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Kariandusi: Acheulean morphology and the question of allometry

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Abstract

Allometry, or size-related variation, is shown to be an important factor in the bifaces of two separate assemblages from the Acheulean site of Kariandusi in Kenya. Such variation has functional and possibly stylistic implications. The paper gives a review of the archaeology of Kariandusi, and then investigates the question of size and shape variation in bifaces. The Upper Sites at Kariandusi, first investigated by L. S. B. Leakey, have yielded many obsidian bifaces which can be dated to approximately 0.7–1.0 myr ago. Material from the Lower Site, including many lava bifaces, is judged to be stratigraphically younger but probably in the same time range. We show by making comparisons with the neighbouring Acheulean sites of Kilombe and the Kapthurin Formation that allometry is present in biface assemblages at least 0.5 myr different in date; that similar principles of allometry operate in all the assemblages; and that where there are differences of allometric pattern, within-site variation is sometimes greater than variation between distant sites. We conclude that the size of a biface at least partly determines the shape in which it was made, and that sites in the time range of *Homo erectus* and early *Homo sapiens* show surprisingly similar allometric patterns.

Résumé

Il est démontré que l'allométrie ou variation dimensionnelle, est un facteur important des bifaces de deux collections séparées du site acheuléen de Kariandusi au Kénya. Une telle variation a des implications fonctionnelles et peut-être aussi stylistiques. Cet article examine l'archéologie de Kariandusi, puis étudie la question des variations de dimensions et de formes dans les bifaces. Les sites plus élevés de Kariandusi, que L.S.B. Leakey a été le premier à fouiller, ont donné de nombreux bifaces d'obsidienne que l'on peut dater d'environ 0,7–1,0 million d'années. Le matériel obtenu dans le site inférieur, y compris de nombreux bifaces en lave, est jugé plus récent stratigraphiquement, mais probablement de la même période. En faisant des comparaisons avec les sites acheuléens voisins de Kilombe et de la Formation Kapthurine, nous démontrons que l'allométrie est présente dans des collections de bifaces dont les dates diffèrent d'au moins 0,5 million d'années; que des principes d'allométrie similaires s'appliquent à toutes les collections; et que lorsqu'il y a des différences de schéma allométrique, la variation au sein d'un même site est souvent plus importante que la variation entre des sites distants. Nous concluons que la dimension d'un biface détermine au moins partiellement sa forme, et que les sites de la période de l'*Homo erectus* et du début de la période de l'*Homo sapiens* présentent des schémas allométriques étonamment semblables.

Introduction

In Africa more than a million years is represented in the archaeology of the Acheulean, which has been revitalized by the discovery of important new sites, the application of palaeoecological studies, and the development of cognitive approaches (Asfaw *et al.* 1992; Roche *et al.* 1988; Potts 1989; Schick 1992; Wynn 1981, 1985; Gowlett 1984, 1986). Wynn and Tierson (1990) have given new stimulus to quesions of morphology by demonstrating different regional preferred shapes in bifaces. They also noted that at Kariandusi it was possible to discriminate between the different shapes of lava and obsidian bifaces. Elsewhere, we have shown that on the Kilombe sites allometry is an important factor in the well-known variation of Acheulean bifaces (Crompton and Gowlett 1993).

Allometry is the study of size-related variation. In our initial paper on this subject we concentrated on the single site complex of Kilombe, demonstrating that allometry occurs in the bifaces from all areas of the site complex, but that not all areas show the same pattern of allometry (Crompton and Gowlett 1993). We interpreted the allometry as adjustments made for different functional needs in different sizes of artefacts, without ruling out the possibility of a stylistic factor.

We turn now to considering whether allometric adjustments have a similar importance in the Acheulean in general. Kariandusi in an obvious site to examine in an extended comparison, having yielded separate series of small obsidian bifaces, and larger lava specimens. The differences between these observed by Wynn and Tierson (1990) are evidently significant, although interpretation is not easy: we aim to determine both whether they include an allometric factor, and whether allometric adjustments were made in one or both assemblages. As an additional control we have extended the analysis to include bifaces from another central Rift Valley site, LHR in the Kapthurin Formation to the west of Lake Baringo. This is a much more recent site, dated to about 250,000 years ago (M. Leakey *et al.* 1969; Tallon 1978; Cornelissen *et al.* 1990). In this study, we are thus embracing sites ranging across about 150 km in space, and through about 750,000 years in time – more than half of the total Acheulean time depth.

Kariandusi itself was one of the first-discovered Lower Palaeolithic sites in East Africa (L. S. B. Leakey 1931). Although it was reinvestigated in 1973 and 1974 no primary-context occurrences were found (Gowlett 1979, 1980). The results of the excavations were summarized in Gowlett (1980), and basic excavation data appeared in an archaeological field guide to the VIII Panafrican Congress of Prehistory. As they seemed unable to offer information on the favoured research questions of the1970s and 1980s the interest in the sites then diminished, but it is now plain that even the finest contexts may offer limited behavioural information, whereas other research questions can be addressed from sites of secondary context. In the frame of renewed interest in the Acheulean our paper has the dual aim of exploring the question of allometric variation, and presenting a more detailed account of the Kariandusi sites.

Setting of the sites

Kariandusi lies on the eastern side of the Gregory Rift Valley, about 120 km north-north-west of Nairobi, and about 2 km to the east side of Lake Elmenteita at 0°28′S., 36°17′E. (Fig. 1). The Nakuru-Elmenteita basin occupies the width of the Rift Valley, flanked by Menengai Caldera on the north and the volcanic pile of Mount Eburru on the south. There is considerable geological evidence to show that at times in the past this basin has been occupied by large lakes, sometimes reaching levels hundreds of metres higher than the present Lakes Nakuru and Elmenteita (Nilsson 1940; Washbourn 1967; Nyamweru 1980; Bishop 1971; Butzer *et al.* 1972).

The sites are at a height of *ca* 1880 m above sea level, thus lying about 75 m above the present day level of Lake Elmenteita. Impressive scarps of the Rift wall rise less than 1 km behind the sites, continuing as the Bahati Escarpment to the north, and the Gilgil Escarpment further south. The scarps behind rise to 2250 m less than 3 km from the sites. Near this point the scarps are dissected by the valley of the Kariandusi River, which has a relatively short course, fed partly by waters from Coles' Hot Springs, only 2 km from the sites. The river runs down to Lake Elmenteita, passing in the latter stages through a deep gorge where it has cut through an accumulation of sediments. McCall (1967) observed that like other rivers in the area the Kariandusi River tapers through loss underground. The deposits containing Acheulean material are best exposed in a side gorge on the left bank of the Kariandusi River, which reaches within about 150 m of the old Nairobi–Nakuru main road. Under present conditions, water flows in this side gorge only rarely.

A block diagram of the site settings is shown in Figure 2a. The position commands a very fine view across the Rift Valley, but at times of high lake stands it seems that only a narrow strip of land would have been readily accessible for exploitation behind the sites (Fig. 2b). It is, however, quite possible in the present day to climb between the scarps in the area behind the sites, and it is therefore noticeable that, as at Olorgesailie and Kilombe, a wide range of environments would probably have been available within a few kilometres of the site. Raw materials for the manufacture of stone artefacts would have been accessible locally in the form of the Gilgil trachyte and welded tuffs.

Archaeological investigations

Kariandusi is possibly the first Acheulean site to have been found *in situ* in East Africa. The diatomite deposits at Kariandusi were already known in the early years of the twentieth century (see further below), but the archaeological sites were not discovered until exploration of this part of the Rift Valley by Dr L. S. B. Leakey's Second Expedition in 1928–29. Leakey (1936) records how the site was discovered by Dr J. Solomon and Miss E. Kitson. Investigations were carried out at the site, and a series of hand-axes was described in *The Stone Age Cultures of Kenya Colony* (L. S. B. Leakey 1931). There is little other mention of Kariandusi in that book, apart from a geological discussion by Solomon (p. 256) who includes a section showing Middle and Upper Pleistocene sediments, and containing Acheulean and 'Aurignacian and Mousterian' artefacts respectively. Further brief comments (L. S. B. Leakey 1936), included the declaration that 'We now have a

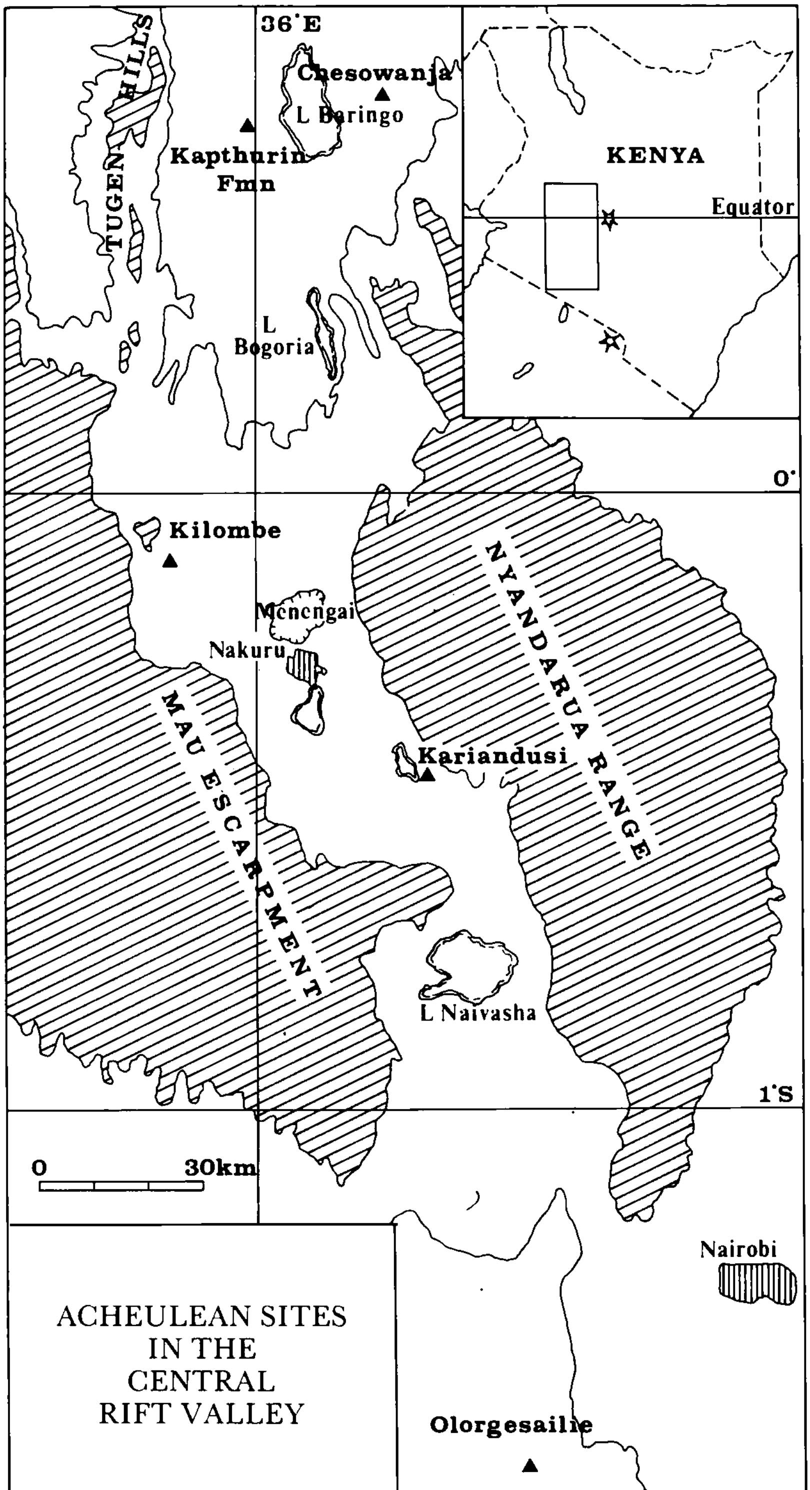

Figure 1 The setting of Kariandusi, showing other Acheulean sites in the Central Rift Valley. The site of Isenya (Roche *et al.* 1988) is about 50 km south of Nairobi.

collection of over two thousand specimens excavated from an area barely 10 feet square . . . .'. L. S. B. Leakey (1934) then believed that 'the Kariandusi River site was a factory site of the time of the fourth stage of the Acheulean', but the 1953 reprint indicated that he no longer adhered to the stage system.

The early descriptions of the site are perfunctory by modern standards, but the artefacts were carefully described and illustrated, and a geological account appended. Work did not resume until shortly after the Second World War, when new excavations were carried out at the Acheulean site in preparation for the First Pan-African Congress of Prehistory, held at Nairobi in 1947. The sites were visited on an excursion made by the delegates, and are mentioned in the pre-publication papers and tour-guides. They do not feature in the *Proceedings* of the Congress (L. S. B. Leakey and Cole 1952), and in a sense their importance had been eclipsed by that of Olorgesailie and Olduvai. The excavations of 1946–7 have been preserved as a museum exhibit, and may still be seen. For this pupose it was necessary that the artefacts be left *in situ*, which restricted the possibilities for description (a problem later encountered by Glynn Isaac at Olorgesailie).

In 1958, M. R. Kleindienst and G. H. Cole were given permission by L. S. B. and M. D. Leakey to make a study of artefacts from Kariandusi and Olorgesailie housed in the Coryndon Museum. Kleindienst recorded that it was possible to study only a small proportion of the Kariandusi finds; results of this study were published shortly afterwards (Kleindienst 1961) and are compared with the results of more recent work below.

In pioneering chronological studies during the 1960s potassium-argon dates were obtained from the diatomaceous sequence, though Evernden and Curtis (1965) questioned the validity of these for the archaeological material (see below). Brief descriptions of the site have also been given by Cole (1954), Howell and Clark (1963) and Isaac (1972; see also Isaac 1975).

Further archaeological work was undertaken in 1973/4 (Gowlett 1979, 1980) because artefacts had been discovered during the stripping of overburden from the diatomite deposits which are quarried in the area. The work was halted by Mr R. Terry, the manager of the diatomite works, in order to allow investigation. By that time a drainage ditch made to protect the quarry face from runoff had revealed the presence of large numbers of bifaces just beneath the surface. These discoveries presented opportunities: first for the National Museums to create an additional display and to extend the existing museum; and second, for far more detailed comparisons to be made with the Acheulean site of Kilombe, which lies about 80 km north-west of Kariandusi (Fig. 1): for a description of work at Kilombe, see Bishop (1978); Gowlett (1978, 1982, 1991, 1993). An initial brief survey made in December 1973 was followed in 1974 by the opportunity to carry out excavation, which was supported by the National Museums (Gowlett 1979, 1980). The new archaeological material is in secondary context and some had been disturbed by recent digging, but in the broader context of Acheulean studies it has yielded useful information, as we now show.

