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MICROSCOPIC USE-WEAR ANALYSIS
A Basic Introduction on How to Reconstruct the Functions of Stone Tools

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FROM TYPOLOGY TO TECHNOLOGY

All remains produced by humans are called artefacts. For prehistoric archaeologists the most important artefacts were made of stone. Stones are usually hard and resistable, especially those used by prehistoric men to make tools. While most organic materials may disappear during time, under "regular" geological conditions stone tools will last over millions of years. Thus, they contain most of the informations archaeologists get from prehistoric life. Over 99% of the time span humans exist, stones played a major role to fulfill almost all functions necessary for subsistence. They were used for cutting, scraping, carving, boring, grinding and more. All the functions today metal is used for were formerly done with stones. The first stone tools which appear at least 3 million years ago had a simple design and were made from pebbles or rocks. Beside flakes they are so-called choppers or chopping tools. Because of some disadvantages, especially the less to control cleavage, prehistoric humans learned to choose silicate rocks like quartzite, radiolarite, chert or flintstone. They showed both great hardness and sharpness and good cleavage qualities.

During the Palaeolithic and Mesolithic stone tools commonly were made by knapping. Because chert/flintstone is quite brittle the working parts of flint tools soon became damaged and scarred during extensive labour. The lifespan of such tools were quite short. Especially for heavy detaching and splinting activities on harder working materials the techniques of stone grinding were developed at the end of the Mesolithic or beginning of the Neolithic. Now it was possible to make sharp and resistant tools out of tenacious and hardly cleavable stones. Mainly basalt-like volcanic rocks could now be transformed to adzes and axes and often replaced flint tools for intensive activities (e.g. wood working). But flint knapping still continued during the Neolithic and the early metal ages.

The prehistoric humans developed a great variety of forms of stone artefacts. Soon, the early prehistoric researchers developed typology to distinguish, sort and characterize them. Typological methods were used for dating, regional allocation and tool classifications. Very often, just typological analyses were insufficient. More exact methods now replace often typology. In the case of classification of tools and tool-forms today, it is mainly the so-called "microscopic use-wear analysis" or "microwear analysis" which gives more complete information about the purposes of stone artefacts.

Before the methods of use-wear analysis were established, artefacts were divided simply into tools and blanks. The definition was: A tool is made by artificial modification of a blank, which can be a flake or a blade or simply a pebble. The modification can be any kind of a retouch, including burin blows. Also visible edge scarring or similar alterations result in a "tool". Unmodified artefacts were normally regarded as debris from the flint knapping or the working process.

This definition could no longer be held upright after the development of microscopic use-wear analysis. Especially, the examination under higher magnifications showed that in many cases unmodified pieces had use-traces and were therefore used as working tools. Unmodified flakes and blades often have at least one sharp edge which can be used for cutting and slicing activities much better than a retouched and blunter edge. To recognize if an artefact is a tool in a real mechanical and not only typological meaning, use-wear analysis is necessary.

The methods of systematical microwear analysis had been developed in Russia with S. Semenov since the 1950's. After he published his studies in 1964 in English, it encouraged researchers in the "West" to follow his methodology which resulted in the middle seventies in establishing the so-called "Low Power" analysis, the main representative of which was George Hamley Odell, and the "High Power" method of Lawrence Keeley. Both methods can give information if an artefact was used or not, the way (motion) of use, the hardness or the nature of the worked material and therefore the former activity and the purpose of an artefact.

TECHNICAL EQUIPMENT FOR MICROSCOPIC USE-WEAR ANALYSIS

Light microscopes are the usual instruments for microwear analysis. For special purposes, mainly the analysis of adhering organic residues on tool surfaces, scanning electron microscopes (SEM) are required.

Stereomicroscopes

Two independent optical systems are combined and give a true three-dimensional image of the examined part of an object. Stereomicroscopes operate usually with lower magnifications between 10x and 40x. The advantage of a stereomicroscope is mainly the 3-D image, a relatively high depth of focus and a greater distance between object and objective. Stereomicroscopes are well suited for the examination of objects with uneven surfaces. Some models are equipped with a zoom-objective and allow a continuously adjustable magnification. Especially the low power analysis of edge damage, i.e. scarring and blunting is the working field of stereomicroscopes.

