EVOLUTION OF THE HUMAN HAND AND THE GREAT HAND-AXE TRADITION

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The hand-axe is both the earliest and the longest persisting of standardized stone tools. They present a continuous history of one tool type from the first to the third interglacial periods, a span of at least 200,000 years and perhaps as many as half a million. Equally remarkable is their geographical range which covers all of Africa, western Europe and southern Asia--fully half of the then habitable Old World. Aside from differences in the local stone that was utilized, hand-axes from this whole area are constructed on the same plan and show no clear regional typology.

Other tool types occur with hand-axes: utilized flakes are found at all levels, and in the later half of the sequence there are cleavers, ovates, trimmed flakes and spherical stone balls. Throughout the sequence, however, the basic design of the hand-axe continues with its intended form apparently unchanged. We thus have a continuous record of man's attempts to produce a single type of implement over most of his tool making history. (See Figure 1.)

Recent discoveries of fossil man have made it increasingly evident that biological evolution of the human body was also in progress coincident with the development of ancient stone tool types. While the exact time of appearance of Homo sapiens is still in some dispute (see Stewart, 1950 and Oakley, 1957), it is not now seriously maintained that the earliest tool makers necessarily approximated the modern or even the neanderthal morphologies. The possibility thus becomes evident that some meaningful interrelationships might be found between the anatomical evolution of man and the development of the early stone industries.

The Great Hand-Axe Tradition is conventionally divided into two major phases, the earlier Abbevillian (formerly called Chellean) and the later Acheulian, on the bases of typology and stratigraphy.

According to most authors, the Abbevillian tools were being made during the first interglacial period (Breuil, 1939 and Oakley, 1950). Leakey (1953), who uses the term Chellean, puts this phase in the Kamasian pluvial which he equates with the second, or Mindel, glaciation. Braidwood (1948) places Abbevillian tools a bit later--in the Mindel glaciation and the earliest part of the second interglacial. The earliest reported datings are from raised beach deposits in Morocco where the first axes apparently just pre-date the Günz glaciation (Oakley, 1950). Variations in the proposed beginning dates depend upon interpretations of geological data, and also, it is by no means certain that the men who made these tools settled all parts of Eur-Africa simultaneously. Variations in the proposed ending dates for the Abbevillian depend both upon the geological data and upon the typological criteria employed to distinguish Acheulian from Abbevillian techniques.

PLEISTOCENE STONE WORKING TRADITIONS

AND RELATED FOSSIL HOMINIDS

	EUROPE AND AFRICA (Hand-Axe Tradition)			EAST ASIA (Chopper-Chopping Tools)
	Neolithic			Neolithic
UPPER PLEISTOCENE	Upper Paleolithic	Homo sapiens		
			Würm Glaciation	
	Mousterian (Final Hand-Axes)	Neanderthals (Human hands)		
MIDDLE PLEISTOCENE			Riss Glaciation	
		Swanscombe (no data on hands)		
	Acheulian			Sinanthropus (apparently human hands)
		Atlanthropus (no data on hands)		Pithecanthropus (no data on hands)
LOWER PLEISTOCENE		Heidelberg (no hands)	Mindel Glaciation	
	Abbevillian			
			Günz Glaciation	
	Pebble Tool Cultures	Australopithecines (semi-human hands)		

Figure 1

According to Watson (1956, p. 30), "Abbevillian implements have deep biting scars left by flakes with prominent bulbs of percussion. Owing to the considerable concavity of the scars the edges have an uneven, approximately zig-zag-line, and consequently the outline of the implement tends to be irregular." He describes the Acheulian tools as having shallower, flatter flake scars and a straighter edge, giving a more regular outline to the implement. Essentially the same comparative criteria are described by such workers as Coutier (1929), Bordaz (1959), Oakley (1950) and Leakey (1953). All of these indicate that the deep flake scars are produced by striking stone against stone, while the flat shallow flakes are struck off with a wooden billet, a soft cylindrical stone or a bone.

