

S. A. SEMENOV

Prehistoric Technology

an Experimental Study of the oldest Tools and Artefacts from traces of Manufacture and Wear

TRANSLATED, AND WITH A PREFACE BY M. W. THOMPSON



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Translator's Preface

THIS BOOK IS THE RESULT of some twenty years of microscopic research on prehistoric stone and bone tools, which has shed a flood of light on both their methods of manufacture and use. Various practical difficulties have had to be overcome, notably that of rendering flint opaque so that it could be examined in reflected light under a microscope. The most important discovery has been that during use microscopic striations ('linear marks') were produced on the tool's surface by friction. The striations reveal the direction of movement of the tool during use and so allow its purpose to be identified with fair confidence. This in its turn throws a sidelight on the way of life of the people who employed the tool.

Apart from the new technique used in the work the book draws together a great mass of scattered information on experimental work in making and testing tools, and also ethnographic parallels that by comparisons throw light on prehistoric tools. Comparisons with modern techniques—as steel burins in metal industry or the way a modern bricklayer cleaves a brick—are rarely adduced in this type of study, but as used by the author here relate ancient to modern techniques as well as making the description more vivid. The book therefore will serve both for reference and as a manual or textbook.

Prehistoric Technology (Pervobytnaya Tekhnika) appeared in 1957 as number 54 in the Materials and Researches on the Archaeology of the U.S.S.R., published by the Institute of the History of Material Culture of the Academy of Sciences of the U.S.S.R. Since this series started in 1940 over 100 quarto volumes have appeared and have earned it a place among the leading world publications on archaeology. The volumes normally deal with special periods or areas and quite often are monographs, as in this case. The Russian edition has been out of print for several years.

This English edition is virtually a complete translation of the Russian edition with the exception of the description of Russian instruments in parts 5 and 7 of section one and another minor omission on page 59 made on the author's instruction (at the translator's suggestion). Omissions in the text have been marked with an asterisk. A list of illustrations and an index, not included in the original, have been added to this edition. In the footnotes titles of articles have been omitted, but the titles of journals given in full, in order to avoid the need for a list of abbreviations. Footnotes concluded with the letter T have been interpolated by the translator. The format is broadly similar in both Russian and English editions.

Dr Semenov has most kindly made available either the prints used in the original edition or (in a few cases) substitutes. A few poor or damaged prints have been omitted, but with the exception of the colour plate in the Russian edition the illustrations are substantially the same in both books. The quality of reproduction is better in the English edition, which also contains one print of high magnification (fig. 47). Scales are not always given in either edition and where they are should be regarded as approximate.

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It is hoped that the translator will be excused for introducing a personal reminiscence of how he first became interested in Russian work on this subject.

In connexion with a doctoral dissertation I wished to make some antler harpoon heads for experiments. It seemed to be worth while to use actual palaeolithic techniques.¹ Reindeer and red deer antlers having been obtained

¹ See Appendix iv of my dissertation *Some Mesolithic Cultures of the Iberian Peninsula* (June 1953) typescript at the Cambridge University Library.

from Finland and Scotland and flint flakes from the Brandon flint-knappers, a difficulty at once arose: how to make a burin. The Brandon knappers averred that it was physically impossible by flaking, and so rather than waste time several 'burins' were cut with a diamond cutter. After prolonged softening of the antler by soaking, it proved fairly easy to cut grooves along the full length of the beam and extract the necessary antler strip. Several harpoons were made, mainly with steel tools, but in one case using one of the burins as a chisel. The rough tools could then be ground smooth with sandpaper. The main failure in the experiment (and perhaps the reason why it was never published) was the ineffective nature of the 'burins'. In cutting the grooves in the antler a long flint flake was used, partly wrapped in cloth and held in the closed fist, and then dragged with the full strength of the body along the beam. The flake was not held like a knife (Gerasimov's method in fig. 78.1), but at right-angles to the groove, so that to the accompaniment of a loud squally shriek antler material was torn off each side of the groove, the waste being rather like sawdust. The movement is identical to that described by Semenov for a burin, and no doubt the explanation for the ineffectiveness of my 'burins' was not so much that they were diamond-cut as that they were too short. The tool must be held in the fist, not between the forefinger and thumb, because the secret of the operation is simply brute force; the whole strength of the trunk and shoulders must be brought to bear.

This digression brings us to a cardinal point of Semenov's book: in modern experiments one can do practically anything with flints; the only reliable guide to the original purpose of a tool is the traces of wear that it bears. As described in the Introduction the study of function can be envisaged as a sort of trident; the central and main prong is analysis of traces, the two auxiliary prongs are practical experiment and ethnographic parallels.

The first section on methods is divided into seven parts, the last three of which deal with the technical problems of microscopic research. The first three deal with natural changes and processes of wear on stone and bone, while the fourth describes the kinematics of working with the hand. We have to be clear in our own minds how tools are moved in different operations, so that the microscopic striations which reveal the direction of movement can be interpreted in terms of function.

