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Obsidian sources and patterns of source utilization in Kenya and northern Tanzania: some initial findings

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Abstract

A pilot study of Kenyan and northern Tanzanian obsidian sources and artifacts has been undertaken to characterize sources and artifacts in order to examine prehistoric patterns of source utilization and to investigate the long distance movement of obsidian in the region. A survey for source localities has revealed 54 localities to date. XRF analyses for 12 elements have been undertaken on samples from each locality and a number of chemically distinct source areas have been recognized. Some 1400 artifacts from 32 sites were chemically characterized and assigned to sources based on the analysis of three elements by an electron microprobe. The study documents long distant movement of central Rift obsidians from MSA times onward, and demonstrates that with the advent of the Pastoral Neolithic there is wider use of obsidian and more specialized reliance on individual sources.

Résumé

Une étude pilote a été enterprise afin de caractériser des sources et des outils en obsidienne trouvés au Kenya et en Tanzanie du nord. Cette étude est dans le but d'approfondir nos connaissances des modèles préhistoriques de l'utilisation des sources et du transport à longue distance de l'obsidienne. Jusqu'à maintenant la reconnaissance nous a permis de localiser 54 sources. Les analyses par la méthode de fluorescence des rayons X de douze éléments ont été menées sur des échantillons provenant de chaque source et un certain nombre d'entre elles ont été reconnues comme étant chimiquement distinctes. Quelques 1400 outils provenant de 32 gisements ont été caractérisés en utilisant la microsonde électronique et attribués à certaines sources grâce à trois éléments. De plus cette étude documente le transport à longue distance des obsidiennes du Rift central depuis le Middle Stone Age. Enfin avec la venue du Néolithique pastoral nous retrouvons une plus grande utilisation de l'obsidienne et une dépendance spécialisée sur des sources particulières.

The study of obsidian sources, their use and the distribution of artifacts made from raw materials from these sources has been profitably pursued by archaeologists and geochemists in a number of areas of the world to date—notably in the Mediterranean/Near East zone, Mesoamerica, the western North American continent and New Zealand. Such research has provided insight into a number of archaeological topics including long and short distance exchange and distribution networks, communication routes, ethnic and/or political boundaries, economic and political alliances, and craft specialization in prehistoric and early historic times. Despite the success of these studies the application of geochemical research to obsidian sources and artifacts in eastern Africa has been relatively slight and slow to develop (for examples, see Muir and Hivernel 1976; Schmid and Stern 1976; Michels *et al.* 1983). Indeed, eastern Africa must be one of very few major geographic areas with abundant prehistoric obsidian sources and artifacts that has not been subject to even moderately intensive research on the chemistry of sources and artifacts. The following paper presents the preliminary results of a pilot geochemical study of obsidian sources and artifacts from the Kenyan and northern Tanzanian portions of eastern Africa.

Previous research

In the southern portion of eastern Africa prior archaeologically oriented research on prehistoric obsidian sources and their utilization has been very slight. In Kenya, M. D. Leakey noted the presence of four optically distinctive obsidians in the industry from the Hyrax Hill Neolithic Site, and P. M. Game demonstrated that two of these types were similar in specific gravity, refractive index, and other petrological characteristics to samples from sources known at Njorowa Gorge and on Mt Eburru (Leakey, M. D. 1945). S. Cole (1954) further reported that these two areas were the only known localities where prehistoric quarries had been found. Cann and Renfrew (1964) listed without further comment the trace element analysis of a handaxe from the Kariandusi Acheulian site, as well as the trace element analyses of two pieces of source material from the Naivasha area. Walsh and Powys (1970) used the refractive index and specific gravity to demonstrate that some of the obsidian artifacts from Kisima Farm in Laikipia District were probably made of obsidian from Mt Eburru some 130 km distant. They were apparently unaware of Game's work and did not appreciate that had they used it, it would have suggested that some of the Kisima Farm material (as well as their comparative artifact sample from Mt Eburru!) probably originated from Njorowa Gorge. Omi and Agata (1977) reported the results of the petrological and chemical analysis of a quarry sample from Mt Eburru and five artifacts collected from sites in the Lake Naivasha/Mt Eburru area. They were able tentatively to assign two of the artifacts to the Eburru source. The remaining three which they did not assign to source had markedly different refractive indices which were, although not noted by them, similar to Game's value for the Njorowa Gorge source.

Bower *et al.* (1977) briefly reported a program of archaeologically oriented sampling of glassy volcanics in the central Rift Valley. Although no locality or analytical data were published, the survey revealed that obsidian source localities in the central Rift region were more numerous than had previously been supposed. Most recently, in connection with the obsidian hydration dating of artifacts from Prospect Farm, Michels *et al.* (1983) reported that chemical analyses had been performed on 138 artifacts and 14 quarry samples from Kenya. However, the detailed analytical results were not presented, nor was an attempt made to assign the artifacts to specific source areas.

For the northern Tanzania area, there is but a single pertinent chemical study. Schmid and Stern (1976) reported the presence of obsidian artifacts high on the slopes of Mt Kilimanjaro and presented chemical analyses indicating the artifacts were probably made of volcanic glass from near the Kibo crater at the top of the mountain.

Despite the paucity of archaeologically oriented geochemical research on obsidian for source and artifact characterization studies, petrological research on volcanic glasses in the region has been moderately frequent. Published analyses (MacDonald and Bailey 1973; Weaver 1973, 1976–77; Jones 1981; Watkins 1981; Baker and Henage 1977) are available for about 35 samples of volcanic glass. About two thirds of these analyses are for sources in the Lake Naivasha and Lake Nakuru basins. The remainder come from other locales scattered up and down the Rift and its margins. These analyses indicate that there is considerable variability in the composition of the region's volcanic glasses, an observation also confirmed by our analyses. However, despite the number of analyses, their usefulness for detailed obsidian sourcing and artifact characterization studies is often limited because of questionable reliability of some older analyses, and for lack of specific provenance data on the source locality for some of the samples.

A survey of sources

The initial impetus for this project stemmed from a challenge by M. D. Leakey to one of us (F.H.B.) to locate the sources of obsidian used in the Naisiusiu Beds LSA assemblage at Olduvai Gorge. Consequently in 1981 we initiated a pilot survey of obsidian sources in Kenya which gradually expanded to the scope of the project reported here. Our coverage of potential source localities undoubtedly remains far from complete, but to date we have located and collected 54 geographically discrete source localities. A review of the previously published analyses indicates that there are a minimum of ten more source areas, each possibly with multiple outcrops from which we have not yet collected and analyzed samples. The locations of known source localities whose obsidians have been analyzed are shown in Figures 1 and 2. The localities are tabulated in Table 1.

The survey documented the generally well known observation that the majority of obsidian bearing localities in the region are centered around the Lake Naivasha basin and Mt Eburru. It also demonstrated that there are a number of obsidian bearing localities in the eastern highlands flanking the central Rift Valley, a fact not widely appreciated previously. Published references also show that there are potential, but apparently relatively minor, sources of volcanic glass present in the northern portions of Kenya, east of Lake Turkana and in the southern end of the Suguta Valley, as well as in the southern Kenyan rift zone, and on Mt Kilimanjaro.

