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Drill bits from Abu Salabikh, Iraq

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Résumé
Cette communication présente l'étude de l'utilisation des mèches de foret de Abu Salabikh (Irak). L'expérimentation confirme leur attribution fonctionnelle. Plusieurs tracéologues se sont consacrés à l'étude des différentes traces provoquées par l'emmanchement. Une nouvelle méthode, mise au point à l'Institut d'Archéologie de Londres a été appliquée à l'échantillon examiné. Même s'il paraît évident que ces outils ont été emmanchés, aucune preuve n'a pu en être faite par l'étude des traces, pas plus sur le matériel archéologique qu'expérimental. On recommandera donc ici plus de prudence quand il s'agira d'attribuer certaines anomalies tracéologiques à l'emmanchement.

Abstract
This paper examines the use of drill bits from the site of Abu Salabikh in Iraq. By comparison with experimental material it is shown that they did indeed function as such. Claims for distinctive wear traces related to hafting have been made by many microwear analysts. Using a new technique developed at the Institute of Archaeology, London, we attempted to identify hafting traces on our sample. Even though these tiny tools were almost certainly hafted we could find no microwear evidence for hafting on the experimental or archaeological tools. It is recommended that a more careful assessment be made before assigning anomalous wear traces to hafting.

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INTRODUCTION

In 1976 the excavators of Abu Salabikh, Iraq , discovered a shallow circular courtyard pit filled with flint knapping waste, discarded sickle elements and microlithic borers (Postgate, 1977, 276). A report on the flints from this pit has already appeared (Payne, 1980, 109-112), but a number of technological features of this mid 3rd millenium B.C. industry were felt to be worth further study by experimental replication and microwear analysis. In these experiments we concentrated on the microlithic spindle-tipped drill bits of a type already known to be widely distributed at this time in south, central and western Asia (see Tosi, 1980 for map and references). Although the experimental study of boring techniques began in the 19th century, when the use of a stone drill with a rounded bit on Mesopotamian seals has already been inferred (McGuire, 1894, 647-648), and although marks of drilling have been extensively investigated in recent years by Gwinnett and Gorelick (1981), no full replication analysis of the hafting and use of the type of borer found at Abu Salabikh has been undertaken before now.

Cores made of fine grained flint were flaked by pressure (Payne, 1980, fig. 4-5) at Abu Salabikh to produce tool blanks, including bladelets retouched to make tiny borers averaging 12 x 4 x 1 mms (*Fig. 1*). Thirteen of these borers were found, and comparison with experimental results shows that they were used as drill bits ; most of them were broken and display a variety of bending and twisting breaks due to stress.

The Abu Salabikh drill bits are of a distinctive type which enjoyed a wide distribution from Mesopotamia to the Indus Valley and beyond in the 3rd millenium B.C. The spindle-tipped borer is characterised by a long, narrow spindle several centimeters long which is made by direct retouch on burin spalls and pressure-flaked bladelets with a well-defined central ridge.

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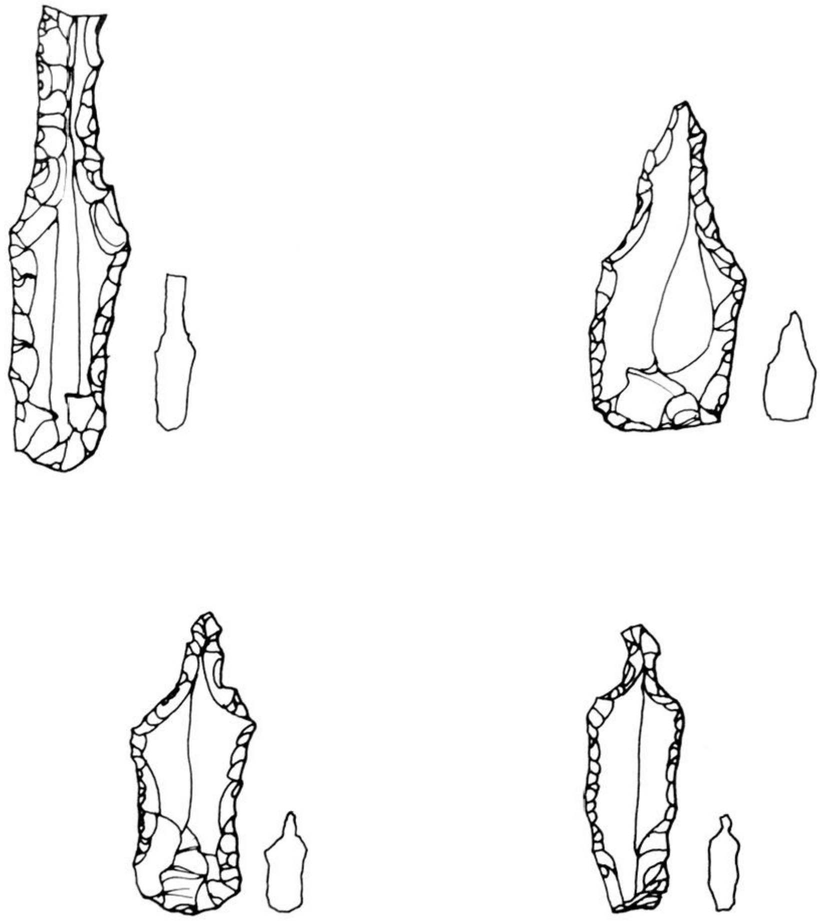


Fig. 1 Selected drill bits from Abu Salabikh.

Examples of spindle-tipped borers and broken spindle tips have been found at a number of sites, often associated with evidence of stone and shell working: Abu Salabikh (Payne, 1980, 112), Uruk (Müller, 1963, Abb. 4, 5-10), Ur (Mackay, 1937, 7, ,note 12 citing p.c. by H. Beck), al-'Ubaid (Hall and Woolley, 1927, pl. 13 :5), Tepe Hisar (Bulgarelli, 1974, 24-27, fig. 8), Shahr-i Sokhta (Piperno, 1973 ; Tosi and Piperno, 1973 ; Piperno, 1976 ; Gwinnett and Gorelick, 1981), Chanhu-daro (Mackay, 1937, 6-8, pl. 2 :5) and elsewhere in the Near East, Central Asia and the Indian sub-continent (Bulgarelli, 1974, 26 note 11 ; Tosi, 1980).

