Section one | Methods

1. Surface changes on stone and bone tools due to natural causes

PATINATION is the most characteristic change which flint and similar stone undergo through natural agencies. Normally black or grey flint turns cream or porcelain colour through patination. Patina can not only cause deterioration in the surface but also deeply penetrate the rock and even quite alter it. Such completely altered flint objects of palaeolithic age weigh less compared to fresh flint and show white in a break.

Patination is produced by an exogenous chemical process from the action of sunlight, weathering and other factors, as a result of which the stone is dehydrated and its colouring matter broken up, forming cachalong, a mineral of the opal family marked by its crystalline softness. It may be noted that shallow patina hardly changes the micro-relief of the surface of the flint and so does not affect traces of use on the tool.

Besides patina palaeolothic flint tools commonly have a shiny surface; the origin of this and its extent is variable. Flint tools of the lower palaeolithic period (Chellean and Acheulian, named after western European sites but also known by material in the Soviet Union) are found in the majority of cases in secondary contexts. Changes in the original surface have been produced by erosion from rain and river water, and, as is well known water erosion is due as much to the movement of the water as to the sand that it carries. The flint's surface is gradually polished under the simultaneous influence of these two factors. The stone's surface can be polished without the action of water if sand-laden wind is the chief agent; we know that flints of quite recent time (neolithic and Bronze Ages) are found with quite a smoothed appearance on sand dunes.

The degree of brightness of a flint's lustre is obviously not dependent on the duration of the erosion alone, so, just as with patination, this is not a reliable criterion of age.

The formation of gloss on a flint is also related to the quality of the stone. Flint of chalk origin polishes the quickest to a smooth glass-like surface. The light dull shade (micro-granularity) which chalk flint shows in a break (fig. 2.3) quickly vanishes, but limestone flint with a hard, rough break-surface, quartzite, and chert polish more slowly. All the same, the appearance of a gloss on a flint surface can in some measure arise without the participation of water, wind or sand. For example, flint objects from undisturbed upper palaeolithic levels in many cases do not preserve their original micro-relief with the characteristic dull break-surface. Observations on material from the Kostenki-Borshevo region, from Gagarino, Timonovka, Eliseevich, Malta and other sites have shown flint objects that were covered by a light gloss almost all over their surface.

The origin of the gloss on flints in undisturbed cultural levels is unexplained, but in all probability it is not connected with patination. Patinated flints from Kostenki I found in the bottom of an earth-house in many cases had just this gloss like all the rest. It may be assumed that the gloss is due to chemical action on the surface from the surrounding materials. If these natural changes on the flint surface have been severe, it not only makes micro-analysis very difficult but renders observation on traces of work quite impossible. Several upper palaeolithic sites (Pushkari I) give just such material. Severe gloss has in this case covered and even quite destroyed traces of use on the tool.

Besides a general weak gloss on some surfaces, different shiny parts can sometimes be observed which attract attention by their brightness. They look like single or groups of scintillations, sharply defined stars or luminous veins. Their origin still remains unexplained.

Sometimes patches that have been polished by sand, water or wind are visible on tools. Commonly in making his tools ancient man used pebbles gathered on river banks or lumps of flint that had lain exposed for a long time. Remains of such pebble surfaces survive on tools with this origin, the shiny unworked parts standing out not only by the sharpness of their edges but also by their colour and relief.

Natural changes in surfaces of tools made of volcanic rocks (granite, diorite, diabase, andesite, sienite and so on) sometimes show themselves in destruction of the rock itself by weathering. In such instances the outer surface breaks up and crumbles first.

During our searches with the binocular microscope for traces of striation on the surface of tools of flint, chalcedony, quartz and obsidian we often noticed, and were delayed by, lines with a stepped or rib-like relief (fig. 2.4 and 5). The dimensions of such rib-like lines were very varied. On some tools they were sufficiently large to be clearly visible to the eye, but quite commonly they could only be detected by magnification. These lines have nothing in common with traces of work, but are a characteristic peculiarity of fracture of certain rocks. With a little practice they are easily distinguished, but they have a nuisance value for the researcher hiding the real traces of work, or impeding observations of the latter when mixed up with them.

In the study of traces of manufacture and use on bones it is essential to distinguish every kind of alteration on the surface of the bone tools and objects caused by the surroundings in which they occur. Let us list here eight types of change which have to be taken into account:

(1) General destruction of the bone and loss of its original form due to physical and chemical processes in the soil (temperature and dampness, action of natural solvents). Such bone even when collected by the analyst himself is quite useless.

(2) Destruction only of the object's surface, its shape being retained. This also has no value for research.

(3) Partial decay of the bone, which we often come across. This has not lost all value for the investigator, if traces of work fully or partially survive. It is very important to note that a working surface rubbed from use is less liable to decay, as the compressed bone texture will resist the destructive action of natural forces for a longer time.

It is not without interest to point out that an analogous fact has been established for this condition in polished metals. On a surface of finely worked metal as a result of adsorption a thin film of physico-chemical character is formed which protects the metal from decay. V. A. Barun said of this fact: 'The less rough the surface, or, in other words the smoother the worked surface, the less influence the surrounding conditions seem to have, and less corrosion takes place.'[1]

(4) Deformation of a generally intact bone, which happens if the bone has been wet and swollen. Later the damp evaporates, but the dried-out bone is not able to return to its original shape.

(5) Traces of plant roots on the bone surface. The organic acids secreted by plant roots eat into the surface of the bone, leaving grooves in the shape of curved, intricately etched lines often reminiscent of worm holes.

(6) Impressions of canine teeth of carnivorous animals and incisors of rodents on the bone surface. These traces are encountered less frequently, and are distinguished readily by the disposition in pairs of the impressions.

(7) Rolled bones. Bones found in a layer moved by water, which have been thoroughly rolled, can be distinguished by the uniform smoothness both of projections and hollows on them. Bone of this type does not require specialist analysis. In examining partially rolled bones (from a washed-out layer) suspicion can arise that traces of use are present, especially if a sharp projection of the bone has been abraded. But a current of water even with sand rarely produces striation traces, as the mechanical pressure of the sand is slight. If such traces are encountered, they are not always on the working part of the tool and do not give a kinematic picture characteristic of human work.

(8) Surface alterations due to atmospheric action prior to its burial in the cultural layer (weathering). In such cases the surface is cracked or even exfoliated, and also has a lighter hue than bone which has not undergone this.

The alterations due to natural agencies enumerated above do not finally exhaust all eventualities which the student may encounter. Several changes still await explanation. Quite commonly undoubted traces of work are found on objects, but as it were partially veiled over; the contours of the object are softened, the corners missing, and there are outlines of inexplicable traces. Whether this is the result of brief weathering or biochemical reactions it is difficult to say.

Still allowing all cases of damage to the surface of bone remains, traces of human work on them are numerous and varied, and of these we can speak with full confidence as a source of archaeological evidence.

[1] V. A. Barun, *The Micro-geometry of a Worked Metal Surface and its Measurement* (Leningrad, 1948), p. 21.

2. Basic traits of manufacture and wear on stone implements

CONTEMPORARY views about the stages of development of material culture in the palaeolithic and neolithic periods are based for the most part on the study of the techniques of manufacture, on the alterations and elaborations of the methods of manufacture of stone tools. Observation shows that the oldest of these tools were made in the simplest way—percussion (*obbivka*), that is by blows with one stone on another. The characteristic trait of such work by strong blows on flint or quartzite nodules are the large scars left on the surface by the detachment of the flakes. If a number of scars should occur in a certain combination on the stone, then this is sufficient for the archaeologist to be able to speak of traces of human activity and not of natural agencies. On flakes the marks of working are the bulb of percussion and retouch, and on upper palaeolithic blades, where the edges give the form of a prism, burin scars and flat, small and steep scars from pressure retouch. On neolithic axes, chisels and knives, besides the traces of manufacture already mentioned, the archaeologist notices a new trait, a ground surface on which even the unaided eye can observe a mass of tiny parallel wear scratches, that is traces of the action of an abrasive agent. Sawing and boring produce so great an alteration of the object worked that not only the method of work is visible but also the nature of the movements, and even the form of the instrument used. The so-called pecking technique on stone, that is striking off tiny chips, can be recognized easily by the rough, bumpy surface of the object.

Together with these visible signs of manufacture there are also microscopic traits on stone tools and objects. These are the tiny holes, 'peepholes' and cracks, which appear on a flinty material from blows and pressure by a hard instrument, that are not visible to the naked eye. Especially important are the scratches and striations that should be seen on the pressure platforms of cores, blades and other parts of stone objects where pressure flaking or retouch has been applied. They not only betray the direction of the instrument's movement but also some of the characteristics of its material. Sparkling, crushing of the edge and projections, starring of the surface, micro-retouch, hardly detectable abrasion and so on: these are all traces of manufacture from which the peculiarities of ancient technology can be identified.