The main part of the book which deals with stone is section two. Three introductory parts give a valuable table of stones used arranged according to the smoothness of fracture surface, an account of obtaining material, and—the most interesting—Semenov's views on the extent to which the quality of tools depended on the properties of available material. The case for a decisive influence is very strongly put, particularly the beneficial effect of chalk flint in those limited areas where it occurs. The translator would certainly agree with most of this cogent section.

Parts 4 and 5, both divided into numerous subsections, deal with the manufacturing of stone tools and identification of their function respectively.

As he is dealing with techniques—in this case percussion—the author does not separate core-tools from flake-tools, a distinction which underlies so much western thinking on the subject. On blade-making, he is not able to offer any final solution of how blades were made, although he believes that the tip of the presser was made of flint. Semenov regards bone and wood as having played a much smaller part in primary working than is generally believed in the west. Perhaps the most remarkable theory is that Solutrean surface retouch was merely a technical device for removing the natural curvature on the blade, very necessary in projectile heads. By the same token we might argue that the Magdalenians abandoned Solutrean retouch because they made their projectile heads of bone. This curvature on the blade is regarded by Semenov as one of the main snags arising in the use of blades, and for this reason he

regards segmentation, the manufacture of microliths by dividing the blade and inserting them into a haft, as the logical culmination in the evolution of blade industries. This view should help to raise mesolithic industries in our esteem! Burin-spalling by a vertical blow the author regards as used not only for making burins, but also as a method of blunting a sharp blade-edge for holding in the hand or hafting. The subsections on pecking, grinding, sawing and boring—predominantly neolithic techniques—are extremely clear and thorough, and should be of great help to the student.

A point that inevitably comes to mind is how far can the 'neolithic revolution' be regarded as a technological revolution in terms of stone-working. The late Gordon Childe used the word 'revolution' to connote a social or economic transformation, the change from hunting to agriculture as the means of subsistence. Practically all the techniques of stone-working enumerated by Semenov were known by mesolithic times; what was new in the neolithic period was the massive application of slightly used techniques to new materials, more particularly grinding previously used on bone now used on granular rock. The eighteenth-century Industrial Revolution was, after all, largely a matter of employing old techniques, like the water wheel, in new ways and on a larger scale. As Semenov says, the technique of grinding brought into use a new range of raw materials which made possible the colonization of large, previously uninhabited areas.

In part 5 we come to the heart of the book, the identification of the function of stone tools from traces of wear on them. The results are not entirely at variance with previous ideas, but rather clarify and make more precise our existing notions. Side-scrapers (from one example) are identified as a tool used in a two-way movement for primary cleaning of the underside of the skin, while end-scrapers were used with a one-way movement for secondary scraping, softening by rubbing. Burins are identified without hesitation as used for grooving ivory, bone and antler, the burin angle acting as a sort of saw-tooth, removing bone pulp from the side of the groove. Two new types of tool identified by Semenov, and only recognizable by microscopic traces, are meat and whittling knives. A moment's reflection will show that in the sort of life led in upper palaeolithic times knives of this kind must have been indispensable. An important discovery is the identification of a flint axe from Kostenki I, regarded by Semenov as used primarily for chopping mammoth tusk. This may provide an origin for the axes which play such an important role in post-glacial industries. The accounts of the use of ground axes and adzes and the traces on stone sickles are a particularly welcome addition to our knowledge. The reasons put forward by the author for the lop-sidedness of neolithic axes, like those for the lop-sidedness of end-scrapers, carry complete conviction, for the translator at least. The final subsection on the abrasive instruments from Verkholsensk is a very fine piece of detection.

The third section on bone lacks some interest for the western reader, because it does not deal with the wide range of tools of reindeer antler found in the French Magdalenian sites. However, against this it does give us much information about the use of mammoth ivory on Russian sites, where it is, of course, much more common than in the west. Of particular interest is the notching technique for severing tusks, using an axe, chisel or burin. The longitudinal division of ivory tusk closely resembled the removal of strips from antler already mentioned; with this difference, that ivory has no soft spongy centre, so that strips could not be snapped out, but had to be struck free with a chisel. Semenov has some very sensible things to say about softening bone, and the translator has added some additional information in the footnotes.

Part 3 deals with Eskimo bone tools and their origin. The curious feature about these has always been that the earlier the industry the finer the bone

tools appear to be; it now seems reasonably clear that the ingenious toggle-head harpoons used for seal-hunting (upon which the winter survival of the Eskimos depends) could not have been made without metal. Eskimo life therefore, like buffalo-hunting on horseback by the prairie Indians, ultimately owed its existence to borrowing from a much more advanced culture.

The parts on handles, burnishers and mattocks are of especial interest. It is reasonably clear that a burin required some sort of handle, because of the force used and the danger of lacerating the hand. The mattocks were essential tools for the upper palaeolithic inhabitants of the Russian steppe in order to dig their well-known semi-subterranean houses. Part 5 describes the use of long bones on later Classical and medieval sites. The 'skates', which are also found in England, are identified as used attached to the feet, not for skating, but for thickening cloth.

