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# NEW PLIO-PLEISTOCENE ARCHAEOLOGICAL OCCURRENCES FROM THE PLAIN OF GADEB, UPPER WEBI SHEBELE BASIN, ETHIOPIA, AND A STATISTICAL COMPARISON OF THE GADEB SITES WITH OTHER EARLY STONE AGE ASSEMBLAGES

*[Text of a paper delivered in Symposium V, "The Earliest Industries of Africa" at the IXht Pre- and Proto-historical Sciences Congress, Nice, 1976. Subsequent research shows that the age of these artifact assemblages lies between 1.4 and 0.7 million years before the present and provides general confirmation for the interpretations presented here (See also Clark and Kurashina, 1979).]*

## INTRODUCTION

During the winters of 1974 and 1975, geomorphological and archaeological reconnaissance has been carried out by research teams from the University of California at Berkeley and Macquarie University, New South Wales, in a part of southeastern Ethiopia that includes the southern end of the Afar Rift and the northern part of the South-East Plateau including the headwaters of the Webi Shebele river *(Fig. 1)*. These are two very different eco-systems: the one, low-lying, arid and hot at an average elevation of 800—1000 m; the other temperate on the high plateau at mean elevations of between 2,300 and 2,500 m, overlooked by formerly glaciated volcanic peaks and mountain ranges rising to more than 4,000 m. The main objectives of this on-going research programme are to locate and sample occupation sites, hopefully with plant remains and fauna, that could be tied into the climatic and ecological sequence recovered by the geomorphologists, to reconstruct the economic base by sampling at selected sites, and to try to assess the extent to which contrasting eco-systems of Rift and Plateau were responsible for differences in the industrial assemblages and other occupational features.

On the west side of the South-East Plateau, the Webi Shebele meanders through the Plain of Gadeb and a number of localities yielding artifacts and fauna were found here over a stretch of some 70 km between where the Webi Gorge begins at Melka Likimi in the east, westward along the river to localities named from Gadeb and situated c. 20 km north of the main road between the towns of Adaba and Dodola. The terrain here is one of heavily cultivated short grassland, mostly treeless, but with occasional junipers and other evergreens surviving precariously in sheltered localities. These show that the forest was certainly more widespread in the past than it is today since the evergreen montane forest has now been confined, largely by human activities, to the tops of the volcanic peaks and the Bale Moutains. Because a pebble chopper had previously been found at Melka Wacana, in association with lacustrine sediments, a sample of which yielded a pollen spectrum studied by Bonnefille

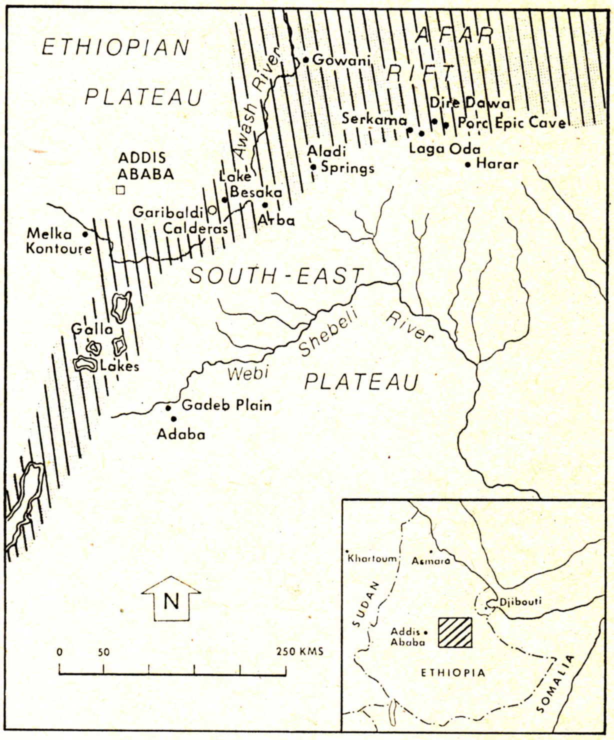


**FIG. 1.**
*Site location map.*

(B o n n e f i l l e, et. al. 1970), we suspected that this high plateau country might provide cultural and faunal assemblages comparable to those from Melka Kunture on the Ethiopian Plateau south of Addis Ababa (C h a v a i l l o n, J., 1976, C h a v a i l l o n, N., 1976).

The Plain of Gadeb is underlain by late Tertiary volcanic and a series of fluvio-lacustrine sediments and tuffaceous beds of Plio-Pleistocene age. The lake came into existence following the eruption during the late Tertiary of lavas that blocked the outlet of the proto-Webi Shebele valley, so that an extensive lake, more than 150 km long and 50 km wide, was able to form behind this barrier. The record of lake level fluctuations and the lacustrine and fluvial sequence are reflected in exposures along the main river and some of the tributaries.

During a further visit in December, 1975, by Dr Williams accompanied by Dr Françoise Gasse and Professor Pierre Rognon of CNRS, Paris, it became apparent that the record is more extensive than we had originally thought. High level diatomites that predate the cutting of the gorge were found and they have yielded forms of archaic appearance that are pre-Villafranchian in age (F. Gasse, pers. comm.) and may be comparable to the Plio-Pleistocene diatomites at the Melka Likimi localities where, in February, 1974, we recovered a polyhedral stone in fresh condition associated with a bovid scapula. It seems possible, therefore, that the early part of the upper Webi Shebele sequence could be of Pleistocene age (M. A. J. Williams, pers. comm.). We especially thank Dr M. A. J. Williams and geologists from Macquarie University and the University of Addis Ababa, who are responsible for the geomorphological investigations and for the preliminary interpretations we are able to put forward here. It must be stressed that any conclusions, both geological and archaeological, now presented should be considered as tentative only pending the completion of work on the material already recovered and further field investigations of specific localities. A series of diatom and pollen samples currently being studied by Dr F. Gasse and Dr R. Bonnefille of CNRS, Paris, should considerably amplify understanding of the palaeo-environment and provide a relative chronology, while the presence of interbedded tuffs and ash layers holds promise of our being able to obtain some radiocarbon dating for the sequence.

Further west, at Gadeb, we now have 15 localities over a distance of 3 km along the river where the Plio-Pleistocene fluviolacustrine sediments are cut through and exposed as cliff sections on the outside of the meanders. A fuller report on the stratigraphic sequence and geological history of the Plio-Pleistocene Gadeb lake will be presented elsewhere and the following summary is to show the location, within the general succession, of the horizons from which the samples to be described here were recovered.

## GEOLOGICAL BACKGROUND

Two major cycles of fluvio-lacustrine deposition dating to the early and Middle Pleistocene are separated by a major erosional episode, the sediments of the later cycle being cut into and banked against the earlier, thus forming two terrace-like features at c. 25 m and c. 12 m respectively above the river; these are followed by two minor depositional episodes of Upper Pleistocene and Holocene age.

At Gadeb Locality 2 a 22 m thickness of sediments of the earlier cycle has been exposed. From the base up these deposits consist of c. 7 m of diatomite, interbedded with sand lenses (Member A), overlain unconformably by gravelly sands and fine gravels (Member B) with Developed Oldowan artifacts at the interface with the diatomite and one fresh Acheulian cleaver eroded from sands in the upper part. Above this, is a thin layer of diatomaceous fine sand (Member C) overlain by bedded fine grey sands (Member D) at the base of which another well-made Acheulian cleaver was obtained together with some fossil bone fragments but no other artifacts. Above again, are some 3 m of reworked pumice and fluvial gravelly sand (Member E) capped by indurated gravels (Member F) filling a stream channel and containing, at the base, rolled and slightly abraded Developed Oldowan tools and fossil bones. Above these are 3 m of sandstones, locally with interbedded indurated gravels, and two intercalated palaeosols (Members G—K).

At least two, therefore, of these Members — B and F — have produced horizons with Developed Oldowan assemblages, and Members B and D also yielded Acheulian cleavers. We carried out trial excavations at three places in Member F, two of which — Gadeb 2B and Gadeb 2G — produced concentrations of Developed Oldowan artifacts and some scraps of fauna, all lying in shallow stream channels. At the third excavation — Gadeb 2D — we recovered only fauna from current bedded sands and fine gravels. Gadeb 2B is at a slightly higher (c. 1.5 m) elevation than Gadeb 2C and is probably, therefore, somewhat later in age; Gadeb 2D is c. 1.0 m lower than 2C. The distance between 2B and 2C is c. 400 m.

Faunal remains have been recovered from several horizons and provisional identifications have been made by M. Denis Geraards attached to the National Museum in Addis Ababa. *Hippopotamus amphibius* is well represented together with one record of a form larger than the modern hippopotamus. Among the bovids in an Alcelaphine represented by a horn core from Gadeb 2D and from the same site come two fragmentary molars, provisionally identified as belonging to *Metridiochoerus andrewsi*, a form present in Beds I and II at Olduvai Gorge. The existing warthog, zebra and elephant are also represented by fragmentary remains from this locality. *Metridiochoerus* has a time range of 1.25 to 2.76 m. y. (Cooke and Maglio, 1972: 313—315; Isaac and Curtis, 1974) suggesting that the Gadeb Locality 2 sequence may belong in the later part of the Lower Pleistocene.

Artifacts from all these Gadeb sites are made from cobbles or chunks of basaltic lava and welded tuff.

## GADEB LOCALITY 2B *(Fig. 5)*

At Gadeb 2B a 2 m×4 m excavation was made by one of us (H. K.) and yielded 585 artifacts lying at the base of a stream channel that is disconformable on the surface of the diatomaceous sands of Member E. The artifact horizon is overlain by coarse sands and horizontally bedded indurated gravels. Like all the others to be described below, this assemblage has clearly suffered some degree of disturbance from stream action subsequent to use and abandonment by the hominid group that made it, and it is, therefore, unlikely that any can be considered to be in primary context. However, the artifacts are confined to a single horizon, show a range of abrasion categories from heavily abraded to fresh with the greater number in the moderately abraded class *(Fig. 2)* and the distribution plots show no preferred artifact orientation but have heavier and light duty classes equally represented. All this suggests that the artifacts have not been moved very far form the place where they were discarded although abrasion and weathering make it impossible to distinguish utilisation on these materials with any certainty; this category, therefore, is likely to be under-represented.

Shaped Tools make up 9 % of the assemblage, less than 1 % are Utilised and the remaining > 90 % are Unmodified Waste, comprising cores, flakes, fragments and chunks. Again, the breakdown suggests that no natural sorting has taken place *(Fig. 3)*.

The assemblage is comparable to the form described by Dr. Mary Leakey as Developed Oldowan Type B (Leakey, M. D. 1967) from the middle to upper part of Bed II at Olduvai Gorge.[1]) The number of Shaped Tools *(Fig. 4)* is small (55) and hardly an adequate sample and almost all the tools fall into the chopper (16), polyhedron (16) and small scraper (20) classes. In addition, there is one proto-biface, one ficron handaxe made by hard hammer and one cleaver-flake showing minimal proximal modification. The choppers are mostly bifacially flaked with mean lengths of 64.62 mm. Sub-classes are almost equally divided between side (6), end (5), side and end (4) forms and one is pointed. The Light Duty scrapers have mean lengths of 52.05 mm and are made on flakes, fragments and chunks.

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1) *It is not yet possible to compare the Gadeb assemblages with the Developed Oldowan occurrences from Beds III and IV from Olduvai (designated Developed Oldowan Type C) since these are not yet published. It can be expected, however, that there may be close comparisons in assemblage composition.*

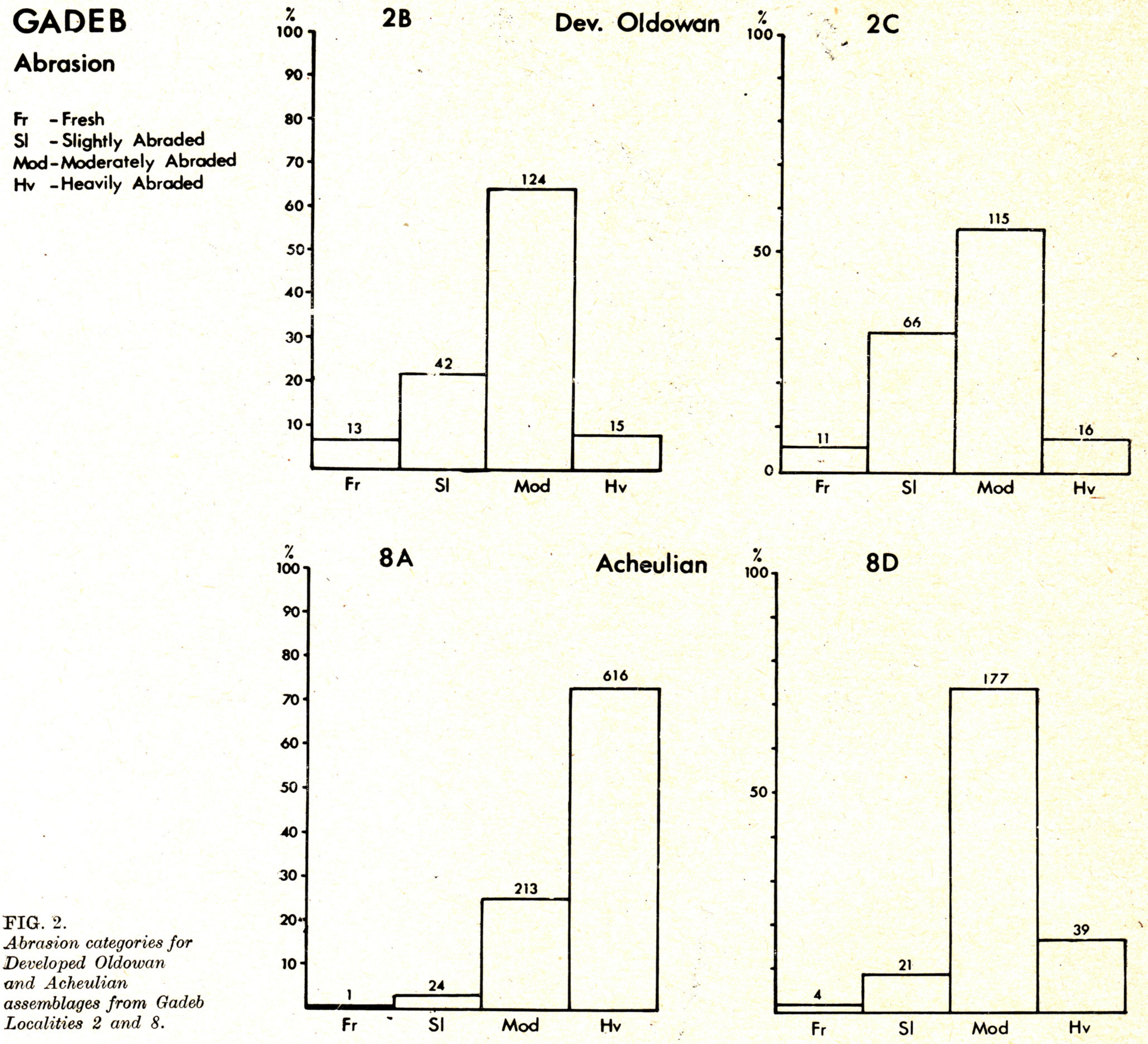



FIG. 2.
*Abrasion categories for Developed Oldowan and Acheulian assemblages from Gadeb Localities 2 and 8.*

They are subdivisible into single (9) and double (1) sided; convergent (2), end (1), nosed (1), notched (1) and denticulate (4) forms; there is also one core or steep scraper.

