Section two | Stone

1. Basic minerals and rock types used in the Stone Age for the manufacture of tools

STONE, like wood, bone and antler, is one of those gifts of nature which man had at his disposal from the first stages of his existence. Stone, however, occupied a special position among these materials. Only by means of stone could man more or less extensively exploit wood, bone and antler for tools. However simple the methods of working these materials, however trifling the changes produced in the natural forms appear to be, without stone tools there was no possibility of development; the working of wood by bone, or the other way round, is a very difficult task indeed. Only in special geographical circumstances where technically suitable stone was absent, but, where instead there were such inadequate substitutes as shells, tortoise shells or fish jawbones, did man contrive to manage with very few stone tools, although needless to say at a lower technical and cultural level.

In considering the rocks which man had at his disposal for his needs we may look at the deciding factors in the choice of material. The important rocks suitable for the majority of tools belong to one mineral group, the quartz group of rocks, which have a single chemical constituent, SiO_2 (Si 46·7 per cent, O 53·3 per cent), and a number of important physical characteristics in common. Varieties within the group have important differences in colour, lustre, fracture-structure, specific gravity, external shape and size, origin, occurrence, impurities, transparency and other features. But these differences are overshadowed by a few qualities in common. Of these an important one is the extreme hardness, an average of 7 on the 10-degree scale of Mohs.[1] Only topaz (8), corundum (9) and diamond (10) are harder. An essential quality of many varieties of quartz, which determined its choice by man, was isotropism (glassy quality), that is completely uniform physical properties in all directions, as opposed to crystalline rocks.

Quartz (silica) is a very important element in the lithosphere, occupying 12 per cent of it, and occurs in a great variety of forms, being part of many rocks, forming complicated combinations, and also occurring in crystalline varieties. Quartz crystals are often encountered in the form of rock crystal. Its crystals, which may be large, are elongated hexagonal prisms terminating in hexagonal pyramids (hexagonal bipyramidism). It is characteristic of this that the individual crystals have isotropic structure and do not break down into new crystals or crystalline grains, as is the case with many other non-isotropic materials with completely ill-knit structure. This means that large crystals are very suitable material for tools. They are not often found on the ground surface and the deposits where they occur were not easy of access to prehistoric man.

Non-crystalline silica is known to us principally as flint, chalcedony, agate, jasper, Lydian stone (*lidit*), hornstone, quartzite, obsidian and other rocks with isotropic properties. Due to their isotropic structure and their consequent conchoidal fracture, when struck these rocks yield an uneven surface with receding concentric waves and very sharp cutting edges.

In the course of development of techniques in working stone prehistoric man attempted, so far as possible, to reduce the conchoidal swelling of fracture and the curvature of the flakes struck off, by a change from working by blows to working by pressing-off. By means of the latter he produced a comparatively slight concavity on the core and reduced the bulb of percussion on the flakes. This can be observed in the techniques of the upper palaeolithic, and especially in that of the neolithic, period. In addition prehistoric man found a method of altering the properties of the rock surface, which was employed in neolithic times. By grinding he could level off the rough surface of diorite, basalt and so on, rubbing away the irregularities left by primary work (flaking and retouch). Thanks to this higher level of technique man was able to make general use of minerals and rocks very dissimilar in their natural properties.

Minerals and rocks used in the Stone Age differ markedly in the micro-relief of their fracture surfaces.

[1] Talc is number 1 on the Mohs scale. If a rock will scratch another it is the harder of the two. T.

With some the surface is shiny and bright, others dull gleaming (waxen), others dull or mat, others rough, others with lumps and hollows, sharp edges and crevices and so on.

We can arrange in order of increasing roughness of the fracture the different rocks preferred by prehistoric man with details of their mineral characteristics in the following table:

1. ROCK CRYSTAL. Quartz group. Hardness 7. Specific gravity 2·5–2·8. Watery-transparent in colour. Glassy lustre. Fracture flat conchoidal. Ill-knit jointing. Crystalline form, hexagonal terminating in hexagonal pyramids. Large crystals occur in rock fissures or on the surface. Rarely used in palaeolithic times. Very simple objects of rock crystal found among the tools of *Pithecanthropus Pekinensis*.

2. OBSIDIAN (volcanic glass). Magmatic rock. Chemical composition variable. Contains 75 per cent quartz (SiO_2). Hardness 6. Specific gravity 2·35–2·5. Colour from black or dark grey to silvery, but there are other colours. Glassy lustre. Conchoidal fracture. Brittle. No jointing. Occurs in certain lavas and surface remains of volcanic origin. Used by palaeolithic man from the earliest times. Example: Chellean and Acheulian hand-axes from Armenia (Satani-Dar). Widely used in neolithic of southern Europe, America and other countries.

3. CHALCEDONY. Varieties: chrysoprase, carnelian, quartzine, sapphirine. Quartz group. Hardness 7. Specific gravity 2·65. Colour variable. Opaque. Dull sheen. Flat conchoidal fracture. Edge in fracture very sharp and thin. No jointing. Latent fibrous crystalline structure under the microscope. Occurs as crust in kidney-shaped lumps or spherolites forming in the voids of veins or fissures in magmatic rocks. Palaeolithic man rarely used chalcedony and only where there was no chalk flint. In the neolithic period it was widely used in many countries.

4. AGATE (onyx). Varieties: sardonyx, carneolonyx. Quartz group. Hardness 7. Specific gravity 2·5–2·7. Colour variable. Opaque. Dull sheen, or mat. Flat conchoidal fracture. Internal structure analogous to chalcedony. On a fractured or polished surface horizontal or concentric lines of different colours visible. Texture sometimes 'mossy' ('panoramic'). No jointing. Sharp, thin edges in fracture. Latent fibrous crystalline structure under microscope. Formed in many effusive rocks (lavas that have flowed). Occurs condensed in almond-shaped or larger forms (geodes). Like chalcedony widely used in neolithic times for the manufacture of small cutting tools and insertions in arrowheads.

5. FLINT. Quartz group. Hardness 7. Specific gravity 2·37–2·67. Besides SiO_2 (90–95 per cent) contains traces of sand, clay and other materials. Black, grey or pink colour. Opaque. Conchoidal fracture. Dull or greasy sheen in fracture. Flint can be subdivided into four types. Three of these were produced in chalk deposits: (*a*) opal-chalcedony (gezites), (*b*) chalcedony (silexes), (*c*) quartz-chalcedony flints (silexites). The fourth group, fresh-water flints, was produced in gypsums. The best qualities (by proportion of SiO_2 and flaking properties) are found in chalcedony flints.