One might expect that the difference between the stone and the wood techniques would tend to divide all finished hand-axes into two neatly definable groups, but this is not quite the case. Leakey (1951) reported that in his excellent succession of tool types from Olduvai Gorge, the best made implements from every level show only a gradual refinement of workmanship as one progresses upwards, and the transition from Chellean to Acheulian cannot be pinpointed. The Somme valley sequence shows the same kind of gradual refinement from earlier to later assemblages within both the Abbevillian and Acheulian phases (Breuil and Koslowski, 1931, '32 and '34). Clark (1959) describes a similar gradual improvement in workmanship over time in the Stellenbosch, of South African hand-axe sequence.

Generalizing on this, Leakey says (1954, p. 131): "During the first half of this [the Chello-Acheulian] period only the hammerstone technique was employed, although naturally even with this technique there was a slow and gradual improvement in the types of tool that were made."

Similarly, Oakley (1954, p. 27) notes that: "Chellean and Acheulian implements collected from successively younger deposits in any one region show on the whole a gradual refinement of workmanship . . ."

The object of this paper is to introduce a theory to account for the improvements in the Abbevillian phase of the tradition, that is, when hand-axes were being made by striking stone on stone and before the cylinder hammer technique was used. During this time there was apparently no change in the fabricating tools employed, in the methods followed or in the intended form of the finished implement--nevertheless the hand-axes improved. The later Abbevillian implements appear to require no new inventions or techniques and they are rather quickly and easily made, as I and many others have found out by personal experiment. This being the case, one might wonder why the earlier Abbevillian tools were so much more poorly made--what kind of limitation was imposed upon the makers? Or, putting the question the other way around, since the earlier people were able to produce only very crude hand-axes, what sort of change enabled their descendants to produce better ones?

A change of this order over a span of some 100,000 years or more is strongly suggestive of the rate of biological rather than cultural evolution. In the many published descriptions of Lower Paleolithic stone working techniques, one cannot find any suggestion that the ancient artisans were in any way different from ourselves in their <u>physical</u> tool making abilities. Where illustrations are offered, the form of the modern human hand is reproduced; where detailed positions of the digits are described, the reader can always duplicate these postures and motions with his own hands. It is sometimes suggested that mental limitations in early man may have affected his tool making abilities. This is no doubt correct, but the additional possibility of physical limitations in his hands seems not to have been considered by prehistorians.

This possibility has been considered by some physical anthropologists. The idea of a brachiating heritage for man has prompted the suggestion that manipulation of tools may have been a factor in the evolution of the human hand. This is most clearly stated by Washburn (1959, p. 24):

> I suspect that a late Pliocene brachiating ape was the ancestor of the Pleistocene Australopithecines, and that the structure of the hand which made tool use possible was evolved at that time. . . .
> However, if an early Australopithecine with an ape-like hand had started to use tools, selection would have changed its descendants. Once these animals became bipedal ground dwellers, using tools a little, then selection would favor shorter fingers and larger thumbs.

This view is quite counter to the usual assumption that the present form of the human hand is primarily a retention of the primitive primate grasping organ. Rather, Washburn thinks that many details of the anatomy of the hand are recent developments in response to the cultural needs for the making and using of tools.

In this paper it will be shown that the evolution of the hand may be reflected in the forms of early tools. Personal experimentation has indicated that the manipulative limitations of the brachiating type of hand impose certain specific restrictions on the handling of stone for the manufacture of tools. The type of stone chipping that is possible when one approximates these limitations is essentially that of the early Abbevillian. The typology of the earliest hand-axes may thus have resulted from the physical characteristics of an ape-like hand. The late Abbevillian or early Acheulian hand-axe, on the contrary, seems to require the full use of the modern type of human hand for its manufacture.

At this point it is pertinent to review the evidence and arguments as to whether man did in fact have a brachiating ape as an ancestor.

In spite of the increasing amount of fossil primate material being discovered, most of the evidence as to the nature of man's immediate precursor still comes from observations on the anatomy and behavior of living primates. This evidence has, from the beginning, indicated to most observers that man's closest relatives are the anthropoid apes--hence their name.

Ideas nevertheless have been put forward that man was derived from some lower primate at some remote period in the tertiary (Boule, 1911-13; Wood-Jones, 1916; and Osborn, 1928). These views now have been rather thoroughly discredited by increasingly detailed evidence showing man's close kinship with the great apes (dentition, serology, growth patterns, personality). The most common reason for wanting to separate man's ancestry from that of the great apes has been a consideration of the superficially great differences between their locomotor apparatuses, especially in the hands. The ape's hand is primarily a suspensory hook designed to bear his body weight in the trees. His fingers are long and strongly developed, while his thumb is comparatively short and weak. Such a hand is considered to be an adaptation to brachiation. These modifications are not found in the human hand, hence it has been called a primitive type. It has then been argued that, assuming evolution to be irreversible, man could not have had a brachiating ape as an ancestor.