Geological background

The Kariandusi area has received special attention not only because of its archaeology, but also because of the commercial significance of the diatomite deposits. Although various specialist reports have been made on these deposits (Pulfrey 1944; Barnard 1950), the best general treatments of the geology of the site area are those provided by McCall (1967;

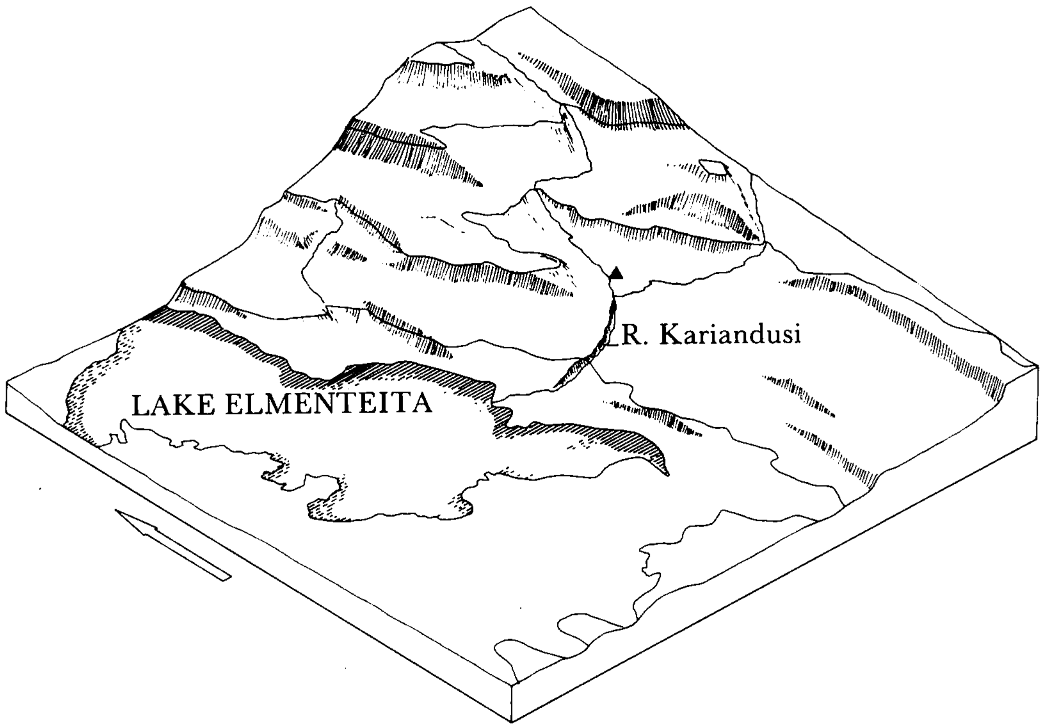

Figure 2a Block diagram of the Kariandusi area, viewed from the south-west, on a base 10 × 10 km; contours at intervals of 150 m.

McCall *et al.* 1967), and the following account depends much on evidence from these publications.

According to McCall, the diatomites at Kariandusi were first reported by Hobley in 1909; the sediments were later described by Gregory (1921). Solomon, a geologist working with Louis Leakey, provided a first general description of the sediments and shorelines of the Nakuru-Elmenteita basin (in L. S. B. Leakey 1931); the discovery of palaeolithic artefacts in the 'Kanjeran' sediments at Kariandusi allowed Solomon and Leakey to confirm their Pleistocene age. Earlier interpretations of the Pleistocene sequence are of course out-dated. Both Leakey and Solomon considered the area ideal for working out a pluvial-interpluvial sequence, and the Nakuru-Elmenteita basin became the type area for such sequences in East Africa. Since the formulation of these early hypotheses, there has been a near-total reassessment of views. Much of this is now old ground, and it is treated in more detail in the papers cited.

Interpretation of the sites depends partly on evaluation of the relationship of the Kariandusi sediments to the history of the Rift Valley itself. The sediments which have been named 'Kanjeran' are lacustrine and well stratified, consisting largely of diatomites and tuffs. Although Leakey believed that the sediments were themselves strongly faulted, Shackleton (1955) was of the opinion that the Kariandusi sediments were deposited on a horst-and-graben surface, originating in the last major faulting of this part of the Rift Valley.

At Kariandusi trachytes underlie the sedimentary sequence, named by McCall (1967)

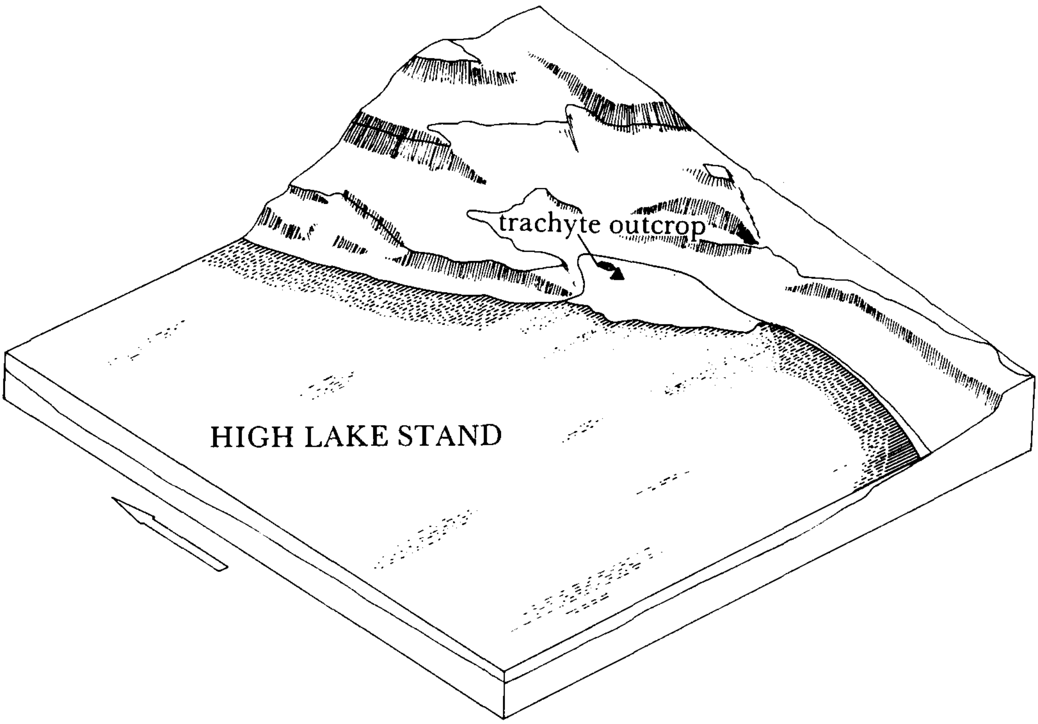

Figure 2b Kariandusi: an equivalent hypothetical reconstruction with high lake level; the area of the lake-side sediments is approximately that indicated by Barnard's survey. The lake shore may have provided relatively easy access to the Eburru area to the south, a possible source of obsidian for artefacts.

as the Gilgil trachyte. According to McCall *et al.* (1967), this has been affected by major faults, while 'the Kariandusi sediments are affected only by minor renewals of movement on the older lines'. The crucial point, remarked both by Shackleton and McCall, is that such faults could not have caused any appreciable remoulding of the Rift Valley. Both authors express the belief that it was already roughed out in its present form at the time of the Kariandusi deposition. This view is supported by later work (e.g. Williams 1978; Nyamweru 1980), and is an important factor in considering the palaeogeography of the sites (Figs 2b, 3). The Kariandusi sediments have an appreciable dip to the west, which has been interpreted as suggesting that slight down-warping of the Rift Valley floor continued after their deposition.

Generalized section

Since the original observations were made by Solomon (1931), the opening of the diatomite quarry has greatly improved the extent of the exposures. This helps to explain the various descriptions of sections offered by different writers. Solomon could observe only the upper part of the section, and overestimated the thickness of pumice and diatomite which underlies the upper diatomite. Pulfrey confined himself to a description of the diatomaceous

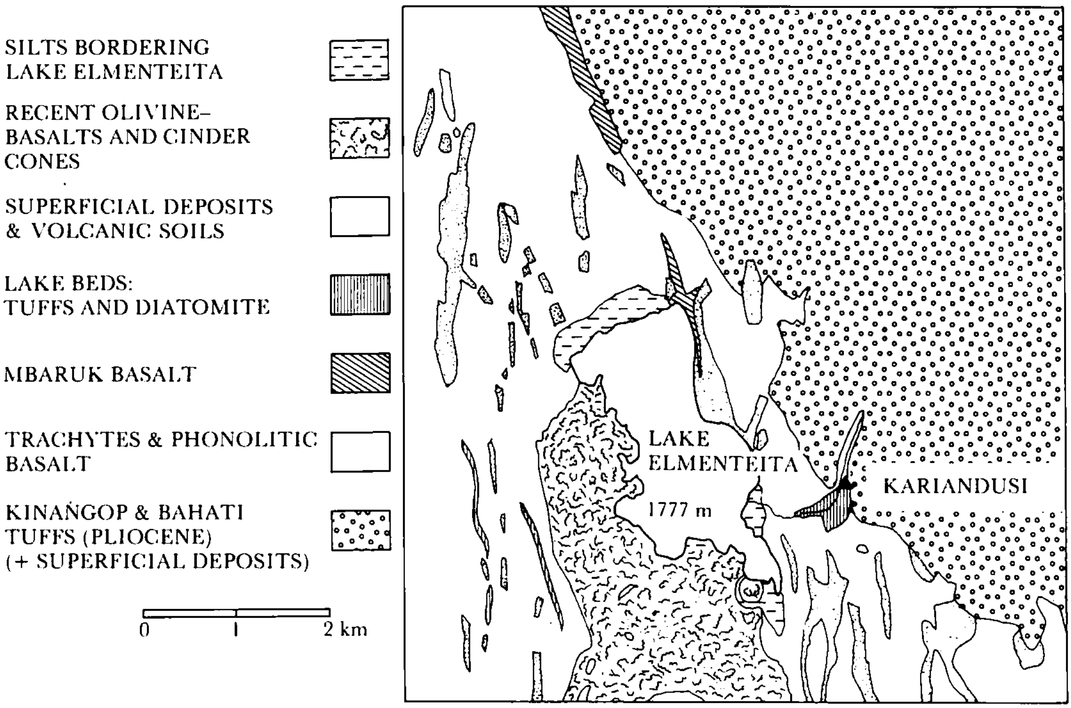

Figure 3 Geological map of the Kariandusi area, simplified after McCall (1966).

layers, and especially of the horizons of pumice and diatomite which lie between the main diatomite and the upper diatomite, but he does not describe the overlying layers with their archaeological content. The first complete section of the deposits is thus that given with Barnard's 1:1,000 scale plan of 1950, redrawn in McCall (1967). This section is rather more generalized than that of Pulfrey. The stratigraphy described by him in detail is lumped together as 'pumice and diatomite'. Similarly, the upper part of the section including the archaeological industries is termed simply the 'upper pumicites' (relabelled by McCall as 'upper pumice beds'); but the plan of the sediments was based on deep boreholes made for commercial purposes, and it allows an almost unrivalled three-dimensional reconstruction of the geometry of a set of Pleistocene lake beds.

Archaeological interest concentrates on the levels overlying the main and upper diatomite. These are locally variable. In his section, Solomon distinguished a band of tuffaceous gravel, immediately overlying the (upper) diatomite, and overlying units of fine stratified tuffs with a little intercalated sandy material. This distinction is readily observable in the exposures, and artefacts have been found both from the tuffaceous gravels and from the finer tuffs (Figs 6 and 7 below). Elsewhere there are no detailed published references to the stratigraphy of these beds. Further discussion here is limited to the individual sections excavated in the area of the side gorge, and no wider-scale mapping has been carried out.

Chronological evidence

The Acheulean is now known to have a time range from about 1.5 to about 0.015 million years (Isaac and Curtis 1974; Asfaw *et al.* 1992). This framework was established largely by the pioneering potassium-argon dating of Evernden and Curtis (1965), but the dates then obtained for Kariandusi seemed excessively old. When they took samples for potassium-argon dating at Kariandusi, Evernden and Curtis were unable to discover primary tuffs at the level of the industry. They therefore dated several samples from different levels in an effort to establish relative age:

		myr
KA 415	water laid tuffaceous sediment overlying main site	3.1
KA 1064	tuff (rounded pumice fragments in tuff) with axe	1.1
KA 965	possibly reworked tuff under hand-axe	0.93
KA 1035	pumice fragments from diatomite 15–18 m below site level	0.95

The date KA 415 was plainly far too old, which may have undermined the credibility of the other determinations. Evernden and Curtis were not satisfied with the archaeological value of the results, noting that 'the last date is probably correct but it does very little towards determining the absolute age of the Acheulian industry at Kariandusi'. A date of this order then seemed excessively old, though Isaac (1972, 1975) later observed that the section above the dated horizons does not imply a long time interval, and was inclined to accept the dates with some reservation.

More recent studies have demonstrated both the great antiquity of the early Acheulean (Isaac and Curtis 1974; Asfaw *et al.* 1992), and that several comparable sites may be much the same age as Kariandusi. Palaeomagnetic evidence from Olduvai Bed IV, from the lower sediments at Olorgesailie, and from Kilombe, has shown that all are over 0.7 myr old (Leakey 1975; Isaac 1977; Dagley *et al.* 1978; Gowlett 1978) and the Olorgesailie evidence has been backed up by a new suite of K-Ar dates (Bye *et al.* 1987).

Confirmatory evidence for the potassium-argon dates has also been obtained from palaeomagnetic sampling at Kariandusi. Trial samples taken in 1974 were submitted to Dr Peter Dagley then of the Sub-department of Geophysics, Liverpool University. Samples from a tuff band in the diatomite did not give significant readings, but two samples from Site C, near the top of the Kariandusi sequence (discussed below) provide evidence of reversed magnetization. The pumice horizon from which the samples were taken overlies archaeological material and, as shown on the general section (Fig. 7), is likely to postdate the artefact horizon at the main site. These specimens were collected from a small area but, taken with the potassium-argon dates, the results strongly suggest that this part of the Kariandusi sequence belongs to the late Lower Pleistocene, probably within the time range 0.7–1.0 myr ago.

The Acheulean industries at Kariandusi were originally considered as broadly contemporary with those from Bed IV at Olduvai Gorge on the basis of the form of the bifaces and the nature of the fauna (cf Cole 1954). It is interesting to see that this assessment has survived major reassessments of the absolute chronology involved.

The Upper Site

The Upper or Main Site is the area investigated in detail by Louis Leakey in 1929–1931 and in 1946/7. Although no new excavations were carried out here in 1973/4, plans and sections of the older work were made. It is in this area that artefacts were first observed. The site lies on the right side of the side gorge, in which there are good exposures of the upper diatomite and of the overlying tuffaceous sediments. Artefacts were visible in this section. Artefacts from the earlier excavations were lifted at the time; those which are left *in situ* on the site come from the 1946–7 excavations. These excavations, an extension of the area previously investigated, cut right across the top of a spur which juts out into the side gorge (Figs 4 and 5).

Since the long section of the excavations is very well preserved, it was possible to draw and level it in relation to Barnard's survey points (Gowlett 1979). The section has a long main face, with short faces angled back at each end (Figs 5 and 6). It can be seen that the artefact horizon occurs in the upper pumice beds, about 3 m above the top of the upper diatomite, and that in long section it runs approximately parallel with the upper surface of the diatomite, thus conforming with the general dip of the sediments. The angled face of the section at the western end shows the artefact horizon dropping away more steeply, towards the deeper part of the channel structure at the edge of which it lies. This part of the section provides a better cross-section of the sedimentary structure.