This type of tool is well suited to being worked with a bow drill on tasks requiring pressure and abrasives to cut hard materials such as stone (Bromehead, 1934 and 1948, 72-73 ; Mackay, 1937, 6-8 ; Gwinnett and Gorelick, 1981, 18 ; Ogden, 1982, 146-150), or to perform repetitive tasks requiring the drilling of a series of holes into beads, bowls or the outline of complex shapes. It may be significant that the same cuneiform sign, zadim, used to mean lapidary worker in the 3rd millenium B.C. was later used to mean bowmaker (Loding, 1981, 14), a transference of meaning which might be related to the use of the bow drill by lapidary workers and seal cutters which has been inferred from tool marks on lapidary work (Mallowan, 1964, 66 ; Moorey, 1967, 98 ; Frankfort, 1970, 37). Many of the spindle-tipped borers are dated to the Early Dynastic III period in Mesopotamia when the extensive use of drilling is characteristic on both shell and stone seals (Al-Gailani-Werr *et al.*, 1982, 70-74). Deimel translates zadim as « stone cutter » and suggests that a stone-workers's tool is represented by the sign (1928, 11 ; 1970, 7). Although he tends to favour the belief that a chisel may be depicted by this sign, it could equally and perhaps better represent a bow drill or bow driven lathe such as is believed to have been used in seal cutting (Nissen, 1977) with the bow, string, drillshaft and wire dripfeeding abrasive slurry (Possehl, 1981, fig. 9-11) depicted.

Spindle-tipped stone drill bits could have been used along with metal spindles in lapidary work during the 3rd millenium B.C., and the shape of the stone tools' tip may imitate the shape and the working characteristics of a metal prototype. Metal spindles are used with a bow drill in modern stone bead-making in West Africa (Shaw, 1945), and the use of metal spindles alongside stone drill bits in 3rd millenium B.C. lapidary work has been inferred by Moorey (1967, 98). SEM analysis of beads from Shahr-i Sokhta shows two different diameters of spindle drills were used in making the perforation (Gwinnett and Gorelick, 1981, 18 ; *cf.* Moorey, 1967, 98). Was the final deep drilling done with a metal spindle which would not snap off as it encountered the uneven stresses associated with breaking through to the hole of the opposed perforation ? The depth of some of the holes drilled suggests that opposed countersunk perforations were used instead of the boring and percussion technique used at Kish and Larsa (Chevalier *et al.*, 1982).

When used with a bow drill in our experiments, the proximal end of the tool was attached by resin, sinew or friction to a cylindrical shaft, leaving the spindle protruding from the haft. The design of the tool allows the bit to be worked with repeated alternating rotary motion at each stroke of the bow, and at an unhurried working pace the bow drill bit can make about 250-350 revolutions per minute (McGuire, 1894, 721). In McGuire's experiments he observed that the drill bit was sometimes worn down to a cylindrical shape by being rotated in hard stone for a long time (1894, 682, fig. 71). Holes in soft stone and shell can be quickly drilled, allowing mass production of pieces in a short time and leading to economies of scale in manufacturing characteristic of urban craft production. Higher-cost work on luxury materials such as lapis where the silica content is high is more time-consuming.

Given their suitability for beadmaking with a bow drill, it is perhaps of some significance that the distribution of this type of drill bit corresponds to areas reached by the lapis trade of the 3rd millenium B.C. and that they have been found in context with evidence of lapis work at Shahr-i Sokhta (Tosi and Piperno, 1973) and Abu Salabikh (Payne, 1980, 112). Although the primary use of spindle tipped drill bits was in beadmaking and sealcutting, their widespread distribution in the 3rd millenium B.C. may also be related to other crafts of the time, notably the manufacture of stone and shell inlay for temples and palaces and cutting the outline of the design of stone bowls or plaques. Bow drills were used, in the absence of a pattern saw, to cut out the outline of linear designs among plasterers, metalworkers and woodworkers in Iraq and Iran up to the present century (Clarity *et al.*, 1964, 181 ; Wulff, 1966, 73, 98). The spindle-tipped borer found at al-'Ubaid (Hall and Woolley, 1927, pl.13 :5, center row) was probably used by workmen on the spot cutting the outline or setting of lapis, stone and shell inlay for the mosaics which decorated the Early Dynastic temple from this site. Visitors to temples would also wish to buy souvenirs, charms and votive offerings which the zadim could manufacture, and it was perhaps while engaged in this mixture of public and private business that the zadim lapidary sat in the gateway of a temple according to a Sumerian text which J. Black is publishing in *Acta Sumerologica.*

In Early Dynastic workshops bow drills have been used to cut a scrics of holes following an incised outline of the representational or geometric figure on strips or plaques of limestone, lapis lazuli and shell. Woolley noted that this carving was delicate work as shell is brittle and would tend to break when cut or carved (1934, 263-264); once a line of drill holes following the line of the figure has been drilled, sanded strips of wood, bone or reed could be used to remove spurs of material between the holes and regularise the outline of the figure. The finished silhouette would not always preserve any direct evidence of the techniques used to produce it. However ivory and shell silhouettes from Mari are sometimes found with a pattern of drilled holes of uniform diameter such as could have been produced by spindle-tipped stone borers spun with a bow drill, and elements of mosaic inlay had holes drilled into them to attach them to the matrix they were set in which could also have been made with this tool (Parrot, 1960, 142, fig. 171 ; Parrot, 1967, pl. 60-69).

OUTLINE OF EXPERIMENTS

In the experiments the bladelets used to produce drill bits were made by percussion and a hand-held pressure technique taught to the authors by a Danish flintknapper, Bo Madsen. Although Iraqi flint was not available, we attempted to match the grain size of the flint used at Abu Salabikh by using fine-grained flint from England and France. This flint was without inclusions, like the pressure *débitage* used to make drill bits at Abu Salabikh ; inclusions interrupt the flow of force making flaking by pressure difficult.