Chalk flints had exceptionally wide use in the palaeolithic and neolithic periods in those countries where there are chalk deposits, that is strata of the Upper Cretaceous system.

6. JASPER. Quartz group. Hardness 7–6·5. Contains 70–73 per cent of pure quartz, the remainder being admixtures of clay and oxides of iron which gives jasper its varied colours (straw yellow, olive, green, cherry red, grey, raspberry). Sometimes one encounters banded or spotty jasper. The fracture is rough conchoidal, mat surface, almost rough. Flakes irregularly and technically therefore worse than flint. Occurs in rocks of palaeozoic origin. Does not contain organic remains. Used in the palaeolithic period in Asia and in neolithic times in several countries.

7. CHERT. Like jasper hardness 7–6 or less. Contains structural impurities. Usually dark grey or greenish in colour. Fracture rough conchoidal, rough surface. Flakes worse than flint and gives shorter, thicker flakes. Occurs in palaeozoic and less often mesozoic strata. Widely used in neolithic times when grinding had come into use. In Siberia and other Asian countries this material was used in palaeolithic times.

8. QUARTZITE. Silicified sandstone. Specific gravity 2·5–2·8. Colour light grey, almost white. Different impurities give this stone red, violet, cherry, greenish and other tints. Dull, glassy lustre. Rough conchoidal fracture. Fracture surface granular, slightly lumpy, rough to touch. In general use in palaeolothic times (from the oldest period) in countries where flint was scarce or absent, for example, in Asia, particularly in its southern half. Rarely used in neolithic times.

9. DIORITE (greenstone). Contains little quartz or none at all. Basic mineral constituent is felspar (75 per cent). Contains hornblende, augite and sometimes black mica (biotite). Hardness 6–5·5. Specific gravity 2·8–2·85. Grey, dark grey or greenish grey in colour. Feeble conchoidal fracture and rough surface with fine or small grains. Outcrops in northern Europe, and occurs as erratic boulders in the south, and is also known in Asia, Africa, Australia, and America. Used by palaeolithic man where other rocks absent, for example in the older palaeolithic of Central Asia (Aman-Kutan). In the neolithic period it was one of the principal materials for axes and adzes, due to its toughness. Some varieties approach nephrite in their toughness and stringy structure.

10. BASALT (trap). Young magmatic rock. Does not contain quartz. Basic constituents: felspar, pyroxene.

Hardness 6–6·5. Specific gravity 2·6–3·11. Black or dark grey in colour. Dull sheen. Rough, uneven fracture. Compact, fine-grained structure. Often occurs as hexagonal columns. Widespread in mountainous volcanic areas. Widely used in neolithic times in southern Europe, and in countries of south-eastern Asia and Oceania.

11. LIPARITE (rhyolite). Magmatic rock of tertiary or post-tertiary origin. It contains quartz, but its basic constituent is felspar. Hardness 6. Specific gravity 2·3–2·7. Colour, white to grey with yellow and red specks. Dull sheen. Rough, uneven fracture surface. Small-grained porphyritic structure. Like basalt, it occurs in volcanic areas. Starting with the mesolithic period it was used in south-east Asia and other countries.

12. NEPHRITE (actinolite). Hardness 6. Specific gravity 3·1–3·3. Colour, usually grass green, less commonly other colours and speckled. Latent crystalline, tough rock. Fibrous structure. Splintery fracture, sharp points, shimmery sheen, slightly laminated. Found in eastern Siberia (area of Lake Baikal), eastern China (Kwen-Lun), Central Asia (Pamir), New Zealand, Tasmania, New Caledonia, North America (New Jersey). Used in neolithic period as a result of the development of new methods of working stone, grinding and sawing.

The above list far from exhausts the whole range of minerals and rocks used by man in the Stone Age as material for stone tools. That would have to include varieties of shale, soft and hard, fossilized wood (varieties of opal), siliceous tufae (geyserite), granites, sandstones, ironstones and ochre. But these taken as a whole were not basic but auxiliary materials in the technology of prehistoric man. They were used as striker-stones, retouchers, rubbing stones, sharpeners for bone and stone tools, grinders for colouring matter, querns, and also as colouring matter. The short list of minerals and their properties illustrates how man only gradually took into his use stones which did not possess conchoidal fracture and great hardness, and which could not be quickly worked by the early methods of percussion, pressure and retouch.

2. Obtaining stone material in the palaeolithic and neolithic periods

THE kind of rocks used by man in the lower palaeolithic period shows that the material was selected on a basis of practical experience. In those countries (Europe, Africa) where there was flint it was chosen in preference to other rocks, because its physical properties were understood. When there was no chalk flint or flint of other formations (rarely found in open exposures), as in southern Asia, man used quartzite,[1] fossilized wood, flinty tufa,[2] rhyolite and other rocks, collecting them in the pebble beds of river banks. Many of the lower palaeolithic tools known to us retain a pebble crust on them. Lower palaeolithic finds made by S. N. Zamyatnin and M. Z. Panichkina in Armenia show that man of this time used obsidian extensively, collecting lumps of it at surface exposures.

In the upper palaeolithic period the range of material was somewhat increased. Besides those rocks (flint, quartzite and so on) out of which tools were made (knives, end-scrapers, burins, awls, etc.) other rocks (granite, sandstones, slate, calcites, ochre, ironstone) are found on the sites, out of which striker-stones, pestles, retouchers, colouring and ornaments were made.

It is difficult to grasp why even by this time with his more advanced technique man should not have obtained all these materials by very simple mining. Yet undoubtedly palaeolithic hunters searched for and collected the necessary raw material on the ground surface. When they did use flint from undisturbed strata, they dug it out of exposures in cliffs and river gorges, never making any significant excavation in these outcrops.

This is explained by the fact that in a hunting way of life collecting played an important part in the economy and did not allow settled life, and wandering did not encourage the development of techniques of extraction. In such an economy the quantity of stone in demand was still not very great.

There are no grounds for assuming the existence of trade in the upper palaeolithic period to which people could resort to get types of stone which were not found

[1] V. D. Krishnaswami and K. V. Soundararajan, *Ancient India*, 7 (1951), pp. 40–46.
[2] L. Movius, *Transactions of the American Philosophical Society* (Series 3), 33 (1943), pp. 348–50.

in their home areas. Sending specially equipped parties into the home areas of other friendly tribes is likely to have taken place, for we know of similar practices among the Australians. The diorite exposures at Mt William in Victoria and the MacDonell Mountains in Central Australia were visited by envoys of different tribes living several hundred kilometres away.[1]

In the neolithic period important changes in technique and economy took place. Hunter-fisher tribes in the northern and farmers in the southern areas of Europe and Asia began to lead a more settled life. The development of productive means and technical practices, wider economic demands and the manufacture of substantial ground tools (adze and axe) created the need for regular and permanent sources of stone. At this time most simple rock mining arose of quartzite, chert, diorite, basalt and even nephrite.

