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TRANSPORT AND SUBSISTENCE PATTERNS AT THE TRANSITION TO PASTORALISM, KOOBI FORA, KENYA*

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The Turkana Basin in Kenya has an extensive record of Holocene activities relating to mobility and economy of foraging and herding communities. Obsidian is only known from a few key localities in northern Kenya. As such, the use of obsidian as a toolstone material, commonly used during the mid-Holocene, provides one way to trace exchange, interaction and population movements during the transition to pastoralism. We employ X-ray fluorescence to characterize obsidian artefacts from four Pastoral Neolithic assemblages. Data reveal a highly mobile and diversified population that used watercraft to access and transport obsidian resources. Specifically, the use of the North Island obsidian source in Lake Turkana indicates that boat use was significant during this transitional period. The incorporation of watercraft transport and aquatic resources in our analyses of Pastoral Neolithic sites affords a greater understanding of subsistence, mobility and economy in this important period in East African prehistory.

KEYWORDS: OBSIDIAN, TURKANA, PASTORAL NEOLITHIC, XRF, CHARACTERIZATION, WATERCRAFT

INTRODUCTION

Geochemical studies of obsidian have been used to address a number of important archaeological problems in many parts of the world. Such investigations have provided evidence for long-distance trade, exchange, contact and resource utilization in eastern Africa (Merrick and Brown 1984; Merrick *et al*. 1994; Negash *et al*. 2006; Negash and Shackley 2006; Ndiema *et al*. 2010), Mesoamerica (Glascock *et al*. 1999; Braswell *et al*. 2000; Burger and Glascock 2000; Glascock and Neff 2003), South America (Bellot-Gurlet *et al*. 1999; Burger *et al*. 2000; Vasquez *et al*. 2001), North America (Shackley 1992, 1995, 1998; Glascock *et al*. 1999) and the circum-Mediterranean region, including the Middle East (Renfrew 1977; Torrence 1986; Tykot 1997, 1998; Gratuze 1999). In this paper, we present one element of an ongoing multidisciplinary project addressing environmental change and the associated cultural response on the east side of the Lake Turkana Basin between 9000 and 900 BP. Specifically, we are examining obsidian procurement as a way of understanding interaction, exchange and population movements in the past. The overall research focus of the umbrella project entails an investigation of the adoption of pastoralism as a subsistence strategy in the region. As part of this larger project that deals with multiple aspects of human–environment dynamics during the Holocene, we have been actively

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pursuing a programme of geochemical characterization of obsidian artefacts and regional sources in an effort to determine where Holocene peoples were obtaining toolstone material. Here, we report results from four sites at Ileret, along the northeastern shore of Lake Turkana. The inhabitants of these sites either kept or had access to domestic stock. These early herding cultures are commonly referred to as the Pastoral Neolithic (PN) in East Africa (Nelson 1973; Bower 1991). We also present the elemental composition of obsidian from three sources within the Lake Turkana Basin (Surgei, Shin and North Island) where obsidian outcrops were sampled for geochemical characterization.

Despite extensive archaeological research on the Holocene in the Lake Turkana Basin, few sources of obsidian have been characterized and published (but see Merrick and Brown 1984; Merrick *et al*. 1994; Brown *et al*. 2009). In Africa, the vast majority of well-documented sources of obsidian are found in Ethiopia, Eritrea, the Great Rift Valley of Kenya, northern Tanzania and northern Chad (Baker and Henage 1977; Omi and Agata 1977; Skinner 1983; Watkins 1983; Negash *et al*. 2006; Negash and Shackley 2006). Obsidian artefacts have been recovered from archaeological sites ranging from the Early Stone Age (ESA) (Negash *et al*. 2006) through the Neolithic (Merrick and Brown 1984; Merrick *et al*. 1994) to recent civilizations such as Aksum in Ethiopia (Phillipson 1977, 2009). Although previous geological research (Watkins 1983; Merrick and Brown 1984) reported a number of obsidian sources in the Lake Turkana Basin, comprehensive geological surveys for potential obsidian sources have not been published to date. However, new research is ongoing by us and others, that will probably provide information on previously undocumented sources of obsidian throughout eastern Africa.

