The tool itself was a rough-out worked by percussion and retouch, flaking or pecking, depending on the material.

Frequently to avoid additional labour a flattish oval pebble would be selected from gravel beds in a river. Sometimes this was done by necessity when the outcrop of desired rock was not in the same area as the settlement, and so a technically favourable rock was not at hand.

The earliest neolithic tools with ground blades have been found in Nøstvet (Scandinavia) in northern Europe and in Bak-Son (Indo-China) in southern Asia, where the axes resemble, by roughness of their appearance, the axes from Campigny or the Danish kitchen middens. They are of irregular shape, and the blade only was touched up by abrasion. Sharpening by grinding should not be confused with incomplete grinding that occurs on the large chopping tools that are found not only in the mature neolithic period but also later when metals had already come in. Incomplete grinding can be explained by the desire for economy of effort, but also, and it is especially important to emphasize this, by the requirement of the time to fix the tool to the handle by lashing. The butt-end, uneven as it was after dressing, possessed certain advantages for giving a purchase in contrast to the smoothly worked surface of a tool which had been ground all over.

Incomplete grinding can in some cases be explained by the fact that some hard rocks (flint, agate, chalcedony), even if available to neolithic man, were extraordinarily difficult to grind. Work for a given duration of time on grinding a flint axe was two to three times less effective than for the same work on a diorite axe. So in one and the same neolithic settlements flint axes will occur with only the blades ground, and axes of igneous rock that are ground all over. An example of this occurred at the neolithic settlement of Ronaldsway, Isle of Man, where both axes of flint and of other rocks were found.[1]

Methods of abrasive working were varied. Sometimes grinding was done by the friction of the rough-out against hard projections on siliceous tufa, gneiss, gabbro, granite, labradorite, and other magmatic rocks of porous or coarse-grained structure. Such traces occur on the cliffs of Scandinavia and southern India[2] in the form of grooves with a diameter similar to that of axes found in nearby neolithic settlements.

Ethnographic parallels are known for grinding axes against hard ground that contains silica sand. For example, the Australians, who use flat river pebbles for axe rough-outs, grind them by friction in the soil.

A more rational method, known from much archaeological evidence, is rubbing against special stone plaques, usually of sandstone or some coarse-grained crystalline rock. Sandstone blocks, regarded as the most valuable abrasive agent, consist basically of quartz grains bound together by clay, lime or quartz cementing matter. In addition to quartz, sandstones contain small crystals of felspar, particles of mica and trifling quantities of other materials. Friable varieties of sandstone, rock in which the grains are held together by a clay cement, allow grinding without the addition of sand, as these natural abrasives possess the property of 'self-sharpening',[3] and plaques of this rock need only have their surfaces soaked with water. Without this intervening (washing-off) agent the abrasive surface would quickly 'salt up', that is the sharp projections become blunted and their interstices choked up by the product of grinding, so that the abrasive soon becomes unserviceable.

Grinding was carried out on abrasive plaques, but the final touching-up of the blade, as we can see by faint traces of scratches on its surface, would be completed with a kind of hone or whetstone. Whetstones for sharpening (trueing) the blade were mainly made of fine-grained lime or clay sandstones of medium or even light compactness, friable and breaking easily with a blow, and quickly wearing in use. They are commonly shaped like small cakes of soap with a recessed (hollowed) area to fit the bulge of the axe or adze and bowed shape of its blade. For sharpening an adze on the facet side of the blade, or a gouge adze, the whetstone had a different shape, or a specially prepared surface was used on the whetstone. Traces of sharpening differ markedly from traces of grinding; the striations from sharpening with a whetstone are more numerous, smaller and shorter, while grinding leaves rougher scratches which are farther apart and fairly long.

Not just axes and adzes but knives also were ground, although it is true that ground knives are less commonly found on neolithic sites. The best known are the elbow-shaped knives of northern Europe and the half-moon-shaped (or close to that shape) knives of northern Asia. Now and again ground planes (Angar area), arrowheads, slate knives (like the knife from Olen Island, L. Onega) and other tools come to light. On their surface there are traces of the two operations of abrasive work; grinding and sharpening.

Examination of the surface of adzes from Verkholensk

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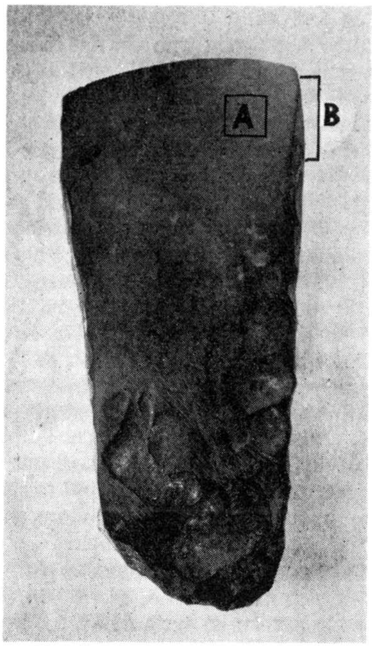
[1] R. J. Bruce, E. M. and B. R. Megaw, *Proceedings of the Prehistoric Society* (1947), pp. 137, 139, pl. XVIII.

[2] B. Foote, *The Foote Collection of Indian Prehistoric and Protohistoric Antiquities* (Madras, 1916).

[3] By this word we mean that wear on the abrasive agent which destroys the links between its grains by the friction of the object against it, so that the blunted grains fall out only to be replaced by new sharp grains from the agent.