Besides one Modified piece and a cobble hammerstone, the remainder of the artifacts represent Unmodified Waste. There are perhaps a surprising number of cores (46), mostly informal or casual specimens having single (8), double (11) and multi-platforms (12) together with 4 proto-biconical and 11 flat biconical or discoid cores. The 91 flakes have a mean length of 46.52 mm, breadth of 40.81 mm and L/B ratio of 1.18. They are thick relative to their length, with broad, inclined platforms and the deep, irregular scars characteristic of hard hammer technique. Nearly three quarters (61) are irregular end—(38) and side—(23) struck but the remainder are classified as long or short quadrilateral and triangular.

GADEB LOCALITY 2C *(Fig. 6)*

The Developed Oldowan B assemblage from a 1.5×3.5 m excavation by Steven Brandt occurred in a thin indurated gravel at the base of a channel fill cut into sands with diatomite clasts and overlain by a metre or more of coarse current bedded sands. Again most of the artifacts are lightly or moderately abraded *(Fig. 2)* and the other circumstances of the occurrence are similar to those described for Gadeb 2B, indicating relatively little natural displacement by stream action. Out of a total number of 622 artifacts, 10 % are Shaped Tools, nearly 2 % are Modified/Utilised and the remaining > 88 % represent Unmodified Waste *(Fig. 3)*. The composition of the Shaped Tools *(Fig. 4)* is again similar to Gadeb 2B, except for additional bifaces and, since no great period of time can separate the two, this would not be unexpected. Choppers comprise 27 %, divided into the sub-classes: side (5), end (7) and side and end

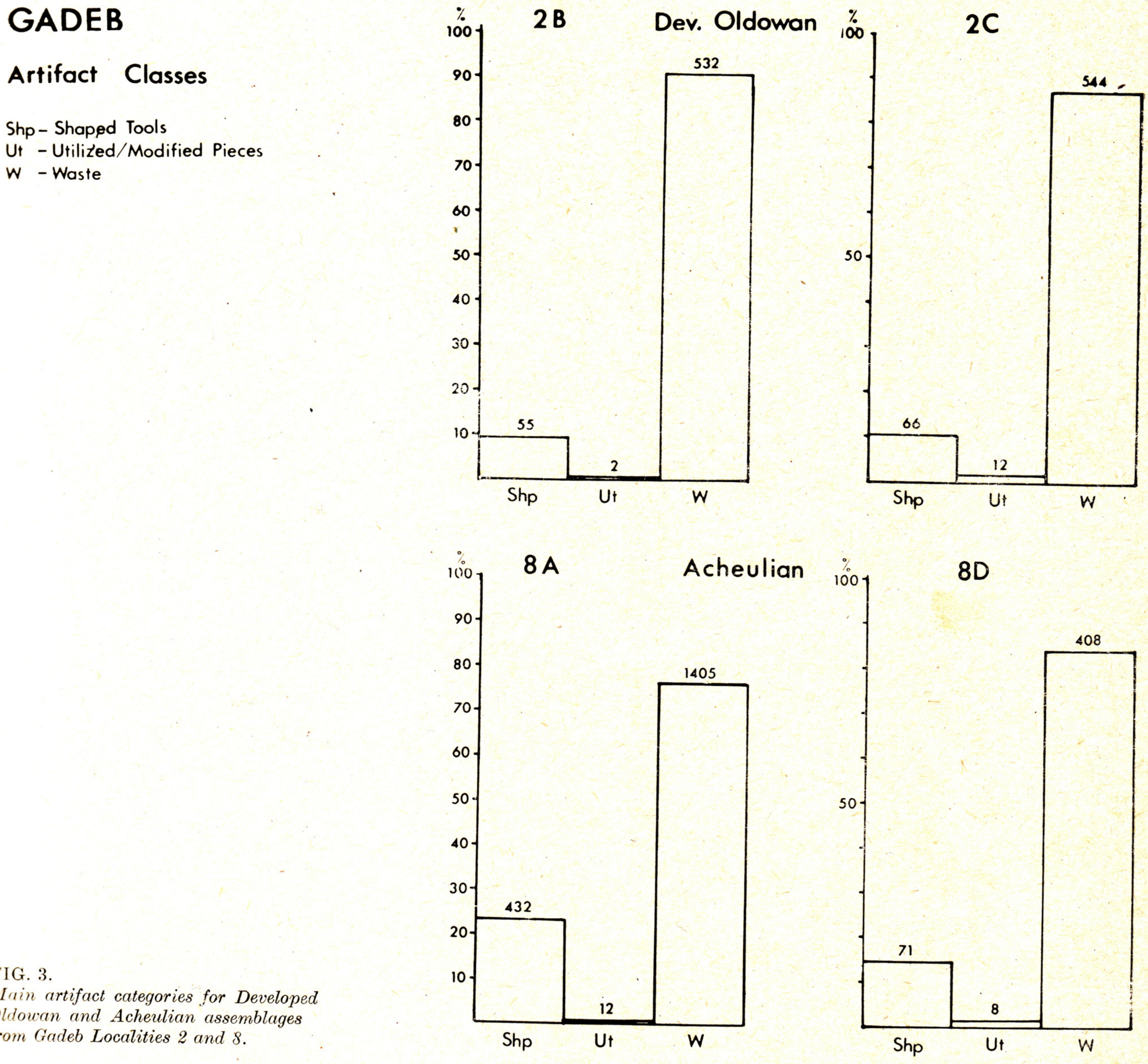


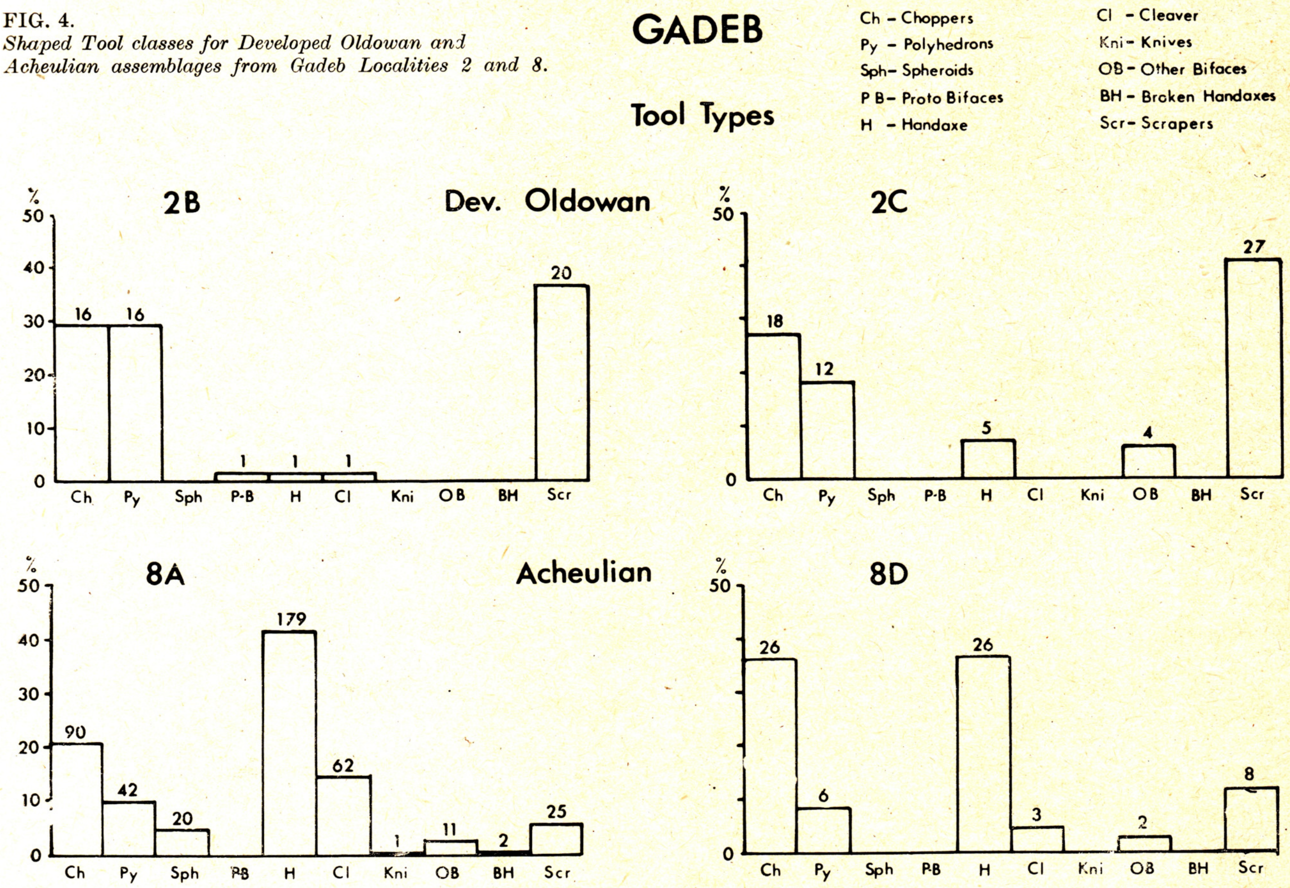

FIG. 3.
*Main artifact categories for Developed Oldowan and Acheulian assemblages from Gadeb Localities 2 and 8.*

(6). Polyhedrons comprise a little over 18 %. The class with the greatest number of tools is that of Light Duty small scrapers (46 %); most of these are single side scrapers (11), notched (5), and end and side (3); the remainder comprising double side (1), denticulate (2), convergent (1), transverse (2) and end (1); there is also one core or steep scraper. There are five bifaces (7.6 %) from the excavation, ficron and elongate-ovate in plan form, shaped by a small number of deep flake scars produced by hard hammer technique. In addition are four bifacially retouched artifacts classified as "other bifaces" which do not have the symmetry of the handaxe form. Minimally Modified pieces comprise 1.9 % including one battered anvil stone.

Cores comprise 4 % of the Unmodified Waste, the same informal sub-classes being present together with six biconical cores and five discoids. Unmodified flakes (18.4 %) have a mean length of 40.36 mm and breadth of 32.9 mm with a mean L/B ratio of 1.32. They are sub-divided into 18 irregular end- and 11 side-struck flakes and nearly 53 % are long and short quadrilaterals (37 and 16 respectively) together with 19 sub-triangular forms. The assemblages from sites in the Afar Rift have indicated that an appreciably greater antiquity should now be assigned to the earlier stages of the Ethiopian blade tradition and, in view of this, the presence of "proto-blade" forms in Earlier Stone Age contexts here is perhaps no reason for surprise.

It will, of course, be necessary to recover larger samples in order to determine the full range of relative frequences of the artifact classes in the Developed Oldowan assemblages from Gadeb, as well as the extent to which local facies might be distinguishable. For example, it would not be unlikely that the occurrences round the periphery of the lake at the foot of the Bale Mountains will show

FIG. 4.
*Shaped Tool classes for Developed Oldowan and Acheulian assemblages from Gadeb Localities 2 and 8.*




differences from those closer to the lake margin. From preliminary observations, however, no significant difference is apparent between the assemblages from Gadeb 2B and 2C and those from other horizons within the earlier sedimentary sequence at this and other of the Gadeb localities.

GADEB LOCALITY 8

At the Gadeb 8 Locality, c. 2 km east of Gadeb 2, sediments of the second depositional cycle are banked against those of the first and, at a number of places, artifacts can be found eroding. Both Developed Oldovan and Acheulian assemblages are represented but time permitted trial excavations in only two of the Acheulian horizons. At Gadeb 8 the complete sequence of nearly 9 m was obtained by the geomorphologists in 5 step trenches.

GADEB 8A *(Figs. 7—9)*

Here the basal sediments are diatomites with some gravel lenses and these are overlain by fluvial gravels and sands on which rests a gravel, sometimes cemented and indurated, with many Acheulian biface tools and diatomite clasts. This gravel is some 10—15 cm thick with lenses of fine sand and is overlain by fine cross-bedded, fluvial sands, more indurated gravels and grey pumice sands. These appear to be the uppermost of the earlier Pleistocene sediments preserved here and they have been channelled and overlain by gravels, loams and calcrete with occasional Middle Stone Age artifacts, suggesting an early Upper Pleistocene age for the top part of the sequence. We would describe the assemblage from the underlying gravel horizon as Upper Acheulian and the sediments as falling into the late Lower Pleistocene.

At Gadeb Locality 8A, a 2×4 m excavation by one of us (J. D. C.) and Steven Brandt, produced the surprising total of 1849 artifacts. These were lying in the gravel of the bottom of a channel of what must have been a fairly strongly flowing stream. They are made from basalt and welded tuff and the majority show heavy to moderate degrees of abrasion *(Fig. 2)*. They cannot, therefore, be in primary context and must have been moved by the stream since the preferred orientation of the long axis of the bifaces is between 45° and 55° East of North. Some also are inclined obliquely with the lower end to the southwest which, on the basis of Dr. Glynn Isaac's experiment at Lake Magadi (Isaac, 1967b) suggests that the stream was flowing in a northeasterly direction, not. that is, greatly different from that of the Webi Shebele in this part of its course today. Such a conclusion raises the question as to whether the makers of the industry might not have been camping in the streambed at low water, in which case the artifacts need not have moved very far. This seems not imporbable if the site was revisited over several seasons, in