The book ends with an essay on regularity in the development of tools in the Stone Age which it would be impertinent for the translator to attempt to summarize. Western archaeologists tend to regard stone tools as type fossils and not to seek underlying evolution throughout this vast period of time. A technologist like Semenov understandably is not interested in cultural divisions, which in any case in the Stone Age are not very meaningful, and seeks to find the technical improvements that the changes imply. While we should be hesitant of seeing 'laws of development', that a Marxist desires to find, nevertheless the sort of underlying changes described by Semenov seem to be real and helpful to our understanding of the subject.

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Such is the gist of the book without doing justice to the cogency of the argument, clarity of thought and prolonged research on which it is based. There are, however, two criticisms which in fairness to the reader ought to be made.

Firstly is the foreign work that is ignored, probably due to the difficulty of obtaining the books in the Soviet Union. In a book that very largely deals with upper palaeolithic industries it is surprising that there is no mention of Mount Carmel or Parpalló. The segmentation of blades is described without reference to microburins, while in describing the longitudinal cutting of ivory no reference is made to the analogous method used on antler in western Europe. Such examples could be multiplied, and, while they do not vitiate the argument, the reader should bear this fact in mind.

The second criticism is of the method. We are told how tools were selected for micro-analysis by fairly obvious signs of wear. It would inspire more confidence if a fixed sample of tools had been taken and record made of how many did or did not bear the given traces of wear. For example the marks of a stone presser-tip on the platform of a blade or core are described by Semenov, but he says that in numerous cases there were no marks (p. 53). This might mean that the blade came off at the first exertion, but it might mean that the presser-tip was of a softer material, such as bone. No doubt the explanation is that with a very laborious process like micro-analysis it would not be practical to attempt it unless there were obvious signs of wear on the tool, but nevertheless the reader should bear in mind the selective nature of the samples.

These criticisms in no way detract from the translator's warm admiration of this very fine book which undoubtedly marks a major step forward in the subject. It only remains for the him to record the pleasure the translation has given him, and his gratitude to Dr Semenov for supplying the original prints for the figures. Warm acknowledgement must also be made to the publisher, Mr Anthony Adams, whose idea originally it was to publish a translation, and to Miss Sarnia Butcher, who has most kindly read and made many corrections to the typescript.

M. W. THOMPSON
Wimbledon, February 1963

Introduction

It is well known what significance the study of tools and the history of manufacturing has for historical science.

Marx stated the necessity for the creation of a history of the development of manufacturing tools and wrote: 'Darwin directed attention to the history of natural technology, that is to the formation of plant and animal organs, which play the part of manufacturing tools in the vegetable and animal kingdoms. Does not the history of the creation of the productive instruments of social man, the history of the material basis of each entity of social organization, deserve the same attention from history? And would this not be the easier to write since, as Vico put it, precisely what distinguishes human history from natural history is that the first is made by us while the second is not. Technology reveals the active relationship between man and nature, a direct process of his existence, consequently of the social relationships of his life and so of the spiritual phenomena that arise from them.'¹

The present study is devoted to the problems of the history of the oldest working tools.

For the study of prehistoric technology archaeological investigation of the remains of the working activity of man of the Stone Age has provided great opportunities, in particular in the palaeolithic period, researches into which began with the discoveries of the 'first tools' (Chellean hand-axes) by Boucher de Perthes in France. However, in studying very ancient technology scholars have encountered great difficulties. Tens and hundreds of thousands of years separate contemporary tools from palaeolithic ones, so not much can be understood by simple observations and comparisons.

Investigators studying the Stone Age have not infrequently attempted to prepare ancient tools with their own hands out of flint and other material, and so by experiment, not only to test their effectiveness and reliability in work, but also to find out the functions they fulfilled in the hands of prehistoric man. Boucher de Perthes, J. Evans, E. Lartet, G. de Mortillet, L. Capitan, L. Leguay, E. Piette, A. Vayson de Pradenne, L. Pfeiffer, V. A. Gorodtsov and many others by means of

actual experiment have achieved solutions to problems of this kind to a greater or less degree, believing this to be the simplest and most straightforward way of doing it. Experimental work in the study of the most ancient techniques of working stone has continued more recently through the efforts of such scholars as: L. Coutier, F. Bordes, A. Barnes, D. Baden-Powell, J. Reid Moir, F. Nowells, and L. Leakey. Several of them have carried out experiments over the course of many years. A film has been made of the work of L. Coutier.

However, although there have been several essential discoveries relating to the method of preparation of stone tools these workers have achieved hardly any success in the elucidation of their function. Even when it was possible to carry out a definite type of work with this or that tool there could be no certainty that prehistoric man employed it for exactly this purpose. Experience showed, for example, that a flint blade can cut meat, or dress skins, or whittle wood; that a burin will incise bone and wood and even bore through these materials; that a point can be mounted in a stick and used as a dart or serve with or without a handle as a knife.