The problem of reconciling man's type of hand with his demonstrably close relationship to the apes has evoked several solutions. Le Gros Clark (1956 and 1959) and Oakley (1954) have suggested that man is indeed a close relative of the apes, but separated from them, perhaps in the Miocene, just about the time that brachiating specializations were first developing in the ape line. Such a common ancestor, both indicate, would have been a generalized higher primate capable of terrestrial, quadrupedal, arboreal and brachiating locomotions

Straus (1940) and Oakley (1954) have stressed an additional peculiarity of the brachiating hand which is not found in man. The digital flexor muscles in the forearm are shortened to such a degree that the fingers cannot be fully extended when the palm is in line with the forearm. This permits the ape to suspend himself from a limb with the wrist somewhat dorsi-flexed and exerting little muscular effort to maintain the grasp. In contrast with this, both man and the Old World monkeys can place their hands flat on the ground with the fingers straight and the hands dorsi-flexed, or bent back, 90° at the wrist. From this Straus concluded (1940, p. 206): "I know of no more striking evidence against the currently popular so-called 'brachiating theory of man's origin.' The upper extremity of man fundamentally is closer to that of a catarrhine monkey, such as the Macaque, than to any anthropoid ape."

The monkeys, however, use their hands in a manner that neither man nor the apes can match. A few minutes' careful observation at a well-stocked zoo will show that monkeys do not normally run with their palms applied to the ground as is usually supposed, but rather they keep their palms off the ground in line with the forearm and with the wrist held straight. Since the fingers are applied flat to the ground, pointing forward, these fingers are dorsi-flexed 90° and more to the palm. This "bending back" of the fingers is structurally impossible for man. When it is also considered that the monkey's thumbs are shorter and weaker than man's, and that they cannot be rotated as far, it then becomes evident that the monkey's hand is no better a candidate for human ancestry than is the ape's. Either type would require several modifications.

Many detailed studies of the brachiating adaptations in the arms and shoulders of the apes have shown these to be practically identical to the corresponding human anatomy. Washburn summarizes this quite simply (1950, p. 68): ". . . brachiation is an elaborate behavioral and anatomical complex, every essential detail of which is shared by man and the living apes."

To maintain this common ancestry of man and the apes in the development of brachiation demands some clear accounting for the human hand. Morton (1926) suggested that ". . . the peculiar manner of human usage has operated to preserve *and to amplify* the primitive grasping qualities of the hand. . ." Gregory (1928 and 1930) held that the human thumb was related to expression of the intellect, and that through use, it has experienced an increase in its late history. Hooton (1946), while also assuming some retention of a primitive form of the hand, thinks that human use has served to further develop the thumb. Washburn (1959), as noted above, considers that the form of the hand resulted from changed selective pressures because of the use of tools, and that it is derived from a fully brachiating form as recently as the late Pliocene.

Some more direct evidence comes from Ashley-Montagu's observations on thumb lengths (1931). He uses the "Pollicial Index" which expresses the total length of the phalanges of the thumb as a percentage of the length of the phalanges of digit III. By this measure, man's thumb length is 56.9 percent, while the ape's thumbs are only 35.2 percent of digit III. Human embryos between 5 and 7 months, however, show an intermediate thumb length of 47.7 percent. Ashley-Montagu concludes that this evidence supports the idea of at least a semi-brachiating ape as the human ancestor. Schultz' data (1930) support this in one particular. He finds that the phalanges of the pollex, in proportion to its metacarpal, are longer in man (53-1/2 %) than they are in the apes (49 %); whereas in digit III, man and apes all measure about the same (59%). This can be taken to indicate a recent lengthening of the phalanges of the thumb in man.