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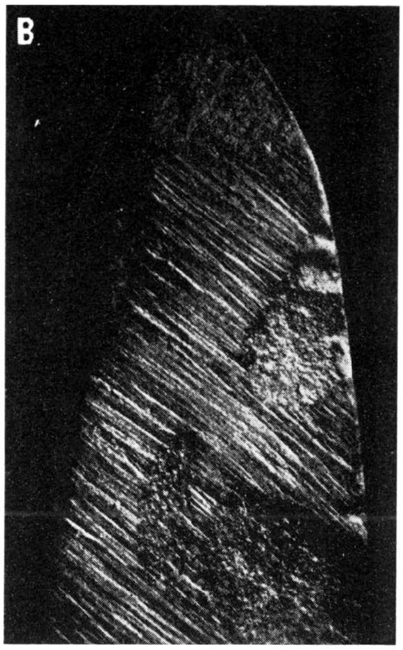

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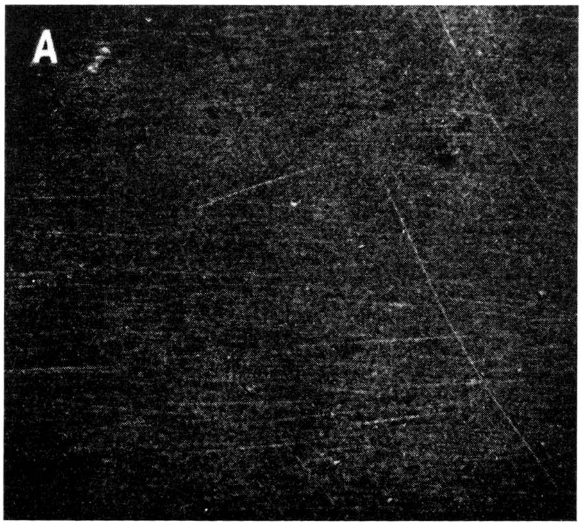

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18 *Neolithic adze from Verkholensk:* 1 *general view;* 2 *enlargement* 5 × *of part A showing sharpening by fine-grained abrasive;* 3 *enlargement of* B 5 × *showing grinding by coarse-grained abrasive.*

confirms that grinding of the rough-out and the sharpening was done with different abrasives, one coarse-grained and the other fine-grained. Micro-photographs of the corresponding parts of an adze, which had not been used after sharpening, give some indication of this (fig. 18.2, 3).

With regard to ground tools it ought to be noted that the use of the term 'polished tools' as a synonym for 'ground tools' is quite improper from the point of view of technology. Although polishing falls into the category of abrasive work it differs significantly from grinding, for the two operations imply different objectives. While grinding completes a stage of the work on the object's shape during which quite an appreciable part of the material is commonly removed, polishing, or smoothing to a lustre, as the term is understood in contemporary technology, merely affects the surface. Polishing in the strict sense of the word was never used in the manufacture of stone tools. The gloss which is commonly seen on stone tools is either due to long use (friction against a soft material, such as skin of the hand, handle or lashing), or the result of the action of physico-chemical factors, that is conditions of deposition in the layer.

j. Sawing

Cutting up soft rocks into pieces was already known in palaeolithic times. For example, in Kostenki I lumps of slate survive with cuts on them from a burin showing lines where attempts had been made to cut through. Traces of sawn grooves made with a flint saw occur on soft stone. Amongst stone objects of the Crimean mesolithic site of Shan-Koba is a flint bladelet with traces of sawing stone on it. Its hard-worn blade is blunted and dulled while the linear traces or striations are strictly parallel to the blade edge on both sides and the microscopic evidence reveals two-way movement (backward and forward).

Systematic sawing of hard rocks only developed in neolithic times, although not to a uniform degree in different areas and countries. We can examine dozens of neolithic sites in the north and south of Europe where not a trace of sawing is discernible. Nevertheless the absence of direct evidence cannot be regarded as proof that sawing was not practised. Sawing is an auxiliary and intermediate stage of stone-working, and traces of it left on rough-outs can easily be completely obliterated on finished articles (axes, adzes, chisels) by grinding, sharpening, or just wear.

Sawing of stone has important advantages over percussion in dividing stone into pieces. These are: (1) the avoidance of cracking and splitting of crystals on the rough-out's surface which are difficult to avoid in percussion work; (2) greater precision in obtaining the right surface and freedom to divide the rock in any direction and to work on any type of rock. These advantages are exploited to the full in contemporary mechanical working of stone distinguished by its high productivity.

In neolithic times man had to rely on muscular force for sawing, whose efficiency is remarkably low. So full sawing (right through) of stone was extremely rare, used only in the cutting-up of precious rocks (nephrite, jasper, jade, serpentine), which can only be flaked with difficulty. Even in these materials the predominant method of work was flaking, and sawing was confined to making grooves. Sawing of hard and precious rocks was usually employed in the manufacture of personal adornments, such as rings and disks. The cutting out and boring of rings required blanks in the form of thin plates which could be obtained roughly by deep double saw-grooves to control a subsequent break. The blank could then be ground down.

Sawing of stone in neolithic times then played an auxiliary part in dividing up the material into rough-outs. This is in marked contrast to the contemporary usage of machines, where the entire cutting up of blocks from start to finish is done by sawing.