L. Pfeiffer experimenting with an end-scraper found that its circular retouched end worked equally successfully for scraping or cutting, if held at right-angles to the working surface, and several functions have been assigned to the end-scraper on the basis of those experiments.

It is very probable that in the time of prehistoric man there was not a rigid division of function between the various categories of tools; sometimes several functions were fulfilled by one tool, or one and the same job was done by different tools. But all the same prehistoric man had a varied inventory of utensils, not contenting himself with just a few forms.

Thus the experimental approach cannot serve as an independent method of study of the function of tools; precise evidence is required of what was the real purpose of the tool in each specific example.

There is yet another weak aspect to the experimental

¹ K. Marx, *Capital* (Moscow, 1951), I, 378. (G. V. Vico, 1688–1744, Italian jurist and philosopher. T.)

approach to the solution of the problem of the purpose of a tool. It is very difficult to re-create the actual conditions of work of prehistoric man and devise in a contemporary laboratory experiments with these objects, used just as he would have done. The palaeolithic hunter worked with stone burins on mammoth tusk and deer antler, with flint side- and end-scrapers he dressed skin, and with knives he disembowelled animal carcasses or cut up meat. Working processes of this kind cannot easily be re-created with the precision necessary for experiment without the replacement of proper objectives by substitutes and direct courses of action by indirect ones. The amateur nature of the experiments and doubts about the results is the reason why the majority of archaeologists leave their work unpublished. We know about them only by brief references in archaeological publications.

It would be a serious error, however, to reject entirely the part of experiment in this matter of studying the function of tools. As an auxiliary method to confirm or make more precise deductions made from the traces left by wear direct experiment is undoubtedly useful. Nevertheless its full-scale application is only possible in those cases which are accessible to us, as, for example, working stone, bone, wood, skin, soil, and other materials, the introduction of which into the practice of the experiment is less difficult than other objects of a hunting culture.

Experiment is important (apart from testing the mechanical properties of ancient tools) for the physiological experience of really assessing the nature of the working skill of prehistoric man, of the live sensation of the expediency of form of a stone tool, and so on.

Checking by experiment is important in study of the efficiency of work of ancient tools. Experiments to test stone sickles, neolithic axes, bows and boomerangs from ethnographic and archaeological collections, carried out in Czechoslovakia, Denmark, Brazil and other countries are by no means valueless. Thanks to experiment it has been possible in a number of cases to assess with an appropriate example the efficiency of implements about which information was inaccurate, due to faulty ethnographic description or prejudiced opinion, casually given by certain ethnographers and archaeologists.

Ethnographic materials play a vital role in the study of the function of ancient tools and the establishment of the techniques of manufacture. However, evidence for techniques of manufacture among backward tribes of Asia, Africa, America, and Australia is far less satisfactory than information about art, customs and beliefs, kinship and social relationships. At the time when the backward tribes of these countries still preserved their technology and economy there was no deep interest among the majority of ethnologists and travellers in the 'prosaic' side of the life of the societies they described. Nowadays these societies have either perished as a result

of the brutal colonial policy of imperialist governments or exist in conditions where to all intents and purposes their original economic life and tools no longer survive.

Ethnographic evidence, either in museums or from field study, in spite of its inadequacy and sporadic character, still retains a great deal of value. As a basis of comparison it is very useful in the investigation of ancient manufacturing.

In the study of the technology of the earliest stages of human development, when the tools commonly are of puzzling shape, giving rise to different opinions and controversy, we have worked out our own method of study. This is based on the fact that tools, independent of the materials out of which they are made and the shape they have been given, bear characteristic macroscopic and microscopic marks which are traces of work. There are two categories: (1) traces of wear and use, (2) traces of manufacture. Traces of wear make it possible to define what work was done with a given tool, that is how the object being studied was used and on what material. Traces of manufacture can explain with what tools and by what means the given object was made.

Traces of work are very valuable documents, as they allow us to understand the whole range of variety of tools in the light of the distinct functions and working activities to which man subjected them.

Traces of manufacture on ancient tools have occupied the attention of archaeologists for a long time. Observation of these traces played a decisive part in the study of the preparation of tools in the palaeolithic and neolithic periods (percussion, flaking, retouch, grinding, sawing, boring and so on), although the evidence of ethnography and, to some extent, experimental work have made no small contribution. By study of the surface of clay vessels it has been possible to distinguish wheel-made as distinct from hand-made pottery. In 1828 Tournal, one of the first defenders of the thesis of the great antiquity of man, put forward as proof of his theory the traces of work by sharp tools surviving on the bones of extinct animals in the Grotte de Bize (Aude) in France. Later, traces of use of sharp tools on bones served archaeologists as quite definite evidence of the contemporary existence of man and mammoth. E. Lartet and G. de Mortillet drew attention to the way such traces could be distinguished from others left by the teeth of animals, notably beavers.