The character of wear on a tool during work depends on various conditions. One of these is the quality of the material of which it is made, its less or greater degree of resistance. The wearability of a tool can depend both on the shape of its working part (angle of sharpness of the blade edge or tip) and on the length of time it is used on the work.

An obsidian knife wears more quickly than a flint one, as on the hardness scale obsidian is more than one point lower than flint. Given a uniform use a flint axe with a working edge of 50° shows a greater degree of wear than another with an edge of 60°, because the blade of the first bites deeper into the wood and so encounters resistance over a larger area of its working part than the second one.

Much depends on the human force applied. There will be quicker wear on an axe relatively if at each blow a force of 15 instead of 10 kilograms is used. Neolithic man took time to work out a rational edge angle of the blade of his adze for the various operations of woodworking: rough dressing of tree-trunks, hollowing out dug-out canoes, fine face-working of objects, or cross-cutting felled timber. Commonly he made a squarish adze with working edge angle of 75°, which required great kinetic effort, so that the tool wore severely and had a poor coefficient of useful work.

Other important factors that influence the degree of wearability of the tool are the speed of work and also the working position of the tool (angle of cutting, angle of striking).

Naturally even sharper differences of wear are due to different properties and characteristics of the material that is itself being worked. More wear on stone and metal tools is produced by working stone, than by working the ground where the wear depends on the nature of the soil. Later on, still within the subject of prehistoric technology, we shall say something on working in bone, wood, skin and meat.

Wear as a physical process is divided into two basic types. The first type is the very rough forms of deformation of a tool during the work. This comprises all kinds of alteration that arise in the course of blows that damage the working part by the dislocation of comparatively large pieces, discoloration, shatter, creation of scars, dents, notches, cracks and so on. The second type comprises the less noticeable manifestations of deformation in the tool which we can call micro-deformation. The latter is observable in those very frequent cases when wear arises from friction between the tool and the object of the work.

Evidence of friction can be very distinct, ranging from the wear of a flint knife in cutting up meat to the friction of a bone or wooden hoe through a sandy soil. The intensity of wear, the degree and character of deformation of the tool are far from uniform. It is well known that even the most yielding material, showing not the slightest resistance to a tool made of the hardest material, with the passage of time will erode the tool's surface and even alter its shape.

In practice we can distinguish three degrees of wear on a tool from friction on another object: (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).

In the process of wear another fact has to be kept in view. In real conditions friction on another object never takes place on ideally clean surfaces. Besides atmospheric conditions with varying degrees of moisture and chemical agents, physical agents constantly intrude themselves between the tool and subject of work; dust, fat and sweat excretions from the hand, quartz grains and other hard particles, which in an unnoticed way act as abrasives. Even in the formation of polished surfaces by friction due to very slight specific pressures (for example, the pressure of a stone knife on the flesh in cutting up an animal, or in the palm or fingers of the hand pressing the tool) these particles constitute supplementary (intermediate) agents of destruction, strengthening the process of dispersion of the particles and alteration of the surface.

Strictly speaking, all aspects of wear on a tool can be reduced to a twofold change: the tool is altered in shape and reduced in volume. These alterations take place predominantly on the working part (butt, tooth, edge, blade, point). The non-working part suffers very slight wear except in those parts which were gripped with the hand or the handle, which caused some friction.

The most widespread mark on stone tools, which is noticeable before all others, is rubbing or, as it is usually called, polishing. On knives a gloss as a rule extends along the blade-edge, reaching from the edge of the blade inwards on to one or both faces depending on the nature of the work. The width of the polished part on the knife blade usually depends on the angle made by the blade to the treated object as well as on its physical properties. Naturally in a soft material the cutting instrument penetrates deeper and traces of work are more widely spread over the working part. With burins, borers and pointed knives gloss caused by use is found on the points, precisely because this part met the greatest resistance from the worked object.

Besides the places mentioned, gloss from use is found on a wide range of angles, points, edges and projections which were used in one or another way in the work.

No less an important mark of work is the shape of the polished area. Generally the lustre caused by use dims and weakens gradually towards its periphery and finally vanishes altogether. This fact is evidence of the direct part played by the live human hand, and shows the vibration of this resilient limb during the course of the work.

In studying gloss due to work it is important to note the nature of the retouch facets on the working part of the tool. The concavity of the facet is usually also polished from close contact with the worked object if this was of plastic texture (meat, skin, soft plant fibres).

However hard the stone, traces of rubbing by the hand were usually left on it, if the tool was used without a handle. Friction of flint against the skin, particularly when dusty and covered with sandy particles, gradually polished the stone surface. The gloss on flint produced in this way is different from other forms of polishing produced by friction with an object in work; its edges lack definition. A medium lustre here becomes weak and vague, which sometimes is reminiscent of gloss from use by a tool on a soft material, for example, in the cutting of meat. The shine extends not only over the projecting points, being quite strong on ridges and angles, but also into cavities, where it weakens.

In the majority of cases this type of rubbing is recognizable by careful analysis. Areas of strong gloss due to this are distributed around the flint, covering several facets which commonly indicate the method of grasping the implement. Moreover, this gloss usually occurs on that half of the implement which could only exceptionally have been the working part of the tool, since the sharp edges have been blunted with steep retouch or removed by a burin blow. The extensiveness of this glossed part confirms that it served as the handle.

Striation traces are rarely found on the handle part of the tool and, an important point, they do not have a definite orientation where they occur.

Traces of use in the form of lustre, or polishing, of different intensity, produced as a result of friction against meat, skin, wood, bone, antler and the hand, are characteristic not only of flint but of tools of other minerals of the quartz group (agate, chalcedony, jasper, hornstone and others).

In some instances when the tool has been used on hard materials the traces of wear have the appearance of dull patches that look ground. On flint saws for sawing stone or hard snail shells, on the working ends of borers for boring in the same material, and on burins for working bone, traces of wear in the form of grinding can often be seen. The appearance of such traces on the end of a burin indicate the great physical force concentrated in a small area of the working part of this tool.

Traces of use in the form of grinding are the most characteristic peculiarity of wear on obsidian tools. A glassy shine is the natural lustre of obsidian, but by friction in the process of work its surface becomes dull and even rough to the touch. This characteristic is due to the exceptional brittleness of the mineral. Under the action of rolling by water and weathering obsidian also loses its natural glassy shine, and forms a dark grey porous crust recalling pumice. The alterations on the surface of obsidian therefore are quite the opposite to what we have seen in tools of flint and kindred rocks.

Obsidian tools, which are softer and have glassy shine on fractured surfaces, retain traces of work carried out for even a short time. So obsidian is in a real sense a rewarding material for micro-analysis, if it occurs in an undisturbed level.

Grinding and polishing are not the only traces of wear on stone tools due to surface attrition, for there are also striations. Use on hard and very unyielding material, for example stone, creates such traces which are usually sharp and can sometimes be detected even with the unaided eye. When the tools have been used on bone, wood and skin the presence of striations in the majority of cases can only be established with the help of magnifying devices.

The formation of striations as scratches, lines, grooves and furrows on tools of such a hard stone as flint, when used on softer materials, takes place because of the accidental introduction into the pores of the worked material and on the tools themselves of small sand grains, the presence of which, particularly in the conditions of primitive techniques of production, can be readily understood.

The clarity and intelligibility of striations depend greatly on the character of the surface of the tool, its material composition and its degree of wearability. The striation lines are best seen and the direction of movement of the tool most clear on smooth level surfaces of chalk flint, even when the use has been of short duration, but hornstone, jasper, agate, chalcedony, quartz and other rocks with a smooth, glassy fracture, also retain striation traces on their surface very well. On a limestone flint with its rough and uneven fracture-surface, granular volcanic rocks, quartzites, sandstones and cherts the striations emerge much less clearly.

On retouched flint tools where the surface is broken by wavy rises striations can scarcely be detected, except for glimpses on small areas that project up between the edges of the retouch scars. Heavily worn blade-edges, blunted and polished to a shine, as, for example, on sickles, often have clear striations even on a retouched edge. In general the amount of wear on the working part of the tool influences the strength with which the striations are manifested. Granular rocks like granite, diabases and diorite become smoothed by prolonged wear, and the smoothed parts show the striations well. As already noted, on an obsidian surface so long as it retains its glassiness the striations show well.

Further use leads by attrition to a mat surface where the striations lose their earlier clear definition.

3. Traces of work on bone tools and artefacts

In the economic activity of man in pre-metal times, together with stone, a remarkably important part was played by bone as a material for tools, weapons, ornaments and in the manufacture of objects of representational art. As opposed to stone the amount of study on bone has been very much less, and in particular in the palaeolithic field has been altogether weaker. The explanation of this is to be sought in the special character of bone. The methods of manufacture of stone tools—percussion, flaking, retouch and later grinding—required profound alterations of the natural form of material between obtaining the raw material and completing the work. Stone in an unworked or slightly worked form played a very minor part in the economy and was altogether a subsidiary matter.

