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NUMBER 3
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THE CUTTING EDGE:

New Approaches to the Archaeology of Human Origins

Editors

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COVER CAPTIONS AND CREDITS

Top: Homo habilis Utilizing Stone Tools. Painting by artist-naturalist Jay H. Matternes. Copyright 1995, Jay H. Matternes. Inspired by a prehistoric scenario by K. Schick and N. Toth in Making Silent Stones Speak: Human Origins and the Dawn of Technology (1993), Simon and Schuster, New York. Pp.147-149.

Lower right: Whole flake of trachyte lava from the 2.6 million-year-old site of Gona EG-10, Ethiopia. Reported by S. Semaw (2006), "The Oldest Stone Artifacts from Gona (2.6-2.5 Ma), Afar, Ethiopia: Implications for Understanding the Earliest Stages of Knapping" in The Oldowan: Case Studies into the Earliest Stone Age, eds. N. Toth and K. Schick. Stone Age Institute Press, Gosport, Indiana. Pp. 43-75. Photo courtesy of Tim White.

Lower left: Prehistoric cut-marks from a stone tool on Sterkfontein hominin partial cranium StW 53. Reported by T. Pickering, T. White, and N. Toth (2000) in "Cutmarks on a Plio-Pleistocene hominid from Sterkfontein, South Africa". American Journal of Physical Anthropology 111, 579-584. Scanning electron micrograph by N. Toth.

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CHAPTER 2

Plio-Pleistocene Technological Variation: A View from the KBS Mbr., Koobi Fora Formation

David R. Braun and John W. K. Harris

Introduction

The earliest studies of Oldowan archaeology were aimed at defining the characteristics of the earliest traces of hominin behavior. These studies form the basis of further Oldowan studies in that they create the temporal and geographic structure of this industrial complex. More recent work begins to explore the variation within this structure. Most notably it is now understood that the Oldowan represents a technological system that is not as simple as it was once thought to be (Semaw 2000; Roche et al. 1999). It is now common to try and understand the Oldowan by investigating the intricate variability of tool forms (de la Torre 2004; Delagnes and Roche 2005). These studies have added a tremendous amount of understanding to our knowledge of stone artifact production at the onset of tool use (Stout 2002; Stout et al. 2005). However, studies of artifact form rarely link technological variability to the overall context of the archaeological sites (but see Rogers et al. 1994; Blumenschine et al. in this volume). The study of the Oldowan is more than just the study of the chipped stone artifacts but rather incorporates the land use and diet of hominins in a way that begins to explore "why" stone tools were made and discarded. These questions require not only an understanding of the paleoecology around these sites but also a model of hominin stone tool mediated behavior. Both of these factors are often lacking at Oldowan localities (although see Schick 1987; Blumenschine and Peters 1998).

In this study we present new excavations of Plio-Pleistocene archaeological sites in the Koobi Fora Formation and suggest possible hypotheses that may explain the variation across Oldowan landscapes. This study represents the initial description of the excavation of two artifact assemblages (FxJj 82 and FxJj 10) and a partial technological analysis of all Oldowan assemblages from the KBS Mbr. of the Koobi Fora Formation, northern Kenya (including FxJj 1 and FxJj 3). Here we combine new technological analysis of the KBS Mbr. sites with information regarding the paleogeography and paleoecology of the basin to explore patterns of landscape scale stone tool usage. Although the KBS Mbr. outcrops over hundreds of kilometers in the Lake Turkana Basin, previously excavated sites from the Koobi Fora Formation in this time period are restricted to a few localities in paleontological collecting areas 105, and 118 (Isaac and Harris 1997a; see Figure 1). Several surface localities were located, however large-scale excavation in the KBS Mbr. was limited to three specific sites: FxJj1, FxJj3, and FxJj10. Research on the archaeology of the KBS Mbr. is extensive (Leakey 1970; Isaac 1976, 1978, 1983, 1984; Isaac et al. 1971; Toth 1982, 1987; Rogers et al. 1994). Initial descriptions of artifact assemblages from the KBS Mbr. designated them as the KBS Industry on account of the decreased amounts of small scraper forms in these assemblages (Isaac and Harris 1978). Further interpretation suggested that the sites from the KBS Mbr. were merely a local variant of a broader entity described as the "Oldowan Industry" (Isaac and Harris 1997b). Assemblages in this time period were considered to be "least effort solutions" to a sharp edge.

This study represents the first excavations in the KBS Mbr. since 1973 when excavations ceased at FxJj 10 (Isaac and Harris 1997a). This new round of excavations in the KBS Mbr. was initiated for two major reasons. 1) The existing assemblages from the KBS Mbr. are some of the smallest Plio-Pleistocene assemblages to date. To compare inferences of behavior from the artifact assemblages from this time period to assemblages in other areas of the basin and different time periods, it was necessary to expand the sample. 2) Archaeological materials from the initial excavations in the KBS Mbr. are paleogeographically restricted. Given the known variability of behavioral signatures exhibited over large areas in the Okote Mbr. at Koobi Fora (Rogers et al. 1994) it is likely that the initial round of research in the KBS Mbr. did not document the full range of behavioral variability.

KBS Mbr.: An Overview

The KBS Mbr. was defined by Brown and Feibel (1986) and is delineated by the KBS tuff at the base and the Okote tuff complex at the top of the member (Brown et al. 2006)(see Figure 1). Radiometric ages on these tuffs provide a chronology of 1.88 to 1.6 Ma (McDougall and Brown 2006; Brown et al. 2006) for the entire member. Several small tuffaceous horizons within the KBS Mbr. allow for more detailed chronology but these horizons are usually not as laterally continuous (Brown et al. 2006). The KBS Mbr. is marked by high lateral and temporal variability. This time period is often modeled as a landscape dominated by lacustrine environments to the west and riverine environments to the north and east (Feibel 1988). The river systems that dominate this time period likely represent a paleo-Omo which was likely a perennial yet very dynamic river system. Feibel (1988) suggests the modified form of the Paleo-Omo river system at this time is likely due to increased uplift in the northeastern portion of the basin. Significant sediment input from river systems to the east (possibly a paleo-Il Eriet) probably modified the character