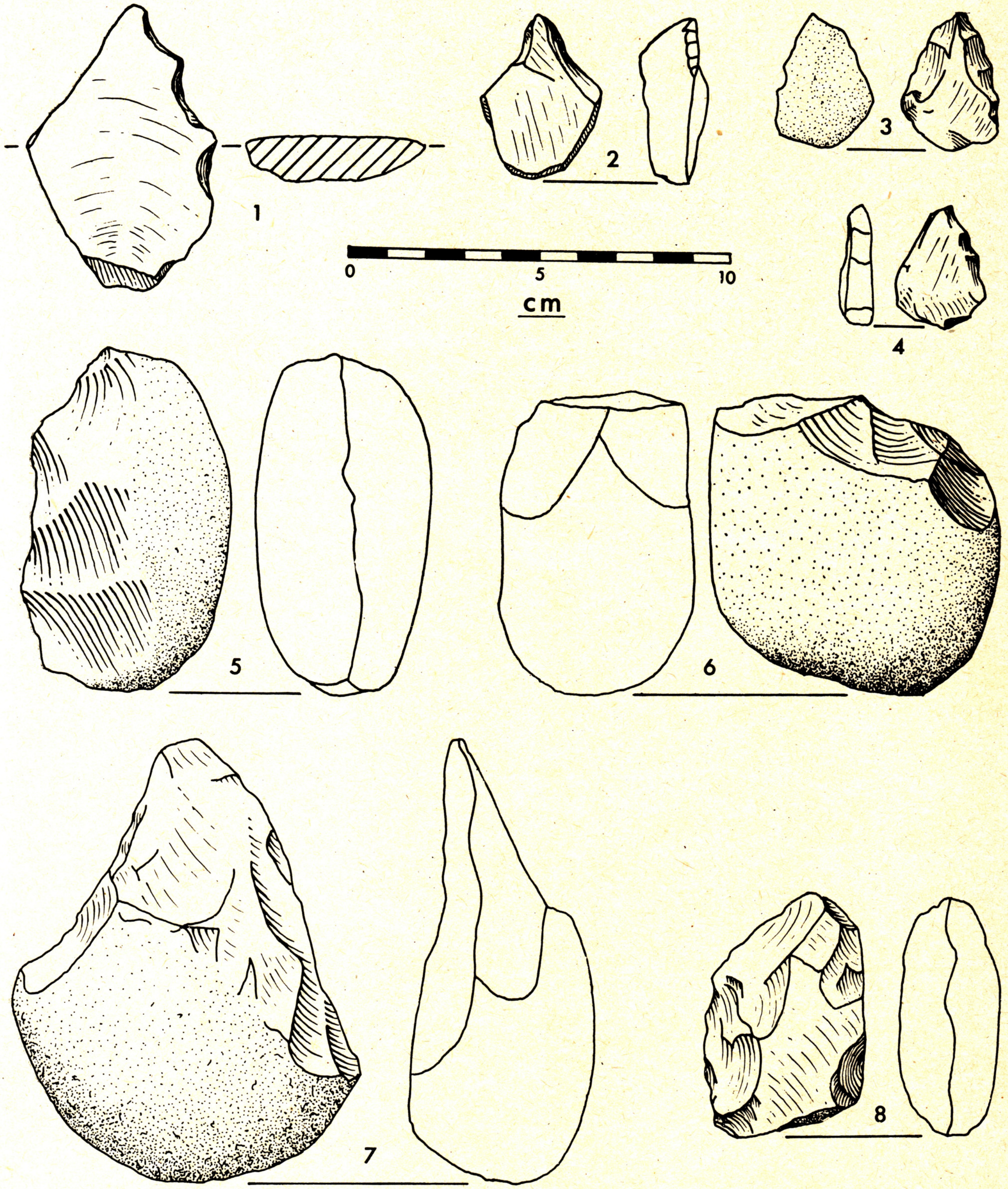



FIG. 5. *Developed Oldowan Type B artifacts from Gadeb Locality 2B.*

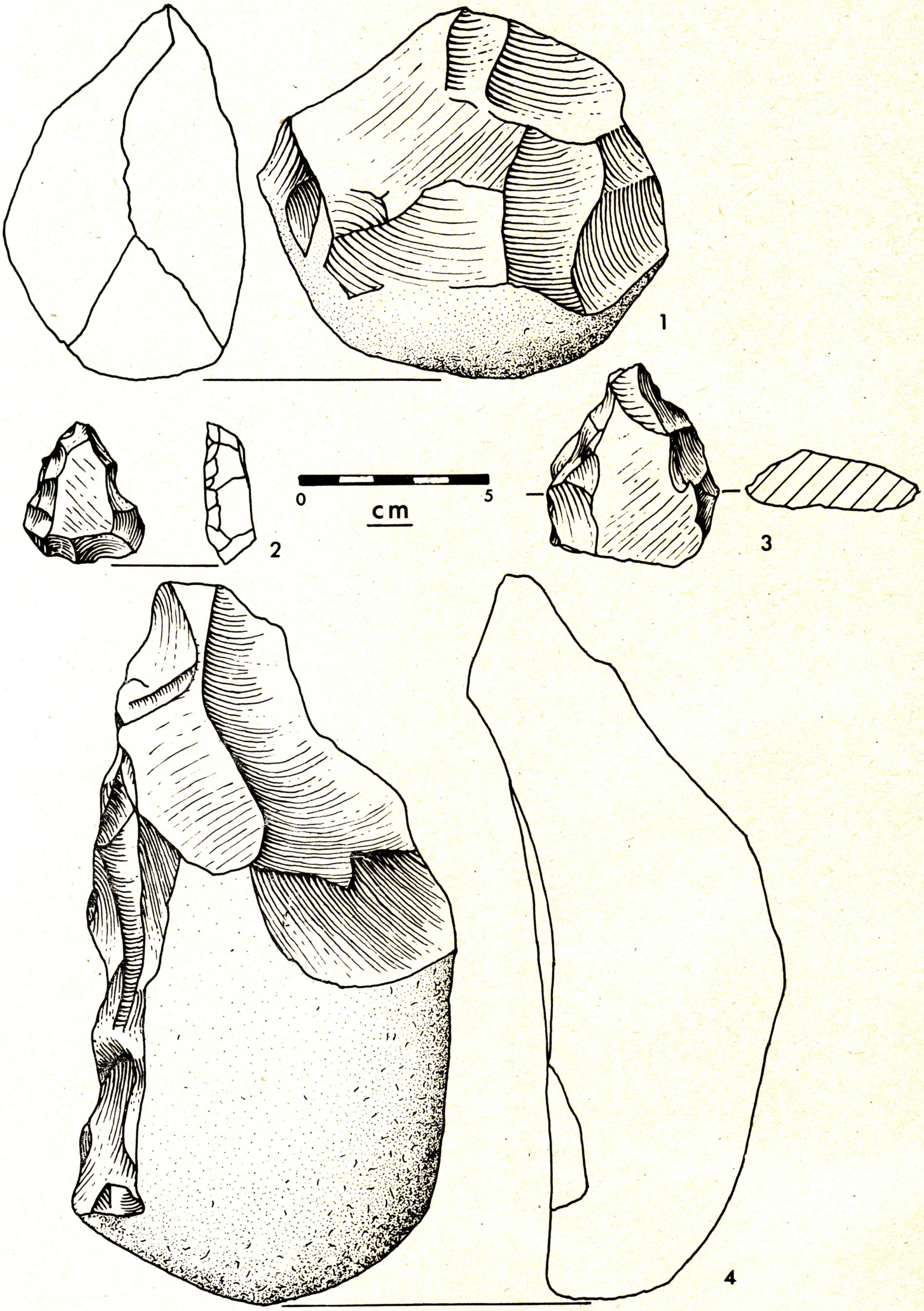



FIG. 6. *Developed Oldowan Type B artifacts from Gadeb Locality 2C.*

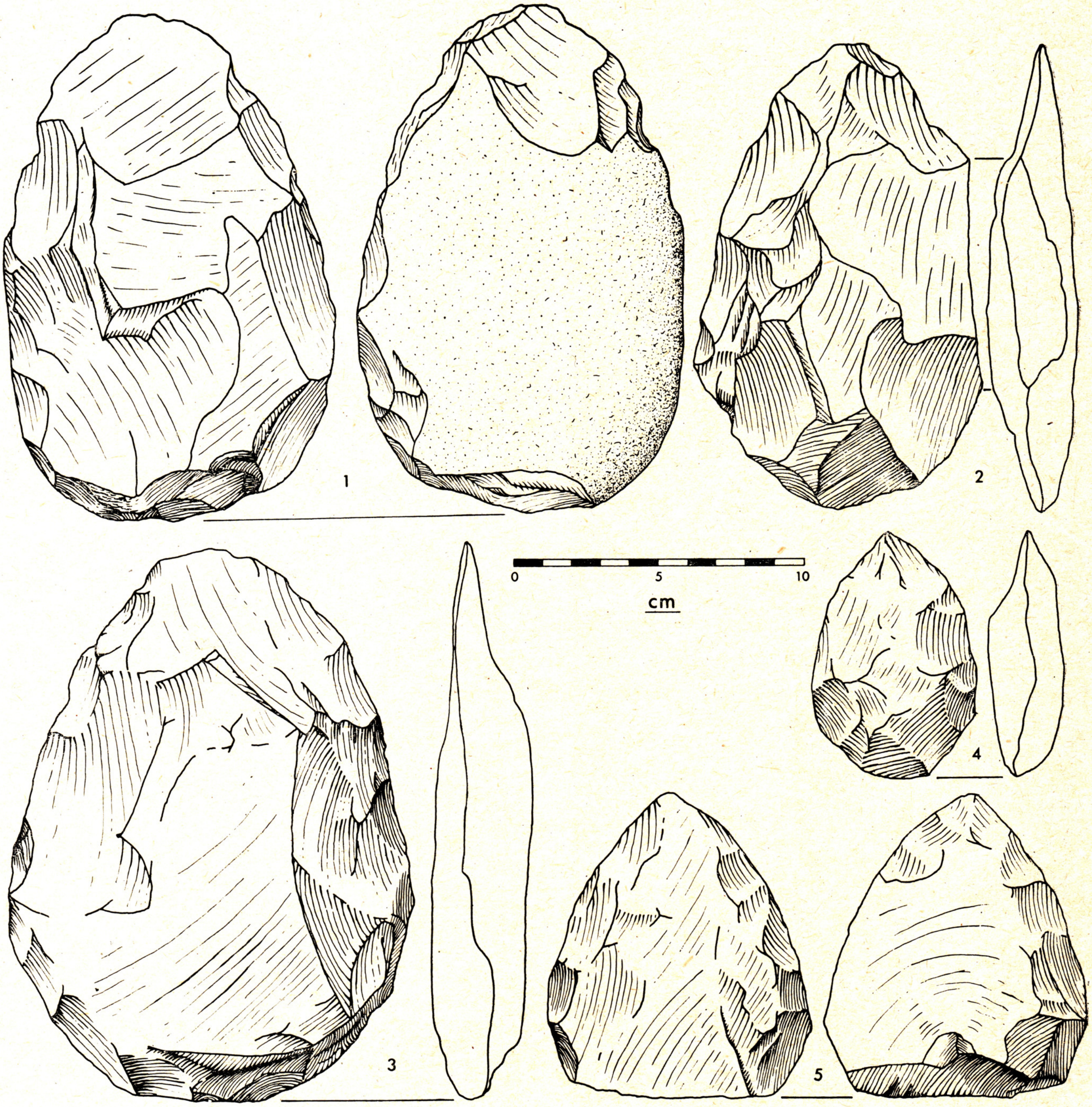



FIG. 7. *Acheulian handaxes from Gadeb Locality 8A.*

which case the heavier artifacts would tend to remain where they were discarded and become buried, while the lighter artifacts and flakes would be carried downstream (G. L 1, Isaac, pers. comm.). This, indeed, appears to be what has happened for the number of Light Duty tools (25) and unmodified flakes (258) appear to be underrepresented when the handaxes and cleavers alone total 241 specimes.

Fossil bone is represented by only one hippopotamus rib, the central part of the shaft of a medium sized mammal and another unidentifiable fragment. From the same sediments, however, came several teeth of *H. amphibius*, Alcelaphine and other bovid material and elephant. It is clear that the majority of the fossils from these Gadeb sites represent hippopotamus.

Shaped Tools *(Fig. 4)* represent 23.4 % of the total assemblage; less than 1.0 % are Modified and the remainder (c. 76 %) are Unmodified Waste, including cores *(Fig. 3)*. Among the Shaped Tools, the most significant are the Large Cutting tools, there being about twice as many handaxes as cleavers. The Acheulian bifaces from Gadeb 8A are mostly refined and made chiefly from large flakes struck from basalt cobbles that have a cleavage which pro-