Neolithic stone mines have not yet been encountered within the Soviet Union, but workings of some kind evidently existed on the upper and middle Volga, in Karelia,[2] on the Dnestr, and in other areas where there is evidence of workshops. In Switzerland, Denmark, northern Germany, Belgium, France,[3] Sicily, and England workings were opened in the form of a shaft, hole or trench. The flint workings at Grand Préssigny, Mur-de-Barrez, and Champignolles are very widely known. In England flint was obtained from holes at Cissbury (Sussex)[4] and shafts at Grimes Graves (Suffolk) In Belgium chalk flint was worked at Spiennes (nr. Mons)[5] by shafts more than 15m deep joined by galleries, and also by holes at Strépy and Obourg. Amongst Egyptian flint mines the numerous well-shafts at Wadi-el-Sheik[6] are conspicuous examples, opened initially in Pre-dynastic times, but used as a source of raw materials in later times. S. Carr, who studied these ancient workings, observed well-like shafts and heaps of waste scattered about the desert sand. The flint was obtained here over a great area along the edges of old valleys, where rivers had flowed in pleistocene times and since dried up because of climatic changes.

Thus arose the rudiments of mining, albeit primitive, but still requiring specialized methods of work and special application of tools and devices: antler and stone picks, stone hammers, sledge-hammers, bone and wooden wedges, the simplest wooden clamps, and also forms of rock-splitting by fire. All this testifies to the new technical achievements of the period.

Commonly, in countries where during palaeolithic and mesolithic times man had had to make his tools out of poor-quality stone, in neolithic times tools appear of technically superior rocks, and also in greater quantity. An example is the area of L. Baikal where, besides the use of chert, we find axes, adzes and knives of nephrite in general use. The hard actinolithic rocks (nephrite, jadeite, serpentine) could not have been worked with palaeolithic techniques, flaking and retouch, because of their fibrous structure. The skills of sawing and grinding had had to be developed first. Nephrite is not found in Siberian palaeolithic sites even as an auxiliary material (striker-stones, retouchers, plaques), as the extraction of this rare material and its working is no easy matter. Yet Siberian nephrite is found as smooth rolled boulders at the base of the outcrop to the west of L. Baikal (Rivers Onot, Chika, Khorok, Zhara-Zhelga), where it occurs as actinolithic slate.[7] The use of nephrite of various colours for tools and ornament started in the neolithic period in China, where it was obtained from the Kwen-Lun Mountains and a variety of nephrite, jadeite, is found in Burma and in the Pamir area, probably the source for the eneolithic population of the Indus basin. In America nephrite was worked by the ancient Mexicans. In New Zealand the Maoris made nephrite axes, adzes and even clubs. Nephrite is found in the island of Tasmania, but the aborigines did not know how to use it for their tools. In Europe the neolithic population obtained nephrite (smaragdite) from outcrops in Silesia, Carynthia, and Styria, and also from the central Alps and southern Liguria.

The neolithic tools of south-east Asia are of especial interest. Upper palaeolithic sites are still unknown there. After the rough hand-axes of Java (Pajitanian), Malaya (Tampanian), Burma (Anyathian), Siam (Fingnoian), which are very inexpressive stone objects, found with remains of *Homo Soloensis* (at Ngandong), we meet nothing before the mesolithic hand tools of the Bak-Son type made of rhyolite. The presence of bamboo and shells in these countries, and the almost complete absence of flint, forced man to manage at an early date with very few stone tools or to use them only in extreme necessity. But in neolithic times, when man changed from hunting and collecting to agriculture, to the construction of pile-dwellings and the manufacture of dug-out canoes, stone axes appear in vast quantities; axes, adzes and chisels of beautiful workmanship made of coloured slates, jasper and agate. In Java slate workings and workshops occur near Punnung and Pajitan,

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[1] B. Spencer and E. Gillen, *The Northern Tribes of Central Australia* (London, 1904), pp. 175–6.
[2] M. Foss and L. Elnitsky, *Materials and Researches on the Archaeology of the U.S.S.R.*, 2 (1941), pp. 182–91.
[3] M. Boule, *Materiaux pour l'Histoire de l'Homme*, I (1884), pp. 65–75; IV (1887), pp. 5–21.
[4] J. P. Harrison, *Journal of the Anthropological Institute of Gt. Britain*, 2–3 (1878), pp. 413–30.
[5] E. Munkk, *Comptes Rendus du Congrès International d'Anthroplogie et d'Archéologie Préhistorique* (Paris, 1891), pp. 569–615.
[6] J. de Morgan, *Prehistoric Man* (Moscow-Leningrad, 1926), p. 146.
[7] A. G. Betekhtin, *Mineralogy* (Moscow, 1950).

whence the stone objects were carried throughout the whole island and even beyond its shores.[1]

In southern India near Bellary (Kapgall) is a neolithic shaft explored by B. Foote. It cuts through a substantial hill which is made up of diorite of two sorts that was extensively used in the manufacture of chopping tools in antiquity. Large neolithic workings also occur on the diorite outcrop near Anantapur. Most of the rough-outs were worked by pecking, and flakes can still be found.

Evidence for neolithic trade cannot be regarded as accidental. Tools of Grand Pressigny flint recognizable by their yellow colour are distributed throughout the greater part of France. Very often nodules of flint, lumps of diorite, basalt, chert and jasper are found in neolithic settlements that are not close to natural occurrences of the rock. For example, on the site of neolithic settlements of central India large pebbles of agate (geodes), lumps of jasper and hornstone weighing several dozen kilograms are sometimes found mixed up with potsherds and other remains. In the opinion of one Indian scholar[2] this type of material could have reached the settlement only with the aid of some very simple means of transport (sleds) propelled by human strength. Hornstone, and particularly agate, was obtained in such large quantities only in India and a few other countries. In India, however, the neolithic population rarely made axes and adzes out of this material, using it more often for small tools.