Bone as a special material created by natural life and easily used by man for technical and domestic purposes required no elaborate treatment and was employed after partial dressing, or only slight alteration, or without any treatment at all. Pointed parts of antler, mammoth tusk or canine teeth are the natural tools of animals; the rod-like structure of ribs and long bones with their natural handles (the epiphyses in the latter case); the narrow section and strength of bones of small animals and birds; the cup-shape of skulls and pelvic bones of large mammals—all these considerably reduced human labour in shaping tools and objects for everyday use. So man was confronted with a wide choice of ready-made shapes from all the wide anatomical range of skeletal material from different species and individuals of different ages in the animal kingdom that surrounded him.

There are now grounds for believing that bone had a more varied application in manufacturing by ancient man than was formerly thought, not only throughout the Stone Age, but later, before the predominance of metal had been achieved.

The Stone Age might perhaps be called the Stone-Bone Age, for during this large period of time stone and bone were complementary to one another. Stone possessed hardness, bone plasticity but also firmness. These two separate essential qualities, hardness and plasticity, were brought together only in metals.

Bone tools in the mass do not lend themselves easily to differentiation and classification, and, often unrecognized, pass outside the researcher's field of vision or are put into the category of faunal remains.

Observation on traces of use reveals that Stone Age man employed all the bones of the skeleton of large animals and a good many from small ones. The bones can be divided into the following groups: (1) antler, ivory, tusk or canine teeth, teeth, and mandibles of carnivores with their canines; (2) long bones; (3) ribs; (4) wide flat bones (pelvis, shoulder, skull); (5) short bones (falanges and other bones of the paws and feet of large mammals).

Traces on bones and bone tools or objects revealing use by man can be subdivided into five basic categories, as follows:

(1) Traces of use on unworked or roughly shaped bones which yield evidence about the purpose of these bones in daily life.
(2) Traces of wear on worked bone tools showing the function of the latter.
(3) Traces on bones and bone objects revealing methods and devices of manufacture with stone tools, and also the level of technology in this.
(4) Cuts on bones made in cutting up the carcasses of animals and separating the sinews, traces of blows given in splitting bones to get the marrow, and so on.
(5) Traces of use of metal tools.

It should be remembered that if the traces are sufficiently well studied and deciphered they allow us not only to identify a tool's function, but also throw fresh light on an aspect of the life of the people who used it. So in the light of precisely defined function we can very often see the part played in the tool's manufacture by objects associated with it.

In the study of traces on bone tools we must bear in mind the qualities and properties of bone structure. The smooth surface of the external compact layer of bone has its own special micro-relief or micro-structure. Fairly light scratches should stand out sharply against the background of this relief under a magnifying glass. On antlers of animals like deer and elk we have to deal with a much more rugged surface.

The external compact layer of bone possesses a laminated structure and is composed of very fine lamellae, which are seen best in old dried-out bone. This second very important structural characteristic of bone allows us to identify wear from the kind of attrition that took place. The inner spongy matter showing through the compact layer is also an obvious mark of wear, provided all possible interference from natural causes have been taken into account.

Besides this we have at our disposal one proof of wear by attrition in the course of work. This is the alteration of the anatomical form of a bone, for each specie of animal has its own definite bone shapes.

Finally, striation traces showing direction of movements constitute by far the most important marks. Only in rare cases when the surface is damaged or obliterated during the work are there no striations. On bone the friction of even such a material as skin usually produces striations in the shape of slight scratches or even clearly visible channels that indicate the direction of movement.

On bone tools made by flaking or whittling traces of wear can be detected, firstly by marks of alterations on the worked surface, which has its own features and relief, and, secondly, by the degree of deformation of the artificially produced form, and thirdly by striation traces.

On traces of wear from friction we need not linger, because this is the most widespread type and shows an endless gradation in degrees of use on tools. These traces are the principal means of identifying different striking tools, such as bone mattocks, picks and wedges.

4. Kinematics of working with the hand and the formation of striations on tools

In the process of work man influences external nature not directly with his own limbs but through the intermediary of tools. Tools differ radically from human limbs. In a technical sense the more an advance the more really different are the physical properties of the material from which they are made from the organic material of living matter. Thus not wood and bone, products of organic origin, but stone and metal seem to be the most important materials for the manufacture of the leading and basic tools of work. With tools of these materials man could not only more successfully influence external nature, but also make other tools. With wooden tools it would have been impossible to work not only metal, stone and bone but even wood itself. As regards stone tools, with their help wood, bone and stone could be worked and even a start made with hammering metals; use of abrasion (grinding, sharpening) was already known. By the use of metals the working of all materials found in nature was put within reach.

Working tools are distinguished from human limbs not only by material but also by their purpose. Human hands are universally the same and their evolutionary origin is multi-functional. Tools were relatively all-purpose only in the early stages, for the origin of their development is specialization and the tendency towards a single function. This specialization achieved greater variety with each period of the history of manufacture. In this connexion there is yet one more very important qualitative difference between working tools and human limbs. The latter differ from tools by their structure; in them only to a very small degree are there the inherent signs characteristic of regular geometrical shapes and bodies. Tools by the nature of their work penetrate into other bodies, the objects of the work, and sever them, change their original shapes, and have a definite tendency to adopt all the more regular geometric shapes, especially in their working part.

All action of a tool on an object has as its purpose the alteration, the transformation of the latter into a form desired by man. Mechanical action, which is our main concern, leads to a transformation of the natural form of the object, to an alteration of its external aspect; the division of the whole object into equal or unequal parts, the separation of one or many small parts from the whole, that is fragmentation.

Through the action of the tool on the object of work one kind or another of friction is created. By friction due to the slipping or displacement of the working part of the tool against the object of work striation traces are formed on the tool. These are traces of the first order. They arise in the process of cutting, whittling, sawing, chopping, boring, drilling, piercing, grooving, grinding. Only a few kinds of action, such as blows or pressure, when the tool does not penetrate into the thickness of the object (shattering and flaking of stone, hammering of metal objects, stamping), which do not have the character of dragging or sliding, give traces of the second order (chip-marks, holes, roughening, dents).

The disposition of traces of the first order, to which as the most important marks we give our main attention, is a regular one. It is true that the human hand cannot in general be compared to the arm of contemporary metal-cutting machine-tools with their rigid grip. The hand produces several weak movements relative to the working position of the tool and shows to some extent a flexible grip even when a hafted tool with its greater reliability is used. Movements of the tool in the hand are due not only to the weak grip but also to certain tactile sensations which affect our working limbs and which give them such delicate movements. All the same, traces of work as a whole regularly reflect the kinematic action of the hand, and striations represent parts of the path of the tool in its movement.

Observation shows that the basic working processes carried out by man have their own kinematic character. For example, in order to make a hole four different methods are possible: punching, gouging, piercing, or boring. The choice of one of these to make the hole depends on a series of circumstances, but first of all on the material to be perforated on the one hand and the material of the tool on the other. Each method of work has its own kinematic peculiarities reflected in the length of the line of movement and its shape (straight or curved). Essential kinematic differences come into the work of a knife in whittling wood, or skinning an animal, or cutting up meat, or gutting fish and its cleaning and filleting; different pictures of the hand-movements, positions of point or blade on the worked object, arise in each case.

The position of the tool in relation to the object of work, the angle of inclination of its working part, is very important in the formation of traces. It is essential to be able to distinguish such matters when the kinematic differences between the methods of work are slight. Into this category of movement falls work with the axe, adze and hoe. Thanks to some individuality of position in the working part of the tool relative to the subject of work striation traces from wear in the different processes do emerge with distinct differences. The differences consist above all in the special position of the lines of striation on the working surface of the tool. Each tool has its own disposition of striation lines on its working part. The lines may run parallel or at right-angles to the axis of the instrument, or to its blade, or diagonally to either axis or blade. They can go in one or several directions; that is they can run parallel or intersect, be straight or curved, continuous or interrupted. Moreover they have varied frequencies and length, as well as other characteristics.

Traces of work on contemporary metal tools (knives, axes, chisels, wedges, saws, needles, awls, razors, cutters, scissors and so on) give a clearer kinematic picture thanks to the plasticity, density and opaqueness of metal, and also to the geometrically regular form and smoothness of the working surface.

On ancient stone and bone tools in which shapes are less definite, hardness variable and surfaces rough, striation traces may be feebly retained and destroyed by the work. This is especially so with retouched surfaces of flint tools. In a number of cases the kinematic picture always remains vague because the lines are weakly retained and those visible give only the shape of the trajectory (part of the tool's movement) without information about the direction of the working movement. For example, striation traces of sawing may not show whether this was done in both directions. In such cases the character of the wear on the surface is a supplementary indication. The surface of a stone tool usually bears hollows (flake facets and holes) and projections (retouch arrises, various impurities and crystal grains) visible under a magnifying glass.