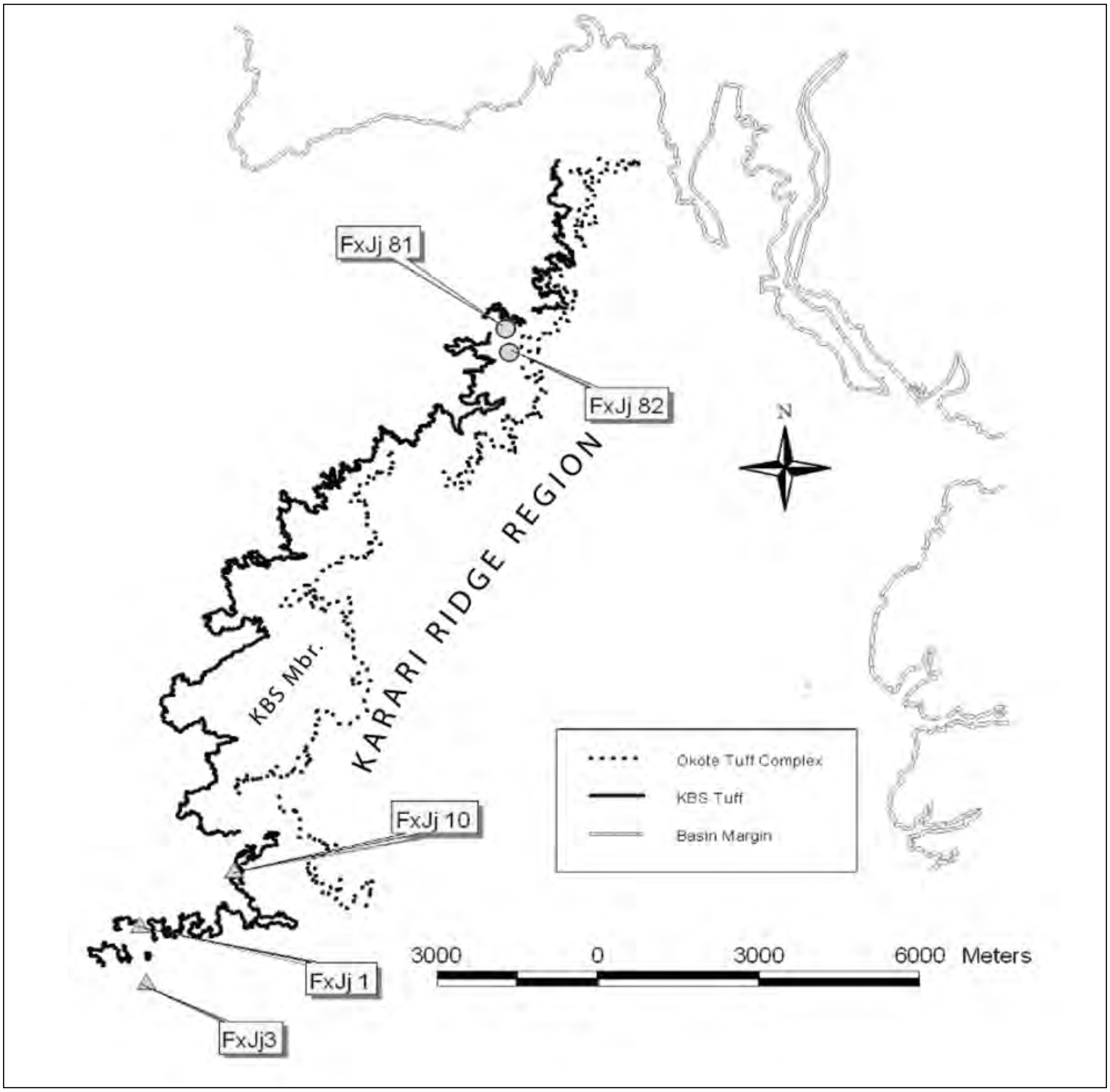

Figure 1. Map of the study region on the eastern shores of the Lake Turkana

of the Paleo-Omo (Feibel 1988; Gathogo and Brown 2006). The Karari Ridge (see figure 1) region of the basin represents a particularly dynamic landscape. Feibel (1988) interprets this area as slightly more upland and dry. Several caliche horizons in this area attest to this interpretation. Faunas from this time period suggest a drying trend with increased numbers of Alcelaphines and Antilopines towards the latter half of the KBS Mbr. (Behrensmeyer et al. 1997). Furthermore the KBS Mbr. is somewhat contemporaneous with a global gradual increase in grasslands possibly associated with the onset of Northern Hemisphere glaciation (deMenocal 1995; deMenocal and Bloemendal 1995; Quade et al. 2004). Despite this general trend there is significant within basin variability and there seems to be a generalized increase in mesic environments from the northeast to the southwest of the eastern side of the basin. In Area 105 where the sites of FxJj 1and FxJj3 are located, abundant fossils of hippopotamus and reduncine bovids suggest a wetter environment (Isaac and Behrensmeyer 1997). Similarly, evidence of broad leaf trees near FxJj 1 in the form of leaf impressions suggest substantial vegetation for some parts of the southwestern part of the study area (Isaac and Harris 1997a).

Previous Excavations in the KBS Mbr.

