EARLY STAGES IN THE EVOLUTION OF HUMAN BEHAVIOR: THE ADAPTIVE SIGNIFICANCE OF STONE TOOLS

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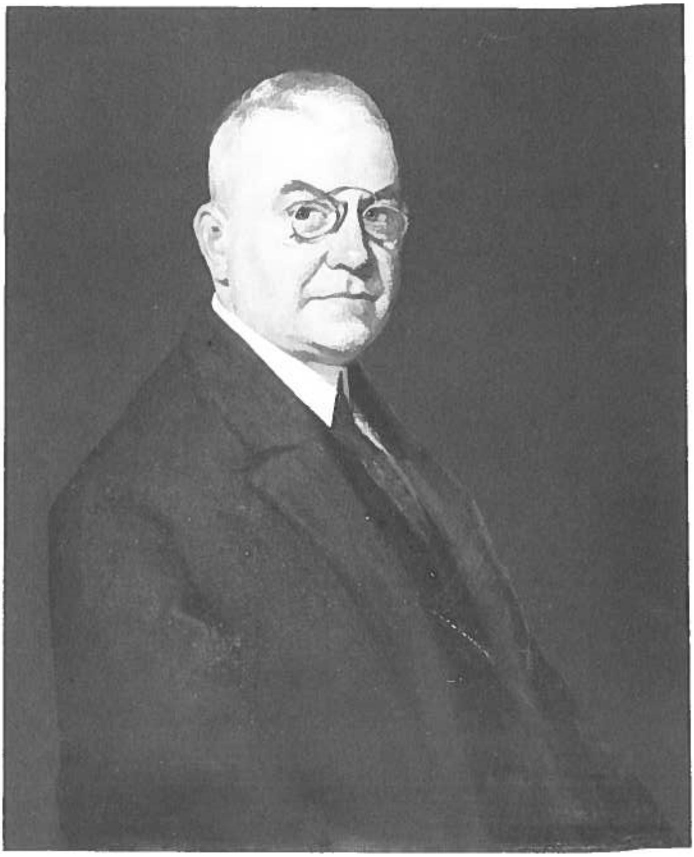

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BY THEIR WORKS SHALL YE KNOW THEM can serve well as a text for this discourse. The oldest tangible works, that is to say the most ancient purposively shaped objects yet found, come from geological layers in East Africa that can be dated as being between 2 and 3 million years old.

These ancient artifacts excite our imagination so that questions rise up in our minds like bubbles in champagne – what were these early tools? What purposes did they serve in the lives of their makers? What kind of beings formed them? What kind of lives did they live? What changes separate us from them?... The questions come quickly and easily but the answers are harder to obtain. In as far as they can be reached, it will, for the most part be through the patient pursuit of archaeology. In this commemorative lecture I will try to characterize aspects of the current state of knowledge and to indicate prospects for its growth.

Stone tools are a central ingredient of the evidence and in order to make my task manageable in the confines of a one hour discourse, I will organize discussion round them. However, it should be clear that stone tools are not the ultimate subject of the essay – our true target subject is the way of life, the behavior, and the mentality of the earliest stone tool makers.[1]

In this lecture we are about to use archaeological enquiry as a vessel to transport us across a vast divide of time and change. Before embarking perhaps one should think a little about the nature of the enterprise. The two similies that follow will perhaps alert us to some important cautionary considerations.

Doing the archaeology of extremely remote periods can fairly be likened to a voyage of discovery. When we find 2 million year old earth layers with archaeological remains in them, we have traversed an ocean of time and arrived at the equivalent of a new world (figure 1). Our finds excite wonder and curiosity, but in the first instance we, like Columbus, are apt to interpret them in terms of our preconceptions. We may think we are in the Indies, when in reality we are at the edges of an unknown continent.

To shift to a different image of what is involved, let us imagine looking down a deep well shaft. Beyond the dimly lighted upper rim, is darkness extending away from the watcher... but in these depths is the gleam of light on water. If the well is not too deep, by straining our eyes we perhaps see a figure – a figure set in an unfamiliar context, but yet a familiar figure. Familiar, because it is our own reflection.

Archaeological enquiry into the very remote past, has recently experienced comparable moments of truth. Awareness is dawning that in part we have been using archaeology and the early evidence as a mirror by which to obtain more or less familiar images of ourselves.

In the first instance the realization that we might, as it were, be on a different continent and the awareness that we were subconsciously seeking to find distant but definite reflections of ourselves in the remote past, came as something of a shock, and we tended to resist the change.[2] Now many of the scientists involved are beginning to recognize that once we have faced up to the challenge, our enquiry becomes an even more exciting voyage of discovery. Can our scientific imagination rise to the occasion? Can we conceive of patterns of behavior and adaptation that could lead to the formation of familiar looking patterns of archaeological evidence and yet which were behaviors unfamiliar to us in that they were structured differently from recent and contemporary human ones? Can we then figure out predictable differences in the archaeological evidence that will distinguish the various possible behavioral models?

To meet this challenge archaeologists will have to function rather in the manner of astronomical cosmologists who use physics and mathematics to imagine extraordinary phenomena such as 'black holes' and then predict the observable characteristics they would display if they existed. Our equivalent input will presumably have to be a knowledge of ecology and an understanding of alternative strategies for exploiting the economy of nature with and without technology, and with and without intricate information exchange (i.e. language).

Full recognition of the existence and excitement of this challenge is not yet widespread and there has as yet been insufficient time for more than a few tentative first responses to the stimulus, with most of them being negative. However, I urge you to think about the material to be discussed in this context.

Swiftly, here is some historical background – well back in the last century, early stone tools began to be discovered in Africa: with the finds coming from both extremities of the continent, for instance in Egypt, the Maghreb and South Africa. At first these amounted to little more than stray finds, but in the nineteen twenties and thirties, early stone age archaeology became a systematic endeavor through the activities of such great pioneers as C. Van Riet Lowe, A.J.H. Goodwin, L. De Morgan, K. Sanford, W. Arkell, R. de Neuville, A. Rhulman, J. Colette, J. Janmart, E.J. Wayland, Louis Leakey and a little later, J. Desmond Clark, J. de Heinzelin, G. Mortelmans and P. Biberson.

It came to be recognized that Africa shared with Atlantic Europe, large numbers of early assemblages dominated by the large bifacial tool forms commonly known as 'Acheulian' handaxes. However it also appeared to these pioneers that there was evidence of prolonged technological development prior to the Acheulian – a phase in which pebbles were sharpened by the removal of a few flakes. This phase came to be known by various labels, 'Pebble culture', 'pre-Chellean', and 'Kafuan' for instance.[3] Literally tons of 'pebble tools' were collected from all over the continent, but there were serious limitations as to what could be learned from these collections. This was so firstly because almost all of them came from gravel deposits where they had no archaeological context. Secondly, in some cases it was not possible to tell natural from artificial fractures. And thirdly, while it was often clear that the fractured stones were old, it was usually impossible to know just how old they were.

The first major prospect of a more archaeologically satisfactory situation yielding very early artifacts came when Hans Reck showed the Olduvai Gorge sedimentary formations to Louis Leakey, and

Louis Leakey promptly won a bet by finding stone tools in them (Leakey *et al* 1931, S. Cole 1975). The lowest layers yielded assemblages with 'choppers' and without 'bifaces'. These tools were stratified beneath Acheulian-tool containing layers. The term 'Oldowan' was given to these oldest assemblages. This term has since come to be widely used for the very early pre-Acheulian stage of prehistory.

Somewhat comparable, promising contexts for early tools were also found in Northwest Africa, but so far it has not proved possible to follow these up by excavation. Most of the specimens have been recovered during commercial quarrying operations and the area cannot as yet serve in the same way as East Africa as a standard of reference for monitoring the evolution of behavior.

Work began at Olduvai on a small scale in the 1930's and then after a disruption by the second World War, again in the 1950's. In 1959 the real break-through occurred. Mary Leakey found the skull of a robust Australopithecine – '*Zinjanthropus*'. A large excavation was made into the layer that had yielded the skull, and the excavation uncovered a dense patch containing thousands of artifacts and tens of thousands of bones and bone fragments. As if this dramatic development were not enough – just at this moment the potassium-argon method reached the point of refinement where relatively young rocks could be dated. Measurements were made on the layers encasing the Zinjanthropus skull and artifact concentration with astonishing results – the layer was almost 2 million years old! (Leakey, Evernden and Curtis, 1961).

The scientific situation I am reporting in this lecture has its point of origin in those momentous discoveries by Mary and Louis Leakey and their geochronological co-workers Garniss Curtis and Jack Evernden. Inspired by this success a search began and over the next decade very early sites were found all along the center of the Gregory Rift Valley in Tanzania, Kenya, Ethiopia and also at 'Ubeidiya in the Jordan Valley, which is where the youngest extension of the Rift cuts into Western Asia. The following are some of the important sedimentary formations which have been found to yield artifacts that are older than a million years. From south to north: Natron, Chesowanja, Koobi Fora, Omo, Melka Kuntouré, Gadeb, Hadar and 'Ubeidiya.[4] See map and time chart in figures 2 and 3.

Let me briefly indicate the empirical characteristics of the dramatic spate of discoveries that began with the Olduvai finds. This can most conveniently be done by means of a series of figures and diagrams.

Figure 4 shows the geological circumstances of the Eastern Rift Valley which cause it to be the major source of significant evidences. There is another hidden reason, namely the fact that the Rift Valley formed within the distinctive biological zone which supported evolving hominid populations – that is the African Savanna.