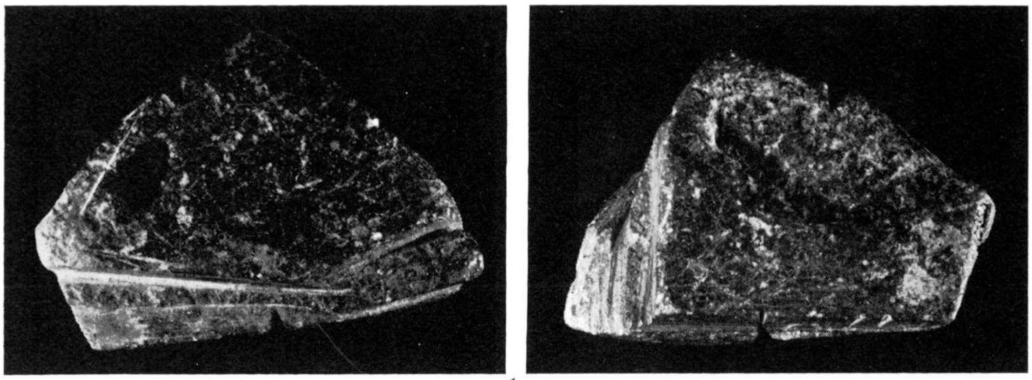
Stones of various kinds with traces of saw grooves have been found in the neolithic settlement at L. Ladoga,[1] in the Siberian sites in the L. Baikal area, in the pile-dwellings of western Europe and in many other places. Besides grooving, the stone saws themselves have sometimes been found, which for the most part consist of little sandstone or emery plaques with a sharply abrasive edge. These natural plaques have parallel lines of wear along their working edge, and similar striations can be detected in the sawn grooves on the stones themselves. There are no teeth on stone saws, for the action of sawing is due to abrasive grains which scratch the rock, and when blunted fall out, only to be replaced by the sharp particles behind them. Some emery saws, as shown by the shiny inclusions in them, contain small crystals of corundum whose hardness is 9, with which it was possible to saw even the hardest rocks. Nevertheless the process of sawing stone, even with the finest abrasives, could not be accomplished without water. The latter washes the saw groove free of worn particles, the stone dust, which quickly chokes the pores of the abrasive, and so by preventing the escape of blunted grains causes useless slipping by the saw.

When the abrasive grains were not hard enough to produce the required action clean silica sand mixed with water had to be poured into the groove. Washing the groove, it can be inferred both by ethnographic parallels and by analogy with contemporary usage in cutting stone with a frame-saw, had to be done systematically. Sawing with the addition of silica sand is commonly accomplished without a stone saw, but using instead bone, or even wood or rope. The Melanesians sometimes used rattan cord and North American Indians skin or textile string, but such sawing methods were never systematically used on stone. Bamboo splinters and flat halves of bivalve molluscs were used as saws by the people of south-eastern Asia and Oceania. Bamboo and shell saws were used like the link strips in a modern frame-saw; the angular particles of the abrasive mass cut along the strips and swept along by the saw movement the particles furrowed out the bottom of the groove.

Examination of neolithic material with traces of sawn grooves (nephrite, serpentine, and other rocks with signs of jointing) reveals that ancient man knew several rules about the orientation of sawing. The grooves often lie parallel to the fibrous lines of the rock, that is are oriented longitudinally.

The method of sawing stone with flint saws used by the neolithic population of the L. Baikal area is of considerable interest. To judge by the material from the graves prismatic blades with a retouched edge were used as saws. A relatively soft stone (steatite) with a greasy (soapy) surface was sawn up in order to make composite

[1] A. A. Inostrantsev, *Prehistoric Man of the Stone Age on the Shores of Lake Ladoga* (St Petersburg, 1882), p. 202.



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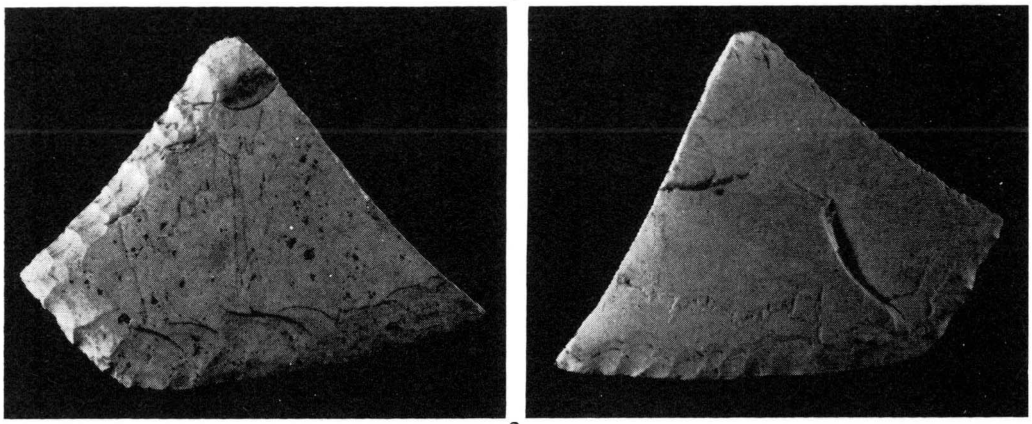

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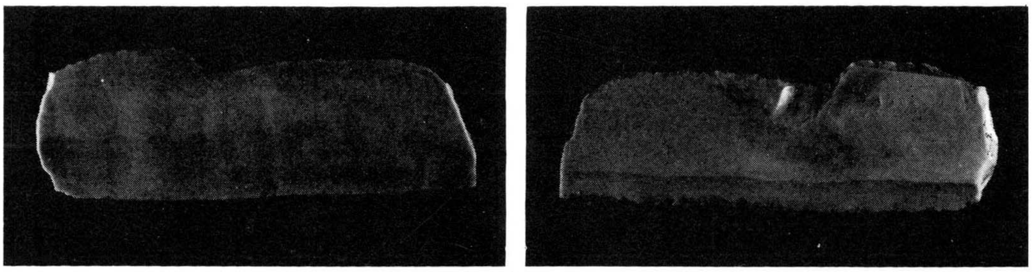

