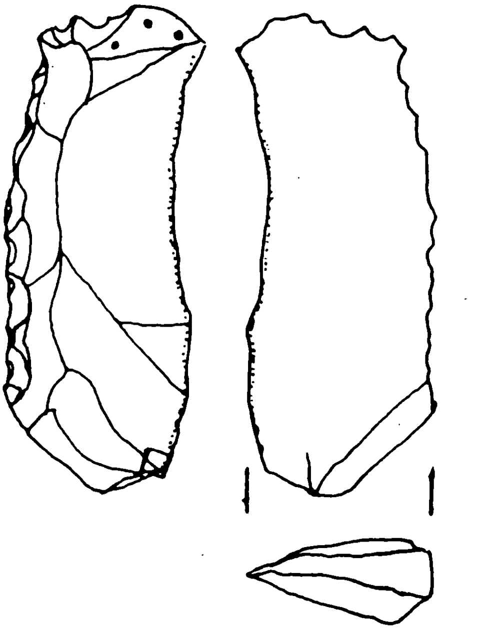
a-exp. Meat 3, s. Pl.14:a



b-ARJ Baulk 600-700.3, s. Pl.14:b

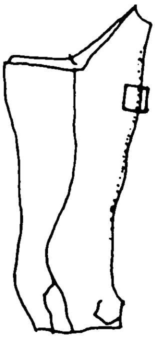


c-exp. Meat 4, s. Pl.14:c

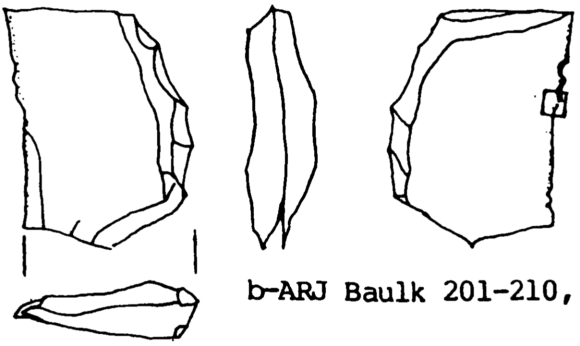


d-ARJ 803.3, s. Pl.14:d

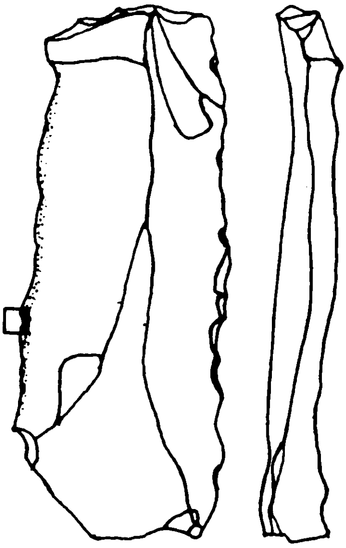
Figure 21 - Blades, Bladelets and Flakes



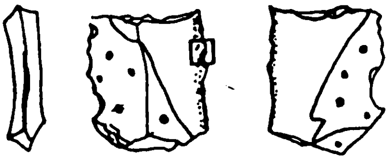
a-exp. Wool 1, s. Pl.14:e



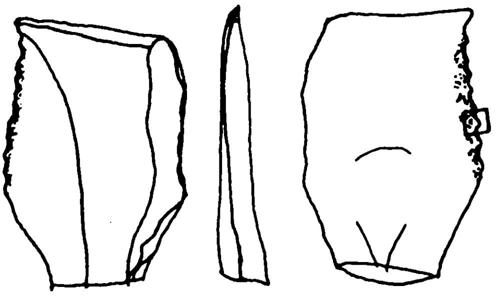
b-ARJ Baulk 201-210, s. Pl.14:f



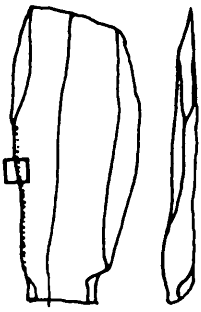
d-exp. Hide 16, s. Pl.14:g



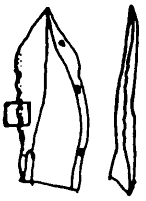
c-ARJ 700.1, s. Pl.14:h



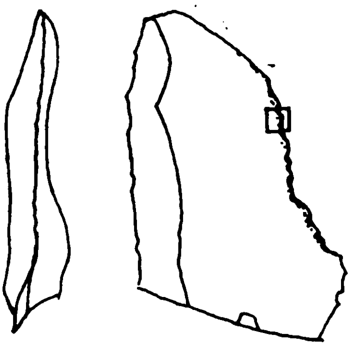
e-exp. Fish 1, s. Pl.15:e



f-exp. Feather 1, s. Pl.15:f

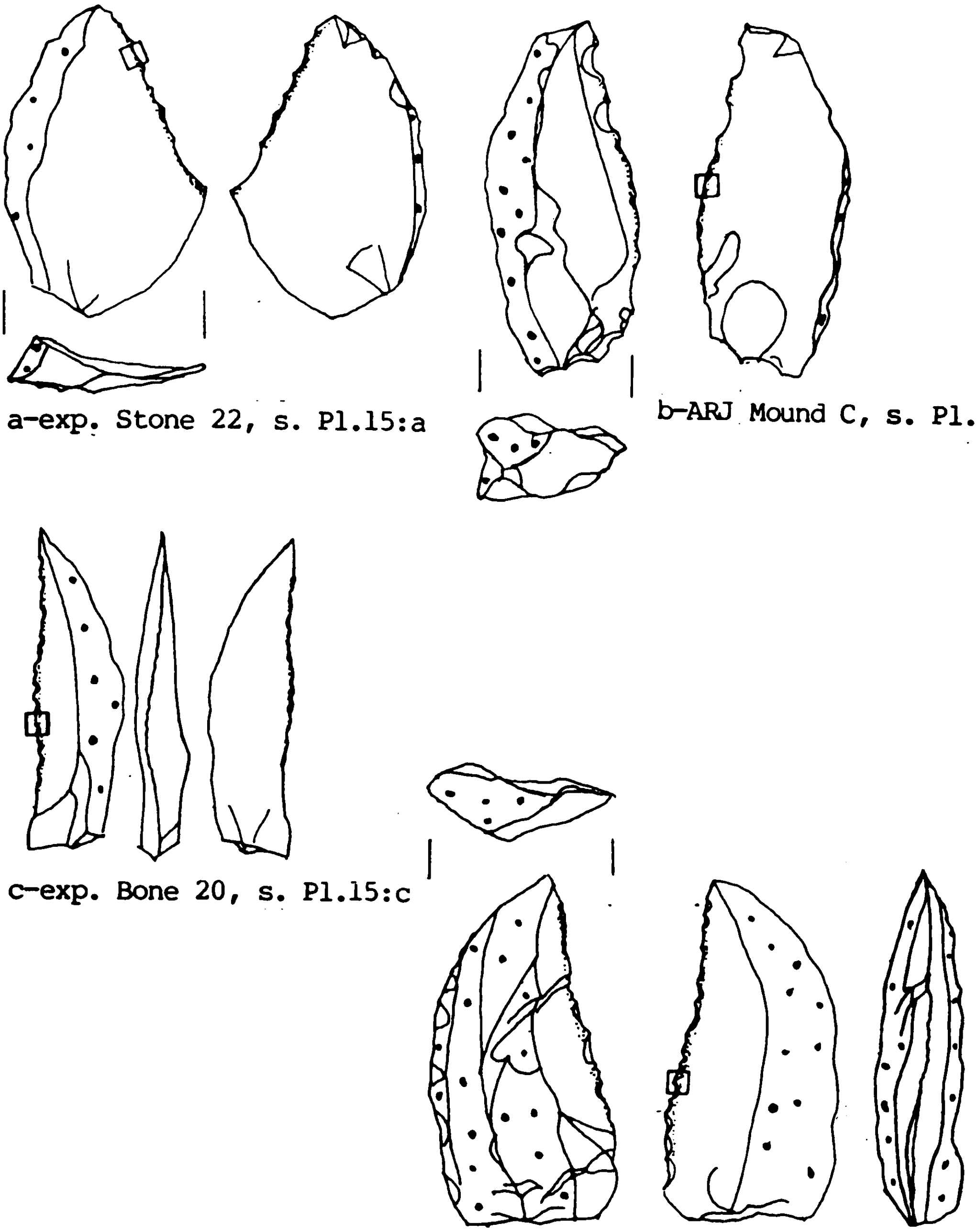


g-exp. Antler 18, s. Pl.15:g



h-exp. Antler 3/1, s. Pl.15:h

Figure 22 - Blades, Bladelets and Flakes



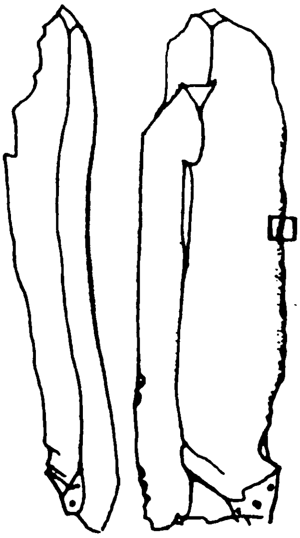
a-exp. Stone 22, s. Pl.15:a

b-ARJ Mound C, s. Pl.15:b

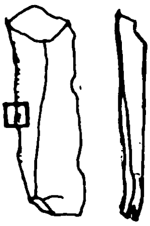
c-exp. Bone 20, s. Pl.15:c

d-ARJ 701.3B, s. Pl.15:d

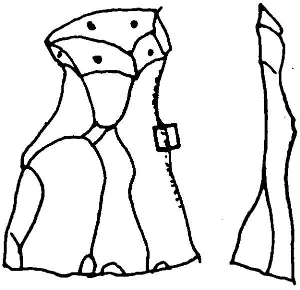
Figure 23 - Blades, Bladelets and Flakes