We carried out a total of 35 experiments using a bow drill. The bow drill set consisted of a bow, drill shaft and limestone capstone. The bow was a bent tree branch, the string was a fallow deer hide, and wooden dowels were used for the drillshafts which had a diameter of 1.3 cm and averaged 24 cm in length. Beads were mounted in bitumen on a board to hold them steady for drilling, using a vertical mounting of the drill shaft. Similar boards are known from West Africa in the 20th c. AD (Shaw, 1945, 46) and from 3rd millenium B.C. Shahr-i Sokhta in eastern Iran (Tosi, 1969, fig. 257). The extra weight of the board, which can be steadied with the foot while working cross-legged seated on the ground, keeps the bead rough-outs from spinning.

All of our copies of the Abu Salabikh borers closely matched the dimensions of those from the site. It is extremely important to use accurate replicas as this will affect the operational dynamics of the tool. Poor copies may affect the nature and distribution of microscopic polishes on the flint surface. It is also important to use replicas instead of discarded ancient tools whose edge characteristics and working efficiency would have been altered by use (as in Piperno, 1973).

Experiments with replicas of Abu Salabikh drill bits helped to interpret preserved archaeological examples of this type of borer. These tools are usually found broken. When the spindle tip shears off due to torsion or flexion the end of the tool which has been mounted in the haft can be used a little longer if the drilling is shallow, but it eventually has to be removed from the haft and discarded. The spindle which has been polished by rotary abrasion and sometimes by abrasives during its use, is sometimes found in isolation. This is not because the tip is a tool in its own right, as has sometimes been assumed (Tosi, 1980, 452), but because torsion and flexion stresses cause the tip of the tool to break off, especially if force is not evenly applied at all times during the alternating movement of the bowstring.

Shearing of spindles was the most common accident in our experiments. Out of the 18 drill tips initially used in the experiments, 12 were unbroken at the conclusion of a task, 4 sheared off from twisting stress, and 2 had flexion breaks. This corresponds to a comparable magnitude of breakage in the Abu Salabikh drill bit assemblage, where 5 bits had torsion breaks, 5 were unbroken and 3 bits had flexion breaks. The close correspondence between experimental and archaeological groups is a further control on our experimental protocol and reflects the relatively complete recovery possible with a sieved flint sample such as that provided by the excavators of Abu Salabikh.

Three different hafting techniques were used in our experiments : 1) resin, 2) sinew and 3) friction. The friction haft was the easiest to use as bits could be replaced quickly. Some bits were hafted with two different mixtures of resin : the first contained about 70% pine resin and 30% beeswax. This mixture proved brittle and tended to melt as a result of friction if the bit went to deep into the contact material. A second mixture of loaded resin was prepared composed of 50% pine resin with the rest made up of beeswax, red ochre, sand and hemp fibre. This worked extremely well, remaining solid without softening despite the build up of friction heat during use. Deer leg sinew was also used to haft drill bits, however this took longer to replace broken drill bits as it was dried for 24 hours before use.

Repeated rotation with a drill bit is a classic way of converting mechanical energy into heat energy, and if the borer is used continuously for a long time or it penetrates too deeply into the material being worked, the resin haft heats up and loosens, allowing the tool to slip in the haft and become misaligned. It is interesting to note that Australian adze slugs tend to work loose from their haft and have to be discarded when after repeated resharpening the working edge (and the heat produced at the working edge) gets too close to the resin haft (Gould, 1980, 14).

The actual experiments consisted of drilling a variety of different materials: pottery, wood, shell and stone (see below: micro-wear investigation). In each instance we attempted to complete a particular task. For example we drilled several pieces of lapis lazuli 4-6 mm thick to make beads. Details of the time needed to complete a task, damage and repair of a given bit were all recorded. The models for experiments came from archaeological, textual and ethnographic sources. One of our ethnographic models came from Afghanistan where the bow drill is still used to repair broken pots (S. Ingerson, personal communication). We attempted to limit our work to probable uses of the bow drill instead of arbitrarily and haphazardly attempting to produce polishes. In this way we hoped to produce a similar range of polish type and distribution on our experimental pieces as would be found on the excavated pieces.

Microwear analysis was divided into two stages. Optical microscopy was used to determine microwear polishes using Keeley's method with modifications. Hafting traces were studied using a digitised image processing technique developed at the Institute of Archaeology in London. The evidence from texts, archaeological context and ancient artwork placed restrictions on the borers' use and enabled a variety of blind test to be conducted by R.U.H.

THE MICRO-WEAR INVESTIGATIONS

The aims

The aims of this investigation were fourfold:

1 – We wanted to conduct a blind test by completing the micro-wear analysis first before comparing our results with other archaeological evidence from Abu Salabikh. This was a somewhat different approach to that of Keeley and Newcomer (1977) who conducted a successful blind test involving only experimental tools which Newcomer had made and used and Keeley had analysed. Their blind test has been seen as evidence for the viability of micro-wear analysis. However, as their test was limited to experimental tools only it did not take into account the many factors which can affect surfaces of flint tools during and after their burial in the ground (Stapert, 1976; Holmes, in press) and which leave their own microscopic traces on the flint surfaces.

2 – We wanted to compare our experimental results with those of other researchers. Where differences emerged we wanted to find out their causes. Previous research into the formation of micro-wear traces (Unger-Hamilton, 1983) and into the effects of chemicals and physical stress on micro-wear traces on flint (Plisson and Mauger, in press) has shown that there may be many reasons for different results. Amongst other factors, we wanted to know whether a different shape of tool or a different method of use would affect the formation of wear-traces; we therefore included two handheld borers in our experiments. Unfortunately, in many recent publications, despite precise conclusions, micro-wear analysts have omitted details of experimentation and photographic evidence in which experimental and archaeological micro-wear traces can be compared. This led us to rely on only a few publications such as Yerkes (1983) and Moss (1983) which were chosen because the former had used experimental drill bits, and the latter piercers.

3 – We wanted to outline the many problems the micro-wear analyst is likely to encounter. These problems, such as flint-surface modifications due to natural causes are rarely mentioned in the literature ; positive conclusions abound and sites with negative results are rarely published.

4 – We wanted to find out whether hafting the drill bits would leave any distinctive « hafting traces » which are often referred to in micro-wear studies (see for example Büller, 1983).