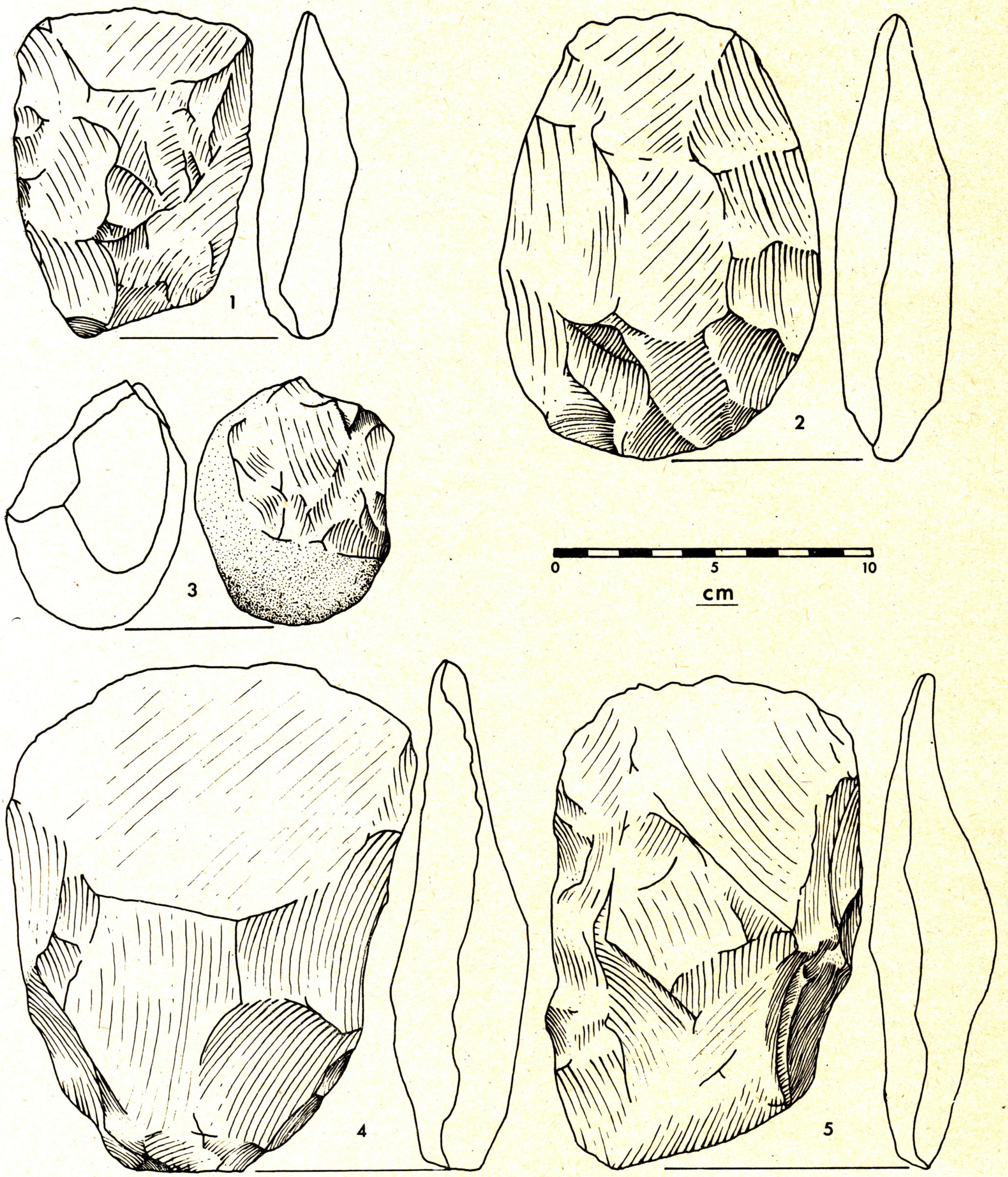



FIG. 8. *Acheulian cleavers and chopper from Gadeb Locality 8A.*

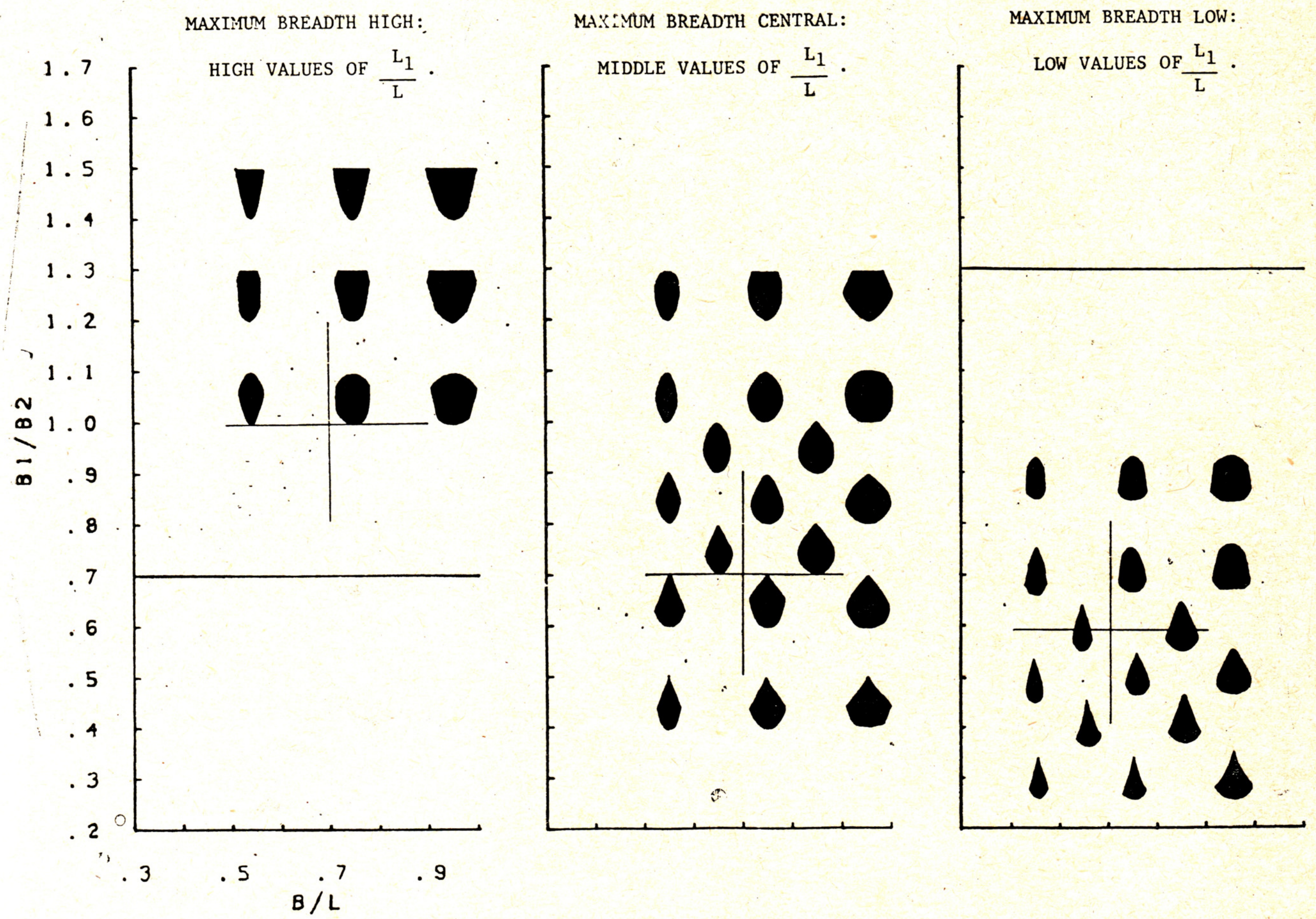



FIG. 11. *Distribution of handaxe and cleaver outline shapes on the tripartite diagrams* (*After D. Roe, 1968: 31*).

end (33); polyhedrons (9.8 %), spheroids, some very regular (4.6 %); and Light Duty scrapers and other small tools (5.8 %) *(Fig. 9)*. These are mostly single side scrapers (16) but a few are double edged (2) and convergent (2), notched (2) and transverse (1) forms occur; there are also two core or steep scrapers.

Cores comprise 10.8 % of the debitage. Of these, 48 % are unspecialised or casual forms with single (22), double (15) and multi-platforms (37). There is one angled or protobiconical core and 17 biconical cores (11.28 %); there are, however, a surprising number of flat, biconical cores or discoids (38.8 %). One specimen appears to be a large, unstruck, proto-Levallois core, approximately sub-rectangular with radial preparation of the upper face. Since we recovered two flakes with facetted platforms classified as proto-Levallois, and yet another from Gadeb Locality 7, this technique must be considered to have been present, though nor extensively used, on the high plateau during the Middle Pleistocene. It was also present in the Afar Rift where we found it particularly well represented at Arba to the southeast of Awash Station, in a form reminiscent of that which appears at Kapthurin in the Lake Baringo basin in northern Kenya where it is associated with a hominid mandible said to belong to *Homo erectus* and with a date of > 600,000 years B.P. (Leakey, M. C. et al. 1969; W. W. Bishop, pers. comm.).

The unmodified flakes at Gadeb 8A are mostly thick and relatively broad, irregular forms (84 %) with plain, inclined platforms; of these 60.3 % are side-struck and 23.7 % end-struck. As at the Developed Oldowan sites at Gadeb 2B and 2C, there are also long (11.6 %) and short (1.2 %) quadrilateral and 2.3 % of triangular flakes. The Gadeb 8A assemblage is classifiable, therefore, as an Upper Acheulian occurrence exhibiting some interesting local variability, in particular as regards the cobble flake forms which have not yet been reported from other localities in Ethiopia.

GADEB 8D *(Fig. 10)*

The second excavation at Gadeb Locality 8 is situated some 800 m west of the first and closer to the base of the cliff in which the complete earlier sedimentary sequence there is exposed. This must be close to where the later sediments are cut into and banked against the earlier series but, unfortunately, slopewash has obscured the stratigraphy

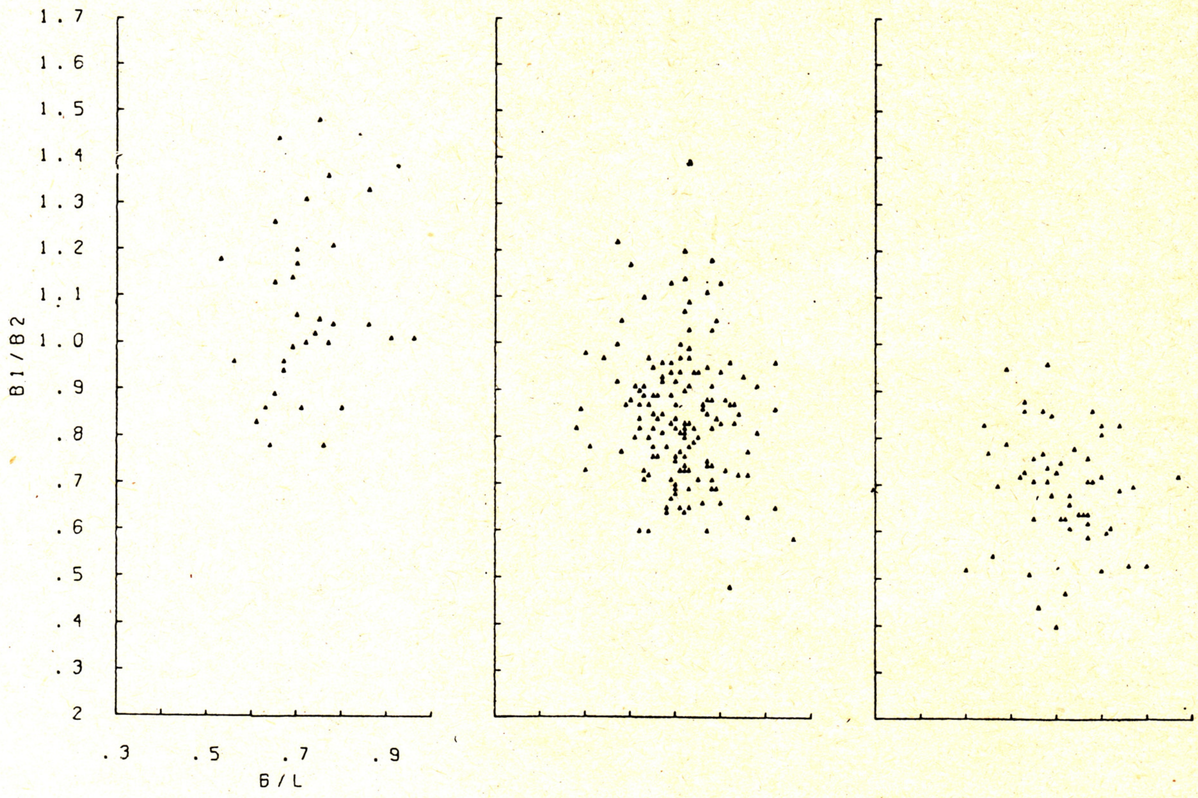



FIG. 12. *Handaxe and cleaver shapes from Gadeb 8A.* 179 handaxes and 62 cleavers (241 total)

here and further excavation and step trenching will be necessary to expose it.

The sequence at Gadeb 8D, as seen in a 3 × 5 meters excavation made by one uf us (H. K.) and Alison Galloway, and in Step Trench 5, differs from that just described. At the base are 4 m of diatomite. Disconformably overlying this is a thin gravel spread with Acheulian artifacts and fauna. This is overlain by a metre of fine sands and more diatomaceous sands above this. The gravel horizon has no thickness and the artifacts lie flat with no preferred orientation. The great majority of the tools show moderate abrasion and there are now a larger number of lightly abraded and fresh examples and fewer exhibiting heavy abrasion *(Fig. 2)*. Together with the artifacts were two large lower canines and other remains of *H. amphibius,* a bovid molar, perhaps *Alcelaphus,* fragments of eht metatarsal of a medium sized zebra and fragmentary limb bones of elephant. All these remains appear to be lying on or near the margins of a lake or shallow channel and to have suffered little redistribution before being totally covered by the sands of the rising lake. We believe the excavation to expose the peripheral part of an occupation floor, therefore. The assemblage shows some marked differences in technology and composition from that just described but, unfortunately, the total number of artifacts is less than one third of that from Gadeb 8A and it is possible, when a larger sample is forthcoming, that the differences may not apper so great.

Shaped Tools constitute 14.6 % of the total; 1.64 % are Utilised/Modified and the remainder (83.8 %) represents cores and Unmodified-Waste. *(Figs. 3 and 4.)* Handaxes and choppers are equally represented — 36.6 % of each. Ten of the handaxes are bifacially retouched 13 are parti-bifacial and there are only 3 unifacial examples; the mean length is 152.8 mm, breadth 84.0 mm and L/B ratio 1.83; plan forms are ficron to elongate-ovate. There are only three cleavers and these show rather rough retouch. Mean length is 184.3 mm, breadth 84.0 mm and L/B ratio 1.98. All the Large Cutting tools show a preponderance of hard hammer technique and, in general, are noticeably less well finished than are those from Gadeb 8A; there are no bifacial knives and only two "other bifaces". The choppers are similar to those found with the Developed Oldowan and are predominantly side (10) and end (9) forms with a few (4) side and end and 3 pointed examples. Polyhedrons (6) are represented but there are no true spheroids. The Light Duty element comprises only 11.3 % consisting of single (3) and double (1) side scrapers, together with two convergent or pointed forms and one each denticulate and notched scrapers. There is a slight increase in the Utilised/Modified category (1.6 %).

Among the debitage, cores constitute 20.3 % of the waste and these are mostly informal classes with one (19), two (9) and more (40) platforms; there are two proto-biconical cores, 3 biconical cores and 10 disc. forms. The proto-Levallois technique

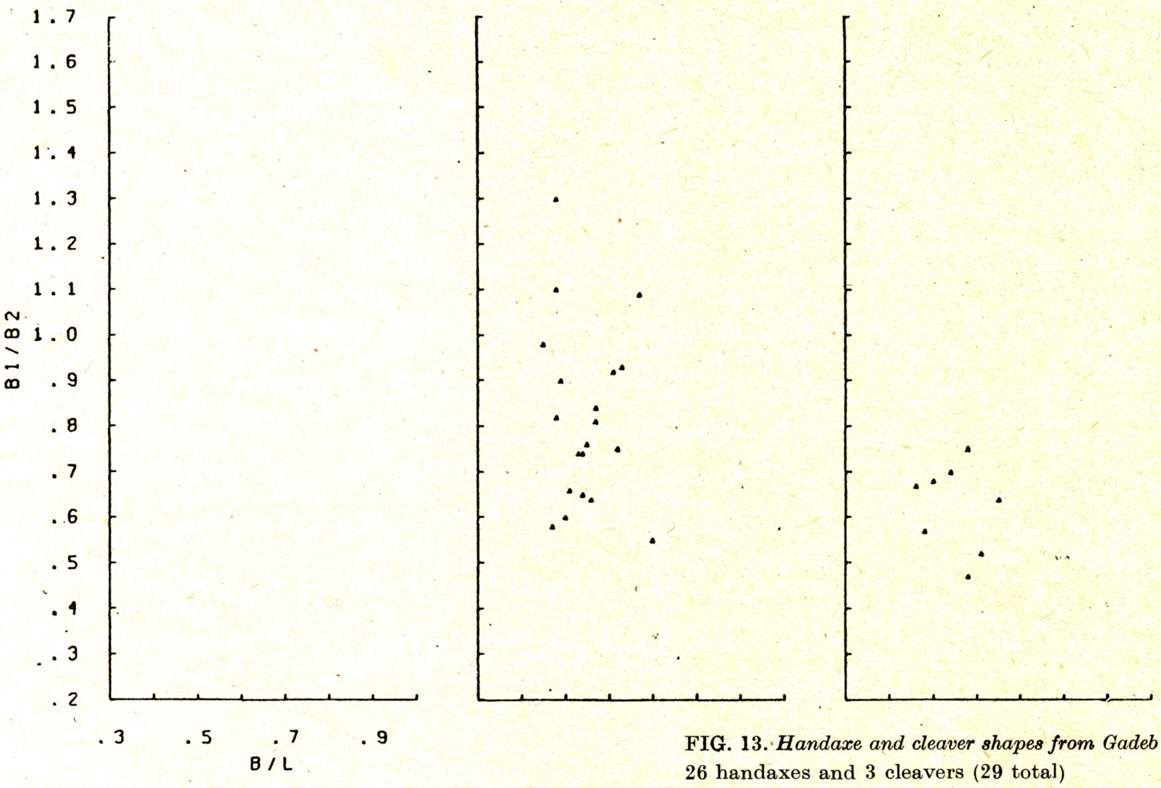



FIG. 13. *Handaxe and cleaver shapes from Gadeb 8D.* 26 handaxes and 3 cleavers (29 total)

is not represented. Again, most of the Unmodified Waste flakes (19.4 % of waste) are irregular, broad and relatively thick — 39 are side-struck, 22 end-struck, 15 are long and short quadrilateral and 3 triangular. The mean length is 59.9 mm, breadth 47.6 mm and L/B ratio 1.27.

In the reduced degree of refinement, in the plan form and somewhat greater mean measurements of the bifaces and the absence of the proto-Levallois technique, the Gadeb 8D assemblage differs from that at Gadeb 8A. *Figs. 11—13* have been drawn using the method devised by Dr. Derek Roe (R o e, 1968 : 31) to demonstrate the plan form of bifaces and, although the 8D sample is too small, it does show clearly the differences between the two bifacial assemblages. Typologically and technically, Gadeb 8D appears to approximate more to a Lower than it does to an Upper Acheulian, but this has to be confirmed. Unfortunately, because the contact between the earlier and later sedimentary cycles is obscured by talus, we are unable to say in which cycle this assemblage belongs though, at present, from the stratigraphy exposed, it is more likely to belong with the earlier, in which case, on account of its height relative to water level in the river, it would antedate the Developed Oldowan assemblages described from the Gadeb 2 Locality.