Grades of 'sands' and 'gravels' have been labelled on the drawn section, but in composition the material is very largely reworked pumice tuff, including many small rounded pebbles of pumice. Similar grades of material are present above and below the artefacts, but larger pieces of rounded pumice occur at the level of the artefact horizon. The horizon contains numbers of large stone blocks (20–30 cm in diameter) and large artefacts, but it is mainly concentrated vertically, with almost all the material occurring at one level, as

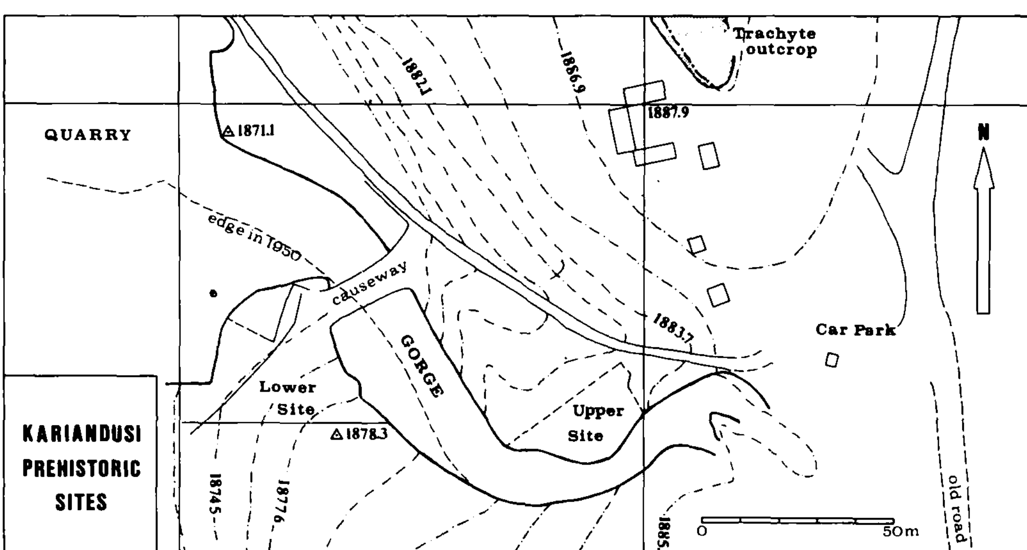

Figure 4 The Kariandusi sites: a map based on part of Barnard's unpublished map of 1950, modified to show the progress of quarrying and position of the Lower Sites.

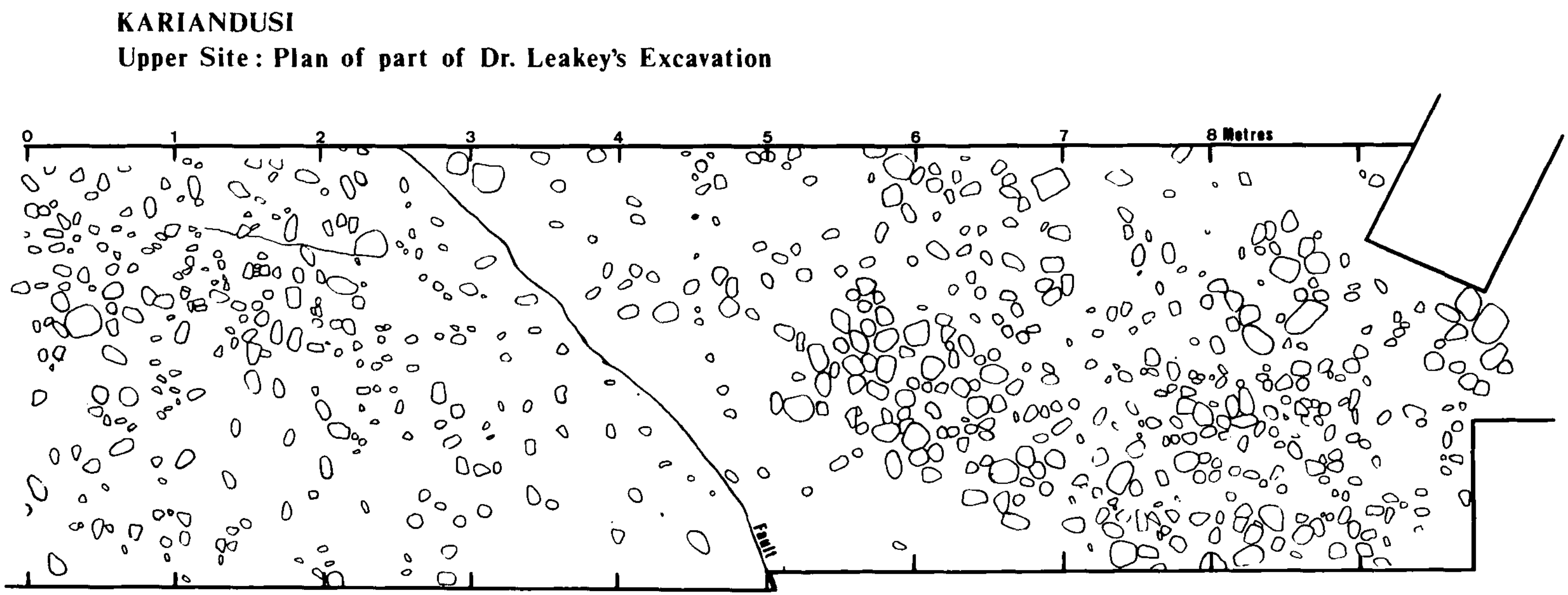

Figure 5 Kariandusi Upper Site: plan of artefacts on the Leakey excavations.

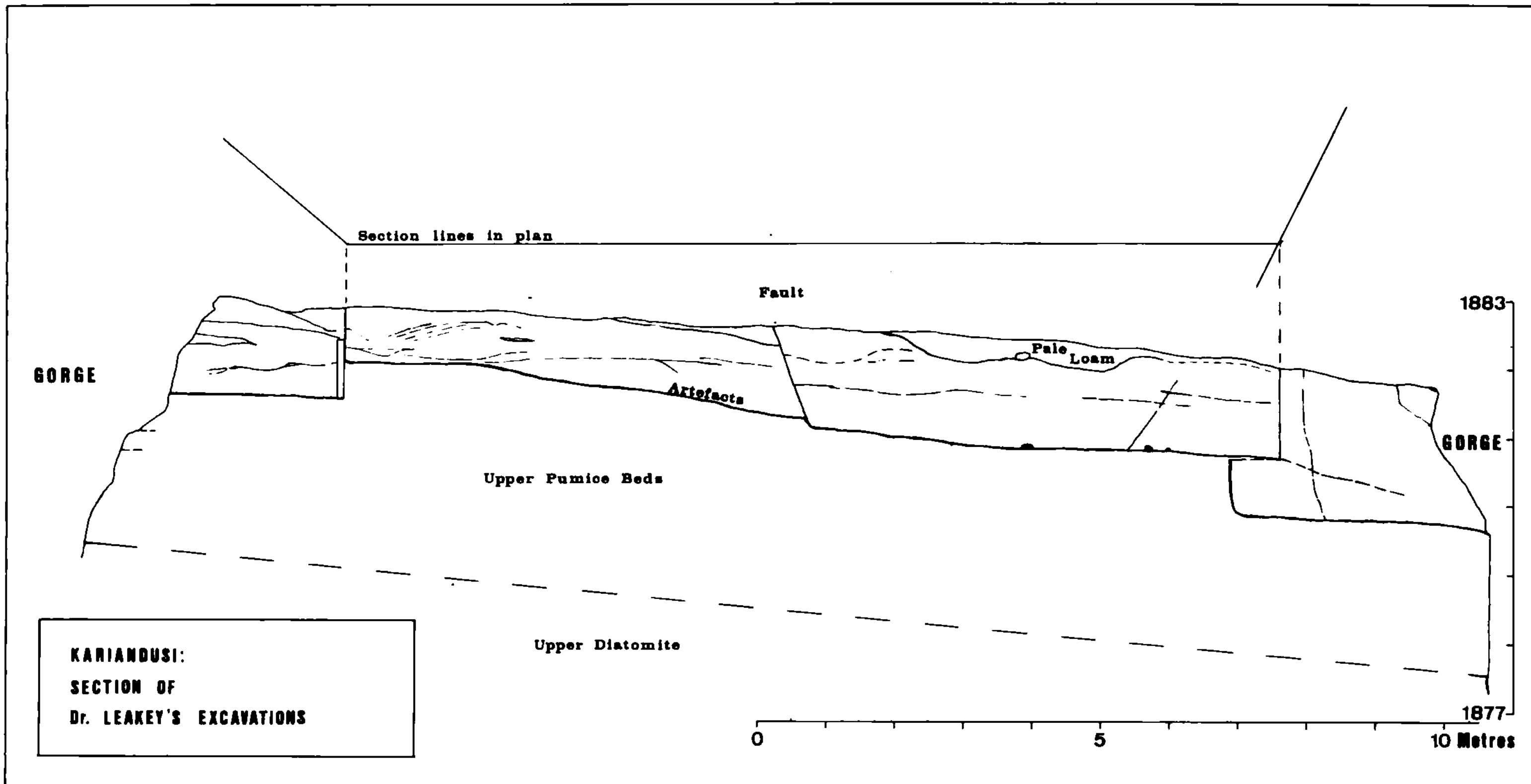

Figure 6 Section of the Leakey excavations.

far as can be seen. In one place, however, an obsidian hand-axe has been left by the excavators on a pedestal of sediment, showing it to have been found some 30 cm above the other artefacts.

A plan of the excavations was made (Fig. 5), compiled from a series of photographs which were taken from overhead after a metre-grid had been strung out over the surface The data were then traced off and reconstituted with allowance for distortion. Although there are obvious drawbacks in making a plan of finds which have been exposed to view for many years, careful examination showed that many finds were still solidly fixed in the matrix of pumice sand and gravel. Many others, though loose, were obviously still in situ, as shown by the form of the underlying hollows. A proportion of the artefacts has been moved since excavation, but one may estimate that the plan forms an 80%-plus accurate record of the larger finds as originally uncovered. Smaller flakes and doubtful items could not usefully be plotted.

The context of early archaeological material is one of the key factors widely acknowledged to need further investigation (e.g. Schick 1991). It is therefore desirable to have as large a corpus of data as possible of the different circumstances in which material occurs, with detailed documentation. The Kariandusi artefacts are derived,but they are still archaeological material in an ancient sedimentary environment, and as such can be compared with other occurrences. Rather than an archaeological plan, they represent the endpoint of a taphonomic process. Preliminary examination of the plan shows that the distribution of artefacts and manuports is very dense. The large numbers of stone blocks or manuports often occur in groups, and amongst them are some pumice blocks. No petrographic analysis of the stone blocks has been carried out, but at the present day there is an outcrop of the Gilgil trachyte on the nearby rise, 80 m from the site. This probably stood out above the sediments in the past, and is very likely to have been the principal source of lava raw material. Large numbers of obsidian artefacts occur on the excavated horizon, including about 100 bifaces. There are also smaller obsidian artefacts, such as scrapers. Some artefacts of lava also occur, notably spheroids and a few bifaces, some of which are heavily abraded. In contrast, most of the obsidian bifaces are in fresh condition.

The presence of stone blocks of local material, coupled with artefacts chiefly of an exotic material, is parallelled elsewhere, for instance at Olorgesailie and Latamne (Isaac 1977; Clark 1967, 1968). Labels on site and the original site guide indicate that the chief faunal remain was horse teeth. This provides taphonomic information suggesting a depositional environment of sufficient water energy that only select dense faunal elements were deposited at this point (cf. the bar deposit at Gesher Benot Ya'aqov: Goren-Inbar *et al.* 1991).

The Lower Sites

During the 1974 season at Kariandusi excavations took place in an area on the opposite side of the side gorge from the Upper Site, further downslope towards the diatomite quarry and the Kariandusi River (Figs 7 and 8). As mentioned above, the finds had been discovered during the stripping of overburden from the diatomite deposits which are being mined in the area. The excavations were intended to investigate this occurrence, and to preserve it for museum display if possible. Sections were drawn of the new site, and at

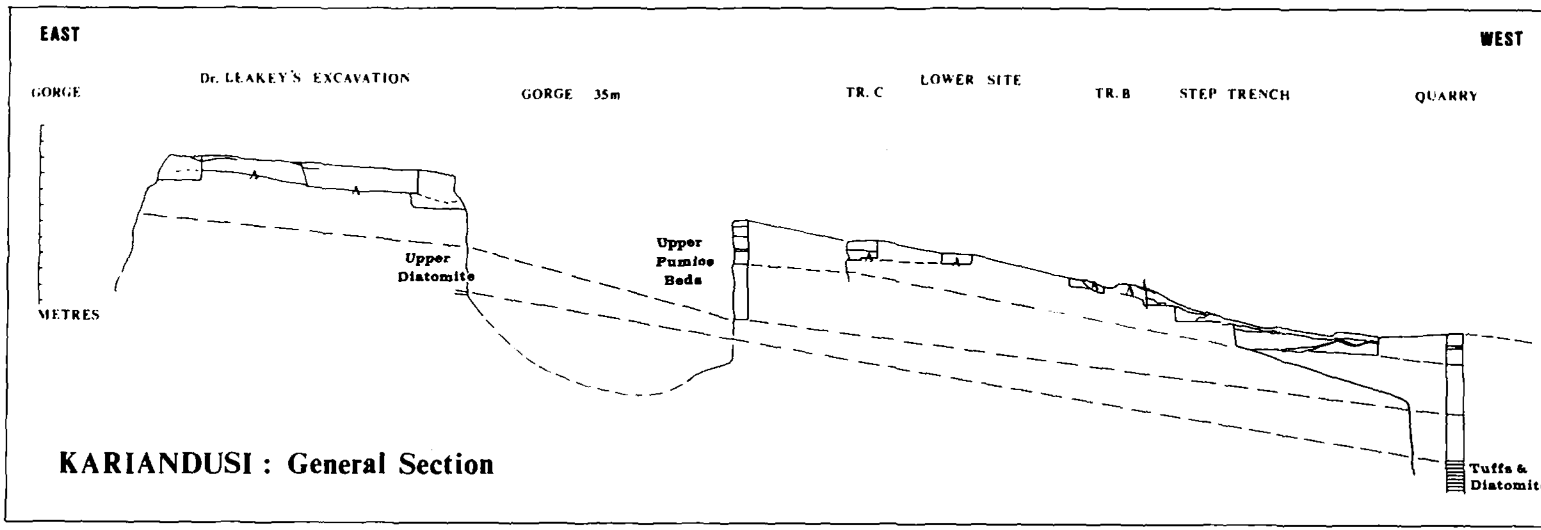

Figure 7 Kariandusi: general section showing the postulated relationships of the Upper and Lower Sites.