The tool's surface wear is indicated by micro-plastic changes on the edges of the hollows and sides of the projections from which we may assess the direction of movement, for it is precisely the projecting parts which are the points on the surface that suffer wear primarily due to friction on the worked material.

THE POINT OR AWL. Let us turn to the simplest kind of work, piercing with a pointed tool. Independent of the type of material worked on and the sharpness of the tool, its working part is worn by friction against the material into which it is thrust. *If the piercing is done by straight pressure of the tool (axial approach) the traces of wear arising from the movement will be straight lines parallel to the axis of the tool.* Deviations from this direction will show themselves in the disposition of lines on the point.

In practice piercing is not done by straight pressure but is accompanied by turns of the hand to right and left in a quarter or half circle. In this case the point's wear is influenced by two movements, a straight and a rotary one; traces on the point will reflect these two forms of movement. Lines parallel to the axis of the tool will be cut by lines going around it; that is at right-angles to its axis, if we think of it in section.

Experiments in piercing have shown a far from uniform clarity of striation traces on metal, bone and flint awls. While the point of the metal displayed all the peculiarities of the movement, on bone they were much less distinct and on flint scarcely or entirely imperceptible. When the kinematic picture is not clear, as on flint awls, it is possible to study the traces by changes in the irregularities of the micro-relief. The projections show polishing on the side of the point, the edge of the depressions on the side of the butt end.

THE DRILL. Piercing with a quarter or semi-circular rotation is the beginning of drilling. Hence it is natural to conclude *that drilling must leave on the working part of the drill only one form of traces—circular lines at right-angles to its axis as a result of the use of one movement only, rotation.* 'Rotary movement' may be regarded as a general kinematic definition of drilling.

Drilling can be done by hand or with a machine and includes interrupted rotation in one direction (one-handed drilling removing the hand each time), continuous drilling with alternating direction (one handed without removing the hand, two-handed rotation of the drill between the palms, drilling with bow and disk drill), continuous drilling in one direction (brace and bit, drill with toothed gear-wheels, mechanical drill). Each of these has its peculiarities that are reflected in the traces of wear. Hand drilling is usually done with a conical stone drill, machine drilling with a cylindrical one. In single-handed drilling a strong centralized force cannot be achieved, because the human hand is only capable of a semi-circular or at most three-quarter circular movement in a rotational direction. In order to make a full turn the hand has to be taken off the drill, change its position and make another half or three-quarter turn (interrupted rotation). This explains why one-handed drilling is nearly always done by alternating the direction of rotation (left to right and back again), as this is the only way of increasing the speed of movement. But in neither method, alternating or continuous, can one-handed drilling maintain a strong centralized rotation. The axis of the tool leans one way or another from the jerks of the hand. This is particularly evident with the alternating method. As a result a hole produced in this way is irregular in outline and has a greater diameter than the width of the drill. The wear striations do not lie parallel to one another, neither on the drill, nor on the sides of the drilled hole.

Two-handed drilling, done with continuous alternating rotation between the palms, gives greater speed to the movement. The hole produced by this has much more regular outlines. However, the axis of the drill with its long pivot also leans to one side during rotation. So the striation marks are not parallel on either the drill or the sides of the hole.

Traces of drilling with bow drill reveal a better standard of work; a hole produced in this way is regularly circular. Traces of drilling appear on the side of the hole as almost parallel circles corresponding to the traces of wear on the drill.

The regularity of formation of traces that has been mentioned is dependent not only on the means of drilling but also on the properties of the worked material. The softer the material the greater deviation in the shape of the hole and the less parallel the striations lie, and conversely the harder the material the less the deviation.

Flint drills, however hard, are brittle tools, and easily break from sharp turns and by leaning from the axis of rotation. So the slant that arises in hand drilling is only possible in the first phases of drilling, before the instrument deeply penetrates the material. Once it has penetrated, sharp turns on a leaning drill will easily break it. In a soft, yielding material like wood some variation in level rotation is quite possible, but in a harder material like bone deviation is more limited. With stone it is almost excluded or only slightly possible, so striation traces on stone drills, used for working on stone, have more regular geometric outlines. The rule just described tells us why bone and stone objects were drilled from both sides.

Striation traces from wear emerge fairly clearly on stone drills used for drilling stone, but with snail shells and bone the picture is less clear, and with wood they can only be detected with great difficulty. On the drill's working end only a vague gloss can be seen, study of which can reveal the direction of movement. If the drill was rotated from left to right, then projections will be more intensively worn (polished) on the right side, and the edge of the depressions on the left. If it was alternating rotation, then the sides of the projections and edges of the depressions will be worn uniformly left and right.

THE SAW. Dividing a whole object into parts along a straight line by alternate two-way movement (backwards and forwards) is commonly called sawing. The working part of the tool used for such work, the saw, is a flat blade. In the Stone Age from the palaeolithic period onwards flakes of flint, chalcedony, quartzite or obsidian with a toothed (retouched) edge served this purpose, and generally were used for severing bones into pieces by transverse cutting. In neolithic times they began to use laminated slate or sandstone saws for dividing stone.

Striation traces of sawing on sawing tools fully reflect the hand movements. *Traces of sawing in the form of straight scratches are always disposed on the side surfaces of the tool parallel to its working edge*. On the toothed part of the blade they are interrupted, but higher up more or less continuous, depending on the straightness of the saw and on the properties of the materials of which it is made. So long as the saw is at right-angles to the surface being worked *the striations from wear will be left uniformly on both its faces*.

Traces of wear on the toothed edge due to a two-way alternating movement, provided there is uniform pressure both backward and forward, differ essentially from traces produced by one-way sawing. In the former the teeth or projecting edges of the facets, if the blade is only retouched, will suffer attrition from both sides, in the latter from one side only. This difference will show itself in the micro-topography of the side surfaces within the toothed area. It shows itself in a different way by the slight wear of the holes (hollows) and attrition of protuberances on the side surfaces in a stone saw. *In two-way sawing the edges of the hollows are slightly worn and the projections worn down from both sides, in one-way sawing from one side (for example, the front side of the projection and the back edge of the hollow if the one-way sawing is done in a forward direction).*

Traces of work on both faces of a saw show up as a more or less even band running along the whole length or the best part of it. On a flint saw used on bone this band has a polished or vaguely dull surface, on obsidian also dull, in flint saws for cutting stone also a dull shade. The peculiarities of traces on a saw face are dependent on form and material both of the saw and the sawn material.

THE REAPING KNIFE (sickle). Amongst the tools on which traces of use also occur as striations parallel to the blade-edge and on both faces we may place the earliest sickles, surviving in the form of flint reaping knives, which occur as slightly trimmed prismatic bladelets. They may be distinguished from saws by the fact that the worn part often has a different shape. The wear traces do not form an even pattern on the side, but instead are shaped like a triangle, one side of which is made by the cutting edge, while the hafted end, being embedded in the handle, remained unaffected.

The wear pattern on the surface of a reaping knife depends on its position in the handle. If the knife was set in a slantwise slot its end would suffer more intensive wear, as in this case the position of the knife is analogous to that of a tooth in the saw as it cuts deeply into the bundle of stalks pressed against it by the left hand. On the other hand, if the knife lies parallel to the handle set in a longitudinal groove, then the wear is distributed rather more evenly along the whole length of its blade. Just the same happens with composite sickles made up of a series of inserted flints. The micro-plastic features of the traces of work on a flint reaping knife or inserted flint of a sickle are of just that general disposition which so clearly illustrates the hand movement, one-way return movement ('towards himself'), as opposed to the sawing movements which are two-way alternating, or repeated forward movement ('from himself'). *On the blade of a reaping knife and sickle all the projecting points are worn on one side, that facing the operator. The wear at the edges of the hollows of these tools is also sharper on one side, not that facing the operator but on the contrary that away from him.*

THE BURIN. Incising comprises a very wide range of operations, but here the word burin is understood in the narrow sense applied to a tool whose incising part (edge or angle) has a very small area and whose axis is vertical or almost vertical to surface being incised. The angle of the axis varies between 80° and 90°. The working part of a burin consists of a single saw tooth, the cutting edge of which cuts a groove in the material by repeated one-way ('on himself') movements gradually deepening the groove. It is the cutting edge of the tool which mainly suffers wear, but due to its small area and the brittleness of the stone striation traces can hardly be detected there. *So the evidence of the line of movement of a burin is not striations on the cutting point but on the side edges. They* *are visible as lines parallel to the cutting plane, but at right-angles to the burin's axis.*

THE SKIN-DRESSING KNIFE. The cutting-up of skin in the palaeolithic period was in all probability done with a flint knife whose working part was similar to that of the knife found fixed in a handle at Malta (Siberia). From the hafting of the blade we can judge the angle of inclination to the working surface at which it was held. Originally a returning movement ('on himself') was evidently normal with the palaeolithic dressing knife, but with the creation of a handle and the application of greater force the movement altered into a forward one ('from himself'). In this way (forward movement) the work was done with the neolithic elbow-shaped knife, known to us from northern sites, and so also in the contemporary use of the cobbler's knife. The expediency of this method can be explained, not only by the possibility of applying great force, but also by the circumstance that in the forward movement one can see the proposed line of cut and more closely guide the blade of the knife along it. Thus the movement in skin-cutting is still a movement in one direction.