Figure 5 shows that when tectonic uplift has exposed appropriate sedimentary formations to erosion, concentrations of artifacts can be searched for, found and excavated. From what is observed along the outcrop as search proceeds and from what has been found in excavations, archaeologists can infer the broad characteristics of the distribution of discarded artifacts across segments of the ancient landscape. The pattern so far discerned (especially at Olduvai and Koobi Fora), is represented in figure 6.

The major findings of the first round of empirical enquiry up to 1975 or so can be listed as follows:

By 2 to 2.5 million years ago

1. Stones were being broken up and flaked to produce sharp edged pieces.

2. The early stone artifacts occur as a widespread *scatter* of isolated items, but they also occur in *small clusters* of a few dozen items ('mini sites') and in *dense concentrated patches* with hundreds or thousands of items ('maxi sites').

3. Sometimes, but not always, substantial quantities of complete bones and bone fragments occur as a part of the mini site and maxi site clusters of artifacts.

4. Prior to about 1.5 million years ago the artifact assemblages lack the large, purposively designed-looking forms that are charac-

teristic of Acheulian industries. The early artifact assemblages are usually classified as examples of the *Oldowan Industrial Complex*, which really represents a stage-of-development concept. Figure 7 illustrates one such assemblage.

I am concerned in this lecture primarily with the contribution of archaeology to our understanding of sequences of change in human evolution, but there are of course other significant lines of evidence, notably the fossil remains of evolving hominids. Figure 8 represents in very simplified form the major pattern of change inferred from the fossils. The empirical situation that emerges from the fossils can be summarized as follows:

1. *Bipedal stance and gait* is evident in fossils representing the oldest known members of the family hominidae. These are the Laetoli and the Hadar fossils at 3.0 to 3.75 mya, with bipedalism evident both from the fossils and from the Laetoli foot print trail.

2. The fossils from between 4.0 and about 2.0 mya are all variations on a single theme – they are all of small to moderate size and all have *small brains* (by modern human standards) and *large teeth* (by any standard). This is the *Australopithecus* stage, with two species known, *A. afarensis* in East Africa and *A. africanus* in South Africa.

3. At about 2 mya there are several signs of change. Sedimentary layers of about this age and younger in many places contain remains of two hominid species. One of the species is larger in body size than earlier forms, has cheek teeth that are absolutely and relatively enlarged and retains a relatively small brain (these are the robust australopithecines *A. robustus* in South Africa and *A. boisei* in East Africa).

Specimens of the other species, when sufficiently complete, often show brain sizes that are significantly enlarged, absolutely and relatively (600-800 cc) and show molars that are somewhat reduced relative to earlier fossils. Body size is variable but not extremely small or large. These are the fossils classified as the oldest known members of the genus *Homo* (*H. habilis*).

4. From 2 million years to around 0.1 to 0.2 mya one series of fossil hominid forms shows a trend of change involving brain

increase and tooth reduction. Whether the trend of change is gradualistic or stepwise is still the subject of debate. Fossils in the middle sector of the time range tend to be classified as *Homo erectus.* Those toward the recent end where brain size approximates modern tend to be classified as archaic *H. sapiens.*

The robust australopithecines apparently became extinct around 1 million years ago.

What is of interest to us in this consideration of the archaeological evidence is the fact that the oldest known evidence of tool making appears at very much the same time as the evidence for the initiation of the two major trends of anatomical change. Coincidence is not sufficient to indicate causal connection but it does invite enquiry.

The idea that tool making and using may have been critically involved in the evolutionary differentiation of human ancestors is not a new one. Charles Darwin in his *Descent of Man* wrote: 'The small strength and speed of man, his want of natural weapons, are more than counterbalanced... by his intellectual powers, through which he has formed himself weapons, tools etc.' Many other authors have developed the same theme since: eg. Keith, Boule, Von Koenigswald, Oakley, Tobias, Graham Clark, to name but a few.

What is new is that we now *know* from the stratified record that stone tools and enlarged brains appeared at much the same time around 2 million years ago. Secondly, from that knowledge several much more fundamental questions arise. For instance, tools could only have an important influence on trends of genetic changes if they had a significant effect on survival and reproductive success. To us as modern humans it may seem axiomatic that tools equal success, but clearly this cannot be true in any simple or universal way, or many other species of monkeys and apes would be large scale tool users. There must have been some special circumstances surrounding the lives of early ancestral forms at some stage which gave tool-using individuals crucial advantages. So we surely want to try to find out about the function and adaptive significance of early tools. The remainder of this review is largely devoted to discussing the start which archaeology has made on this enquiry. There are many other important issues in the archaeology of early man, but in this lecture I shall restrict myself largely to advances in the understanding of stone tools as a novel subsystem in the lives of hominids that existed 1.5 to 2.5 million years ago.

THE ADAPTIVE SIGNIFICANCE OF EARLY TOOLS

The following portion of the essay is best presented as a series of questions to which at least partial answers can be offered as a result of research which has been done over the last decade.

1. A preliminary question – *Given a small brained, bipedal savanna hominoid, in what aspects of its life can we envisage simple tools providing evolutionary advantages* (ie. added fitness)?

In moving toward answering this we need not use the archaeological record, but considerations of the comparative ecology, feeding strategies and behaviours of a broad spectrum of primates, plus that of relatively large 'omnivores' such as pigs and bears (Hatley and Kappelman 1980) to say nothing of carnivores. The activities of recent humans are a major source of ideas, but if we are not simply to see the past as a pale version of the present they must be used with caution. It is necessary for archaeologists to go out into savanna environments and look for opportunities (and problems) in which use of simple equipment should make a significant difference. Table 1 (see p. 45) offers some initial suggestions arranged in various permutations so as to stimulate thought. The entries on this table have the status only of hypotheses for testing. The table is not intended to solve the problem of ascertaining what early tools *were* used for by listing what they could have been used for.

2. *When did artifacts begin to be made?*

As we have seen, the first well documented, excavated series of very early artifacts to be dated by modern geo-chronometric techniques were those from Olduvai Gorge Bed I. The *Zinjanthropus* site was dated at 1.75 my. Since then this age determination, astounding as it was when it was first made, has been amply confirmed by many more K/Ar dates and the application of other techniques. We now know that Bed I at Olduvai belongs in the Olduvai Normal Event of the geomagnetic polarity time scale. This Event, which has been dated by hundreds of measurements made all over the world, has an age of between 1.7 and 1.9 million years.

The age of the KBS Tuff and the associated artifacts at Koobi Fora was the subject of a long and at times strongly contested controversy, but this has now been settled in favor of the younger age, first advocated by paleontologists. The KBS Tuff has since yielded a very consistent series of dates which from each of two different laboratories give mean values that are very close: 1.88 + .02 (McDougall 1981) and 1.8 + 0.1 (Drake, Curtis *et al* 1981). Paleomagnetic determinations show that these early artifacts date from Olduvai Event times.

It has become clear that the Olduvai Bed I artifacts and the Koobi Fora KBS artifacts are indistinguishable from each other in age, and are just a little younger than 2 million years.

As figure 3 shows there is one fully confirmed and documented case of artifacts that are a little older than 2 million. These are the series discovered by H.V. Merrick and co-workers (1973) and by J. Chavaillon (Coppens *et al* 1973) in Member F of the Shungura Formation in the Omo Valley. These, as far as I am concerned, are the oldest definitely known and well dated artifacts.

In addition there are two or three instances of artifacts that may prove to be still older. These are from the Shungura Member E (2.0-2.18 my) and perhaps Shungura Member C (?2.4 my) (See Chavaillon and Boisaubert 1977, De Heinzelin in press). Another very important possible instance is that discovered by Hélène Roche near Hadar (2.7 my) (see Roche and Tiercelin 1977; Roche 1980; Harris in Lewin 1981). Artifacts recently discovered in the very basal layers of Swartkrans in South Africa (Brain 1981) may also be very early. However, in my opinion none of these instances that purport to be significantly older than 2 my can as yet be regarded as definite and confirmed.

3. *What forms do the earliest known handicrafts take? What sort of mentality do they bespeak?*

Figure 7 shows that any given assemblage is apt to involve a very varied array of shapes. Equally it has been found that assemblages differ one from another. Does this mean that the artifacts represent a complex system with many distinct designs? Do the assemblage differences indicate either systematic activity differences or cultural differences? Answers to this kind of question have varied according to the intuition of individual archaeologists and we have all struggled with the problem for some years.

In writing the monograph which is in preparation on the material from Koobi Fora I and my co-worker John W.K. Harris have tried the following approach. Essentially we have sought to use the well known scientific method of residuals. We put the range of forms found through a step-wise analytical process in which we seek to account for variation in form by reference to a series of factors which can be ranked in the complexity of method and cultural complexity implied. One starts with the simplest:

Step 1. How much of the range of forms within an assemblage can be accounted for merely by the application of least-effort flaking procedures to the most readily available forms of stone?

Step 2. Would any form that is not accounted for in step 1 be accounted for if the maker were economizing on stone, for instance, so as to save having to make a trip to fetch more stone?

Step 3. If there is a residue of forms unaccounted for by steps 1 and 2 could these represent modification to suit items for particular tasks such as scraping, boring etc. (Note – many of the forms accounted for under 1 and 2 are also suitable for such tasks but by the rules of this procedure they are not so designated if they can just as well be explained by a simpler level of causation).

Step 4. Finally, if significant forms and features remain unaccounted for, one is free to ask, are these 'stylistic' features? Could they be expressions of arbitrary differences in local or regional 'culture'?

The application of this type of logic is in its early stages, but it does seem to be helping us towards an orderly way of assessing the level of mental and cultural complexity that the early assemblages represent.

It appears that the great majority of forms are accounted for by steps 1 and 2, and only a very few forms seem clearly to call for a step 3 explanation. Before 1.5 million years ago there is almost no sign of arbitrary imposed designs that do not have least-effort strategy bases. One can argue that such forms come in with the Acheulian artifact patterns at about 1.5 mya.