Study of traces on ancient tools was one of the tasks of the Laboratory of Historical Technology in the State Academy for the History of Material Culture in the first years of its existence. N. P. Tikhonov wrote: 'This comprises study of the technique of manufacture beginning with the extraction of the material and going right up to the final division into different shapes and forms. It is necessary to study with the microscope and spectroscope the appearance of the surface, to discover

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the traces of instruments and means of boring, grinding, etc., and so by analogies with contemporary traditional methods in the same regions re-create the technical environment in which work took place.¹ All the same, such laboratory work never took place. Nor did studies of the traces of wear on tools ever materialize, although various archaeologists retained their interest in the subject. In particular P. P. Efimenko in 1934 selected a number of flint tools from Kostenki I with traces of wear from use in the form of polishing on various parts of the surface, which formed the material used in our own first researches.

The credit is due to G. A. Bonch-Osmolovsky for correctly identifying the dents on the fragments of long bones from the cave of Kiik-Koba (Crimea) which made these objects recognizable as retouchers. Previously the view of H. Martin had prevailed among western archaeologists that the traces, well known on long bones from palaeolithic sites, were due to use of the bones as anvils.² Bonch-Osmolovsky, studying the traces of work on bones, in particular cuts on the epiphyses of bones of domestic dog, rightly concluded their origin as due to the use of this animal as food by the mesolithic hunters of the Crimea. He wrote: 'We can confirm from these examples that material from palaeolithic sites is by no means so dead as is often thought; it is the object-seeking, formal typological approach, carried to the point of dogma, which kills it.'³

The same worker first put forward an important argument in favour of a functional approach to the material. Using the experience of his own observations, he stated: 'Completely different types of tool of the lower and upper palaeolithic periods had one and the same purpose. This proposition is an essential blow to the formal typological treatment of the industry from a site which indissolubly binds each different shape to a function and almost turns this into a fetish.'⁴ Our researches on materials drawn from several periods fully support this contention.

The work of M. V. Voevodsky on traces on clay vessels of their method of manufacture, as well as the investigations of G. G. Lemlein on the techniques of manufacture of ancient stone beads from the evidence of perforation, grinding and polishing, were begun at about the same time as our work.⁵

The remarkable method of B. A. Rybakov used in the study of the artistic metal objects of medieval Russia deserves special mention.⁶ It is based on detailed study

of the surface of the jewellery and the recognition of identical marks left by jewel-workers from which we can define the centres of production and the market areas.

Important observations about the technique of manufacture of the log coffin from Pazyryk (Grave. 1) were made by M. P. Gryaznov from study of traces left on the wood by metal adzes.

The first stage of our work (1934-8) was confined to a narrow range of problems; methods of study of traces of wear on palaeolithic flint implements were worked out. Predominantly upper palaeolithic material (from Kostenki I, Timonovka, Malta, and so on) was employed. It was quite evident from the beginning that few traces of wear on tools of such a hard material as flint would be distinguishable with the unaided eye or with a simple magnifying glass, but normal microscopic examination by means of a monocular instrument would not allow inspection of the multiplicity of things desired. By use of a binocular lens with maximum magnification of 45× a start could be made with the first microscopic research on surfaces of ancient stone implements.

Rubbing or polishing was adopted as a basic criterion of wear on a flint tool. Rubbed parts on a flint vary in degree of shine, shape, and size. Even a comparatively trifling mark due to insertion in a handle has produced valuable evidence. Above all, the number of tools with evident traces of use was significantly increased. Besides this the examination of a large number of those flints which we are accustomed to call flakes and regard as waste products revealed examples that bore traces of use, showing that they were tools.⁷ Concurrently with working out a means of selecting tools with traces of use, the peculiarities of these traces were closely studied in order to distinguish marks due to the action of natural agencies, as well as false traces arising from deliberate or accidental interference by contemporary man. Study of this entailed the examination of the micro-structure of flint on a fracture face, inquiry into the effect of patination on traces of use, attention to signs of submersion in rivers or desert sands, and also, an extremely necessary matter, study of the distribution of the traces of use in relation to the overall shape of the implement. Such observations were necessary to identify the working part of the tool with precision, and differentiate it from the area of marks left by friction of the skin of the hand when the tool had been used without a handle.

¹ N. P. Tikhonov, *Reports of the State Academy for the History of Material Culture*, 11-12 (1931), pp. 44-45.

² G. A. Bonch-Osmolovsky, *Palaeolithic Period of the Crimea, I, The Cave of Kiik-Koba*, Quaternary Commission of the Academy of Sciences (1940), p. 17.

³ G. A. Bonch-Osmolovsky, *Reports of the State Academy for the History of Material Culture*, 8 (1931), p. 27.

⁴ *Ibid.*, p. 26.