Reflected light microscopes

These microscopes are designed for the examination of opaque materials. A material is opaque if its thin-section is not transparent. The common use of a reflected light microscope is for metallurgical and mineralogical analysis. Here, the objects are usually absolute plane and polished samples. For the use on artefacts this is the major problem: reflected light microscopes have a very limited depth of focus and worse, there is only a small distance between objective and object. Normal achromatic lenses have an objective distance of 2.1 mm at 20x magnification (=200x with 10x-eyepieces) and only 0.5 mm at 40x magnification (=400x with 10x-eyepieces). At this magnification the depth of focus is only 2 µm (0.002 mm)! Special (but expensive) "long-distance objectives" are recommended for the analysis of uneven tool surfaces to avoid contact between objective and artefact and possible damage to both. The working distance of a long-distance 40x-objective is 2.8 mm. But the low depth of focus remains unchanged. The use of reflected light microscopes requires a special object-mounting device. Ordinary mounting tablets with metal clamps cannot be used for artefacts. They have to be placed on a plasticine pillow. To avoid finger-contact during analysis a simple mounting device can be constructed in the form of a spherical, in any direction adjustable object mount with one half of a table-tennis ball filled with plasticine (or better type-cleaner gum for mechanical type-writers) and the inner ring of a scotch-tape (Pawlik 1992).

Scanning electron microscopes (SEM)
Instead of light, SEMs use an electron beam. This requires a vacuumized analyzing chamber. The image is sequentially built up on a video monitor. The magnification of a scanning electron microscope can reach more than 10000x. Unfortunately, there are some limitations with regards to artefact analysis. The limited size of the analyzing chamber normally allows only pieces smaller than 10 cm to be placed inside. Non-conducting objects like stone must be prepared first to get them conductive. Usually, this is done by covering the object with a metal film of Gold-Palladium, the so-called "diode sputtering". Also the object has to be fixed by a conducting glue (graphite-based) on the object mount. Both treatments cause irreversible effects on tool surfaces and are therefore not very popular among lithic analysts or museum and state department officials.

On the other hand, micro-analyser attachments like EDAX (energy dispersive analysis of x-rays) allow the determination of the contained elements. Its x-ray detection combined with statistical computer analysis automatically creates hardcopies or histograms of the elementary composition of a sample. This kind of micro-analyser is very important for residue analysis and is also used for developing some theories of polish formation (see below).

THE LOW POWER ANALYSIS

Subject of the Low Power analysis is the examination of edge damage caused by mechanical stress. Mainly the various forms of scars were analysed. The precondition is that different working materials, movements and intensity cause different and distinguishable edge damage patterns.

A classification of edge damage patterns was first published by R. Tringham, G. Odell and others (1974). They carried out an experimental program, which focused on the mechanical parameters and the hardness of the working materials. Soft and hard materials like hide, plants, bone, wood, etc. were worked with longitudinal, transversal and rotating activities.

As a result it was noticed that harder materials cause faster edge scarring. Characteristic damage were short and deep negatives, so-called "step scars" (Plate 1). Step scars were only produced by harder materials, while soft material working only cause few and smaller negatives. Longitudinal motions result in scarring on both sides of an edge, depending on the working angle. Perpendicular angles show equal scarring on both sides. Transversal motions cause pressure on only one side of an edge, the non-contact surface. Because the contacting part of the working edge is usually small, scars occur mainly dense and interlocked on that small contacting part. Tringham *et. al*. observed that during transversal motions trapezoidal shaped negative forms were never built up, while rotating motions caused them frequently.

However, after his experiments Keeley stated that edge damage is on steep-angled edges rare and cannot be certainly determined (Keeley and Newcomer 1977). Also, scars resulting from tool use cannot be distinguished from modification negatives on retouched edges. In his opinion, too many non-intentional processes can affect edge damage patterns similar to those produced by working activities. Edge damage is therefore insufficient as single criteria for use-wear analysis. In his opinion it was necessary to add a "High Power" analysis of micro-polishes (see below).