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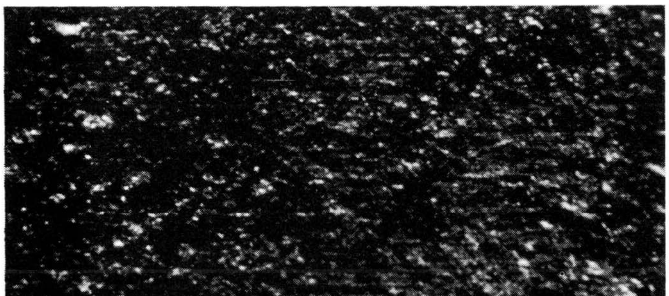

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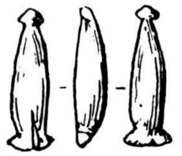

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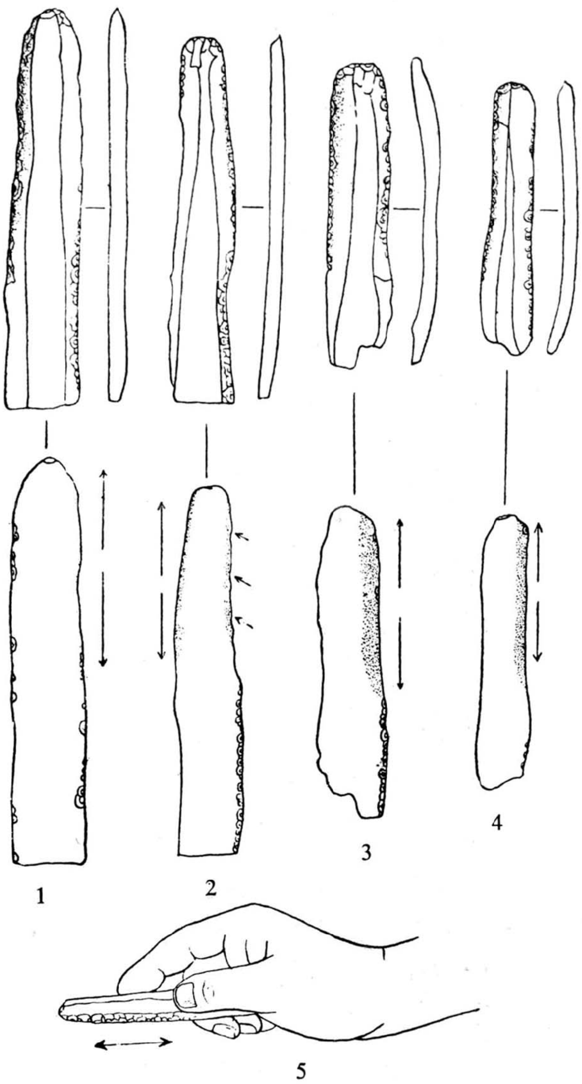
19 *Neolithic period of L. Baikal area;* 1 *piece of sawn steatite with a flint saw;* 2 *piece of tabular flint used for sawing stone;* 3 *flint saw on blade;* 4 *micro-photograph of traces left by sawing on the flint blade;* 5 *steatite weight of composite fish-hook.*

fish-hooks. From a small lump the craftsman sawed off a small piece not more than 3 cm long and 4 mm thick, which he then ground with an abrasive to produce the weight of a fish-hook with a triangle at one end and a lumpy swelling at the base for attachment. The rough-out was generally made by sawing the stone right through, for the craftsman did not care to risk spoiling the work by splitting. Traces of work on a flint saw which was found in position in a groove gave excellent opportunity to verify the characteristics of the microscopic marks of wear on a saw from use on stone (fig. 19.1, 4). In one assemblage of a flint saw, a stone with grooves and weights for fish-hooks, a saw of thin tabular flint with a convex working edge, retouched on both sides, was found. It was evidently the fragment of a flint knife re-used as a saw.