## PALAEO-ENVIRONMENT

We have every expectation that it will be possible to reconstruct the palaeo-environment at these localities in the upper part of the Webi Shebele basin since mammalian fossils are preserved and, although those recovered to date are fragmentary and mostly from the surface, those obtained *in situ* from excavations indicate that more complete material will be forthcoming when larger scale excavations are undertaken in the future. From the fossils recovered in 1975 it can be seen that the commonest animal represented in association with the artifact concentrations is the hippopotamus. Alcelaphine antelopes, zebra and pigs indicate an open grassland environment nearby with elephant making use of a range of localities from forest to lake margins.

The pollen spectrum previously analysed by Bonnefille (B o n n e f i l l e et al. 1970; B o n n e f i l l e 1972: 256—260) coming from Melka Wacana from the diatomite horizon with a bifacially flaked chopper, and probably correlating with the diatomites in the lower part of the sequence at Gabed Locality 2, provides an indication of the prevailing ecological conditions in the upper Webi Shebele basin during the earlier Pleistocene. Tree pollen of evergreen montane forest species reaches 43.4 %, those of *Podocarpus* and *Juniperus* making up more than 30 % of the total number of pollens counted. Grasses comprise 78 % of the non-arboreal pollen, the remainder belonging to the Chenopodiaceae, Cyperaceae and Compositae. This spectrum is indicative of an environment not greatly different from that of today except that, while grassland was present round the margins of the lake, the forest must at that time have also been in its immediate vicinity. The values for montane forest pollens are significantly higher than they are in the pollen spectra from the Earlier Stone Age occupation sites at Melka Kunture at a somewhat lower elevation (2,000—2,300 m) at the southern end of the Ethiopian Plateau (B o n n e f i l l e, 1972 : 261 et seq.). Indeed, the elevation of the Gadeb localities must be among the highest yet known Earlier Stone Age sites and it can hardly be doubted that the makers of the Developed Oldowan and Acheulian tool-kits were exploiting there the resources of several micro-environments — the lake margins, the grassland and the montane forest.

As in other parts of tropical Africa, the artifact concentrations are found in association with the lake margin or in stream channels draining into it and in one instance, with a river channel, but there are also three occurrences in which an isolated, quite unabraded Acheulian cleaver is found in association with the fine sediments of shallow stream courses and this raises the question of the purpose for which a single specimen might have been made, carried in, used and discarded.

### COMPARISONS

As yet detailed comparisons between the Gadeb locality assemblages and those from Melka Kunture are not possible, but a qualitative assessment suggests that some interesting differences exist between them even though the environment must have been generally similar and the time period was the same. The Developed Oldowan from Gadeb shows a general affinity with the Developed Oldowan B assemblages from the middle and upper part of Bed II at Olduvai Gorge (e.g. with those from the MNK (Main Horizon) (L e a k e y, M. D., 1971b : 155) and the BK (ibid : 222) sites, Percentages of choppers, polyhedrons, bifaces and scrapers are within the same order although the Olduvai sites have rather more polyhedrons. Gadeb has a higher percentage of Light Duty tools while at Olduvai the Heavy Duty equipment is significant. The Gadeb 8A Acheulian occurrence with evidence of the proto-Levallois method of flake production appears to have more in common with the Upper Acheulian, while Gadeb 8D, if one can judge from the small collection at present available, is more similar to that from EF-HR in mid-Bed II at Olduvai Gorge (L e a k e y, M. D. 1971b : 136—7) or those from Peninj (I s a a c, 1967a : 246). There are more choppers at Gabed 8D than at the East African sites but, while percentages for bifaces and Light Duty tools are comparable, the Heavy Duty tools form a significant part of the equipment at EF-HR and Peninj. Possibly, they may reflect ecological differences, so that recovery of fully representative samples of artifacts and associated biota in Gadeb sites, which reflect the subsistence base in the forest/lake plain ecotone at c. 2,500 m, may go a long way to helpe explain these seeming differences. A more precise attempt to relate the Gadeb assemblages to those from other Developed Oldowan and Acheulian sites in the Plio-Pleistocene time range is made in the second part of this paper.

Our preliminary investigations show, therefore, that when these Gadeb and other new localities in the upper Webi Shebele basin on the South-East Plateau are further worked on in future field seasons, they may be expected to provide interesting supplementary evidence for behavioural traits and economy of the hominid populations of Lower and Middle Pleistocene times in the high places of Ethiopia and, perhaps, even of their Pliocene ancestors. In particular, they can be expected to furnish some evidence of the extent of re-adaptation that was necessary for successful occupation of this high altitude eco-system and, in addition, many data on assemblage composition and stylistic variation for comparison with other Developed Oldowan and Acheulian occurrences in eastern Africa within the time range of 1.5—0.5 m. y.

One of the objectives of this paper is to compare the artifact composition of the Gadeb Developed Oldowan and Acheulian assemblages with that of other Lower Palaeolithic/Earlier Stone Age sites in Africa and the Middle East. Accordingly, two kinds of comparative analyses have been made with the aid of multivariate statistical techniques on a set of 69 assemblages: 7 from the Middle East, 5 from North Africa and 57 from sub-Saharan Africa. Available radiometric dates indicate that the majority of these assemblages fall within the time period generally referred to as Lower and Middle Pleistocene. For this study 2 Oldowan, 9 Developed Oldowan and 58 Acheulian assemblages are considered. These represent most of the published Lower Palaeolithic/Earlier Stone Age sites for which data are available that can be classified by the typological systems developed by K l e i n d i e n s t (1961) and L e a k e y, (L e a k e y, M. D. 1971b : 3—8) for assemblages from East Africa. Some assemblages have, regrettably, had to be excluded since the data as available do not lend themselves to reclassification by these systems.

Two multivariate statistical procedures are employed, which are particularly useful for discerning regularities of ordering and mapping the material in a more explicit space. First, Principal Component Analysis and, second, Factor Analysis with orthogonal varimax rotation, were performed on the input data matrix given in *Table 1.* We have used Biomedical Library routines (BMDOIM for Principal Component Analysis and BMDP4M for Factor Analysis [D i x o n, 1974: 193—200; 1975: 357 to 391]) which were originally developed at the University of California, Los Angeles and installed at the Computer Center of U. C. Berkeley on the CDC 6 400 system and at the U. C. Medical School, San Francisco on the IBM 370/145.

### METHODS

Before discussing each of the two multivariate techniques it is appropriate to explain briefly the basic mathematical assumptions involved in multivariate statistics. Multivariate statistical analysis has

TABLE 1. *Input data list: percentage frequencies of tools*

| ASSEMBLAGES | Choppers | Polyhedrons/Spheroids | Light Duty Tools | Heavy Duty Tools | Large Cutting Tools | Other | Utilized/Modified Pieces | Total Shaped Tools | Total Artefacts | Environment | Industry | Case Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OLDOWAN** | | | | | | | | | | | | |
| OLDUVAI FLK OCC FL | 28.3 | 15.0 | 30.0 | 15.0 | 0.0 | 11.6 | 5.4 | 60 | 2470 | 1 | 0 | 1 |
| OLDUVAI FLKN 5 | 76.6 | 13.3 | 0.0 | 10.0 | 0.0 | 10.0 | 19.2 | 30 | 151 | 1 | 0 | 2 |
| **DEV. OLDOWAN** | | | | | | | | | | | | |
| UBEIDIYA K-20 | 49.5 | 17.3 | 11.0 | 4.8 | 3.5 | 13.9 | | 163 | | 1 | 1 | 3 |
| GADEB 2B | 29.1 | 29.1 | 34.5 | 0.0 | 7.2 | 0.0 | 0.3 | 55 | 589 | 3 | 1 | 4 |
| GADEB 2C | 27.3 | 18.2 | 40.9 | 6.1 | 7.6 | 0.0 | 1.9 | 66 | 622 | 3 | 1 | 5 |
| OLDUVAI BK | 14.1 | 28.8 | 32.1 | 2.4 | 5.2 | 17.4 | 5.7 | 721 | 6801 | 1 | 1 | 6 |
| OLDUVAI MNK MAIN | 21.4 | 37.5 | 14.8 | 5.3 | 2.0 | 19.0 | 8.4 | 448 | 4399 | 1 | 1 | 7 |
| OLDUVAI TK-UPPER | 9.9 | 27.1 | 34.9 | 4.8 | 8.2 | 15.0 | 6.1 | 292 | 5180 | 1 | 1 | 8 |
| OLDUVAI FC WEST | 30.1 | 36.9 | 8.7 | 11.2 | 3.9 | 10.2 | 12.7 | 206 | 1955 | 1 | 1 | 9 |
| OLDUVAI FLKN SC | 26.0 | 40.7 | 13.5 | 0.0 | 0.0 | 19.8 | 32.9 | 96 | 234 | 1 | 1 | 10 |
| OLDUVAI HWK EAST | 32.8 | 34.0 | 11.7 | 3.9 | 3.2 | 13.5 | 20.5 | 409 | 1989 | 1 | 1 | 11 |
| **LOWER ACHEULIAN** | | | | | | | | | | | | |
| UBEIDIYA K-30 | 46.2 | 2.7 | 8.2 | 17.0 | 15.0 | 10.9 | | 180 | | 1 | 2 | 12 |
| LATAMNE | 4.6 | 4.9 | 47.0 | 13.2 | 30.0 | 0.3 | 5.8 | 370 | 2825 | 1 | 2 | 13 |
| STIC | 6.7 | 7.2 | 6.8 | 18.9 | 56.8 | 3.6 | 4.5 | 553 | 1018 | 1 | 2 | 14 |
| GADEB 8D | 36.6 | 8.5 | 7.0 | 2.8 | 45.0 | 0.0 | 0.2 | 71 | 487 | 3 | 2 | 15 |
| PENINJ RHS | 7.7 | 0.0 | 13.5 | 25.0 | 40.3 | 13.5 | 8.5 | 52 | 235 | 1 | 2 | 16 |
| OLDUVAI EF-HR | 15.4 | 15.4 | 3.3 | 3.3 | 53.8 | 8.8 | 5.0 | 91 | 522 | 1 | 2 | 17 |
| SWARTKRANS | 50.0 | 9.1 | 4.5 | 13.6 | 18.1 | 4.5 | 18.2 | 22 | 30 | 1 | 2 | 18 |
| STERKFONTEIN | 31.5 | 37.0 | 1.4 | 13.7 | 11.0 | 5.5 | | 73 | | 1 | 2 | 19 |
| **UPPER ACHEULIAN** | | | | | | | | | | | | |
| JOUB JANNINE II | 15.7 | 27.5 | 20.0 | 2.2 | 35.7 | 0.0 | | | | 1 | 3 | 20 |
| MAAYAN BARUKH | 2.7 | 0.3 | 3.3 | 0.0 | 85.4 | 8.3 | | 3164 | 3775 | 1 | 3 | 21 |
| TABUN F | 20.8 | 0.0 | 43.6 | 0.0 | 31.9 | 3.7 | 0.6 | 3859 | 4370 | 3 | 3 | 22 |
| KISSUFIM | 5.4 | 0.0 | 39.4 | 0.0 | 52.7 | 2.5 | | 203 | 379 | 1 | 3 | 23 |
| CAP CHANTIER | 20.1 | 0.0 | 13.2 | 0.0 | 52.6 | 14.1 | 15.0 | 834 | 1731 | 1 | 3 | 24 |
| KHARGA | 3.1 | 0.0 | 2.4 | 7.6 | 85.9 | 1.0 | 2.7 | 290 | 298 | 4 | 3 | 25 |
| ARKIN 8 | 34.3 | 8.6 | 6.9 | 20.8 | 21.2 | 8.2 | | 534 | 2891 | 4 | 3 | 26 |
| SIDI ZIN | 0.0 | 0.0 | 23.2 | 0.0 | 69.2 | 7.6 | | 198 | | 1 | 3 | 27 |
| GADEB 8A | 20.9 | 14.4 | 5.1 | 2.6 | 57.0 | 0.0 | 0.6 | 430 | 1847 | 3 | 3 | 28 |
| MELKA KONTOURE | 11.1 | 14.4 | 23.3 | 0.6 | 49.4 | 1.1 | 17.1 | 180 | 742 | 3 | 3 | 29 |
| KAPTHURIN | 14.7 | 1.3 | 10.7 | 2.7 | 58.7 | 12.0 | 11.1 | 75 | 2261 | 1 | 3 | 30 |
| LOCHARD | 16.5 | 1.6 | 35.0 | 4.8 | 35.6 | 6.4 | 9.4 | 188 | 1265 | 1 | 3 | 31 |
| KARIANDUSI | 1.8 | 1.5 | 11.5 | 6.0 | 78.5 | 0.9 | 12.8 | 339 | 717 | 1 | 3 | 32 |
| OLORGESAILIE 1 | 1.4 | 0.0 | 92.8 | 1.4 | 4.2 | 0.0 | 9.3 | 70 | 428 | 1 | 3 | 33 |
| OLORGESAILIE 2 | 5.7 | 9.4 | 69.8 | 5.6 | 9.4 | 0.0 | 12.2 | 106 | 451 | 1 | 3 | 34 |
| OLORGESAILIE 3 | 3.4 | 3.4 | 73.5 | 3.5 | 16.0 | 0.0 | 19.8 | 87 | 465 | 1 | 3 | 35 |
| OLORGESAILIE 6 | 2.6 | 5.3 | 50.0 | 1.4 | 39.3 | 1.3 | 13.8 | 150 | 740 | 1 | 3 | 36 |
| OLORGESAILIE 7 | 4.5 | 12.5 | 8.1 | 1.8 | 72.3 | 0.9 | 4.9 | 112 | 205 | 1 | 3 | 37 |
| OLORGESAILIE 8 | 4.4 | 2.9 | 14.0 | 2.1 | 76.2 | 0.0 | 10.8 | 135 | 443 | 1 | 3 | 38 |
| OLORGESAILIE 9 | 2.0 | 3.0 | 6.0 | 0.0 | 88.8 | 0.0 | 13.0 | 99 | 215 | 1 | 3 | 39 |
| OLORGESAILIE 10 | 2.0 | 5.4 | 47.9 | 2.0 | 41.2 | 1.4 | 15.2 | 148 | 890 | 1 | 3 | 40 |
| OLORGESAILIE 11 | 3.4 | 3.4 | 81.3 | 0.0 | 11.9 | 0.0 | 16.1 | 59 | 434 | 1 | 3 | 41 |
| OLORGESAILIE DE/89B | 3.4 | 1.1 | 14.5 | 2.1 | 71.8 | 7.1 | 2.8 | 703 | 5059 | 1 | 3 | 42 |
| OLDUVAI WK | 8.7 | 8.0 | 17.5 | 19.0 | 34.1 | 12.6 | 23.3 | 241 | 494 | 1 | 3 | 43 |
| ISIMILA K19 | 6.7 | 0.0 | 23.4 | 1.1 | 69.0 | 0.0 | 11.4 | 90 | 528 | 2 | 3 | 44 |
| ISIMILA K18 | 14.1 | 0.0 | 54.9 | 7.6 | 20.5 | 2.2 | 9.2 | 93 | 1546 | 2 | 3 | 45 |
| ISIMILA LH15 | 19.5 | 0.0 | 12.2 | 36.6 | 31.7 | 0.0 | 10.0 | 41 | 328 | 2 | 3 | 46 |
| ISIMILA J12 | 0.0 | 0.0 | 7.5 | 2.5 | 90.0 | 0.0 | 4.7 | 40 | 148 | 2 | 3 | 47 |
| ISIMILA K6 | 0.0 | 1.1 | 2.8 | 10.6 | 85.1 | 0.0 | 5.5 | 177 | 305 | 2 | 3 | 48 |
| ISIMILA LJ6-7 | 5.7 | 2.3 | 41.0 | 5.7 | 43.2 | 1.1 | 14.5 | 88 | 932 | 2 | 3 | 49 |
| ISIMILA K14 | 9.6 | 7.2 | 21.6 | 4.0 | 57.0 | 1.6 | 10.6 | 125 | 434 | 2 | 3 | 50 |
| ISIMILA H9-J8 | 8.4 | 4.2 | 5.3 | 4.2 | 76.9 | 1.1 | 7.0 | 95 | 186 | 2 | 3 | 51 |
| ISIMILA UJ6-7 | 10.5 | 0.0 | 9.5 | 4.3 | 76.0 | 0.0 | 16.2 | 95 | 233 | 2 | 3 | 52 |
| NSONGEZI C1 M-N | 1.8 | 0.0 | 54.6 | 12.7 | 30.9 | 0.0 | 4.8 | 55 | 1280 | 2 | 3 | 53 |
| NSONGEZI C13 M-N | 8.2 | 0.0 | 40.8 | 18.3 | 32.7 | 0.0 | 27.4 | 49 | 219 | 2 | 3 | 54 |
| NSONGEZI C17 M-N | 16.1 | 0.0 | 42.5 | 26.5 | 13.8 | 1.1 | 13.3 | 87 | 615 | 2 | 3 | 55 |
| KALAMBO 5 | 4.5 | 0.7 | 24.8 | 10.5 | 59.4 | 0.0 | 4.2 | 816 | 6696 | 2 | 3 | 56 |
| KALAMBO 6A | 5.2 | 0.0 | 10.3 | 5.2 | 79.3 | 0.0 | 11.2 | 58 | 187 | 2 | 3 | 57 |
| KALAMBO 6B | 8.4 | 0.9 | 37.4 | 15.0 | 38.3 | 0.0 | 5.0 | 107 | 1456 | 2 | 3 | 58 |
| KALAMBO 7 | 5.8 | 0.0 | 33.3 | 11.8 | 49.0 | 0.0 | 4.7 | 51 | 686 | 2 | 3 | 59 |
| KALAMBO 8 | 2.0 | 0.0 | 36.4 | 11.1 | 50.5 | 0.0 | 4.2 | 99 | 2308 | 2 | 3 | 60 |
| KALAMBO A1/56/J | 9.5 | 2.4 | 28.5 | 21.5 | 38.1 | 0.0 | 7.3 | 42 | 343 | 2 | 3 | 61 |
| KALAMBO A1/56/V/VA | 3.8 | 1.0 | 21.1 | 9.6 | 64.5 | 0.0 | 8.4 | 104 | 440 | 2 | 3 | 62 |
| KALAMBO A1/56/58 | 9.4 | 1.6 | 23.4 | 28.1 | 37.5 | 0.0 | 5.6 | 64 | 267 | 2 | 3 | 63 |
| BROKEN HILL | 4.2 | 26.6 | 56.3 | 1.1 | 12.9 | 0.0 | 7.3 | 94 | 164 | 2 | 3 | 64 |
| BAIA FARTA | 23.5 | 0.0 | 9.2 | 4.6 | 62.7 | 0.0 | 7.5 | 64 | 183 | 2 | 3 | 65 |
| CORNELIA | 15.9 | 41.6 | 13.8 | 14.8 | 10.7 | 3.2 | 12.1 | 94 | 239 | 1 | 3 | 66 |
| AMANZI 2-1 | 7.3 | 0.8 | 41.7 | 0.0 | 39.3 | 10.9 | 7.8 | 247 | 1621 | 1 | 3 | 67 |
| MONTAGU 3 | 4.7 | 0.0 | 7.1 | 16.8 | 45.1 | 26.7 | 0.1 | 1166 | 85163 | 1 | 3 | 68 |
| MONTAGU 5 | 1.4 | 0.0 | 18.6 | 14.0 | 43.9 | 22.7 | 0.1 | 563 | 66816 | 1 | 3 | 69 |