The collection and characterization of source samples is particularly important, as a number of PN lithic assemblages in Lake Turkana are composed of up to 96% obsidian (Barthelme 1981, 1985; Ndiema *et al*. 2010). To date, few studies have been conducted to assess the geological provenance of artefacts from Pastoral Neolithic sites within Holocene sediments, defined as the Galana Boi Formation on the eastern side of the Turkana Basin. This has been hindered by a lack of obsidian source data. The only published geochemical investigations of obsidian artefacts for PN sites in Lake Turkana Basin are at the sites of GaJi4, Gaji2 and FwJj5 at Koobi Fora and Ileret (Merrick and Brown 1984; Merrick *et al*. 1994). Limited numbers of archaeological specimens from Barthelme's (1985) excavations were characterized using X-ray fluorescence (XRF) and electron microprobe analyses as part of a larger obsidian sourcing and characterization study in East Africa (Merrick and Brown 1984; Merrick *et al*. 1994). Obsidian provenance work by Merrick and colleagues (1994; see also Merrick and Brown 1984) suggested the presence of four distinct geological sources (table 4 in Merrick and Brown 1984: 144). One of the specimens in Merrick and Brown's (1984) analysis bore a close chemical resemblance to a source from the Masai Gorge in the central Rift Valley highlands located over 500 km away. Even though obsidian tools are known from many of the PN sites within and outside the Lake Turkana Basin (Ambrose 2001; Ndiema *et al*. 2010), few comprehensive sourcing studies have been undertaken. Those studies that have been conducted are hindered by a lack of source data. As a result, little is known about the movement of obsidian during the Holocene, and the potential scale and complexity of exchange, contact and/or interaction that may have existed as part of the transport of toolstone within the Turkana Basin. This study assigns geochemical signatures to particular artefacts to develop possible associations between artefacts and geological sources of obsidian. The geochemical provenance study we report on here documents that obsidian was procured from at least five possible sources. Remarkably, one of these sources would only have been accessible using water transport. This documents a part of the PN cultural repertoire that has not been documented previously.

RESEARCH AREA

Lake Turkana is located in arid northern Kenya at about 3°N, 36°E (Fig. 1). This is one of the oldest and largest (7500 km^2 and 125 m maximum depth) closed-basin water bodies found in the semi-arid East African Rift system (Yuretich 1979; Owen *et al*. 1982). The lake is approximately 250 km long. The widest section of the lake measures 40 km, and the narrowest section is approximately 20 km from the eastern to the western shores. The main sources of water to Lake Turkana are surface discharge from the Omo River, which drains the Ethiopian Highlands to the north, and groundwater inflow received from local rainfall.

East African palaeo-environmental data for the late Quaternary and Holocene indicate that Africa—in general, and East Africa in particular—has experienced significant episodes of climate change during the Holocene. The lacustrine rift basins of East Africa are excellent recorders of past climate and provide an unprecedented record of hydrological fluctuations in the northern Kenya rift during the Holocene (Wright 2007; Garcin *et al*. 2009). Data obtained from different geological proxies, such as studies of diatoms, lake-level changes, lake chemistry and lake-drawn sediment cores (Butzer 1980; Harvey and Grove 1982; Owen *et al*. 1982; Lamb *et al*. 2004), indicate that the early to mid-Holocene climate was wetter than it is today. Lake levels rose across East Africa beginning *c*. 11 000 BP, with Lake Turkana, in particular, reaching 80 m above 1976 lake levels around 9500 BP (Butzer 1980; Harvey and Grove 1982). A regional dry phase in East Africa began *c*. 6000 BP, with peak aridity around 4000 BP. At the height of this period, Lake