Put another way, I am suggesting that in spite of the diversity of forms, the early assemblages were fundamentally simple. They display a good empirical knowledge of conchoidal fracture. This immediately yields two major classes of manufactured objects. There is (1) the lump of stone from which flakes have been struck, and (2) the flakes themselves. The first class can be regarded as '*cores*'. However in the early time ranges the lumps with flakes removed have been regarded as the principal *tools* with designations such as chopper, discoid, scraper or polyhedron being added. The flakes, unless retouched, have conventionally been regarded as '*waste*' or '*debitage*'.

I now prefer to regard the whole series as representing a single system which generated a range of potentially useful forms, some relatively massive and with stout jagged edges, the other relatively light and thin with sharp, knife-like edges and pointed angles. To avoid prejudging purpose and function, we now propose to call what were designated as trimmed and retouched tools (and cores) as *Flaked Pieces* (FPs) and what were designated as 'debitage' we propose to call *Detached Pieces* (DPs). A relatively small number of items in the early (Oldowan) assemblages involve purposive modification of the edges of small detached pieces, these necessarily calling for a step 3 explanation. These are so-called light duty or flake scrapers. Observed frequencies of this step being taken are low compared with most subsequent stone industries. Set out below is a list of site labels with the number of retouched 'flake' forms shown as a fraction of the total, followed by the calculated proportion that these represent.

Olduvai			*Koobi Fora*			*Omo Shungura*		
Site	*Number*	*P*	*Site*	*Number*	*P*	*Site*	*Number*	*P*
DK	23/1198	.02	FxJjl	1/131	.01	Site 123	0/167	–
Zinj	22/2397	.01	FxJj3	0/121	–	Site 57	0/30	–
FLKN6	0/123	–	FxJj10	4/320	.01	FtJil	0/130	–
FLKN5	0/151	–	FxJj50	4/1405	.003	FtJi2	0/95	–
FLKN4	1/76	.01	FxJj20M	8/2497	.003			
FLKN3	0/171	–	FxJj20E	4/1205	.003			
FLKN1-2	12/1205	.01	FxJj20AB	3/3462	.002			
HWK1	2/181	.01	FxJj18GL	25/1556	.02			
HWK2	4/302	.01	FxJj18GU	7/216	.03			
HWK3	39/1280	.03	FxJj18NS	16/993	.02			
HWK4	19/601	.03	FxJj18IH	21/3267	.01			

[The Olduvai values are based on Mary Leakey (1971), the Koobi Fora values on Harris (1978) and on my own data, and the Omo on Chavaillon (1973) and Merrick *et al* (1973)].

Hitherto in reports on early stone artifact assemblages by myself and others, large, relatively massive *flaked pieces*, such as so-called 'choppers', discoids etc., have been given the technical distinction of being called '*tools*'. However, it is our impression that in at least some instances, the production of flakes was a major consideration. In some cases particular flaking 'habits' seem to have developed and these could produce a regular, repeated series of flaked piece forms ('cores'). The 'Karari scrapers' reported by my partner in the Koobi Fora work J.W.K. Harris (1978) seem to be one such series (figure 9).

In summary then I am arguing that the very early stone-tool making hominids were operating a tool making system that was *conceptually* very simple but which was nonetheless highly effective. For the most part they took such stones as were to hand and flaked them so as to produce sharp edges with a minimum of bother. At the Omo, pigeon egg size quartz pebbles were mainly available. These were simply smashed, so as to produce sharp flakes and fragments. The assemblages are not aesthetically pleasing, but doubtless they were useful. At Koobi Fora, somewhat larger well rounded basalt pebbles and cobbles were what were most readily available, and these were flaked with the production of somewhat more organized looking but basically simple core and flake forms.

At Olduvai a varied range of angular quartz slabs and blocks and rather irregular lava cobbles were the dominant starting forms.[5] The result is something like a combination of Koobi Fora and Omo characteristics but with an even wider range of resultant sizes and forms. At Olduvai there is a third major series – pounded pieces (PP): that is to say pieces which have been modified by battering and pounding... for example 'spheroids' ('bolas') and 'anvils'. These kinds of artifacts are much less in evidence at Koobi Fora and the Omo.

Objections can be made to all this – most notably it would be fair to ask – how does one know how much of an assemblage is accounted for by simple least-effort flaking procedures? This brings me to a major component in the archeology of early man, namely experimental stone working. Quite extraordinary contributions are being made by two remarkable young scientists who are pursuing this line of research. Nicholas Toth is working as a member of the Koobi Fora team and Peter Jones is working with Mary Leakey's Olduvai research group. Because he is a research colleague and because I know the results better I will use Toth's work to illustrate the impact that these studies are having on our understanding.

Nicholas Toth began his study by learning to copy the early stone artifact forms using the same kinds of raw materials as had the hominids in ancient times (Toth in Bunn *et al* 1980, Toth 1982). Next he compared both cores (FPs) and the detached pieces (flakes and fragments) with the assemblages that our team was digging up. It soon became apparent to him that the ancient assemblages were incomplete in very interesting ways. It emerged that cores go through a life cycle and produce different kinds of flakes at different stages of their life history (figure 10). Toth began to perceive that the ancient assemblages only made sense if one recognized that the cores were moving about with different sectors of their yield being discarded at different places. Not only were the cores moving, but certain classes of flakes were also being preferentially taken away.

Toth has taught us that we need to think of the early toolmaking as a dynamic flow system with different kinds of fallout occurring at different nodes within the system. I, for one, find this a much more interesting way of thinking about early artifacts than the static set of categories that I had always used before.

Another major new addition to our way of conducting enquiries, has been the search among the excavation finds for pieces that can be fitted back together. 'Conjoining' or 'refitting' serves to emphasize the dynamics of how the record formed (figure 11). I might also point out that there is a certain poignancy to finding joins between pieces that were knocked apart by some proto-human ancestor some 1.5 million years ago. One has the sensation of contact across the abyss of time. Conjoining work has been done with particular energy for our research group by Ellen Kroll, Kathy Schick and Nicholas Toth. Henry Bunn has shown that it can be successfully done for bones as well (Bunn *et al* 1980; Bunn 1982). (Note – comparable fresh perceptions have been achieved in Europe for instance by Cahen, Keeley and Van Noten (1979), and by Newcomer (1971) and others. These surely helped to inspire the work of our group).

4. *What role did early stone tools play in the lives of those who made them?*

It is an embarrassing fact that until very recently, although we had tens of thousands of specimens of early artifacts, we did not know the uses to which they were put. We could and did speculate, but we had no direct evidence. However the past few years have brought the excitement of definite information.

Recognizing the possibilities that opened up as a consequence of the pioneering work of Laurence Keeley (1977, 1980) Nicholas Toth took some 56 artifacts of siliceous rocks and submitted them to Keeley for scrutiny. It emerged that some 10 or 12 showed the subtle microscopically visible polishes that are due to use. In a number of cases the substance against which the flake edge had moved could be identified. The results reported in Keeley and Toth (1981) were as follows:

Polishes of the kind induced by cutting meat:	4 specimens
Polishes of the kind induced by cutting wood:	3 specimens
Polishes of the kind induced by cutting plant stems:	2 specimens

Their historic paper lifts us in one bold step from total uncertainty to a little bit of knowledge. We can begin, cautiously to investigate early tools not simply as items of technology but as agents of adaptation. It is interesting that in this first glimpse, at least three different kinds of use seem to be documented, namely food acquisition (meat), tools being used to make tools (wood whittling) and the enigmatic cutting of plant tissues. Could this last represent food getting? – cutting bedding? – or slicing fleshy bark or some other long forgotten activity?

The other new line of evidence has been termed by my colleague Diane Gifford as 'smoking gun' evidence. After careful searching, two young scientists, Henry Bunn (1981) and Richard Potts (1982; Potts and Shipman 1981) have found fairly numerous marks inflicted by stone tools on fresh bones which subsequently were fossilized. The marks occur on various body parts of many different kinds of animals ranging in size from small gazelles up to hippopotami and elephants. Some marks were clearly formed in the course of dismembering carcasses, that is cutting limbs free of the trunk, cutting one part of a limb free from another, taking a jaw apart from a skull, etc. Other marks seem to imply cutting skin away from the non-meat bearing distal extremities of limbs. Still other cut marks imply the removal of meat from the shafts of bones.

That stone tools served to give early hominids access to meat from large carcasses has been a long-standing speculation. Now we actually know that this was indeed one novel adaptation connected with the invention of sharp edged tools.

Another line of research which bears on our understanding of the adaptive significance of early tools is the feasability testing of replicas of the various forms. Again this kind of study is being pursued by Nicholas Toth (1982) and Peter Jones (1979, 1980, 1981). The studies are in their early stages but they already show that simple though the early artifact production systems were, the forms produced make possible the execution of most of the basic tasks listed in Table 1.

In particular it emerges that plain, unretouched flakes are excellent tools for cutting into a carcass and dismembering it. Both Toth and Jones have shown that even an elephant carcass can be effectively tackled with such simple equipment. However Toth also reports that in cutting up a large animal the hand gets cramps if a small flake is used and he prefers to use an Acheulian style biface once the initial slit in the hide has been made. Flakes also serve well for whittling wood for instance in order to sharpen a stick as a digging-stick or a spear.

Toth has also been able to rank the stone tools for the ease with which they perform basic tasks and conversely to designate for each basic task which tools serve best. For many tasks plain flakes such as abound in the early assemblages top the ranking or are very effective. Severing a branch however is better performed by a heavier tool such as a 'chopper' or 'core scraper' (or if Acheulian forms are included in the rankings, a cleaver).