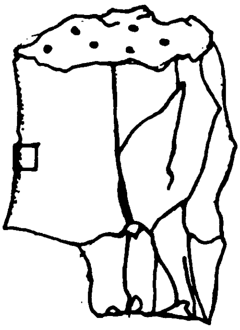
a-exp. Meat 11/1, s. Pl.16:a



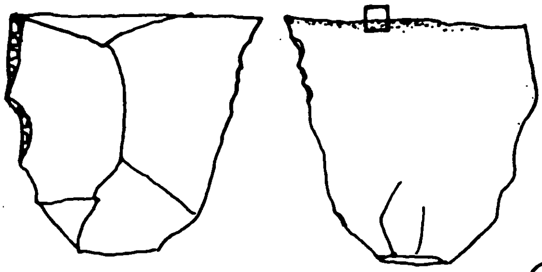
b-exp. Meat 9, s. Pl.16:b



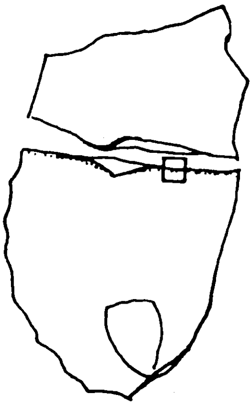
c-exp. Vegetable 1, s. Pl.16:c



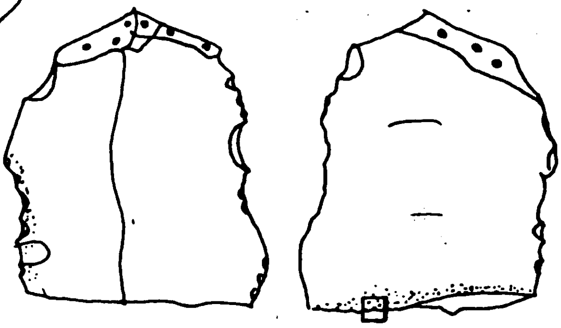
d-exp. Horn 1, s. Pl.16:d



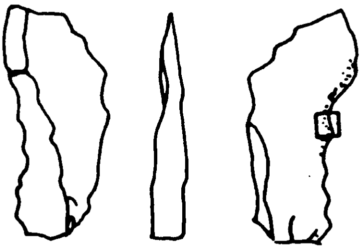
e-ARJ 900.1, s. Pl.16:h



f-exp. broken blade, s. Pl.16:e

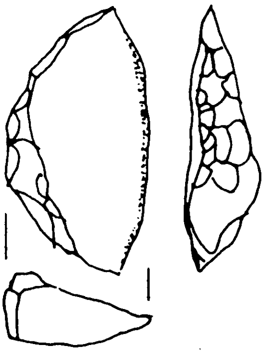


g-ARJ 102.4, s. Pl.16:f

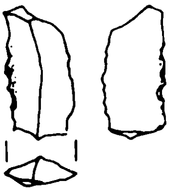


h-exp. Wood 1/5, s. Pl.16:g

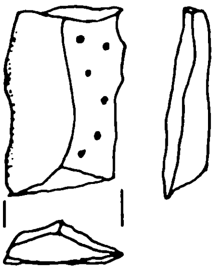
Figure 24 - Blades, Bladelets and Flakes



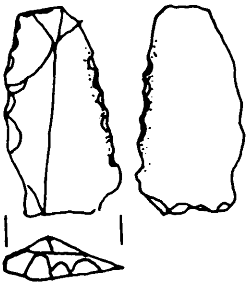
a-ARJ I-IV, Surface, (L.C.)



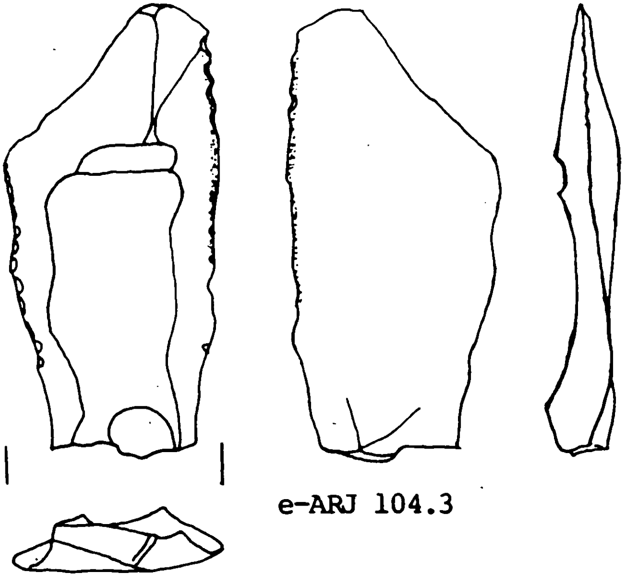
b-ARJ Baulk 101-401



c-ARJ 102.2

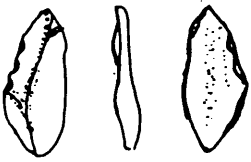


d-ARJ 104.2

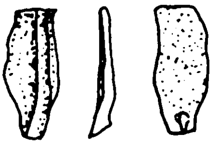


e-ARJ 104.3

f-ARJ 200.0

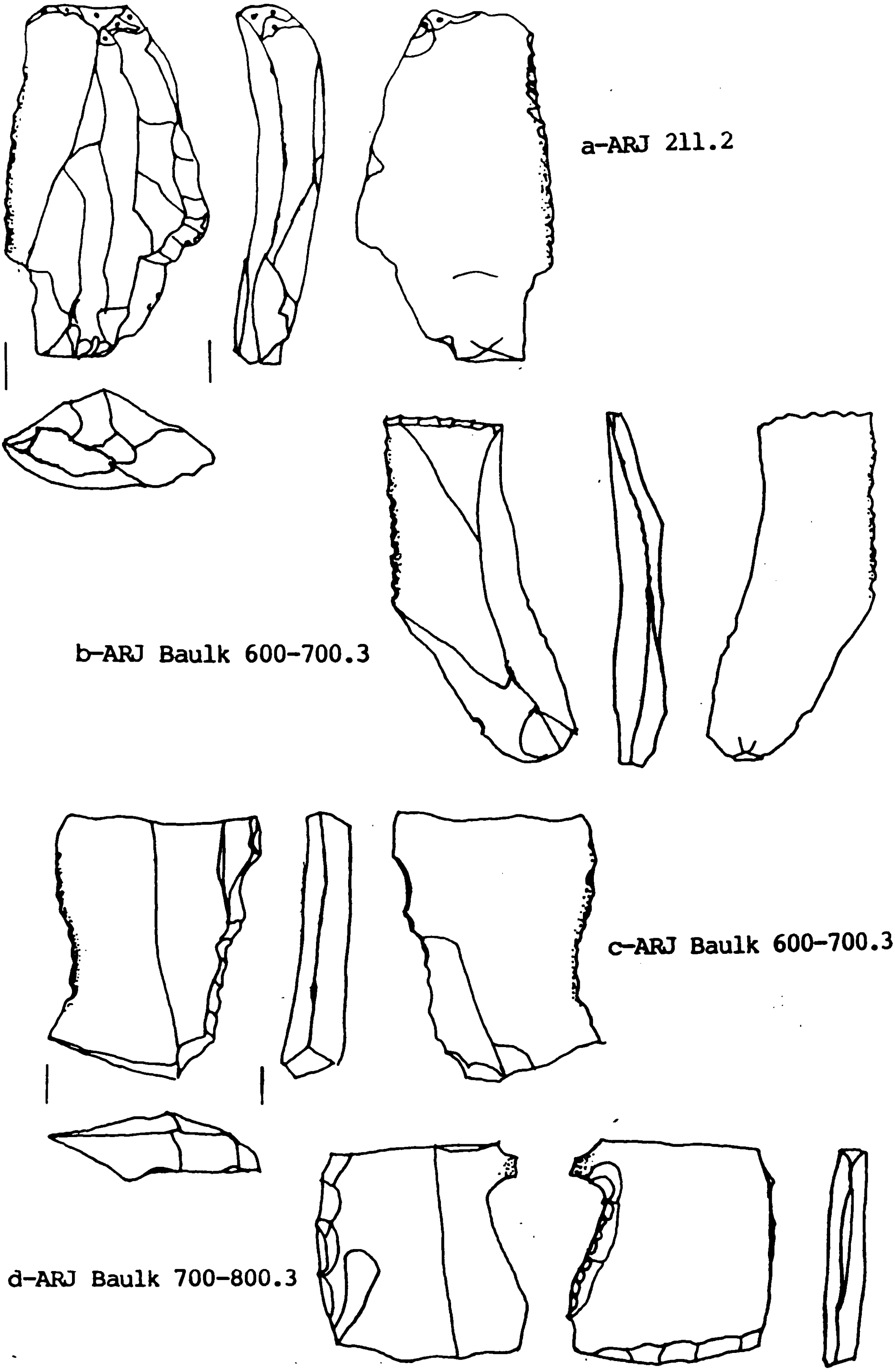


g-ARJ 202.2



h-ARJ 202.2

Figure 25 - Blades, Bladelets and Flakes



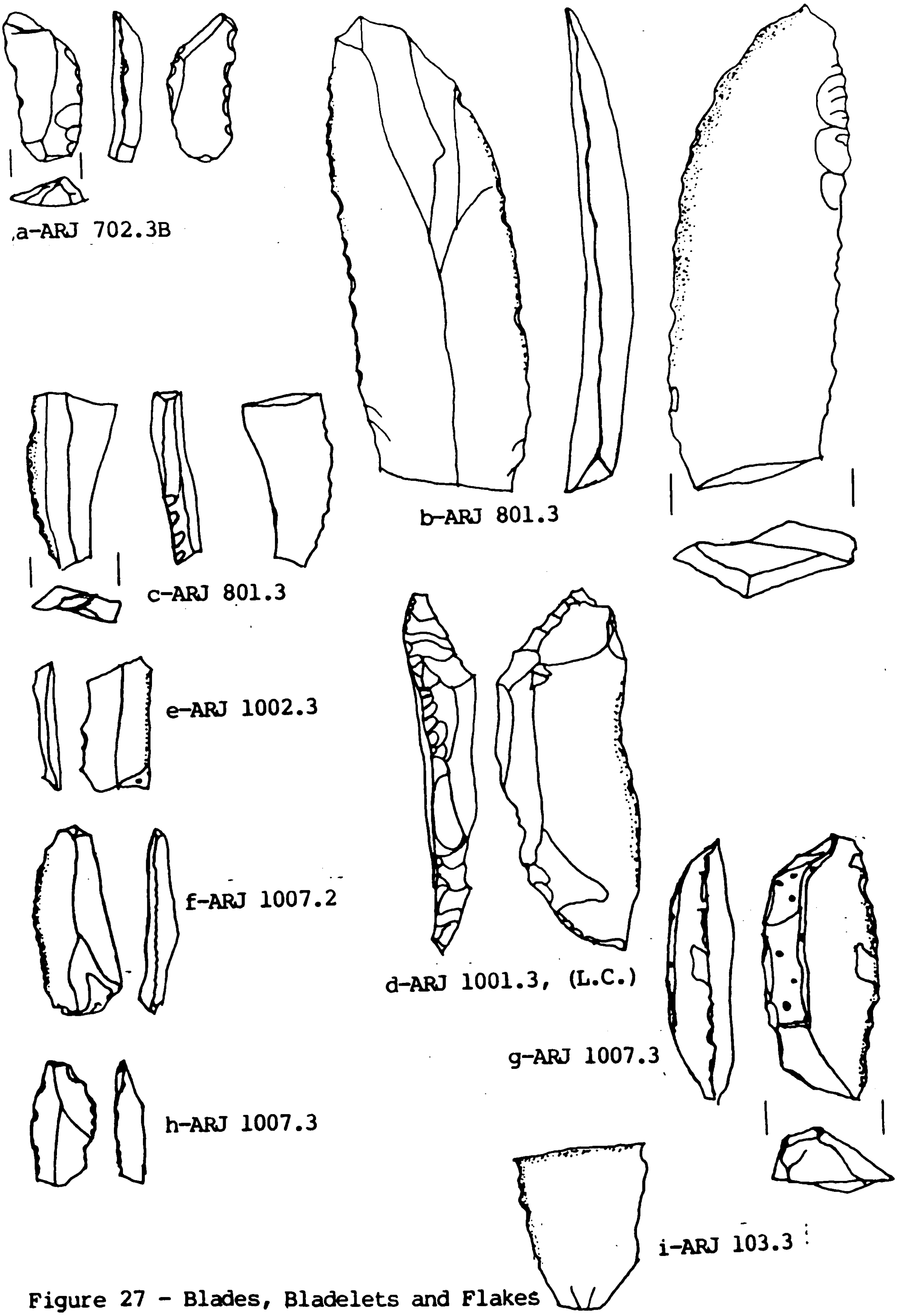
a-ARJ 211.2

b-ARJ Baulk 600-700.3

c-ARJ Baulk 600-700.3

d-ARJ Baulk 700-800.3

Figure 26 - Blades, Bladelets and Flakes



a-ARJ 702.3B

b-ARJ 801.3

c-ARJ 801.3

e-ARJ 1002.3

d-ARJ 1001.3, (L.C.)