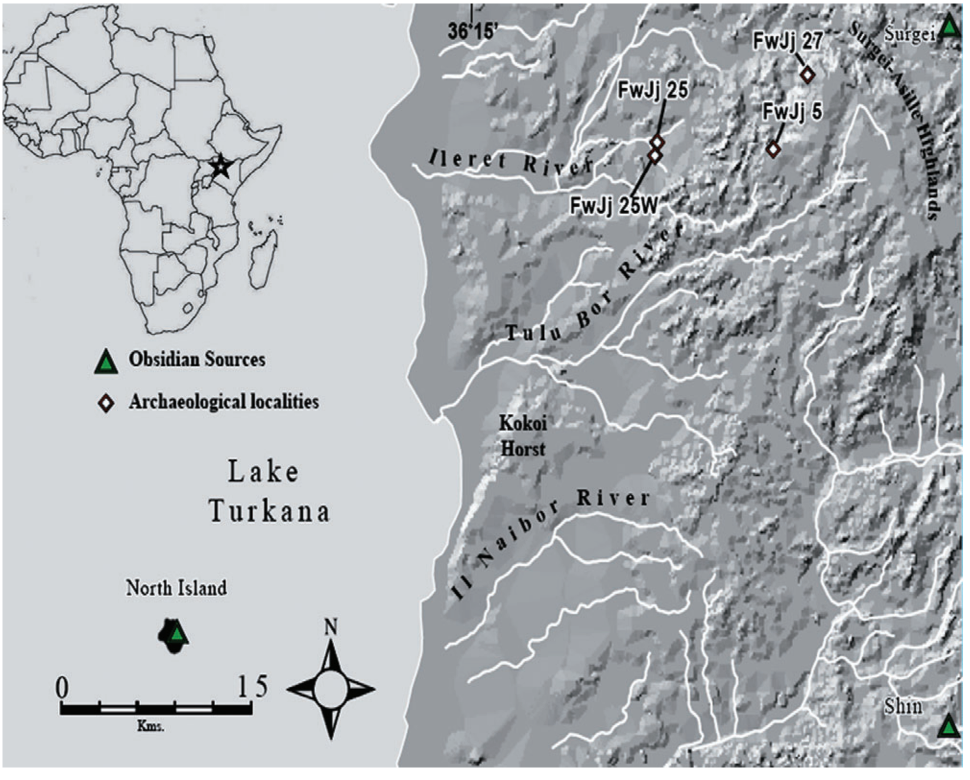

Figure 1 *A locational map of the study area.*

Turkana receded dramatically. The past 4000 years have been characterized by numerous lake-level fluctuations that demonstrate the highly responsive nature of Lake Turkana to changes in the East African climate. New geochronological investigations using radiocarbon (Butzer 1980; Owen *et al*. 1982) and Optically Stimulated Luminescence (OSL) dating techniques (Ashley *et al*. in press) show evidence for increased climatic variability generally within the mid-Holocene timeframe. This time period also hosts the occupation of several archaeological sites, including FwJj27, FwJj25, FwJj25W and FwJj5. In this paper, we limit our analysis to Pastoral Neolithic sites located at approximately 55 m above the 1976 lake levels (Butzer 1980; Owen *et al*. 1982; Olago *et al*. 2009).

METHODS

Obsidian is found in the Turkana Basin at chill zones at the edges of the Miocene pyroclastic centres on the margins of the Turkana Basin, which are often covered by many metres of poorly welded ash. Very few sourcing studies have been published on obsidian in the Lake Turkana region. The most comprehensive was a preliminary study of obsidian sources in Kenya and Tanzania conducted by Merrick and Brown (1984) and Merrick *et al*. (1994), which used X-ray fluorescence (XRF) and electron microprobe to characterize archaeological obsidian. Their relatively small data set of archaeological obsidian specimens ($n = 30$) from sites along the northeastern shore of Lake Turkana revealed a primary reliance on outcrops of obsidian located approximately 60 km east of the modern lake shore, on the Surgei plateau. The other known obsidian source on the outskirts of the Turkana sedimentary basin is the Shin volcano, located to the south-east of our research area. Multiple undocumented obsidian sources probably also exist to the east of Lake Turkana, and to the north in Ethiopia. However, data for this paper are limited to the sources that are well documented within the Kenyan side of the Lake Turkana Basin. Data from southern Ethiopia, a likely source area for obsidian found in the Turkana Basin, are under study (Brown *et al*. 2009).

In this study, we investigate raw material transport using collection of obsidian artefacts that were recovered during excavations and systematic surface sampling at sites FwJj27, FwJj25, FwJj25W and FwJj5 (Barthelme's Stone Bowl Site [1985]). These four localities were chosen for further investigation because they have yielded evidence of aquatic species, wild and domesticated fauna, bone harpoons, decorated and undecorated pottery, retouched tools, unstandardized outils écaillés and cores (Barthelme 1985; Ndiema *et al*. 2010) in lacustrine beach sands 55 m above 1976 lake levels. Archaeological materials were covered by Holocene sediments that accumulated as the lake level fluctuated and eventually regressed to modern levels.

Obsidian artefacts were initially examined to determine if visual characteristics could be used to identify categories of *visual types* that may be correlated with geochemical types. Two main visual types were identified: the first was a translucent obsidian that appeared black in reflected light and green in diffused light. This visual type represented approximately 42% of all obsidian recovered at all our sites. The second visual type was opaque obsidian that appeared black in reflected light and brown or 'root beer' in diffused light. This colour was only visible along the thinnest margins, as this material was almost entirely opaque. This visual type represented approximately 18% of all obsidian recovered from our sites. The remaining obsidian artefacts (40%) were not easily assigned to either visual type. Although there was a loose correlation between visual type and geochemical groups, this is not a reliable method for assigning artefacts to geochemical sources.