In summary then, the information now coming in is consistent with the view that the simple early stone tools did give their users adaptive advantages in getting food. We know that they were cutting into large carcasses and we know that they were shaping wood. If they were forming digging sticks this would in turn have given them access to deeply buried tubers not available to other primates. Other potential foodstuffs to which tools would help gain access would be cracking open tortoises, hacking grubs and honey out of logs and so forth. Several of the classes of food to which tools might have given preferential access, contain concentrated high quality nutrients, eg. meat, tubers, nuts and honey. Hence the adaptive importance of the invention of sharp edges could well have been considerable.

None of the early stone tools is especially suited to be a weapon and I would suspect that in as far as these were used in early Pleistocene times the main weapons would have been the thrown stone (A.B. Isaac ms) plus simple clubs, staves, lances and thorn branches. Making neat examples of these would be facilitated by the use of stone tools but all of these means of enhancing fitness are essentially possible without the use of sharp edged tools. (See also the work of A. Kortland 1980, and other references cited in the bibliography).

One other class of equipment deserves to be mentioned. Carrying devices such as trays, bowls, baskets and pouches eventually became a fundamental part of human adaptation (R. Lee 1979: Appendix E). We do not know when these began to be used. Bowl-like and tray-like objects can be picked up as naturally occurring objects in the savanna (Isaac and Toth, personal observation) but cutting tools could have made it possible to make these when they were otherwise unavailable.

If meat scavenged from large dead carcasses was becoming an important potential food for some hominids in the late Pliocene 2 to 3 million years ago, it is conceivable that a strong need for cutting tools arose. An 'invention' does not usually catch on unless it fills a need. The tools would have been needed both to get in through the hide, and perhaps equally important to remove portions of the carcass so they could be quickly taken for slow consumption in a place of safety. Many fierce carnivores compete for access to carcasses and it would have been dangerous for hominids to have lingered in the vicinity of the dead animal. Tools would have enabled the hominids to make a quick foray, get hunks of meat and leave (figure 12).

In connection with the adaptive significance of early tools, it is interesting to look at the characteristics of diet in recent humans, that is to say to look at the end product of the evolutionary process. Diets recorded in ethnographies are immensely varied – but they do have some tendencies in common that set them apart from non-human primate diets. They tend to be two pronged, on the one hand they include far more meat than do other primate feeding regimes and they focus on starch-rich plant parts (eg, tubers or grain). These are high quality foods with concentrated nutrients, and they are only accessible on a large scale to a primate with the assistance of tools. Being concentrated they are also *portable*. Now most large bodied animals can 'opt' for and do opt for bulky diets of low quality. Humans are relatively large bodied primates and making an evolutionary shift counter to the usual trends must imply a change in nutritional strategy and/or advantages in aspects of life other than feeding. Differential reproductive success is one possibility and interspecific competition also.

At the same time that at least one hominid form 2 mya was getting involved with tools another became larger in body size and evolved even bigger teeth than it had before. Competition with these robust forms for common but lower quality foods may have pushed the ancestor of the genus *Homo* in the direction of seeking rarer, high quality foods that required tool use for access (S. Ambrose, in preparation).

Foods of this kind are widely dispersed. They call for a wide ranging way of life and may also be more effectively acquired if information is shared within a social network. This brings us to the next question.

5. *What are the social and cultural implications of early stone tools?*

This is an important, fascinating topic, but yet one on which it is difficult to turn speculation into testable, falsifiable hypotheses – so I will be brief.

Clearly even relatively simple tool making would have involved concepts and skills which would have to be learned during the process of growing up. This would be facilitated by a prolongation of infancy and juvenile dependance. As Parker and Gibson (1979) have pointed out this almost certainly involved lengthened and intensified mother-infant bonding. Relative to other primates, chimpanzees show this kind of modification to the life cycle, humans even more so. It seems a safe speculation that shifts in this direction would have begun or have been intensified as tools became varied and important. Alan Mann (1975) has argued that the growth series of australopithecines in South Africa already show modifications in the direction of human-like prolonged slow and delayed maturity.

Larger brains are costly in terms of nutritional requirements for growth and maintenance, they also call for the birth of more than usually helpless young. At some stage or other in human evolution these factors may well have led natural selection to favor individuals who participated in social systems which provided child-bearing females with some help in food acquisition and with protection. Such a social matrix would also facilitate the transmission of varied skills from generation to generation. If the social system which began to develop was from the start some kind of central place foraging system, then communicating information about past encounters, future arrangements and the spatially remote, would have become more advantageous than it is in the lives of any living non-human primate. Natural selection could *begin* to favor the evolution of the mental abilities that make language possible.

The stone artifacts occur both as a scatter across the ancient landscape and in dense patches as so called sites. Clearly there were some places where making, using and discarding stone tools was preferentially concentrated. Whether this was through repeated activity bouts of solitary individuals or through usage by larger social groups is harder to tell. I am inclined to the view that these places were social foci, and that the accumulation of bones as well as stone artifacts at these places indicates that food was repeatedly carried in for consumption. In fact when these sites were first excavated it seemed intuitively obvious to us as modern humans that they were fossil camp-places, home-bases – or as I now prefer to designate the concept *'Central Place Foraging Loci'*. But here we come to a place where it is clear that we may be reconstructing our ancestors in our own image. Ascertaining how these early dense concentrations of artifacts plus bones formed, is perhaps the major challenge facing the archaeology of early man. It is a subject dear to my heart (Isaac 1969, 1978, 1981, in press) and since it would take a whole separate lecture or two I will not pursue it further here. (See also Binford 1981).

It is sometimes argued that tool-making traditions such as we find in the early stone age could only have been transmitted with the aid of language. I do not agree with this. One learns to make stone tools primarily by alternating watching with personal trial and error. The cognitive ability to conceive an elaborate design and execute it may or may not have been linked in evolution to the development of language abilities, but tool making *per se* does not call for this kind of communication. An orangutan has been taught to make simple stone tools (Wright 1972).

The application of the method-of-residuals-logic to interpreting early stone tools, makes it seem clear that evidence for elaborate culture is at a minimum. The tools are opportunistic rather than made to a set socially prescribed pattern. To be sure the tools do indicate socially learned behavior which constituted a simple level of culture, but there is little sign of arbitrary fixed designs, or of set rules or of style. These phenomena appear in the archaeological record only much later.

If I were to hazard a guess about the mentality of the earliest tool making hominids it would be that it was definitely non-human, even though these creatures of 2 million years ago had begun to be involved in some behaviors which are now characteristic of humans alone among the primates.

What is important about the archaeological evidence for tool making, for meat eating and perhaps for central place foraging is not that these traits made the early enactors human, but that the traits helped to establish a situation in which individuals were exposed to natural selection patterns which transformed their descendants, over 2 million years into humanity as we know it.

In this discourse I have chosen to focus attention primarily on the most basic component of the early archaeological evidence – the oldest surviving works of ancestral proto-human hands and minds. The study of these objects is but one part of a much more daring and imaginative endeavor, namely the search for information about the true nature of an original, distinctive but now vanished cultural system. The makers of the earliest stone tools began to drop litter and to form an archaeological record, but because they became litterbugs they did not necessarily become fully human! If we eventually succeed in knowing a little about their vanished way of life, our glimpses will have some of the drama of explorers visions of a new continent.

NOTES

1 Modern archaeological research is almost invariably accomplished by cooperating teams of people each of whom tackles a different portion. The material that I present to you in this lecture depends extensively on information and insight gained while working as part of the Koobi Fora archaeology research team. It was my good fortune to be invited in 1970 by Richard Leakey to coordinate that team, and I have done so ever since. I have cited sources from within the team whenever feasible – but there is also a generalized debt to the group that I wish to acknowledge here. My wife is very much a part of this group and many of the ideas in this essay have been argued out with her. She and another group member, Jeanne Sept, have done the line illustrations.

The study of early evidence about human life has come to involve a goodly company of diverse international participants, and there is a growing active involvement by young East African scientists. Not all of ones indebtedness to this community can be individually acknowledged, but without participation in the network of trusting exchange that these colleagues support, one would not be in a position to offer a review such as this one. I would single out J. Desmond Clark and S.L. Washburn as having been particularly influential in the development of my thoughts.

2 Awareness of a need to consider early hominid adaptive systems as original and not simply as precursors of the human patterns, has been around for some time and growing (see Jane Lancaster 1968; Jolley 1970). By the mid seventies it was beginning to guide research. Then in 1981 the issue was brought dramatically to general attention by Lewis Binford's book '*Bones: Ancient Men and Modern Myths*'.

3 The once famous '*Kafuan*' early stone age culture is now regarded as of dubious validity. Most of the broken stones in the Kafu gravels were probably the result of natural fractures (Bishop 1959).

By contrast the early artifacts at Olduvai, Koobi Fora and the Omo occur in fine grained sediments that are often devoid of stones other than the dense concentrations of flaked stones. Their artifactual status is quite certain.

4 In this review I have used the early assemblages from Olduvai, Koobi Fora and the Omo as the principal materials on which to base my discussion. This leaves out of account material from Melka Kuntoure and Chesowanja which also derive from the 1.5 to 2 million year old time range. I have done this because detailed reports on this important material are not yet available to me and I have not been able to study it personally. As far as I am aware this material conforms in general to the features discerned in the sites that are discussed, but doubtless the monographic reports, when available will add valuable new dimensions.

5 At Olduvai the situation is really more complex than is indicated here. A range of rock types were available and the early hominids showed changing patterns of preference eventually involving transport of some stone over long distances. This has been well reported in M.D. Leakey (1971) and by R.L. Hay (1976). Choice and transport are topics to which a whole lecture could be devoted.