## REFERENCES FROM WHICH DATA EXTRACTED

*The Near East:*

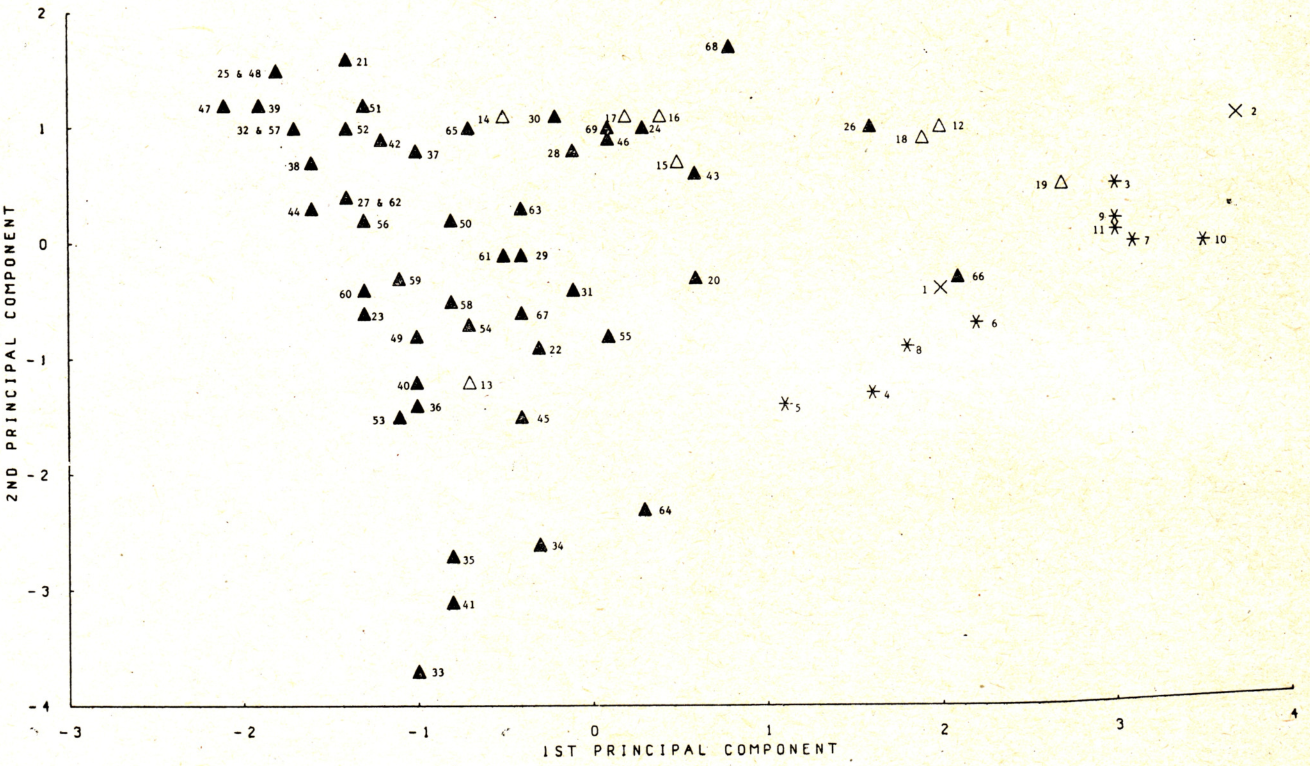
| | |
|---|---|
| Joub Jannine II | (F. Hours, 1975) |
| Kissufim | (A. Ronen et. al, 1972) |
| Latamne | (J. D. Clark, 1968) |
| Maayan Barukh | (M. Stekelis and D. Gilead, 1966) |
| Tabun (F) | (D. A. E. Garrod and D. M. A. Bate, 1937) |
| Ubeidiya | (O. Bar Josef and E. Tchernov, 1972) |

*North Africa:*

| | |
|---|---|
| Arkin 8 | (W. Chmielewski, 1968) |
| Kharga | (G. Caton-Thompson, 1952) |
| Sidi Abderrahman (STIC, Cap Chantier) | (P. Biberson, 1961) |
| Sidi Zin | (E. G. Gobert, 1950) |

*Sub-Saharan Africa:*

| | |
|---|---|
| Amanzi 2—1 | (H. J. Deacon, 1970) |
| Baia Farta | (J. D. Clark, 1965) |
| Broken Hill | (J. D. Clark, 1959; M. Kleindienst, 1961) |
| Cornelia | (J. D. Clark, 1974b) |
| Isimila | (M. Kleindienst, 1961) |
| Kalambo Falls | (J. D. Clark, 1968) |
| Kapthurin | (M. Leakey et. al, 1969) |
| Kariandusi | (M. Kleindienst, 1961) |
| Lochard | (M. Kleindienst, 1961) |
| Montagu (3, 5) | (C. M. Keller, 1973) |
| Nsongezi | (G. Cole, 1967) |
| Olduvai | (M. D. Leakey, 1971b) |
| Olorgesailie (1, 2, 3, 6, 7, 8, 9, 10, 11) | (M. Kleindienst, 1961) |
| (DE/89B) | (G. Ll. Isaac, 1968) |
| Peninj RHS | (G. Ll. Isaac, 1967) |
| Sterkfontein | (M. D. Leakey, 1970) |
| Swartkrans | (M. D. Leakey, 1970) |




KEY FOR SYMBOLS

FIG. 14. *Principal component analysis: Components 1 vs. 2.*

1. INDUSTRY: × *Oldowan*; ✳ *Dev. Oldowan*; △ *Lower Acheulian*; ▲ *Upper Acheulian*

2. INFERRED PREHISTORIC ENVIRONMENT: ⬡ *Open grassland and Park Savanna*; + *Deciduous woodland and some gallery forest*; ▲ *Montane grassland and Forest ecotone*; □ *Semiarid dry thornbush/Steppe*

been designed to examine data which consist of several measurements or observations made on a number of cases or objects. The main interest is to focus upon the relationships, interdependence and relative importance of the variables represented. The rationale for multivariate operations is perhaps best expressed by J. C. Nunnaly who states that, "the effort in science is to find a relatively small set of

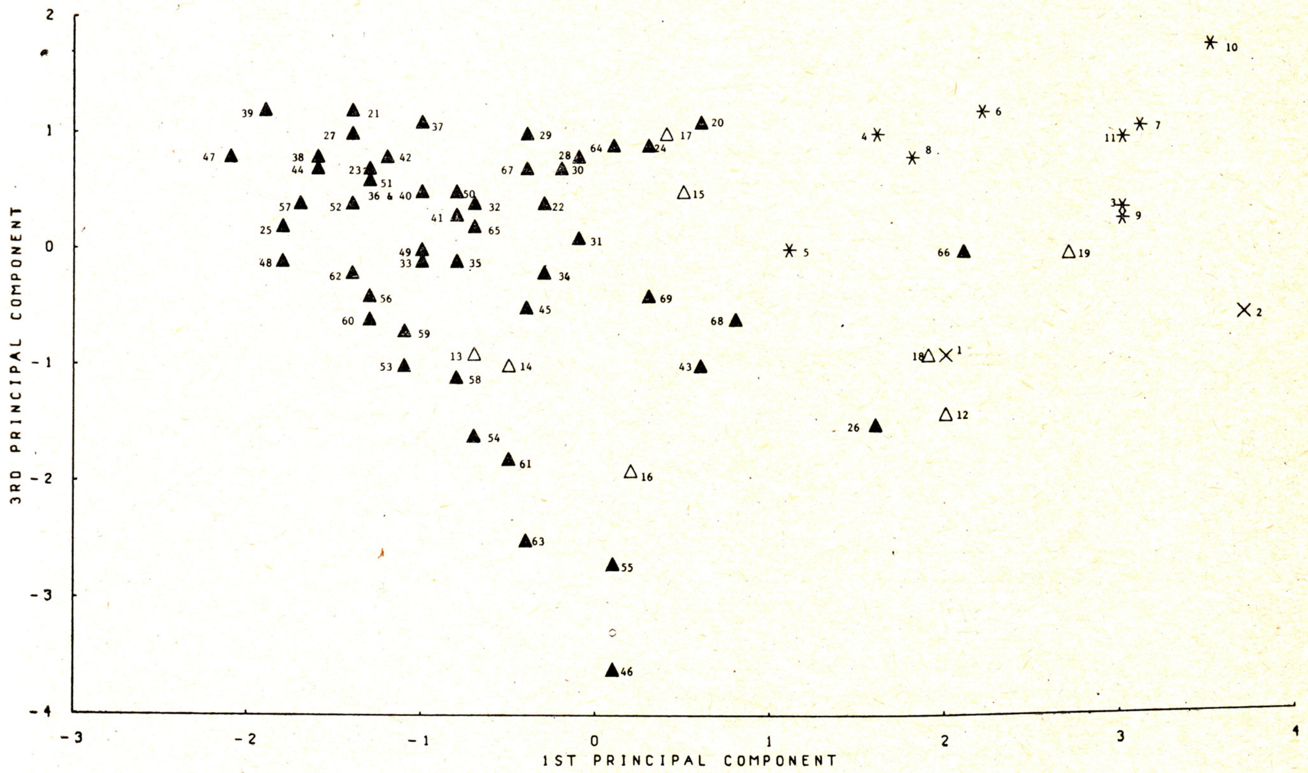



FIG. 15. *Principal component analysis: Components 1 vs. 3.*

variables which will suffice to 'explain' all other variables. A small set of variables 'explains' a larger set if some combination of the smaller set correlates highly with each member of the larger set . . . To achieve such a small set of 'explainer' variables is the essence of scientific parsimony" (Nunnaly, 1967 : 151). While the variables are considered correlated, it is important that the cases be treated independently.

Although there are several forms of multivariate distributions, the mathematical model on which both principal component analysis and factor analysis are built is multivariate normal distribution. As in univariate statistics, it is assumed that a random sample of multidimensional observations is gathered from independent sampling units. While the central limit theorem leads to the univariate normal distribution for a single variable, the general central limit theorem for more than one variable leads to the multivariate normal distribution (Anderson, 1958 : 1—18). These techniques are aimed at the reduction of the number of variables through linear transformations so as to recognise the significant combinations in some optimum manner. One outcome is the simplification of the dimensionality of the problem using the geometric concept of the test space model. This model represents each test case as a point in a 'p'-dimensional Cartesian space. In this study the 'p' components or factors become the 'p' orthogonal axes spanning the space, each axis erected at rightangles to all the others. An end result is a familiar bivariate scatter plot as will be seen in *Figs. 14—19.*

Observations made on several dimensions of the same artifact or assemblage are quite common in archaeological data analysis, However, effective use of principal component analysis in the archaeological context is a comparatively recent innovation. Some of the outstanding examples have been those of F. R. Hodson (1970) on the La Tène fibulae from Münsingen, based on thirteen morphological attributes, of J. P. White and D. H. Thomas (1969) on modern flakes made by New Guinea Highlanders and of the as yet unpublished but pioneer study of earliest East African stone tools by Isaac and Corruccini (in MSS). In physical anthropology the works of A. J. Boyce (1969) on anthropometric measurements of hominoid skulls and of R. Ciochon and R. Corruccini (1975) on the morphometrics of Platprrhine femora, have shown some promising results. While the above works are concerned with the variation, ordering and grouping at the level of 'individual objects', there have been some studies made at the aggregate level. As in the research problem treated in this paper, an archaeological lithic assemblage can be viewed as a set of artifacts, each of which belongs to a classificatory unit defined by the archaeologist. Each discrete typological unit of a site's stone tool assemblage is considered as a variable. A similar approach has been adopted in studies by L. Binford and S. Binford (1966) on the Mousterian of southwestern France and the Near East; by R. Hodson 1969) on Upper Palaeolithic assemblages from southwest France and central Europe; by R. M. Rowlett and R.. Pollnac (1971) on the Marnian La Tène cultural assemblages from France; by L. Binford (1972) on the Acheulian of sub-Saharan Africa; by R. Pollnac and A. Ammerman (1973) on the Italian late Upper Palaeolithic; and by I. Azoury and F. R. Hodson (1973) on the Ksar Akil assemblages. Considering the successful achievements of these studies it is rather surprising that multivariate analysis has not been more seriously adopted in palaeoanthropological studies.