⁵ M. V. Voevodsky in *Ethnography*, 4 (1930), pp. 55-70, and *Soviet Archaeology*, i (1936), pp. 51-79.

⁶ B. A. Rybakov, *Handicrafts of Ancient Russia* (Moscow, 1949).

⁷ S. A. Semenov, *Short Reports of the Institute for the History of Material Culture*, 4 (1940), p. 23.

In perfecting the method it was important to distinguish traces of wear on palaeolithic tools which are visible to the eye as chips and dents on the edge. These marks of use are often hardly different from light retouch employed intentionally to sharpen a blunted edge or blunt too sharp a one.

In the first period of our micro-analysis of palaeolithic tools we made an observation whose significance has only been given its proper weight in the last decade. We established that almost all tools with signs of wear, besides gloss or polish, bore striations in the form of minute lines, scratches, or grooves showing the direction of movements of the tool and its position on the object being worked. Striations from wear were found especially on the working edge of end-scrapers from the palaeolithic site of Timonovka.¹ These marks can be examined in this case with small magnifications and normal sources of light. Striations from wear seem the most important key to discovery of unknown functions of ancient tools, for they allow us to establish the kinematics of work in the use of these tools.²

The study of traces of wear on flint tools both in respect of size (micro-topography) and linear direction (micro-geometry) required a graphic method of recording the evidence by means of drawing and micro-photography. Great difficulties were encountered in the recording of traces of wear by means of micro-photography, since an attempt to reproduce the size of these marks is limited by the degree of possible enlargement. These difficulties have only recently been partly overcome by the use of stereo-photography.

The first stage of research on tools concluded with a successful experiment on the neolithic materials from the graves on the River Angar excavated by A. P. Okladnikov. Here the work was not merely to determine the function of the different categories of tools, for to some extent it shed light on the whole branch of an economy based on fishing.³

In the last ten years we have transferred our methods from stone tools to the bones in the archaeological material. Bones, teeth and antlers of animals were often used by man after a very small amount of treatment or sometimes even in an unworked state. Commonly therefore quite a series of unexplained bone objects present themselves not only from the palaeolithic period but even from the quite recent past.⁴ The sole reliable source of information about their function is the traces of use they bear.

The functional analysis of bone objects has its own special features and required different methods of work to settle new problems. Among these we can count: (1)

recognition of the traces of human use among the traces of natural agencies; (2) study of the plastic and structural characteristics of the different kinds of bone (ivory, long bones, antler); (3) experiments on the processes of wear of bone and on the processes of working it with stone and metal implements.

Through the study of traces of working on long bones, ribs, broad and flat bones, ivory and antler, many of the most elementary devices of palaeolithic technique, hitherto unknown or unexplained, were discovered.

Simultaneously with the work on bone we carried out studies on tools and objects of palaeolithic and neolithic times of mineral and rock (obsidian, nephrite, slate, quartzite, and rocks of volcanic origin) to which we had previously given very little attention. Traces of use and working on these materials also have their own peculiarities. By explaining and interpreting the marks we made intelligible the great nameless mass of river pebbles and sandstone and slate plaques, used as striker stones, retouchers, pestles, mortars for grinding colours, sharpeners for knives and axes, and other material needs of prehistoric man.

It is important to note that on the new materials (bone and different types of stone) the striations mentioned above continued as the leading feature. Together with these, traces of use of a micro-plastic but non-linear character were found in significant quantity. These have no common characteristic and consist of holes, chip-marks, effaced projections, scars, cracks and so on. Particles of material (colouring, chalk, silica sand, resin, metallic oxides, etc.) were observed on the tools' surfaces.

Remains of mineral colouring matter were generally found in the pores of rough stone surfaces. In palaeolithic sites where colouring so often occurs in the cultural layers its traces were often found on the objects, but this as a rule must have arisen accidentally; prehistoric man sometimes left colouring matter scattered about his hut, or sometimes it was brought by water into the layer.

The combination of wear and colouring matter on a tool deserves attention. Red or brown colouring matter (ochre) tends to be concentrated on working parts of the tool. This is the case particularly with stone pestles and slabs or flags used in the pounding and grinding of mineral colouring materials. Less often we find these tools made out of bone. Commonly the investigator first notices colouring on a tool of this type, and then signs of wear in the form of scars or striations from friction are identified afterwards. Sometimes, on the contrary, the colouring matter is only found with a magnifying glass, because it is deeply concealed in the

¹ S. A. Semenov, *Bulletin of the Commission for the Study of the Quaternary Period*, 6-7 (1940), pp. 110-13.

² Kinematics—'Science of motion considered abstractly without reference to force or mass'. Concise Oxford Dictionary. T.

³ S. A. Semenov, *Materials and Researches on the Archaeology of the U.S.S.R.*, 2 (1941), 203-11.

⁴ S. A. Semenov, *Short Reports of the Institute for the History of Material Culture*, 15 (1947), 138-42.