In making small unground tools (arrowheads, knife- and dagger-blade insertions, saws, scrapers, awls, burins sickles and so on) in India, as in the neolithic period in many other countries, semi-precious stones were widely used: chalcedony, agate, onyx, rock crystal, jasper, Lydian stone, garnet, bloodstone, hornstone. These occur as nodules, pebbles and even almond-shaped knobs. They are met comparatively frequently in nature but for the most part not as large objects; one can pick them up in river beds and gravels, which was what was done in antiquity. But usually they are filled with cracks and hollows due to their origin in veins, fissures and concretions of magmatic rocks. Mastery of minerals of this type is very difficult, and implies the rudiments of mineralogical technique in the neolithic period. The substantial quantity of objects of the above-named stones found in the New Stone Age allows us to appreciate the growth of technology in this period.

3. Significance of the properties of material in the technique of working stone

FOR a long time we have been aware of several essential differences observable in the external aspect of palaeolithic tools found in different countries over large areas of land. This difference has been especially confirmed by comparison of the stone tools of the countries of Europe and the Mediterranean area on the one hand and of Asia on the other. Although there are of course significant local peculiarities in palaeolithic tools in the Europe-Mediterranean area, there are several overall common characteristics: a substantial number of well-made Chellean and Acheulian hand-axes, highly finished forms of Mousterian points and scrapers. The tools of the upper palaeolithic sites of this area have very characteristic features.

We see quite a different picture in Asia. While in the Europe-Mediterranean area the upper palaeolithic tools as a rule were made on blades struck from cylindrical cores, and so had regular elongated shapes with thin sections, in Asia, for instance Siberia, the tools differ in having less expressive external features. The blades there were shorter, less regular, more massive; the different types are less clearly distinguished one from another. On the whole the stone tools of Siberia are much less frequently made on blades struck from cylindrical cores. In the mass the Siberian palaeolithic tools have a more primitive character.

S. N. Zamyatnin devoted a special article to this problem, and wrote: '. . . in the technique of stone-working in the Siberian palaeolithic sites a feature most characteristic of this period is absent, which in Europe and Africa we find everywhere and which gives the tool series such a characteristic appearance. I am referring to the prismatic core, the development of which allowed the manufacture of a new type of implement, the long knife-like flake with parallel edges struck from it, which reached a high degree of regularity and thinness at the

[1] R. Heine-Geldern, *Anthropos*, 3–4 (1932), pp. 543–619.
[2] P. T. Srinivasa Ayyangar, *The Stone Age in India* (1926).

end of the palaeolithic period. Looking at a collection it strikes one at a glance that the use of this technique was very limited, if not quite absent, in the Siberian and Chinese areas'[1]

As examples of this Zamyatnin quotes the well-known Siberian sites (Malta, Buret, Afontova Mountain), sites on the Yenisei and in the Altai mountains discovered by G. P. Sosnovsky, A. P. Okladnikov's sites on the river Lena, the upper cave at Chou-Kou-Tien and sites in the Ordos area (Sho-Tong-Koy, Shara-Usu-Gol). In all these, besides the primitiveness mentioned, the insignificant number of burins of upper palaeolithic type is noticeable, as well as the absence of end-scrapers on blades. Instead of end-scrapers there are miniature round scrapers. Scrapers in several sites are of massive Mousterian type and often tools of hand-axe form are found.

While very properly criticising the tendency of some western archaeologists to regard these differences as a sign of the backwardness of the East compared to the West, Zamyatnin gave no definite cause to explain the peculiarities, although he draws attention to three factors: material, technology and economy. He denied the essential significance in quality of material as the explanation of the special features of the stone tools of Asia. Economy also failed to qualify as a fundamental cause, for in Europe and Asia alike the main means of subsistence in upper palaeolithic times was hunting mammoth and reindeer. Nor can the characteristic differences of the Asian tools be attributed to technology, since there can be greater variations in methods of work between local areas than between the large areas mentioned. When we are dealing with a matter of differences and peculiarities of most general traits observable over vast areas of ground, the cause of the differences cannot be sought in peculiarities of the manufacturing process. This view is confirmed for example by the absence of essential differences in the character of bone tools in Europe and Asia. The peculiarities in shape of the female statuettes of Siberia, that is artistic creations, to which Zamyatnin refers, cannot be put in the same rank as peculiarities in stone tools, as the latter developed in quite a different way.

Strictly speaking the purely formal division of geographical areas by techniques of working stone, a division for which there is no full causal explanation, can be made independently of any wish of the investigator to introduce the concept of race as a factor influencing technological development. Leaving this aside, study of the problems of sources and properties of the stone materials actually available to palaeolithic man in various countries might set us on the right road to an answer.

On what serious basis can the technology of the palaeolithic population of Europe and the Mediterranean area be arranged? The predominant material here was chalk flint. This occurs in the form of nodules of varying size, from small knobs and concretions about the size of a hen's egg up to lumps weighing several dozen kilograms. Each nodule is encased in a white opaque crust which is less hard and consists of hydrated silica. Rather less commonly chalk flint is bedded in veins or layers of variable thickness from thin irregular strata of 2–3 cm thick up to 15–20 cm and more. Its different colours and shades depend on the admixture of potassium, lime, alumina, ferric oxide, and other compounds.

It was the nodular flint that mainly caught the eye of palaeolithic man in Europe. Often occurring in fresh gravel and alluvial deposits it was relatively easy to obtain and work. The geo-chemical and mineralogical properties of chalk flint, its isotropism, conchoidal fracture (especially in a fresh state, when the nodule had only just left its parent bed) allowed him to make successfully tools of a very finished appearance.

The origin of this flint is closely bound up with the marine deposits of the Cretaceous period, that is clays, shales, sandstones and limestones, and chalk itself. The latter is a comparatively rare rock but was the essential medium in the formation of chalk flint.

In the Soviet Union flint-bearing chalk occurs only in the south European areas with its northern limits in the districts of Ulyanovsk, Voronezh and Bryansk. Flint found in northern areas occurs either in the lower strata of the Cretaceous system or in strata of previous formations, and besides having different qualities was less accessible to man of the Ice Age. In western Europe Upper Cretaceous strata with flint nodules or veins occur in England, northern France, the Netherlands, Denmark, Westphalia, and also in southern Mediterranean areas. Lower and Middle Cretaceous deposits are widespread in northern, eastern and southern Africa and Hither Asia. The flint occurring in the limestones of these deposits is different from the chalk flint of Europe. Over all the rest of the Asian continent Cretaceous formations are feebly represented and deposits of Upper Chalk almost entirely absent.

In the greater part of Asia palaeolithic man was compelled to use predominantly pebbles of chert, hornstone, jasper, quartz and rhyolite, all products of erosion and weathering of ancient sedimentary and metamorphic rocks. Such material could not yield fine cores and blades, with tools made on them like the tools of Europe and north Africa in the upper palaeolithic period.