The nature of the occurrence of the obsidian at the sampled source localities is variable, as is its quality. In many source areas including the Karau, Oldonyo Nyegi, Njorowa Gorge, Masai Gorge and Eburru areas, the obsidian with the best flaking properties is found in seams along the chill zones at the bases or tops of lava flows. At other localities the obsidian is commonly found as lapilli or nodules embedded in pyroclastic deposits which can vary from soft ash to well cemented tuff. These nodules can vary from small pebble size to boulder size, up to a meter in diameter. At least some of the obsidian present at most of the sampled localities is of adequate quality for stone working. However, the obsidians sampled from the

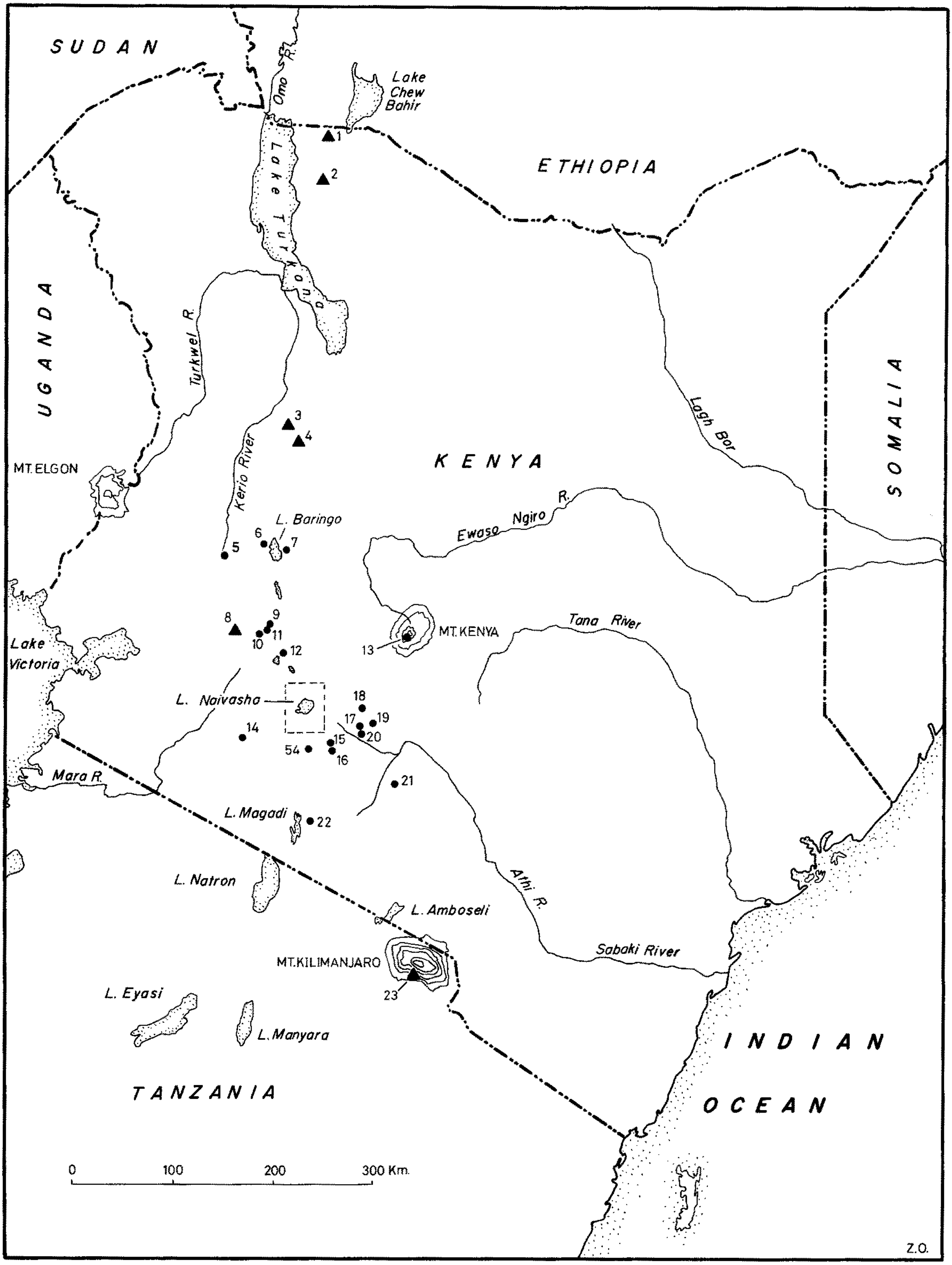

Figure 1 Known sources of analyzed volcanic glass in Kenya and northern Tanzania. Source localities are keyed to Table 1. (See Figure 2 for inset of the Lake Naivasha area sources.)

Table 1 Obsidian source localities. Locality numbers are keyed to Figures 1 and 2.

Locality	*Petrological Group*	**Reference** (if other than our analysis)
1. Suregei-Asille (multiple localities)	*1* and *33*	Watkins 1981
2. Shin	*2*	Watkins 1981
3. Nasaken	*3*	Weaver 1973
4. Emuruangogolak	*4*	Weaver 1976–77
5. Salawa Hill	*5*	
6. Kampi ya Samaki	*6*	
7. Karau (multiple localities)	*6*	
8. Londiani	*7*	Jones 1981
9. Kisanana	*8*	
10. Kampi ya Moto	*9*	
11. McCall's Siding	*9*	
12. Menengai (multiple localities)	*10*	McCall 1967; MacDonald & Bailey 1973
13. Mt Kenya	*11*	
14. Olagirasha	*12*	
15. Gicheru (two localities)	*13* and *14*	
16. Kedong Escarpment	*14*	
17. Gacharage	*16*	
18. Githumu	*12*	
19. Mangu	*12*	
20. Githuya	*12*	
21. Lukenya (multiple localities)	*12*	
22. Ol Donyo Nyegi (multiple localities)	*15*	
23. Mt Kilimanjaro (multiple localities)	*17* and *18*	Schmid & Stern 1976; Williams 1969
24. Kinangop Escarpment	*24*	
25. Longonot	*23*	MacDonald and Bailey 1973
26. Akira	*22*	
27. Njorowa Gorge	*20*	
28. Hell's Gate no. 1	*20*	
29. Fischer's Tower	*20*	
30. Oserian no. 2	*21*	
31. Oserian no. 1	*20*	
32. Kibikoni	*25*	
33. N.L.E.S. no. 3	*25*	
34. N.L.E.S. no. 2	*25*	
35. N.L.E.S. no. 1	*25*	
36. Mundui	*19*	
37. Sonanchi	*19*	
38. West Naivasha no. 1	*31*	
39. Baixia road metal quarry	*32*	
40. West Naivasha no. 3	*32*	
41. Masai Gorge	*32*	
42. West Naivasha no. 2	*32*	
43. Ilkek	*32*	

Table 1 *cont.*

Locality	*Petrological Group*	Reference
44. Eburru Rd	*26*	
45. GsJj 52	*30*	
46. East of Cedar Hill	*28*	MacDonald and Bailey 1973
47. Eburru steam jet	*29*	
48. Eburru steam condenser	*29*	
49. GsJj 50	*29*	
50. Cedar Hill	*27*	
51. Opuru	*35*	
52. Eburru Station west	*27*	
53. Eburru Station	*29*	
54. Suswa	*34*	
55. Njorowa Gorge South no. 1	*20*	

Salawa Hill (5), Akira (26), Suswa (54), Kampi ya Moto (10) and McCall's Siding (11) localities are generally of very poor quality and are unlikely to have been used frequently as raw material for artifact manufacture.

Evidence for the prehistoric utilization of some of the localities as quarry/workshop sites is readily apparent. At the Kedong (16), Kibikoni (32), Mundui (36), Eburru Quarry (49), GsJj 52 (45), Eburru Steam Condenser (48), and Kisanana (9) localities moderate to large quantities of flaking debris are associated with the outcrops, attesting to their prehistoric usage. However, obvious traces of extensive mining activities are very rare at any of the localities. M. D. Leakey (1945) reported that at Njorowa Gorge there were fifteen or more separate galleries cut into a horizontal seam of obsidian. It is believed that these were located near or at the Hell's Gate no. 1 locality (28) where the chill zone at the base of a thick comendite flow has produced a seam of good quality obsidian. However, the traces of these workings appear to have been largely obliterated by the recent collapse of the undercut lava cliff face. Other more problematic instances of quarrying can be observed at the Njorowa Gorge South no. 1 locality (55) and at a locality on the western side of Oldonyo Nyegi. At the first of these localities the better quality material at the base of the chill zone has been largely removed, forming a rock shelter-like feature. At the second, there is a small rock shelter in the base of a chill zone with a few pockets of good quality obsidian remaining in the floor and lower walls of the shelter. Traces of quarrying debris at both these localities are not obvious, for the talus slope in front of each is heavily vegetated, but the shelters may very possibly owe their origin to quarrying. The lack of evidence for obvious mining probably should not be too surprising. At many central Rift source localities loose blocks of obsidian are still quite plentiful on the surface of the outcrops, and even today extensive mining would not be necessary to collect adequate supplies. We should also mention that at a number of the sampled localities, including Lukenya Hill, Kampi ya Samaki, and several localities around Oldonyo Nyegi, the obsidian bearing tuffaceous agglomerates contain quite low densities of obsidian lapilli and quarrying would have been relatively unproductive. In these instances the nodules are most easily collected from pebble lag concentrates on the eroded exposures of the agglomerates and from the stream channels dissecting the exposures.