Traces of wear on the working part of a skin-dressing knife, as with a burin, are found on both side surfaces, not at an angle of 80°–90° but of 45°–90°, for the angle of inclination of the axis of the knife to the cutting surface depends on the shape of the cutting part.[1]

THE WHITTLING KNIFE. Work with this knife gives rise to wear on one side of the blade only. This is produced at a working angle of 25°–35° to the worked face, and as a result the side of the knife facing the object suffers attrition, but the opposite face only suffers wear from parings. The greater the angle of the cutting edge the smaller the paring is, and conversely a reduction of this angle gives a larger paring. In stone whittling knives the blade-edge angle averages 35°–40°, but in metal ones 12°–13°. From this it follows that the back face of a metal knife suffers more intensive wear than the back face of a stone whittling knife, because the thicker paring in the former case causes more wear on its back face. A thin paring curls up into a circle or spiral hardly touching the knife's back face.

Whittling of wood or bone with a knife can be done in two ways. In the first the working movement is backwards ('towards himself') and in the second forwards ('away from himself'). One can whittle with both methods with a metal single-bladed knife with low edge angle and without edge facets, that is both 'towards himself' and 'away from himself'. With a neolithic one-sided whittling knife which always has a facet on one edge one can only whittle in one kind of way, arising from the fact that the edge with facet cannot as a rule be placed downwards on the material, but has to lie face upward. So for whittling in both ways the neolithic craftsman had to have two single-edged knives with blades on opposite sides; looking from the butt end the facet edge was on the right on one, on the left on the other.

In palaeolithic two-edged knives, made on quadrangular prismatic blades, it would have been possible to use each of the edges for whittling by both means. Yet palaeolithic man rarely used both edges for whittling; most commonly he blunted the second edge with retouch or took it off with a burin blow, for resting his finger on, and worked with one edge.

Traces of wear on whittling knives, as already explained, occur on one side of the blade. The striations (very fine scratches and lines) are sometimes at right-angles to the working edge, but more usually somewhat inclined towards the working end of the knife, caused by the pressure of the human hand, which pushes the blade in a parallel direction to the whittling surface. In a number of cases there are even distinct lines parallel to the blade-edge, due to the fact that a whittling knife with a blunt edge is used in a saw-like movement on wood or bone in order to make it easier to penetrate the material. The flat unfaceted side was used for whittling with a neolithic knife, but with a palaeolithic knife the ventral side of the blade was normally the working side, as the facet closely limited the working edge on top. If the working edge of a whittling knife has undergone slight retouch, the latter is on the dorsal side and not on the under side, as retouch makes the working edge too rough, increasing its resistance to the material worked. During use the blade of the whittling knife may be chipped, shown by tiny scars on the under face, but these are unevenly distributed and so cannot be regarded as intentional retouch.

A MEAT KNIFE is distinguished by more complicated kinematic characteristics. It was used by the hunter for cutting up the carcasses of game, cutting the skin free, and cutting meat while eating. The movement of this knife and functions are much more varied than with other knives. The resistant materials of the animal's body, consisting of elastic fibres of skin, muscles, ligaments and cartilage, which bend and stretch under the pressure of the knife, naturally could not be severed at one particular angle, so there was not one but several cutting planes. At the moment of cutting open the animal's belly the knife movement could have been down and forward (ripping), when the axis of the tool would be inclined, or instead pressing upwards with a saw motion, just as a modern kitchen knife is used on meat. In cutting free and removing skin from the carcass and in dismemberment and removal of the intestines the knife was

[1] The palaeolithic knife from Malta has its blade inclined at 45° to 60°, while neolithic elbow-shaped knives have the blade inclined to the axis at an angle which varies from 45° to 90°.

almost completely buried in the body of the animal and in contact with tissue at all points on its surface. Consequently the working end of the hunter's knife is burnished and polished on all sides, the more so if it is pointed at the end (a point).

Research has revealed that in cutting meat palaeolithic man did not use just the knives, which we can call 'hunting' knives, that is blunt-ended or pointed knives, made from fairly long prismatic blades. In everyday practice he very often also used knives made of short blades, or even flakes, held between the thumb and first two fingers. The index finger pressed from above on the back, which was worked by retouch or a burin blow.

Traces of wear on meat knives present themselves as polishing on both faces, but also within the flake scars and hollows. Striations from wear on a meat knife only arose if some extraneous abrasive particles fell on the meat (quartz, felspar, lime, etc.). *On knives that had long use as meat knives striations have covered the polished areas and very often run almost parallel to the blade-edge on both sides, or commonly they intersect, especially noticeable on the ends of long hunting knives.*

THE AXE in use has a very marked linear form of movement which is therefore very well defined by striations. Seen sideways the axe's trajectory is curved, but from the front it is straight. At the moment of striking an object its axis is not vertical but inclined to 50°–60°. Consequently its blade (parallel to the handle in an axe) is inclined at a similar angle to the striking surface. *Striation traces on an axe therefore run diagonally and occur uniformly on both faces.*

THE ADZE is a cutting tool very similar to the axe in kinematic characteristics. Seen sideways the trajectory of an adze hardly differs from that of an axe, and in front view it is also straight. Even in its shape the neolithic adze strongly recalls an axe, differing only in its profile, where the working edge is asymmetrical, although this is not an absolute rule, for adzes with symmetrical profiles are also encountered. However, in its method of seating in the handle the adze is sharply distinguished from the axe, for the blade is at right-angles to the handle, which causes a different geometry of traces on the blade. *While on an axe the striations lie diagonally, that is at an angle to its axis, on an adze they lie vertically, that is parallel to the tool's axis. In addition, while on an axe traces of wear are disposed uniformly on both faces (cheeks) of the working part, on an adze they belong fundamentally to the forward face, although appreciably shorter striations and feebler wear occur on its back face.*

THE HOE has constructional and kinematic traits that are broadly similar to those of an axe and adze. Structurally the hoe is more analogous to the adze, also hafted with the blade at right-angles to the axis of the handle. The axis of a hoe or its digging-blade lies at 70° to 75° to the axis of the handle, but kinematically a hoe is closer to an axe. The line of movement of a hoe is curved, seen sideways, but from the front indistinguishable from that of an axe or adze. A hoe like an axe can fall vertically or inclined at a fair angle, when it is necessary to dig ground by side-blows with the hoe's axis inclined first left and then right. *Consequently on the digging blade of the hoe its front face, which encounters the main resistance from the dug ground, bears striations that lie at an angle and not parallel to its axis and that intersect with each other. If the front face of the hoe is convex, then the striations form a fan shape, and the intersecting lines are weaker. On the back surface of a hoe traces of wear are feebler, as the resistance of the ground is less.*

The peculiarities of the disposition of the traces of wear on hoes have a range of variations depending on the shape of the digging blade, force of the blow and consistency of the ground. Yet in spite of the discrepancies in the characteristic traces the most permanent and important functional criteria for a hoe are wear on both faces and intersection of the lines on both front and rear faces of the digging blade.

A SHOVEL differs radically from a hoe both structurally and kinematically. Shovelling earth does not require a blow and presupposes work on soft or loose soil by means of pushing or pressing. The working (cutting) part of the shovel consists of a blade, whose sharpness depends on the material of which it is made.

Metal shovels, of course, have a thinner edge than wooden or ancient antler shovels, like those from the Gorbunovo peat bog. Ancient wooden and antler shovels obviously were intended for use on very soft and loose soil or snow. In working any kind of hard or heavy soil this was first broken up with picks, hoes or pointed sticks, and shovels were only used to throw it up.

Although shovel blades suffered wear on front and back it was the back part that encountered the stronger resistance. Striations occur parallel to the axis of blade and handle, as the line of movement of a shovel at the moment it sank into the soil remained straight.

We have lain before the reader some basic and very elementary examples of the dependence of striation patterns of wear on the kinematics of working with the hand. This dependence holds good for tools of stone, bone, wood and metal of all periods, which bears witness to the fact that, while basic hand tools and their methods of use change with changing quality, strength and methods of manufacture, they alter in response to definable laws of movement.

5. Optical devices and sources of light for studying the surface of archaeological materials

RESEARCH on the surface of objects for traces of one or another human activity constitutes a special aspect of the micro-analysis employed in the study of functions of ancient tools and artefacts.

Initially this came down to the choice of optical instruments. Binocular optics with three-dimensional, stereographic vision seemed most suitable for this purpose. Without doubt binocular lenses reduce the possibilities of micro-analysis, for the powers of these instruments are limited; for example, a binocular magnifying glass gives a magnification of 38×, binocular microscope 180×. However, although the magnification of binocular lenses is not great, the limits seemed sufficient in the early stages and micro-analysis with them gave positive results.