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crevices, while the wear is visible to the naked eye. The presence of colouring on the surface of pounders, plaques and flags in conjunction with striations is a very reliable clue for identifying these tools, even although we are only dealing with the usual river pebbles and lumps of paving-stone type without any traces of preliminary shaping or dressing. Moreover, the presence of colouring prevents us confusing pestles and mortars with identical tools used for the mincing-up of food, on which as a rule colouring does not appear.

Rubbing tools used on skin and fur also sometimes bear colouring. Some bone burnishers of palaeolithic times made out of animal ribs have coloured, spatula-shaped working ends. In all probability these were used on skins that had already been coloured or the colouring matter was rubbed into the skin with them. It is known from ethnographic evidence that colouring matter was mixed with animal or plant fats, and applied to skin to make it impermeable and more lasting.

On stone and bone tools of later periods particles of other materials have been observed. In the Classical town of Tyrithace in the Crimea two large flat pebbles weighing 400–600 hg were found in the excavations in 1947–8 by V. F. Gaidukevich. On one side each pebble bore marks of prolonged friction. On the less flat side of one pebble were remains of ochre, and here faint traces due to a circular movement of the pebble were visible. The surface being rubbed almost to a shine. The second pebble was quite flat with straight, fine striations all running in one direction. In addition, on the edge of the flat side was a small hollow scar retaining an appreciable amount of a hard, shiny mass, consisting of grains of sand and lime. It appears that this was an instrument for smoothing the plaster on the walls of buildings. The first pebble evidently was a burnishing stone for polishing the plaster to provide a surface for colouring.

For more detailed study of traces of use on tools of flint and other glasslike minerals and also on ground tools (neolithic and early metallic periods), in the second period of our researches we used a binocular microscope with a maximum magnification of $180\times$ natural size and a monocular microscope, with binocular attachment, which gave even greater possibilities. The first result of our researches with the new devices was the identification of a palaeolithic axe from Kostenki I and of ancient stone sickles from Luka-Vrublevetskaya.

In the course of the work new difficulties arose with the techniques of investigating the surfaces of stone tools. The translucency of the glasslike mass of flint, rock crystal, chalcedony, agate, and other similar minerals of the quartz group was a serious obstacle in studying the surface of tools at high magnifications in reflected light. This required a special treatment of the surface with magnesium powder, the application of a thin layer of

diluted Indian ink, or colouring with methyl violet or a metallizer. Magnesium powder and metallizers had already been used in micro-photography; colorizers were first employed in photographing surfaces of stone and bone in our own work. The peculiarities of the archaeological material and of the problems involved did not allow us just to copy the methods of microscopic analysis employed in other sciences. In particular the well-developed method of slicing used in the study of minerals and rocks is completely impracticable in the study of the function of stone tools. On the other hand, stereo-photography and micro-stereo-photography, otherwise very little used (in mineralogy, metallurgy and biology), have a vital importance in the study of traces of work on tools and artefacts of ancient man.

Microscopic observation on jewellery of coloured metals, bronze, silver and gold, has yielded quite fruitful results. The opaqueness of metal, its solidity and plasticity, together with the quality of retaining even slight changes on its surface, have favoured the study and micro-photography in reflected light of traces of techniques of hot and cold working on metal objects. However, work in this field began only a few years ago and its results will be published later on, as well as our work on ornament on clay pots and on techniques of working wood.

Recently we have put together our researches on the techniques of working stone in the palaeolithic and neolithic periods from traces of work. Methods of stone-working have always attracted the attention of scholars, just as originally they were used as a basis of the divisions into periods of the Stone Age. Microscopic studies of stone tools, for instance of the pressure areas on cores and prismatic blades with traces of work, adornments with traces of sawing and perforation, and so on, have provided corrections to previously held views about the working of stone at that time.

Have these traces such clear differences from each other that they definitely show the different functions of tools and methods of work?

The method of study of functions by traces of work is based on the kinematics of working with the hand, the special features of which are expressed in the striations due to wear (geometry of traces). In addition the size of the traces of wear indicates the character of the material being worked, its structural and mechanical properties (topography of traces). These two types of evidence, geometric and topographical, when analysed, are related to the form of the working part of the tool, its general shape, dimensions, weight, and the material of which it is made. All these matters taken into account together supply a solution to the question of the purpose of this or that tool.

Research on methods of making tools is based on study of traces surviving on the surface of the object

from the action of other tools on it. Traces of manufacture indicate the shape of the working part of the implement, the angle of the movements used and other peculiarities of the process of manufacture. The results of observation on the traces of manufacture on tools have fully borne out the evidence yielded by the study of traces of wear.