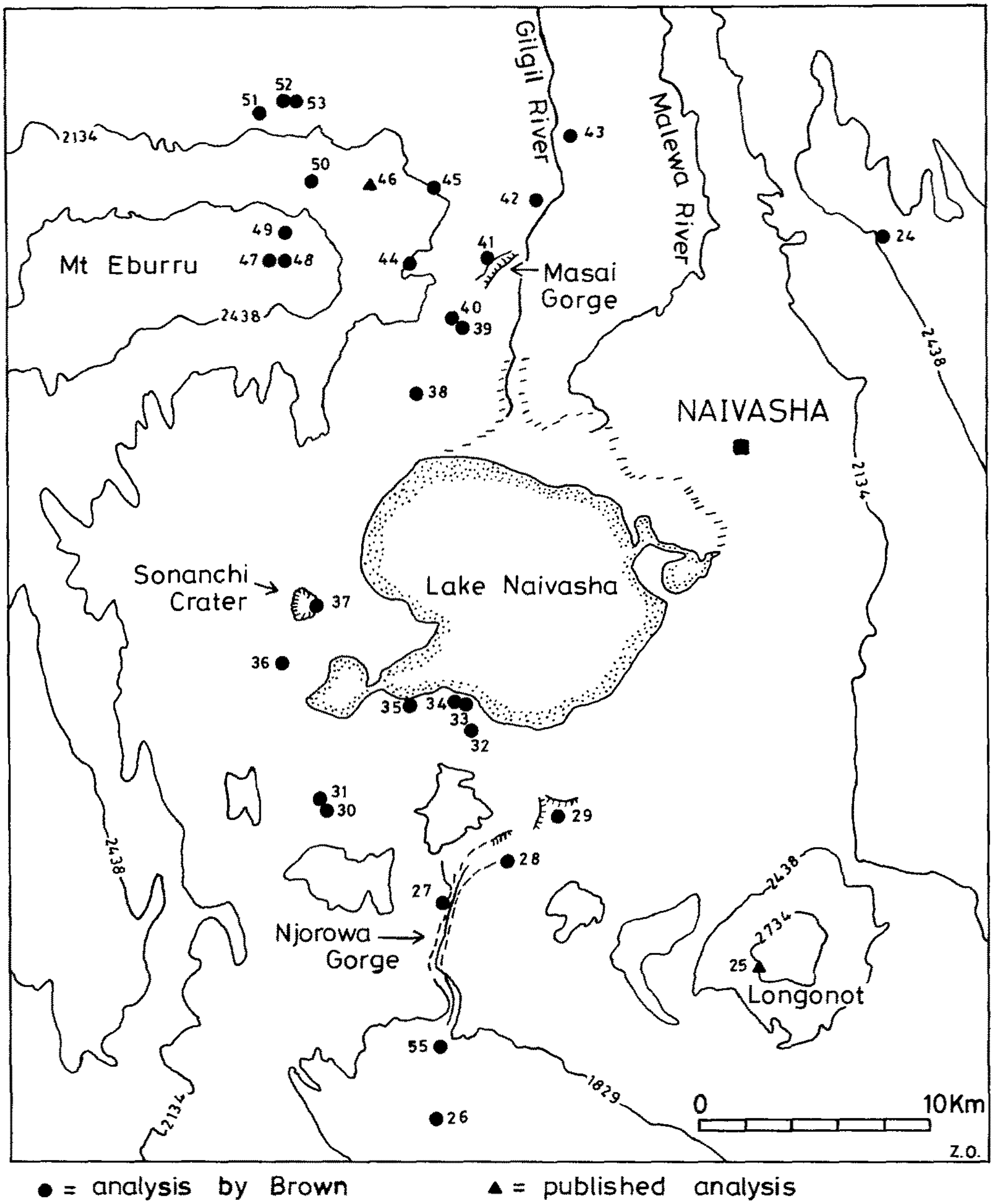

Figure 2 Known sources of analyzed volcanic glass in the Lake Naivasha region. Source localities are keyed to Table 1.

Source chemistries and artifact analyses

One or more samples from each of the localities collected by us has been analyzed by X-ray fluorescence analysis for 12 elements (Fe, Ca, K, Ba, Mn, Nb, Rb, Sr, Ti, Y, Zn and Zr). These elements were selected for analysis because they appeared to have the greatest potential for source and artifact discrimination. The detailed results of the chemical analyses will be presented elsewhere by F.H.B. but are briefly summarized here. These analyses and reference to other published analyses led to the recognition of 35 petrologically distinctive groups of source obsidians of known location in Kenya and northern Tanzania (Table 1). Outcrops assigned to each of these petrological groups with one possible exception (*Group 12*) have discrete geographical distributions around single volcanic centers. Consequently each of the petrological groups can be considered as representing a single source area. The known outcrops in each of these source areas are usually found within a 20 to 50 sq. km area, although the largest, the Njorowa Gorge source area appears to have an area of approximately 250 sq. km.

Figures 3 and 4 illustrate by means of bivariate plots the clustering of the analyses by