FxJj1

The site of FxJj 1 was the first site discovered in the Koobi Fora Formation. It was discovered during paleontological and geological survey in Area 105 in 1969 by Anna Kay Behrensmeyer. The site was then named the KBS site (Kay Behrensmeyer Site) and excavation occurred from 1969 through 1972 recovering a total of 138 in situ artifacts. The artifacts recovered from these excavations appear to have been deposited on the floodplain of a channel that is probably part of a southward prograding delta. Fine grained deposits that contain tuffaceous sediments directly below the archaeological horizon record the in fill of a paleo-channel. The site is situated in the bend of a channel that had largely been filed by tuffaceous sediment and must have been in flat swampy conditions. The archaeological collection from FxJj 1 includes smaller detached pieces and the flaked piece assemblage accounts for only 5 in situ and 7 surface finds. Many of the pieces preserve evidence of the outside surface of rounded river cobbles. The low incidence of refitting pieces and the lack of extremely small flaking debris led the Isaac to suggest at least minimal post-depositional water transport of the artifacts and bones at the site. The excavations also recovered numerous faunal specimens. Macromammal remains are dominated by reduncine bovids suggesting possible wetland environments nearby. The presence of fish, crocodile and hippopotamus bones indicates the presence of perennial water source. However, grasslands must have been adjacent to the site as alcelaphine bovids and hypsodont suids (*Metridiochoerus*) were also found at the site. Overall the site represents the infrequent, yet localized, discard of artifacts by hominins in a wet environment that was likely seasonally inundated and had extensive ground cover. The behavioral association between the bones and artifacts was never established with bone surface modifications, Stratigraphic association between the bones and artifacts argues that at least some of the bones are representative of hominin food refuse (Bunn 1997).

FxJj 3

This archaeological site was found in much the same context as FxJj 1. In the southern part of Area 105 there are several outcrops of a large channel system that has been choked by sandy tuffaceous sediment. Modern erosional gullies have exposed the cross section of these channels which is the context of the Hippo and Artefact Site (as it was originally named). The stratigraphic section is largely similar to the depositional context of FxJj 1, yet slight differences in the grain size of the sediments suggest less erosion of the land surface that hosted the discard of artifacts at FxJj 3. Extensive survey was conducted in the region around FxJj 3 to determine if the archaeological finds were transported by the hypothesized paleo-river system. The artifact and fossil bone collection appear to be an isolated event. The original surface finds included 64 artifacts and over 1000 fossil bones. The latter included much of one individual hippopotamus skeleton. Excavations confirmed that the area represented a localized patch of artifacts and bones of about 5 m in diameter. As at FxJj 1, the artifact collection is dominated by detached pieces which are relatively small. However, in the main and adjacent excavation, pebbles to cobbles (upwards of 4 cm in max dimension) were recovered. Along with the artifacts several fossil bones were recovered suggesting a similar environment to that proposed for FxJj 1. The presence of reduncine bovids, extinct pygmy hippopotamus, and two species of crocodile suggest a well watered environment. The behavioral association between the bones and the artifacts cannot be confirmed through bone surface modification studies. Isaac and Harris (1997a) suggests that the abnormally high incidence of bones in fortuitous association with the concentration of artifacts in the area is suggestive that the bones were somehow associated with the deposition of the artifacts. Alternatively, FxJj 3 may have been an area where fresh water was abundant which attracted both hominins and animals to this locale. At present there is no evidence which can determine which hypothesis is more likely. At most we can assume that hominins occupied an area that was seasonally wet (as indicated by the presence of vertisols) near a small channel in a prograding delta.

New Excavations in the KBS Mbr.

FxJj 82

The site of FxJj 82 is a large locality situated in deposits of the KBS Mbr. in Area 130 along the Karari Ridge region of Koobi Fora. The site is located southwest of FxJj 16 and almost due east of the hominin localities KNM-ER 1805 and KNM-ER 1806. The site was discovered during survey in Area 130 in October of 2001. A large carbonate ridge associated with the site is a conspicuous feature in northern Area 130 and caps the section at the KNM-ER 1805 and KNM-ER 1806 localities (Figure 2).

FxJj 82: Local geology

The KBS Mbr. in Area 130 has a complex stratigraphic history. Excavations at the KNM-ER 1805 emphasize that the stratigraphy is dominated by a series of cut and fill structures (Isaac and Harris 1997b). The KNM-ER 1805 and 1806 localities are associated with sediments 1-1.5 m above an orange tuffaceous sands and approximately 1 meter below the base of the Okote Tuff Complex (signaling the base of the Okote Mbr.)(Figure 3). The Okote Tuff Complex does not outcrop at the FxJj 38 locality and correlations were made between the base of the Okote Tuff Complex and the carbonate (caliche) horizon that overlays the artifact and fossil bearing horizons at FxJj 38. The FxJj 82 archaeological horizon appears to be lower than the KNM-ER 1805/1806 horizons. The artifacts and fossil horizons are associated with an orange pumiceous horizon. Geological sections exposed adjacent to the archaeological excavations show that the artifact horizon is approximately 5 to 6 meters below the base of the Okote Tuff Complex. Geological trenches (Geo Trench I, II, III, and IV) associated with the excavation shows that the Orange pumiceous horizon was secondarily incorporated a large soil horizon. Carbonate from this soil were subsequently affected by groundwater carbonate deposition that formed large mats of carbonate. This formed a carbonate horizon of variable thickness that incorporates the horizon where most of the artifacts and fossil bones were recovered from (Figure 4).

Recent studies of stratigraphy of the Koobi Fora Formation and correlations with the Shungura and Nachukui Formation have implications for the stratigraphic position and paleogeographic context of FxJj 82 (Brown et al. 2006; McDougall and Brown 2006). Although deposits near FxJj 82 record evidence of the KBS tuff (1.87 Ma) about 10.8 meters below the archaeological horizon there is considerable evidence in several locations in the Turkana Basin for substantial gaps in the sedimentary record in the Upper KBS Mbr. (Isaac and Behrensmeyer 1997; Brown et al. 2006). Furthermore the majority of the horizons in northern Area 130 that include tuffaceous sediment and pumice gravel appears to fill previous channels. This suggest that fluvial regime in Area