To minimize sampling bias, equal proportions of retouched tools, large debitage, formal and micro-debitage were sampled (Eerkens *et al*. 2008). A random number generator was used to select artefacts for analysis. Instrumental characterization of artefacts and sources was undertaken using energy-dispersive X-ray fluorescence (ED-XRF) for both artefacts and sources. Any artefacts that were too small for adequate characterization were eliminated from the analysis. Trace element analyses were performed at the Archaeological X-ray Fluorescence Laboratory at the University of California, Berkeley, using a Spectrace/ThermoNoran™ QuanX energy-dispersive X-ray fluorescence spectrometer. The spectrometer is equipped with an air-cooled Cu X-ray target with a 125 µm Be window, and an X-ray generator that operates in the range 4–50 kV/0.02–2.0 mA at 0.02 increments, using an IBM PC based microprocessor and WinTrace™ spectra reduction software. The X-ray tube is operated at 30 kV/0.14 mA, using a 0.05 mm (medium) Pd primary beam filter in an air path at 200 s live time to generate X-ray intensity K_α line data for the elements titanium (TiO_2), manganese (MnO) and iron (as Fe_2O_3 total) and, using the L_α line, for rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr) and niobium (Nb). Major and trace element intensities were converted to concentration estimates by employing a least-square calibration line established for each element from the analysis of international rock standards, certified by the National Institute of Standards and Technology (NIST), the United States Geological Survey (USGS) and the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1994). Line fitting is linear (XML) for all elements except Fe, where a derivative fitting is used to improve the fit for high concentrations of iron and thus for all the other elements. Further details concerning the petrological choice of these elements for obsidian characterization are available in Shackley (1995, 1998, 2005)—see also Hughes and Smith (1993).

The data from the WinTrace™ software were translated directly into Excel™ for Windows™ for manipulation and then into PAST for statistical analyses. To evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 was analysed during each sample run for obsidian artefacts and sources to check machine calibration. Standard values are included in Table 1.

RESULTS AND DISCUSSION

A total of 800 pieces of lithic material were recovered during recent excavations of these sites, including materials made of basalt, chalcedony, jasper and obsidian. Of the obsidian specimens, 140 were analysed and the results reported here. No correlation between raw material type and artefact type was noted, except for correlations explained by raw material nodule size (ranked artefact type versus raw material nodule size; Kendall's tau = 0.79; $p = 0.02$). OSL dates from FwJj27, FwJj 25 and FwJj25W cluster around 4000 BP (Ashley *et al*. in press). FwJj5, Barthelme's Stone Bowl site (1985), may be much younger at 1000 BP, and contains artefacts such as stone bowls and Nderit ware ceramics. This ceramic tradition is widely regarded as associated with the first pastoral peoples to occupy northern Kenya.

Ten elements were measured using the above methodology and are presented here in parts per million (ppm) values (Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb and Ba). The elemental compositions of both the artefacts and geological reference samples are presented in Table 1 and plotted in Figures 2 and 3. Figure 3 shows results of ED-XRF characterization of archaeological samples from FwJj27, FwJj25, FwJj25W and FwJj5 and source compositions from Surgei, Shin and North Island. The data in Table 1 and Figure 3 clearly show that the archaeological collections of obsidian artefacts from FwJj27, FwJj25, FwJj25W and FwJj5 incorporated several different

Table 1 *Elemental composition of geological source specimens from the Surgei, Shin and North Island sources*