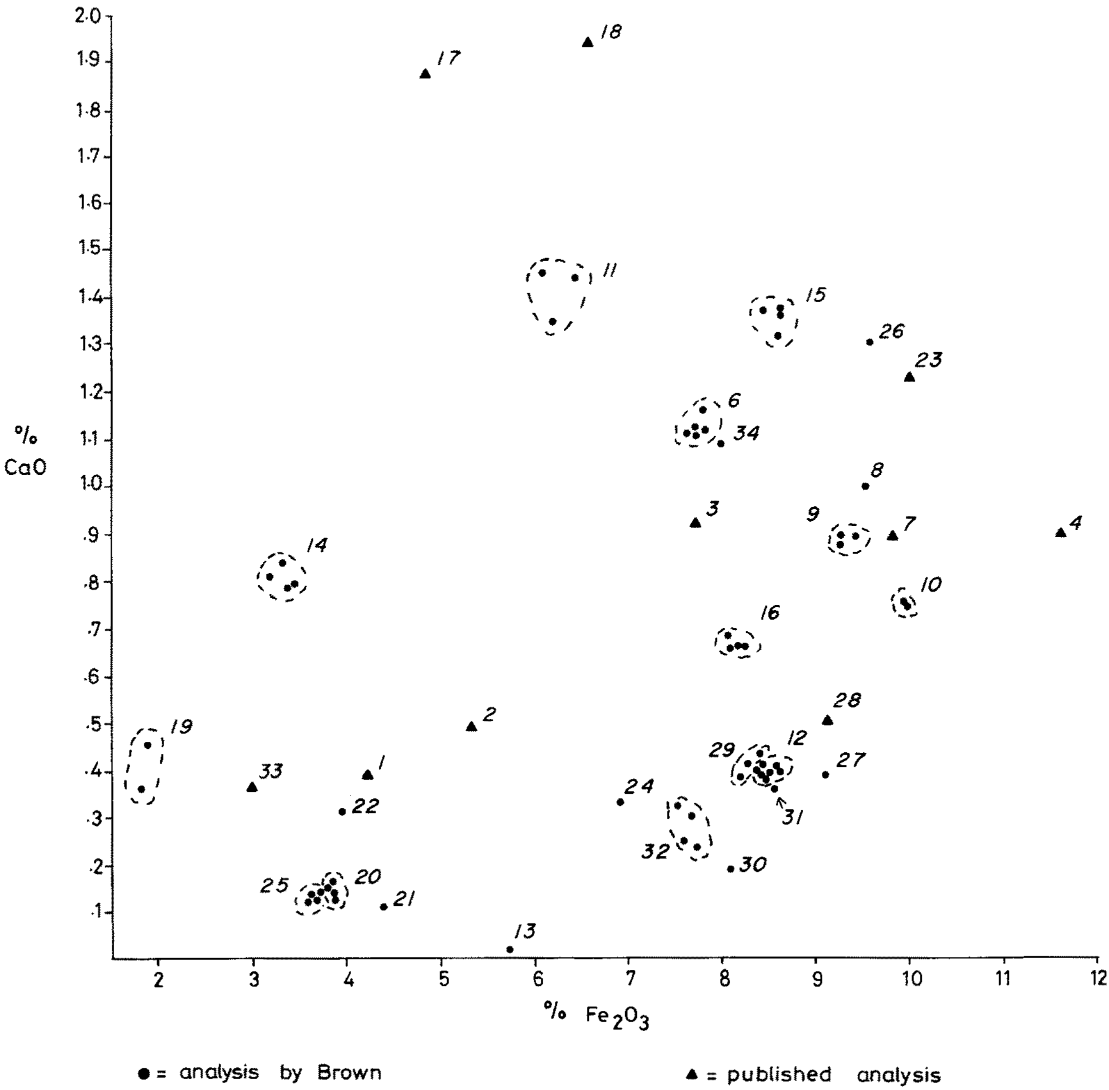

Figure 3 Plot of the total iron (as Fe_2O_3) versus calcium (as CaO) for analyses of source material from individual localities. Dashed lines surround localities assigned to a single petrological group. Petrological groups are keyed to Table 1.

petrological groups using three of the best discriminants, Fe, Ca and Ti. As the figures illustrate, these three elements in combination do not provide complete discrimination between all the petrological groups recognized. For adequate distinctions between some source areas, for example between Njorowa Gorge (*20*) and Naivasha Lake Edge South (*25*) and between Karau (*6*) and Suswa (*34*) additional elements are required for the characterization of the sources.

The XRF analyses demonstrate that, on the whole, the individual source areas of volcanic glass frequently have distinctive chemistries. So distinctive are they in many instances that characterization of sources and artifacts can be done on the basis of major and minor elements, rather than on the basis of the rarer trace elements as is commonly required in obsidian sourcing studies in many other parts of the world. This finding enabled us to use an electron microprobe for the rapid chemical analysis of a series of some 1400 artifacts from sites in Kenya and northern Tanzania. Details of the analytical technique used can be found in Merrick and Brown (in press). In the pilot artifact study only three elements Fe, Ca, and Ti were chosen for microprobe analysis because they appeared to offer good prospects for source discrimination. Although the discriminatory value of these three elements breaks down for some source areas with values in the 7.5 to 9% Fe_2O_3 range, the analyses permitted the preliminary assignment of the majority of the analyzed artifacts to 15 known source areas. The microprobe analyses also indicated that a minimum of 22 other unknown sources were represented by artifacts among the sampled assemblages, although as a group these formed less than 6% of the sampled artifacts.

The sites and assemblages chosen for examination during the pilot study were generally chosen to provide broad areal coverage in order to examine the long distance movement of obsidian, although some sites, notably in the Lukenya Hill region, were extensively sampled

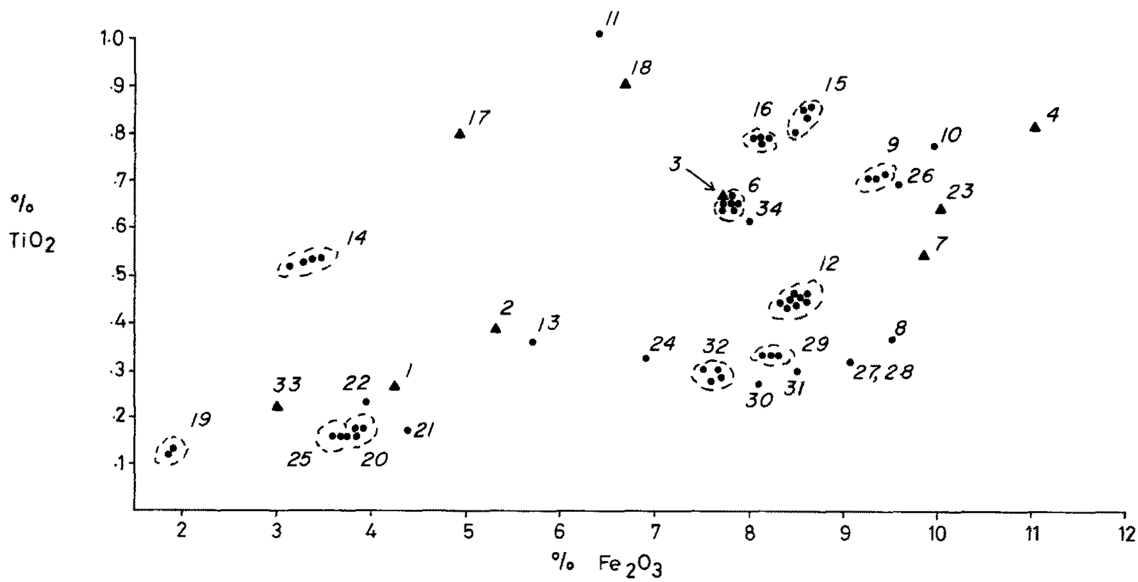

Figure 4 Plot of the total iron (as Fe_2O_3) versus titanium (as TiO_2) for analyses of source material from individual localities. Dashed lines surround localities assigned to a single petrological group. Petrological groups are keyed to Table 1.

to examine trends in obsidian utilization through time. The locations of the sampled sites are shown in Figure 5. For the majority of sampled assemblages the artifacts chosen for analysis were selected by a process of systematic sampling. These samples have been marked with an * in the tables and it is believed the proportions of sources are generally representative of the assemblages from which the samples were drawn. The remaining samples are 'grab' samples and our confidence in their representativeness is considerably less.

The confidence placed in these assignments deserves comment. The assignments are based on the analysis of three elements only. Figures 3 and 4 demonstrate that the petrological groups are relatively distinctive in these elements, but there is considerable similarity among several of the petrological groups found on Mt Eburru, and between the Njorowa Gorge and Naivasha Lake Edge South groups. This combined with the observation that the microprobe analyses of pieces of material from a single source fall in a normal distribution about the mean value for the source makes assignments to one or another of some of the chemically similar Eburru groups problematic, and distinction between the Njorowa Gorge and the Naivasha Lake Edge South groups impossible, using just these three elements. Nonetheless though there may be some potential ambiguity in these assignments, from the point of view of assessing the long distance movement of obsidian, there is little effect, as all of the obsidian in question comes either from a relatively small area around Mt Eburru, or from around the south end of Lake Naivasha. One other potential difficulty should also be mentioned. As our survey of sources is still incomplete, it is possible that additional source areas may be found which will have similar Fe, Ca and Ti values as the presently known source areas. In this event, the artifacts with those values would need additional analysis and the assignments will require re-evaluation.

Regional patterns of obsidian utilization: first results

Although the temporal and spatial distribution of studied sites is still very patchy for the region, it is now becoming possible to paint the broad outlines of the regional history of obsidian use, and to begin to examine the emergence of the long distance movement of obsidian and differential patterns of source utilization.