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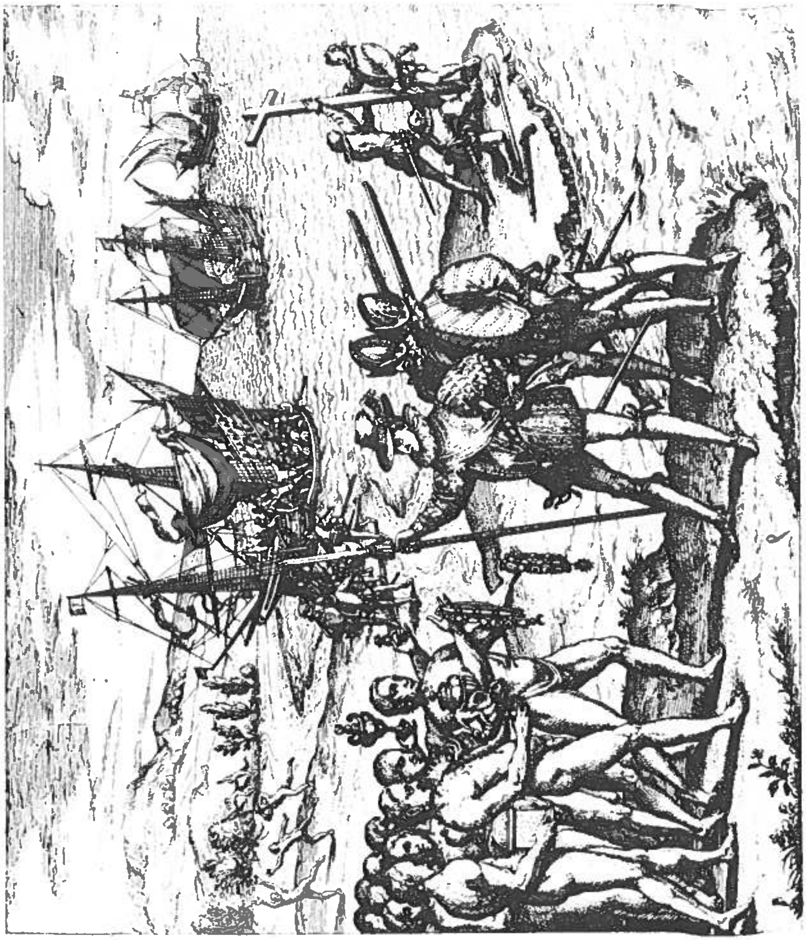


Figure 1. First encounters – Christopher Columbus reaches the edge of an unknown continent (from an engraving by Theodor de Bry).

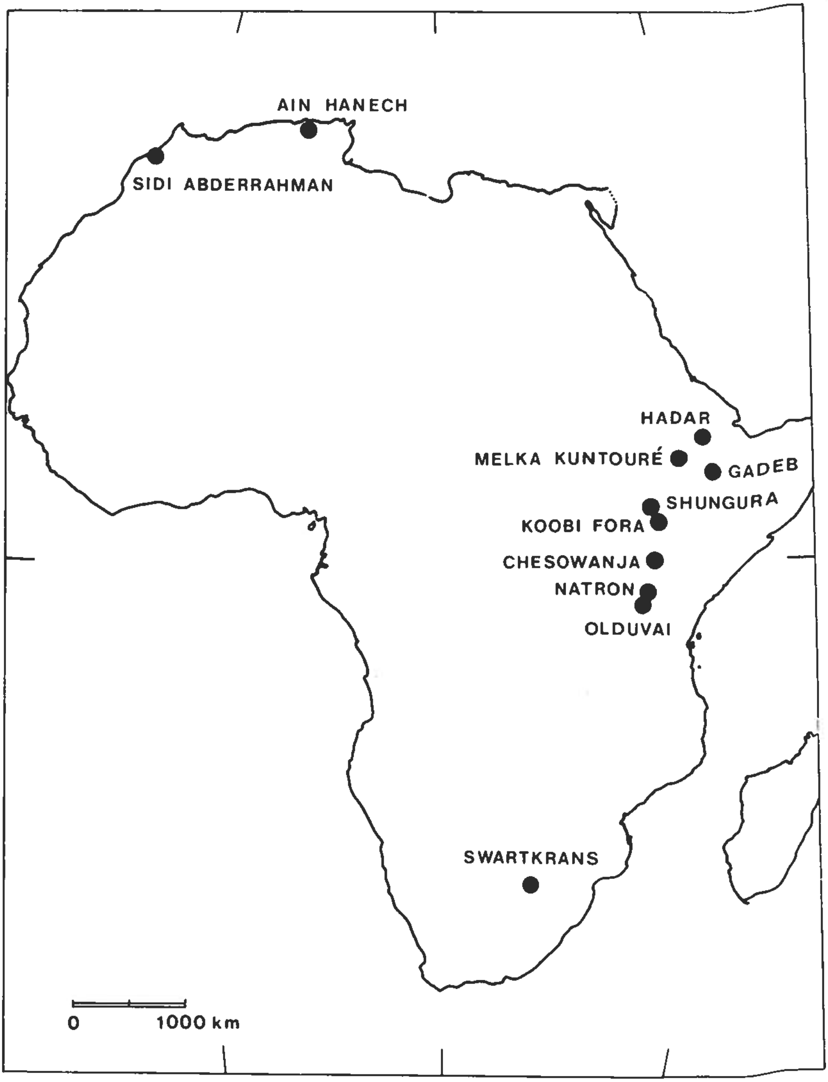


Figure 2. Very early archaeological sites in Africa.

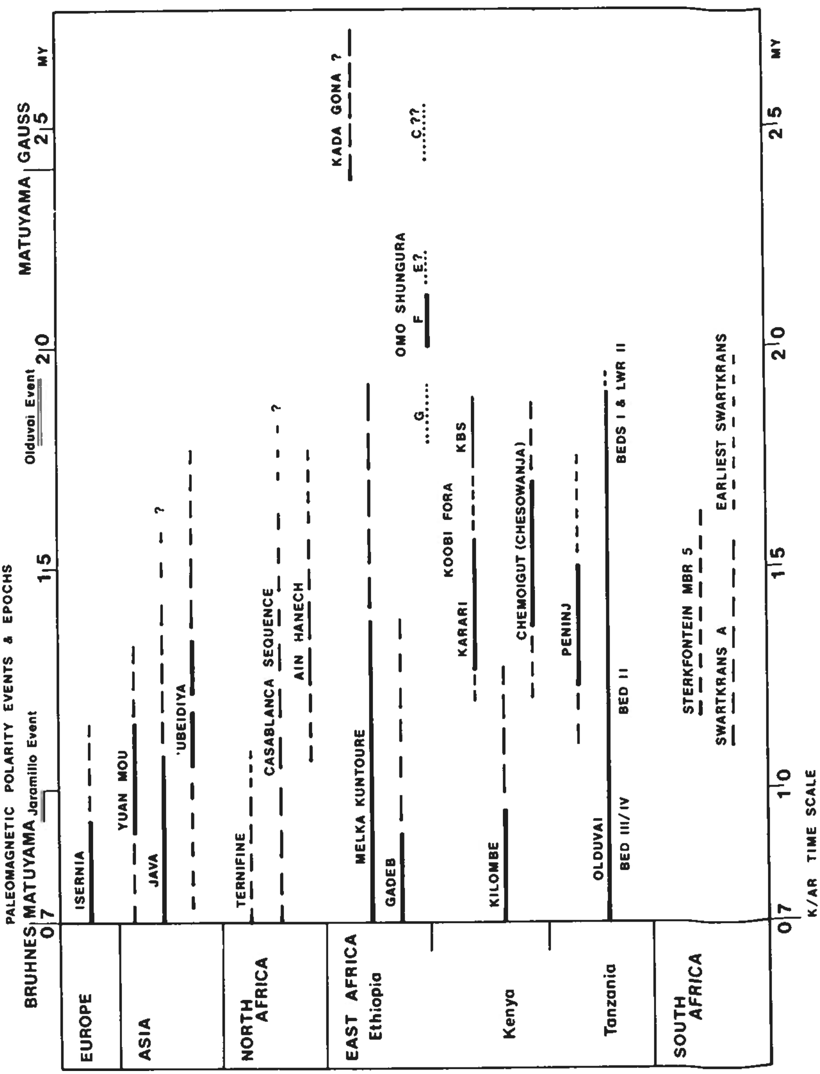


Figure 3. A chronological chart of African archaeological sites known to be older than 700,000 years. Selected, well dated Euro-Asiatic instances are also shown.