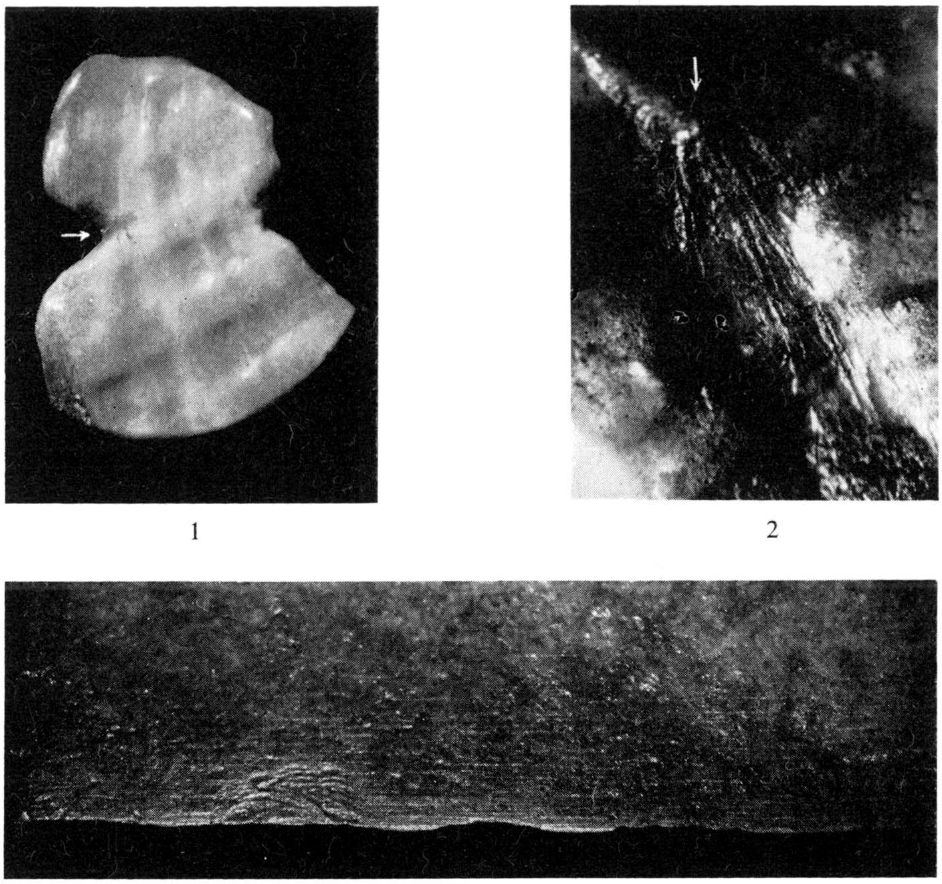
As a second example of the use of flint saws for minor work on hard material we may cite the objects from Jebel cave excavated by A. P. Okladnikov. This cave is in Turkmenistan, near the Caspian Sea. In all probability in early neolithic times a craftsman in jewellery had worked here, as is indicated by the different articles found here made from the sea shell *Didacna*, predominantly beads and pendants. Micro-analysis identified flint saws (fig. 20), drills (bow drills and reamers) for perforating beads, whittling knives, awls, scrapers, burins, strikers, grinding plaques and other tools. The inhabitants of the cave, in addition to the shells bearing traces of such work (fig. 21.1, 2), used other materials: amber, calcite, talc, quartz, tortoise bones, fish teeth and various fossils. The shells that were sawn up were evidently in a mineralized condition, as the traces of use, parallel striations, stand out sharply (fig. 21.3), which indicates that a hard resistant material had been worked. The used surface of the saws has a mat appearance.

On the problem of the existence of mechanical sawing in neolithic times there is still no definite contradictory evidence. R. Forrer made a reconstruction of a sawing machine making use of a pendulum,[1] which has found its way into many popular accounts of prehistoric culture and technology. It appears to be a witty attempt by the author to transfer into the distant past a model of the simplest machines upon which mechanical inventors were working only comparatively recently. The snag is that a pendulum swings through a chord and would saw a curved groove into the stone. No archaeological material known to us bears evidence of the use of such a method, nor is there any ethnographic analogy for such a machine among tribes at a neolithic level of culture, or even those with a higher level of technology.



20 1–4 *Neolithic saws from Jebel cave with arrows indicating the direction of the striations (in one case, 2, the blade has been used also as a whittling knife); 5 method of holding the blade reconstructed.*

[1] R. Forrer, *Reallexikon der prähistorischen, klassischen und frühchristlichen Alterthümer* (Berlin, 1907), p. 780.



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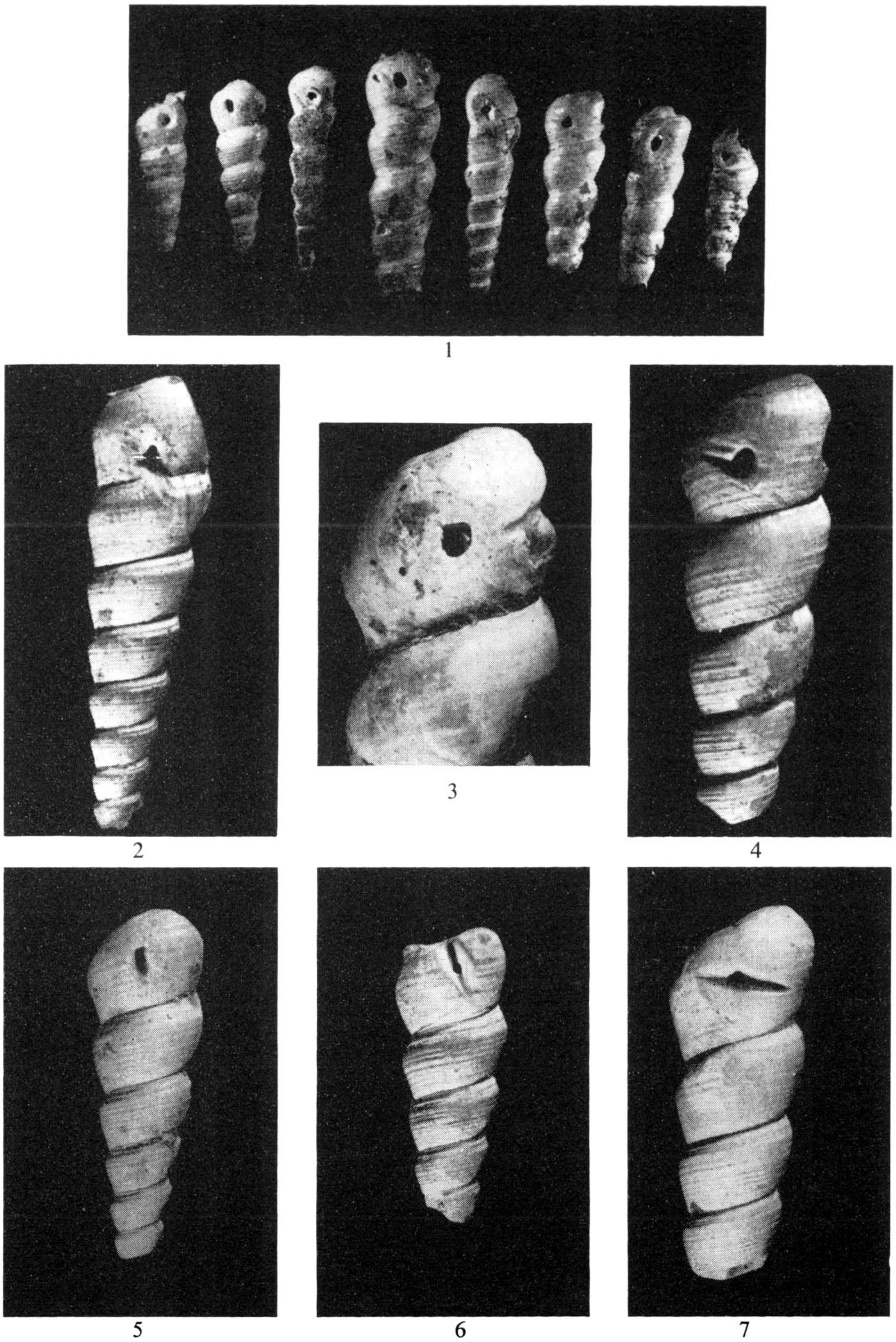
21 *Traces of sawing on shells from Jebel cave (neolithic period): 1 piece of shell sawn from both sides (3 ×); 2 traces of sawing on the shell enlarged 15× ; 3 traces on a flint saw enlarged 20 ×.*