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[1] S. N. Zamyatnin, *Studies of the Ethnographical Institute*, 16 (1951), p. 13

The dependence of the morphological characteristics of stone tools on the quality and properties of the source material is insufficiently appreciated by scholars. The quality of the material formed part of the natural environment in which man lived; it showed its influence in the economic life and technology of society, impressing its mark on the types of tools, methods of work and manufacturing practices.

There is evidence of what part the character of the material plays in the choice of methods of work among backward tribes from the well-known study of Spencer and Gillen among the aborigines of Australia. They recorded that tribes of Central Australia simultaneously made and used roughly dressed tools, retouched tools of quartzite and ground axes of diorite, that is tools of both palaeolithic and neolithic form. Some quartzite knives were as rough as the Tasmanian ones, but with them were a series as fine as those from European upper palaeolithic sites. The type of tool depended on the quality of the material that the Australians had to hand.

King recorded beautiful retouched spearheads, leaf-shaped with denticulated edges, recalling Solutrean forms, made out of quartz and fine-grained milky quartzite, when such material was available. Where there was no such material the spearheads took on a more primitive aspect.[1]

Many workers, including Roth and Klaatsch, have confirmed the mixture of highly-developed types of stone tools with rough forms of eolithic appearance in Australia. In some places on the north coast and off-shore islands where there is no suitable material stone tools were entirely absent; instead the natives used shells or teeth of marine animals and kangaroos.[2] Spencer and Gillen wrote: 'If the Aranda or Varramunga should die out the future research-worker will be very confused by their stone industry with its intermixture of palaeolithic and neolithic types'.[3]

4. A study of the oldest methods of working stone

a. Percussion

PERCUSSION can be regarded as the oldest method of working stone. By this primeval striking method man changed the form of stone by deliberately breaking it into pieces with a few strong blows. In contemporary techniques of working stone this is called hewing or quartering when a lump of stone is roughly shaped. It is possible that in certain cases palaeolithic man had had to detach pieces of rock as flakes from an outcrop, for example in exposures of obsidian veins, diorites, rhyolites, quartzites, limestones and dolomites, using a heavy maul for this purpose. However, such activity, very familiar in neolithic times and representing an initial stage of mining, obviously was but rarely employed in early palaeolithic times.

Percussion techniques have interested many archaeologists and attempts have often been made to make very simple tools. Among Russian workers Gorodtsov carried out experiments on the banks of the river Istra, 40 km from Moscow, using the flint that occurs there. At the same time as his experimental work Gorodtsov made observations on the formation of natural eoliths in the cliffs of the valley, produced by temperature changes, falls of rock, water movements, and cracking by fire. He established that natural agencies very often produced traces closely similar to those left by human activity; eoliths may resemble flakes, even rough blades with signs of retouch. Similar results of the action of natural agents have been observed by Verworn, Arcelin and Breuil.

Among English archaeologists experimental work in making the simpler stone tools has been done by Reid-Moir who made hand-axes and tools of Levallois type.[5] Tools of Clactonian form have been made by Baden Powell,[6] experimenting in the field of primary palaeolithic technique. The French archaeologist, F. Bordes, studied percussion on glass, vitrified metallic slag, flint,

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[1] P. King, *Narrative of a Survey of the Intertropic Coast of Australia* (London, 1827), II, p. 68.
[2] K. Klaatsch, *Zeitschrift für Ethnologie*, 11 (1908), p. 407.
[3] B. Spencer and E. Gillen, *The Northern Tribes of Central Australia* (London, 1904).
[4] V. A. Gorodtsov, *Soviet Ethnography*, 2 (1935), pp. 61–85.
[5] J. Reid-Moir, *Pre-Palaeolithic Man* (Ipswich), p. 67.
[6] D. E. Baden-Powell, *Proceedings of the Prehistoric Society*, 15 (1949), p. 38.

obsidian and other materials. The distinguished Chinese student of Pekin man, Pei Wen Chung, carried out prolonged researches on shatter and cracking in hard rocks under the action of natural agencies. He compared the products of natural alterations with the tools found at Chou-Kou-Tien.[1]

The results of all this experimental work and observations by archaeologists of different countries have still not been drawn together, but we can say at once that the deductions of the various writers do not fully coincide on the points that interest us.

From all the work it has emerged that the manufacture of bifacial hand-axes is well within the capabilities of modern man without any experience in hand craft. Our experiments testify to this, carried out near Tikhvin in 1935 in a limestone quarry where nodules of grey flint of tertiary origin occurred.

There can be no dispute, too, that the best results are obtained by working flint nodules taken at their point of natural deposition while they still contain moisture. Nodules that have lain on the surface and lost their moisture are appreciably more difficult to work, even if they have not become cracked. From dried-out flint the flakes come off shorter and more abruptly.

All workers are agreed that some stone 'artefacts' arise from natural causes and can be very difficult to distinguish from real tools made by early palaeolithic man, especially if they are not associated with his skeletal remains, or animal bones, or other undoubted traces of human activity.

Almost all experimenters recognize that the dressing of a tool like a hand-axe must have been done not against an unyielding body (anvil or rest), but in such a way that when the tool was being struck the man held it in his left hand raised to the level of his waist or chest.

Controversy arises over what material ancient man preferred for a striker; stone, bone, wood or what else? It was the mistaken opinion of Gorodtsov that the circular stones with traces of blows on their surface often found on palaeolithic sites were not strikers, but missiles or strikers used for flint working with an intermediary. He wrote: 'My prolonged experiments have shown that circular stones are quite unsuitable for dressing and especially for refined flaking technique. Their defectiveness is due to unsuitability for side blows, while in direct, less effective blows, the point at which the blow is directed is smothered. This is why I have reached the positive conclusion that for knapping and more elaborate flaking the striker must have been elongated in shape.'[2]

The view of Gorodtsov to some extent coincides with the opinion of Bordes, who also assumed elongated strikers, but with this difference, that he often worked not with stone strikers but with wooden ones. He believes that man made tools only of Chellean and Clactonian types with stone strikers. Tools of Acheulian type, in his opinion, were made with wooden strikers, and the part played by these grew as techniques of stone-working developed.[3]

Bordes based his view on his own experiments. Probably unstable materials (glass, slag) could be worked, albeit with difficulty, with a hard wooden striker of short length used like a stick. Some positive effect may be produced by striking with a wooden tool on a material such as metallic slag due to the physical law about the power of the force in movements of high speed. As regards flint its working undoubtedly required, not only great rapidity of movement in the blow, but also physical effects which a wooden striker cannot produce.