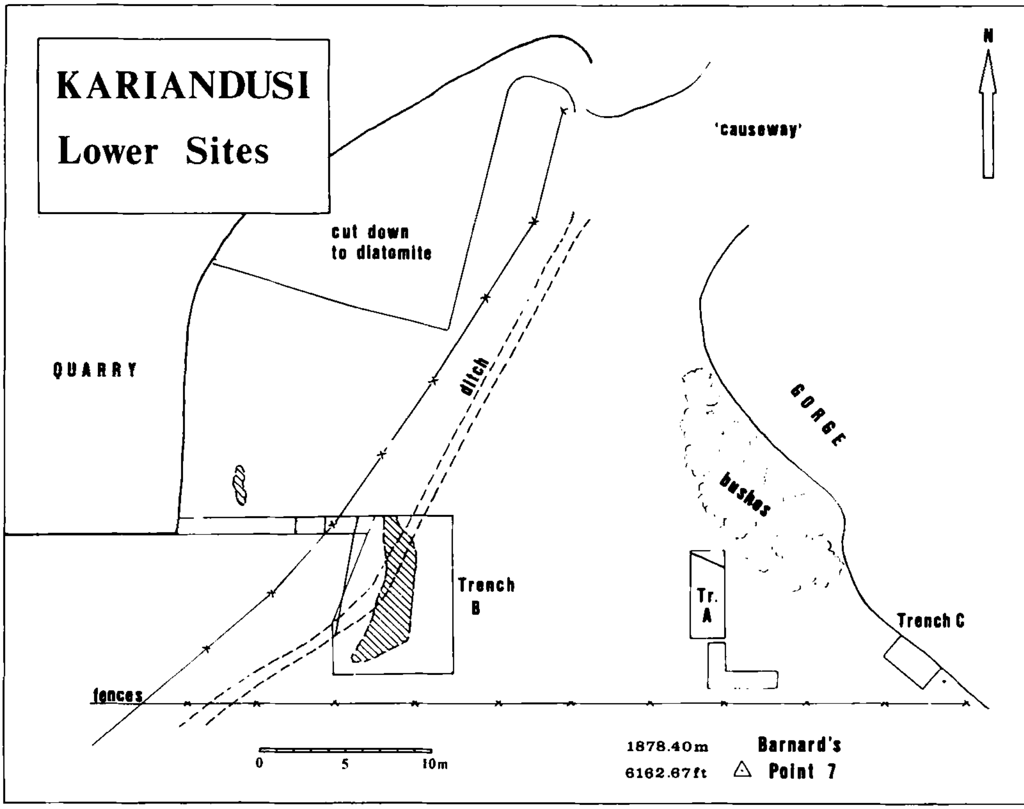

Figure 8 Plan of the Kariandusi Lower Sites. The hatched zone in Trench B indicates the dense distribution of lava bifaces.

intervening points in the gorge, in an effort to establish the stratigraphic relationship betwen this locality and the Upper Site.

Within the area of the Lower Sites, investigations were made in three places. Trenches A and C were both excavated into the top of the pumice series at locations near the side gorge where the upper pumice beds have a total thickness of *ca* 7 m.

Trench A was cut to a depth of 60 cm through had compacted fine-grained pumice tuffs, the fine laminae in which suggest deposition in standing water. An artefact horizon was reached at the base of this, at a level of about 5 m above the top of the upper diatomite, but the material appeared to be abraded or rolled. Because of the difficulty in digging in this area, this trench was abandoned. At one side the trench had cut the backfill of an older trench, though it is not known when this was excavated.

Trench C was dug into the face of the gorge through the same deposits (Fig. 9). It was cut to house a stairway for access to and from the gorge. The same horizon as in trench A was located. This was fortunate, in that an obsidian hand-axe and two large obsidian scrapers were found *in situ*, among cobbles of lava, and with a large pumice boulder or bomb. These finds came from a horizon underlying the fine-grained blue-grey pumice tuffs (Fig. 9) which were sampled for palaeomagnetic determinations, and which gave indications of reversed magnetization (P. Dagley pers. comm.). On this basis it can be stated

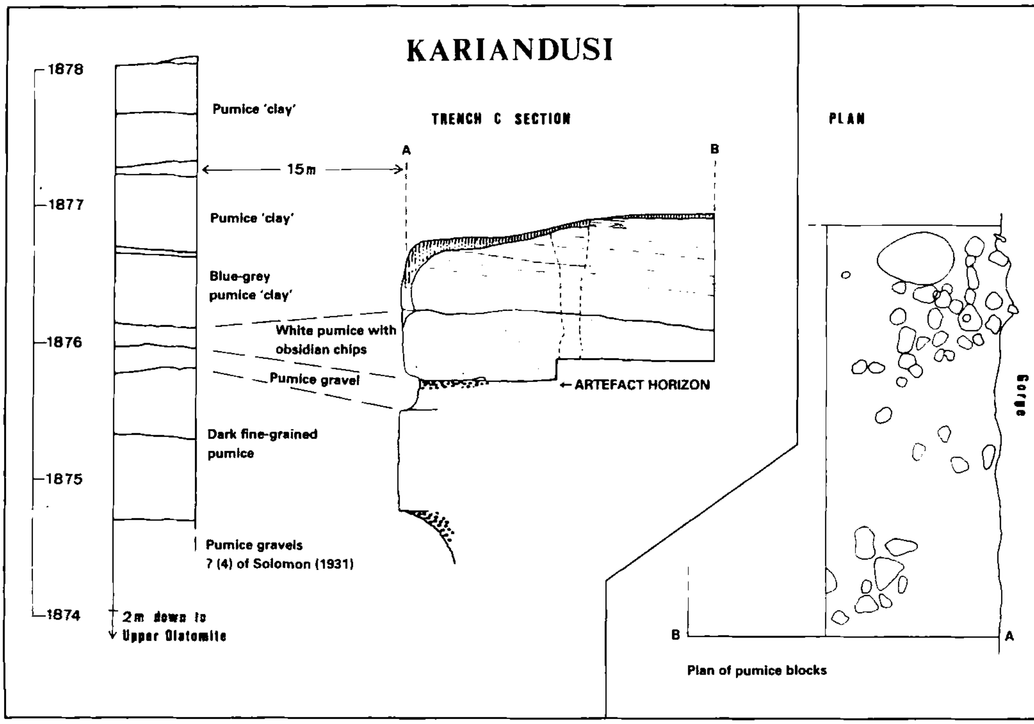

Figure 9 Section of Trench C and (left) sediments of the upper pumice beds in the gorge 15 m in the direction of the Upper Sites.

with near certainty that at least some of the Kariandusi artefacts belong in sediments aged over 0.73 myr.

Trench B is in the area where artefacts had been disturbed by the stripping of overburden and the digging of the drainage ditch. A step trench was made northwards from this area, to connect with the exposures in the quarry face (Fig. 10). Altogether an area of *ca* 50 m^2 was investigated, but the artefacts recovered were not in primary context, and this limited the scope of the work. A large number of artefacts had been disturbed by the digging of the ditch, so that hundreds of hand-axes and other artefacts were recovered from the upcast soil lying by the ditch. It was found that the artefacts had been lying close to the surface in a mass with a geometry of several metres long, by about 2 m wide and around 50 cm thick. The finds may derive from the side of a former channel, of which there is some evidence. The artefacts are mingled with detritus, perhaps from the higher levels of the channel bank which have now eroded away. Most of the artefacts seem to be on the flank of the former channel floor, and they may have been wedged up against a bar formed by more resistant sediment on one side of the minor fault which is shown in the section in Figure 10. Many of the artefacts have traces adhering to them of a matrix of cemented sandy material. The general situation shows that the artefacts were not in primary context. Their condition was not fresh, but slightly abraded, mainly on edges, for example between flake scars. It was noticeable that almost all of the hundreds of artefacts were in a similar state of abrasion.

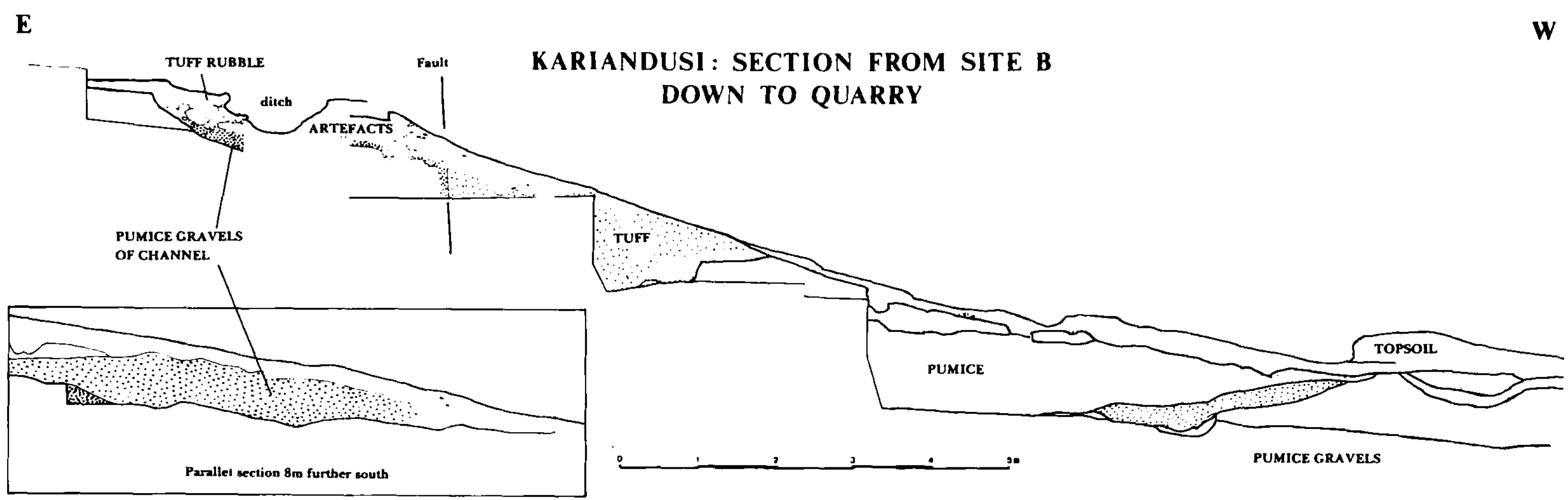

Figure 10 Section from Trench B down to quarry.

Interpretation of this locality can be made only with caution, as it is not a sealed deposit, is close to the surface, and has been considerably disturbed. A large number of flakes occurs with the bifaces amongst the artefacts, and many stone blocks are also present. It is likely, therefore, that the material derives originally from a workshop site near one of the trachyte outcrops, probably the one which occurs immediately to the north of the diatomite deposits less than 100 m away (Barnard 1950). On many Acheulean sites such large collections of artefacts are dispersed over a wide area, and it is possible that the artefacts have been concentrated in one place through the collapse of a channel bank. Mixed in with the artefacts is detritus of consolidated tuffaceous material. The derivation of this is uncertain, but it does not now seem hard enough that it would survive transport by water, and it may have tumbled down from a higher level of channel bank which has been planed off by subsequent erosion.

These circumstances do not provide precise knowledge about the original situation of the artefacts. Unlike those from the Upper Site or trenches A and C, they are not stratified in the upper pumice bed sequence. At one time they may have been incorporated in upper parts of these beds, which have now been eroded away. Barnard recorded that southerly-trending channels were cut through the soft diatomite-pumicite series, both to east and west of the main diatomite deposit, and that they were filled with silts and boulders of 'Gamblian' (Holocene) age. One of these channels is now plainly visible in the north face of the diatomite quarry near the present Kariandusi River. It is likely that the cutting and silting of these channels was connected with changes in the lake levels in the basin, and it seems probable that the Acheulean artefacts achieved their present position during one of the phases of this channelling, or perhaps in an earlier sequence of similar events. This is a tentative suggestion, but it does seem that the lava bifaces are likely to be stratigraphically younger than the obsidian bifaces of the upper site. This observation would be valid whether the lava bifaces derived from higher levels of the upper pumice beds, or were deposited initially in the channel. It also seems likely that the specimens have not travelled further than 100 m from the upfaulted block of Gilgil trachyte which is posited to be the raw material source.

The artefact assemblages

Artefacts from the Upper Site

Kariandusi was originally excavated in an era when finds were divided up and sent to museums around the world and, as the later excavations were designed partly for display, there exists no comprehensive collection or catalogue of finds. In an attempt to render study reasonably objective, attention on site was restricted entirely to the bifaces (Tab. 1), and only obsidian specimens were included. Obsidian bifaces have not been recorded elsewhere in the immediate area (apart from one on Site C), and about half of the pieces studied were still plainly in their original places, fitting snugly into depressions in the sandy matrix. Lava bifaces are in a minority on this floor, and their exclusion can be justified on various grounds: they form a different subset by raw material, and in any case some of them are heavily abraded, suggesting a different origin and taphonomic history.

The sample studied amounts to about 60 bifaces which were all recorded photographic-

Table 1 Biface measurements from Kariandusi. The second samples of obsidian and lava bifaces were measured by thickness, length and breadth only, and do not feature in the multivariate analyses.

Measurements and ratios for bifaces from Kariandusi	**Hand-axes, lava set**		**Cleavers, lava set**		**All bifaces, lava set**	
	Mean S.D.	**N**	**Mean S.D.**	**N**	**Mean S.D.**	**N**
L	160 ± 24	84	179 ± 20	16	163 ± 24	100
B	92 ± 11	94	103 ± 8	16	94 ± 11	110
T	49 ± 9	94	51 ± 7	13	49 ± 9	107
T/B	0.54 ± 0.11	94	0.50 ± 0.07	13	0.53 ± 0.11	107
B/L	0.58 ± 0.08	84	0.58 ± 0.06	16	0.58 ± 0.07	100
BA/BB	0.77 ± 0.16	84	1.13 ± 0.17	15	0.83 ± 0.20	99
TA/TB	0.73 ± 0.26	83			0.73 ± 0.25	84
TA/L	0.17 ± 0.05	83			0.17 ± 0.05	84
PMB/L	0.41 ± 0.09	84	0.53 ± 0.10	15	0.43 ± 0.10	99
	Obsidian bifaces Sample 1		**Obsidian bifaces Sample 2**		**Lava bifaces Sample 2**	
	Mean S.D.	**N**	**Mean S.D.**	**N**	**Mean S.D.**	**N**
L	123 ± 27	60	128 ± 24	28	165 ± 24	43
B	79 ± 13	60	76 ± 12	30	95 ± 11	43
T	37 ± 7	60	35 ± 6	28	47 ± 10	43
T/B	0.47 ± 0.06	60	0.46 ± 0.07	30	0.50 ± 0.11	43
B/L	0.64 ± 0.09	60	0.60 ± 0.06	30	0.58 ± 0.07	43
BA/BB	0.84 ± 0.22	58				
TA/TB						
TA/L						
PMB/L	0.41 ± 0.11	58				

ally, using a long focus lens and a graduated surround. It has been shown that this process entails no major loss of accuracy relative to measurement by calipers or the drawing of outlines, but it facilitated measurement in the field. As a set, the obsidian bifaces are quite distinct from other East African assemblages known to us. Closest similarities may be with other obsidian biface assemblages, for example from Ethiopia (Chavaillon 1976; Clark 1980), but for the moment they can be compared only with assemblages made in other raw materials.