Direct paleontological evidence is not very extensive. The Miocene and Lower Pliocene fossil apes exhibit only the beginnings of the development of brachiation. Napier and Davis (1959) exhaustively described the post-cranial remains of *Proconsul africanus* and found that this form showed many generalized features indicating an arboreal quadrupedal heritage combined with other features that appeared to be adaptive to brachiation and nothing to indicate terrestrial adaptations. The *Proconsul* hand, as far as preserved, is about mid-way in its proportions between *Pan* and *Homo*, but differs from both in preserving an articulation of the pisiform with the ulna--a non-brachiating arrangement. They found that the bones of *Limnopithecus* showed the same sort of partial modification towards brachiation. Known specimens of *Dryopithecus* and the larger species of *Proconsul* were difficult to diagnose, but appeared to indicate even less modification for brachiation.

If the post-cranial remains of these 5 species of Tertiary apes are at all typical, the human separation must not have occurred until well into the Pliocene. Only at such a late date, apparently, were the brachiating modifications fully evolved.

Following the gap of the Pliocene, the next fossil evidence of the human hand comes from the Australopithecines. There are two bones known from the hand of *Plesianthropus*, a capitate and a proximal phalanx. The capitate is described by Broom (1946) and by Le Gros Clark (1947) who come to the same conclusions: that the bone is somewhat intermediate between the human and anthropoid types. Broom thought it indicated that the thumb development was better than in any of the living anthropoids, but did not say that it approached the human condition. The proximal part of a first phalanx is described by Broom as being nearly, but not quite human. He says (1946, p. 74): "When compared with the corresponding bone in the bushman, the proximal end is a little narrower and the shaft a little broader, as if it were part of a finger that was a little longer and a little more slender than in man." This sounds not unlike a description of a finger from a small brachiator's hand.

While there has been no direct comparison made between the hand bones of Proconsul and Plesianthropus, the separate descriptions of each would indicate some similarity in that they are both referred to as being intermediate between the hands of Homo and Pan. The Australopithecine hand cannot be considered as a direct derivative of Proconsul or a related genus. A further development of brachiating modifications of the arm since the time of Proconsul would be necessary for it to match the human condition. This would not likely have left the hand unaffected. More probably, the Australopithecine hand was rather ape-like, but in the process of modification towards the human condition.

Broom also describes what he consideres to be the second metacarpal and its first phalanx and a first phalanx of digit V, which he ascribes to Paranthropus. The metacarpal is longer than human and its phalanx is shorter; the metacarpal's distal end is grooved for sesamoids. Broom considers that this rules out brachiators as the ancestors of man. Actually, the sesamoids and the proportionally short phalanx are characteristic of baboons, and it would be more reasonable to assign these bones to a large species of Papio.

From the Middle Pleistocene hominids there is known only one bone of the hand. This is the right lunate of Sinanthropus described by Weidenreich (1941, pp. 66-69). The bone is essentially human, and is peculiar only in its great breadth which has not been related to any other features of the hand. Unfortunately, this bone cannot in any direct way be related to the makers of the hand-axes, except that its date appears to be somewhat later than the earliest parts of the sequence.

Middle Pleistocene hominids from the hand-axe regions (Atlanthropus, Heidelberg and Swanscombe) are known only from cranial remains and cannot provide any direct evidence as to the structure of their hands.

The Upper Pleistocene Neanderthals had very human hands. It has been noted that the carpus is relatively small and metacarpal I is relatively short. These differences, however, are relatively minor. (Boule and Vallois, 1952, and Patte, 1955.)

McCown and Keith (1939) found that the Skhūl hands (of probable third interglacial date) had attained all the essential characteristics of the modern human hand. The Tabūn woman, however, showed the slightly short first metacarpal characteristic of neanderthals.

Evidently the Upper Pleistocene populations clearly possessed the essentially modern type of hand, and there is some indication that this was the case in the Middle Pleistocene as well.

In order for any discussion of the development of the human hand to be very meaningful, it is important to establish what kinds of manual operations are actually performed by the various types of primates.

Napier (1956) has clearly described the grasping methods of the modern hand. He finds that just three basic positions cover all uses of the entire hand in manipulating objects:

1. In the "power grip" an object is clasped between the flexed fingers and the palm. The thumb may be fully rotated and applied to the dorsal aspect of the fingers to strengthen the grip, or applied to the object itself to vary its position. The wrist is normally flexed toward the ulnar side. Examples of the use of this grip are holding the handle of a hammer or knife, trying to unscrew a tight jar lid, lifting a water pitcher, or any other occasion where a strong grasp is desired.