Sample no.	*Location*	*Source*	*Ti*	*Mn*	*Fe*	*Zn*	*Rb*	*Sr*	*Y*	*Nb*	*Zr*	*Ba*
NI1	North Island	Source	3 395.694	893.953	41 929.587	138.734	114.907	154.98	81.174	677.654	120.658	810.242
NI2	North Island	Source	1 308.526	298.752	28 474.213	196.779	124.542	14.819	93.628	708.415	141.632	42.418
NI3	North Island	Source	3 333.274	948.326	43 612.344	143.887	123.88	102.037	82.92	729.601	134.376	905.035
NI4	North Island	Source	1 492.177	616.46	29 200.72	207.231	104.568	21.949	91.213	795.859	102.901	160.652
NI5	North Island	Source	2 181.75	922.87	31 256.9	201.486	116.078	11.144	80.284	657.022	96.421	456.64
NI6	North Island	Source	2 770.948	890.077	39 405.042	136.378	131.614	84.548	86.108	757.875	130.313	725.597
NI8	North Island	Source	2 753.567	905.042	39 693.353	153.113	131.741	77.716	86.427	757.258	132.024	579.901
NI9	North Island	Source	3 424.29	1 111.646	47 677.195	172.377	148.258	80.568	94.329	808.874	146.034	958.955
NI11	North Island	Source	2 734.965	990.309	40 201.358	144.599	139.637	89.36	87.95	805.358	142.46	1 120.407
NI12	North Island	Source	3 072.326	900.799	40 056.205	143.839	135.316	89.732	87.669	764.249	131.97	846.352
SH1	Shin	Source	1 220.68	561.056	25 406	214.442	132.264	37.301	106.87	1 080.43	134.843	54.33
SH2	Shin	Source	1 408.672	856.155	26 745.294	203.146	119.125	14.644	111.451	1 093.547	146.358	63.907
SH3	Shin	Source	1 408.672	856.155	26 745.294	203.146	119.125	14.644	111.451	1 090.547	146.358	63.907
SH4	Shin	Source	1 220.68	561.056	25 406	214.442	132.264	37.301	106.87	1 086.43	134.843	52.61
SRG	Surgei	Source	1 712.7	576.701	28 530.5	248.356	130.712	37.953	138.055	1 179.54	147.822	52.36
SRG3	Surgei	Source	1 495.185	868.231	69 066.768	262.248	126.681	24.665	142.004	1 171.17	150.309	–4.333
SRG4	Surgei	Source	1 352.65	657.556	30 517.7	262.38	163.838	44.693	121.93	1 188.24	149.62	53.62
SRG5	Surgei	Source	1 671.212	611.458	33 582.643	289.83	163.857	20.297	138.463	1 285.346	154.26	25.366
SRG6	Surgei	Source	1 095.178	6 603.909	138 460.197	287.547	122.489	26.008	158.482	1 090.978	137.12	63.715
SRG8	Surgei	Source	1 635.707	535.721	33 922.181	279.947	134.382	19.56	129.705	1 219.486	151.39	30.258
SRG9	Surgei	Source	1 419.714	550.652	29 573.49	249.171	139.894	32.335	130.714	1 199.633	153.47	102.721
SRG10	Surgei	Source	2 572.476	7 285.15	39 614.559	299.763	146.068	37.048	136.421	1 231.074	154.758	186.397
SRG11	Surgei	Source	1 581.475	683.7	31 229.627	263.845	165.086	32.114	131.673	1 240.754	154.788	105.981
SRG12	Surgei	Source	1 775.166	609.513	31 198.84	263.514	169.155	21.595	137.775	1 246.316	164.354	53.926
SRG13	Surgei	Source	1 743.646	602.101	38 952.345	289.091	155.958	16.364	129.344	1 303.822	163.089	18.421
SRG14	Surgei	Source	1 956.943	2 397.843	46 267.435	261.698	138.57	34.596	137.391	1 324.483	156.206	527.207
SRG15	Surgei	Source	1 735.213	688.359	31 671.958	287.681	153.489	22.336	138.426	1 221.611	155.74	62.107
SRG16	Surgei	Source	1 860.377	577.047	31 287.249	255.685	146.918	15.901	132.296	1 246.275	163.376	49.935
RGM1-			1 499.4	12 850.11	37.279	146.908	24.376	224.873	10.008	805.543	26.511	20.065

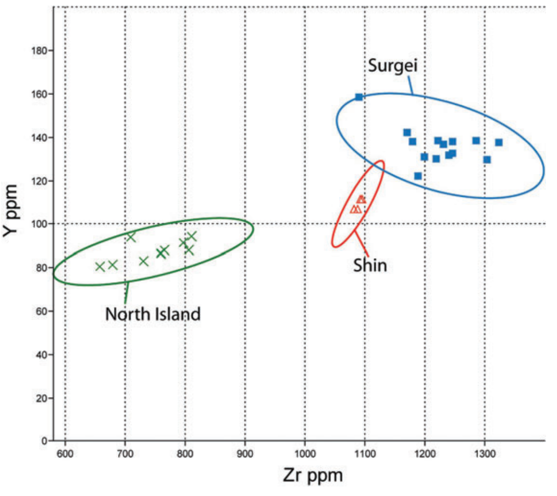

Figure 2 *Scatter plots for geological samples characterizing geographically distinct obsidian outcrops.*