The functions of implements can be determined in relation to the basic characteristics of the economic activity of ancient man. As essential work we may list: (1) shaping wood by whittling and chopping with a knife, axe, adze and chisel; (2) digging with a stick, mattock, scoop, etc.; (3) dismembering the carcasses of animals and cutting meat with a knife; (4) treating skin with side- and end-scraper and burnisher; (5) perforation of skin and fur for sewing with stone or bone awls; (6) boring wood, bone, and stone with drills of various kinds; (7) dressing stone with striker-stones and retouchers of stone and bone; (8) working bone with a burin; (9) grinding and polishing stone with various abrasive agents; (10) sawing stone with stone saws; (11) pounding, crushing and trituration of grain, colouring matter and so on by means of pestles, mortars, plaques, querns; (12) reaping with stone sickles, and so forth. Tools with relatively prolonged use of this kind bear its traces of wear. Accidental, auxiliary and supplementary functions had no great significance in the life of man and are only attested if the new traces are sufficiently strong to replace the old ones. Some neolithic axes and adzes that went out of use were employed as hoes or scrapers, or bear marks of blows with a hard object, but the signs of secondary functions are quite obvious.

Thus study of traces of work allows us to speak about ancient tools and their functions not conditionally and approximately, as we do with the typological method, but makes it possible to explain the actual and concrete purpose of each tool, as it was when in use.

Precise definition of function of ancient tools has allowed us to recognize certain branches of manufacture. Thus, for example, when we knew that in the palaeolithic period a bone mattock fixed in a handle was employed as a striking, earth-digging tool, we began to understand the methods of construction of the semi-subterranean houses of that period. The basement of such a house up to 25 cubic metres in volume dug in thick loam, as at Kostenki I, would have been very difficult to excavate using a simple sharpened stick, but became feasible with the help of a bone mattock. The old theory about the use of pit-traps for catching large animals by palaeolithic man now has a much more real basis, since we know that earth-digging in this remote epoch was carried out with far from primitive equipment. If we may be allowed the comparison, the heavy bone mattock with broad blade, the type found at Eliseevich, was as much more effective than the simple

stick in earth-digging as the axe was more efficient than the knife in dealing with wood.

Traces of work that have been identified by analysis will become characteristic signs for the definition of categories of tools and thus greatly simplify the recognition of the latter in sites of different countries and of different dates. Then implements would not be distinguished one from another by form or material but by whether they had one and the same function, like, for example, a stone hoe from neolithic China, an Eskimo mattock made of walrus tusk, and the iron hoe of a Nigerian cultivator. They will have uniform signs of wear which cannot be confused with traces of wear on other tools. Of course, these traces will not be identical, for the types of mattock, the material out of which they are made and even the ground which is being worked are different. Yet allowing for all these differences there will be no fundamental differences of wear on the tools.

Nevertheless not all implements from antiquity can be subjected to analysis with equal success. Stone, bone and metal objects whose surface has not survived in the condition it was left by man cannot be analysed. So stone tools rolled in a stream, weathered bone objects, bronze and iron objects that have suffered from severe corrosion, can be studied by their shape only. Even then some evidence about the purpose of the object can be elicited if its surface has not been entirely destroyed and some small parts survive in their original state.

The identification of function is more difficult when the tool is represented not by a whole series but by a single example. Marks of wear vary in their degree of clarity, and preservation is an irregular matter. In the case of a single implement marks of use may appear feebly or be quite covered over by other marks. The latter may arise when the tool was not used for its proper purpose, as not uncommonly happened in antiquity, just as in life today. In a series of objects the shape of the tools has to be considered, but the important matter here is the great possibilities for analysis that the surfaces have. Not perhaps on all but on one or another of the specimens the investigator will see not only the primary but also secondary traces of use, which will play no small part in the recognition of the implement's function.

The study of the function of some tools presents difficulties in spite of clear traces of wear, a range of material, and complementary signs of definite use by man. Deductions that emerge from an analysis of traces sometimes seem unexpected even for the investigator himself and so need support from ethnographic evidence. For example, such peculiar instruments as the bone rasps from Olbia demand research over a long period of time. Even after a correct identification of function, there will still remain a number of unexplained details.

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From what has been said it follows that the study of traces of wear and manufacture is not a means entirely free from error for settling all problems arising from ancient manufacture, of explaining all difficulties and of disposing of existing controversies. This method deepens archaeological perspective by employing a new source of knowledge about the activity of ancient man, permitting us not only to have a more accurate definition of the material to hand, but also to grasp something about those things which have not survived. The method under discussion, of course, does not exclude other methods of research on the archaeological materials.

Combined study of the shape and material of ancient implements as well as of traces of wear on them has brought important accessions to knowledge about the characteristics of the construction of the hand and fingers of prehistoric man,¹ about methods and habits of work, and about the origin of right-handedness, and so on. Theories of comparative chronology and division into periods can sometimes be altered by the study of the technology of ancient manufacturing, since this allows us to differentiate traces of work by metal instruments from those left by stone tools, and so to find evidence for the use of tools not themselves present in the archaeological site.

¹ S. A. Semenov, *Reports of the Institute of Ethnography of the Academy of Sciences of the U.S.S.R.*, 11 (1950) pp. 70-82.