k. Boring

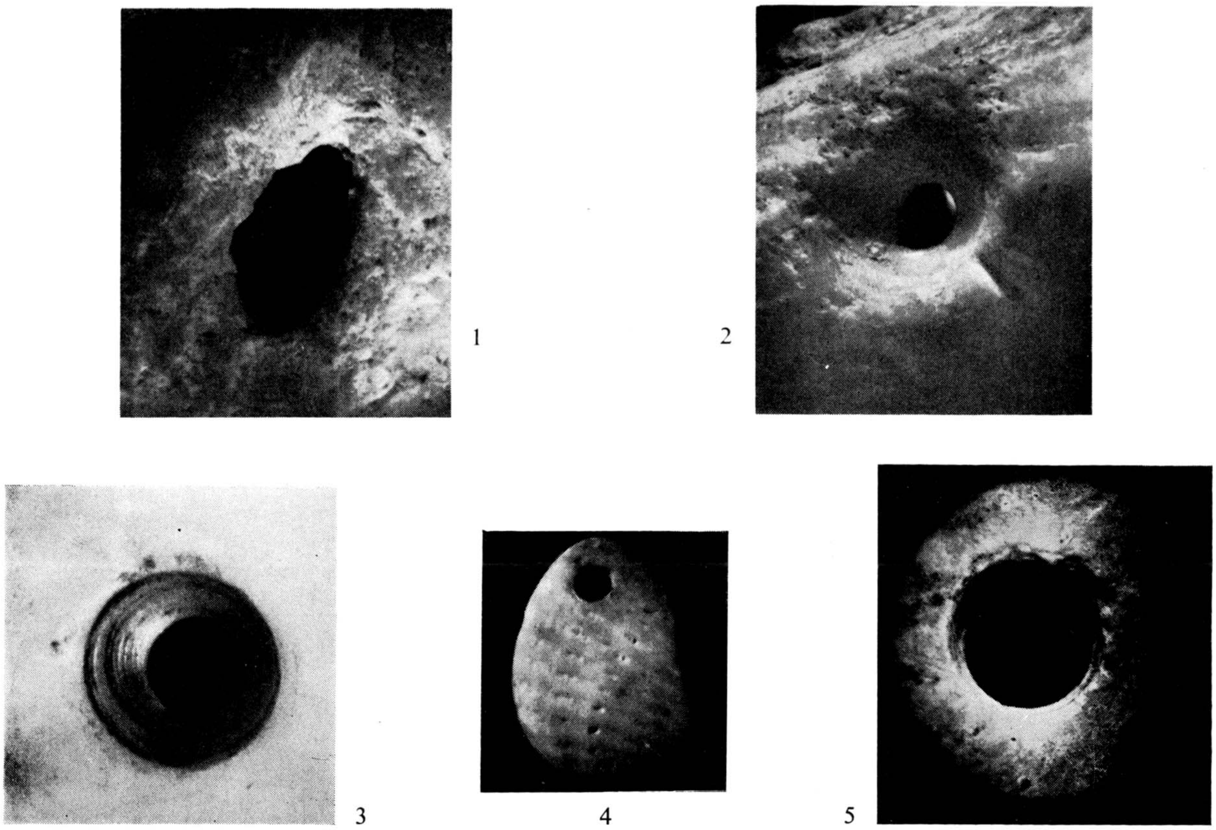
Boring held a prominent place in Stone Age technology. This is because it was not an auxiliary or intermediate stage of working stone, like sawing, but constituted a quite independent technological process. In the operation of hole-making through a material boring is frequently the final stage of the work.

Boring started in palaeolithic times. Its origin is to be traced to the need for uniting two or more objects either as working tools or as adornments to be worn on the body. Boring of stones for adornment evidently precedes its use on tools as a means of work. Originally no doubt it was done partially by a circular movement of the hand and partially by even more rudimentary methods. The perforations in fossil spiral shells found at Sagvarjile, dug by N. Z. Kiladze in 1952, illustrate this (fig. 22.1). These perforated marine shells (*Turritella duplicata*, Zinne) were found in upper palaeolithic levels associated with other stone and bone tools. About a score of shells were found in all, perforated for suspension as adornments, and their compact deposition and arrangement in a closed circle show that they had been threaded as a necklace.