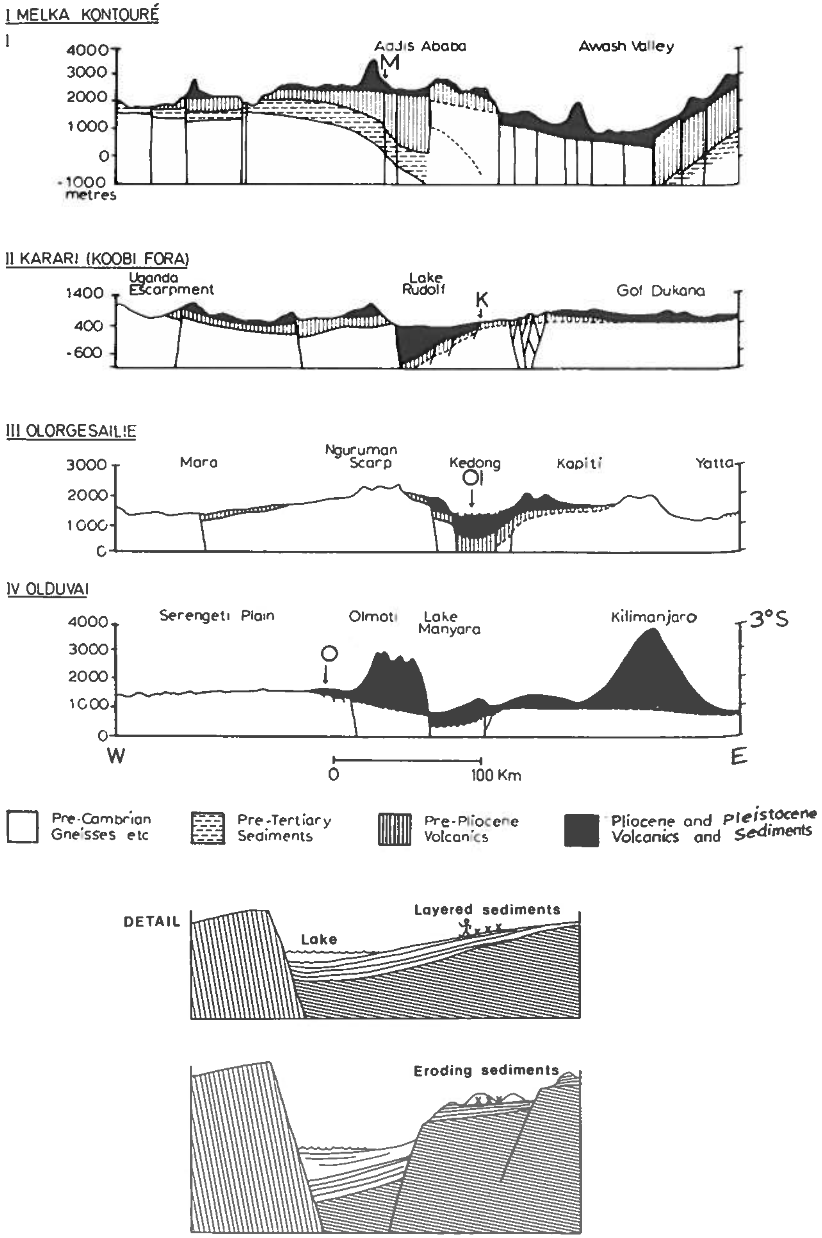


Figure 4. The geological circumstances of the eastern Rift Valley provide our best samples of information about the lives of early toolmaking hominids.
(Top) a series of profiles showing structure and rock types.
(Below) Diagramatic representations of how the fossil and archaeological record forms and then becomes available through earth movements and erosion.

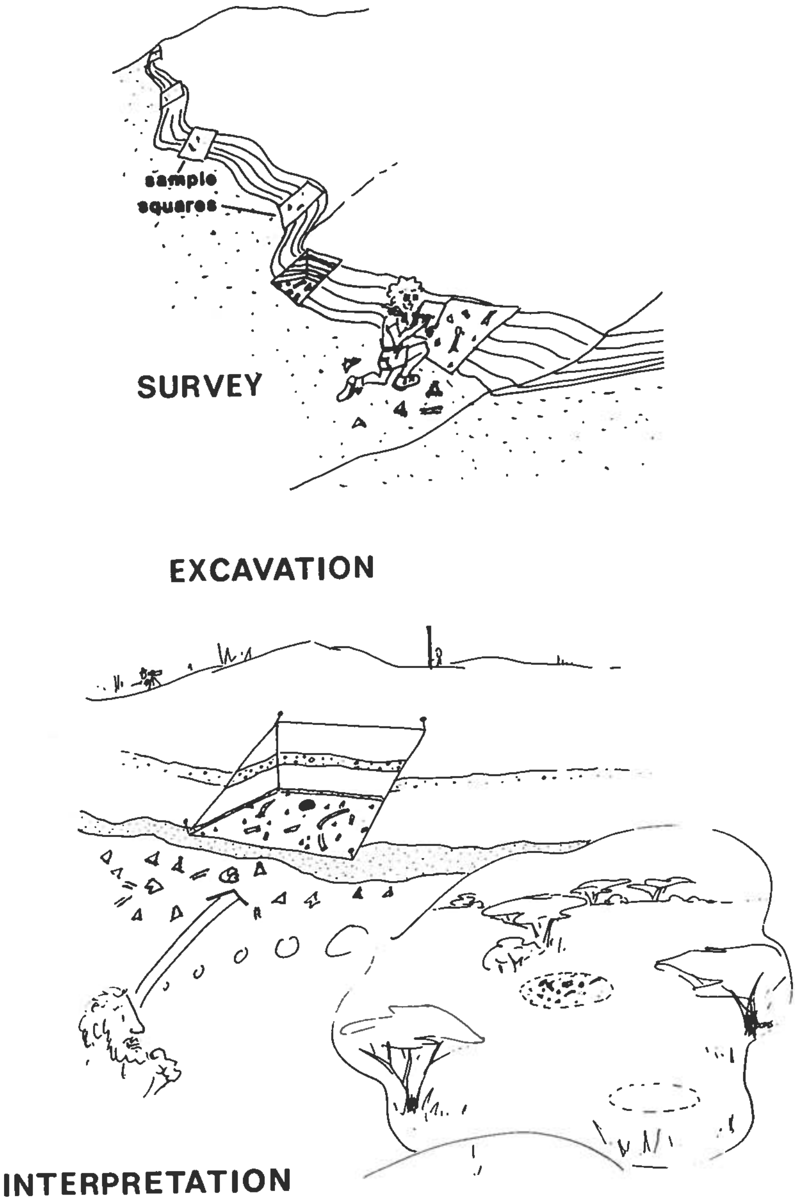
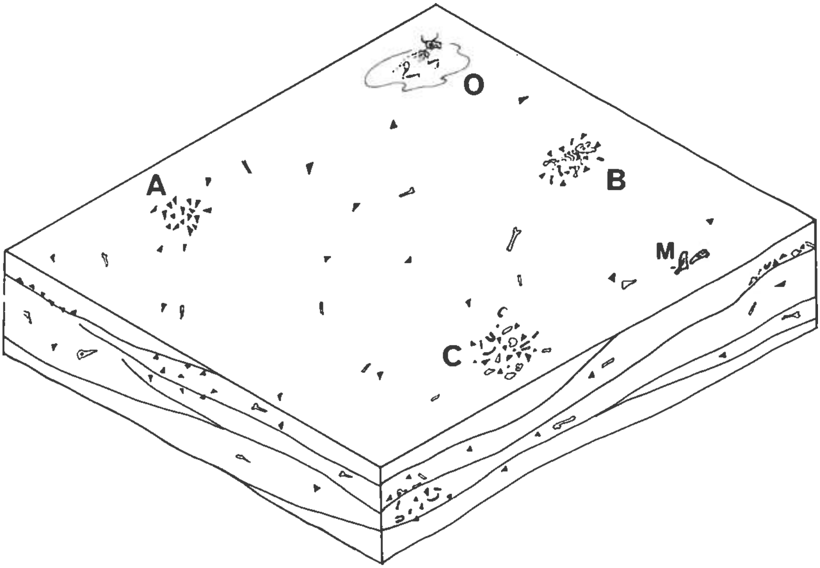


Figure 5. After erosion has cut into ancient layers archaeologists can survey along the outcrops seeking places where high densities of artifacts are being exposed (top). Characteristically archaeologists excavate back into the uneroded portion of the layer and interpret the concentrations of stones and bones that they uncover as sites which formed on ancient land surfaces (below).



A = artifacts only
B = carcass of a large animal plus artifact (= 'butchery')
C = artifacts plus bones from different animal carcasses (= 'camp')
O = bones only (= 'osteological site')
M = bones with cutmarks but no associated artifacts

Figure 6. From observations along outcrops and from excavations archaeologists can infer the existence in landscapes of 2 million years ago, of the pattern represented in this block diagram. An arbitrary area of flood plain is shown. On it is a scatter of isolated artifacts and bones, plus concentrations of 5 kinds: A, B, C, O and M. These are what archaeologists call sites.