Relative to most East African assemblages made from lava, the Kariandusi obsidian bifaces are shorter (Fig. 11) and this is well apparent when the lengths are plotted in relation to those of the Kariandusi lava set. Only about 25% of the obsidian bifaces attain the mean length of the Kariandusi or Kilombe lava bifaces (*ca*150–160 mm), and a proportion of them is smaller than any bifaces from Kilombe or the lava set. On the other hand, the mean values for length of both samples (123 and 128 mm) are considerably greater than those of Developed Oldowan B bifaces from Olduvai (e.g. SHK, 107 mm; BK, 76 mm: M. D. Leakey 1971). They are also longer than many of the bifaces from Chesowanja (Harris and Gowlett 1980).

For analysis the obsidian bifaces have been treated as a single group throughout as, unlike many lava collections, they cannot be divided clearly into a hand-axe group and a cleaver group. The obsidian does not seem well suited to the production (or perhaps

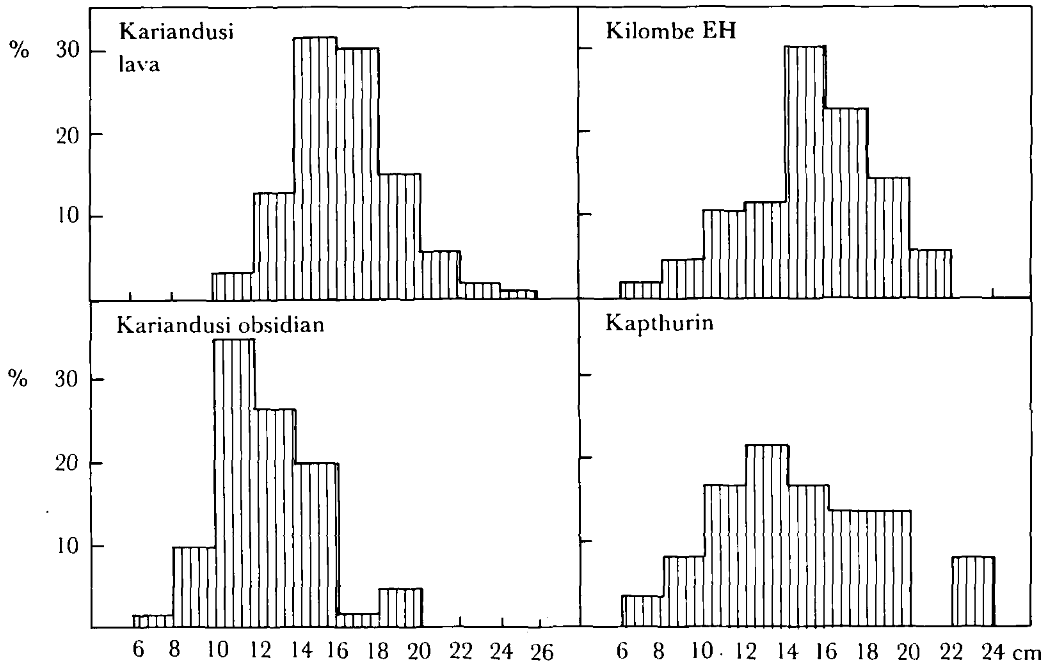

Figure 11 Frequency distribution of the different biface sets by length.

function) of classic cleavers. Chavaillon (1967) does however record the presence of obsidian cleavers at Garba in Ethiopia, many of them showing signs of 'edge damage'; at Melka-Kontoure, in contrast, obsidian appears to have been preferred for very small bifaces (Chavaillon 1976).

Some biface forms occur which are not common in other assemblages, and in some cases the criteria for distinguishing butt and point are difficult to apply. Some bifaces are thicker at the end which is pointed in plan, and so have a rounded 'butt', which in section is sharp like a cleaver edge. In these cases the long section rather than the plan-view has been taken as a guide. The material includes a number of specimens which are mainly unifacially worked, with little secondary working on the ventral face (cf. Figs 12, 13, 14). There may well be a gradation from bifaces into other forms such as scrapers, although the size of sample makes it impossible to test this. Isaac (1977) made graphic representations of the possible forms of such gradations for material from Olorgesailie. It seems that the biface-scraper gradation in this Kariandusi assemblage may be a more marked feature than at Kilombe, for example, where there is little apparent overlap between bifaces and scraper forms.

In other respects, as defined by measurements and ratios, the obsidian bifaces do not stand out notably from other East African assemblages. The thickness/breadth (T/B) ratio is comparable with those from Kilombe, while the breadth/length (B/L) ratio suggests only slightly broader forms.

Other artefacts *in situ* on the Upper Site were not studied. M. R. Kleindienst examined some material in the National Museums collections, as mentioned above, and formulated histograms of the frequencies in the main tool categories. A sample in the museum collec-

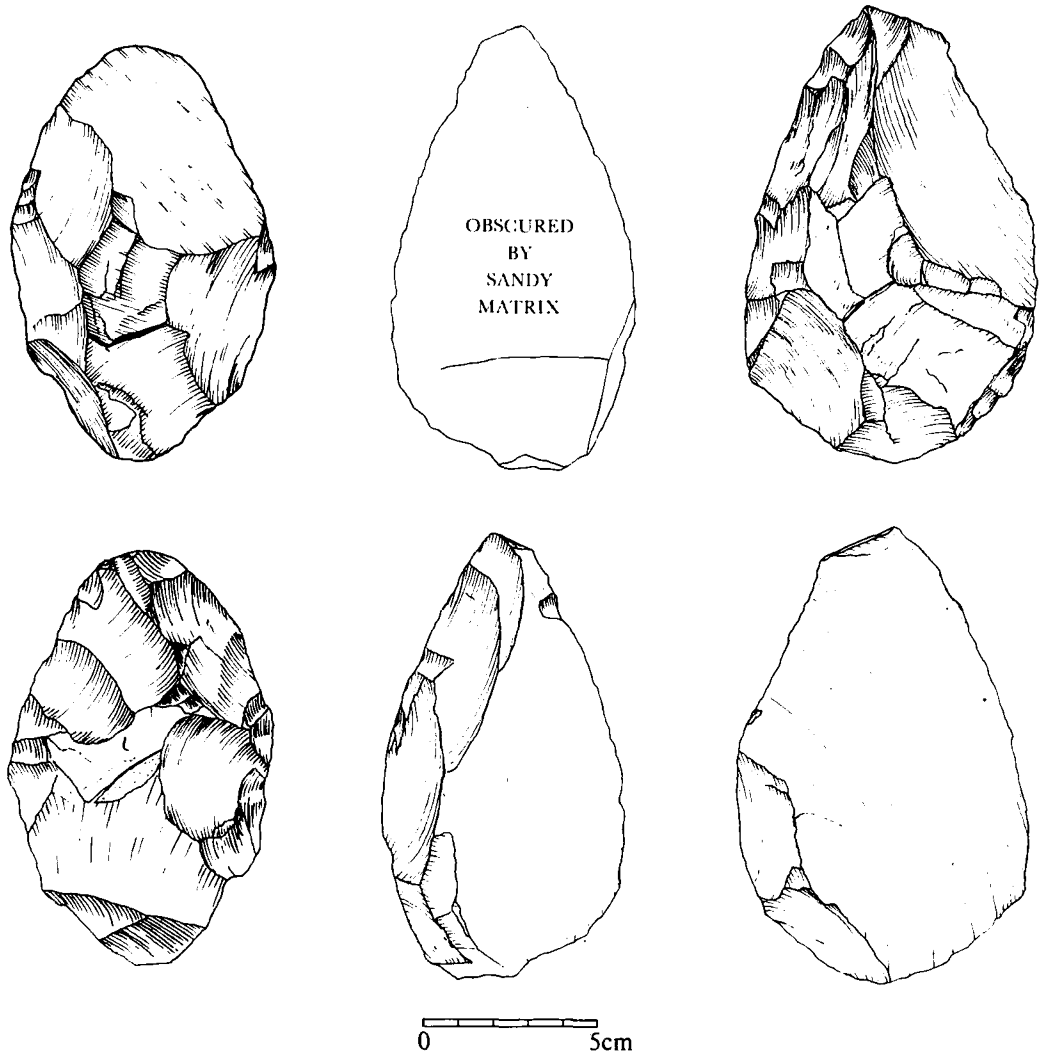

Figure 12 Obsidian bifaces from the Kariandusi Upper Site.

tions was also analysed by J. A. J. G. with very similar results (Fig. 15). This suggests that the basic Kleindienst typology can be applied fairly impartially by different workers, and it highlights the very low proportion of heavy-duty material at Kariandusi. Virtually only core-scrapers are represented in this category.

Artefacts from the Lower Site

The lava bifaces from Kariandusi are as a series longer and heavier than the obsidian bifaces (Figs 16 and 17 illustrate specimens of typical size). With mean lengths of 163 mm in the first sample and 165 mm in the second, the lava bifaces are slightly longer on average than those from Kilombe. They correspond closely in length with H/9A and Meng in the Olorgesailie bifaces, Peninj and Olduvai TK (Isaac 1977:136). Measurements and

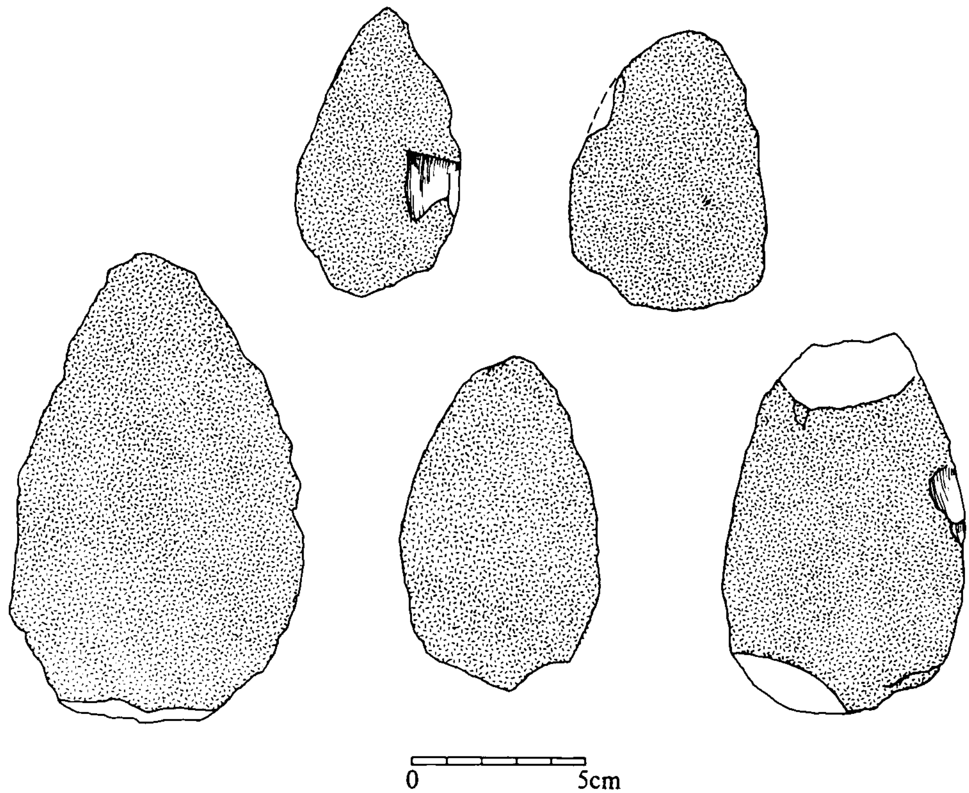

Figure 13 Obsidian bifaces in ventral view, showing the near absence of secondary working (all flake facets are marked; main flake surfaces are shaded).

ratios defining planform show very close similarities with Kilombe, and hence also with the series of all Olorgesailie bifaces (Isaac 1968, 1977). It is not possible to calculate accurately the proportion of cleavers in the lava set because of the conditions of recovery, but it seems to average around 16% of all bifaces, making a very close comparison with Kilombe. As at Kilombe, cleavers tend to be slightly longer than hand-axes, by 19 mm on average. Cleavers, and some of the more ovate hand-axes, very frequently show signs of 'edge damage'.

In contrast with the similarity in plan, the Kariandusi lava specimens are relatively thicker than the Kilombe bifaces. Mean values for thickness/breadth (T/B) in the separate samples and categories range from 0.50 to 0.54. Only the sample from Area Z at Kilombe shows a comparable figure. The T/B figures from Kariandusi can be compared with those from Lower Pleistocene assemblages from Peninj (Isaac 1967, 1984) and Olduvai EF-HR (M. D. Leakey 1971), where the mean values range from 0.55 to 0.60.

In general characteristics, then, the Kariandusi lava bifaces compare much more closely with Kilombe bifaces than with the obsidian bifaces from Kariandusi itself. In handling the collection, a more robust nature and lower standardization are apparent in relation to the Kilombe material. A few specimens are more finely finished, including one probably

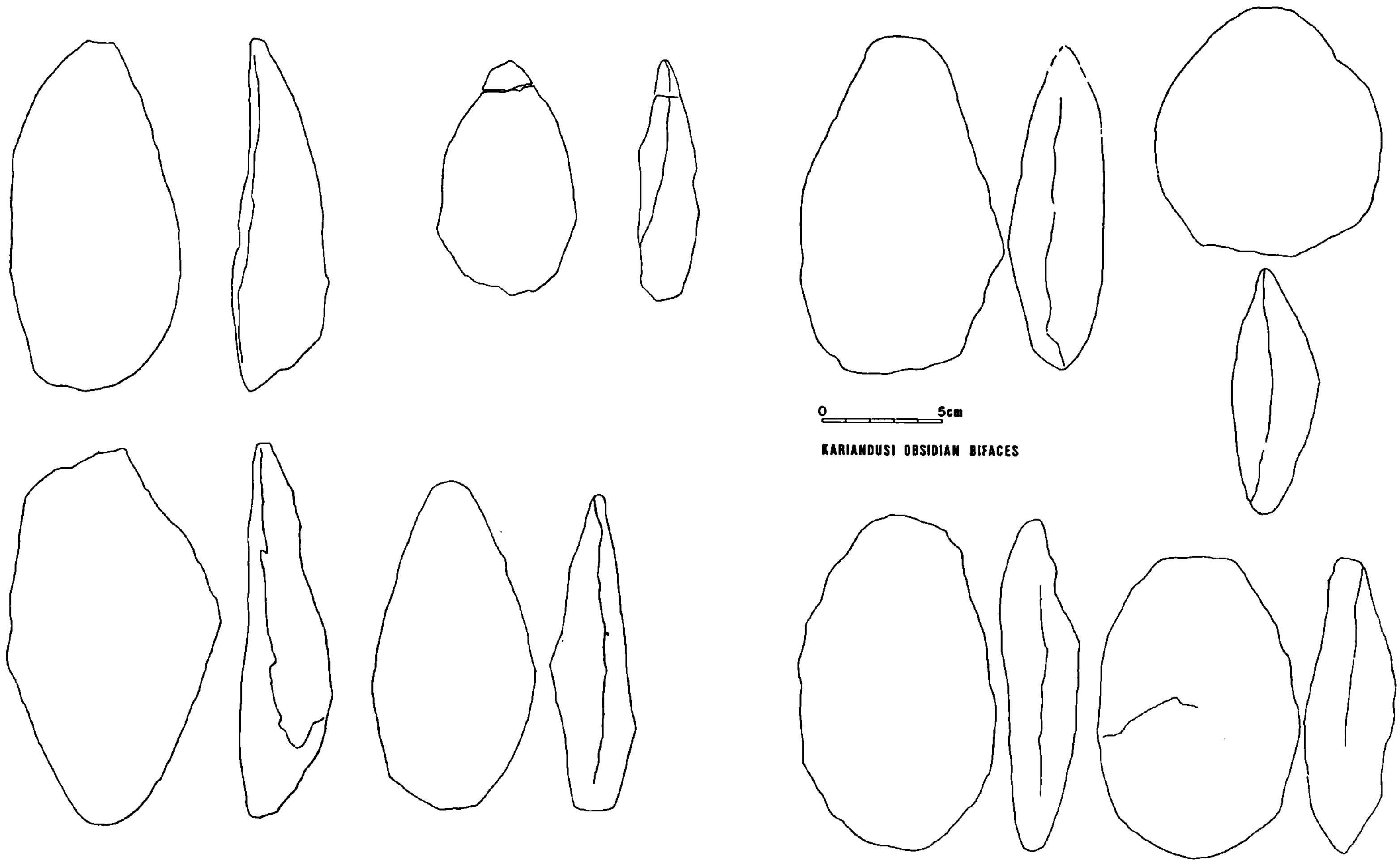

Figure 14 Outlines and long sections of obsidian bifaces.