2. With the "precision grip" the object is held between the palmar (flexor) aspects of one or more fingers and the same surface of the fully rotated thumb. The wrist is often dorsi-flexed. This grip is used in picking up and handling almost all objects where great strength is not required (including unscrewing a jar lid after the seal has been broken).

3. The "hook grip" is basically that used by the anthropoids in suspending themselves from a limb. This is like the other grips in that the flexed fingers form one side of the clamp, but the resistance of the object, rather than the palm or thumb, forms the other side of the clamp, so to speak. Napier did not consider this grip common enough to rank it with the other two. Examples of the hook grip are of three types: (1) pulling down so that the body's weight acts against a resistance as in closing a sash window or holding the straps while standing on a street car; (2) pulling up against the weight of an object as in lifting a wheelbarrow or carrying a brief case; and (3) pulling horizontally against a resistance as in opening most drawers or pulling the oars of a rowboat.

Less common manipulations which might be added to Napier's list are (a) the "pinch grip" where the thumb is rotated only 90° and applied to the side of the flexed digit II--often used in holding small pieces of paper; and (b) the "cigarette grip" where the object is gripped between the second and third digits. Finally, pushing or pulling with one finger, pushing with the back of the hand or heel of the palm virtually exhausts the normal uses of the hand.

A comparison of these grips with those used by the great apes reveals both similarities and differences which may be correlated with their anatomy. The following descriptions of hand use are based on observations of the higher primates at the Fleishhacker Zoo in San Francisco, California.

Of the three major grips described by Napier, the anthropoids were seen to use only two: the hook grip for lifting large objects and suspending themselves, and the power grip to pick up and manipulate most objects larger than the size of a golf ball. At no time did they use the precision grip--this appears to be an anatomical impossibility. The great length of the fingers and the shortness of the thumb, while permitting the finger tips to touch the tip of the thumb, will not permit the palmar surfaces of these digits to oppose one another directly. This may be appreciated by the reader if he attempts to oppose the palmar surfaces of his thumb and fingers. In approximating the ape's condition, one might arbitrarily discount the last phalanx of the thumb to achieve the proper relative proportion. It now becomes virtually impossible to oppose the finger surfaces to the surface of the remaining proximal phalanx of thumb.

In place of the usual human precision grip, the apes utilized a variety of methods to pick up small objects such as leaves, popcorn, peanuts as well as all kinds of regular food. Most commonly used was the pinch grip with the thumb placed against the side of the flexed digit II and also against the side of metacarpal II. The cigarette grip between digits II and III was common, with the fingers more tightly flexed than is usual in man. Other grips occasionally used were: finger tips to thumb tip, finger tips to palm, distal phalanges tightly flexed against proximal phalanges and the fully rotated thumb applied against the dorsal aspect of the flexed fingers.

All four types of apes used all of these grips in the frequency noted, except that the Asiatic apes were never observed to use the "cigarette" grip. (Another point of peripheral interest was noted particularly with the chimpanzee and orang-utan. This was the use of the mouth in handling objects. These apes would frequently pass an object, not intended to be eaten, from one hand to the mouth or to the other hand almost indiscriminately as though having three "hands" with which to hold things.)

The basic differences between human and anthropoid uses of the hands are easily summarized. The apes differ (1) in using the hook grip far more often, and (2) in never using the precision grip at all.

My reason for describing these limitations of hand use in the apes should be quite obvious--that such limitations were also shared by early man in his first attempts to fabricate stone tools.

It may be argued that the hands of earliest man were not as specialized as those of the recent apes. The direct evidence from the Australopithecine fossils and Ashley-Montagu's observations of thumb lengths indicates a thumb perhaps mid-way between the human and anthropoid proportions, but there is also indirect evidence for a more ape-like thumb in earliest man. While there are no living apes with thumbs somewhat longer than in any of the apes, the writer has watched the manual operations of several species of <u>Cercopithecus</u>, <u>Cercocebus</u> and <u>Macacus</u> to see if there were any differences. Several hours' observation, including passing objects directly from my hands to theirs, showed that they have essentially the same limitations as the apes and cannot use the precision grip.

Whether our first bipedal ancestors had just been semi- or full brachiators, their hands would still have been limited in function because of short and relatively weak thumbs. It was a relatively simple experiment to apply this concept to the actual making of hand-axes.