Baden-Powell supported this point of view, and after testing wooden strikers ('the stick technique') rejected them in favour of quartzite pebbles and rolled flints, believing the latter to have been the best tools for knapping. He selected egg-shaped pebbles 5 to 7·5 cm long for his tests.[4]

Gorodtsov did not test wooden strikers in his experiments. Our own trials with the 'stick technique' have also met with very ill success. Strikers of oak, birch, beech, and box quickly disintegrated into fibres from blows on flint, and no longer being serviceable had to be constantly replaced. Some effect was produced only by using them on the edge of a flint already dressed with a stone striker, which could be better called percussion retouch. Initial working in which the pebble or nodule has to be broken up into quarters, its cortex removed and substantial flakes struck off, was quite impractical with this implement. Wooden and even bone strikers were broken and splintered by strong blows on flint.

Dressing of flint nodules or any other rock was done from the beginning to the end of the Stone Age by means of striker-stones. These belong to that small category of tools which very often were not worked themselves, being simply ordinary river pebbles, elongated or flat in shape. The characteristic traces of wear for striker-stones, which distinguishes them from other tools, are signs of battering observable on their surface. The working part of the striker-pebble commonly has an uneven surface with deep scars and chip-marks. As an example of such a tool we may cite the striker-stone from the Mousterian site of Volgograd on

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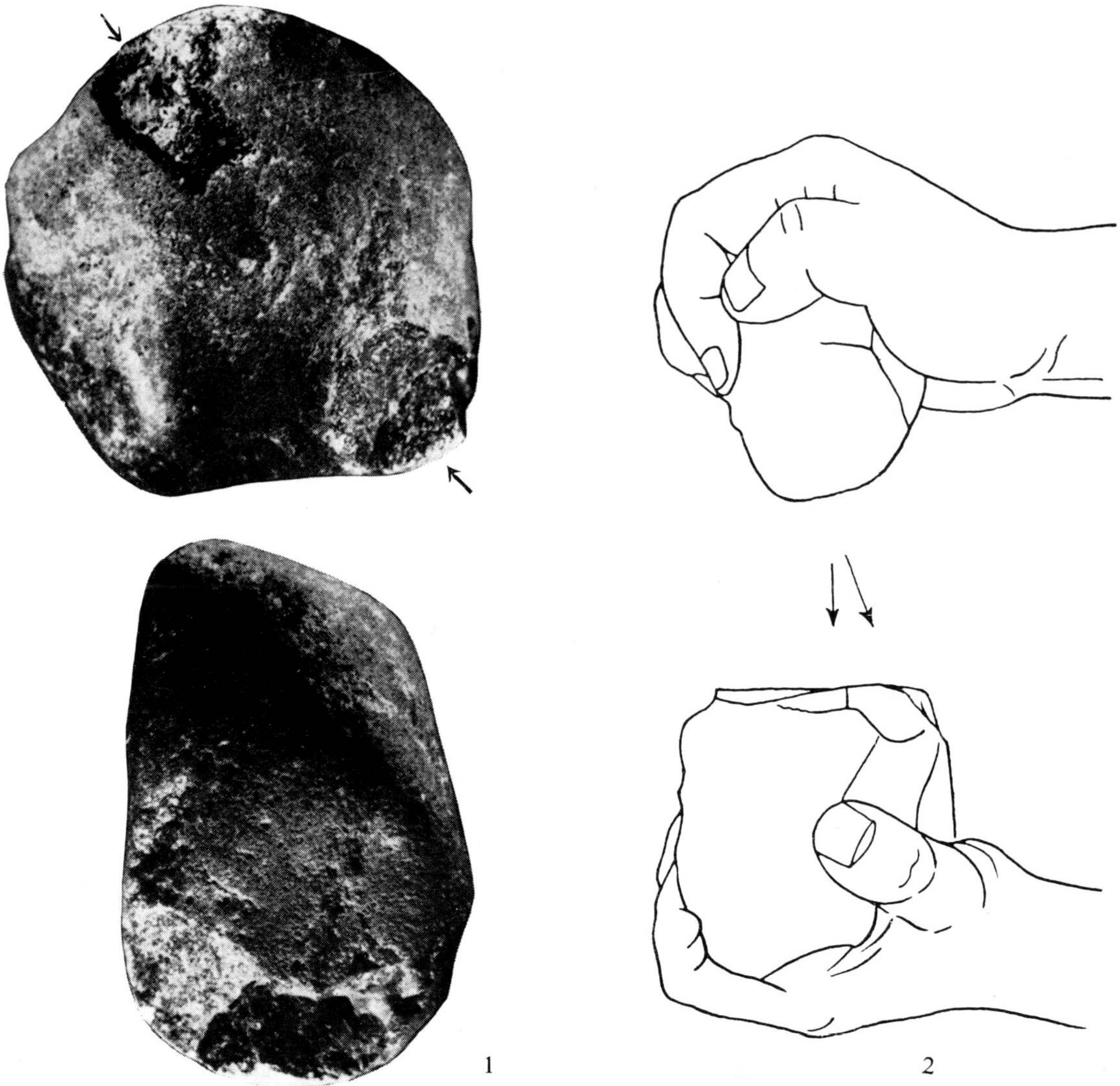
[1] Pei Wen Chung, *Revue de Géographie physique et de Géologie dynamique*, 9 (part 4), p. 54.
[2] V. A. Gorodtsov, *Soviet Ethnograpny*, 2 (1935), p. 73.
[3] F. Bordes, *L'Anthropologie*, 51 (1947), pp. 3, 28, 29.
[4] D. E. Baden-Powell, *Proceedings of the Prehistoric Society*, 15 (1949), p. 38.



4 1 *Striker-stone from Volgograd with scars from use indicated by arrows;* 2 *method of use of a striker (reconstruction of flaking a core).*

the Volga, dug by Zamyatnin in 1952–4. This quartzite pebble of slightly flattened shape weighed about 400 hectograms. Its surface retained several scars produced by hard blows, and on parts traces of a large number of light blows (fig. 4).

River pebbles alone, of course, were not used as strikers. Beginning in the upper palaeolithic period, and possibly earlier, together with pebbles, worn cores were also widely used as strikers. These tools, whose surface is extensively starred, are well known in the upper palaeolithic, used not only as strikers but also as retouchers and pestles. They have a circular, often spherical, shape and commonly are smothered with traces of blows, pressure, friction and other kinds of activity. For precise definition of the function of each implement of this kind therefore, careful examination of the surface is necessary. So Gorodtsov's view that the spherical flints were used as missiles or strikers with an intermediary cannot possibly be sustained, because the objects in question bear traces of blows and pressure on hard material, which could only have been flint.