At the so-called "Ho-Ho Conference" (Hayden 1979) it was established that the forms of the cross-section of use-scars correlate much more with the hardness of a working material than does its shape (Figure 1). It was Odell again (1981) who found in further experiments that:

1. Very soft materials create small and shallow negatives with irregular shape and feather termination.
2. Middle soft materials (e.g. soft fresh wood, after Odell) cause edge damage with a feather-distal cross-section as well, but they are usually larger and visible even without magnification lens.
3. Middle hard materials (fresh wood, fresh bone and soaked antler) cause larger hinge-terminations.
4. Hard materials (bone, antler and hard wood in a dry state) cause extensive edge damage. After an initial phase where bigger feather-negatives were produced, working hard materials cause mainly step-terminations.

Soon, this model was criticised by P. Vaughan (1985). In his analysis he found out that there is a much wider variation in the building of edge damage patterns and their forms. He showed that not only the distal but also the form of the proximal termination of use-scars depend on the working material. In his experiments, harder materials formed mainly shallow proximal cross-sections but middle-hard and softer materials produced a too wide variability of negatives to establish certain rules. More characteristic seemed to be the so-called "second-edge-row," a band of smaller negatives which truncates the edges of bigger scar complexes and therefore developed after them. A complete second-edge-row was a safe indicator for hard materials and even partly formed second-edge-rows are a sign for middle-hard working materials. However, in Vaughan's analysis only 50% of the hard material experiments and only 20% of middle-hard material experiments generated this feature. Therefore, lacking of a second-edge-row is, on the other hand, no evidence for soft materials.

Cautionary note: Some of the author's own experiments (Pawlik 1992) had shown that use-wear analysis only by using Low Power is problematic. The established models of edge damage formation depend too often on stable working conditions. If some factors change, these models are no longer valid. E.g. a water-soaked working material like bone produces edge damage different from the same material in a dry state. Also different edge angles, the various mechanical forces and change of motion or handling affect the formation of edge damage and the negative forms. In many cases, edge damage from intentional work is not distinguishable on retouched working edges. Very soft materials like meat produce absolutely no scarring, except when contact with bone or gristle. Soft and tenacious materials like hide, leather, sinew and soft plants cause few edge scarring but more or less intensive rounding and blunting (esp. leather-working, Plate 2), sometimes combined with macro-striations. With a certain degree of probability, it is just possible to distinguish worked materials in softer and harder groups. A special feature can occur on artefacts used as weapon insets: the so-called "impact scars," long and narrow negatives with a burin-blow shape. They show usually step or hinge terminations as a result of the hit (either the hunted animal or the soil or perhaps a tree trunk if missed).

THE HIGH POWER ANALYSIS

The High Power analysis requires reflected light microscopes with a magnification range between 100x and 500x. The subject are alterations on tool surfaces which develop through use as a result of working activities, hafting procedures and also soil movements. Any material, maybe except meat, is able to cause these alterations, independent of their hardness. These alterations are called micro-polishes. All kinds of micro-polishes have one thing in common: they reflect light more than the unaffected parts of an artefact surface. The best known polish type is "sickle gloss". Sickle gloss is often already visible with the naked eye. It was first examined with the aid of a microscope by F. Spurrell in 1884. It was only followed up in 1964, when the Russian S. Semenov published his exciting microscopic research in English. Semenov showed that there are various forms of microscopic use-traces and surface alterations on artefacts. However, it was Keeley who could classify especially the types of micro-polishes first by carrying out several experiments using repliques of stone artefacts on several working materials; then, he examined and documented the resulting micro-polishes (as well as other use-wear features) and made an attempt to compare them with micro-polishes on palaeolithic artefacts. In their famous "blind test" Keeley and the experienced experimentator Mark Newcomer proved that this method was able to distinguish the various polish types and to recognize the worked materials and the tool motions (Keeley & Newcomer 1977). The design of the blind test was as follows: Newcomer simulated certain activities using self-made stone tools on hard materials like bone, antler and wood, and soft materials like meat, hide, leather and plants. Then he handed over the used tools to Keeley who didn't know anything about the activities Newcomer carried out. With his methods of use-wear analysis, especially the High Power analysis of micro-polishes, Keeley was able to recognize the activities and working materials in ca. 70% of all cases correctly. This stunning result gave the starting shot for the development of microscopic use-wear analysis worldwide.