For several months the writer practiced stone flaking and making hand-axes by what he supposed was the original Abbevillian technique--hand-held hammerstones striking flakes from the nodule which was held in the other hand. A number of hand-axes were made in this way, using hammerstones of various sizes and weights. A sample of this work was shown to Dr. T. D. McCown, who judged it to be more like the sort of thing to be encountered in an early Acheulian context. A typical example of this series is illustrated in Figure 2.

After considering the possible limitations on hand use, assuming man to have had a recent brachiating ancestry, I attempted to approximate these limitations with my own hands. The reasoning was that keeping the thumbs firmly placed against the second metacarpals would functionally most closely match the anthropoid hands. While the apes do have a short thumb, it was thought that pulling the human thumb completely out of operation might compensate for the extra long anthropoid fingers.

The manipulative limitations, which resulted from this technique were quickly apparent. The only hammerstones which could be held firmly and without completely enclosing them in the hand were rather large ones, weighing about two to three pounds or more--from about half to fully the size of the hand-axe blank being worked.

In addition to this, the ability to make fine discriminations of movement was greatly reduced. When the power grip is used, the elbow and the wrist are the joints which control the movements of the hammerstone. This follows from the fact that one side of the grip is the palm which is not subject to movement within itself. When the precision grip is used, fine motions of the fingers and thumb permit a greater degree of control over the hammerstone--lighter strokes, more carefully placed, can then be achieved.

Further experiment has shown that the true power grip and my original thumbless grip are functionally about the same. Permitting the use of the thumb as a brace, but not as one side of the clamp, did not alter the facts that only relatively large hammerstones could be used and that the wrist was the last joint of the arm which has any control over the motions of the stones. (The only effect of this limited thumb use seemed to be that I dropped the hammerstone less often.) Figure 3 illustrates one of the best formed hand-axes made by the power-grip technique. The basic characteristics of early Abbevillian tools are shown in the large, deep flake scars and the wavy edge formed between them. It is not possible by this technique to trim these edges to a straighter line, because the hammerstones used are too large to permit carefully placed light blows inside the larger flake scar concavities.

There is another point of interest which follows from using this technique. The hammerstone must be gripped firmly and raised about two feet to deliver a good blow, but the delivery need not be a powered downward thrust--the weight of the stone is often enough to carry it down with sufficient momentum to strike off a large flake. The short olecranon process of the brachiators, and the consequent lack of mechanical advantage in the powered extension of the elbow, is thus no detriment to this action. The grip of the hand and the flexion of the elbow are the only motions requiring great strength in order to utilize the Abbevillian technique as defined here. The brachiators are admirably pre-adapted for just these actions. The holding of the nodule in the other hand is also primarily a matter of strong grip and elbow flexion only.

The effective use of the hand-axe, however, would probably be facilitated by a powerful extension of the elbow in many instances. As Martin (1934)

ERRATUM

Due to an error which was not detected until after this issue was in press, line three of page 123 should read "Figure 3" rather than "Figure 2". In line twenty-nine of the same page, "Figure 3" should read "Figure 2".

has noted, the greater-than-anthropoid length of man's olecranon may well be a result of tool use rather than an indication of a ground ape ancestry.

Mention must be made of the anvil technique which has been proposed by many prehistorians as that used by the Abbevillian flint knappers (Coutier, 1929; Coghlan, 1943; Breuil, 1949; etc.), and by others as a possible or alternate method (Oakley, 1950; Leakey, 1953; Watson, 1956; Bordaz, 1959 and Clark, 1959).

Baden-Powell (1949), while reporting on his manufacture of Clactonian tools, found the proposed anvil technique unsatisfactory because the striking platform is hidden from the view of the worker while he brings it down on the anvil. Instead, he prefers the greater control of holding both pieces in his hands and being able to see what he is doing. The present writer has also found this to be a limiting factor which tends to result in poorer workmanship.

With the anvil technique, the weight of the unfinished hand-axe replaces the weight of the hammerstone in causing the struck flakes to be large and thick. Thus we have essentially the same limitations applied to both the anvil and power grip techniques--the blows are struck with great force, and the accuracy is limited. It is easy to see why the anvil idea gained favor to account for Abbevillian workmanship; since with hammerstone flaking it appeared so simple to make a better tool, a cruder method had to be postulated. Had the limitations inherent in the brachiating type of hand been considered earlier, the anvil technique need not have been postulated to account for the known archaeological specimens.