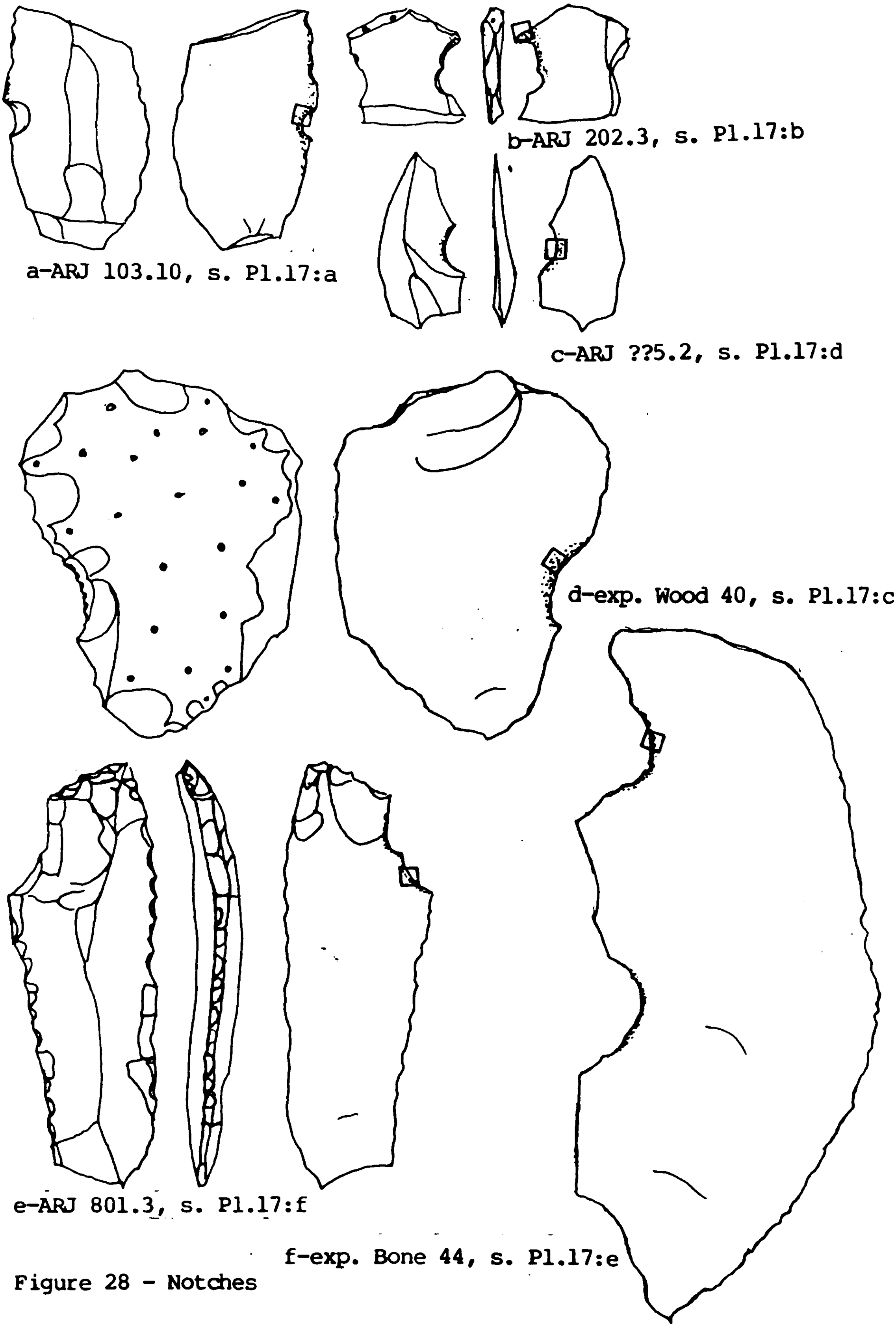
f-ARJ 1007.2

g-ARJ 1007.3

h-ARJ 1007.3

i-ARJ 103.3

Figure 27 - Blades, Bladelets and Flakes



a-ARJ 103.10, s. Pl.17:a

b-ARJ 202.3, s. Pl.17:b

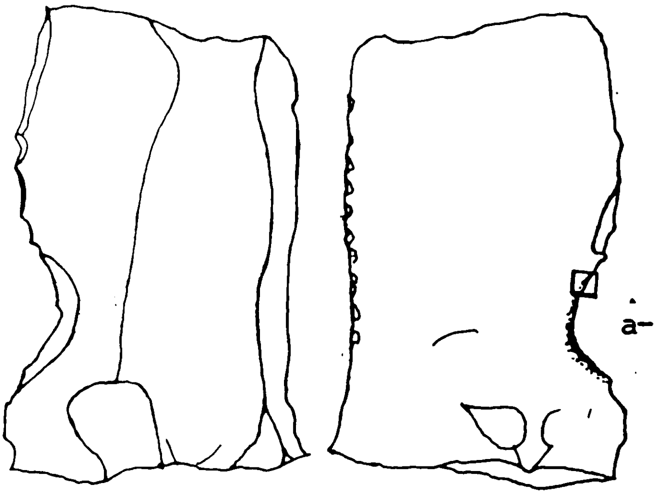
c-ARJ ??5.2, s. Pl.17:d

d-exp. Wood 40, s. Pl.17:c

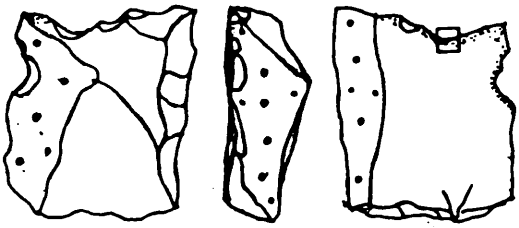
e-ARJ 801.3, s. Pl.17:f

f-exp. Bone 44, s. Pl.17:e

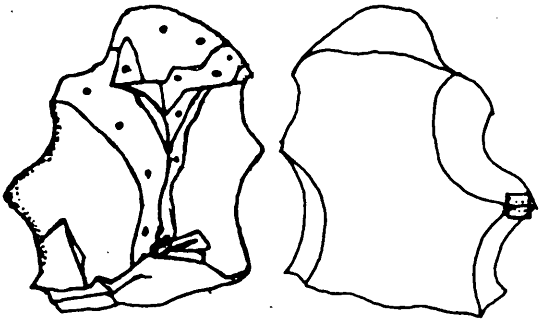
Figure 28 - Notches



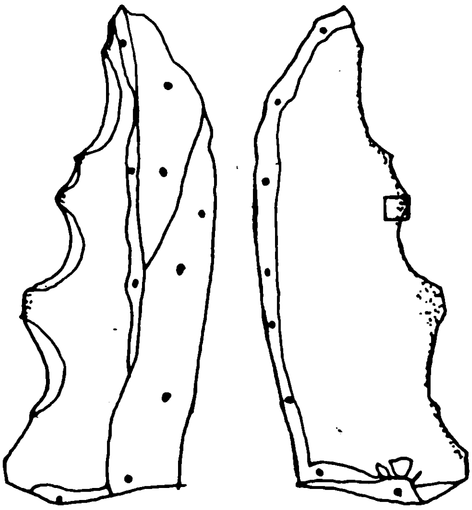
a-exp. Stone 21, s. Pl.17:g



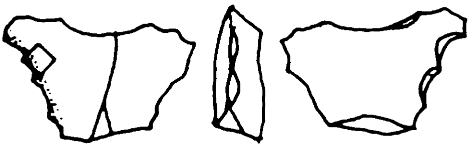
b-ARJ 1011.2, s. Pl.17:h



c-ARJ 103.3, s. Pl.18:b

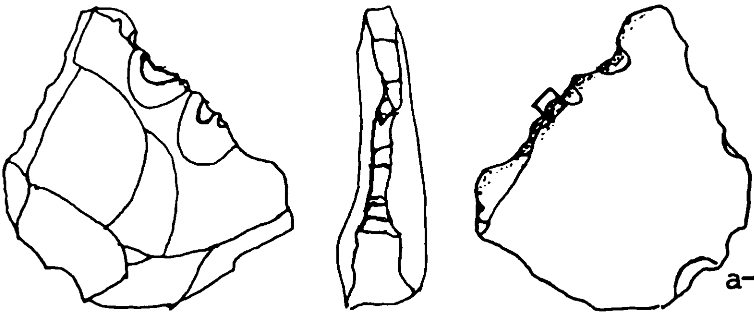


d-exp. Wood 45, s. Pl.18:a

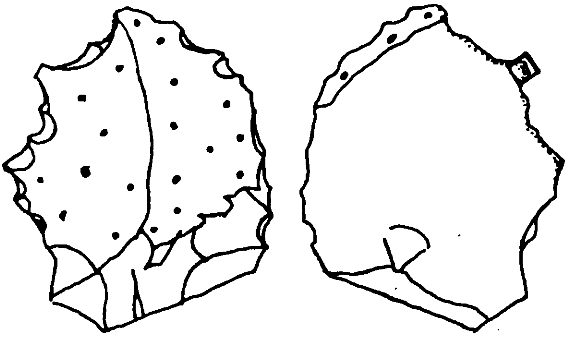


e-ARJ 213.3, s. Pl.18:c

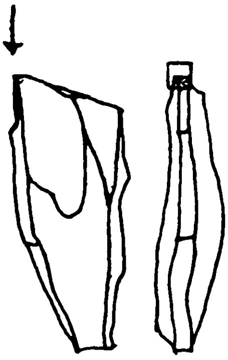