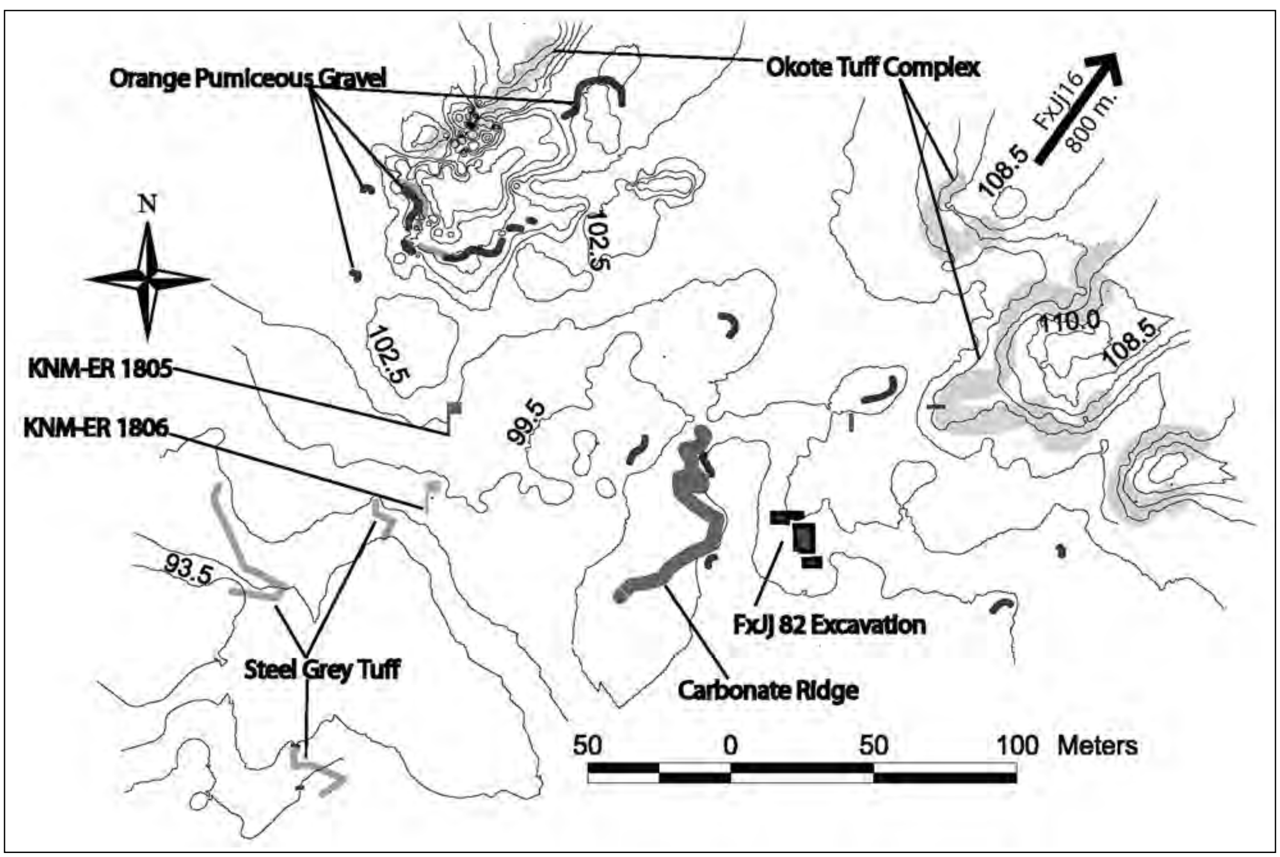

Figure 2. The region around FxJj 82 showing previous hominin finds and major stratigraphic markers.

130 during the upper KBS Mbr. was very dynamic. Geological Trench III records a large grey tuffaceous horizon approximately three meters below the archaeological horizon at FxJj 82 that is most likely the Steel Grey tuff described by Brown et al. 2006. In several locations in Area 130 this tuff is overlain by an orange pumiceous gravel that likely correlates with the similar horizon found in the excavation at FxJj 82. However, sediments north and west of the FxJj 82 excavation record instances where the steel grey tuff has been eroded away and the orange pumiceous horizon overlays the large cross bedded sand that underlies most of the sediments in this area. Based on the assumptions between local tephra and extensive studies of the tephra-stratigraphy (Brown et al. 2006; McDougall and Brown 2006) the archaeological horizon at FxJj 82 is approximately 1.64 Ma.

The site stratigraphy was divided into Layers 1, 2, 3, and 4 (Figures 4-More complete site stratigraphy is provided in Braun 2006)). Layer 1 is orange in color and includes several pumices of pebble to gravel size. This layer also includes several pebbles (< 4cm) of various felsic volcanic rocks and metamorphic rocks. Layer 1 has variable levels of carbonate concretions. Layer 2 is an indurated carbonate horizon that includes a matrix of sandy silt. The carbonate concretions often coalesce to form a mat of carbonate. In some areas this horizon records evidence of pedogenesis in the form of slickensides and slight mottling. Small clasts (3-8 mm) of felsic and mafic volcanics as well as metamorphic rocks are often found locked into the carbonate nodules. Layer 3 is similar to Layer 2 yet without the pebble and gravel component. This horizon is often difficult to distinguish in section because it often is incorporated into the carbonate horizons of layer 2. The relationship between layer 2 and 3 often appears unconformable. Despite artifacts in both horizons the two layers seem to be part of a complex series of small scale cut and fill events. Unfortunately, sedimentary structures are not easily visible in these sediments. They may have been obliterated by subsequent pedogenesis. Layer 4 represents low velocity deposition or overbank deposits in the form of silts. Lateral to the site this horizon appears to have undergone extensive pedogenesis. These four layers are present in all three trenches however they are often lenticular and cannot be found in each wall section. This is a testament to the dynamic sedimentary regime in Area 130.

FxJj 82:Paleoenvironment

The site of FxJj 82 is situated in an interesting position both paleogeographically and chronologically. The paleosol profiles from the upper KBS Mbr. have been used to document the onset of extensive grasslands in the early Pleistocene (Cerling et al. 1988). Changes in the macromammal fauna of the KBS Mbr. suggest changes in the overall ecology of the KBS Mbr. The loss of large arboreal colobines (*Rhinocolobus turkanaensis, Paracolobus mutiwa*) has been attributed to the loss of arboreal habitats through the KBS Mbr. (Feibel 1988).