Heese (1933) illustrates one of the presumed anvils from the South African Stellenbosch I. This is a thick cylindrical stone about 25 cm. long showing use flaking at both ends. While it is somewhat larger than the stones used by the present writer, it no doubt would have served quite well as a hammerstone rather than as an anvil for shaping very large hand-axes.

The other characteristic of the brachiating hand, the inability to fully extend both the palm and the fingers at the same time, does not seem to be directly related to making stone tools, It is important, however, in throwing missiles. To throw an object effectively, it is essential to fully extend all parts of the hand in the release. If this is not possible, and the hand remains somewhat cupped, the object must be released well before the end of the arm's swing is reached. As might be expected, this rather limits the distance and affects the accuracy of throw. Nevertheless, such thrown missiles may have been useful to early man, and any improvement in throwing-ability would have been even more useful.

The spherical stone balls so common in the African Paleolithic might have been missiles by themselves, or may have been tied together to form bolas. In either case, a full extension of the fingers would probably have been required to throw them to any really effective distance. These stones occur in the later parts of the Chelles-Acheul sequence and are not reported with the earlier hand-axes (Clark, 1955). This may be taken to indicate that the digital extension as well as the thumb development of the human hand were both approaching the modern condition by Acheulian times. The absence of these stone balls in earlier contexts, of course, is no indication of when the human hand first acquired the capacity for full extension.

Summary

It is proposed that the Abbevillian hand-axes were made by a technique not hitherto described. This technique is percussion with hammerstones held in the hand in the power grip only--that is, gripped between the fingers and the palm with the thumb serving only as a side brace.

Such a grip appears to have been imposed upon the earliest tool makers because of their short thumbs and long fingers inherited from a recent brachiating ancestry. This is the same sort of grasp, in the absence of the typically human precision grip, that is used by the anthropoid apes to handle heavy objects.

Experiments by the author using only the power grip have yielded hand-axes of the early Abbevillian type; whereas with full use of the thumb, late Abbevillian or early Acheulian hand-axes were easily produced. The power grip restricts the user to rather large hammerstones, and greatly limits the accuracy with which blows can be directed. Essentially the same limitations are imposed by the anvil technique, for somewhat different reasons. It is believed that the power grip can account for the earliest hand-axes more easily than can the anvil method.

It is suggested that the final evolution of the human hand was coincident with the Abbevillian phase of the Great Hand-Axe Tradition.

REFERENCES CITED

Ashley-Montagu, F. M.
1931 On the primate thumb. American Journal of Physical Anthropology, 15; No. 2:291-314.

Baden-Powell, D. F. W.
1949 Experimental Clactonian technique. Proceedings of the Prehistoric Society 15:38-41.

Bordaz, Jacques
1959 Tools of the old and new stone age; part I, first tools of mankind. Natural History Magazine, January.

Boule, Marcellin
1911-13 L'Homme Fossile de la Chapelle-aux-saints. Annals de Paleontologie.

Boule, Marcellin and Henri V. Vallois
1952 Les Hommes Fossiles, 4th ed. Paris; Masson & Cie.

Braidwood, R. J.
1948 Prehistoric men. Chicago Natural History Museum, Popular Series, Anthropology, No. 37.

Breuil, Henri
1939 The Pleistocene succession in the Somme Valley. Proceedings of the Prehistoric Society, New Series, V:33-38.

1949 Beyond the bounds of history (English trans. by Mary E. Boyle). London, P. R. Gawthorn, Ltd.

Breuil, Henri and L. Koslowski
1931-32,34 Etudes de Stratigraphie Paleolithique dans le Nord de la France, la Belgique et l'Angleterre. Anthropologie XLI:449-488; XLII:27-47, 291-394; XLIV:249-290.

Broom, Robert and G. W. H. Schepers
1946 The South African fossil ape-men, the Australopithecinae. Transvaal Museum Memoir No. 2; Pretoria.

Clark, J. D.
1955 The stone ball: its associations and use by prehistoric man in Africa. Congres Panafricain de Prehistoire, II Session, Alger, 1952. Pp. 403-417.