The manufacture of Chellean and Acheulian hand-axes has been fully carried out with a striker-stone. Experimental manufacture of the tool under laboratory conditions shows that the dressing can be done without any means of support (anvil). The nodule of flint, quartzite or obsidian was held in the left hand at waist- or chest-level. This was done to avoid a bounce blow from the side of the support producing a flake on the nodule in the wrong place. The left hand at the time of the blow 'gave like elastic', thanks to which the force of the blow nearly always was directed to the right spot. A modern mason or bricklayer goes about it in the same way when he has to dress a brick or cleave it at a required point. However, the danger of a bounce blow only arises if the object is on a stone rest. Bone, wood and especially earth were probably used by man for support during dressing. We have to remember that a more or less elastic and plastic support could only be used successfully when the stone tool was very light and could not be worked in the hand, or conversely if the nodule or rough-out was too heavy. The former would be required for Acheulian and Mousterian points, bifacially worked by percussion retouch on a bone anvil, and the second for 'gigantoliths' and some large tools probably worked on the ground.

Percussion as a method of work was widely used in the Stone Age. The breaking up or cleaving of stone into pieces can be regarded as its crudest form, just to get sharp lumps and flakes suitable for use as tools. From this arises striking or flaking off a part desired for use from a large nodule of flint or piece of obsidian. Connected with dressing is the removal of the cortex or pebble crust from the rock and cleaning it of patina and all other types of accretion and impurity. These methods of working stone by blows led to the Chelleo-Acheulian technique of making bifacially-worked hand-axes trimmed by rough retouch. Vayson attempted a rational classification of these tools based on the shape of their working part.[1]

There are two views on the problem of the origin of hand-axes. On one view the hand-axe arose to meet the need for a tool that would be suitable for various purposes (chopping, cutting, scraping, digging and so on). Such a tool could not be made in the first instance in any other way than by bifacial dressing if there had to be united in one tool the necessary weight for blows, a point, two sharp edges and a thick butt. According to the second view the hand-axe is merely a touched-up core of the lower palaeolithic, arising from a developed technique of detaching rough flakes from a nodule (of flint, quartzite or obsidian).

In our view posing the problem of the origin of hand-axes without getting clear in our own minds what it is that we want to know about the oldest tools makes the matter too theoretical. Of course, almond-shaped hand-axes are not the products of some idea that suddenly struck Chellean man, for they must have arisen gradually from prolonged experience; the manufacture of hand-axes presupposes a fair degree of experience in knapping stone. These considerations, as well as the 'associated' tools,[2] consisting of rough flakes with scars and facets on the edge, indicate that hand-axes were by no means the only tools of the period.[3] The character of the tools of Pekin man testifies to this.

Mousterian methods of working constitute in essence a new achievement in knapping. The creation of these methods was a step forward in 'the economy of labour used and then economy in material'.[4] The laborious task of bifacial dressing was replaced by striking off a large prepared flake, which, it is true, then required retouch, but it was a completely different object with fine edge and point thanks to its narrow section. Bifacial dressing could produce one or two tools of hand-axe type from one flint nodule; the new technique allowed you to make as many points and scrapers, as flakes or leaf-shaped flakes you could strike off the nodule.

Baden-Powell, who carried out experiments over the course of several years on working stone, demonstrated some aspects of the technique of flaking which have been confirmed by our own work. In his tests he used pebbles 12–15 cm long. He clove the pebble into two halves, so that he got two cores, each with one side flat (the broken surface) and one with the bulge of the original pebble. The flat side formed the striking platform with flakes being struck off all round the edge. The first flake struck from the core had cortex over its back; the second flake had two surfaces divided by an arris, one being covered by cortex, the other part of the scar of the first flake. The third flake was struck off on the edge of the core between the scars from the first two flakes. It had two or even three scar arrises on it like a leaf-shaped blade, but no cortex.

Baden-Powell's blow on the very edge of the platform yielded a very thick flake. The angle of declension of the platform which was turned towards the operator was

[1] A. Vayson, *L'Anthropologie*, 30 (1920), pp. 441–90.
[2] V. Commont, *L'Anthropologie*, 19 (1908), pp. 527–72.
[3] M. Z. Panichkina, *Materials and Researches on the Archaeology of the U.S.S.R.*, 39 (1953), p. 31.
[4] G. A. Bonch-Osmolovsky, *Chelovek*, 2–4 (1928), p. 182. The same can hardly be said of contemporary Levallois technique which was very extravagant of material. T.

45° off horizontal. The angle of the blow varied from 80° to 140°. Before selecting a striking point the overhang on the core's edge and sharp angles formed by the previous blow had to be struck off. The flaking was done without resting the core on a hard support (anvil), just as in flaking hand-axes (fig. 4. 2).

Percussion dressing arising in its simplest form in pre-Chellean times played a basic part in lower palaeolithic times. Later it was used in the initial stage in preparing the cores from nodules in upper palaeolithic and mesolithic times, in making the rough-outs for axes in neolithic times, and also in a different kinds of touching-up, which required a technique of blows.

By way of example of the prolonged use of the most simple methods of working stone we may cite the settlement of the Tripolye culture excavated by T. S. Passek at Polivanov Yar. This illustrates how the development of technique enriched society with new methods of work in which old methods frequently were applied where necessary. The nearby exposures of flint gave rise to a workshop on the site for primary working, as well as for the manufacture of objects.

The inventory of half-finished and completed items found in the workshop area is rather large, and so we limit ourselves to basic objects:

(1) Nodules of grey flint 4–5 hg in weight, partly or quite freed from cortex.
(2) Cylindrical cores of various sizes with scars of blades removed.
(3) Unworked blades.
(4) Worked blades (end-scrapers, awls, reamers, reaping knives, blades of composite sickles, dart and arrowheads and so on).
(5) Striker-stone and pestles.
(6) Flint retouchers of various forms.
(7) Rough-outs for adzes and axes with or without grinding; fragments of rough-outs broken in dressing.
(8) Ground axes and adzes.
(9) Axe and adze sharpeners.
(10) Sharpener slabs for bone tools.
(11) Mortars for pounding hard materials, and so on.

Many of the tools mentioned showed signs of long use.

The flint nodules after extraction from their original deposit were subjected to preliminary flaking to remove the cortex, which has a spongy structure and contains crystalline impurities that sometimes penetrate the flint below. This was roughly flaked off by blows with a heavy striker-stone leaving as a nucleus the preliminary stage of a working core. After this the quality of the material and the possibility of further work could be assessed.