Classification of micro-polishes

High Power analysis allows a determination of tool use, handling and hafting, working direction and worked material. Very important is the knowledge of the formation process of micro-polish. It is necessary to carry out many experiments simulating prehistoric tasks to get familiar with the development and appearance of all kinds of microwear. Micropolish need a certain duration of labour to develop. Depending on the hardness of a worked material and/or the motion micro-polish passes three steps of development (after Vaughan 1985):

1. Generic weak polish > 2. Smooth pitted polish > 3. Well-developed polish

The initial generic weak polish is mostly indeterminable. The smooth pitted polish is more developed. It shows a certain linkage of smooth polish spots as well as darker depressions and pits between. According to Vaughan's observation this polish was only short lived and resulted soon in the third stage, the well-developed polish. Along the way to the well-developed stage the intensity of reflection spreading over the working part and polish linkage increase. All these parameters can vary, depending on the different worked materials as well as some characteristic polish features. These polish features had been observed and documented at many experimental studies done by a number of use-wear analysts. Some characteristic wear features are:

- Striations
- Surface texture
- Polish bevels
- Pits and micropits

Striations are very important indicators for the direction of tool motion (Plate 3). They are small grooves of different length, depth and width on the polish surface. Striations have never been observed directly on an unpolished tool surface, they appear only on polish surfaces. Striations run parallel to the working direction. Their origin is still questionable. Some analysts believe that smallest particles of the silicate of the tool get between tool and worked material and cause striations. Other analysts make dirt and grit particles responsible. It is remarkable that sometimes polish shows a directed appearance as well. These linear polishes are therefore also called "superficial striations". As with the deep striations their direction also correlates with the working direction. They may appear especially on tools used as weapon insets, sometimes together with impact scars (see above). Striations are almost absent on softer materials. The harder the material is the more common striations are. Highly abrasive materials, especially inorganic materials like softer stones (e.g. limestone, jet or slate) and clay cause heavy and dense striation with a "brush-stroke" appearance.

Surface texture can be either smooth or rough, flat or domed. Smooth surfaces also have a higher reflection. They are typical for harder organic materials, while softer materials, esp. hide/leather show a more greasy and rough texture with poor reflection quality. Also typical for harder organic materials like bone or antler is the development of ***polish bevels***, small polish bands along the very edge of a working part (Plate 4). These bevels often show extreme reflection, smooth and undulate texture and are more common with transverse than with longitudinal motions. Sometimes short striations are visible on such polish bevels.

Another feature indicates the nature of the worked material. Characteristic for the contact with hard organic materials are often ***micropits***, small depressions around 1 µm in diameter which give the impression of needle stitches on the polish surface (Plate 5). They occur in high numbers frequently on bone, antler and intensive wood polish and can also be observed with sickle gloss polish. Especially, intensive contact with opal-phytoliths, ivory or jet show an inverse feature, seemingly elevating "micro-bubbles" on the polish surface. The real nature of these micro-bubbles has not yet been discovered, but they are a clear indicator, commonly for plant polish. Diffuse depressions, so-called "potlids" with bigger size and not clear distinguishable shape and depth occur sometimes on soft material polish types, e.g. from leather working.

Theories of polish formation

Since it was observed that micro-polishes correspond to the nature of the various working materials, it has been of great interest how these polishes build up. Simply, two ways can be responsible for the formation of micro-polishes, abrasion and deposition:

1. *Abrasion model* (Del Bene 1979; Meeks et. al. 1981 and others)

This model states that polish is formed due to the loss of surface material and smoothening of the surface. The mechanical interaction between the worked material and the tool surface cause relatively high forces at minute areas at the higher elevations of the microtopography of the tool. These elevations become more and more truncated during working. The truncated parts reflect more light than the unaffected surface.

2. *Deposition models*

2.1 *Friction-fusion model* (Witthoft 1967)

Silica, when fused, does not normally return to a crystalline state, but hardens as a super-cooled liquid. During working, large frictional heat are evolved within minute zones and are almost immediately dissipated because they are so local. Nevertheless, they can be sufficient enough to cause melting or fusion of the glass surface on a submicroscopic scale. To Witthoft, this is the difference between sickle gloss and other polish types, which are mainly formed by abrasion. The reason for this heat is the contact with opal-phytoliths contained in grass plants.

2.2 *Amorphous silica gel model* (Anderson 1980, 1982)

Somewhat further than Witthoft's hypothesis goes this model. Some factors, especially of chemical nature cause dissolving of silica under lower temperature (just above 25°C), e.g. friction heat, acids, extreme pH-factor and others. This melted silica embeds parts of the worked material when it falls out as amorphous gel. With the aid of scanning electron microscopes and micro analysers like IBA (iron beam analysis) and other element analysis evidence seemed to be found for this model.