Method of study

The experimental drill bits and borers were cleaned in a solution of warm water and a mild detergent and were examined under an Olympus Vanox Incident Light Microscope at magnifications of x50-x200. They were photographed using Ilford F P 4 film. After the initial examination the tools were immersed in White Spirit in order to remove the residues of the resin which had been used for hafting. Although White spirit, in contrast to various other chemicals does not seem to affect the appearance of wear traces at all, it was nevertheless thought wiser to examine the drill bits before immersion. After this a second investigation under the microscope was carried out.

The surfaces of the excavated drill bits from Abu Salabikh were found to be obscured by sand particles adhering to the tools. They were therefore cleaned in an ultrasonic cleaning tank as well as in water and detergent. The excavated tools were also investigated and photographed before and after cleaning. Finally the wear-traces on the experimental tools were compared with those on the excavated tools.

Edge damage on flint tools is held by some researchers (Tringham *et al.*, 1974 ; Roy, 1982) to indicate the nature of the material on which a tool had been used, which will be called the « contact material » in this paper. However this was not the case in our experiments : there was no consistency in edge damage related to different contact materials. In fact, apart from breakage, remarkably little edge damage was observed on the experimental drill bits and it is therefore not considered an indicator of contact material in this context.

Polish and striations which are visible at magnifications of x50-x400 have been shown to indicate the nature of the contact material by Keeley and Newcomer (1977). We have used Keeley's approach (1980) in this work.

Most of our photographs show wear-traces at x200. The photographs showing the wear-traces on drill bits used with abrasives were taken at x100 in order to document the characteristic modification of the flint surface. The brief descriptions of the polishes and striations are based on what has been observed at the same magnifications. The model of polish formation underlying the descriptions is based on observations under the Scanning Electron Microscope (SEM) which indicated that polish is formed as a result of abrasion and a very thin coating of amorphous silica (Unger-Hamilton, 1984).

Micro-wear traces on the experimental tools

R.U.H.'s experiments had shown that the use of a hammerstone to retouch leaves strong microscopic traces in the form of « stone polish » *–i.e.* a flat bright area with striations. This could be confused with traces from use, if the supposed direction of use was the same as that of the retouch blows. However the antler tine used to retouch our experimental tools left only weak microscopic traces in the form of isolated striations which were too faint to be confused with traces from use.

Microscopic traces from the drilling of inorganic materials.

Lapis lazuli caused characteristic « stone polish » comparable to that noted by other researchers (Moss, 1983, 103, pl. 6 :8). Other materials used in experimental drilling included malachite, native copper, turquoise, hippopotamus ivory and pottery (the pottery came from the site of Abu Salabikh and was contemporary with the drill bits). These polishes could in most cases be distinguished from each other by polish and striation types, with the exception of malachite and pottery which looked similar.

Microscopic traces from the drilling of organic materials.

Drilling seasoned ash (*Fraxinus excelsior*) left a smooth area of polish, without any striations, at the tip of the drill bit similar to the polish mentioned by Yerkes (1983, 505, fig. 2 :A-B). However boring the same plank of wood with larger borers led to a different, more diffuse polish with some striations.

The polishes on our experimental tools from the drilling of soaked fallow-deer (*Dama dama*) antler and from drilling cow (*Bos*) bone looked quite distinct. These polishes did not resemble those from the same contact materials shown by Yerkes (1983, 505, fig. 2E [antler] and 505, fig. 2C-D [bone]) which looked « pitted ». Yerkes had soaked his antler (exact species not indicated) for three days, but the polish could have been altered by the solutions of hydrochloric acid (HCl) and potassium hydroxide (KOH) he used to clean his tools. Keeley (1980, 43) also referred to the « pitted » appearance of bone polish after cleaning with HCl and sodium hydroxide (NaOH). Observations under the SEM (Unger-Hamilton, 1984) have shown residues from bone adhering to the surface of a flint tool after cleaning with detergent and after six months of storage. It is likely that such loosely attached residues are removed with HCl which attacks calcium compounds. Alkaline solutions of KOH and NaOH could attack the surface of the flint itself, provided the solutions are strong enough (Keeley, 1980, 29).

Cardium and scallop shell caused similar areas of polish with bundles of fine striations (*Pl. 1* **c**) exactly like the shell polish shown by Yerkes (1983, 506, fig. 3C).

Micoscopic traces from the drilling of various materials with the addition of abrasives.

Lapis lazuli drilled with the addition of sand and water caused a very distinct polish (*Pl. 1* **a**) with a pattern of concentric rings, different to the polish caused by lapis on its own, or with the addition of sand, or water only. This pattern of concentric rings was also found on the polish caused by drilling copper with sand and water. A similar pattern was observed under the SEM on bore impressions from drilling with wood drill bits also used with sand (Gwinnett and Gorelick, 1979).

Distribution of the polishes.

The distribution of the polishes over the surface on the drill bits varied according to the softness or hardness of the contact materials. We believe that tool shape also affects the depth of penetration into the contact material, *i.e.* a long narrow tip such as one of our drill bits could be used to penetrate deeper than a short, thick tip.

Residues from contact materials.

After both cleaning processes had been completed the only traces of residues which could be detected under the microscope were some black flecks of lapis powder on the drill bit used to drill lapis without the addition of abrasives. Similar residues were seen by Tosi and Piperno (1973) on excavated drill bits from Shahr-i Sokhta. No sand grains could be seen on the drill bits which had been used with sand.

Hafting traces.