Laboratory examination has shown that the perforations in the shell walls were done in two ways, by scratching through and sawing through (fig. 22.2–7). The first method is crude work with a burin; the burin angle was pressed hard on the shell surface at the desired point. Each pressure with the flint burin left a small cut 1–3 mm long and 0·5 to 0·33 mm deep, which might be more accurately called a furrow. By numerous exertions of pressure with the burin angle on a small area the shell side was cut through, and then the hole was widened and made more regular. On the shell around the holes traces of work are visible, where not worn off during



22 *Shells of Turritella from the palaeolithic site at Sagvarjile (Georgia):* 1 *collection of perforated shells forming part of a necklace;* 2 *and* 3 *perforation scratched through;* 4 *and* 5 *perforation scratched and sawn;* 6 *and* 7 *perforation sawn.*



23 1 *and* 2 *Traces of work on shells of Turritella from Sagvarjile (palaeolithic period):* 1 *perforation scratched through (8 ×) and* 2 *perforation showing scratching sawing and hand drilling;* 3 *striations (3 ×) of a bow drill on a conical perforation in a shell of Didacna from Jebel cave (Turkmenistan);* 4 *and* 5 *cyclindrical bore with bow drill in a shell pendant (42 × and 58 ×).*

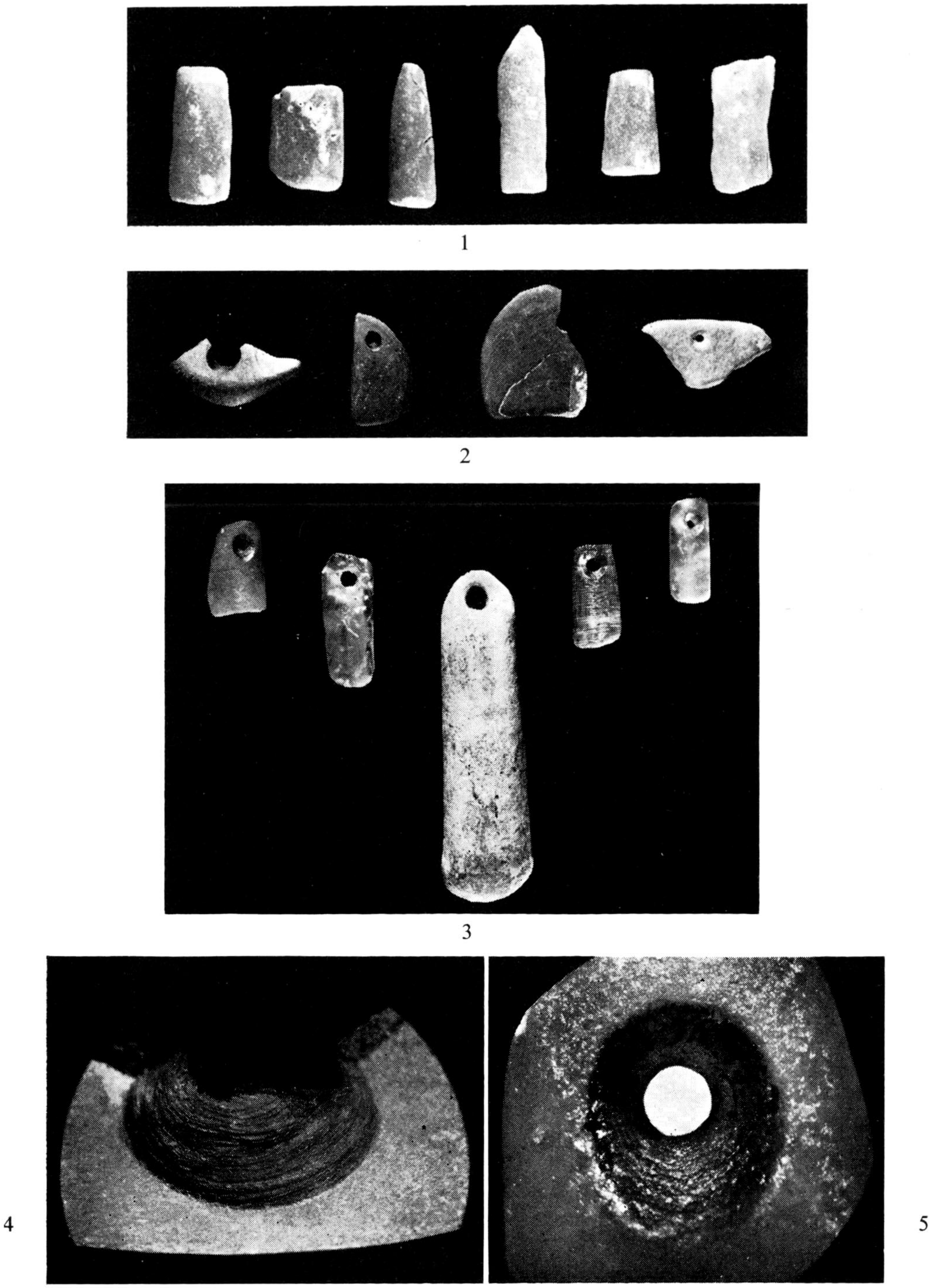
suspension on the human body as adornment (fig. 23.1). The traces have an uneven nibbled surface with irregular holes and crack lines.

The second method of perforating was analogous to that used in palaeolithic times for severing bone transversely by first sawing a groove across it with a flint blade. The groove was made with a small retouched toothed blade on the first twist in the shell either transversely or longitudinally. On certain shells the hole was obtained by a double saw groove, done evidently to enlarge the size of the hole. A combination of saw groove and a cross-scratch or cut can also be seen (fig. 22.4), where apparently it had been intended originally to use the first method to make the hole, but it was abandoned and the work completed by two parallel saw grooves.