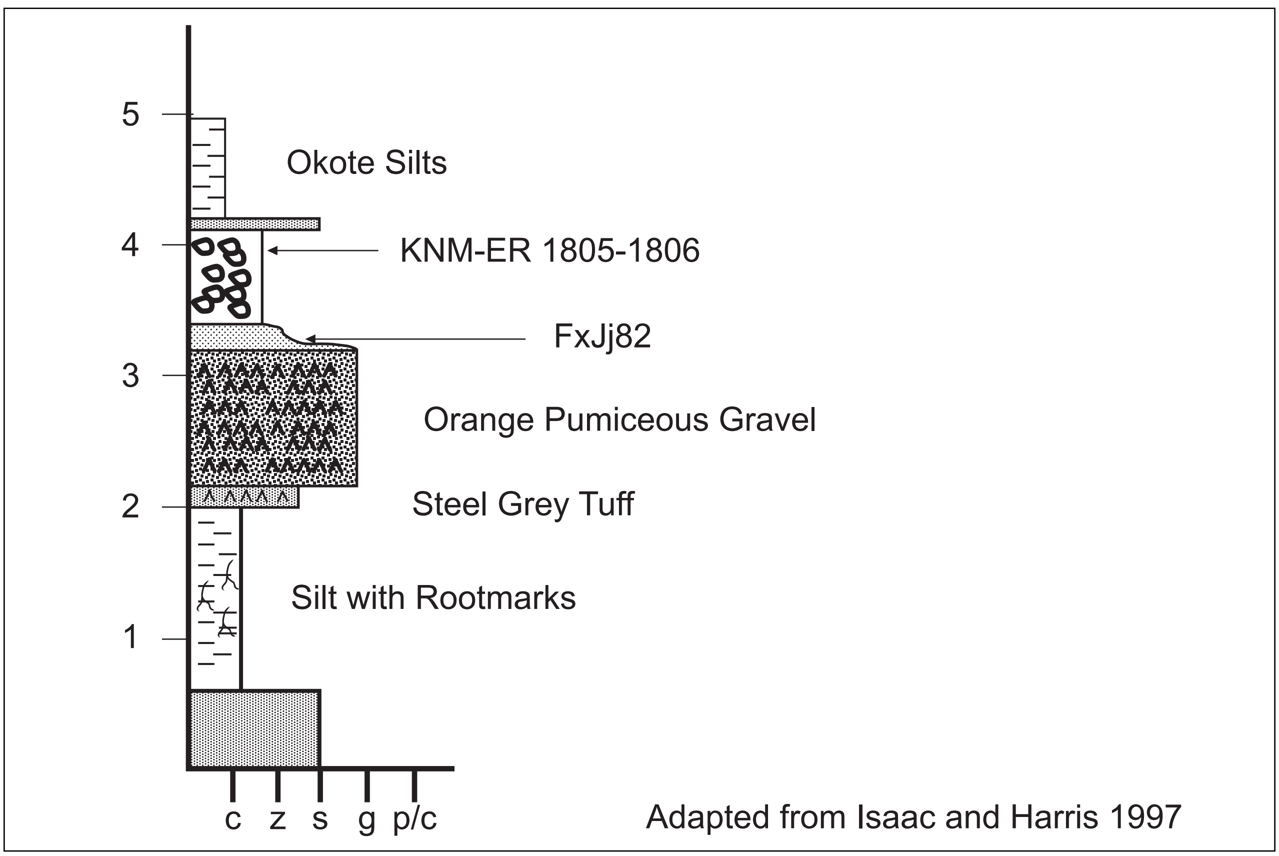

Figure 3. Stratigraphic column showing the relationship between FxJj 82 and the KNM-R 1805 and 1806 localities.