## PRINCIPAL COMPONENT ANALYSIS

Principal component analysis was originated by Hotelling (1933) for research in educational psychology and it has been widely applied since in many other disciplines. The objective of principal component analysis is to construct new variables replacing the original with as few newly constructed variables as statistically possible. The technique defines a unique set of reference axes for a given combination of variables using the maximum variance criterion. Each principal axis derived is a normalised linear function of variables which is statistically uncorrelated and geometrically orthogonal to the preceding components. The largest portion of the variance is accounted for by the first principal component. Of the remaining variance the second axis accounts for the maximum and the third the next largest and so on. The sum of the variance of these components must be equal to the original set of variables examined. In carrying out this procedure, however, one should be aware of a drawback which is usually inherent in multivariate analysis. Some information contained in the variance-covariance matrix of the original variables is unavoidably lost with this technique. In this regard, however, principal components are considered optimum amongst existing multivariate techniques as the sacrificed information is kept to a minimum (Kshirsagar, 1972 : 459).

Principal component analysis is applied here as a descriptive technique for studying the dependence or correlations of archaeological data. Sixty-nine major 'Early Stone Age' assemblages (Oldowan, Developed Oldowan, Lower Acheulian and Upper Acheulian) reported from the Middle East, North Africa and sub-Saharan Africa are examined as representative archaeological cases *(see Table 1).* Six categories of Shaped Tool forms are taken into consideration as typologically discrete and meaningful divisions and statistically useful variables (Clark, 1976).

The category groupings of Shaped Tools used in this analysis are considered to be most meaningful for comparing Early Stone Age assemblages in Africa and the Mediterranean basin. They are based upon the typology/terminology established for the East African Acheulian by Kleindienst (1961) and M. D. Leakey (1971b) and now widely used by workers south of the Sahara.

Most of the major tool categories shown here are composed of several classes of shaped tools as recognised in the original site reports but, in almost all cases, they can be grouped within one or other of six major categories as indicated below:

MAIN CATEGORY

| | |
|---|---|
| Choppers | various kinds of chopper (side, end, etc.) unifacial (chopping tool) and bifacial |

TABLE 2. *Correlation coefficient matrix for 6 variables*

| | Choppers | Polyhedrons/ spheroids | Light duty tools | Heavy duty tools | Large cutting tools | Other |
|---|---|---|---|---|---|---|
| Choppers | 1.0000 | .4143 | —.3449 | .1255 | —.5430 | .2798 |
| Polyhedrons/ spheroids | .4143 | 1.0000 | —.1518 | —.1426 | —.5873 | .3208 |
| Light duty tools | —.3449 | —.1518 | 1.0000 | —.1482 | —.4059 | —.2925 |
| Heavy duty tools | .1255 | —.1426 | —.1482 | 1.0000 | —.1994 | .0422 |
| Large cutting tools | —.5430 | —.5873 | —.4059 | —.1994 | 1.0000 | —.3237 |
| Other | .2798 | .3208 | —.2925 | .0422 | —.3237 | 1.0000 |

TABLE 3. *Principal Component Analysis: Eigenvalues and variance explained by each component*

| | Component 1 | Component 2 | Component 3 | Component 4 | Component 5 | Component 6 |
|---|---|---|---|---|---|---|
| Eigenvalues | 2.2915 | 1.40527 | 1.09006 | .727867 | .484553 | .000702 |
| Proportion of total variance | 38 % | 24 % | 18 % | 12 % | 8 % | 0 % |
| Cumulative % of total variance | 38 % | 62 % | 80 % | 92 % | 100 % | 100 % |

| | |
|---|---|
| Spheroids/ polyhedrons | polyhedrons, sub-spheroids and spheroids "globular cores" (Arkin) |
| "Light Duty" tools | small (< 10 cm) scrapers (various forms: side, end, nosed, concave, etc.) "points", backed knives, awls, borers, proto-burins, burins, and other small tools |
| "Heavy Duty" tools | core-scrapers, picks, core-axes, trihedrals, "other large bifaces" |
| "Large Cutting" tools | proto-bifaces, handaxes, cleavers, cleaver flakes, bifacial knives, large (> 10 cm) side scrapers |
| "Other" | discoids, modified battered nodules, miscellaneous tools |

The data entered in the original matrix are the percentage frequencies of tool categories within each assemblage of Shaped Tools. Values for Utilised/Modified pieces are percentages of the total number of artifacts.

The correlations among the standardised, equally weighted six variables were computed and the matrix *(Table 2)* was subjected to analysis. Principal component loadings pattern extracted from the correlation matrix is given in *Table 4.* It is intriguing that the first component appears to be a measure of general chronological ordering, for there exists a bipolarity of tool categories. More archaic Oldowan tool forms are represented by choppers, polyhedrons/spheroids and "other" and appear in the positive direction whereas characteristically Acheulian forms, Large Cutting tools (handaxes, cleavers, knives and large flake scrapers) are in the negative direction. More than one third of the total variance (38 %) in the six original variables is accounted for by this first component.

TABLE 4. *Principal component loadings pattern*

| | Component 1 | Component 2 | Component 3 |
|---|---|---|---|
| Choppers | .784 | .182 | —.091 |
| Polyhedrons Spheroids | .771 | —.124 | .361 |
| Light Duty Tools | —.207 | —.951 | —.096 |
| Heavy Duty Tools | .157 | .199 | —.934 |
| Large Cutting Tools | —.793 | .566 | .207 |
| Other | .612 | .283 | .137 |
| Eigenvalue | 2.292 | 1.405 | 1.090 |

The second principal component accounts for approximately one quarter (24 %) of the total variance. This component is also a bipolar one having two opposing variables, namely Light Duty tools with negative loadings and Large Cutting tools with positive loadings. The third component explains a relatively small percentage (18 %) of the total variance. This component is negatively correlated with Heavy Duty tools but there are no variables with a substantially high positive loading. Although it is difficult to speculate as to the original usage of tool forms, this and the preceding components could be interpreted as specific cultural activity or function dimensions. While other lines of evidence, such as associated fauna and flora, land use patterns and the palaeoclimate would assist in defining the actual cause of variable correlation, we are currently limited by a paucity of such information.

As reported in *Table 3,* the first three principal components absorbed 80.0 % of the total variance. As a practical problem in principal axes of data reduction, it has been suggested that one consider only those components whose eigenvalue is greater

| | | | |
|---|---|---|---|
| *Tropical Wooded Steppe.*<br>Olduvai<br>Peninj<br>Kapthurin<br>Olorgesailie<br>Lochard<br>Kariandusi<br>Montagu Cave | *Sub-Tropical Grassland and Steppe.*<br>Swartkrans<br>Sterkfontein<br>Cornelia<br>Sidi-Zin<br>Latamne | *Mediterranean and Cape Macchia.*<br>'Ubeidiya<br>Sidi Abderrahman<br>Joubb Jannine<br>Ma'ayen Barukh<br>Kissufim<br>Amanzi | OPEN GRASSLAND PARK SAVANNA AND MACCHIA |
| *Woodland Savanna*<br>Isimila<br>Kalambo Falls<br>Kabwe (Broken Hill)<br>Nsongezi<br>Baia Farta | | | DECIDUOUS WOODLAND WITH GALLERY FOREST |
| *Montane Grassland and Forest/Savanna Ecotone*<br>Gadeb<br>Melka Kunture<br>Tabun | | | MONTANE GRASSLAND AND FOREST ECOTONE |
| *Sub-Desert Steppe and Desert.*<br>Kharga Oasis<br>Arkin 8 | | | ARID STEPPE AND DESERT |

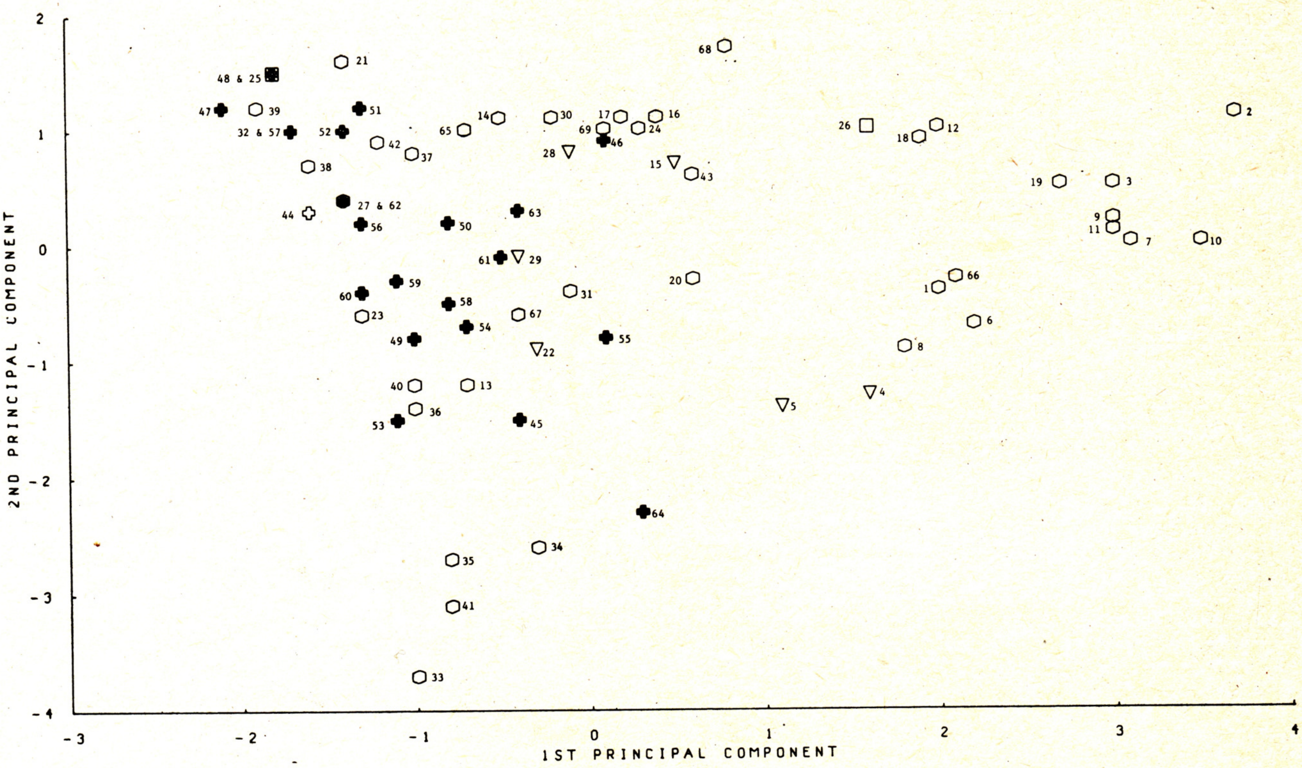



FIG. 16. *Principal component analysis: Components 1 vs. 2 with symbols denoting inferred prehistoric environment.*

than 1.0. Eigenvalue is a mathematical term which expresses the proportionality of variance. Although the maximum number of orthogonal transformations equal to the number of variables, in this case six, was extracted, no meaningful archaeological interpretation could be made beyond this arbitrary cut-off point.

When the 69 individual assemblages are projected onto the principal axes, their interrelationships become visible, leading to easier interpretation. In the multidimensional space created by these axes, assemblages with similar tool composition appear close together; inversely, assemblages distinctly different in composition do not appear in close proximity in relation to either axis.

*Figures 14 and 15* clearly show the generalised time continuum depicted by the first component. Bracketted by the Oldowan site of Olduvai FLKN 5, Bed I (no. 2) and the Upper Acheulian site of Isimila J12 (no. 47), the assemblages occur in overlapping clusters from Oldowan to later Acheulian. This overall picture suggests a conservative, gradual shift of technological development with a trajectory towards a higher occurrence of Large Cutting tools and a simultaneous reduction in the importance of choppers and spheroids. As the trend towards the increase of the Acheulian characteristics progresses, there is also a remarkable increase in the variation of other tool categories. Broad, regional clustering on the scale of North Africa, sub-Saharan Africa and the Middle East was not detected and, if such exists, it is probably obscured by the immense time period and other factors involved. Assemblages within a single site complex show a relatively restricted range of variation, as at Kalambo Falls, Isimila and Olorgesailie, strongly suggesting the existence of regional cultural traditions. Focusing upon the four Gadeb assemblages, Gadeb 2B (no. 4) and 2C (no. 5) show close affinity with the Developed Oldowan B sites represented by Olduvai BK (no. 6) and Olduvai TK Upper (no. 8). It further shows that 2B has more archaic features than 2C though, from its stratigraphic position, it appears to be slightly later. Similarly, this analysis seems to support our suggestion, made on typological and stratigraphic grounds, that the Gadeb Acheulian occurrence 8D (no. 15), best compared here with the Early Acheulian assemblages at Peninj (no. 16) and Olduvai EF-HR (no. 17). is culturally older than the neighbouring site of Gadeb 8A (no. 28) which itself compares well with Kapthurin (no. 30), Montagu 5 (no. 69), Isimila LH 15 (no. 46) and Melka Kunture (no. 29). It is also of particular interest that the Sterkfontein middle breccia occurrence (no. 19) appears to have more archaic features than that from Swartkrans (no. 18); the former comparing best with Developed Oldowan sites such as Ubeidiya K20 (no. 3) and the latter with Ubeidiya K30 (no. 12).