The Early Stone Age

The region's earliest evidence for the use of obsidian occurs in Acheulian contexts at the Kariandusi (Leakey, L. S. B. 1931) and Kilombe (Gowlett 1978) sites, both probably dating to greater than 0.7 million years ago (Gowlett 1980). Only a single piece was noted at Kilombe, but at Kariandusi obsidian forms approximately 15% of the industry. We have not yet analyzed material from either site so the specific sources of the obsidian are not yet known, but at least for Kariandusi, the source is likely to be relatively near (i.e. with 50 km) as the site is situated in the central Rift Valley near several volcanic centers known to produce obsidian. Apart from these two sites obsidian is not present on most Acheulian sites in the region. Obsidian is perhaps more widely used in Early Stone Age contexts in Ethiopia (cf. Muir and Hivernel 1976). There, as far as one can tell, the general pattern is for relatively low frequency of usage of nearby sources, although movement of obsidian of up to 100 km has been reported (Clark 1980). Certainly for Kenya and northern Tanzania there is not yet any definite evidence of movement of obsidian from source to site greater than 50 km.

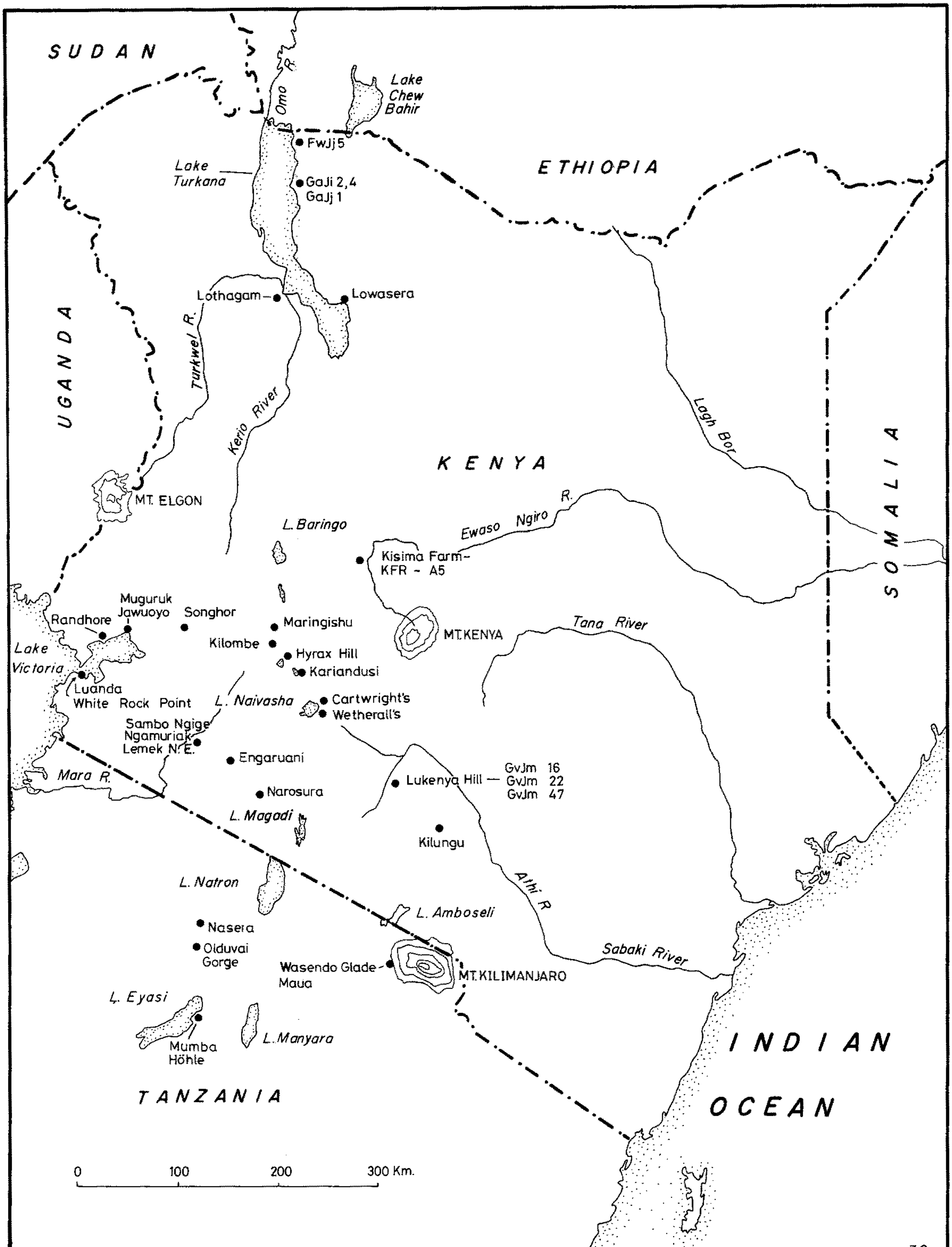

Figure 5 Sites which have been sampled or mentioned in the text.

The Middle Stone Age

From Middle Stone Age times onward obsidian is found in frequent use in almost all sites within a 50 km radius of major obsidian sources in the central Rift Valley (cf. Anthony 1978; Merrick 1975). A similar situation appears to prevail in Ethiopia near major sources (Wendorf and Schild 1974; Muir and Hivernel 1976). Outside the immediate vicinity of the major central Kenyan Rift sources the frequency of obsidian use falls off rapidly. For example at GvJm 16 at Lukenya Hill, some 65 to 105 km from the two nearest known major sources, obsidian forms between 6 and 19% of the assemblages in the MSA levels (Merrick 1975). At sites further distant the frequency of obsidian continues to fall rapidly such that at the western Kenyan sites of Muguruk and Songhor obsidian occurs as well under 1% of the industry (McBrearty 1981 and pers. comm.), and is not present in the possible MSA levels at Randhore (Gabel 1969). In northern Tanzania the frequency of obsidian in the MSA levels at Nasera Rockshelter is also very low (Mehlman 1977), as is also the case for the MSA levels at Mumba Höhle (Mehlman pers. comm.). For northern and eastern Kenya MSA sites have generally not yet been adequately reported to assess the frequency of obsidian use, although it appears that obsidian was not commonly used (cf. Whitworth 1965).

Artifact samples from five Middle Stone Age sites were analyzed and characterized to source (Table 2). These were taken from the Cartwright's and Wetherall's sites on the edge of the Kinangop Plateau (Leakey, L. S. B. 1936), two levels at the GvJm 16 site at Lukenya Hill and the western Kenyan sites of Muguruk and Songhor. Unfortunately none of these sites is adequately dated as yet. The stone assemblages at both Cartwright's and Wetherall's are completely dominated by obsidian, and both sites lie within 40 km of all of the major Eburru and Lake Naivasha area sources. Although the two sites are in analogous topographic positions along the Kinangop Escarpment and are only 17 km apart, marked differences in the patterns of obsidian source utilization are apparent. Only three source areas are represented at Cartwright's while an eclectic assortment of obsidian from probably nine source areas is present as Wetherall's. The Cartwright's assemblage is dominated by obsidian from the Masai Gorge source area (56%) and the Njorowa Gorge/Naivasha Lake Edge South area (40%). Local Kinangop material forms the remaining 4%. The total absence of Sonanchi area obsidian in a relatively large sample at Cartwright's is notable. Sonanchi area obsidian is one of the finest flaking obsidians and is usually found in at least small proportions in central and southern Kenyan sites of all time periods from the MSA onward. There are several possible explanations for its absence. These include (1) the possibility that the Cartwright's assemblage predates the eruption of the volcanic center, (2) that access to the Sonanchi source area was precluded by other groups or (3) that the Cartwright's assemblage was accumulated when Lake Naivasha stood at a maximum high stand, at which time there is a good possibility that all presently known outcrops of the source area may have been under water. The latter possibility is favoured, although there is no conclusive evidence to eliminate either of the other two possibilities.

It is in the MSA that, for the first time, we have definite evidence of the movement of obsidian in any appreciable quantity beyond 50 km from its source. At the GvJm 16 site at Lukenya Hill local obsidian (*Group 12*) forms 33% and 48% of the obsidian in the sampled assemblages, but the majority of the obsidian in both is non-local and has travelled between 65 and 135 km from source to site. The obsidians from the western Kenyan sites of Muguruk

Table 2 Source assignments for artifacts from MSA sites. Straight line distances over land to sources are given in parentheses.