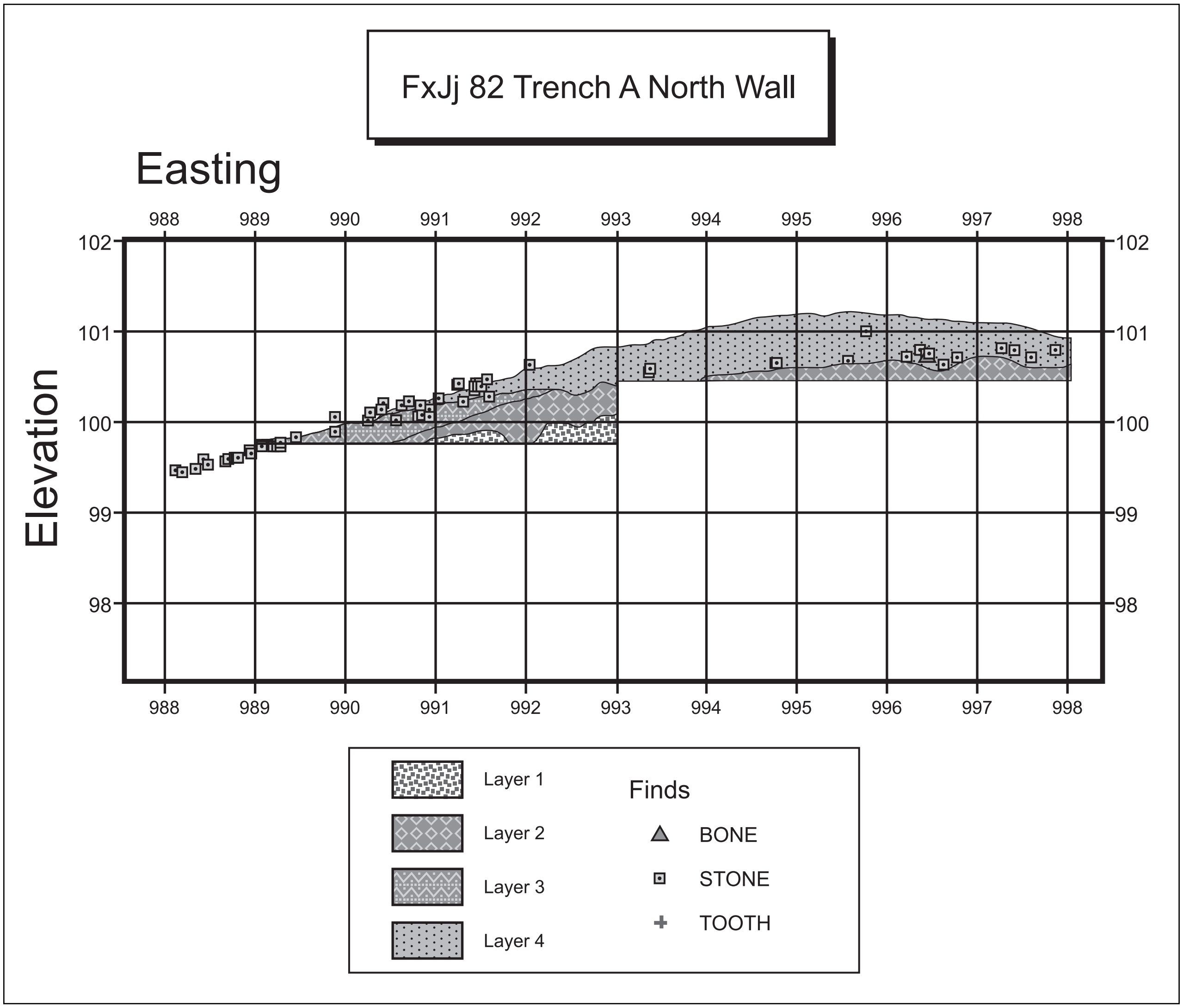

Figure 4. Site stratigraphy of the North Wall of FxJj 82 Trench A.

A steady decline in the abundance of reduncine forms toward the end of the KBS member further reinforces the generalized decrease in wetland habitats toward the end of the KBS Mbr. (Harris 1983). Feibel (1988) has suggested that the extensive caliche development in the Karari region at the upper part of the KBS Mbr. is the result of drier habitats due to the slightly elevated nature of this area. Pedogenic carbonate analysis by Wynn (2004) has suggested a rapid shift in environments toward modern values for stable carbon isotopic ratios at around 1.81 Ma. Wynn (2004) has argued that, mean annual precipitation in the Turkana basin decreased rapidly at about 1.65 Ma, especially relative to more humid conditions with higher precipitation rates in the earlier parts of the KBS Mbr. Finally, the fauna associated with FxJj 82 suggests an extremely variable habitat. The presence of several grazing antelopes (Antilopines, Alcelaphines) as well as hypsodont suids (*Metridiochoerus*) imply a xeric environment. However, the presence of elephant and rhinoceros bones suggest that sufficient vegetation was available to support a suite of large mammals. Based on the evidence of a variety of environmental proxies it appears that the landscape around Area 130 when hominins deposited artifacts at FxJj 82 was laterally variable and likely much drier than earlier periods of the KBS Mbr. Excavations at FxJj 82 recovered 541 artifacts, 264 non-artifactual stones and 141 bones. A listing of artifacts by raw material and artifact type can be found in Table 1. The faunal collection includes bovids (*Parmularis cf. altidens*; *Antidorcas* sp.) suids (*Kolpochoerus andrewsi*, *Metridiochoerus* sp.), equids, hippoptamids (*Hippopotamus gorgops*) and probiscideans.

FxJj 10

Initial excavations at FxJj 10 were conducted from 1972 through 1973. New excavations in 2003 were established in the areas were the highest density of artifacts were recovered during the 1973 investigations (Figure 5). A series of trenches were laid down over a large lateral extent to determine the extent of the archaeological horizon and the vertical dispersion of artifacts within this horizon. Trenches 1 and 2 were located directly next to the 1973 excavations and recovered the majority of the artifacts. Trenches 3 and 5-6 were located grid east of

Table 1. Raw material and typological breakdown of FxJj 82 collection (n=541)

Raw Material	Angular Fragment	Core	Snapped Flake	Split Flake	Whole Flake	Total
Asille Basalt	9.78	2.31	1.60	1.95	4.63	20.28
Chalcedony	3.38	.18	.54	0	1.42	5.51
Gombe Basalt	31.49	5.69	4.45	6.76	14.77	63.17
Rhyolite (Pantellerite)	4.80	.89	.71	1.24	1.42	9.07
Jasper	.71	.18	.18	0	.18	1.24
Quartz	.35	.18	0	.18	0	.71
Unknown	0	0	0	0	0	0