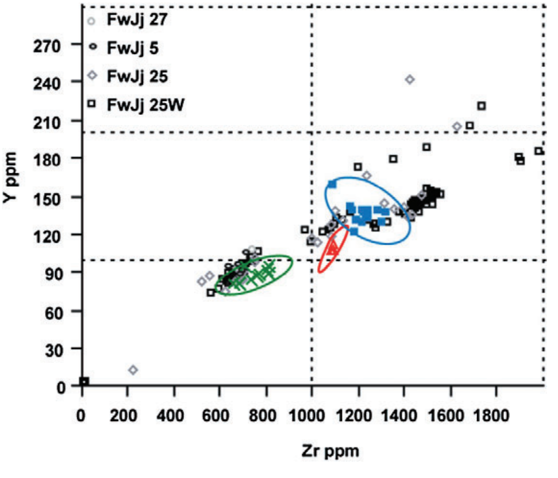

Figure 3 *A two-dimensional scatter plot of zirconium and yttrium for archaeological and geological samples from the Lake Turkana Basin.*

sources of obsidian. Based on the fact that the sources do not overlap significantly (95% confidence intervals; Fig. 2), we assume that at least three geochemically distinct sources are present in the assemblage. We recognize these distinct sources as Surgei, Shin and North Island (Fig. 1). A principal components analysis of the trace element chemistry also shows similar distinctions between sources. However, this multivariate analysis shows significant overlap between the Shin and North Island geochemistry. That said, many artefacts fall within the 95% confidence interval of North Island source geochemistry (Fig. 4).

Due to the large geographical extent of the Surgei outcrop, there may be multiple, geochemically identifiable subsources within the Surgei obsidian source. The Surgei obsidian source (UTM coordinates 37N 223478, E485868 and 37N 212660, E484106; WGS 84 datum) is located

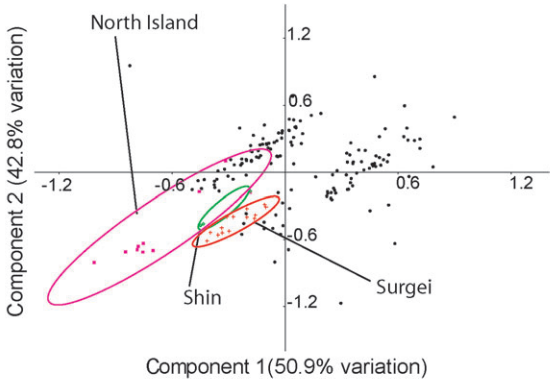

Figure 4 *Principal components analysis of trace element chemistry of source samples and artefacts (data are normalized using a logarithmic transformation to ensure linear relationships in the variance–covariance matrix): 94% of the variation in the data is explained by the first two principal components. The first principal component is positively correlated with Nb (r = 0.77) and Zr (r = 0.75). The second principal component is negatively correlated with Sr (r = –0.73) and Y (r = –0.63).*

along the north-east edge of the Surgei–Asille Plateau. Obvious traces of flaking debris at outcrops, associated with mining and related prehistoric activities, are rare at Surgei (Merrick and Brown 1984; Merrick *et al*. 1994; Ndiema pers. comm.). Evidence of quarrying at Surgei may have been obscured for multiple reasons. Outcrops of obsidian are relatively inconspicuous and numerous livestock tracks in the region may have obscured evidence of this activity. In addition, this region is currently exposed to intense erosion during seasonal rains, which may have removed quarry debris/or rapidly buried evidence of quarrying behaviours.

The smaller Shin volcano (37N 220914, E485520) is located along the south-west limit of the volcanic margin of the Lake Turkana Basin. The Shin source is so small that at distances of 20 m away from the outcrop, secondary sources (clastic sediments and cobbles) are infrequent. At distances of 1 km or more, obsidian is completely absent from modern-day drainages. This suggests that if this source was used by prehistoric peoples, obsidian was procured directly from the outcrop and not obtained from secondary sources (i.e., conglomeratic facies). However, the obsidians sampled from both the Shin and Surgei localities are generally of poor quality and are unlikely to have been used frequently as raw material for making stone tools.