1959 The prehistory of Southern Africa. Penguin Books Ltd.

Coghlan, H. H.
1943 The evolution of the axe from prehistoric to Roman times. Journal of the Royal Anthropological Institute 73:27-56.

Coutier, Léon
1929 Expériences de taille pour rechercher les anciennes techniques paléolithiques. Bulletin de la Société Prehistorique Francais, Tome XXVI, No. 3:172-174.

Gregory, W. K.
1928 Were the ancestors of man primitive brachiators? Proceedings of the American Philosophical Society 67:129-150.

1930 A critique of Professor Osborn's theory of human origin. American Journal of Physical Anthropology, 14, No. 2:133-164.

Heese, C. H. T. D.
1933 The evolution of Paleolithic technique. Annals of the University of Stellenbosch, II, Sec. B, No. 2.

Hooton, E. A.
1946 Up from the ape. New York, Macmillan Co.

Leakey, L. S. B.
1951 Olduvai Gorge. Cambridge University Press.

1953 Adam's ancestors. London, Methuen & Co., Ltd.

1954 Working stone, bone and wood. In A history of technology, C. Singer, E. J. Holmyard, A. R. Hall (eds.). 1:128-143. Oxford, The Clarendon Press.

Le Gros Clark, W. E.
1947 Observations on the anatomy of the fossil Australopithecinae. Journal of Anatomy 81, Part 3:300-333.

1956 History of the Primates. London, British Museum of Natural History.

1959 The antecedents of man. Edinburg, The University Press.

Martin, C. P.
1934 A comparison of the joints of the arm and leg and the significance of the structural differences between them. Journal of Anatomy 68:511-520.

McCown, T. D. and Sir Arthur Keith
1939 The stone age of Mount Carmel, Vol. II. Oxford, The Clarendon Press.

Morton, D. J.
1936 Evolution of man's erect posture. Journal of Morphology and Physiology, 43, No. 1:147-179.

Napier, J. R.
1956 The prehensile movements of the human hand. Journal of Bone and Joint Surgery, British Number, Nov. 1956, pp. 902-913.

Napier, J. R. and P. R. Davis
1959 The fore-limb skeleton and associated remains of Proconsul africanus. Fossil Mammals of Africa, No. 16. London, British Museum of Natural History.

Oakley, K. P.
1950 Man the tool-maker. London, British Museum of Natural History.

1954 Skill as a human possession. In A history of technology, C. Singer, E. J. Holmyard, A. R. Hall (eds.). 1:1-37. Oxford, The Clarendon Press.

Oakley, K. P.
1957 Dating fossil men. Memoirs and Proceedings of the Manchester Literary and Philosophical Society 98:75-94.

Osborn, H. F.
1928 Present status of the problem of human ancestry. Proceedings of the American Philosophical Society 67:151-155.

Patte, Étienne
1955 Les Néanderthaliens. Paris, Masson et Cie, pp. 345-352.

Schultz, A. H.
1930 The skeleton of the trunk and limbs of higher primates. Human Biology, 2, No. 3:303-409.

Stewart, T. D.
1950 The problem of the earliest claimed representatives of Homo sapiens. In Cold Springs Harbor Symposia of Quantitative Biology, 15:97-108; Origin and evolution of man.

Straus, W. L., jr.
1940 The posture of the great ape hand in locomotion, and its phylogenetic implications. American Journal of Physical Anthropology, 27, No. 2:199-207.

Washburn, S. L.
1950 The analysis of primate evolution with particular reference to the origin of man. In Cold Springs Harbor Symposia on Quantitative Biology, 15:67-78; Origin and evolution of man.

1959 Speculations on the interrelations of the history of tools and biological evolution. Human Biology, 31, No. 1:21-31.

Watson, William
1956 Flint implements. London, British Museum of Natural History.

Weidenreich, Franz
1941 The extremity bones of Sinanthropus pekinensis. Palaeontologia Sinica, New Series D, No. 5.

Wood-Jones, Frederick
1916 Arboreal man. London, E. Arnold.

FIG. 2 HAND-AXE MADE BY POWER GRIP TECHNIQUE

(One half actual size)

FIG. 3 HAND-AXE MADE BY PRECISION GRIP TECHNIQUE

PHOTOS: JOSEPHA HAVEMAN