With regard to simple magnifiers of one or several lenses enlarging from 2× to 20× in laboratory conditions only a glass with magnification of 6–10× proved useful. More powerful (short-focus) lenses produce discomfort in the work, as they reduce the field of vision and give rise to eye-strain. Experience in research convinces one that the normal pocket lens is mainly useful for looking over and selecting material in the museum case, where it would be impracticable to take mechanical optical devices, or for the archaeologist under field conditions.

In a workroom for studying the tools in hand binocular lenses are essential, as well as a binocular microscope, specially set up to study surfaces in reflected light. As they give stereoscopic vision, they allow at comparatively small magnifications examination of objects both in the flat and in depth, a clear view of surface changes, detection of chip-marks, lines, scars and cracks, and comparison of worn and unworn parts of the surface. Moreover, through binocular lenses the object is not seen reversed as in the normal monocular microscope. Work with binocular lenses does not tire the vision, as the strain is shared by both eyes.

The construction of clamp-stands is very important in the use of binoculars in the laboratory when archaeological material is studied. When using either a lens or a microscope a clamp-stand with straight vertical column and heavy base is necessary, its horizontal bar movable up or down, backward and forward, and also around the column in a circle or transversely.

The fixing of optical instruments in the necessary position is done by means of screw-clamps on the sleeves with which the column and arm of the clamp-stand are firmly held. A stand of such construction allows observation of the surface of large objects with the use of a small movable rest for the object, or with this held in the hands, as it is commonly necessary to do.

The binocular magnifier, owing to its large field of vision and good lighting, plays an important part in the preparatory study of the whole surface of the tool in the search for traces of use. In using binocular lenses, particularly those of small magnification, the object under examination can be held in the hand gradually moving and turning it about under the lens and a directed ray of light. This saves a lot of time that would be lost in setting up a circular rest and fixing the object to it. One should resort to the binocular microscope only when the tool's surface has been carefully studied with the magnifying glass and detailed analysis is necessary of the traces of work that have been detected, their configuration and direction.*

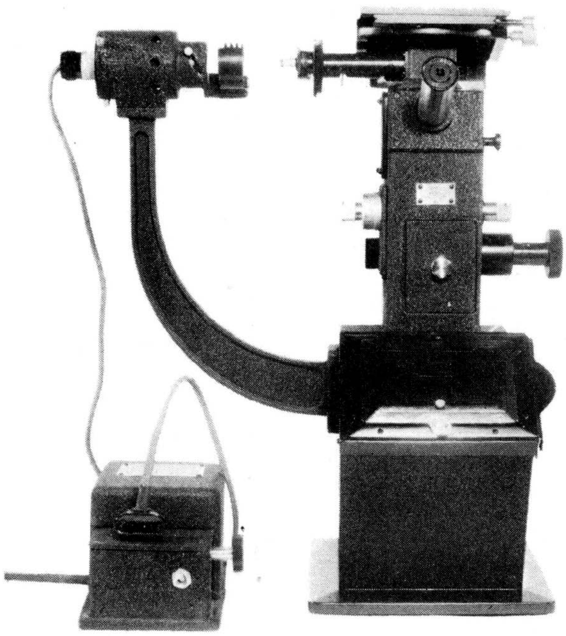
A rest with ball-joint is a crucial piece of equipment in microscopic research; without it the use of the microscope is impossible. At high magnifications even a slight jerk of the hands produces a sharp vibration of the image. A hinged stand can be made by the investigator himself by using the ball-head of a camera tripod. A ball-joint allows the object to be inclined in all directions up to an angle of 90° and also turned through a vertical axis. The main drawback with the ball-joint top of a camera tripod is the rough construction of its screw clamp, which produces sharp jerks during regulation and does not respond to the delicate adjustment that microscopic precision requires.*

In certain cases the observations require the use of a monocular microscope, the majority of which are mounted on stands designed for examining slides in a direct light. . . .* With the monocular microscope the investigator is interested above all in exploiting the possibilities which detailed examination offers of very small areas at magnifications of 300× to 500× or more. For this purpose the best instrument is a monocular microscope which has had binocular eyepieces fitted. In such a microscope observation is made through one set of lenses, but both eyes look into a dual eyepiece. . . .*

In practice the most important part of micro-analysis is lighting. Modern microscopy has a variety of illuminators or lamps for examining opaque objects through monocular microscopes at high magnifications. . . .* When the delicate structure of the micro-relief of a surface has to be studied a one-way illuminator is indispensable.

In studying the surface of a stone tool with binoculars

1 Above. *Binocular microscope MBS-1 attached to clamp-stand and lamp, with transformer and object on ball-jointed rest.* **Below.** *Metallographic microscope MIM-6 with camera, lamp and transformer.*



at relatively low magnifications one can in many cases do without special lighting. A medical lamp with metal hood and flexible spiral joint allows the lamp to be adjusted to any position and regulation of the amount of side-light to meet requirements.

Special illuminators are required for tools with weak traces of use when using the binocular microscope. It is necessary to resort to the latter very often, as traces of work on palaeolithic tools are in general elusive and difficult to recognize.*

Independent of the source of light, that is of kinds of illuminators and lamps used, the special devices for directing light are of great importance in studying microscopic objects as well as in micro-photography. As explained above, in practice only diagonally reflected light can be used in studying tools and other archaeological material. . . .*

6. Preparation of the surface of objects under examination

An ancient artefact even after being cleaned, washed, labelled and placed in store still retains on its surface particles from the surroundings in which it lay for thousands of years. Examined under binoculars, one can always find loess, clay, black soil, charcoal, ochre and much else from the cultural layer.

In a good many cases these particles are of great significance in identifying the purpose of the tool. Perhaps therefore it would be advisable in general not to wash and clean finds on the excavation site, but to do this in the laboratory after their preliminary examination. However, in studying traces of work the tool must be free from extraneous matter, including lime concretion. The latter very often covers parts of tools and objects of stone and bone with a hard crust.

A hindrance to micro-analysis is the later handling of tools by the archaeologist which commonly gives them a deceptive sheen resembling traces of use. Sweat and fatty excretions of the hand mixed with dust leave a thin shiny film on the surface which covers parts of the tool important for research. So the surface must be cleaned with spirit or benzine and washed in hot water with a light application of soap. Only then can optical observations be carried out. If the traces are clear and can be clearly recognized, so that the functional interpretation raises no doubt, study of the surface can be confined to examination without special preparation, but such instances are not characteristic. For the most part the linear texture of traces does not clearly emerge even in the binocular microscope, because of the transparency, translucency or glassiness of the flint; the light which passes through it takes the contrast out of the image. On a metallic surface, for example, the micro-relief stands out more sharply under the binoculars than on flint, where it disappears, dissolving as it were.

A natural factor partially neutralizing the glassiness of flint and facilitating study of the traces of work is patination, which increases the definition. However, one cannot rely on patination alone to bring out the traces of work, especially if it is combined with a roughness of surface.

Flint is a rock of fine-grained structure, which causes the dull colour of its surface in a fresh fracture. If the flint tool has parts polished to a mirror-like shine, then with the light at a certain angle it will be possible to detect very fine striations, and ideally a smooth surface will give uninterrupted linear marks. If the tool only had short use and did not acquire a mirror-like shine but only some degree of polishing or burnishing in working on a soft object, the striations will be very difficult to detect. The traces will show as short cuts and stand out as hollows that lose themselves against a background of small scintillations. To make them intelligible it is necessary to neutralize the flint's translucency.

In the study of traces on flint tools with an uneven surface it is impossible to find one angle of light which brings out the full picture; examination requires constant adjustment of the binoculars and ball-jointed rest. The general picture is therefore the sum of many images given by the instrument at different angles. This kind of analysis resembles study of the structure of crystals as done by petrographers with Federov's polarized microscope and rest.

Examination of the striations on the mirror-like parts is practical without the use of light filters. By inclining the horizontal surface of the rest in different ways and changing the position of the sources of light there will be a moment when the striations on the shiny surface will be visible if not wholly, then at least partially.

Spectrographic analysis in studying traces on a shiny area should be used only if the more rational methods of observation are impossible. Among the latter we may include devices for preparing the surface of the objects under study.

The translucency of flint can be neutralized by dusting with magnesium powder, when the flint surface is covered by a fine layer of white dust—magnesium oxide. However, quite apart from the disagreeable procedure of dusting in the flame of burning magnesium, such a method does not always give satisfactory results. The micro-relief of the surface is covered by a layer of magnesium oxide, and the finer texture of the traces loses its sharpness or may vanish beneath it.