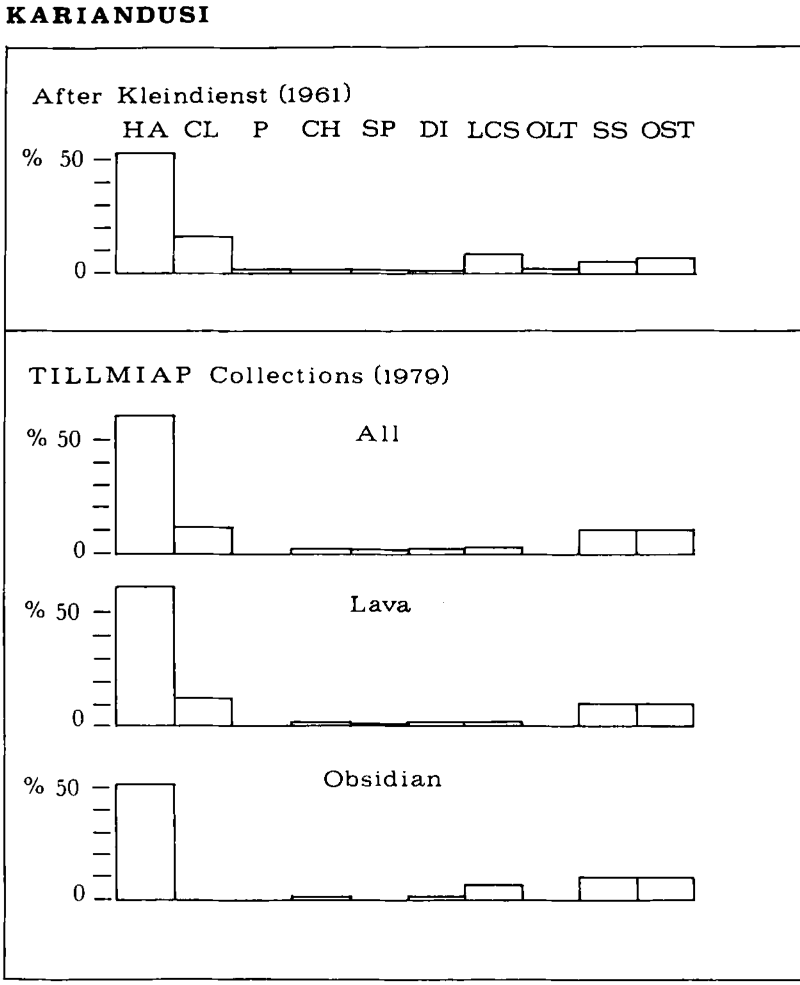

Figure 15 Histograms of assemblage composition (from Gowlett 1979).

HA = Hand-axes
CL = Cleavers
P = Picks
CH = Choppers
SP = Polyhedrons/Spheroids
DI = Discoids
LCS = Large and core scrapers
OLT = Other large tools
SS = Small scrapers
OST = Other small tools

A re-examination of material in the National Museums provided a very close typological match with Kleindienst's earlier study. The hand-axe and knife categories of Kleindienst have been combined, and small scrapers and other small tools were arbitrarily equalized. Note the near-absence of heavy-duty material.

made of rhyolite (Fig. 16) which could possibly come from the Eburru region at least 15 km to the south.

A series of lava flakes was measured from the Lower Site, and was of interest since the larger flakes overlapped in size with the associated bifaces (Fig. 18). A few flakes were as long as 14 cm, and about 30% of the 272 flakes were over 8 cm long. If the length frequencies of flakes and bifaces are considered together, a bimodality is evident based on percent-

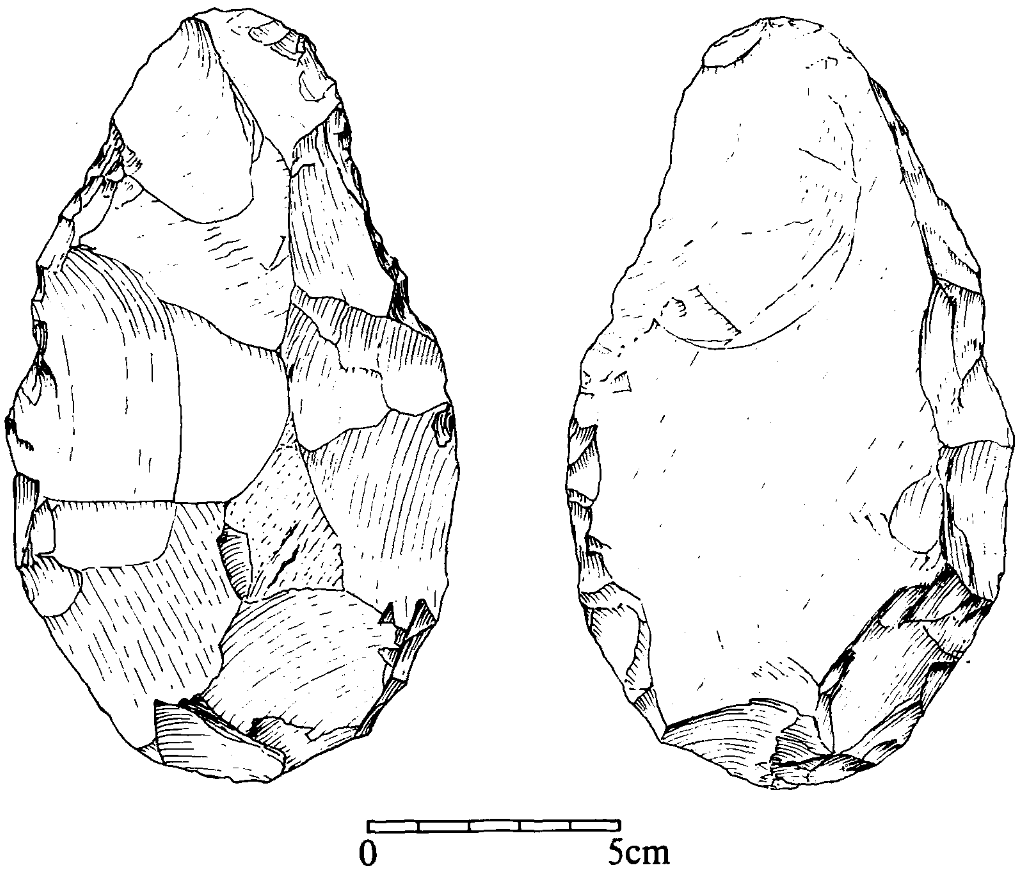

Figure 16 Hand-axe from the Lower Site, made of a fine-grained red lava, probably rhyolite.

age figures (Fig. 18). The actual numerical proportions of flakes and bifaces cannot be established from a disturbed series such as this, but it is plain that the assemblage has one of the highest mean values for flake length of any Acheulean site. It is unfortunately difficult to make exact comparisons, since some workers have excluded flakes longer than 10 cm from collections measured (e.g. Isaac 1977). The Cave of Hearths, layer 5 and Canteen Kopje have greater mean lengths (Mason 1962), but similar series of long flakes are noticeably absent at Olorgesailie and Kilombe, although these sites are generally less disturbed and in finer-grained deposits. The high proportion of large flakes in the Kariandusi lava set may suggest that the site is close to the factory area where the biface blanks were actually made.

As in the Upper Site, there is a very low frequency of heavy-duty tools. One core-scraper is remarkably similar to Karari scrapers (Fig. 19; J. W. K. Harris pers. comm.; Isaac and Harris 1978).

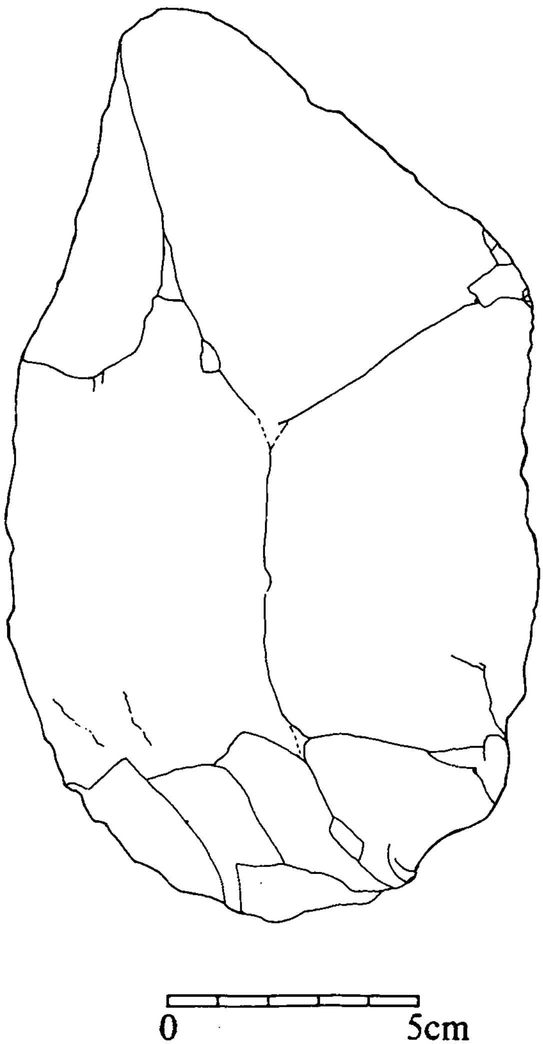

Figure 17 Angled cleaver of lava from the Lower Site. Such specimens are fairly symmetrical in the butt area, but have a canted cleaver edge.

Shape variation and allometry

Several questions arose from our recent work on size-related variation or allometry at Kilombe (Crompton and Gowlett 1993). First, is size-related variation an important aspect of variation on all Acheulean sites? Then, if so, does it operate in consistent patterns which can be recognized? Is it influenced by such matters as raw material variation?

There are several attractions in making Kariandusi the focus of a broader study. The sites are approximately contemporary. The lava bifaces appear to be similar to those from Kilombe, though less standardized. The obsidian bifaces are clearly different both in size and finish. Then addition of the Kapthurin bifaces brings in a much greater time-range of material, and also a new technical consideration: most of the bifaces are made by

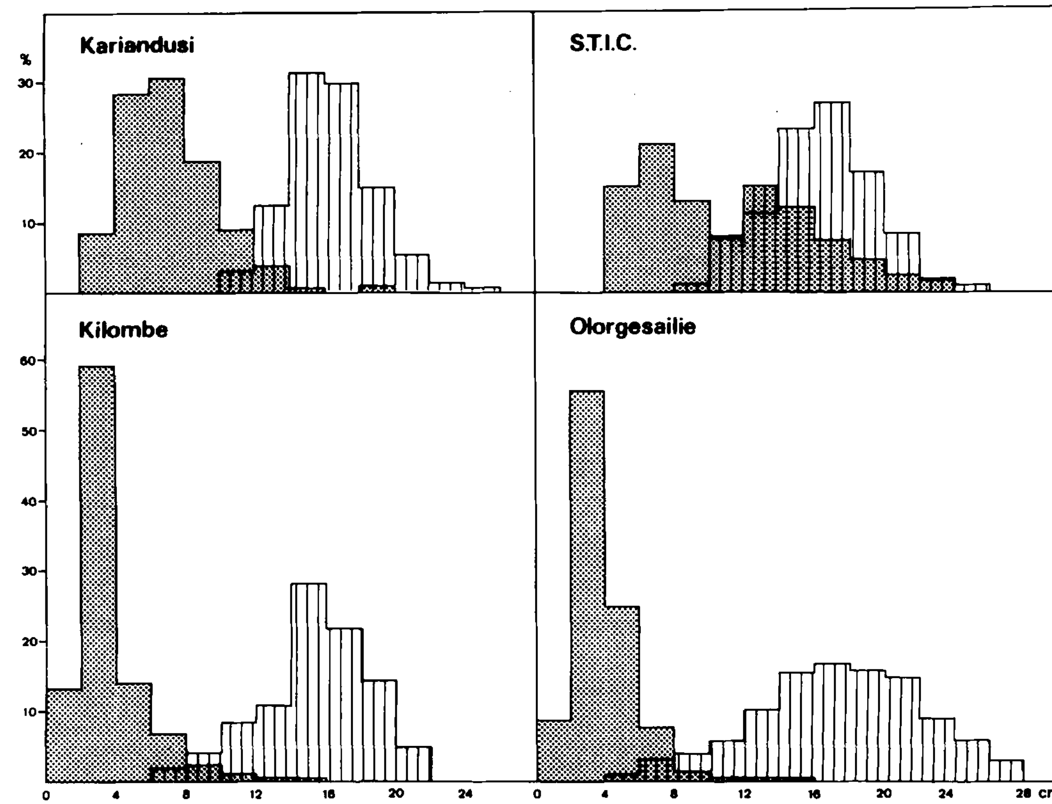

Figure 18 Frequency distributions of flakes and bifaces by length, from Kariandusi Lower Site, the STIC Site at Casablanca (Gowlett 1993) Kilombe and Olorgesailie (data from Isaac 1977). Kariandusi shows a far higher propoftion of flakes over 10 cm long than the other East African sites.

Levallois technique. The bifaces were sometimes produced in a single blow after preparation on the core, and they may show little or no secondary trimming.