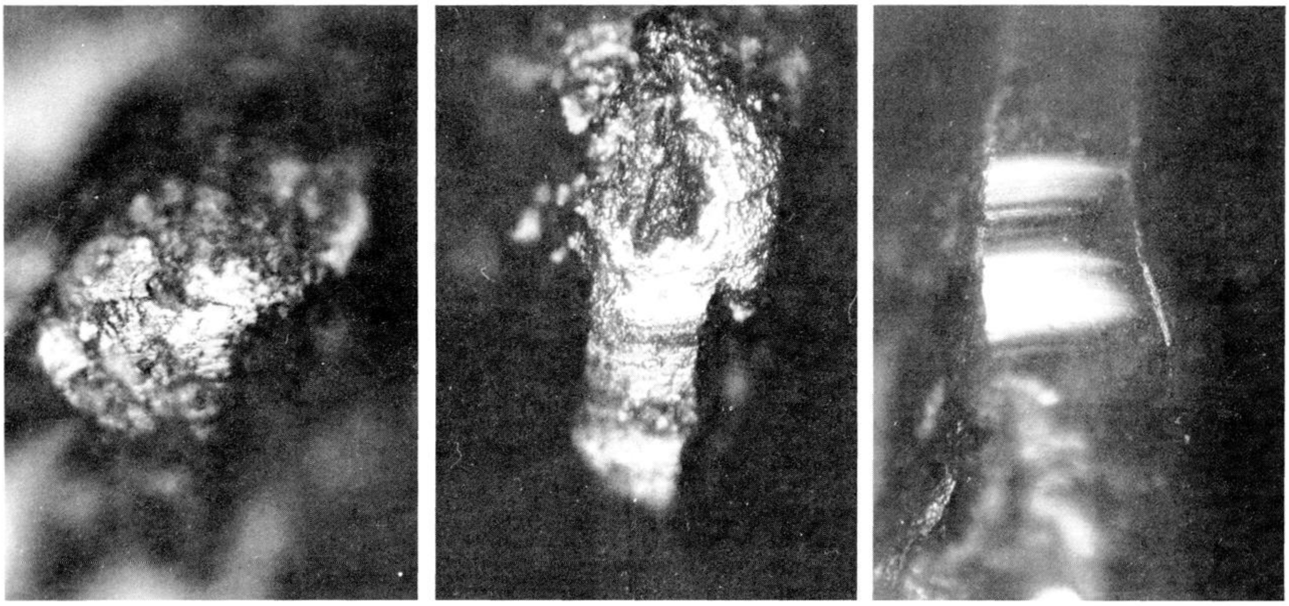
No traces related to hafting could be seen on the tools.

Macroscopic traces.

Gloss –which is visible to the naked eye– was observed on all the drill bits used to drill hard inorganic materials (with or without abrasives) and wood ; gloss was not present on the drill-bits used to drill pottery and the other organic materials.

Summary of the investigation of the experimental tools.

1) The majority of polishes formed by different contact materials looked distinct. We were therefore hopeful about the micro-wear analysis of the excavated tools.



Pl. 1 **a** *: Experimental drill bit, used on lapis lazuli with sand and water; magnification x100, side view.* **b** *: Abu Salabikh drill bit; magnification x100, oblique view of side and tip.* **c** *: Experimental drill bit used on cardium shell; magnification x200, side view.*

2) Most polishes looked similar to those reported and shown by other researchers. Differences found in these experiments may have been due to cleaning methods or a different variety of contact material. The possibility also exists that idiosyncratic differences in tool use by different workers may result in minor variations in polish distributions and appearance.
3) A difference in tool shape and/or action during use led to slightly different wear-traces.
4) Addition of abrasives altered the polish completely and we could not tell the difference between two contact materials when the same abrasives had been added.
5) It appears that inorganic residues may become firmly embedded in the tool surface and could provide evidence of the contact material.
6) No hafting traces could be detected.
7) The presence of gloss visible to the naked eye was confined to the drilling of hard inorganic materials and wood. It could therefore be used as a vague indicator before microscopic examination.

The investigation of the excavated drill bits

The macroscopic examination.

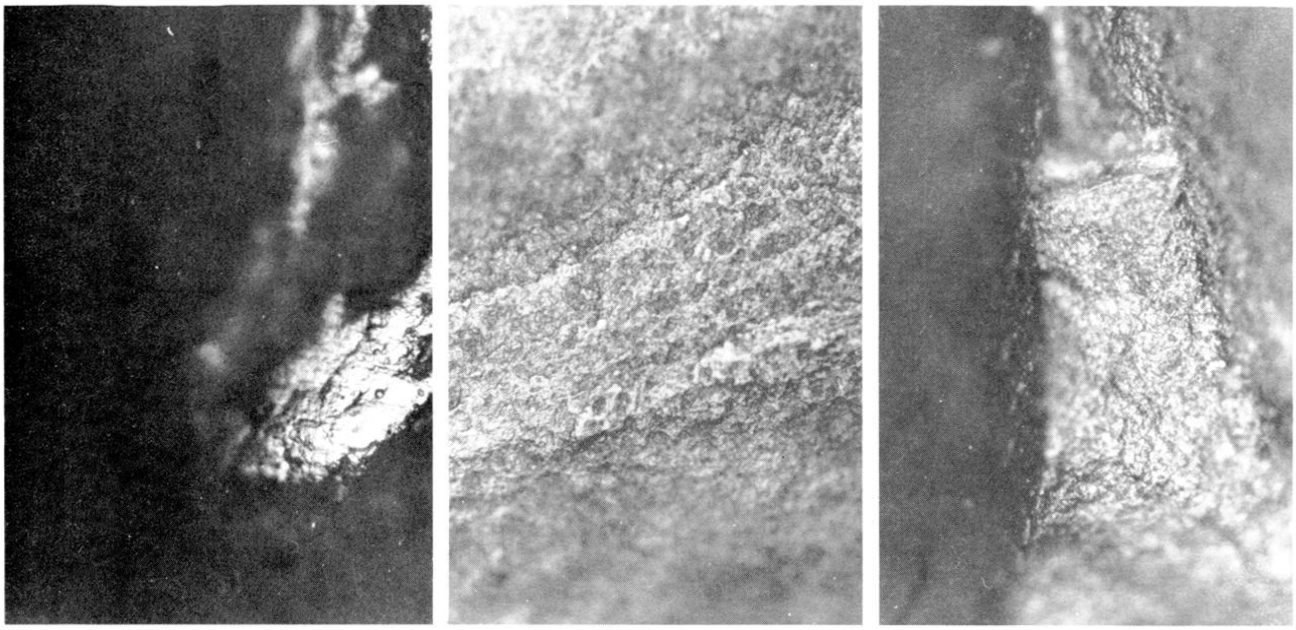
The macroscopic examination of the 13 drill bits from Abu Salabikh showed that sand grains adhered to most of the tips. This had suggested to us the possibility that sand may have been used as an abrasive, although only one tool had a glossy tip and none of the experimental tools used with abrasives showed any traces of sand on their tips.