North Island (37N 172080, E449563) is 25 km from the eastern shore of Lake Turkana and 18 km from the western shore. The island is a caldera complex, characterized by cinder cones and craters, as well as abundant obsidian flows, though little evidence of archaeological material has been observed. During high lake-level stands through the Holocene, obsidian would have been exposed above the level of the lake, even at the maximum of 80 m above 1976 levels. Moreover, the lowest lake-level stands during the Holocene were at 376 m a.s.l., which is 20 m below the 1976 level (Butzer 1980; Harvey and Grove 1982; Owen *et al*. 1982). Thus, even at the lowest lake levels during the Holocene period, North Island was always completely surrounded by water, and was never accessible by a terrestrial bridge.

The determination that 20–25 of the archaeological specimens are geochemically similar to the obsidian source on North Island raises important questions about the manner in which obsidian was transported during the Holocene in the Turkana Basin. In particular, the indication that artefacts from FwJj5 and FwJj27 are geochemically similar to obsidian outcrops from North Island is unexpected. These two sites are the furthest from the ancient lake shore.

Fishing, including procurement of deep-water species that may have been done by boat, is clearly documented in hunter–gatherer sites from the early Holocene, and represented a diversification of subsistence practices that took advantage of seasonal and aquatic resources (Robbins 1984, 2006; Lane *et al*. 2007; Prendergast and Lane 2010). Sutton (1974, 1977) referred to these groups as an 'aquatic civilization'. The presences of harpoons at archaeological sites that date to the early Holocene are evidence for this. Fishing using harpoons appears to have become less common as subsistence practices changed to include domesticated animals. The inclusion of the North Island obsidian source in archaeological assemblages from the mid-Holocene and later may represent a continuation of boat use long after deep-water fishing techniques fell out of practice. This suggests that watercraft were involved in subsistence or trade practices that extend beyond fishing. Robbins' work on the western side of Lake Turkana presented the importance of the lake-edge environment for early herder populations in Lake Turkana (Robbins 1984). Yet the research presented here, documenting an island obsidian source used in the mid-Holocene, provides clear evidence that watercraft must have been used to obtain stone tool materials from North Island, since at no time in prehistory was the North Island source accessible by land. Evidence of prehistoric populations procuring raw materials using watercraft has been reported elsewhere, including obsidian in the Mediterranean area (Tykot *et al*. 2005). Boat use in the early Holocene has been documented elsewhere in Africa. Most notably, the discovery of an 8000-year-old dugout canoe in northeastern Nigeria clearly demonstrates boat transport at this time (Breunig *et al*. 1996).

Barthelme (1981, 1985) and Phillipson (1977) pointed out the large numbers of fish and the absence of fishing paraphernalia at the site of GaJi4, near Koobi Fora, and at Lowasera, a Holocene archaeological site at the southeastern end of the lake. Despite a significant lack of bone harpoons, fish may have still been gathered using nets that perhaps were deployed from boats into deep water. Ethnoarchaeological research among the El Molo and the Dassanech of Lake Turkana today indicate that they still use rafts and dugout canoes for water transportation (Gifford 1977; Kiura 2005, 2008). The same boat technology used to fish in deep water could have been used to procure obsidian from the island source at North Island.

Previous research suggests that prior to the transition to pastoralism, the people of the Lake Turkana Basin were foragers who incorporated a significant amount of fishing in their subsistence economy (Phillipson 1977; Sutton 1977; Robbins 1984, 2006; Stewart 1989). Bone harpoons are common at Holocene sites older than 6000 years. The frequency of these specialized fishing toolkits decreases dramatically and sometimes vanishes at more recent sites. It is possible that fishing still played some role in the subsistence activities at these later sites, as evidenced by fish bones in later assemblages. However, this may have been the product of more complex toolkits, such as nets, aided by use of larger watercraft, such as canoes.

Faunal assemblages at many Holocene sites in the Turkana Basin also contain high frequencies of wild fauna—53% of NISP versus 32% of NISP for domestic fauna (Barthelme 1984; Marshall *et al*. 1984). If the people who produced the Holocene archaeological assemblages in the Turkana Basin used rafts or dugout canoes for water transportation, then they represent a subsistence economy that does not compare to modern analogues—especially those of strict pastoralists. As we look at changes that occurred with a transition to pastoralism from the hunting and gathering way of life, these groups may have been local hunter–gatherers who adopted domesticated animals in times of climate-induced scarcity. Alternatively, they may have focused their subsistence efforts on indigenous food resources that made animal domestication attractive. Another possibility is that these groups spent the majority of their time hunting and gathering local resources, but may have kept livestock as part of a social dynamic associated with interbreeding coalitions with adjacent pastoralist groups (Cronk 1989). Distinguishing these different scenarios may require incorporating other independent lines of evidence, such as faunal remains and ceramics, as well as examining patterns in obsidian procurement. Furthermore, new data on unknown and uncharacterized obsidian sources in the Rift Valley, the Turkana Basin and elsewhere will be necessary for a complete picture of trade and exchange, and population movements in the past. This work is currently ongoing.