Figure 29 - Notches and Denticulates



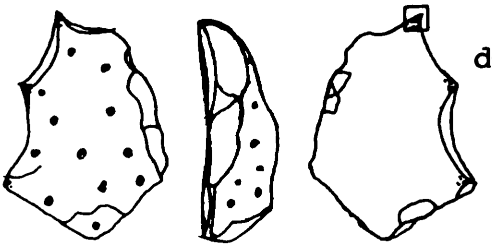
a-ARJ 500.1, s. Pl.18:d



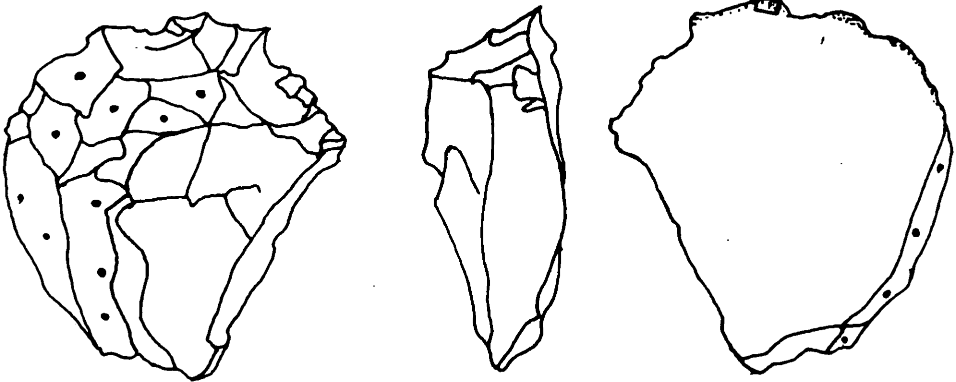
b-exp. Hide 19, s. Pl.18:e



c-exp. Stone 16, s. Pl.18:f

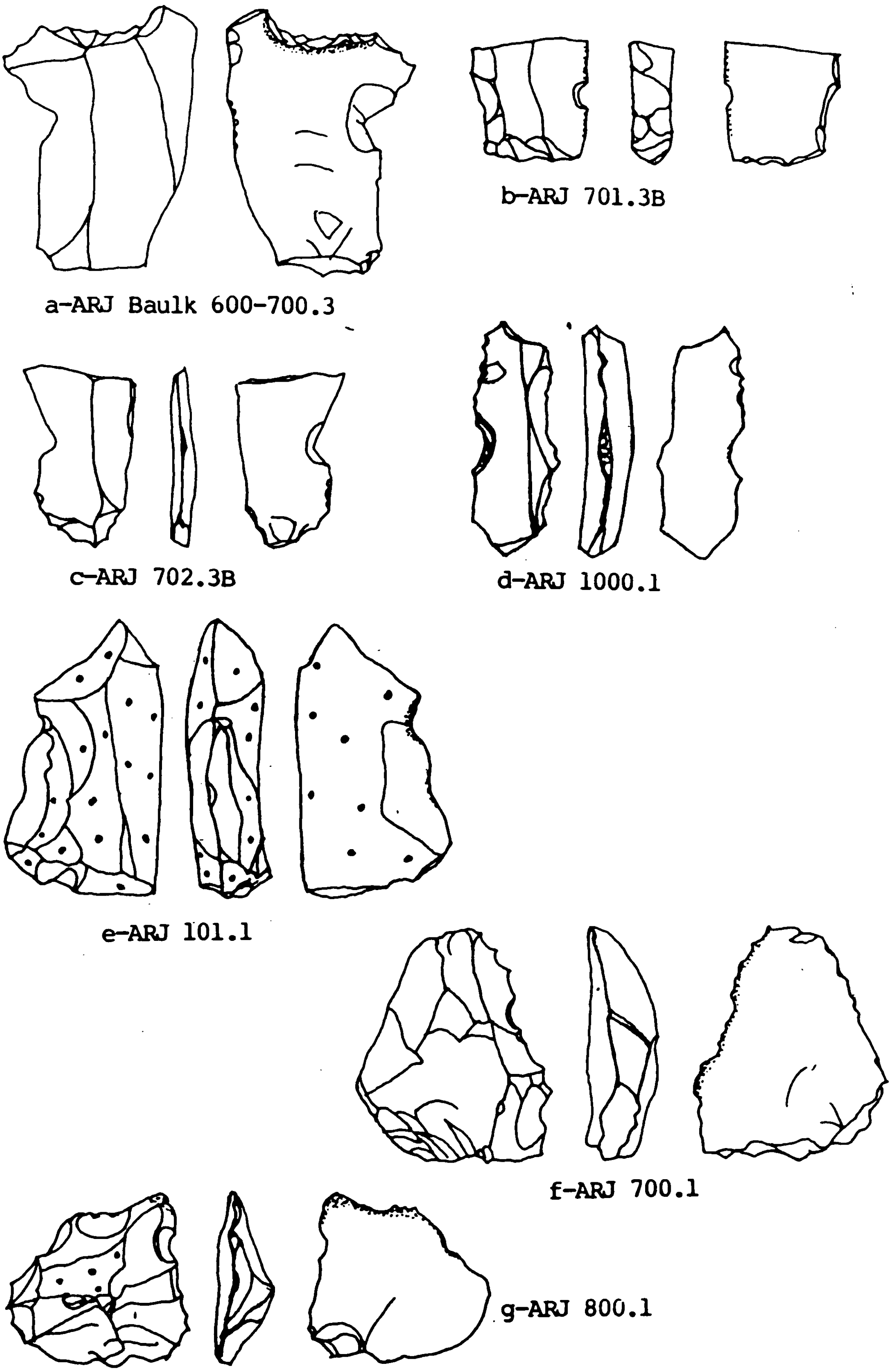


d-ARJ 101.1, s. Pl.18:h



e-ARJ 1002.3, (L.C.), s. Pl.18:q

Figure 30 - Denticulates



a-ARJ Baulk 600-700.3

b-ARJ 701.3B

c-ARJ 702.3B

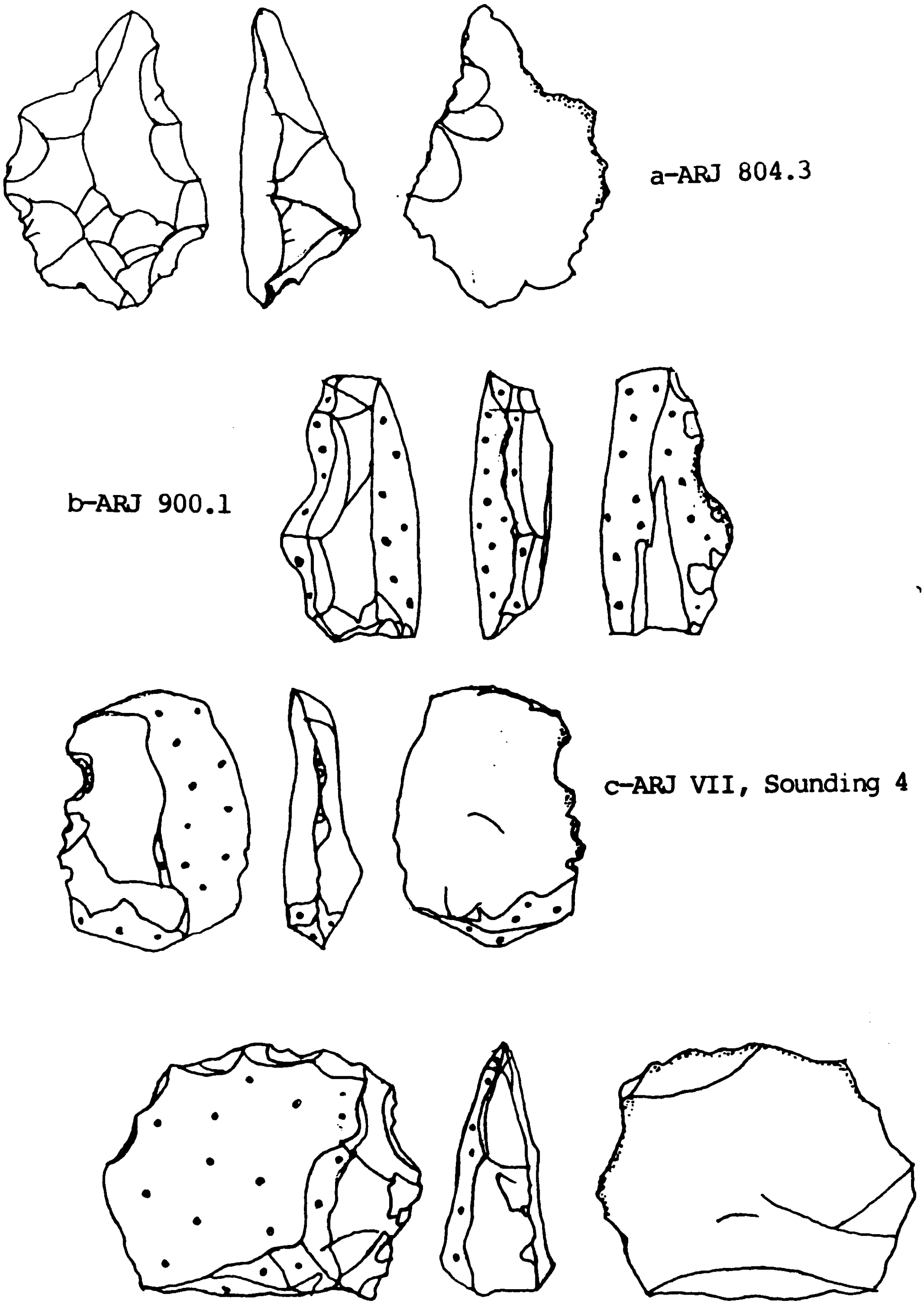
d-ARJ 1000.1

e-ARJ 101.1

f-ARJ 700.1

g-ARJ 800.1

Figure 31 - Notches and Denticulates



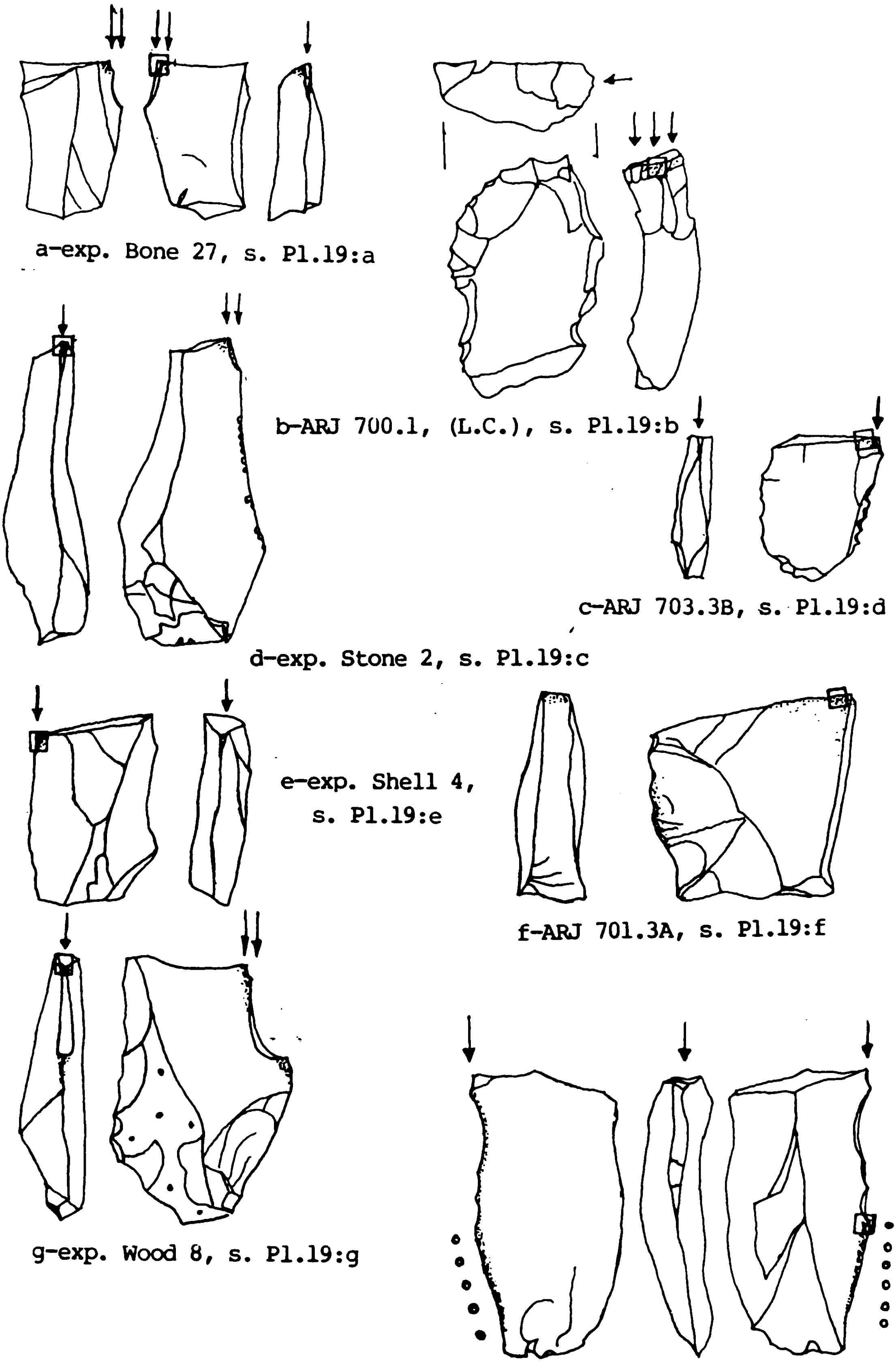
a-ARJ 804.3

b-ARJ 900.1

c-ARJ VII, Sounding 4

d-ARJ 1001.3

Figure 32 - Denticulates



a-exp. Bone 27, s. Pl.19:a

b-ARJ 700.1, (L.C.), s. Pl.19:b

c-ARJ 703.3B, s. Pl.19:d