However, there was and still is controversial discussions about this model. Some other researchers believe that the particles of the worked material are not really embedded stable but only adhering on the surface. While on experimental pieces the element composition of these particles can be detected, they will be removed by erosion processes on archaeological artefacts. Using similar equipment for their polish analysis Meeks *et. al*. (1982) and Yamada (1993) found no other components than silicate within micro-polish.

EXPERIMENTAL FRAMEWORK

Microwear analysis became only possible by doing extensive experiments. Carrying out experiments is the only way to get information of the nature of use-wear types. Microwear analysis without experimental knowledge is not possible. The necessary experiments should be designed as realistic imitative simulations of prehistoric activities as much as possible. Best is to carry out tasks and to produce products similar to those known from an archaeological context or ethnographic background. For the beginner in microwear analysis experiments are important to get familiar with analyzing techniques and the appearance of different edge damage and polish types. These experiments should include some frequently tested working materials like hide, wood and bone to compare own observations with those published by experienced analysts. Besides that, it is generally necessary for future developing of microwear analysis, that they should consider every possible material used in prehistoric times. Microwear analysis is still far away from being a perfect method of tool use reconstruction. More and comprehensive experimental research work is one of the most important ways to serious microwear analysis.

Recording of experiments

Useful experiments need a detailed documentation of their processes. This includes a description of the used tools, worked materials and the work itself. A possible data recording similar to that used by the author for his own microscopic use-wear analysis is listed here:

1. Description of the tool
- tool number
- raw material
- tool type and form
- activity zone(s)
- drawing/photo of the tool
- handling/hafting

2. Working material
- kind of material
- origin
- state (dry, fresh, soaked, etc.)
- intended product

3. Working parameters

- duration of use (in min.)
- number of strokes
- weight difference after working (if possible)
- kinematic (transverse, longitudinal, rotating motions); after Unrath 1984 (Figure 2)
- working angle
- leading angle
- contact angle
- edge angle
- contact/non-contact surface
- non-use-factors

4. Others
- storage after use
- cleaning procedures
- numbers of photos/video
- comments

POST-DEPOSITIONAL SURFACE MODIFICATION

As well as working materials any other contact may cause edge damage and micro-polishes, which can be resembled with use-traces. During sedimentation a lot of influences can affect a tool's surface.

Patination

Patination is a surface alteration of silex, which result from chemical influence of the sediment. Organic acids can affect the inner structure of silex and may dissolve the grains. Patination changes the color and structure of silex. Some silicate materials like the Middle-European hornstone patinate heavily. The altered surface has a chalk-like surface and the original brown material can become completely white. Under reflected light microscopes this alteration sometimes looks like a milky cover spreading over the entire tool surface. In heavy cases it is impossible to recognize any polish because it is covered by patination as well. High Power analysis will not be possible on such heavily patinated tools.

Sediment polish

Also mechanical forces may appear during sedimentation. Water, temperature and geological factors cause minor movements of the soil and embedded artefacts. The contact between the sediment and the artefact surface is able to produce "polish" which can affect the entire artefact and superpose the original use-polish. Also the texture of sediment polish can show an appearance similar to hide or leather working polish.

Usually sediment polish will affect the entire tool surface in the same manner, while use polish is formed only on the working parts of a tool. This is another reason why the examination of the whole tool surface is necessary.

Bright spots

Bright spots were observed and described in extent by Irene Levi-Sala (1986). She noticed on some artefact surfaces small but extremely high reflecting spots usually with smooth and flat surfaces dispersed irregularly over the surface (Plate 6). In her experimental program concerning post-depositional surface modifications she found out that contact between stone and stone tools can cause this bright spot feature. Bright spots are regarded therefore as a result from the contact between artefacts themselves or between artefacts and other stones after deposition. Also resulting from tool use or tool-making, bright spots may occur on striking platforms, retouched parts as well as on hammerstones or firestriking tools.