In the earlier study of the Acheulean at Kilombe (Crompton and Gowlett 1993), we used the new technique of multivariate allometry to analyse variation, and in particular size-related variation, in the three-dimensional form of bifaces, also utilizing principal components analysis and discriminant analysis to investigate the structure of variation. We were able to demonstrate that size-related variation exists at all localities, but the pattern of allometry is not constant across the whole site complex (Fig. 20). Coherent constellations of variables appear in principal component analyses, which we have interpreted as 'rule sets', and at each locality several 'rule-sets' were being applied.

Despite the homogenous appearance of the Kilombe assemblage, the rule-sets were slightly different from locality to locality, so that we were able to identify individual localities by discriminant analysis. The scale and pattern of variation is more consistent with the concept of functional variability than with style, although we have not ruled out a stylistic element. Bifaces from one locality in particular, Z, stood out in all analyses, and allometric relationships here were in some cases opposite to those in other localities.

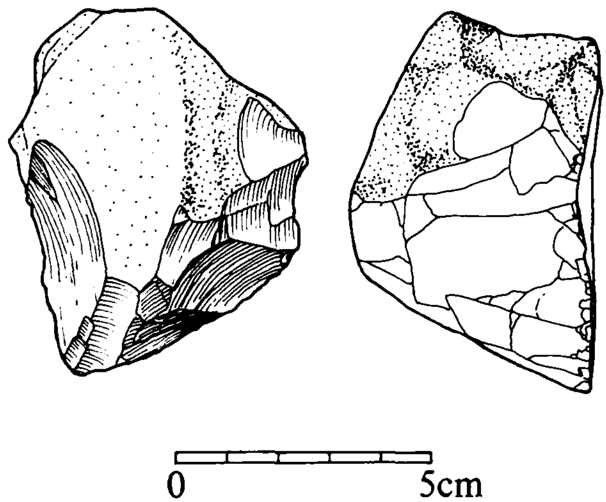

Figure 19 Heavy-duty or core/scraper from Kariandusi. This resembles 'Karari scrapers' and isolated examples from Kilombe.

At other locations, bifaces tended to become thinner as they got larger. However, Z bifaces became thicker, and more massive as they got larger, except that the increased thickness elsewhere seems to have been compensated for by very marked thinning of their tips.

The details of our analytical procedures are given in Crompton and Gowlett (1993), but will be summarized briefly as they apply to the present study. A maximum 11 variables define length, breadth and thickness of the biface at various points, and asymmetry. Prior to analysis of multivariate allometry, these data were first examined using discriminant analysis (SPSS DISCRIMINANT) to establish the value of our variables in distinguishing subsets of the bifaces studied, and by PCA, Principal Components Analysis (SPSS FACTOR), to define the major constellations of variables contributing to three-dimensional shape-variability. Coefficients of multivariate allometry were then derived from a second, independent PCA of the covariance matrix of log-transformed variables. These coefficients express the rate at which each variable grows in respect to the first principal component, which is generally accepted to represent size.

While the bifaces have been measured by 11 variables at Kariandusi (Fig. 21), one of these (TM) was not taken for the Baringo specimens. Apart from analysing the 11 variables at Kariandusi, we have also, therefore, rerun the analyses on the basis of 10 common variables, nos. 1–8, 10 and 11. This also enhances comparability with the Kilombe results. Our Kilombe studies (Crompton and Gowlett, 1993) make it clear that variable 9, TM, is largely redundant if T is available.

Similarity of groups: discriminant analysis

Initially, a discriminant analysis confirmed the finding of Wynn and Tierson (1990) that the multidimensional form of the Kariandusi obsidian bifaces can be distinguished from those made of lava. (We have used discriminant analysis in an empirical heuristic manner

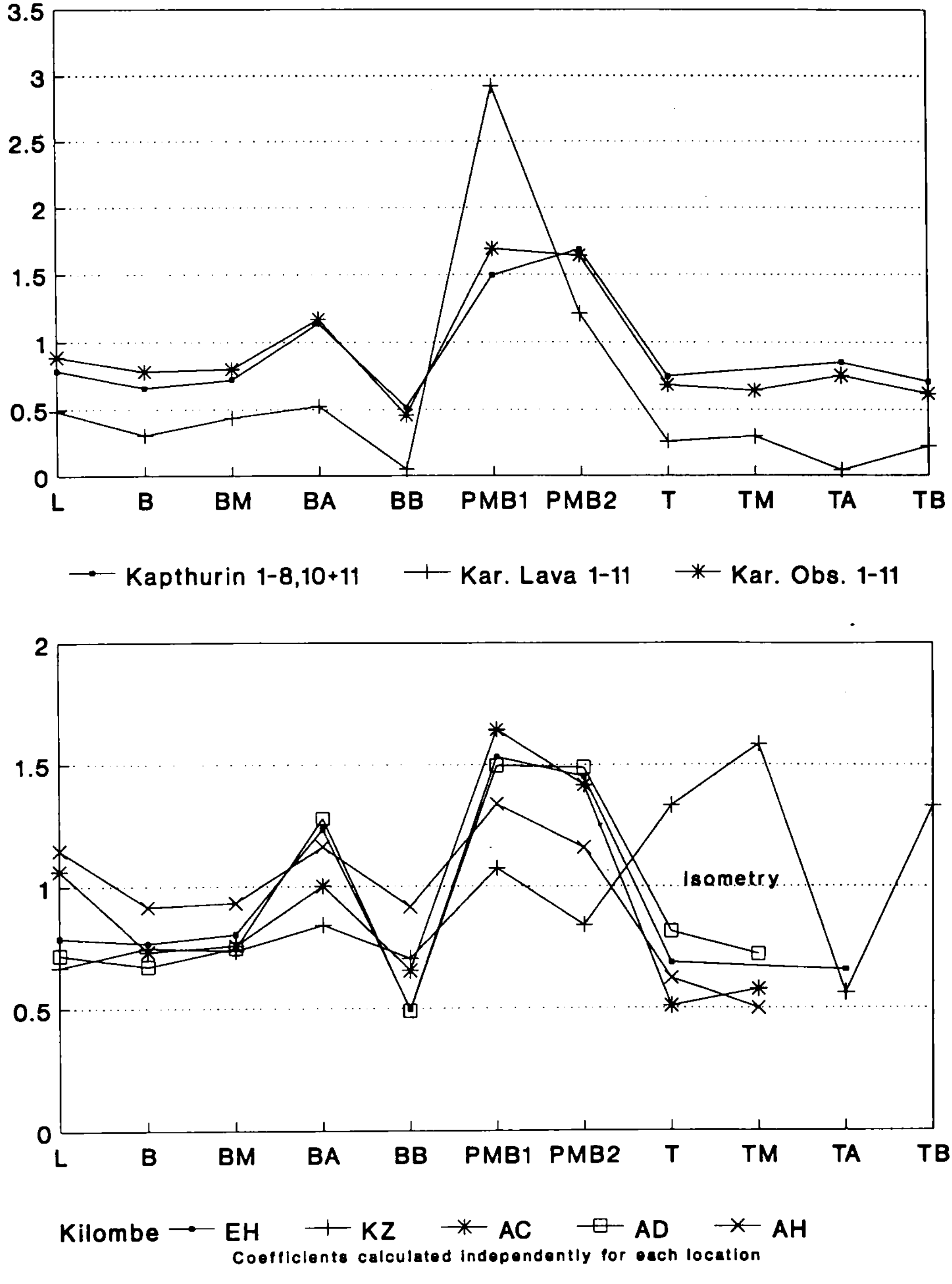

Figure 20 Comparison of coefficients of multivariate allometry. Kilombe (below) with those for variables 1–11 at Above: Kariandusi, measured using variables 1–11, and Kapthurin measured using variables 1–8, 10 and 11. Below, Kilombe localities using variables 1–9, and 10–11 where available.

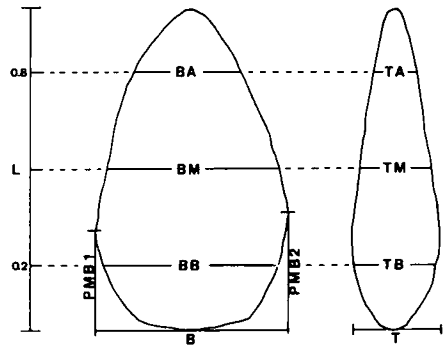

Figure 21 The variables used for biface measurement in this study.

to make comparisons.) Wynn and Tierson used a polar coordinate measuring technique to derive 22 variables measuring planform (two-dimensional) shape. They suggest that it is quicker and better at measuring asymmetry than measurement sets such as we have used, based ultimately on the system of Roe (1964, 1968) and Isaac (1968, 1977). They point out that their technique need not make assumptions about the design axes of the biface. Although acknowledging that their method does not include thickness measures, they indicate that on balance its advantages outweigh the disadvantages. In later papers we shall present simple alternative techniques which we have developed for studying the axes of bifaces.

For the present it is useful to compare the results of analyses of the same material, using the same discriminant analysis programme (SPSS DISCRIMINANT), but utilizing two-dimensional planform data on the one hand and three-dimensional data on the other. Wynn and Tierson's discriminant analysis of their Kariandusi dataset achieved 75% correct identification to material group, representing a 25% increase over the 50% prior probability of group membership. In discriminant analysis of all 11 of our variables, we achieved 92% correct classification to material group, an increase of 42% over prior probability. The sample sets are not identical (Kariandusi material is widely dispersed in the museums on site, in Nairobi, Oxford, Cambridge and perhaps elsewhere), but we feel that this result amply justifies three-dimensional measurement, whether based on the Roe/Isaac system, or a three-dimensional extension of Wynn and Tierson's technique.

The obsidian bifaces of Kariandusi are thus relatively easily distinguished from those made of lava. On the other hand, in a discriminant analysis of the Kariandusi lava bifaces together with the Kilombe bifaces, using all 11 variables, the percentage correctly identified to site falls to 64% (prior probability being, of course, 50%); only a slightly better performance (68%) being achieved if the thickness variables TM, TA and TB are dropped.

In a third discriminant analysis, we compared the Kapthurin bifaces with both the obsidian and lava bifaces from Kariandusi, using variables 1–8, 10 and 11 as TM was not available for Kapthurin. Here, the prior probability of group membership was 33% , but 77% of bifaces were correctly identified to groups (Kariandusi lava, Kariandusi obsidian, and Kapthurin bifaces). 83% of Kariandusi obsidian bifaces and 84% of Kariandusi lava bifaces were correctly identified to group, but only 54% of Kapthurin specimens. 33% of the Kapthurin bifaces were incorrectly classed as Kariandusi obsidian bifaces, versus 12%

as Kariandusi lava specimens. It is interesting, on the other hand that that Kariandusi obsidian specimens incorrectly identified were twice as often identified as Kariandusi lava specimens. Discriminant analysis tends to support the suggestion that Kariandusi lava bifaces resemble bifaces from Kilombe more closely than they do obsidian bifaces from the same site, whilst the latter show some similarities to the much later specimens of the Kapthurin sample, made on lavas but using the Levallois technique.

Principal Components Analysis

We have used Principal Components (PCs) to analyse the structure of variation within each biface assemblage. For Kariandusi, three principal components were necessary to explain a satisfactory proportion of the variance among the lava bifaces, but for the obsidian bifaces and the lava bifaces from Kapthurin two PCs sufficed to achieve this. Again this indicates a broad similarity in the pattern of variation between the lava bifaces from Kariandusi and those from Kilombe (where three components were required), and links the Kapthurin and Kariandusi obsidian series.

Principal Components Analyses of the Kariandusi, Kapthurin and Kilombe bifaces (Fig. 22) all show broadly similar loadings on the first PC (PC1): B, BM and BA showing high loadings, with L slightly less, but butt breadth BB relatively lower in every case. Thickness variables have a universally low loading on PC1: this distinction is particularly marked for the Kariandusi lava specimens. Note however that Z is again rather distinctive in a relatively depressed loading for TA. Plots for the second principal component (Fig. 23) at Kilombe were in essence a mirror image of the allometry plots (Fig. 20), and this appears to be true to a lesser extent for the Kariandusi and Kapthurin series: thickness loadings are high, with TA relatively depressed in all cases; PMB loadings are relatively low, but intermediate between thickness and breadth variables, which have low loadings here. BB is again distinctive, and independent of the other breadth variables, showing no consistent pattern between the three samples, whereas at Kilombe all locations show a peak for this variable. However, it is the Kariandusi obsidian bifaces, rather than the lava specimens, which show a particular similarity to the Kilombe series in their loadings on PC2, in the very high loadings for BB and very low loadings for the 'asymmetry' variables PMB1 and PMB2.

In the principal component analyses, then, the broad pattern of variation is similar at the three sites: Kilombe, Kariandusi, and Kapthurin. We feel we are justified in arguing that similar constellations of variables exist in biface form at all these Acheulian sites, representing rules on the one hand for the planform (breadth and length) and on the other for thickness, with superimposed rules concerning butt breadth and tip thickness, which behave rather independently of other breadth and thickness variables. However, variables constellations, which we interpret as rule-sets, were slightly different in each case.

Multivariate allometry

Finally, after this exploration of the data, we submitted the material to an analysis of multivariate allometry. The programme used is based on a multivariate generalization of the allometry equation (Jolicoeur 1963) and has been developed recently to output chi-

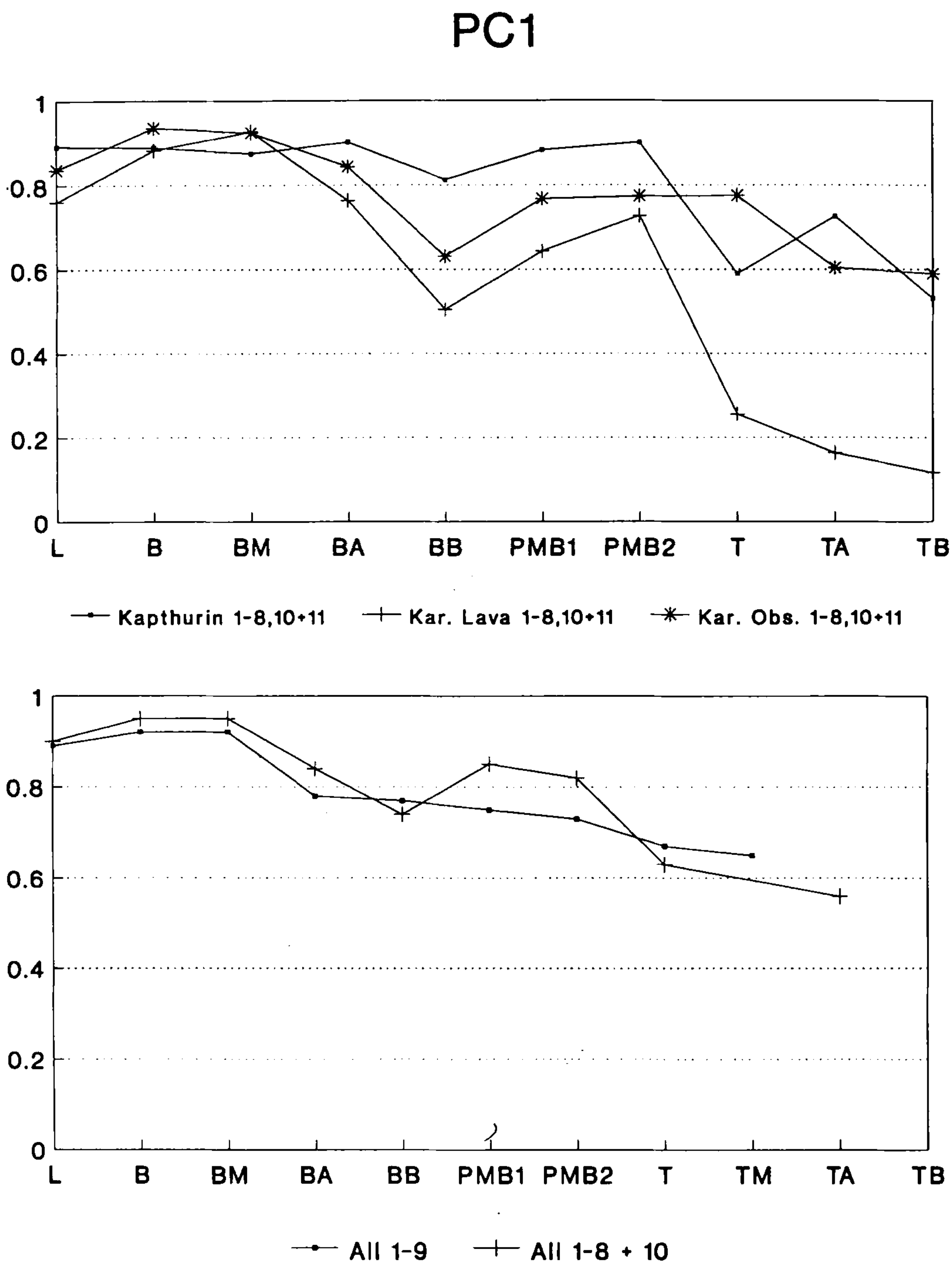

Figure 22 Comparison of loadings on Principal Component 1 for Kariandusi and Kapthurin (top) with those for Kilombe. General form is very similar throughout, except that thickness variables are markedly less accounted for by this component in the Kariandusi lava set.