d-exp. Stone 2, s. Pl.19:c

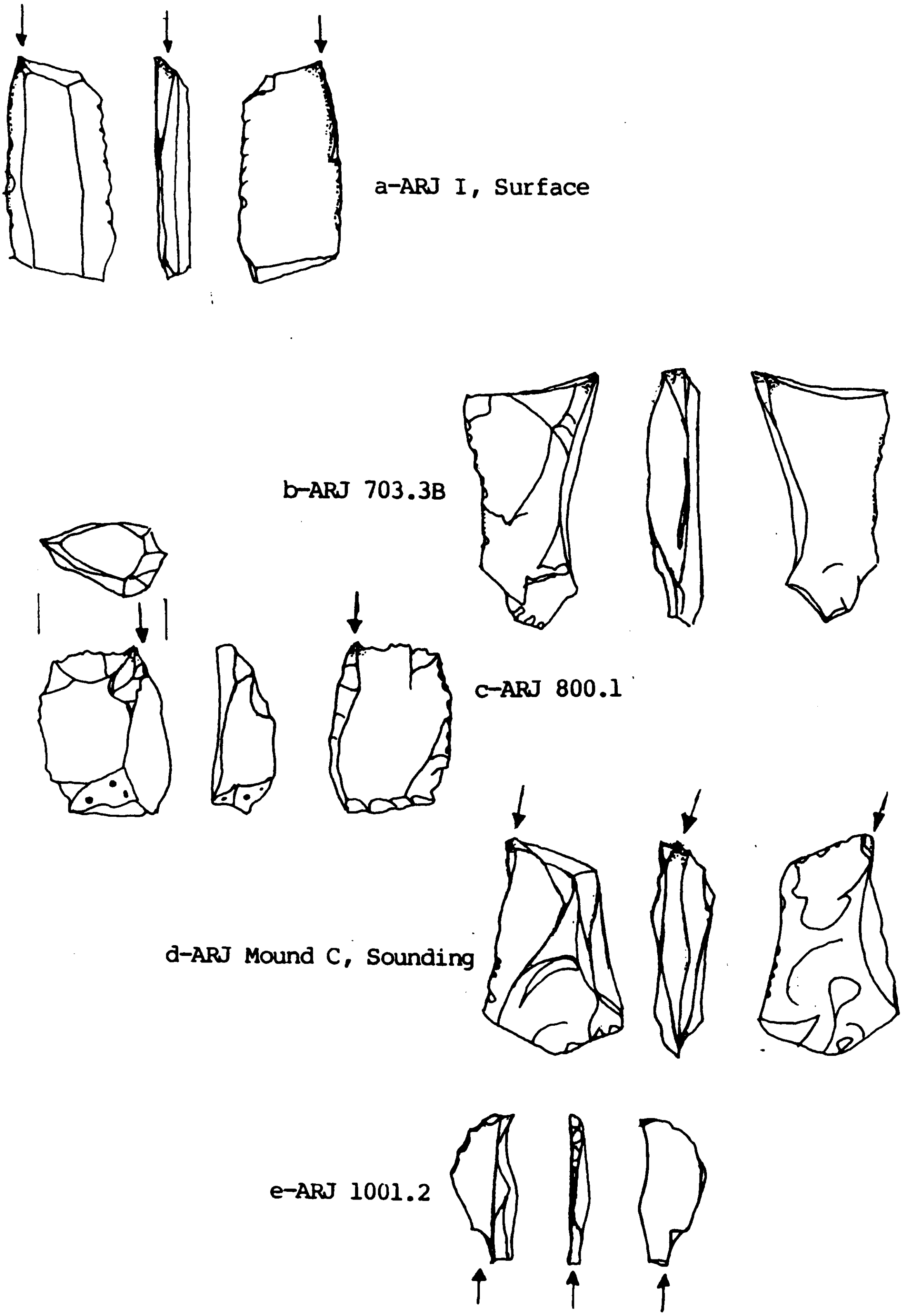
e-exp. Shell 4, s. Pl.19:e

f-ARJ 701.3A, s. Pl.19:f

g-exp. Wood 8, s. Pl.19:g

h-ARJ 212.3, s. Pl.19:h

Figure 33 - Burins



a-ARJ I, Surface

b-ARJ 703.3B

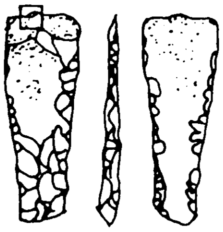
c-ARJ 800.1

d-ARJ Mound C, Sounding

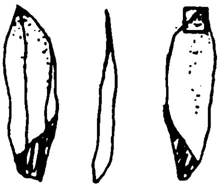
e-ARJ 1001.2

Figure 34 - Burins

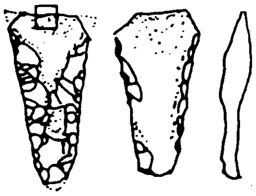
a-exp. Meat 12, s. Pl.20:a,e



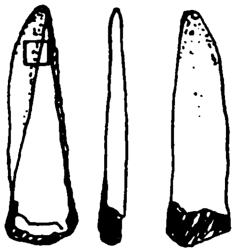
b-ARJ 701.3B, (L.C.), s. Pl.20:b,f



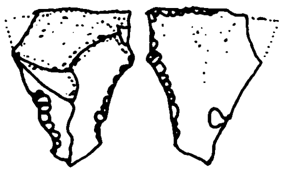
c-exp. Meat 12, s. Pl.20:c



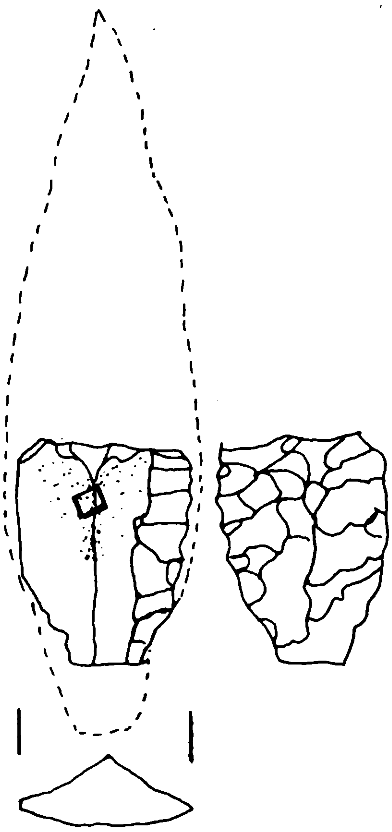
d-ARJ 700.2, (L.C.), s. Pl.20:d



e-exp. Meat 13, s. Pl.20:g

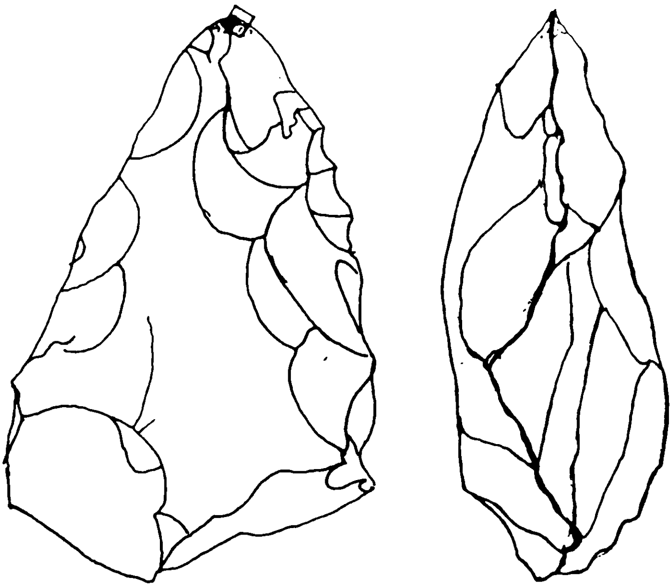


f-ARJ 803.3, (L.C.)