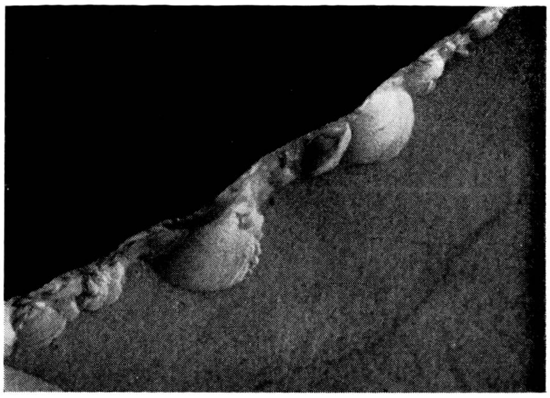
A simpler method than magnesium dusting for reducing translucency is to treat the parts being studied with a colorizer. For this purpose black finely ground Indian ink is to some extent suitable. After careful washing the working part of the tool is covered by a solution of Indian ink. The film of ink must cover the flint surface evenly and with maximum thinness, within the limits of tenths of a micron. It partially holds back the rays of light and allows a better vision of the micro-relief and wear traces under the binoculars.

The advantage of Indian ink over other opaque pigments lies in the fact that it can be easily washed off the flint's surface. All that is needed is a small operation with an artist's paint-brush to produce a surface suitable for research. The necessity for careful washing with hot water and soap goes without saying, as the Indian ink will not lie evenly but collect in patches after spirit and benzine have been used on the surface. However, no formula for concentration can be given beforehand; it can be left to the student to observe and judge for himself on the concentration of the solution and the evenness of the film, and reach the desired effect by experience. The use of Indian ink improves optical analysis; streaks, lines and scratches will come out more clearly; traces that do not appear in normal conditions will emerge. The micro-topography of the surface becomes more accessible to our view.

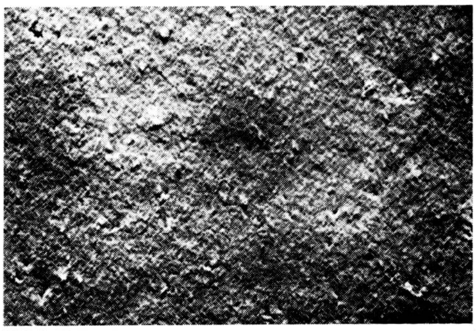
The use of Indian ink for the purposes mentioned simplifies research on ancient stone tools, but it has a negative side. Ink is almost impossible to lay at the same time very thinly and in an even layer. Filling up the irregularities of the micro-relief, it covers them over and collects in patches. In studying the small part of an object it is necessary to wash off the ink frequently and apply another slip.

In practice the best results have been obtained by using chemical colorizers, especially methyl violet, which will in some measure chemically react with the

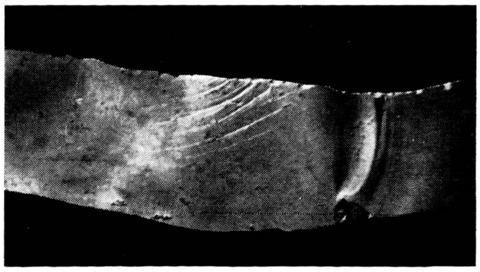
1



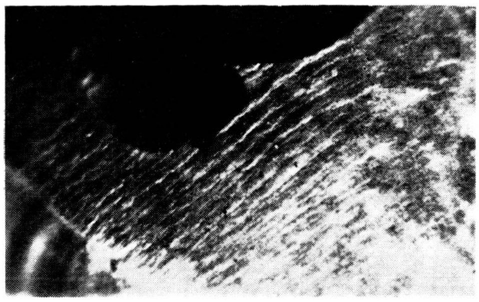
2



3



4



5

2 *Retouched edge of flint enlarged 10 ×: 1 natural condition; 2 coated with silver: 3–5 natural fracture surfaces of flint: 3 freshly broken flint dusted with magnesium (20 ×); 4 rib-like structure of surface (2 ×); 5 conchoidal appearance of rib-like structure (5 ×).*

patina on flint. A weak solution of methyl violet dabbed on the flint surface with a paint brush can bring out very minute striations. After the colour solution has dried out it has to be wiped over with a cloth or rag of thin soft material, for example cambric.

Colouring with methyl violet is an effective way of studying objects of unpatinated flint and other rocks. In addition the surface under examination can be subjected to metallization with the aid of a vacuum machine (with silver, chrome, copper etc.), or silverized by applying a solution of silver nitrate. A very fine layer of silver completely eliminates the translucency of flint and gives definition to details of the micro-relief on parts of the surface not covered by silver (fig. 2.1 and 2).

Bone tools may also be coloured by Indian ink or methyl violet in weak solutions, if the surface of the working part is sufficiently well preserved, and especially if it has been polished by use.

7. Photography of traces of wear

IN the workroom exceptional importance is attached to the graphic presentation of the results and evidence of archaeological researches. Archaeologists have not yet introduced into their general practice all those means of establishing and documenting evidence which contemporary techniques place at their disposal. This is particularly the case in micro-photography, stereophotography and micro-stereophotography which have been in use for some time in other spheres of knowledge.

Micro-photography now possesses its own methods and techniques and constitutes a regular branch of auxiliary science.[1] Without it laboratory researches could not be undertaken in biology, medicine, mineralogy, petrography, metallurgy and other branches of science.[2] Micro-photography should not be confused with micro-tracing. The latter is a laborious process requiring special skill and a markedly more elaborate method of documentation.

Taking micro-photographs in workroom archaeology for studying traces of work on ancient tools and artefacts has its own special requirements.

Undoubtedly in laboratory researches by archaeologists there is a place for the study of slides of different vegetable and animal remains, and also slides of stone, pottery and metal objects. Such work is gradually beginning to win a place for itself in archaeology. But here we have a practice already established in other sciences with its methods fully worked out. Research on traces of human activity on working tools is to a large extent a new field both in methods of observation as well as in documentation. Micro-photography of traces of work, which are three-dimensional, encounters greater difficulties as the need for greater magnification grows. It is true that this applies to all micro-photographic work, but with traces of use low limits of magnification are a more limiting factor than with flat objects.

Any archaeologist can carry out macro- and micro-photography with small-model, mirror cameras ('Exact', 'Praktiflex', 'Zenit' and others) with short focal lenses (1 : 3·5; f=50 mm.) with the use of one accessory, a supplementary tube. The latter is placed between the exposure chamber and the lens and acts as an extension to the camera bellows. The limits of magnification with a small camera with supplementary tube are not large (2× to 10×), but the prints can be enlarged up to 8× to 30×, given a perfectly adjusted camera and enlarging apparatus.

The essential value of using a small camera with tube is that this simple device can be employed not only in the laboratory but on the excavation site, where the necessity to record various details of the object directly in the cultural layer, and even of the layer itself, may arise. The small camera, moreover, makes it possible to take pictures of objects as a whole or even groups of objects, if the number of rings in the tube is reduced, or if it is taken out altogether.*

In all major work when microscopic documentation goes hand in hand with micro-analysis apparatus of more complicated type is required. In this case it is micro-photographic eyepiece attachments and universal micro-photographic stands that are the two most suitable pieces of equipment.*

In all photography, including micro-photography, lighting plays a crucial part. We have already described the lamps used in micro-analysis of traces of work and their methods of use. The same lamps are suitable for

[1] L. I. Tsukerman, *Practical Guide to Micro-photography* (Moscow, 1950); C. Shelaber, *Micro-photography* (Moscow, 1951).
[2] Professor S. M. Potatsov, *Legal Photography* (Moscow, Leningrad, 1948); N. V. Terziev, B. R. Kirichinsky, A. A. Eisman, E. B. Cherken, *Physical Researches in Criminal Law* (Moscow, 1948).

micro-photography. We should note that in the micro-analysis of traces of work lamps can be used with or without filters.* Essentially short-wave radiation is preferable in the practice of micro-analysis, because the defining power of the lens is greater the shorter the wavelength of the light falling on it.

Therefore in micro-photography methods of work with blue and violet light filters have been in use for a long time, but recently ultra-violet lamps have been introduced permitting examination of a larger number of details on an object.[1]

In the photography of traces of use on stone and bone objects another important matter besides light filters is the proper preparation of the area being photographed. Just as in analysis the colourless translucent surface of flint (and to the same extent the surface of bone) tools requires dusting with magnesium, or colouring with a metallizer, or smearing with Indian ink, so as to give definitive light and bring out the linear outlines of the traces.

In field as in work-room archaeology stereophotography and micro-stereophotography play an important part.

In order to get a more or less accurate reproduction of an object on a negative using a single lens, besides the frankly technical matters (exposure, development and so on), one has to maintain the following conditions:

(1) The outlines of the subject must meet the requirements of full and detailed reproduction.
(2) The disposition of the dark and light patches by their relative brightness require carefully thought out and technically devised lighting.
(3) To avoid distortion of the linear perspective with a normal camera either a correct position has to be chosen for the camera or the object being photographed has to be moved.
(4) Reproduction of the visible perspective requires adjustment of the lens to a proper focal distance.