The use of saw grooves for perforation had very limited possibilities: it was practicable only on hollow convex objects of cylindrical or conical shape (like long bones, shells, bamboo and so on). In order to widen the holes produced by scratching or sawing man of the Sagvarjile cave sometimes used a flint reamer rotated as in drilling; the roughly conical form of the perforations indicates this (fig. 23.2).

The external surface of the spiral shells has not survived uniformly. The convex parts are strongly rubbed and even polished to a shine, while in the hollows of the shells the surface is mat or its degree of shine less. This difference proves that the perforated shells had been used, that is worn on the human body against which they had rubbed in movement. Further evidence of this is the polishing of the upper edge of the perforation evidently from friction by the thread on which the shell hung.

The question of whether the shells were already mineralized when they were worked, or not, still cannot be answered conclusively. However, it deserves mention that the hardness of the shells when mineralized is very



24 *Upper palaeolithic bored objects from Kostenki XVII:* 1 *rolled pieces of belemnites;* 2 *flat pebbles of slate and sandstone bored for suspension;* 3 *four belemnites and an elongated pebble bored for suspension;* 4 *and* 5 *micro-photographs of bores in slate* (4) *and belemnite* (5) *pendants.*

high, about 5 on the Mohs scale, and so to perforate this material with very simple techniques was a difficult matter. This fact offers some reason for supposing that the shells were worked before mineralization took place. Nevertheless this kind of work should be compared not to work on bone but to that on stone, whose physical properties are closer.

The stone pendants made of soft rock found in this cave had been perforated by scratching through and had all the marks characteristic of the perforated shells. On some palaeolithic stone objects hand rotation was the single method used to achieve perforations. Biconical perforations like this occur in the slate lenses from Kostenki IV. Pendants from Kostenki XVII have been drilled from both sides, and consist of slate pebbles (long and flat) and parts of belemnites, which look like semi-transparent golden amber (fig. 24.1, 3).

Pendants were bored, as the traces show, by a relatively swift rotation of the drill, evidently fixed to a rod which was operated between the palms of the hand (fig. 25.12).[1]

Thus even in palaeolithic times we already have two methods of perforating stone: (1) a combination of scratching and sawing through, and (2) rotary drilling. The more accomplished method of drilling was rotation of a wooden rod between the palms, but its use was confined to making small perforations, which did not require considerable force. The hill tribes of New Guinea use this method at the present day to drill wood and stone without a bow-drill, although the bow is known in this area. Like the Australians the tribes employ a stone drill fixed in a wooden rod which is rotated between the palms, the stone being lashed to the rod with vegetable fibres.[2]

In neolithic times the technique of boring came on to a new plane altogether, thanks to the adoption of the simplest mechanical devices in the bow and disk drills, and also the use of hollow drilling.

The range of neolithic and early Bronze Age objects that underwent drilling is fairly extensive. These were principally things worn on the body: pendants, beads, amulets, rings, disks, imitation tools and weapons with a symbolic or magical significance. The perforations may be peripheral (in lugs) or central, and small or large (as in bangles). Among perforated tools and weapons should be mentioned: stone spindle whorls, net-weights, hammers, maceheads and battle-axes.

Drilling small holes in objects of soft slaty rock, commonly used for adornment in neolithic times, was done with hand drills of flint or other minerals of the quartz family (chalcedony, agate, quartzite). Traces of the work show that the drilling was done from both sides and in three ways. First they drilled a deep hole on one side in the desired point, and then they made a similar hole on the opposite side. Then a narrow drill (reamer) was used to perforate through, and the hole was now widened by one-way (not alternating) rotation. With alternating rotation the sharp edge of the 'reamer' would very soon have blunted. Moreover, with the hand it would have been more difficult to get a circular aperture with an alternating movement; the hand when it rotates to right and left does not make a full circle about its axis of rotation. In non-alternating and non-continuous rotation the movement of the hand would be smooth, carefully avoiding the risk of snapping or harming the side, if a hole near the edge was being drilled in a lug.

In studying the neolithic technique of drilling deviations from this arrangement will be found. Sometimes irregular perforations occur; an attempt may have been made to use a single drill, and so on. But generally the sequence set out here will occur, a sequence that was worked out in upper palaeolithic times, mainly on bone objects.

Drills for counter-drilling are not large, their short working part being conical with broad shoulders. They were made, like other drills, from flint blades or retouched flakes and their dimensions varied only slightly. They were designed for making small perforations; as regards reamers the diameter of small examples averages 1·5–2 mm, large ones 20–30 mm. An example of the first is one from Khakhsyk (Yakutia) and of the second one from Voi-Navalok (Karelia). Large reamers were used for enlarging perforations made by different means, the initial hole into which they were inserted being made by the pecking technique, by numerous light blows with a sharp stone, as we can see on the weights from Voi-Navalok.

Cylindrical boring of small holes appears in mature neolithic times with flint drills shaped like narrow, strongly-retouched rods, and the work was done not by hand but with a bow drill. Drills of this type were found in the neolithic sites of Balakhna and in Jebel Cave (Turkmenistan). The working end was worn by rapid centralized rotation and the striations when magnified formed regular concentric circles with a projection (bulb) in the middle. With this kind of bow drill borings could be made right through from one side provided they did not have to go very deep. For deep perforations drilling was done, as with the hand method, from both sides, but without the need for counter-drills (fig. 25.7–10).

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[1] S. A. Semenov, *Materials and Researches on the Archaeology of the U.S.S.R.*, 39 (1953), p. 455.
[2] H. Tischner, *Mitteilungen aus dem Museum für Völkerkunde in Hamburg*, 21 (1939), p. 47.