SOURCE	Sonanchi		Njorowa Gorge		Oserian 2		Masai Gorge		GsJj 52		Upper Eburru		W.N.1		Cedar Hill		Kinangop		Kedong		Highlands		
Petrological group	*19*		*20/25*		*21*		*32*		*30*		*29*		*31*		*27*		*24*		*14*		*12*		
Assemblage	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	n	(km)	Total
*Cartwright's			20	(35)			28	(16)									2	(5)					50
*Wetherall's	5	(38)	16	(24)			7	(25)	9	(30)	2	(35)	3	(34)	1	(35)	3	(12)			1	(45)	47
Lukenya Hill																							
*GvJm 16 (X_I–98.50–98.45)			17	(105)			1	(135)											2	(65)	11	(6)	32
(X_I–98.00–97.00)	1	(125)	3	(105)	1	(115)	2	(135)	2	(135)			3	(130)					5	(65)	16	(6)	33
Muguruk	1	(190)									1	(185)											2
Songhor			1	(145)																			1

* Indicates artifacts drawn from the assemblage by systematic sampling.

and Songhor also document long distance movement of obsidian. The three pieces analyzed from the latter two sites all appear to be of central Rift origin and to have travelled up to 190 km from source to site.

The Later Stone Age

In LSA contexts the use of obsidian almost totally dominates at sites in the immediate vicinity of central Rift sources. In the zone between 50 and 150 km from the major central Rift sources obsidian usage may increase slightly compared to the preceding MSA. At Lukenya Hill in the earliest LSA levels at GvJm 22 obsidian varies between 6.7% and 13.8% (Gramly 1976), while in the slightly later LSA levels at GvJm 16, it varies between 10% and 30% (Merrick 1975). Although precise figures for the pre-pottery levels at the KFR-A5 rock shelter in Laikipia District have not been published, obsidian seems to form between 10% and 15% of the assemblage (Siiriäinen 1977).

To the south beyond 150 km from the major central Rift sources obsidian continues to be rare. In the LSA assemblage in the Naisiusiu Beds at Olduvai Gorge obsidian forms 5% of the assemblage (Leakey, M. D. *et al.* 1972), while Mehlman (1977) notes that the frequency of obsidian in the early LSA levels at Nasera is markedly less than at Olduvai. To the north obsidian is also rarely used. At Lowasera on the southeastern side of Lake Turkana obsidian is the most common of the fine grained raw materials, but lava dominates the assemblage (Phillipson 1977). At Lothagam, west of the lake, obsidian forms less than 1% of the industry (Robbins 1974).

Obsidian samples from eight sites were analyzed and assigned to sources (Tables 3 and 4). Samples were included from the Naisiusiu Beds site at Olduvai Gorge, Level 6 of the KFR-A5 rock shelter, and from two rock shelters on Lukenya Hill, including GvJm 22: Occurrences E and F (Gramly 1976) and GvJm 16: Culture-Stratigraphic Unit B (Merrick 1975). We also analyzed three artifacts from Engaruani, an open pan site in the Lemek area (Marshall and Robertshaw 1982), and, from northern Kenya, pieces from two mid-Holocene bone harpoon and pottery bearing sites, GaJj 1 (Barthelme 1981) and Lowasera (Phillipson 1977), east of Lake Turkana.

The initial study of the Olduvai Gorge Naisiusiu Beds obsidian provided conclusive chemical evidence of the long distance movement in the pre-pottery LSA of central Rift obsidian up to 250 km from source. Partial analyses for major and trace elements were done by XRF technique on eight artifacts from the site, dated to about 17,000 bp (Leakey, M.D. *et al.* 1972). The data (Table 5) show all of the specimens are clearly of a single type of obsidian which closely matches the obsidian from the Sonanchi (37) and Mundui (36) localities of the Sonanchi source area near Lake Naivasha. The striking chemical similarity between the sources and the artifacts is compelling evidence that the artifacts were made of obsidian from the Sonanchi area.

The central Kenyan sites examined are all outside the immediate vicinity of the obsidian rich central Rift area, and lie in the zone between 50 and 150 km from the major central Rift sources. Most of the occurrences sampled drew the bulk of their obsidian from the major low lying central Rift sources, Sonanchi, Njorowa Gorge and Masai Gorge. The general rarity of obsidian from the upper Eburru sources is noteworthy. Both the Laikipia site and the Lukenya Hill sites appear to have drawn most heavily on the respectively nearest major

Table 3 Source assignments for artifacts from LSA sites. Straight line distances over land to sources are given in parentheses.

SOURCE	Sonanchi	Njorowa Gorge	Masai Gorge	GsJj 52	Upper Eburru	Kinangop	Kedong	Highlands	Karau	Kisanana	Unknown		
Petrological group	*19*	*20/25*	*32*	*30*	*29*	*24*	*14*	*12*	*6*	*8*	*W*	*Others*	
Assemblage	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n	n	Total
Olduvai Gorge	8 (255)												8
Lukenya Hill													
*GvJm 22													
Occurrence 'E'	3 (125)	27 (105)				1 (110)		18 (6)				1	50
Occurrence 'F'	3 (125)	1 (105)					5 (65)	9 (6)			27	6	51
*GvJm 16 'B'													
99.50–99.55		15 (105)				1 (110)	2 (65)	17 (6)			11	1	47
99.05–99.00	4 (125)	30 (105)	1 (135)				3 (65)	8 (6)			4		50
98.60–98.50	9 (125)	25 (105)				1 (110)	6 (65)	7 (6)			1	2	51
98.30–98.25	18 (125)	14 (105)				3 (110)	4 (65)	1 (6)			5	4	49
KFR-A571/6	6 (155)	1 (160)	23 (135)	8 (135)					9 (70)	1 (95)		4	52
Engaruani	1 (85)	2 (85)											3

* Indicates artifacts drawn from the assemblage by systematic sampling.

Table 4 Source assignments for artifacts from northern Kenyan LSA and Pastoral Neolithic sites.

	Sources					
	Suregei	Masai Gorge	Unknown			
Petrological groups	*1*	*32*	*D*	*F*	*G*	
Assemblages	n	n	n	n	n	Total
LSA with bone harpoons and pottery						
GaJj1	2					2
Lowasera	10		6			16
Pastoral Neolithic						
FwJj 5	2	1?		1	1	5
GaJi 2	1			2		3
GaJi 4	20					20

central Rift source area, Masai Gorge at the eastern end of Mt Eburru for the Laikipia site, and Njorowa Gorge for the Lukenya Hill sites. The Laikipia site also drew a significant portion of its obsidian from the Karau source area near Lake Baringo, which is the closest known minor source. In addition to the central Rift sources, the Lukenya Hill sites regularly drew a very considerable portion of their obsidian from local source localities, available within 6 km of the sites. In this connection we suspect the artifacts assigned to the unknown *W* source are from local Lukenya Hill area source localities as well. Table 3 illustrates the observation that the individual Lukenya sites GvJm 16 and GvJm 22 also show a great deal of internal variability in the frequency of particular sources used through time. The factors involved with this are undoubtedly many, but clearly closer examination of the industries, their faunal associations and dating will be required to make headway in understanding this variability.

The small number of analyzed specimens from the northern Kenyan bone harpoon bearing LSA assemblages from the GaJj 1 and Lowasera sites are dominated by *Group 1* obsidian, whose only presently known source is north of the Suregei Plateau along the northeast edge of the Lake Turkana basin. The distances from sites to source were

Table 5 Partial chemical analyses of Olduvai Gorge Naisiusiu Beds LSA obsidian artifacts and comparative source material (oxides in Wt %; all others in ppm).