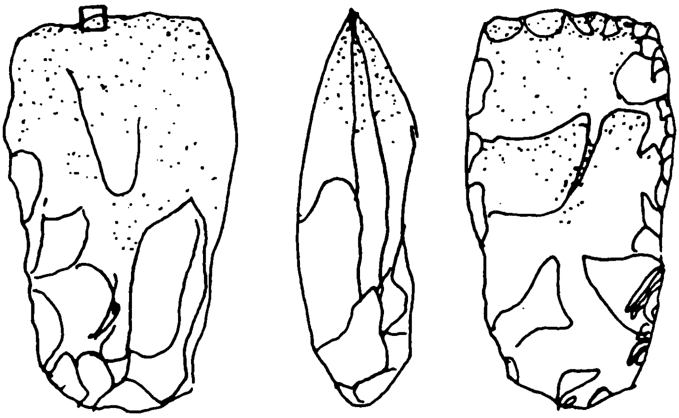


g-ARJ I, Surface, s. Pl.20:h

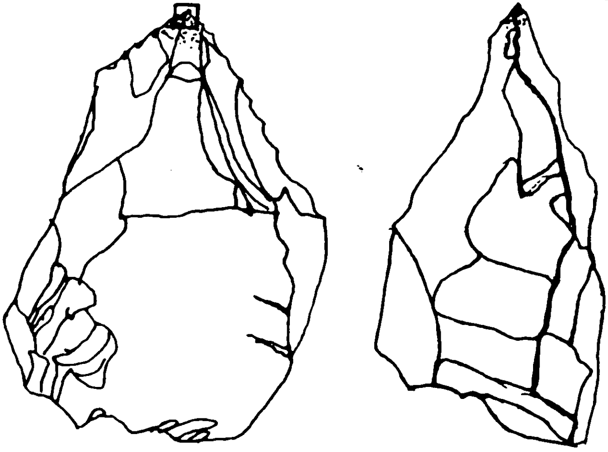
Figure 35 - Projectiles



a–exp. Bone 43, s. Pl.21:a

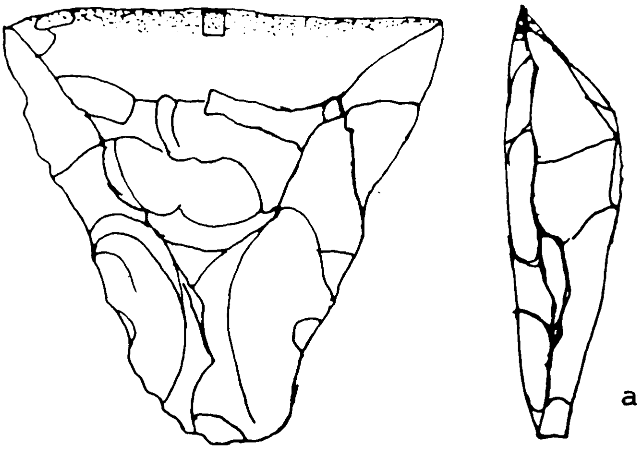


b–ARJ I-IV, Surface, s. Pl.21:b

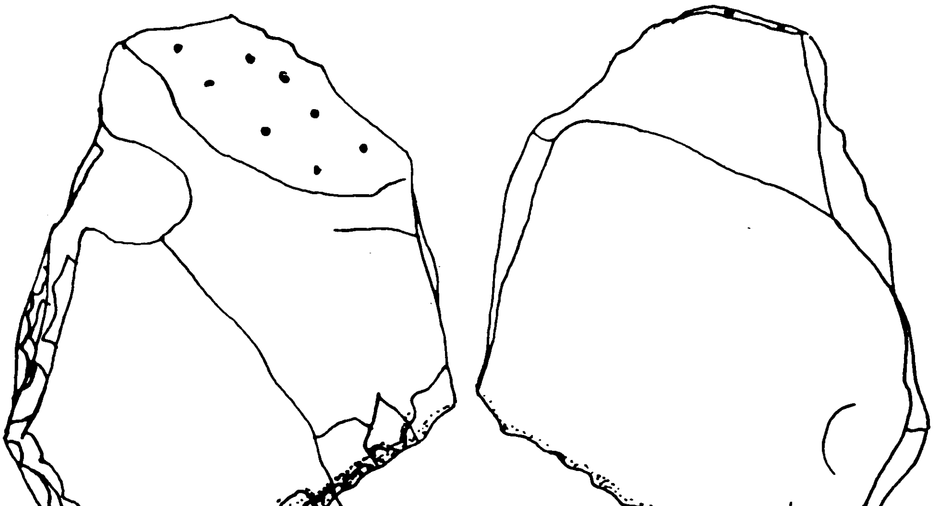


c–exp. Wood 26, s. Pl.21:c

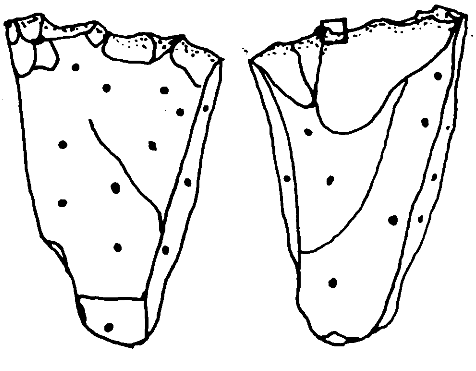
Figure 36 - Axes, Adzes and Choppers



a-exp. Wood 51, s. Pl.21:e

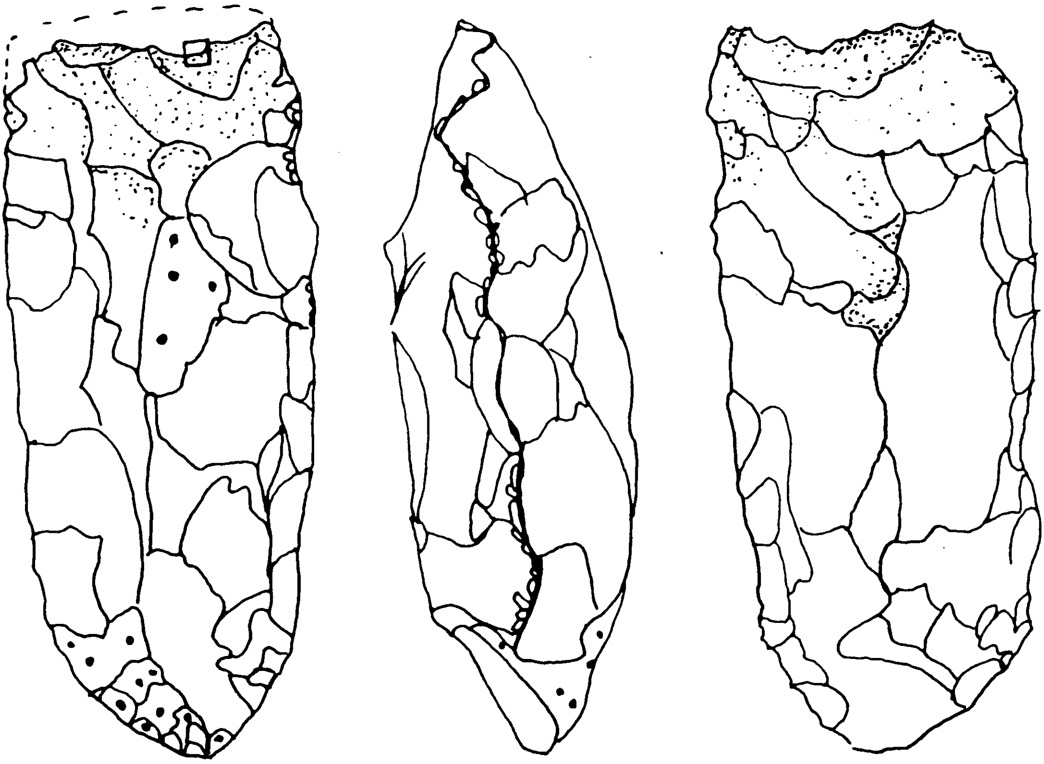


b-ARJ 222.2, s. Pl.21:d

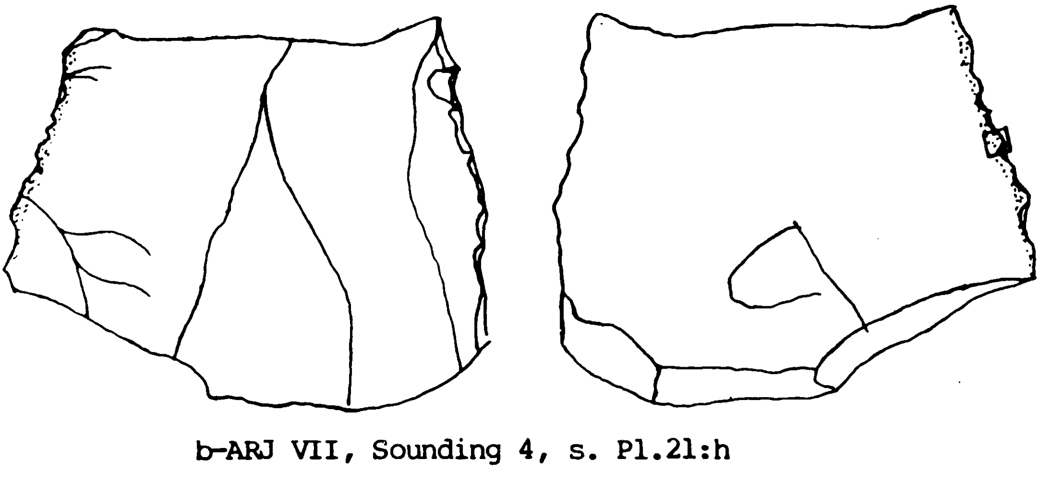


c-ARJ VII, Sounding 1, s. Pl.21:g

Figure 37 - Axes, Adzes and Choppers

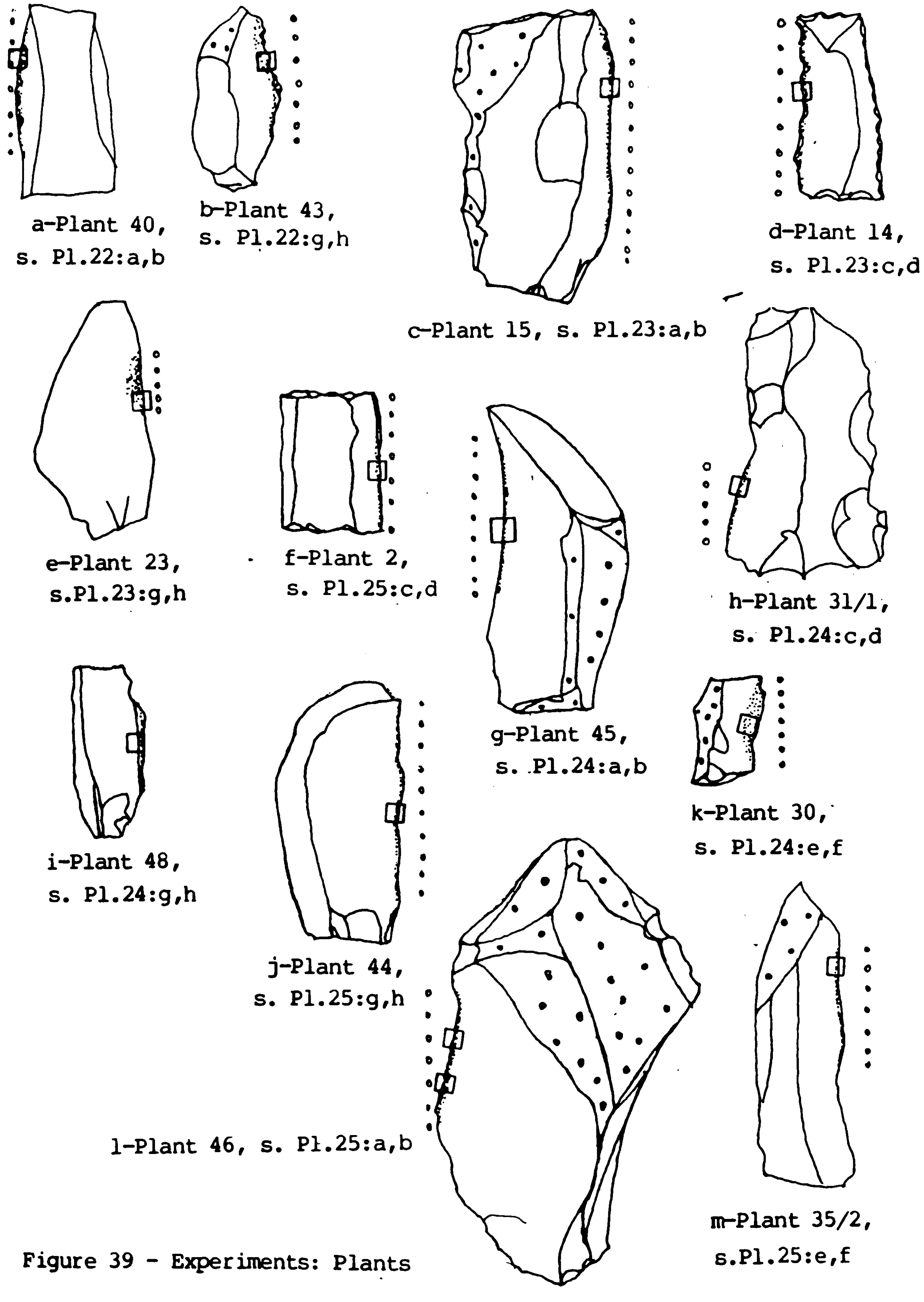


a-ARJ VI, Surface, (L.C.), s. Pl.21:f



b-ARJ VII, Sounding 4, s. Pl.21:h

Figure 38 - Axes, Adzes and Choppers



a-Plant 40,
s. Pl.22:a,b

b-Plant 43,
s. Pl.22:g,h

c-Plant 15, s. Pl.23:a,b

d-Plant 14,
s. Pl.23:c,d

e-Plant 23,