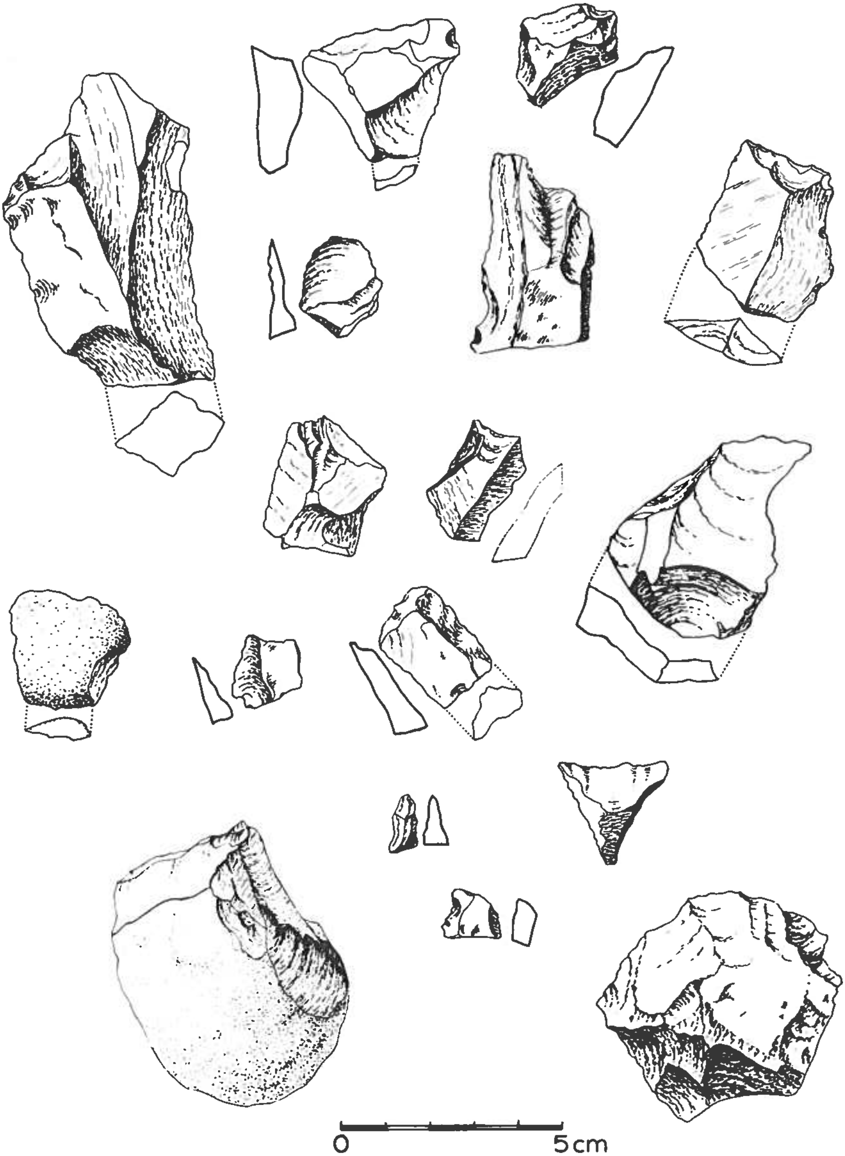


Figure 7. A versatile, but opportunistic array of sharp edged forms –: two cores (lower) and an assortment of flakes and flake fragments from the KBS site at Koobi Fora (1,8 mya). Usually flakes and flake fragments outnumber cores more than 19 to 1. Drawn by A.B Isaac.

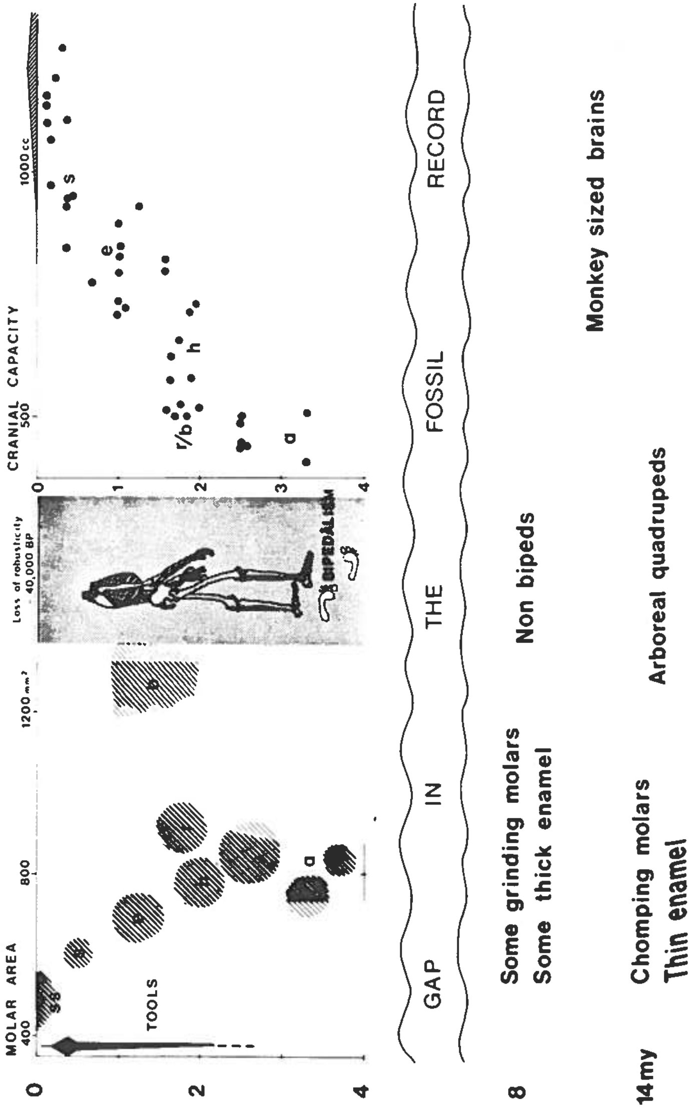


Figure 8. A simplified synopsis of information from fossils concerning human evolution: only in the 0–4 million year old range are fossils identifiable as human ancestors known. For this time range the center column shows that bipedalism was established by 4 mya and did not undergo important changes after that. Between 4 and 2 mya fossils give evidence of large toothed (left) small brained forms (australopithecines). At about 2 million years ago, some forms began to show the start of trends towards reduced cheek-tooth size (left) and to enlarged brain size (right). At about 2 mya the same layers that contain fossils showing the start of this trend, also contain the oldest known artifacts.

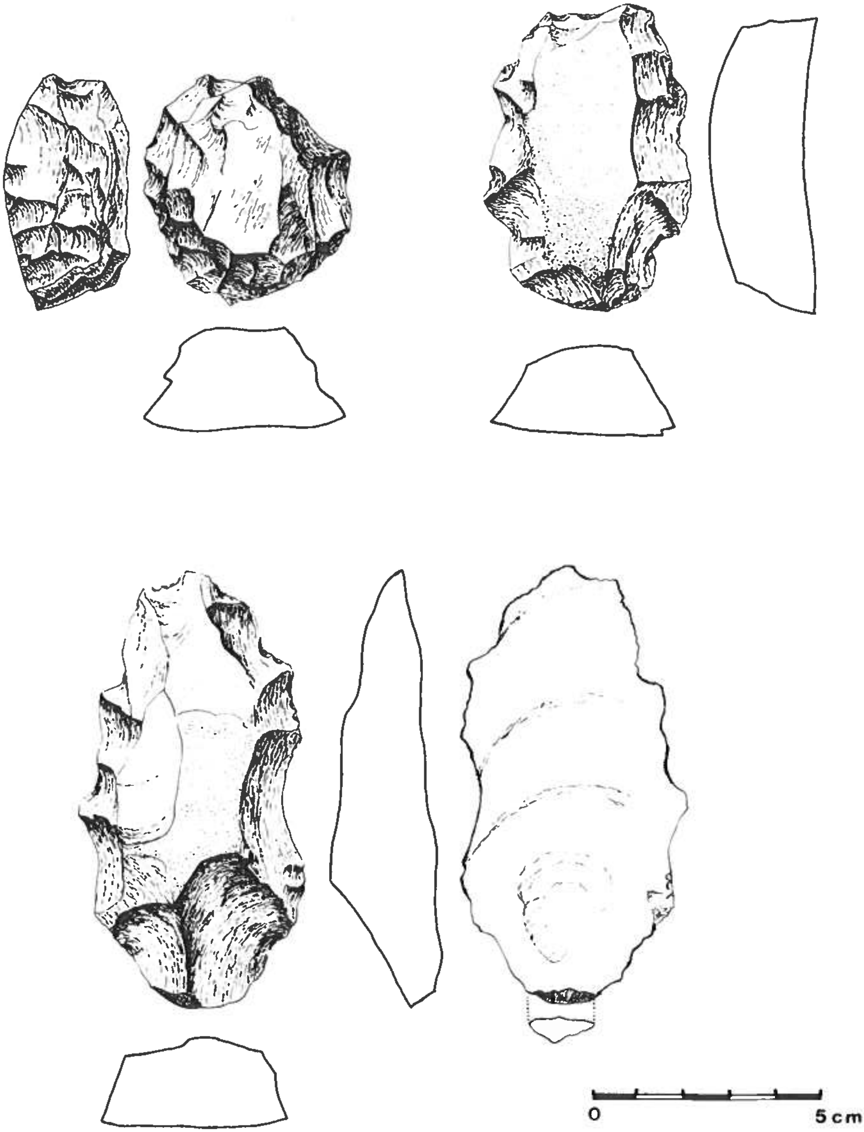


Figure 9. Neatly flaked pieces from 1.5 my old sites at Koobi Fora. These Karari scrapers may have been deliberately designed tools – but it is also possible that they represent fossilised habits – that is to say, that one orderly predictable way to generate a supply of sharp edges was to keep knocking off flakes round the perimeter of a hemispherical segment of cobble. (Drawn by A.B. Isaac.)