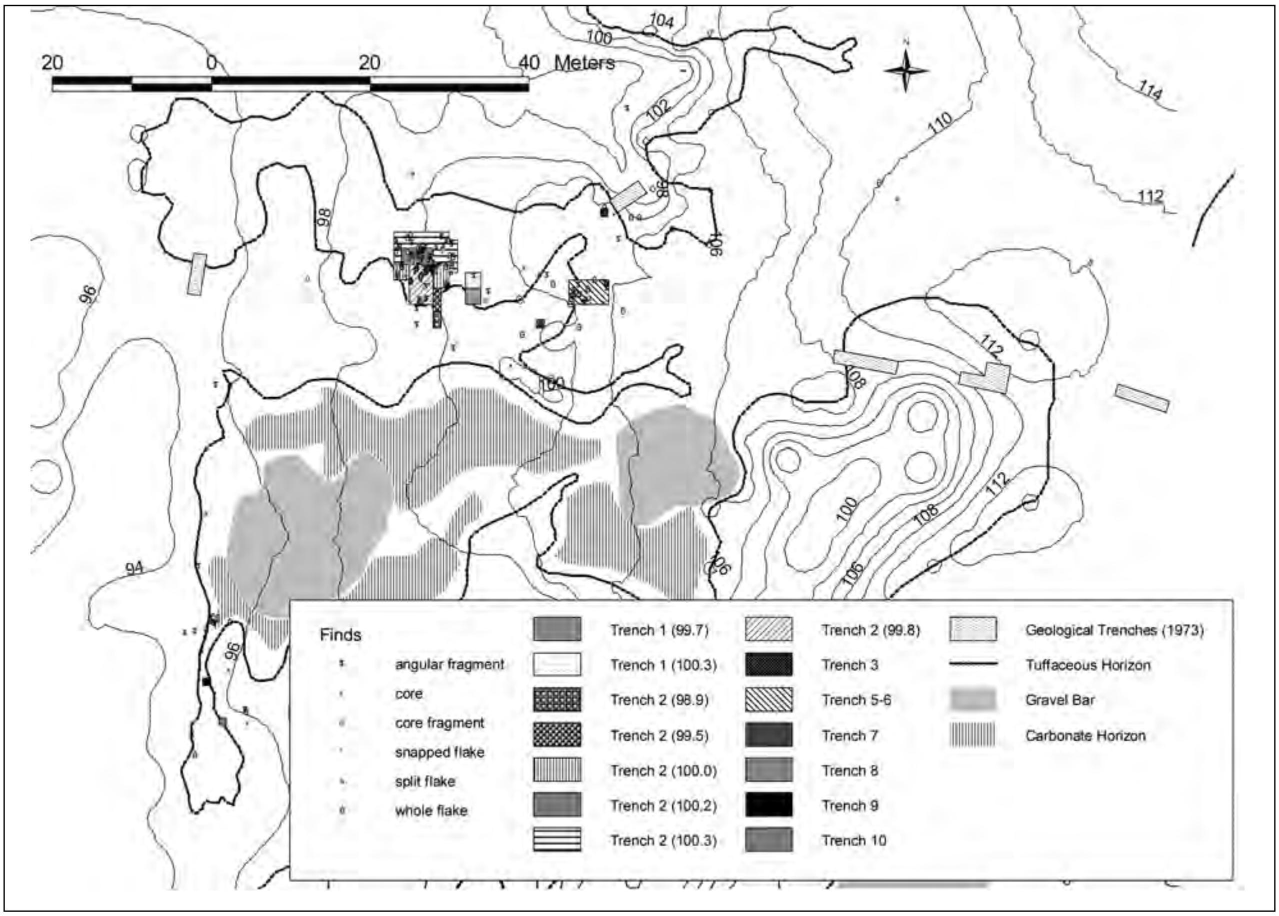

Figure 5. FxJj 10 excavations and surrounding Plio-Pleistocene deposits.

the main excavations and documented the southwesterly dip of all the horizons including the archaeological one. Even though the 2003 excavations were much larger in the area excavated (2003: 89 square meters; 1973: ~19 square meters) the number of artifacts recovered was comparable. The 1973 excavations recovered far more surface pieces than the 2003 excavations suggesting that the FxJj 10 locality was a very large archaeological occurrence that was subsequently eroded over a period of several years.

FxJj 10: Local geology

Paleontological area 118 where the excavation of FxJj 10 is located is not as well studied as some of the other regions of the Karari Ridge. The shallow exposures and numerous faults make the area more difficult to interpret. The initial description of the site assumed that the large fault about 100 meters south of the main excavations was responsible for the erosion that exposed outcrops of the KBS tuff (Isaac and Harris 1997a). It was assumed that the prominent tuffaceous horizon in Area 118 was the KBS tuff because of similar outcrops in nearby Area 105. However, subsequent analysis of the