s.Pl.23:g,h

f-Plant 2,
s. Pl.25:c,d

g-Plant 45,
s. Pl.24:a,b

h-Plant 31/1,
s. Pl.24:c,d

i-Plant 48,
s. Pl.24:g,h

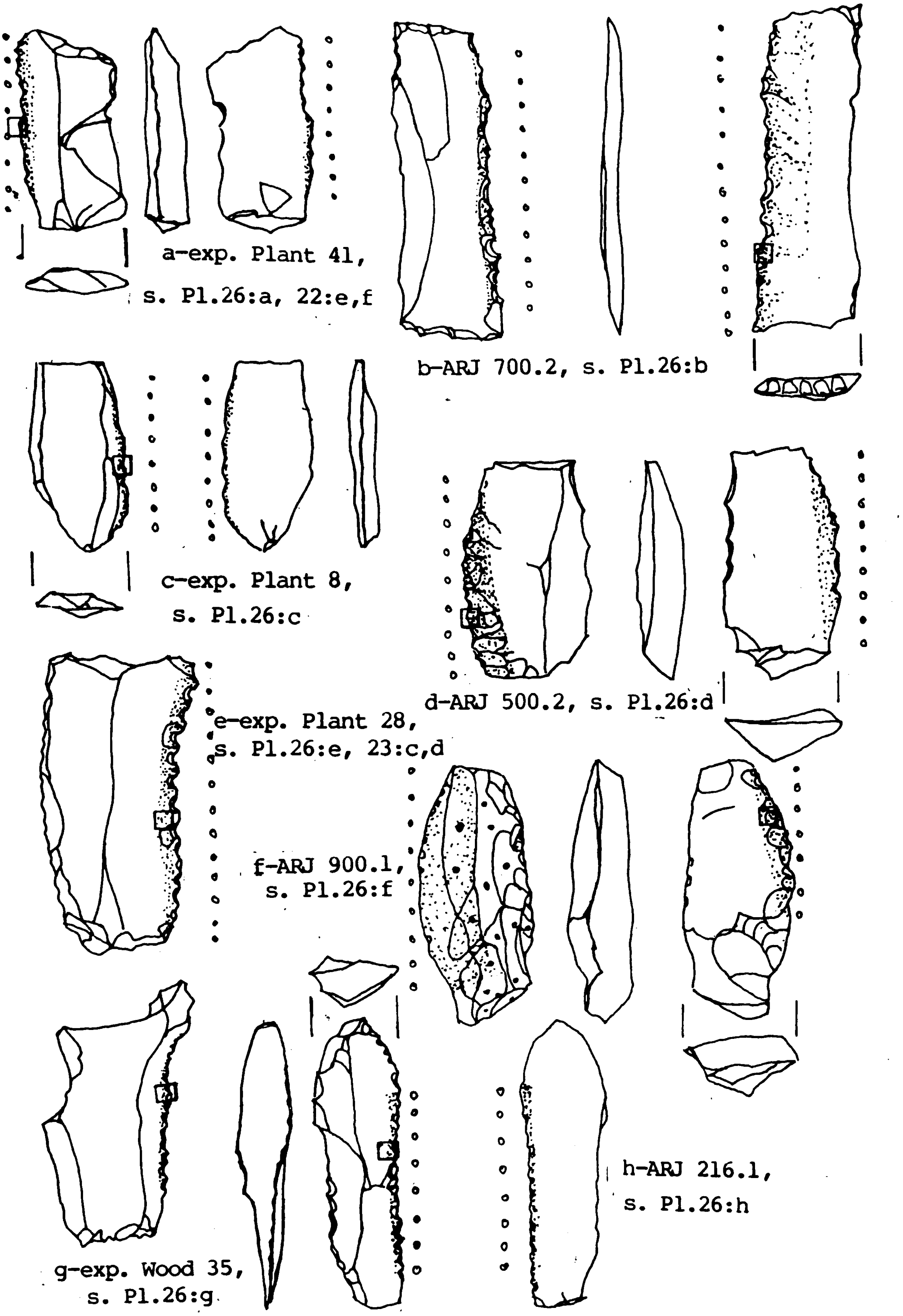
j-Plant 44,
s. Pl.25:g,h

k-Plant 30,
s. Pl.24:e,f

l-Plant 46, s. Pl.25:a,b

m-Plant 35/2,
s.Pl.25:e,f

Figure 39 - Experiments: Plants



a-exp. Plant 41,
s. Pl.26:a, 22:e,f

b-ARJ 700.2, s. Pl.26:b

c-exp. Plant 8,
s. Pl.26:c

d-ARJ 500.2, s. Pl.26:d

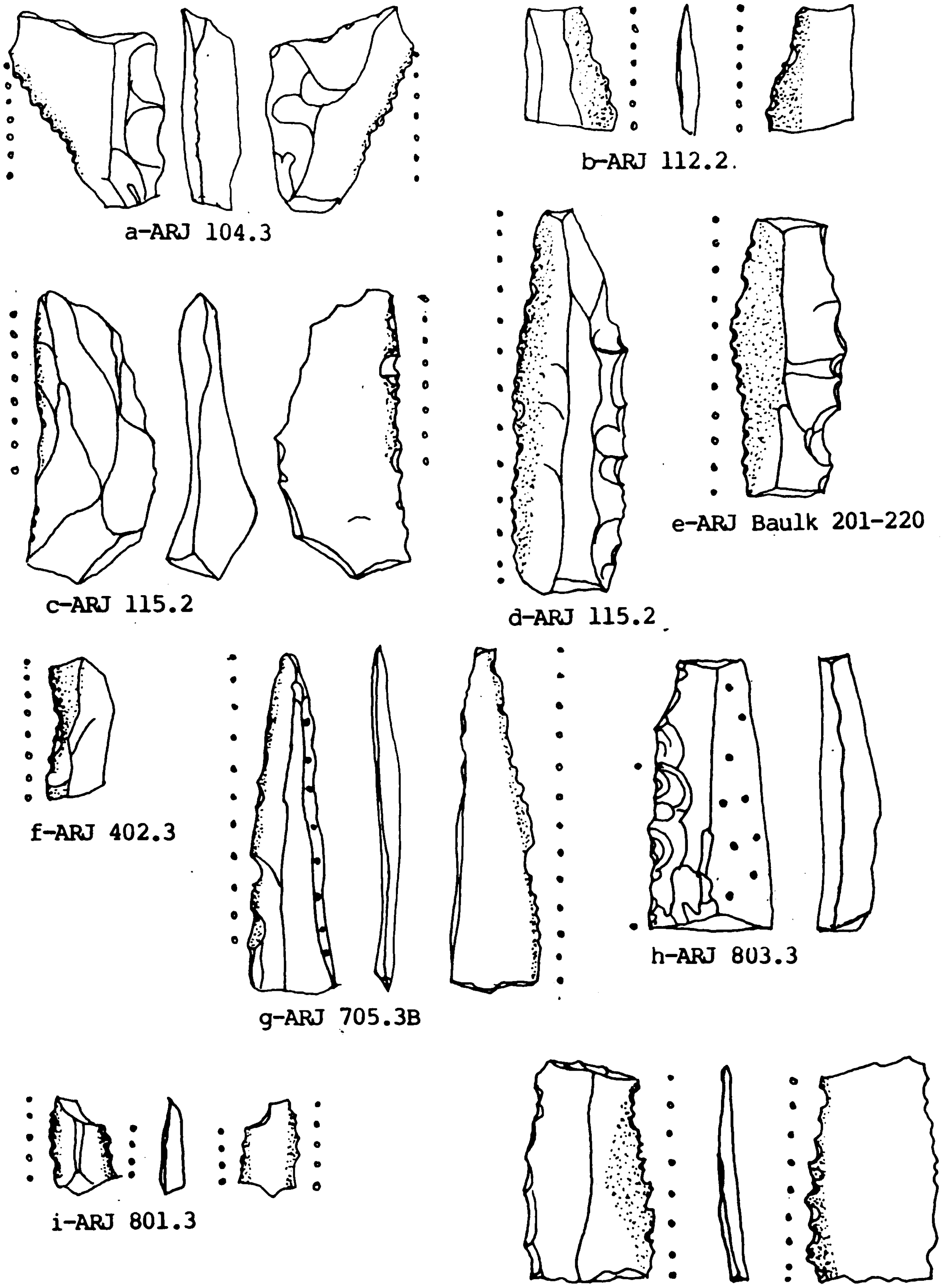
e-exp. Plant 28,
s. Pl.26:e, 23:c,d

f-ARJ 900.1,
s. Pl.26:f

g-exp. Wood 35,
s. Pl.26:g

h-ARJ 216.1,
s. Pl.26:h

Figure 40 - Arjoune: Plants



a-ARJ 104.3

b-ARJ 112.2.

c-ARJ 115.2

d-ARJ 115.2

e-ARJ Baulk 201-220

f-ARJ 402.3

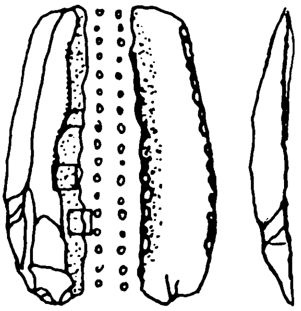
g-ARJ 705.3B

h-ARJ 803.3

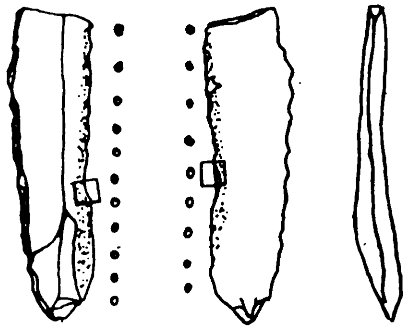
i-ARJ 801.3

j-ARJ 900.1

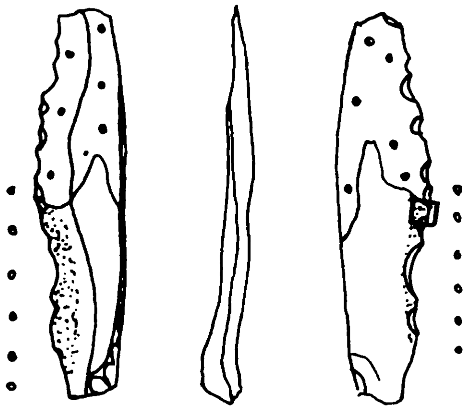
Figure 41 - Arjoune Blades.