RESIDUE ANALYSIS

Residues are organic and inorganic remnants left on tool surfaces after tool use. Organic residues need favourable sedimentation circumstances to survive. In most cases, especially concerning palaeolithic artefacts, organic residues are destroyed by weathering. However in few exceptional cases, like in some Archaic sites in the USA [e.g. Arizona and Texas (Briuer 1976; Shafer and Holloway 1977)] or at a Bronze-age site in Italy (Hurcombe 19186), Holocene artefacts showed residues of plant fibres or epidermis cells. Botanical analysts or archaeologists with a botanical background can determine the nature of the worked plants by examining these residues. Besides plant epidermis, residues of animal hair were found on artefacts, identifying them as butchering tools. More, it was possible to recognize two different types of hair: rodent and lagomorph, i.e. gnawer-like and hare-like.

Also, blood residues have been found on stone tools from the American Archaic (6000-1000 BP) during a routine low power analysis (Loy 1983). After testing them with chemstrips for positive haemoglobin they were examined under a high power microscope. Crystallized haemoglobin could be determined by its morphology and different species recognized. In this way, Loy detected blood residues from caribou, bear, sheep, elk, hare and seal.

With the aid of scanning electron microscopes, P. Anderson (1980) saw evidence that micro-polish is formed by embedded phytolith-crystals of plants in the melted silica-gel (see above) as well as inorganic residues (minerals) from other materials like bone, antler, wood, etc. According to Anderson protein, calcium- and phosphoric-compounds are detectable parts of use-polish. All these crystals show specific forms and can be allocated to their origin. An exact determination of working materials seemed possible, now.

However, other analysts doubted this hypothesis of residue accumulation. In a following experimental work a 90 m 2 corn-field was harvested with replicated sickles (Meeks *et. al.* 1982). The examination of the flint implements with the same method Anderson used, showed many polish features already known from Keeley's work but no embedded phytoliths or other mineral components in the micro-polish. Some silicate plant material adhering on the working edges of the tools, could be removed easily with ordinary cleaning procedures. Opposite to Anderson's studies, Meeks *et. al.* found no evidence of deposition, neither on experimental tools nor on archaeological sickle implements. Even the examination of cross-sections both of experimental and prehistoric tools showed no sign of residue accumulation.

To this controversy, R. Unger-Hamilton (1984) added a cautionary note that freshly knapped silex shows surface features which resemble phytolith-structures. At least, unused samples of the same raw materials should be added to such a residue analysis as reference.

A more certain kind of residue can be hafting material, mainly the mastics or resin used to fix the tool into its haft. These mastics were often made by the distillation of birch bark into a sticky tar (Sandermann 1965, Funke 1969, Rottländer 1994).
Identifying the presence of hafting traces on stone tools is of importance not only for reconstructing the use and handling of stone tools. Hafting and retooling has to be considered as another important activity after the use of tools. This fact might also be important in case of further interpretations of site activities and functions related to microwear analysis. Hafting residues helped to recognize and characterize the normally weak developed hafting polish caused just by minimal movements of a stone implement against its haft (Pawlik 1995). Hafting mastics can be very resistant against sedimentation processes. Especially Meso- and Neolithic artefacts show adhering hafting materials. However, in many cases hafting residues occur as very small spots and are only detectable with high power analysis and scanning electron microscopes (Plate 7).

PROCEDURES OF ANALYSIS

Cleaning

Artefacts have to be cleaned before analysis. Any adhering dirt or grease can interfere with the examination. More than Low Power, the High Power analysis requires proper tool surface and a thorough cleaning. Also, cleaning must be done carefully. A too intensive contact with brushes or other cleaning tools and the use of aggressive detergents and chemicals can produce false use-wear, alter surfaces or remove probable adhering residues.

Well-suited for artefact cleaning is the use of an ultrasonic tank with soapy detergents or weak alkalines like potassium hydroxide (<5% KOH). In almost all cases such a treatment for approximately 10-15 minutes should be sufficient. Only against very resistant adhesives can a maximum 10% solution of formic acid be used after the normal ultrasonic cleaning. The use of stronger acids like hydrochloric acid is not recommended because of observed alteration of micro-polish surfaces (Keeley 1980; Vaughan 1985). After the ultrasonic cleaning and also occasionally during analysis the artefacts should be rinsed in a 50% alcohol solution to remove any grease or adhering fingerprints. To avoid direct contact with the examined artefacts, thin cotton or surgery gloves are helpful.