Artifacts	Fe_2O_3*	CaO	K_2O	Mn	Nb	Rb	Ti	Y	Zn	Zr
OS-1	1.86	.35	4.8	277	193	279	747	92	107	480
OS-2	1.87	.34	4.8	278	198	284	725	92	107	480
OS-3	1.91	.44	4.8	273			819		107	
OS-5	1.92	.40	4.9	281	190	282	812	89	110	484
CS-1	1.86	.36	4.8	274	196	286	760	91	107	489
CS-30	1.94	.44	4.8	276	187	285	856	91	109	479
CS-70–1	1.96	.44	4.9	278	196	281	876	92	106	487
CS-70–2	1.94	.41	4.8	273	196	285	853	88	107	488
Sources										
Sonanchi (37)	1.90	.45	4.8	257	191	276	790	88	108	483
Mundui (36)	1.85	.36	4.8	236	193	278	697	87	106	482

* Total iron expressed as Fe_2O_3.

respectively about 60 and 160 km. At Lowasera a second but unknown source *D* is also represented and forms nearly 40% of the obsidian. Neither of these sites displayed any of the central Kenyan Rift obsidians, the nearest sources of which are well over 300 km distant.

The Later Stone Age with pottery and Pastoral Neolithic

Some of the most interesting results of the pilot study relate to sites dating to the last several millennia which contain pottery and are assignable (using the terminology proposed by Bower *et al.* 1977) either to the Later Stone Age or to the Pastoral Neolithic complex. Beginning in the 2nd millennium bc with the appearance of agricultural and/or pastoral economies in the region, the pattern of obsidian use becomes more variable. In all sites within the immediate proximity of the central Rift sources obsidian is the dominant material. In the zone between 50 and 150 km distant several interesting patterns become apparent. For the first time some sites, primarily in the southern part of this zone, display a very high frequency of obsidian use and the quantities involved are not inconsiderable (cf. Odner 1972; Marshall and Robertshaw 1982). At other sites in the zone the previous pattern of low frequency of use continues (cf. Siiriäinen 1977; Merrick 1975). Beyond 150 km from the central Rift, one continues to find generally low frequency of use, although there are assemblages (mainly in northern Tanzania) which are dominated by obsidian although the quantities are very small (cf. Bower 1973; Leakey, M. D. 1966; Mehlman 1977). The source utilization patterns discerned in the pilot study are summarized by area below.

To the south of the Lake Naivasha basin a number of Pastoral Neolithic and possible Pastoral Neolithic assemblages were sampled. These come from both east and west of the Rift in the zone ranging from 50 to 150 km from the major obsidian sources around Lake. Naivasha. West of the Rift the sites sampled included Narosura (Odner 1972), Ngamuriak, Sambo Ngige, and Lemek North East (Marshall and Robertshaw 1982). East of the Rift at Lukenya Hill samples were analyzed from sites GvJm 16 (Merrick 1975), GvJm 22 (Gramly 1975) and GvJm 47 (Bower *et al.* 1977). A small grab sample was also analyzed from a Pastoral Neolithic site near Kilungu in Machakos District.

A notable dichotomy occurs in the frequency of obsidian usage among these sites. Narosura, Ngamuriak, Sambo Ngige, Lemek North East and GvJm 47 are all open midden sites, indisputably assignable to the Pastoral Neolithic, and seem analogous to modern pastoralists' encampments. At all of these sites obsidian is present in large quantities and forms upwards of 80% of the stone assemblage. In contrast, the GvJm 16 Unit C assemblages and the Occurrence C assemblage at GvJm 22 at Lukenya Hill are from rock shelter occupations. On the dating and ceramic evidence these are generally contemporaneous with the Pastoral Neolithic open sites. In the rock shelters, however, obsidian forms only 15% to 40% of the assemblages.

Marked differences in the source utilization patterns among the open pastoralist sites are also apparent (Table 6). The two stratigraphic levels sampled at Narosura, the type site for the Narosura ceramic tradition, are heavily dominated (96% and 88%) by Njorowa Gorge obsidian. Sonanchi obsidian is regularly present in low frequencies, but Eburru area obsidian is generally very rare. In the admittedly small sample from Lemek North East the assemblage, also with Narosura style pottery, appears to be completely dominated by Sonanchi area obsidian. Eburru area obsidian does not appear. In marked contrast to the

Table 6 Source assignment for artifacts from LSA with pottery and Pastoral Neolithic sites. Straight line distances over land to sources are given in parentheses.

SOURCE	Sonanchi	Njorowa Gorge	Masai Gorge	GsJj 52	Upper Eburru	W.N. 1	Kinangop	Kedong	Highlands	Karau	Kisanana	Suregei	Unknowns		
Petrological groups	*19*	*20/25*	*32*	*30*	*29*	*31*	*24*	*14*	*12*	*6*	*8*	*1*	*W*	*Others*	
Assemblage	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)	n (km)			Total
*Narosura															
60 to 70	1 (95)	48 (85)	1 (110)												50
80 to 90	3 (95)	44 (85)	1 (110)			2 (105)									50
Lemek N.E.	18 (100)														18
Ngamuriak	3 (100)	1 (100)			6 (110)										10
Sambo Ngige	1 (100)	2 (100)	1 (115)		8 (110)										12
Lukenya Hill															
*GvJm 47	1 (125)				49 (140)										50
*GvJm 22 'C'	20 (125)	3 (105)		1 (135)		3 (130)		2 (65)	6 (6)				15		50
*GvJm 16 'Unit C'															
99.40–99.35	4 (125)	11 (105)			2 (140)	2 (130)		4 (65)	11 (6)				13	3	50
98.80–98.75	6 (125)	14 (105)	1 (135)				1 (110)	6 (65)	7 (6)				12	3	50
*Maringishu	2 (72)	3 (100)	18 (75)		17 (75)	1 (85)					1 (7)			3	45
*KFR–A5 1/2	3 (155)	1 (160)	15 (125)	17 (135)	2 (140)	3 (145)				3 (70)		1 (430)		3	48
*Jawuoyo	20 (190)	7 (200)	3 (190)		19 (185)	3 (190)									52
Kilungu P.N.	3 (165)	6 (145)			2 (175)										11
Luanda	8 (220)		3 (225)			6 (225)									17
White Rock Point	7 (220)	3 (230)			9 (215)										19

* Indicates artifacts drawn from the assemblage by systematic sampling.

sites with Narosura style pottery, the Ngamuriak and Sambo Ngige sites, both attributable to the Elmenteitan ceramic tradition, have a predominance of obsidian from the upper Eburru area sources. This observation, while perhaps not so obvious from Table 6, which reports grab samples, has been confirmed by the visual examination of much larger series of artifacts from the two sites.

East of the Rift Valley, the GvJm 47 occurrence at Lukenya Hill, reported to be a late Pastoral Neolithic occurrence of uncertain ceramic affinities (Bower *et al.* 1977), is almost completely dominated by upper Eburru area obsidian. Chemical analysis of additional pieces of optically sorted obsidian indicates that obsidians from the Njorowa Gorge, Cedar Hill and Kedong areas are present, but in frequencies well under 1% of the assemblage.

In a small sample from the Kilungu Pastoral Neolithic site, which has pottery similar to that at Narosura (D. P. Collett pers. comm.), southern Naivasha area obsidian is most frequent. This pattern matches that at the other sites with Narosura style ceramics.

The emerging pattern of source utilization at pastoralists' open sites in the southern region seems to be a predominance of southern Naivasha area obsidians on sites in the Narosura ceramic tradition and a predominance of upper Eburru area obsidians in Elmenteitan tradition sites and in sites of uncertain ceramic affiliations.

The patterns of source utilization in the three Lukenya Hill rock shelter samples stand in marked contrast. In addition to the less frequent use of obsidian, all three samples have a much wider range of sources represented (Table 6). Overall, the patterning of the obsidians used in these levels is very much more similar to the broad spectrum pattern of utilization observed in the earlier LSA assemblages at each of these sites, than it is to the contemporaneous pastoralists' open sites. Although there is the obvious difference in site type and probably differences in site function, this finding may support the prediction of Bower *et al.* (1977) that co-existing hunter/gatherers and pastoralists would display markedly different patterns of source utilization. Clearly additional comparisons and analyses of the stone industries, ceramics and associated faunas are required to shed more light on this problem.