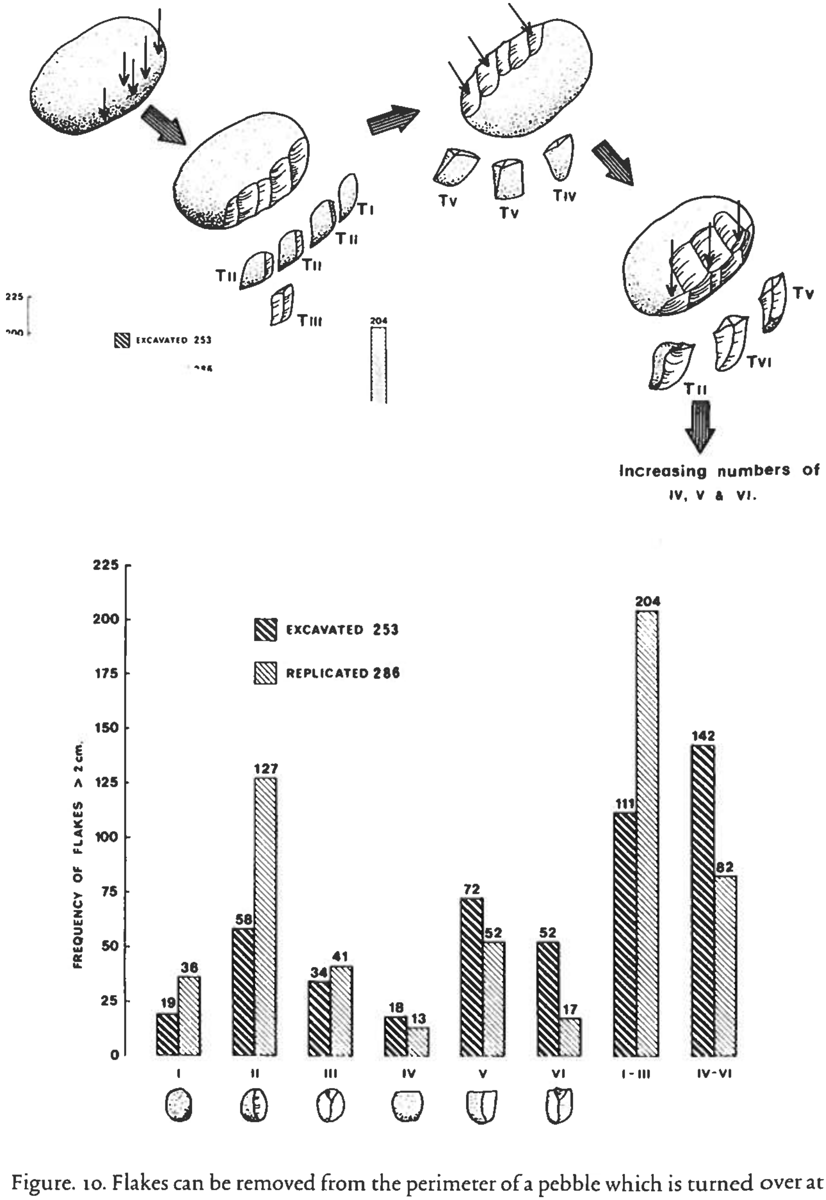


Figure. 10. Flakes can be removed from the perimeter of a pebble which is turned over at intervals. The flakes show changing technological characteristics as the process goes on (types I–IV). If a core is introduced after flaking has been commenced, or if some flakes are taken away, there will be a mismatch between the flakes found at a site and the set predicted from the cores found at that site. N. Toth has shown that this relationship can be a clue to the dynamic flow of carrying-making-using-carrying etc that ran across the landscape, with assemblages as fall-out. This histogram shows a real case of such evidence at site FxJj50. (Toth in Bunn et al 1980.)

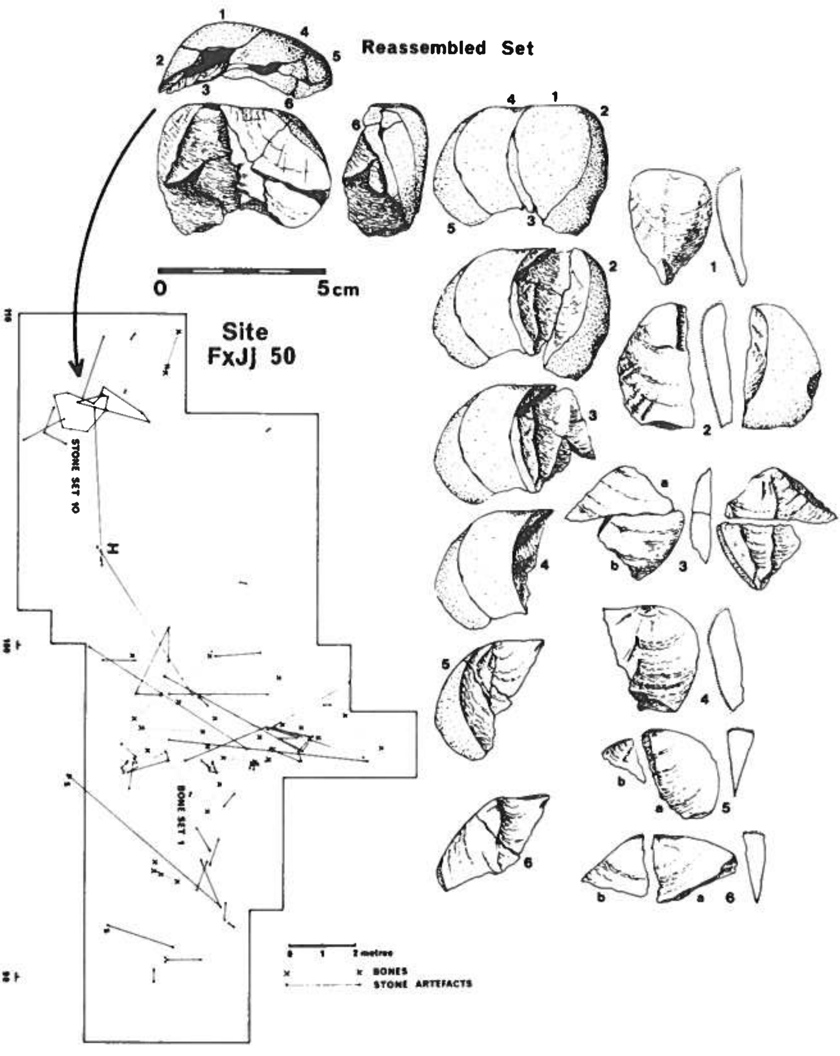


Figure 11. At some sites, stones which were struck assunder 1 1/2 to 2 million years ago, can be partly fitted back together again. Here are a set of flakes from the early stages of trimming a flat cobble – the cobble itself which had been formed into a core or a 'chopper' was taken away. The flakes were found as a cluster within site FxJj50 a well preserved example of a type C site (Bunn et al 1980). (A.B. Isaac del.)

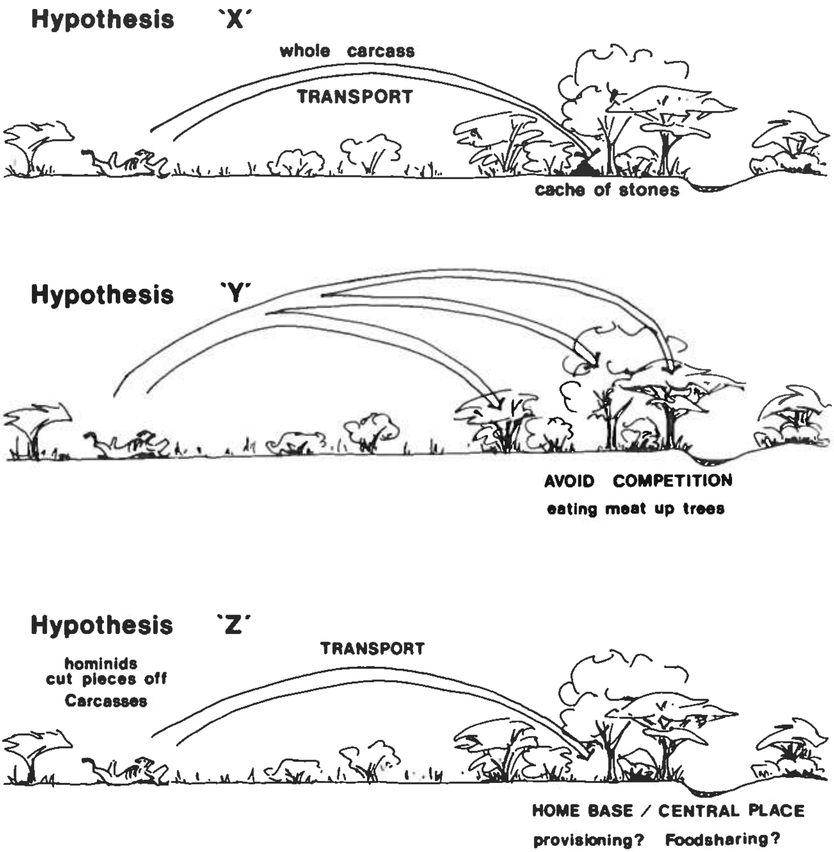


Figure 12. Alternative hypotheses as to why concentrated patches of discarded artifacts and broken up bones began to form 2 mya. X – carcasses are carried to places where stone has been stockpiled (Potts 1982); Y – portions of carcasses were cut off with flakes and carried to sheltered places for solitary consumption with more tools being made and used in the area; Z – meat is carried back to particular (sheltered) places for at least partly collective consumption.

	Action	Application to/in	Unshaped tools: Stones	Unshaped tools: 'Sticks'	Unshaped tools: Broken bones	Unshaped tools: Bark tray skin bag	Shaped tools: Flake	Shaped tools: Flaked stone	Shaped tools: Sharpened stick
FOOD ACQUISITION	POUNDING HAMMERING	eg nuts marrow bones tenderising hide maccerating bark etc	⊛					•	
	CUTTING & SEVERING	hide sinews meat		•	•		Flake knife ⊛	•	
	DIGGING	bulbs, corms, tubers burrowing animals		•	⊛				Digging stick 3a *
	HACKING OPEN	grubs honey chelonians	•	•	•				
	CARRYING	small food items eg berries, nuts, tubers lizards				*			
MAKING OTHER TOOLS	CHOPPING HACKING	to cut off a branch	•					Chopper 1 ⊛	
	WHITTLING PARING	to sharpen a stick/stave					2 ⊛ Sharp flake		
WEAPONS	THROWING	prey (birds, small game) predators conspecific competition	*	•	•				
	CLUBBING	ditto, especially larger immobilized or cornered		*	•				
	PIERCING	ditto		•	•				* 3b Spear

* = Highly effective

⊛ = Highly effective + known archaeological evidence

• = Some selected forms are usable

Table 1. Some basic functions for tools and forms that make them possible. On the left are natural, unshaped objects. On the right simple shaped objects.

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