Eight of the drill bits had lost their tips through breakage.

The microscopic examination.

The microscopic examination revealed that only one tool –the tool with gloss– showed the concentric ring pattern characteristic of the addition of sand and water during drilling (*Pl. 1* **b**). This leads us to believe that the other drill bits had not been used with abrasives.

It is possible that the drill bits with the concentric ring pattern had been used to drill



Pl. 2 **a** *: Abu Salabikh drill bit ; magnification x200, side view.* **b** *: Surface alteration on dorsal ridge before hafting.* **c** *: Surface alteration on dorsal ridge after hafting.*

stone with a hardness grade of 7 or less on the Mohs scale, perhaps chalcedony (7), malachite (4), turquoise (slightly less than 6), or lapis (6) (Smith and Phillips, 1962, 429, 449, 440, 437). Adding sand to drill any material other than stone proved unnecessary but sand grains of quartz, which has a hardness of 7 on the Moh scale and can be used to drill other forms of SiO^2 such as carnelian and chalcedony (Bromehead, 1934), cannot be used to good effect to drill harder stone (Hodges, 1976, 107).

Most drill bits showed isolated bright metal flecks, but none showed the characteristic « metal polish » from drilling copper. From this we concluded that the flecks did not originate from use, but that they were perhaps due to excavation with trowels or the metal sieve used to recover all the pieces from the pit the Abu Salabikh drill bits were found in.

Nearly all tools –even those which had lost their tips– had isolated traces of weak polish which looked different in each successive examination. Most of the unbroken tools showed striations the fineness and number of which indicated the working of shell. As these striations were not seen on any bright areas of polish (as was the case with experimental « shell polish ») they oculd have been due to a number of factors such as postdepositional surface modification (Holmes, in press ; Plisson and Mauger, in press). Apart from the drill bit with the concentric ring pattern only two drill bits showed a polish which on present evidence could be identified with some degree of certainty as « shell polish » (*Pl. 2***a**).

Summary of the investigation of the excavated drill bits.

The wear traces could be assigned with some degree of certainty on only 3 out of 13 tools. One tool had probably been used to drill stone with the addition of abrasives and the other two had probably been used to drill shell, though the wear traces on these tools looked somewhat weaker than the equivalent polishes on the experimental tools.

Altogether the comparison of the wear traces on the excavated tools with those of the experimental tools had proved difficult and mostly uncertain. This may have been due to any of the following factors, most of which are largely unknown and are too often ignored in micro-wear analyses:

1 – The used edges of the tool may have been lost through breakage or resharpening.

2 – Traces from breakage or manufacture might be very similar to traces from use.

3 – Different grain size of flint might have led to a different appearance of the polish (Unger-Hamilton, 1983 ; Bradley and Clayton, in press ; Holmes, in press).

4 – There may be flint-surface modifications due to natural causes (Stapert, 1976 ; Holmes, in press) which could obliterate or even resemble wear traces.

5 – Polishes may have disappeared due to chemical attack or physical stress after burial of the flint tools (Plisson and Mauger, in press).

6 – The tool may not have been used at all, or not long enough for any distinct wear traces to occur.

7 – The wrong contact materials may have been used in the experiments.

8 – Contact materials may have been treated in a way unknown to us. Previous research has shown that water present in or added to the contact material plays a decisive role in polish formation (Anderson-Gerfaud, 1981 ; Gysels and Cahen, 1982 ; Unger-Hamilton, 1983).

9 – Repeated examination of the undetermined drill bits had shown that polishes can look quite different according to the angle of the flint surface to the microsope lens.

Consideration of these factors led us to be sceptical about the optimism engendered by Keeley and Newcomer's (1977) blind test in which polishes on modern flint from known sources used on relatively predictable materials had been compared : their tools had not been buried for thousands of years and subjected to trampling, metal sieving and cleaning during excavation.

Comparison of our results with other archaeological evidence.

After our doubts this comparison came as a pleasant surprise (R.U.H.). Although there was no beadmaking waste in the pit where our drill bits were found at Abu Salabikh (5120/21), a surface concentration of the same kind of drill bit was found elsewhere on the site together with beads and chunks of lapis, carnelian and shell. In the excavation report (Payne, 1980) these tools had been described as « borers » and « micro-borers ». As the existence of a concentric ring pattern on one of the tools suggests that the tools were used with a mechanical drill such as a bowdrill, we prefer the term « drill bits ». However in contrast to Payne's report that the proximal end of the borers « is always worn and slightly polished, perhaps by movement in a handle » (Payne, 1980, 112) we found no evidence of hafting damage or microwear.

EXPERIMENTAL INVESTIGATION OF HAFTING TRACES

To investigate possible sources of hafting traces it was decided to study the drill bits with the intention of using a new technique currently being developed at the Institute of Archaeology. This involves photographing the wear traces, digitising the negative to produce a grey level array from which statistics can be derived, with which to mathematically characterise the wear traces. These statistics can then be used to objectively classify the traces by texture analysis (see Grace, Graham and Newcomer, in press).

In this case the classification had the limited aim of deciding whether any traces were significantly different from unused flint, and of detecting their origins if possible. The drill bits from the original experiments were re-examined microscopically and two cases of some alteration of the flint surface were observed, but these traces covered such a small area and were so indistinct that no conclusions as to their origin could be reached. Therefore it was decided to carry out a further experimental programme with the specific aim of detecting hafting traces.

The experimental programme is illustrated in Table 1. The « loaded » resin haft consisted of resin mixed with ochre and sandy grit in which the drill bit was held entirely by the mastic. This was achieved by heating the mastic, inserting the drill bit and allowing the mastic to cool and harden. Wedge hafting was achieved by making a mortise in the end of the drill shaft in which the bit was held in place by the pressure exerted between the drill haft and the contact material. This technique is similar to that described by Keeley (1982), as « jam » or wedged hafts, and was chosen because such hafts, « characteristically allow movement of the tool in the haft » (Keeley, 1982, 799), and therefore are more likely to produce hafting traces. A refinement of this technique was to insert small chocks of wood between the drill bit and the shaft to reduce movement in the haft, and allow the drill bit to be centred along the axis of the shaft more accurately. The forcing of the slivers of wood into contact with the drill bit would perhaps produce characteristic hafting traces. Hafting with sinew was done by cutting a deep slot into the drill haft, into which the drill bit was inserted and held in place by wrapping the sinew around the haft and the protruding edges of the drill bit. The edges were allowed to protrude so that they would be in contact with the sinew. This was to test whether any wear traces would be produced attributable to the sinew. « Sinew polish » from hafting have been reported by Büller (1983). The contact materials were selected as relevant to the archaeological specimens and the previous experimental program.