The only far distant southern samples of likely Pastoral Neolithic association analyzed are of surface material from the Maua and Wasendo Glade sites in the west Kilimanjaro area (Antiquities Department 1978a and b). These samples were submitted through the courtesy of Dr Waane of the Tanzanian Division of Antiquities. The analyses demonstrated long distance movement of central Kenyan Rift obsidian into the Kilimanjaro region, a distance of about 250 km. The Maua sample contained only obsidian from the Sonanchi and Njorowa Gorge sources, while the Wasendo Glade sample contained a single piece of Njorowa Gorge obsidian, but was dominated by obsidian from two chemical groups, *A* and *E*, whose sources are unknown. As the quality of this obsidian is poor, suggesting relatively low desirability for long distance transport, and as the chemistry is most similar to obsidians reported from Kilimanjaro, local sources are the best guess as to their origin (for example the sources in Weru Weru Valley reported by Downie and Wilkinson (1972)).

To the north of the Lake Naivasha/Mt Eburru area somewhat different patterns of source utilization appear to be present among Pastoral Neolithic assemblages. A sample of 45 retouched pieces was analyzed from the Maringishu site, located in the Rift Valley some 70 km north of Mt Eburru. The site is an open midden. Obsidian is the dominant material in the stone assemblage and the ceramics show great similarity to the ceramics of the Hyrax Hill

Neolithic Site (Bower *et al.* 1977). Although the analysis of only retouched pieces may complicate the comparisons, the Maringishu assemblage appears to be dominated by obsidian from the upper Eburru and Masai Gorge areas (Table 6). The southern Naivasha area obsidians, Sonanchi and Njorowa Gorge, are present but relatively infrequent. The very low frequency of obsidian from the Kisanana source is mildly surprising as this source is just 7 km distant and provides good quality obsidian in moderate abundance. Additional analyses of the flakes and fragments from the site are planned, for visual inspection suggests that Kisanana obsidian may be significantly more common in the flakes and fragments than in the retouched tools.

Further to the northeast, a sample from Level 2 of the KFR-A5 rock shelter in Laikipia District was analyzed. This level has cremations and ceramics which are generally referrable to the Pastoral Neolithic, although to exactly which ceramic tradition is uncertain (Siiriäinen 1977). Obsidian forms approximately 15% of the stone assemblage and Masai Gorge and Eburru area obsidians predominate. Njorowa Gorge and Sonanchi area obsidians are relatively infrequent. The Karau source is represented, but less frequently than in the earlier Level 6 at this site. Noteworthy is the single piece of northern Kenyan *Group 1* obsidian which, if the assignment is confirmed, may have traveled upwards of 400 km, suggesting contact with the eastern Lake Turkana region. Overall the Pastoral Neolithic level at the KFR-A5 shelter displays a rather eclectic pattern of obsidian source utilization, a pattern akin to that of the Lukenya Hill rock shelters.

From the northernmost parts of Kenya samples were analyzed from the Pastoral Neolithic open sites designated GaJi 4, FwJj 5 and GaJi 2 in the Ileret and Koobi Fora areas east of Lake Turkana (Barthelme 1977). Obsidian forms 95% of the lithic material in the GaJi 4 assemblage, but only 14% and 23% in the other two assemblages (Barthelme 1981). As in earlier sites in this area, the local *Group 1* obsidian is the dominant obsidian present (Table 4). Several other unknown sources, including *F* and *G*, are also represented. A single piece of obsidian from FwJj 5, the Ileret Stone Bowl Site, has a chemistry which is a reasonably close match in the three elements analyzed for the Masai Gorge obsidian from the central Kenyan Rift. However, the color of this piece is not typical of Masai Gorge area obsidian, so the assignment is problematic at best pending additional analysis. In the absence of chemical data on more northern Ethiopian sources the possibility that unknowns *F* and *G* originate from that area cannot be excluded. However, the overall emphasis on local obsidian is clear, and unfortunately does not bear out Ambrose's (1982) optimistic prediction that obsidian sourcing would demonstrate either a strong northward, Ethiopian, or southward, Kenyan, cultural connection for these sites.

From western Kenya, obsidian was sampled from the Luanda and White Rock Point shell middens along the edge of Lake Victoria. These sites contain Kansyore style ceramics and are generally of mid-Holocene age. Obsidian is relatively rare and forms 1.3% and 7.5% respectively of the assemblages (Robertshaw *et al.* in press). Southern Naivasha area and Eburru area obsidians are about equally represented (Table 6). On the northern side of the Winam Gulf obsidian was sampled from the lower levels of the Jawuoyo rock shelter, which is likely to date to the 1st millennium bc (Gabel 1969). The site is situated some 180 km from the major central Rift sources, and obsidian forms considerably less than 1% of the stone assemblage. Again all of the obsidian appears to be of central Kenyan Rift origin, with southern Naivasha area and Mt Eburru area sources about equally represented (Table 6).

Long distance movement of obsidian and 'trade'

In the previous discussion we have tried to avoid implying the mechanisms by which obsidian may have moved from source to sites in the past. Frequently in the literature the term 'trade' has been loosely used (cf. Cole 1954; Bower *et al.* 1977; Michels *et al.* 1983) to describe the long distance movement of obsidian, particularly during later prehistoric times. Seldom however, has the nature of this 'trade' been discussed in any detail, although in a recent article we have been erroneously cited as the source for the statement that 'early pastoral peoples in the Central Rift were part of an extensive exchange network, in which obsidian was a major item' (Robertshaw and Collett 1983:297–98). It is our contention that the mechanisms by which obsidian may have been moved through the area at various times in the past are not certainly known at present.

We have demonstrated that as early as MSA times very small quantities of central Rift Valley obsidians are found up to 190 km from their sources. In LSA times central Rift obsidian is documented as traveling a minimum of 250 km, and in perhaps somewhat greater quantities than previously. The documented distances in both the MSA and the LSA will undoubtedly increase as additional assemblages from Kenya and northern Tanzania are analyzed. Throughout this period the zone of high frequency use extends no more than 50 km from the sources. Sites in the zone 50 to 150 km from sources seldom contain more than 25% obsidian in their assemblages. Only with the advent of pastoral economies around 4000 years ago does the principal use of obsidian extend into the 50 to 150 km zone, and then only in the southern portion of Kenya and northern Tanzania.

Despite the absence of any reliable estimates of prehistoric territorial or range sizes for the region, it is probably not unreasonable to suggest that, in the context of hunting and gathering economies, the zone of high frequency use of obsidian reflects primary access to the sources. The sheer quantities of obsidian and the lavishness of its use in many of these sites make it difficult to imagine that the site's occupants relied on exchange to obtain their supplies. Beyond 50 km obsidian use declines rapidly, and presumably at some distance exchange rather than treks to sources becomes the primary means of movement of obsidian from source to site.

With the appearance of the large open Pastoral Neolithic sites in the southern region not only does obsidian use predominate over a wider area, but it appears there is much greater reliance on single or more limited numbers of sources at any individual site. Also, if the different ceramic traditions reflect different cultural groups, different peoples apparently have access to different sets of sources, and these are not necessarily the closest sources. However, whether these changes also reflect the appearance of regular exchange networks within or between pastoralist traditions, or between pastoralists and hunter/gatherers still remains in question. The area in which high frequency utilization of obsidian occurs in the Pastoral Neolithic is, on a comparative scale, relatively small. The zone of high frequency obsidian utilization among early Neolithic villages of the Near East was some three to four times larger (Renfrew 1969). The entire area of extensive obsidian utilization is one which until recently was occupied by a single pastoral people, the Maasai. While we suspect that central Rift obsidian in the most distant Pastoral Neolithic sites in northern Tanzania owes its presence to some form of exchange, this need not necessarily be the case in sites within the 50 to 150 km zone where it is extensively used. The distances from sources to

Lukenya Hill and the Loita Hills and Plains where most of the sites have been reported are generally on the order of 100 to 130 km. This distance we would argue is not so great that pastoral peoples could not have supplied their needs by occasional treks to sources. At this stage the existence of an extensive exchange network involving obsidian remains a hypothesis needing further examination. Clearly the topic of exchange networks and the role obsidian may have played in them during the last several millennia is an intriguing area for future study.

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