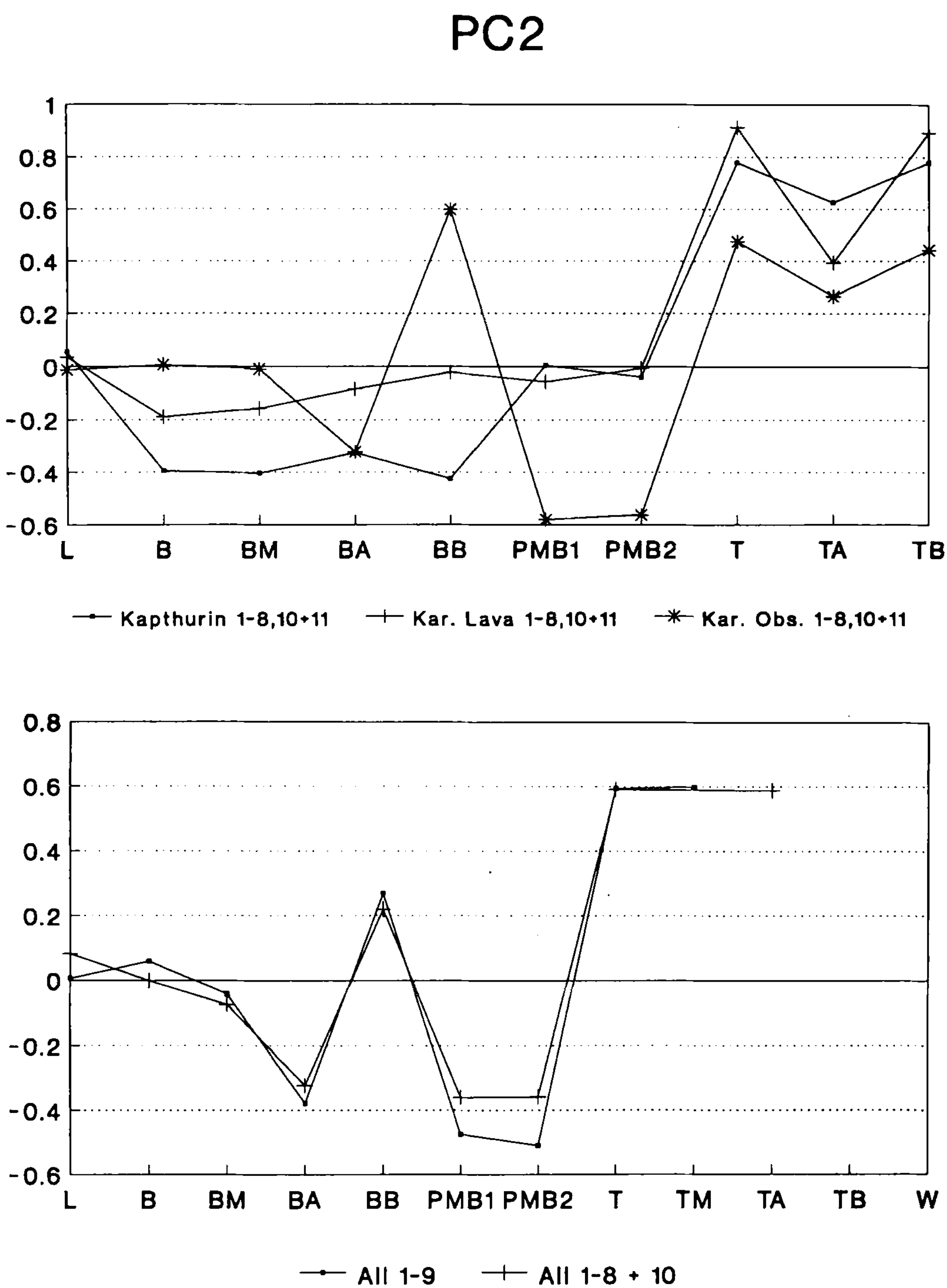

Figure 23 Comparison of loadings on Principal Component 2 for Kariandusi and Kapthurin (top) with those for Kilombe. Thickness variables have a high loading in all series. The Kariandusi obsidian series has a similar pattern to the Kilombe localities.

square tests of the set of allometry coefficients, indicating whether significant departures from geometric similarity exist, and individually, for each coefficient, indicating whether it differs from isometry (a coefficient of 1).

The Kapthurin, the Kilombe and the Kariandusi lava biface series all show significant departures from isometry ($P<0.01$), but the obsidian bifaces do not. This is because relatively little of the variation (60% approximately, versus 72% for Kapthurin) lies in PC1, while the dataset is smaller (53 cases) than is the lava sample (73 cases). Although only 48% variation was contained in PC1 in the Kariandusi lava handaxes, the larger dataset gives significant chi-square tests. We could therefore say that size-related variation, which largely resides in PC1, is not always a statistically significant element in biface variation in the East African Acheulian, but that this will depend on sample size (and probably also actual size of specimens), and that pattern is also an important element in assessing significance.

Perhaps the most important result in this paper is the demonstration that the multivariate allometry plots (Fig. 20) for Kariandusi, Kapthurin and Kilombe show a striking overall similarity. Breadth shows negative allometry, with the exception of BA, tip breadth; BB, butt breadth, is always particularly negatively allometric; length is usually negatively allometric with respect to overall size, or at most slightly positively allometric (AH, AC at Kilombe). The 'asymmetry' variables PMB1 and PMB2 are positively allometric everywhere, except that the Z sample shows negative allometry of PMB2. Thus, similar rules for size-related adjustments do seem to apply across the East African Acheulian sites so far examined: the butt is kept relatively narrow, presumably related to the way the bifaces are held, bifaces are narrower as they become larger, and length does not generally track overall size. The tip, however becomes broader as the size increases, which we have identified in our work on Kilombe as the 'cleaver factor' (although it is not restricted to typological cleavers). While thickness variables are negatively allometric at most of the Kilombe sites, neither the obsidian specimens from Kariandusi nor the Kapthurin series show significant negative allometry in this respect (possibly because they do not contain so many absolutely large specimens, in which weight-saving may have been an important consideration).

The Kapthurin (lava) and Kariandusi obsidian specimens have almost identical allometry plots, remarkable in series differing so much in age and material. Compared with these, at first sight, the lava specimens from Kariandusi appear to be as distinctive in their patterns of allometry as are the Z bifaces at Kilombe. However, since the allometry coefficients, subject to rounding error, sum to 1, massive allometric variation in one variable, in say, a positive direction, has an effect of depressing values for other variables (in this case, making the coefficients more negative). Hence in comparing patterns for each site we need to look at the relative contributions of variables more than the absolute position of the curve. It then becomes plain that the Kariandusi lava set differs substantially from the obsidian and Kapthurin series in the allometry of just two variables: PMB1 (point of maximum breadth) and TA (thickness near the tip): PMB1 in intensity but TA in direction.

PMB1 shows that the lava bifaces at Kariandusi stand out in having pronounced asymmetry of plan especially for the large specimens (Fig. 20: compare PMB1 and PMB2). The Kariandusi biface makers using lava seem to have desired increased asymmetry, for some functional or stylistic reason – an effect present at Kilombe but far less marked (site AC, rather than Z, shows the strongest asymmetry). The Kariandusi lava bifaces are very robust, showing butt thicknesses that compare more closely with Lower Pleistocene assemblages such as Peninj and EF-HR than they do with the Kilombe material. This allows us to suggest that the unique positive allometry of thickness in the Kilombe Z bifaces is a result of deliberation rather than accident. The greater thickness of the lava specimens at Kariandusi seems to have been compensated for by introducing negative thickness allometry at the tip, however, just as it was at Kilombe Z. Both Z and the lava specimens show that TB (thickness near the butt) is relatively more positively allometric than is TA (thickness near the tip).

In contrast, the obsidian and Kapthurin specimens show more negative allometry for TB than TA: but neither coefficient is significantly allometric in both cases. These two assemblages have in common the production of complete bifaces from a flake blank, sometimes with very little secondary working. The development of a full Levallois technique of blank production seems to have enabled the later biface makers at Kapthurin to equal in lava the performance of the earlier Kariandusi biface makers who used obsidian.

Our preliminary conclusions are that similar 'rule-sets' about three-dimensional biface form appear to have operated at each of the three locations, and for bifaces in different materials: the two major sets being concerned with planform shape and with thickness. On top of these were imposed rules related to the breadth of the butt, which was universally reduced as the biface mass increased, (whilst its thickness was maintained isometric with other breadth variables or underwent positive allometry) and related to tip thickness. At Kapthurin, Kilombe, and for the Kariandusi lava bifaces, significant departures from geometric similarity of shape were noted with increasing size, and the broad patterns of these allometric changes are very similar at all locations.

Allometric factors may be partly responsible for the ease with which the Kariandusi lava and obsidian sets could be separated by discriminant analysis (Wynn and Tierson 1990; this paper). Variations in Length/Breadth ratio are likely to be allometric, but the greater relative thickness of the lava set is apparently not.

The most surprising finding is that the early small obsidian bifaces from Kariandusi are closely similar in allometric pattern to the much later and larger lava bifaces from Kapthurin LHR. They are less like the large lava bifaces from the adjacent Kariandusi Lower Site. On the other hand, these latter show gross similarities to the Kilombe series, and in particular show similar adjustments to increased mass to those occurring at the Kilombe Z site. The distinctiveness of the Kilombe Z bifaces, however, extends beyond these characteristics, and the two sets are not closely similar.

General conclusions

Kariandusi has an obvious importance as one of the first known early Acheulean sites in East Africa, although the quality of its contexts has tended to limit its interpretative value. Further work in the area might well locate additional exposures which could be investigated. In our work Kariandusi has served a very useful purpose by helping to establish a comparative frame for examining the question of allometry in the Acheulean.

We may now summarize our conclusions on this point:

(1) all the biface sets in our study show allometric departures, which are remarkably similar in their general patterns.

(2) known time-space relations between assemblages are not always reflected in these allometric patterns, i.e. there may be more variation within a site complex than between far distant sites.

(3) the allometric pattern of the Kariandusi lava set is distinctive in some respects, but the unusual pattern of the Kilombe Z bifaces does not recur anywhere at Kariandusi or Kapthurin.

On the basis of these results we can conclude that allometry is likely to be a general factor in Acheulean variation: the size of a biface at least partly determines the shape in which was made. As in a previous paper (Crompton and Gowlett 1993), we believe that functional needs, especially of weight-saving in large specimens, are responsible for the allometry, although we do not rule out a stylistic element. The Acheulean represents a domain of more than one million years extending over most of three continents. A phenomenon on this scale cannot be proven to be a cultural entity in any general sense: it is merely linked by bifaces, which represent a set of ideas in stone-working, and perhaps a common functional response. Regionally, however, the Acheulean may be linked by sets of components, for example the heavy-duty material and scrapers traced in Kleindienst's comparisons of the East African Acheulean (Kleindienst 1961). Wynn and Tierson (1990) have also illustrated regional differences in the Acheulean, but otherwise there remains the well known repetitiveness which has been pointed out by so many authors. Allometry demonstrates, paradoxically, a greater set of links at least between the East African Acheulean sites, but also confirms a pattern of variation where close sites can be more different than sites far separated temporally or geographically. If anything this enhances the impression of 'variable sameness' in the Acheulean.

The data allow us to make a hypothesis of sampling: apart from the common biface facies, it may be that there are other uncommon facies of assemblage, which occurred at low frequency and so are rarely represented archaeologically, but which nevertheless endured over long periods. Thus heavy-duty artefacts are rare, but appear to involve recurring forms, such as the scraper illustrated (Fig. 19). Hefty 'core-axes' are well demonstrated as a feature of the later Sangoan, within the last 100,000 years (Clark 1971; McBrearty 1988, 1991), but it is just possible that such a feature occurs occasionally at far earlier dates, a 'ghost facies' of which the distinctive Kilombe Area Z is a candidate member. A step in future work is thus to see how far the Sangoan conforms with an Acheulean pattern of allometry.

Finally we consider the makers of the Acheulean at Kariandusi and elsewhere. *Homo erectus* is the candidate for Kariandusi and Kilombe, for want of alternatives, whereas Kapthurin certainly falls within the time-range of *H. sapiens*. It can be debated whether the two species are linked as chronospecies on an evolutionary cline (anagenesis), or whether there is some rapid evolutionary event leading from one to the other (punctuated equilibrium). On the basis of a mosaic of features in specimens close to the transition, the latter presents some difficulties (Bilsborough 1992), although alternative interpretations are possible (Bilsborough and Wood 1986). Here we have taken archaeological material clearly in the time-range of *Homo erectus*, and shown its great similarity in structure to other Acheulean material from the time-range of *Homo sapiens*. The sites give no direct link with hominids, but there are no alternative candidates. As there is so little evidence of behavioural differences, it suggests either that importance of change in the cranium and brain can easily be overrated for this period, or that we may be saddled with an apparent transition at 0.5–0.4 myr ago largely as a result of classificatory accidents in the history of the subject. Continuity in the archaeology can be argued strongly from the evidence which we have presented.

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