Recording of use-traces

First of all, it is necessary to get an exact drawing, scan or - even better - photographs of all sides of an artefact at 1:1 scale. Any use-wear observed has to be marked on the drawing/photo as well as the locations of taken microphotographs. It is recommended to photograph every visible characteristic microwear. Black and white film is sufficient, hereby. It is useful to prepare a standardized recording sheet where archaeological information, artefact photos and description of observed use-wear are registered. Some analysts created their personal recording systems, coding and quantifying morphological and use-wear features for further evaluation with the aid of computer programs. Especially, if larger artefact assemblages are analysed, coding and recording of use-wear features within a database can be helpful in regard of a following statistical analysis.

INTERPRETATION LEVELS

Both, High Power and Low Power analysis are methods for functional determination of artefacts. To be successful, they should be carried out together. Microwear analysis may give clues to the purpose of an artefact, then. Experimental work and blind tests have proved, that with a high degree of possibility it can be detected:

- If an artefact was used or not
- The working part(s) of an artefact
- The ways of use, i.e. the motion

More problematic will be the determination of the contact material. Today, most analysts confess that similar materials cause similar use-wear patterns, e.g. bone polish and wood polish. They can hardly be distinguished in experiments and even less on archaeological tools. Multi-analyst blind tests have shown, that the level of interpreting the former contact material is limited and should not go too far (Unrath *et. al.* 1986). It is more secure and serious just to specify the contact material in "material groups". A number of experiments with various working materials have shown that the following material groups can be determined more reliable:

- Hard organic materials (e.g. bone, antler, ivory, wood, etc.)
- Hard inorganic materials (shell, stones)

- Phytolith-plants (=> sickle gloss)
- Soft and tenacious materials

Within the last group, it is sometimes possible to make further distinctions to an organic or inorganic origin. Recognizing hafting and handling traces is of high importance for a functional interpretation. Site-specific functional interpretations which are based on use-wear analysis of artefacts, have to consider this fact. The following questions have to be answered before doing any interpretation concerning behaviour, intra-site activities and site functions:

- Was the artefact found *in situ* or were there possible transportation processes during sedimentation? (refitting analysis will give informations)
- Was the artefact used bare-handed or was it hafted?
- Is the place of artefact deposition really the former working place or could it be just the retooling place?
- Was the artefact used only briefly as an expedient tool or could it have been transported from site to site? (check intensity of wear, "exotic" raw materials)

Only in cases where enough evidence is given to answer these questions, a functional analysis of artefacts can be extended to a functional determination of a site.

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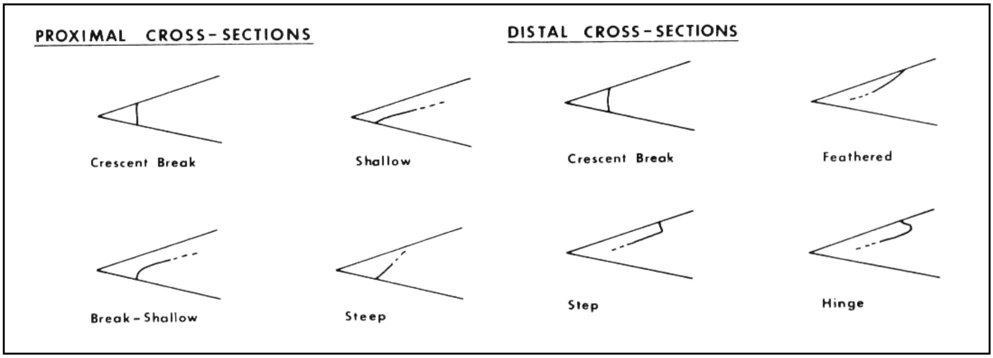

Figure 1 Classification of edge scars, cross-sections (after Vaughan 1985: 21)