Rolled river pebbles of a different rock were not employed as striker-stones at this site, but instead, flint cores which had already been used for flaking. As evidence of this were the traces of blows on the surface of cores, forming a starred pattern due to the intersection of numerous cracks. The cores used as striker-stones had differing shapes: oblong, circular and discoidal. The oblong ones were commonly used at both ends, the circular ones over all or most of the surface, whilst the discoidal ones remained unused on their edges where they had been held, and rubbed or polished by the fingers. Thus the cores from this site had been worked themselves by other cores. The patches of starring on some of the oblong cores were quite uneven, with projections and angles, crushed or even destroyed, which must be the result not of blows but of pushing or pressure. Such traces are very similar to those on the edges of the side pressure areas on cores from the upper palaeolithic site of Timonovka, regarded by us as retouchers (fig. 5.1–2).

Certain of the medium and larger strikers retained traces of another kind on their worn surfaces, where the rough starring characteristic of strikers had been rubbed and smoothed. So it may be assumed that these were pestles for grinding and pulverizing some kind of hard matter, possibly an additive in pot-making. Some of the larger examples had been used as crushers.

Consequently at Polivanov Yar we can regard it as established that cores were extensively used as manufacturing tools. Very similar facts were observed at Luka Vrublevetskaya.

Besides core retouchers, Polivanov gave us a large number of retouchers for use in fine pressure work on blades. These tools are large narrow flakes with sharp or blunt ends. Bifacially worked retouchers shaped like spearheads were also found, which possibly actually were broken spearheads re-used as retouchers.

The use of cores for pressure and strike retouch was evidently more or less characteristic of the whole Stone Age. In the northern forest zone of the Soviet Union, at points very isolated from the southern late neolithic Tripolye culture, one sees just such a simple technique of primary working of flint tools with its rather palaeolithic character.

Krizhevsky found evidence of a workshop at Gorodishchenskaya Mountain near Rzhev. Among his material we recognized cores with all the signs of use as retouchers (fig. 5.3, 4). They have inclined striking platforms on the rim of which is clearly visible a dull, rough-to-the-touch part produced by light blows and pressure on flint. On some cores this rim has a rough almost starry structure (fig. 5.4). In the use of these retouchers blows evidently preponderated over pressure. With these were found proper striker-stones, one of which is interesting in that traces of use show themselves in two ways (fig. 5.5). It is a massive flake of irregular shape with a patch of cortex on its surface. Its edge (AB) has been battered and blunted by blows. On the convex side and visible even to the naked eye is a second patch of scars from lighter sliding blows (C). These scars were caused as the striker-stone after each blow fell away, knocking its bulgy part against the object being worked. So before us was an interesting document revealing in great detail the technique of knapping stone, and confirming that a rough starred surface is the functional sign of a striker-stone.

b. Retouch by direct blows, with an intermediary, and counter retouch

The working of tools in flint and similar rocks passed through various stages of development. From an original shattering of a pebble or nodule with the object of getting fragments with sharp edges, gradually the objective altered to dressing the stone into the shape of a Chellean hand-axe. The number of necessary blows in making these increased. The transition to retouch meant essentially the creation of a new finer method of shaping tools, requiring many light and more frequent blows to remove small parts of the surface of the tool being made.

Consequently percussion retouch is one of the methods of secondary working of stone tools with a striker-stone, a more developed kind of dressing. Yet it is essentially different from pecking, which is an even more developed, finer form of dressing.

Flake retouch can be applied only in making tools of flinty rocks and then only on the edge, while pecking was employed predominantly for secondary work on granular rocks, and could be used at any point on the worked object's surface. The latter also differs in the direction of the blows which fall at right-angles to the worked surface. In flake retouch the striker-stone will fall at all angles from 0° to 90°, but always on the edge of the object worked.

Working by retouch arose very early, for obviously it was already in use in the lower palaeolithic period. At all events by Acheulian times retouch was already a mature method of stone-working. The hand-axes of Acheulian type found at Satani-Dar (Armenia) by Zamyatnin and Panichkina have retouched edges, and the tools of Pekin man bear numerous traces of retouch.

This method of completing work on stone tools was extensively used in the later phases of the Stone Age, as it was a simple way of touching-up a rough-out before grinding, or blunting a sharp edge, or in other operations.

In later times retouch was commonly done not with a single striker but with an intermediary, such as a stone or bone rod. Retouch with an intermediary has some advantage over simple retouch; a blow with a striker-stone on a flint does not always remove the precisely desired part of the struck surface, for the working part of this tool has a large surface. An intermediary with a narrow point made it possible to flake off a small part of the worked object at a more specific point.

We understand the use of an intermediary in stone-working only from ethnographic parallels, in particular from the evidence collected by Holmes in America and several other writers. The object has still not been identified in the archaeological material, although its existence in neolithic times is hardly open to doubt.

There is some reason to suppose that retouch with an intermediary was never widely employed in the Stone Age. Stone, wood or bone which could have been used as intermediaries were not sufficiently resilient. A wooden stick quickly splinters and becomes unserviceable. A stone intermediary also loses its shape at the end from the blows; moreover, it is very difficult to make and frequently breaks. A bone intermediary made from a long bone is the best of the three, but it is split by blows owing to its lamellar structure.

In counter retouch a wooden baton is used to strike the object being worked, which knocks its edge against a stone upon which it is resting, and so a tiny fragment of the object flies off. Counter retouch requires little physical force, as apposed to pressure work, and produces a steep retouch comparatively quickly on the edge of the blade or flake. It can be used to make a notch, or take off an angle or projection or a large part of the object being worked or trimmed.

We know about this method from ethnographic evidence. The effectiveness of counter retouch, as well as of retouch with an intermediary, has been proved by many archaeologists, including ourselves, but convincing traces on the so-called bone anvils, that really show use in counter retouch, are still not known to us. Bone anvils with traces of use usually were pressure retouchers or rests and supports in percussion retouch. Experiment has shown that successful counter retouch can be done with a stone anvil, such as a pebble.

Counter retouch had a snag in that it commonly gave rise to accidental, unforeseeable flaking, chipping and cracking. So it could not have been used in all forms of fine retouch, especially in the manufacture of shaped objects like barbed neolithic arrows or flint sculptures.

c. Flaking by pressure

Amongst methods of working stone the flaking of blades off prismatic cores can be regarded as the least studied. It has long been known to archaeologists that the flaking of prismatic blades was done not by blows but by pressure. However, the details have remained uncertain in spite of the fact that many students have been interested in blade-making.

The development of blade flaking constitutes a crucial point in the history of stone-working, for without it ancient technique would have been in a cul-de-sac. Its study is made difficult by the fact that blade flaking from