Similarities in the assemblage composition between FwJj5, dated to 1000 BP (OSL), and FwJj25 and FwJj25W, dated to 4100 BP (OSL), have been summarized on technological and stylistic grounds. These sites may have been seasonal occupation camps. The groups that produced these assemblages may have been transhumant, perhaps in search for resources such as water or migrating game. Aquatic resources would have provided an additional relatively secure and predictable food supply. Gifford-Gonzalez (1998, 2000) has argued that herders moving into new, higher-risk environments in Kenya and Tanzania may have been forced into trade and exchange relationships with local foragers. Each of the groups in these relationships would have held equal economic and social footing, because foragers possessed intimate knowledge of the landscape, climate and resources. Although pastoralists may have held an economic advantage because of their supply of livestock, they would have required the indigenous knowledge of their neighbouring forager groups. It is possible, therefore, that the occupants of these sites were foragers with access to domestic stock, as well as wild and aquatic resources. To acquire all these resources this population would probably have incorporated a system of high residential mobility.

The mobility of populations can be assessed through the procurement of traceable resources, such as obsidian. Obsidian may have been quarried directly, through travel to sources at Surgei, Shin and North Island; or obtained through trade and exchange networks that linked the inhabitants of sites FwJj5, FwJj27, FwJj25 and FwJj25W to other pastoralist and hunter–gatherer groups outside the immediate Lake Turkana area. Trade, as well as direct procurement, may have at least partially occurred through the use of boats or other watercraft. However, boats may have been used for trade and exchange of other materials as well, linking the region through a series of interaction networks.

Given the lack of information on other obsidian sources in the region and beyond in this part of East Africa, there could easily be other sources that are currently undocumented and uncharacterized. Furthermore, a discussion of other *known* sources not represented in our assemblages is outside the scope of the current paper. There appear to be no close chemical matches with any of the more northerly Ethiopian Rift sources currently known (Negash and Shackley 2006; Negash *et al*. 2006, 2007), and none with the somewhat better-documented central Kenyan sources (Merrick and Brown 1984; Merrick *et al*. 1994). As additional data are obtained, by us and others, on new obsidian sources in the region, interpretations and source assignments may be modified to account for new data. There is a possibility that currently unknown sources may also be available in south-west Ethiopia or southern Sudan.

CONCLUSIONS

Archaeological obsidian assemblages that date to the dynamic period of subsistence shift and environmental change during the Holocene in East Africa have the potential to provide insights into aspects of mobility and the adoption of pastoralism by serving as a record of trade and exchange, population movements and interaction. The earliest Lake Turkana Pastoral Neolithic sites of about 4000 BP are associated with a drop in the lake level from +80 m to 45 m (Barthelme

1985). Perhaps drying climates led to the opening of new pastures/browsing resources in an area that was comparatively free of tsetse. Perhaps both population movement and diffusion of livestock occurred among local populations of hunter–fisher–foragers.

The clear association between fish at the earliest Pastoral Neolithic sites at Lake Turkana could mean that: (1) the mid-Holocene was characterized by subsistence adoptions and diversity in subsistence systems where populations were able to access and use different types of resources, including aquatic resources; (2) the mid-Holocene was characterized by high mobility that may have included water-based transportation, as evidenced by the use of the North Island obsidian source; or (3) there was an increased diversity in the subsistence systems and mobility patterns. Stewart (1989) showed that when the lake level fell during the mid-Holocene, fish species diversity increased in archaeological assemblages. Stewart argues that the initial fishing adaptation during the early Holocene at Lake Turkana 'represents small hunting groups exploiting fish resources on a seasonal basis' (Stewart 1989, 246). Therefore any fish-eating prohibition was a comparatively recent development. Instead, fish may have been an important prehistoric resource throughout the early-to-mid Holocene, and boat transportation may have been a significant means for mobility, resource procurement and exchange. The inclusion of obsidian from isolated North Island in archaeological assemblages on the eastern shore of Lake Turkana suggests that people routinely travelled to North Island, or interacted with populations living on the island. Future research in the region may reveal that, as prohibitions against fish consumption became widespread, the use of boats for transport and exchange, and therefore the use of the North Island obsidian source, may decrease significantly. We hope to address this question in future studies.

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