Even when all the above rules have been observed in taking the picture with a normal camera there are still limitations of reproduction in the result; to get a more accurate reproduction or bring out other details one has got to take several views at different angles.

The above requirements which apply to normal photographs lose much of their meaning in stereophotography.[2]

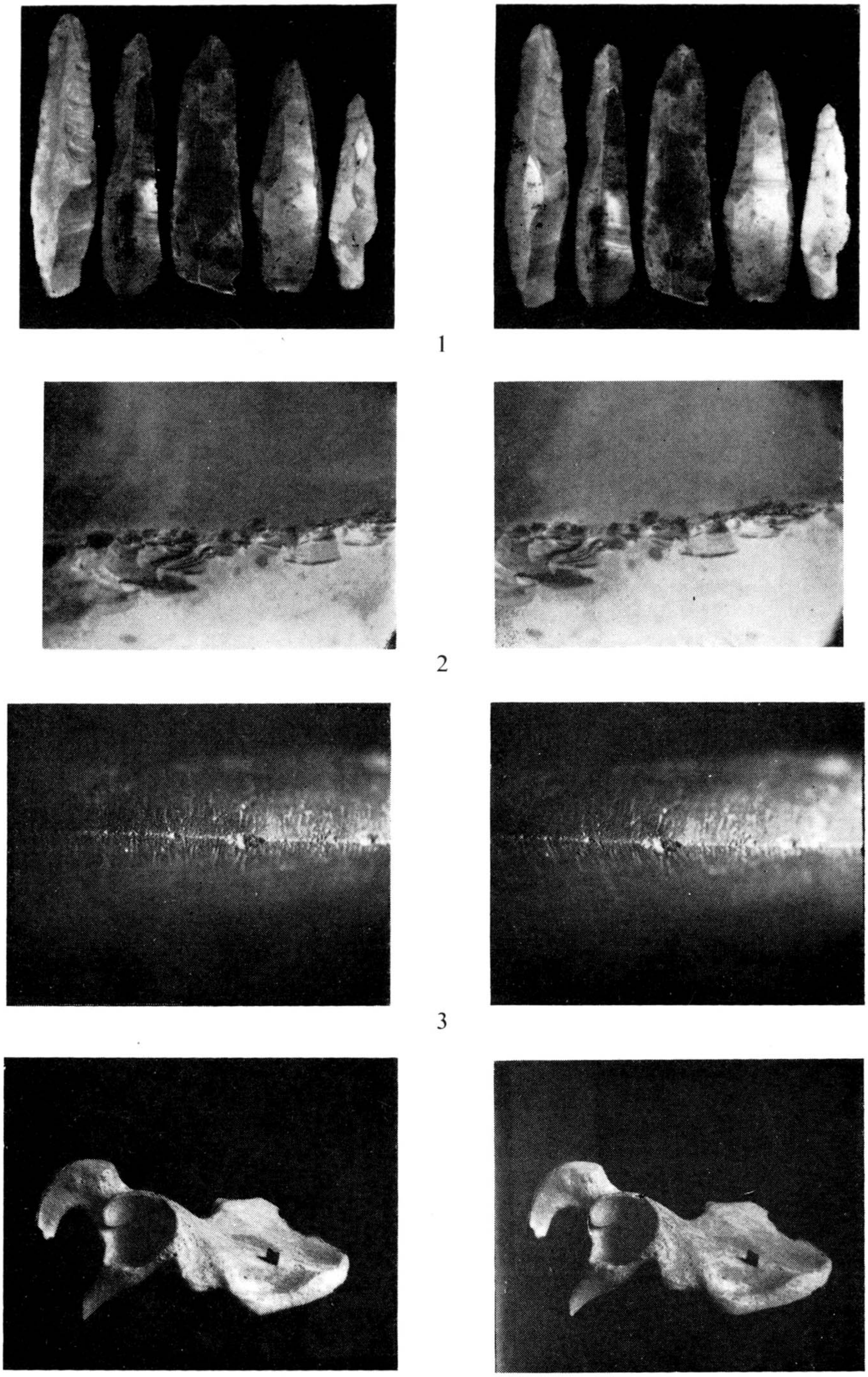
In the first place the clarity of the picture and its details are due to photographs on two planes, which on account of the exceptional sharpness of short-focus lenses used in stereoscopic apparatus give a mass of detail often not detectable by eye. Secondly the light patches of the picture and the illumination are on different planes, which emphasize the vividness and reality of the object. Thirdly the laborious correction of linear perspective by using single photographs taken with lens readjusted to the right focal interval each time, is automatic in stereoscopy, because looking at the image in the stereoscope with a focal distance equal to the focal distance of the camera lens the object in the picture appears just as it appeared to the observer in the original. Fourthly the artificial method of getting a visible perspective from separate pictures with uneven clarity on different planes is unnecessary. The stereoscope overcomes this by showing depths and the different parts on different planes creating a remarkable similitude of real perspective, in spite of uniform clarity of reproduction on all planes.

Moreover, we must bear in mind that in normal photography many subjects are difficult or impossible to reproduce. Such are subjects with different planes of perspective very near the front and with lines interlacing in different planes (foreshortening). To reproduce them would often require an artist who would show them by complicated conventions. In stereophotography such subjects present no difficulty. For example leaves and branches in a tree-top, a mass of machinery, or, what archaeologists come up against more often, the panorama of an excavation with objects resting on monoliths, bone heaps, collections of human skeletons in collective graves, the intricate perspective of structures being uncovered in earthworks—all these are reproduced in sharp contrasts on the stereo-print.[3]

As a distinct merit of stereophotography we may regard the natural reproduction of shine on objects, the transparency of water and glass, shadows, smoke and cloud, which greatly raises the value of this type of reproduction.

By its methods and techniques field research takes time to reach completion. The archaeologist is always confronted with the task of excavating the site with precision and maximum attention to detail, so that there should be no doubt about the completeness of his record and accuracy of his evidence. Therefore his field work, the quality and fullness of his observations, depends upon various factors. Amongst the chief of these is the shortness of the summer season, which threatens the archaeologist with insufficient time to complete examination of vital details and aspects of the site being studied. There are all the facts to be recorded in diaries, sketches, drawings and normal photography, which occupy his

[1] M. A. Volkov, *Photography in Invisible Bands of the Spectrum* (Moscow, 1935); A. I. and G. A. Didebulidze, *Photographic Reproduction of the Invisible* (Tblisi, 1946), p. 149.
[2] A. Donde, *Stereoscopic Photography, Its Theory and Practice* (Moscow, 1908); A. W. Judge, *Stereoscopic Photography* (London, 1926).
[3] A. K. Klementev, *Stereoscopy in Architecture and Building* (Moscow, 1952).



3 *Stereo-photographs of various objects:* 1 *upper palaeolithic flint blades;* 2 *method of blunting by retouch for handle on blade from Kostenki I;* 3 *traces of use on ground axe from Verkholensk;* 4 *human pelvic bone transfixed by flint head from Fofanov, L. Baikal area.*

attention and whose significance he assesses in the course of the excavation. Every student knows from experience that the longer something is the object of his interest the more the observations accumulate, which will not only bring corrections but commonly a radical alteration of deductions. Field research in practice has its own peculiarities which rarely allow the student to return to the site or the right part of it, so that work can be continued in the next season. The excavations finished and recordings completed, the finds are then removed and taken for ever from their original position and conditions of deposit. Verification of recorded data and the search for additional evidence are no longer possible.

So an archaeologist is extremely concerned that, together with his own documentation, facts and details that he himself took note of, he should have others which escaped his attention or to which he did not attach proper weight. This evidence, these details, can be noted and assessed by studying his photographic record. Stereophotography alone, especially in colour,[1] with its great power of making things stand out, can provide this kind of documentation, recording many facts and details from various views. Stereophotography has one more advantage. The print allows accurate estimate of the size and disposition of objects in cases where measurements were not made at the time of discovery.

We have in mind stereo-photogrammetry,[2] which forms an important branch of metro-photograhy and plays a large part in strict scientific methods of measurement, especially in geodesy and astronomy.*

From what has been said above it follows that stereoscopic photography is of great value whenever precise and full documentation of the objects being studied is required in their natural three-dimensional aspect. On stereoscopic prints of palaeolithic flint knives one can see not only the retouch but the whole bow-shape of the blade without a sectional drawing (fig. 3.1). The way a blade has been blunted by retouch, traces of wear on the blade of a neolithic axe or the position of the flint arrowhead that killed him in the pelvic bone of a man (fig. 3.2–4), are all reproduced by stereoscopic photography with many details. It will be fully appreciated that, pressed into service for recording and documenting of a different kind, on traces of work on ancient tools and objects which are three-dimensional, microstereophotography is of no small value.*

---

[1] S. P. Ivanov, *About Coloured Stereoscopic Photography* (Moscow, 1951).

[2] N. M. Tokarsky, *Educational Library of the State Academy for the History of Material Culture*, 3 (1931).