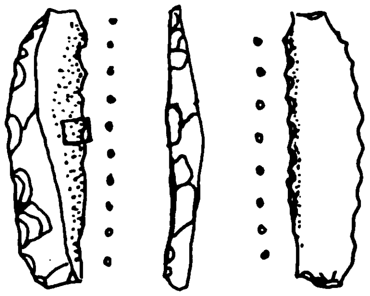
a-WB2 50/4739, s. Pl.27:a,c



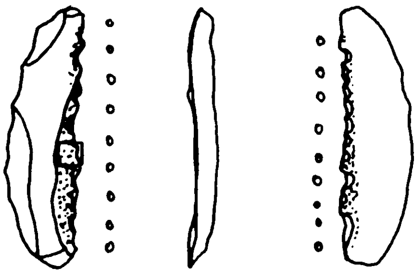
b-WB1 50/4740, s. Pl.27:b,d



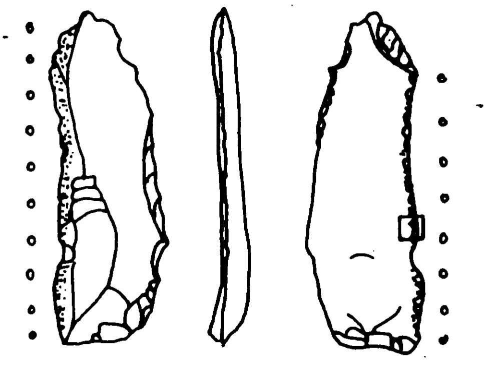
c-KB 58/1995, s. Pl.27:e



d-KB 58/2010, s. Pl.27:f

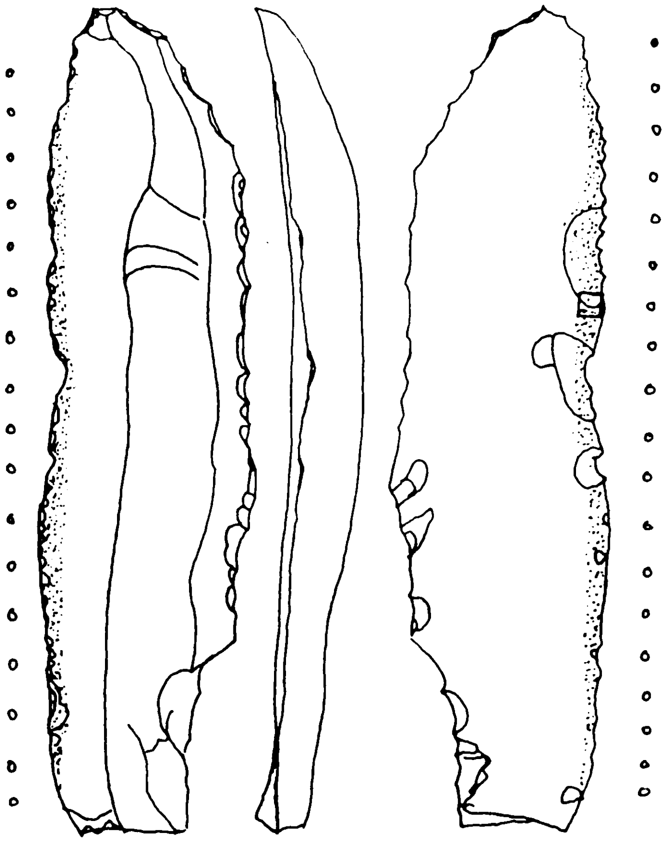


e-KB 58/2607, s. Pl.27:g

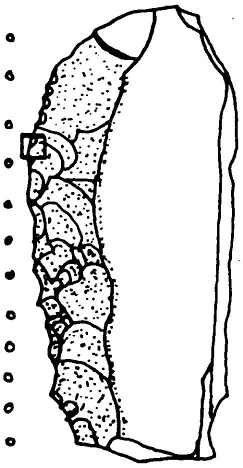


f-KB 58/1976, s. Pl.27:h

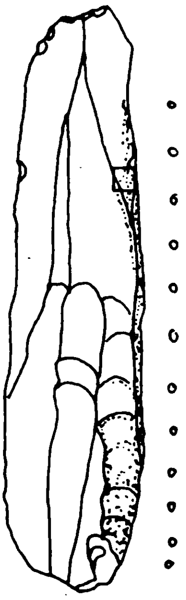
Figure 42 - Kebara and El Wad: Plants



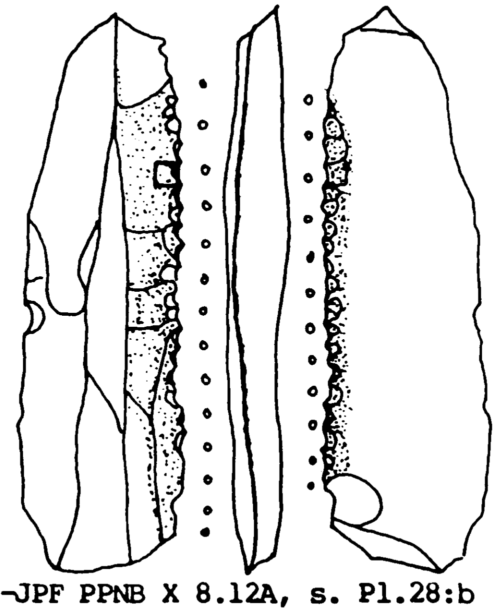
a-JPF PPNA SSiv 300.25, s. Pl.28:a



b-JPF PPNA SSii 300.27, s. Pl.28:c

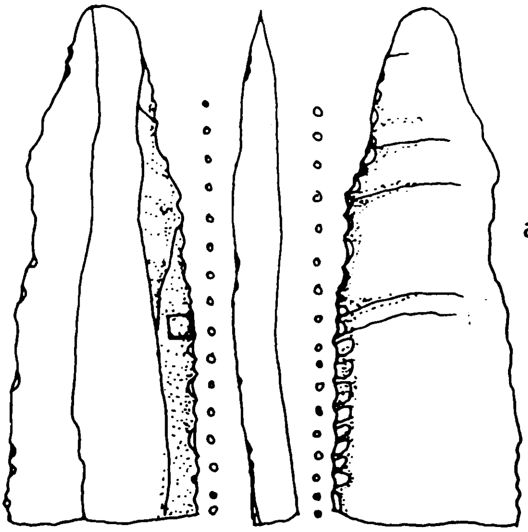


c-JPF PPNA PPii 300.15, s. Pl.28:e

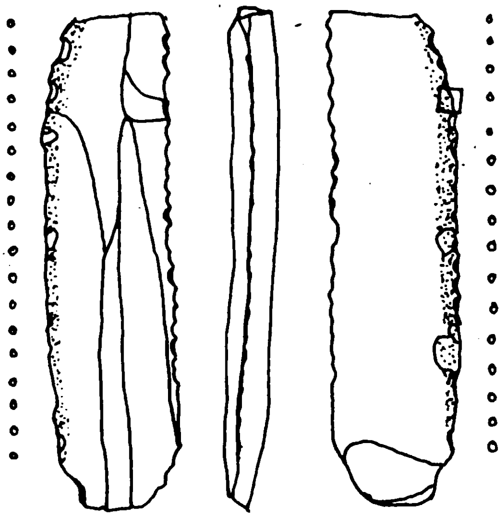


d-JPF PPNB X 8.12A, s. Pl.28:b

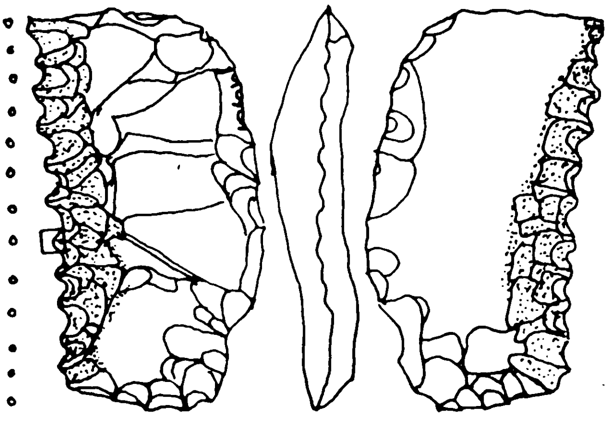
Figure 43 - Jericho: Plants



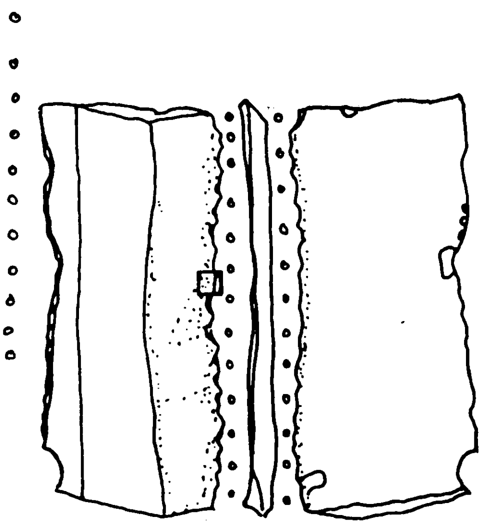
a-JPF PPNB X 100.1, s. Pl.28:d



b-JPF PPNB X 8.12 A, s. Pl.28:f



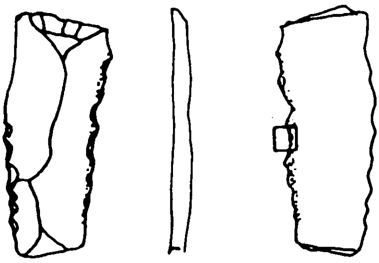
c-JPF PN J 101.5, s. Pl.28:g



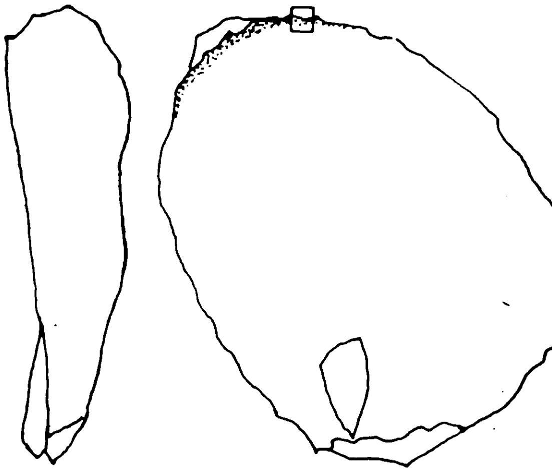
d-JPF EB D 1.5, s. Pl.28:h

Figure 44 - Jericho: Plants

a-exp. rubbing reed, s. Pl.29:a

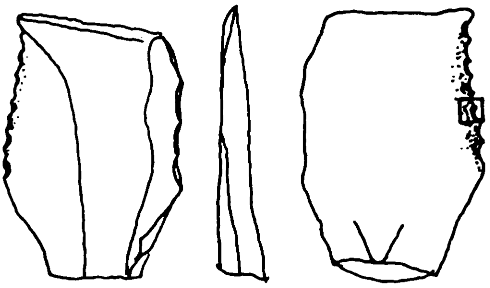


b-exp. cutting reed, s. Pl.29:b



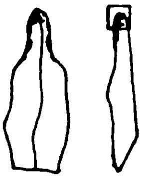
c-exp. Hide 2, s. Pl.29:c

d-exp. Ivory 1, s. pl.29:h



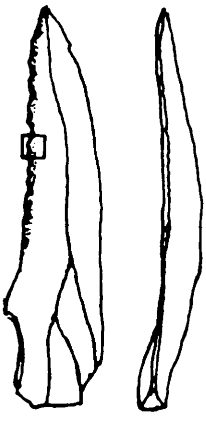
e-exp. Fish 1, s. Pl.29:d

f-exp. Copper 1, s. Pl.29:e



g-exp. Stone 10, s. Pl.29:g

Figure 45 - Miscellaneous



h-exp. Bone4 45, s. Pl.29:f