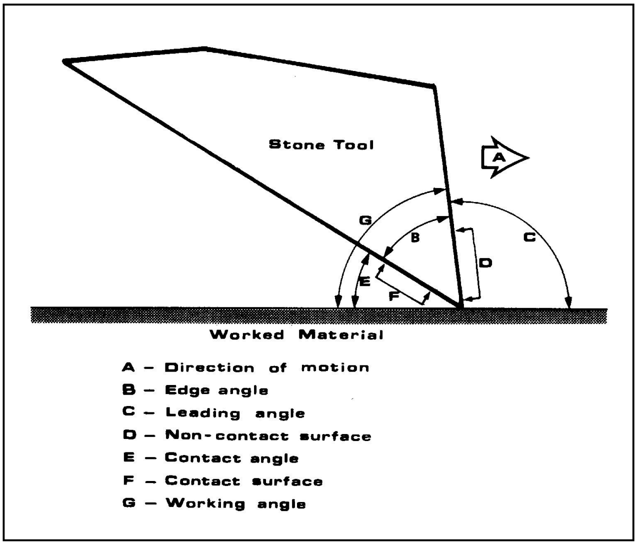

Figure 2 Working kinematics (after Unrath *et al.* 1986: 124)

Plate 1 Step scar under low power stereomicroscope (scale 8:1).

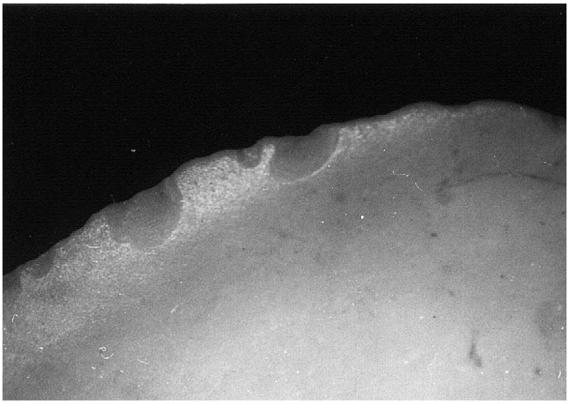

Plate 2 Edge rounding caused by working leather (scale 12.5:1).

Plate 3 Striations (scale 80:1).

Plate 4 Polish bevel on tool edge caused by working on ivory (scale 320:1).

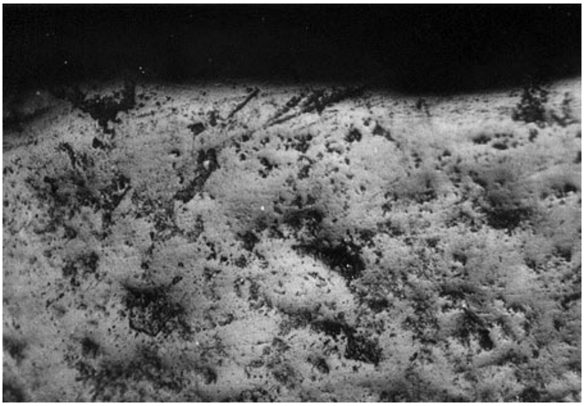

Plate 5 Micropitting on plant polish (scale 150:1).

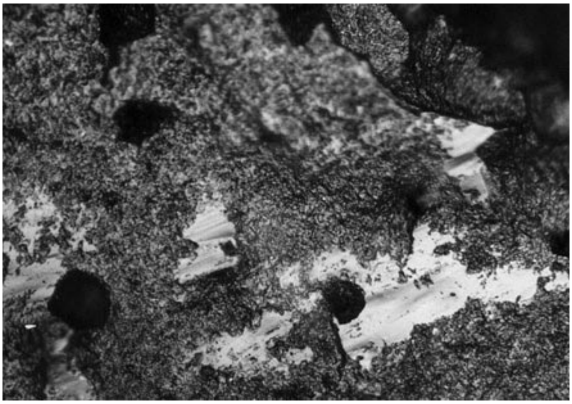

Plate 6 Bright spots (scale 150:1).

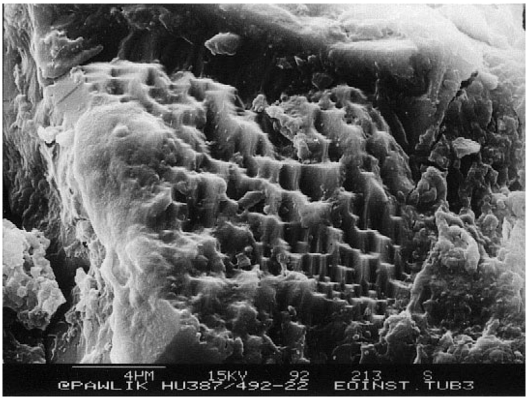

Plate 7 Hafting residues under the SEM: primary cell material within transformed amorphous tar (scale 3000:1).