The earliest (Oldowan) stone tool assemblages appear to be confined to the drier, open tropical savanna and steppe habitats but, by the end of the

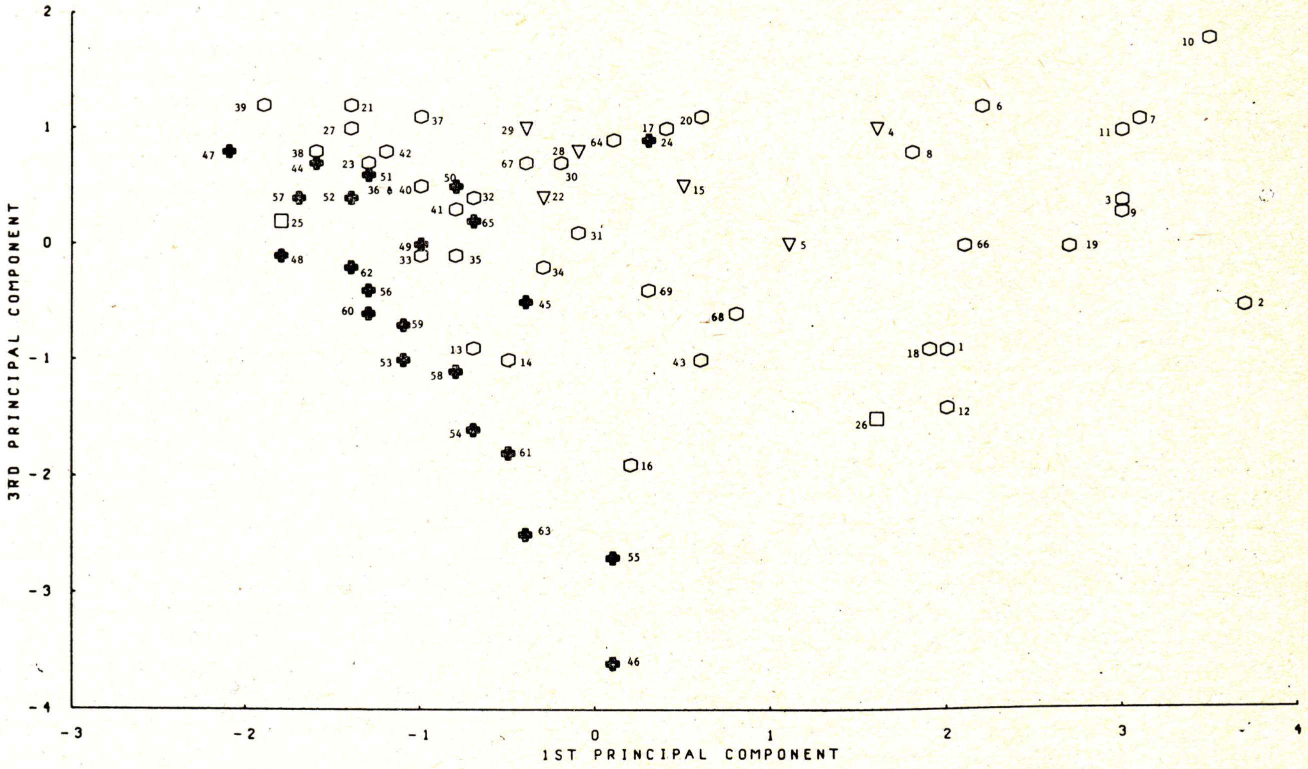



FIG.. 17. *Principal component analysis: Components 1 vs. 3 with symbols denoting inferred prehistoric environment.*

Middle Pleistocene, hominid distrubutions had expanded over a wide variety of additional environments and climates from the tropics to the borders of the continental ice sheets in Eurasia. In fact, with the probable exclusion of the lowland and montane tropical rainforest, the makers of the Acheulian Industrial Complex appear to have been capable of adjusting to almost all other kinds of habitat and of using a greater number of the wide range of different resources these provided. Since it might be expected that this gradually expanding ecological variability would be reflected in the toolkits, we have attempted to show whether any differences are apparent from principal component analysis.

We have, accordingly, grouped the 69 assemblages by the environments in which they occur today, using as a basis the vegetation maps prepared by Keay (1959) and the Oxford Regional Economic Atlas for the Middle East and North Africa (1960), since, where geomorphological, palaeontological and/or pollen data exist, it is apparent that the palaeo-environments do not significantly differ from those of the present time. In the following cases, however, we have made some adjustment in that we consider the palaeo-ecological evidence to suggest that Tabun Cave, in Acheulian times, would have lain in the ecotone between grassland and montane forest; that Lochard, Kariandusi and Montagu Cave sites belong more probably in wooded grassland; and we have classified the Nsongezi and Baia Farta sites as having been in woodland with gallery forest associated. With these exceptions, we have assumed general comparability with the present day and have grouped the sites under four main types of environment as shown above.

Symbols denoting these preferred palaeo-climatic environments at the time of occupation were imposed upon the plots of the first three principal components *(Fig. 16 and 17)*. The pattern is clear that there is indeed, a diversification in the range of environmental exploitation from open savanna/parkland and macchia to the occupation of a wider range of environments that includes deciduous woodland, montane grassland and desert steppe.

## FACTOR ANALYSIS

In the preceding section, the principal component technique was shown to consist of an orthogonal transformation of the coordinate axes to more comprehensible new orientations. By presenting the total variance of all observations into successively diminishing portions, an objective means was arrived at of determining the new coordinates. The first three axes accounted for most of the total variance (80 %) and it was possible to describe and interpret these orthogonal axes in terms of the function of some chronological order or possible inherent cultural activity differences.

For the study of multinormal dependence structures, it is at times appropriate to use a technique for explaining the covariances of the observation.

TABLE 5. *Varimax factor loadings pattern*

| | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| Choppers | .754 | —.191 | .234 |
| Polyhedrons/Spheroids | .822 | .035 | —.262 |
| Light Duty Tools | —.163 | .965 | —.091 |
| Heavy Duty Tools | .015 | —.044 | .970 |
| Large Cutting Tools | —.790 | —.567 | —.226 |
| Other | .609 | —.324 | .002 |
| Eigenvalue | 2.266 | 1.397 | 1.124 |

Although principal component analysis performs this task in some degree through its factorisation of the covariance matrix, it is still merely a transformation rather than the result of a fundamental model for covariance structure. It has been argued that, through the statistical technique of factor analysis, deficiencies of the principal component solution are minimized and interpretability of the factor parameters is increased. Our analysis shows that rotation of the reference axes by varimax, in the subspace established through principal component analysis procedure, does not effectively increase the virtues of parsimony and interpretability.

Six-factor solutions were extracted from 6×6 stone tool correlation matrix *(Table 2)*. The factor loadings for the first three solutions are shown in *Table 5*. Fifty iterations were made for convergence of the six-factor solution with a maximum convergence criterion for rotation of 0.0001. From the earlier principal component analysis it was predicted that three common factors might suffice to describe the dependence structure parsimoniously. In an attempt to increase the interpretability of the factor loadings pattern, a rigid orthogonal rotation of the coordinate axes of the six- dimensional factor space was made by the varimax method. The rotated loadings should normally permit an easier identification of the latent-factor dimensions; however, this was not the case with this study.

The three factors extracted from the six Shaped Tool categories have been plotted in *Figs. 18 and 19* and the loadings have the values shown in *Table 5*. The result is that the new first factor has not increased the industrial separation which can be thought of as a time factor, as compared to the unrotated factor loadings pattern for principal components. The second rotated factor is a bipolar factor, Light Duty tools with positive loadings vs. Large Cutting tools with negative loadings. This factor may again be interpreted as an activity specific factor or a general size factor as with the second principal component. The factor loadings pattern remains almost the same as the unrotated factor predecessors. With the third factor, a clear bipolarity is not demonstrated and, in the positive direction, only Heavy Duty tools show a substantially high loading. One must be cautious of over-emphasising the importance of factor analysis by the varimax rotation; using this technique, almost any body of data will produce some simple structure, though this may possibly be meaningless (Armstrong, 1967 : 17—21). This study suports the suggestion recently made by Doran and Hodson (1975 : 190 to 205) that Principal Component Analysis is a more desirable technique for archaeological application.

## CONCLUSION

For a general summary of multivariate data structure, principal component analysis on the Early Stone Age assemblages from Africa and the Middle East has shown itself a clear and useful approach for looking at both variables and cases (tool categories and assemblages). The model proposed in this study is that overall patterns in the frequency of the occurrence of stone artifact types/classes reflect the general chronological ordering of the lithic assemblages. This is particularly visible with principal component analysis. Minor variations in the frequency of different artifact types in the same locality, such as Olorgesailie, Kalambo Falls and Isimila may reflect fluctuations in environment, subsistance strategies, social organisation or differences in depositional context. The results of this study indicate that the Gadeb sites cover the range from Developed Oldowan through Early to Later Acheulian in Eastern Africa. Comparative studies of design or stylistic elements such as the shape of handaxes would be meaningful and might reveal finer differences at an idiosyncratic level.

We are aware that there are unspecified degrees of error in the data themselves — unavoidable errors caused by natural or cultural disturbance prior to or after the deposition of the artifacts; excavation techniques and selective collecting in the field; and inconsistencies in the classification in the laboratory. We may be striving too hard to extract information despite certain elements of unreliability or uncertainty in the quantitative data available at the present time. However, we hope that this study will help to show some of the possibilities that the use of multivariate analysis techniques has for recognising statistically valid groupings and comparing Palaeolithic assemblages of stone tools.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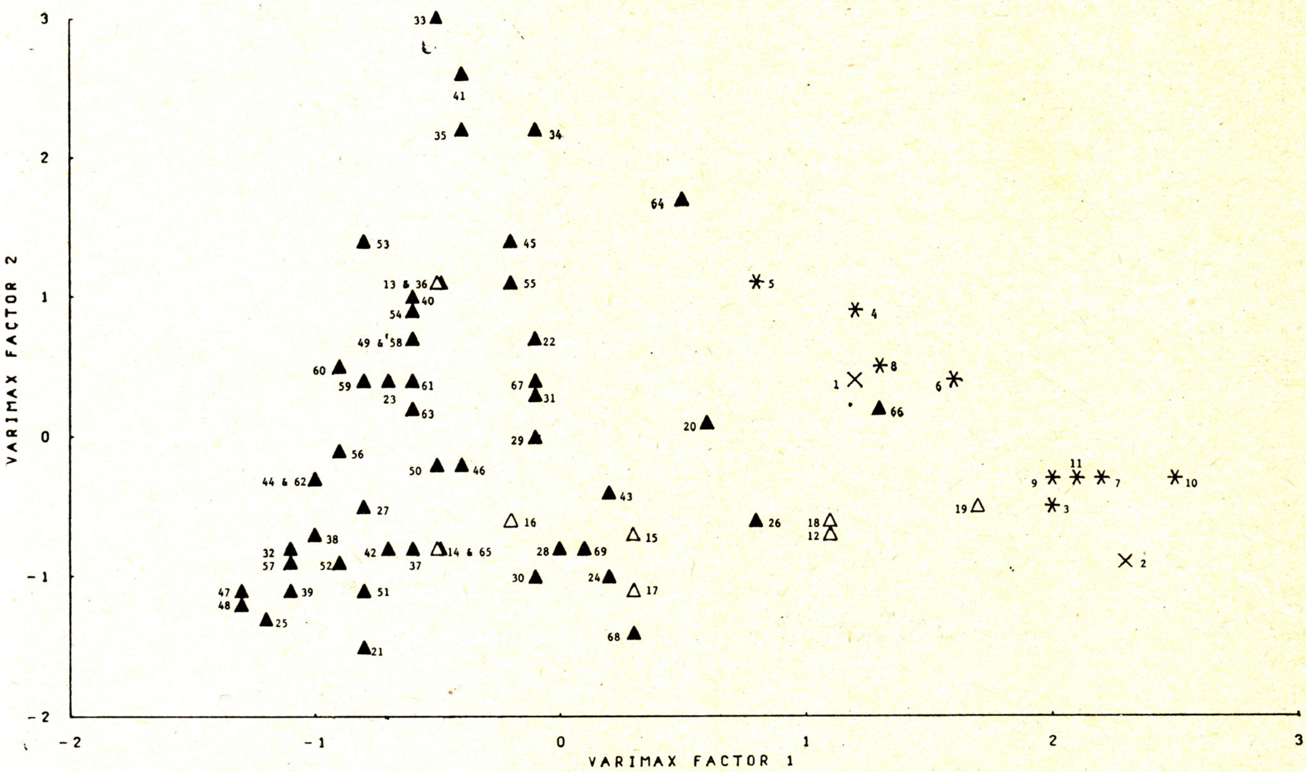


FIG. 18. *Varimax factor analysis: Varimax factors 1 vs. 2.*

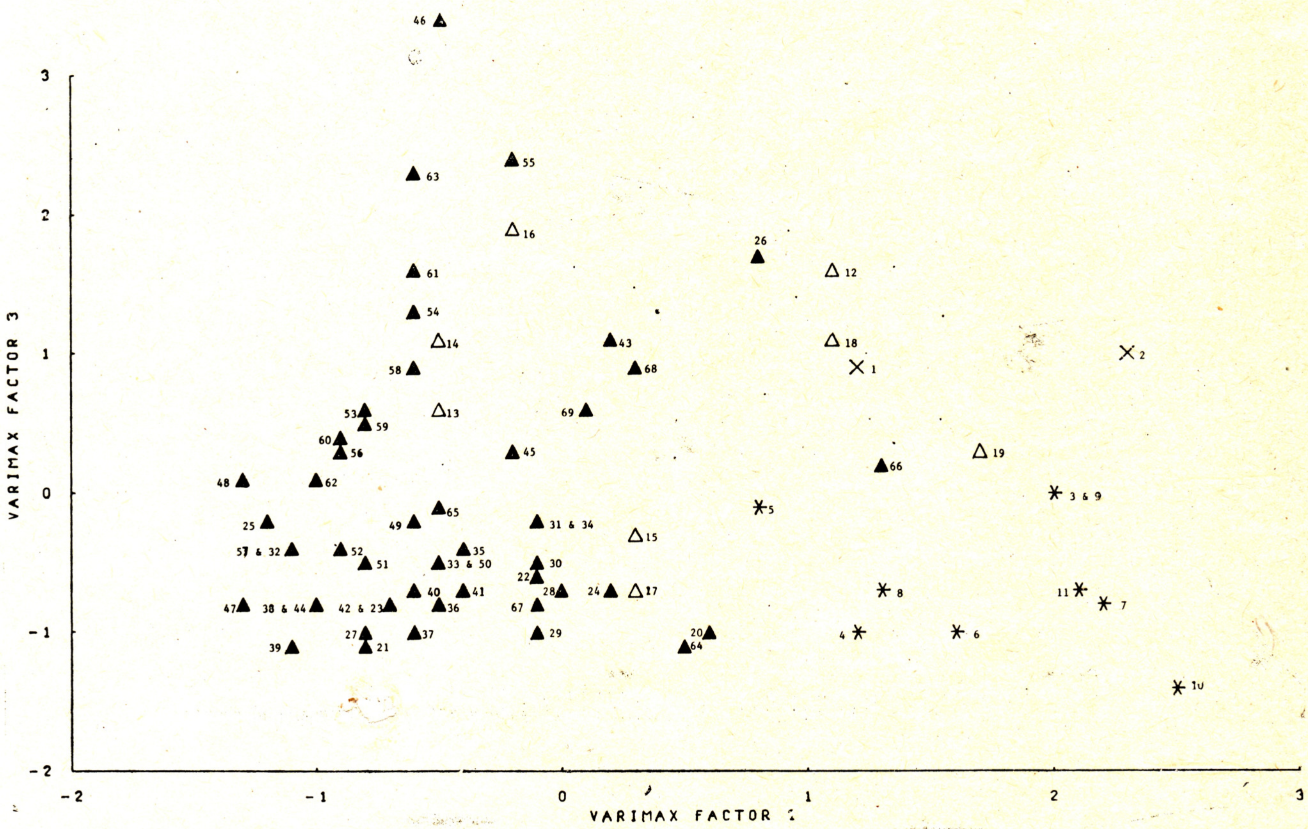


FIG. 19. *Varimax factor analysis: Varimax factors 1 vs. 3.*

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