DRILL BIT	TYPE OF HAFT	MATERIAL DRILLED	DURATION
1	'loaded' resin	shell	10 minutes
2	wedged	shell	10 "
3	wedged	stone	10 "
4	'loaded' resin	ivory	10 "
5	wedged plus chocks	turquoise	5 "
6	sinew bound	malachite	7 "
7	sinew bound	malachite	7 "
8	wedged plus chocks	lapis lazuli	10 "
9	wedged plus chocks	lapis lazuli	10 "

Table 1 Experimental program used in the investigation of the hafting traces

To attempt to isolate the origin of any traces, micrographs at 200 magnifications were taken of the tools at each technological stage. Photographs were taken of areas of the blanks as soon as they were removed from the core and after being retouched to form drill bits. The drill bits were then photographed after being hafted and used in the bow-drill. Outline drawings of the blanks and the drill bits were made so that the position of each photograph could be recorded. We attempted to photograph the same areas on the blanks and the drill bits both before and after use, to produce exactly comparable photographs ; this was not always possible as some blanks required extensive retouch to reduce them to drill bits, in some cases removing the photographed area of the blank. All areas showing any visible alteration of the flint surface at 200 magnifications were photographed, after the drill bits were retouched, and again after they had been hafted and used. A large number of photographs were taken to obtain as complete a visual record as possible, so that any wear traces observed could be assigned to the technological stage at which they appeared (see *Fig. 2*). A number of these photographs were selected for digital scanning and subsequent texture analysis, the results of which are illustrated in Figure 3. The values of the statistics are expressed as differences from unused flint, so that the nearer the point is to the origin, the closer the similarity of that texture sample to unused flint. The process by which these statistics are derived is explained in the paper by Grace, Graham and Newcomer (in press).

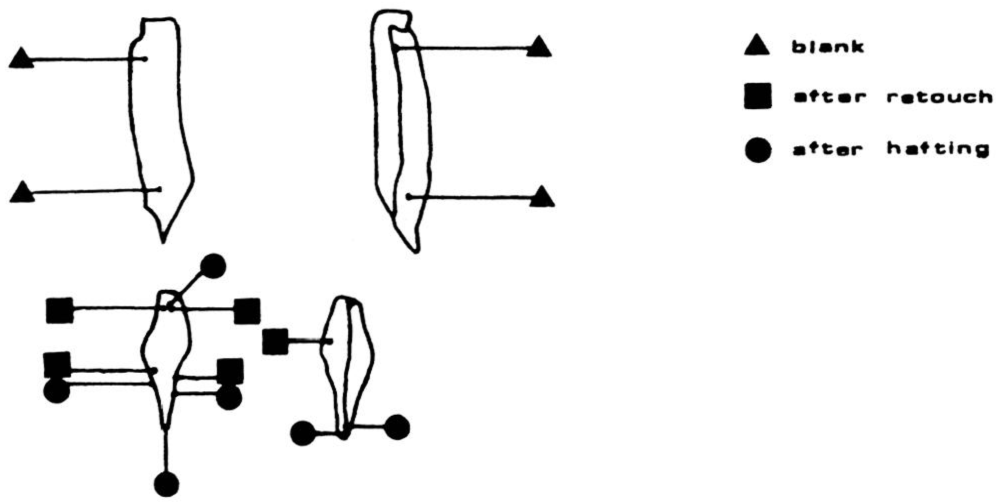


Fig. 2 Outline drawing of drill bit number 3, showing position and number of photographs.

As can be seen from Figure 3 most of the samples cluster around the origin indicating their similiraty to unused flint, and thus exhibiting little surface alteration. This group includes textures of blanks, retouched drill bits and used drill bits, from photographs of the same area of the same tool. This illustrates that in most cases no surface alteration has taken place, either from retouch or hafting. Included in the diagram (*Fig. 3*) are 5 examples of photographs taken of use wear produced at the tip of the drill bits, and other examples of various use wear polishes from different flint tools. These use wear polishes produced by wood, antler and bone have quite different values from unused flint so that any hafting polish should be clearly differentiated from unused flint by this technique. The area marked around the origin of Figure 3 represents 15% of the total range of variation from unused flint. Allowing for the natural variation of flint textures, points within this area are not considered significantly different from unused flint. There remain six points outside this area. Point A is from a photograph taken of the bulbar scar of a blank, and the slight surface alteration may be due to the pressure exerted between the core and the blank when it was struck. Points B, C and D are from photographs taken of retouched drill bits before they were hafted. In all three cases these areas were on dorsal ridges on the drill bits. A possible explanation is that as the tools were pressure retouched on a hide pad, small chips of flint were removed that congregated beneath the tool, so that when pressure was applied during retouch the drill bits were pressed down on to the flint chips causing flint on flint contact. Also pressure against the hide could be sufficient to produce hide polish. The dorsal ridges would provide a particularly vulnerable area for surface alterations under these circumstances (see *Pl. 2* **b**) ; and it is interesting to note that traces on dorsal ridges have been interpretated as evidence for hafting by Keeley (1982, Fig. 1,5 :805), and Frison (1968, 152).

The incidence of such « retouch traces » prior to hafting on the drill bits could be considered more probable because these tools are retouched around most of the periphery, but the

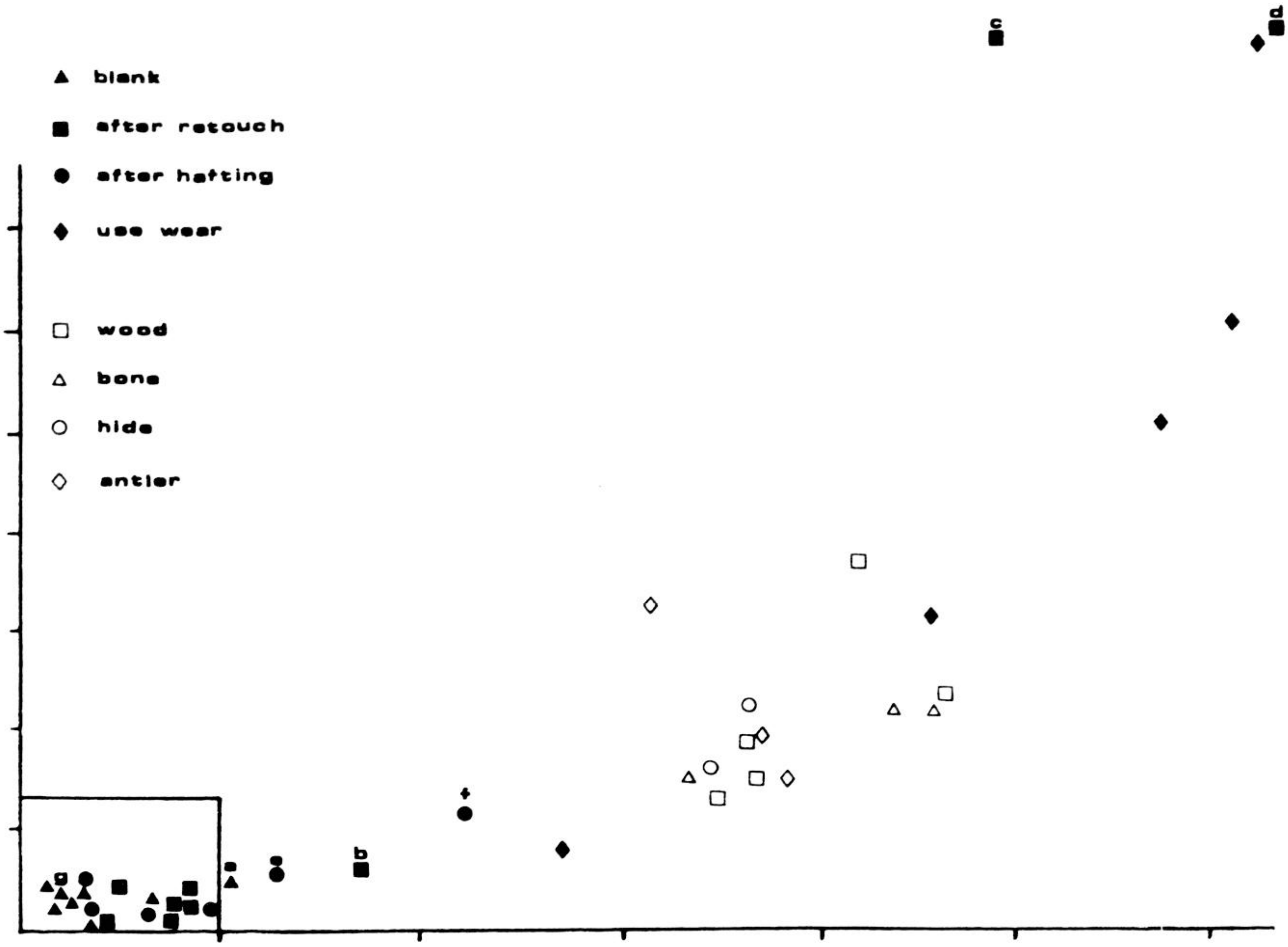


Fig. 3 Scatterdiagram with values plotted for unused and used flint tools (see text for detailed explanation of the method used).

retouching of the non-utilised end of hafted tools is more extensive than with unhafted tools of other types. The shaping of endscrapers to fit the haft, or the backing of bladelets for hafting as knives or sickles are examples of this.

Points E and F are from used drill bits. Point F is also from a dorsal ridge (see *Pl. 2* **c**), of the hafted end of drill bit number 2; point E is from the central part of the ventral surface of drill bit number 9. Neither of these examples has a polish that is sufficiently distinctive to identify any contact material that may have caused it, and therefore cannot be matched to any particular type of haft. Number 2 was wedge hafted and number 9 wedge hafted with the addition of chocks, so that if these surface alterations were due to hafting they should exhibit the characteristics of wood polish. Not only do they not do so, but the two surface alterations are quite different.

From 9 drill bits hafted by various techniques, only two small and indistinctive areas of surface alteration were observed that occured after hafting. A far higher incidence of positive hafting traces would be expected to appear on 9 drill bits if hafting traces occur with any frequency, especially considering the intensity of use and the amount of friction between tool and haft involved in using drill bits in a bow drill. The drilling action involves considerable vertical pressure applied on the capstone as well as the vigorous rotational movement of the drill. The rotational action of the drill takes the form of alternate clockwise and counter-clockwise movement causing lateral vibration as the inertia of the previous movement is overcome.

The fact that surface alteration occured on the retouched drill bits before hafting indicates that they may be other origins for traces that may have been attributed to hafting. Wear traces of the manufacture of tools have been reported before by Keeley (1980) and Moss(1983). Antler traces from the soft hammer rubbing over the surface of the tool during retouch have been observed (Moss, 1983, Fig. 6.8d :103). But when the manufacturing traces are indistinct and not identifiable to a known process, perhaps there has been a tendency to ascribe these traces to hafting because they appear on the assumed hafted area of the tool. In this study surface alteration occured on dorsal ridges of tools during retouch, although these areas are well away from the edge where such traces as « hammerstone stripe » might be expected.

The results of these experiments show that wear traces do occur during retouch and possible minor surface alterations can occur when the blank is removed from the core. Haft wear has been defined as wear traces, « which make little sense as traces of utilization, but does conform to what is known or expected of wear from minor movement of a tool against its haft », (Cahen, Keeley and Van Noten, 1979, 681). The surface alterations from the manufacture of these tools fall within this definition, and could easily be confused with genuine haft wear.

With prehistoric material the tools can only be observed after all stages of manufacture, hafting and use have taken place ; and so it is impossible to be precise in assigning the traces to a particular stage in the process. By careful observation of this process, we have demonstrated that wear traces on the non-operational end of a tool are not necessarily due to hafting, and we suggest that extreme caution should be applied before attributing any traces to hafting.

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