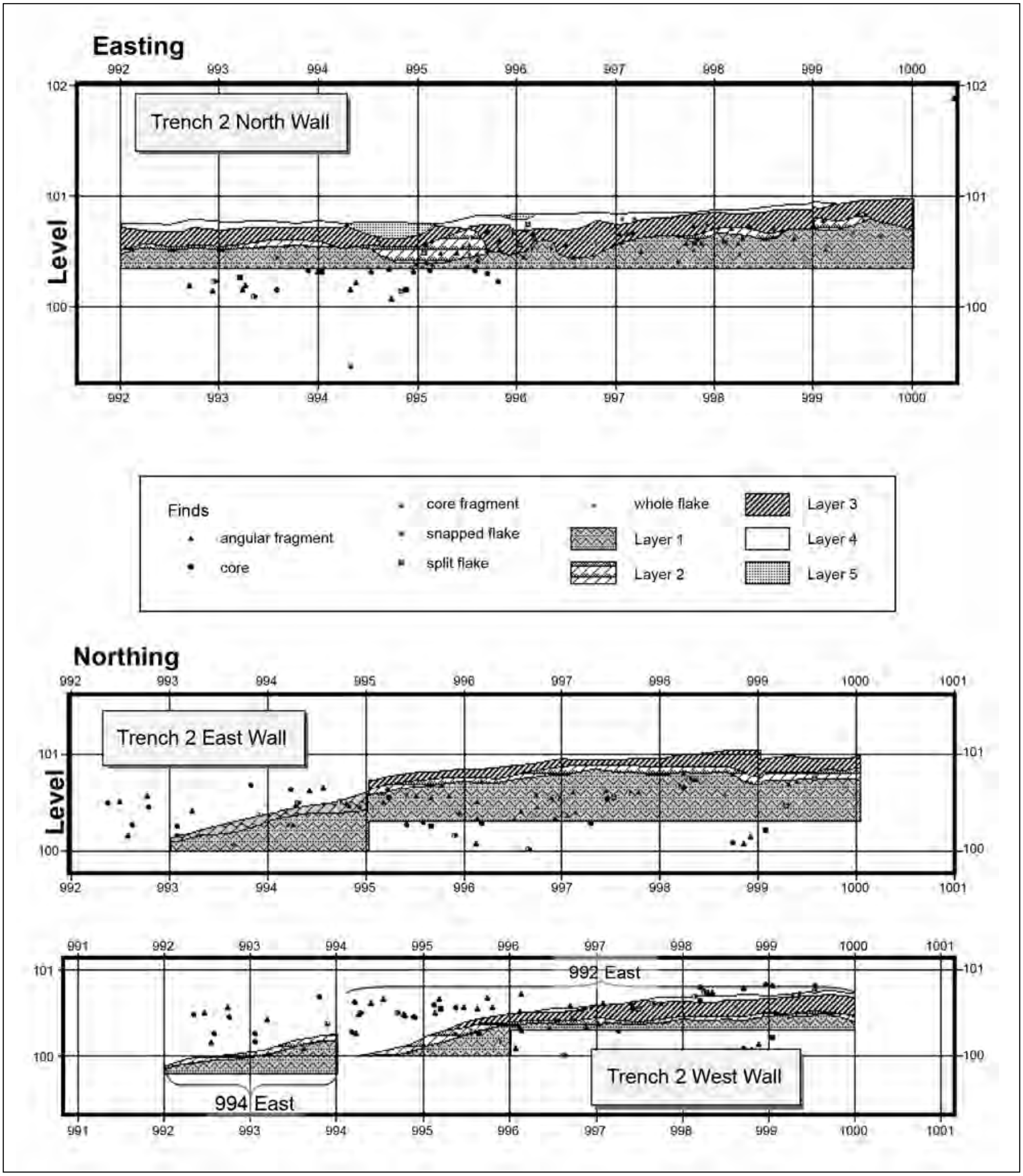

Figure 6. Wall sections of Trench 2 at FxJj 10

geochemistry of the tuffaceous horizons in Area 118 suggests that this horizon is actually the Orange Tuff (Feibel pers. comm.) This designation is further supported by evidence of an orange pumiceous horizon visually similar to the horizon seen in northern Area 130. This orange pumiceous horizon is found at the base of a channel in sediments approximately 120 meters south of the main excavations at FxJj 10. The area around FxJj 10 hosted a tributary of a relatively large fluvial system during late KBS Mbr. times. The appearance of tuffaceous horizons in this channel suggests this was a tributary of the axial river system (proto-Omo). As the Orange tuff at FxJj 10 forms the substrate on which artifacts are deposited, both FxJj 10 and FxJj 82 may represent relatively contemporaneous archaeological occurrences.

The archaeological horizon at FxJj 10 is positioned at about the level of the Orange tuff and is associated with a layer that has undergone extensive pedogenesis. The horizon that underlies the archaeological horizon is a sandy tuffaceous horizon that probably represents proximal floodplain deposits of the nearby channel. Soon after the deposition of the sandy tuffaceous horizon there was a cessation in deposition that led to the pedogenesis of the tuffaceous sandy horizon. A large discontinuous caliche horizon signals the possibility of somewhat xeric conditions in the region during this time. This paleosol horizon is the horizon in which the majority of the artifacts were found (Figure 6).

Although previous excavations had focused the recovery of *in situ* specimens at two trenches, the present study recovered *in situ* archaeological material over a large lateral area. None of the 10 trenches that were excavated in 2003 reached the density of pieces recovered in the 1973 excavations (e.g. 1973 Trench B: 16.5 artifacts per square meter/2003 Trench 2: 1.3 artifacts per square meter). However despite the broad area covered all but Trenches 3, 9 and 10 recovered artifacts. An area over 1000 square meters records evidence of hominin artifact discard at almost the exact same horizon. Original surface collections by Isaac and Harris suggested artifacts were associated with this horizon over an even larger area (Isaac and Harris 1997a: 109). Isaac and Harris (1997a) proposed a possible scenario where artifacts were frequently deposited in the area round FxJj 10 over a long period of time which resulted in a diffuse scatter of artifacts over a large area. The 2003 excavations support this scenario because many artifacts appear to be incorporated in the paleosol and these specimens can be found in situ over an extensive lateral area. During the hiatus in deposition after the floodplain of the nearby channel had been covered by tuffaceous sediments, pedogenesis began. This stable land surface was occupied by hominins repeatedly. Access to cobbles in the nearby channel allowed them access to raw material to make artifacts. These were subsequently incorporated into the paleosol. Intense chemical weathering, likely due to rapidly fluctuating wet and dry periods (seasonal inundation of the floodplain) caused the destruction of both bones and teeth and aided the formation of the extensive carbonate horizon.

The site stratigraphy is divided into five horizons. Layers 4 and 5 represent modern erosion and infill events that occurred during the exposure of the archaeological horizons in Area 118. Layer 4 is recently disturbed silts and clays that probably derive from Layers 2 and 3 and have subsequently slumped downwards off the sometimes steep erosional faces in Area 118. Layer 3 is a sandy silt horizon with some evidence of pedogenesis that has numerous carbonate nodules and some gravel lenses. Carbonate nodules often coalesce to form a solid caliche horizon. Layer 2 is a paleosol that is often discontinuous in the wall sections. It varies from increasing fractions of silt and sand across the length of the excavation but it is characterized by extensive pedogenic weathering including ped structures and mottling. Layer 1 is a silty tuffaceous sand that includes rare pumices. Archaeological finds are usually found at the contact between Layer 2 and 1. Many artifacts were found on the surface suggesting the vertical dispersion of artifacts prior to excavation was extensive. Indeed Isaac and Harris (1997a) comment on the relatively large vertical dispersion of elements in this excavation. This may be the product of soil process but also may be the result of post-depositional processes.

FxJj 10: Paleoenvironments

Unfortunately due to the intense weathering of fossils in Area 118 there are very little macromammal remains that can be used to determine the environments around FxJj 10. The original 1973 excavations recovered six fossils that were too weathered to determine their taxonomic affiliation. The 2003 excavation did not recover a single fossil specimen. Some fragments of enamel were recovered through screening but these were not diagnostic. Only one specimen had a morphology that would indicate that it was medium sized bovid. Considering that FxJj 10 is likely contemporaneous with the regional shift in climate indicated by Wynn's (2004) analysis of the Turkana Basin, it is very likely that Area 118 was experiencing xeric conditions around the time of the deposition of the Orange tuff. The extensive caliche horizon in the region may also lend credence to the designation of FxJj 10 as the hominin occupation of a dry habitat region.

The excavations at FxJj 10 during the 2003 field season recovered 161 artifacts. The typological and raw material breakdown of these finds can be seen in Table 2. The present analysis incorporates another 564 artifacts

Table 2. Raw Materials at FxJj 10 (n=725)

Raw Material	Angular Fragment	Core	Snapped Flake	Split Flake	Whole Flake	Total
Asille Basalt	1.89	.63	.42	.42	.84	4.20
Chalcedony	0	0	0	0	0	0
Gombe Basalt	46.12	5.66	10.06	6.92	25.78	94.55
Rhyolite (Pantellerite)	.42	0	0	0	.63	1.04
Jasper	0	0	0	0	0	0
Quartz	0	0	0	0	0	0
Unknown	0	0	0	0	0	0

from the 1973 excavations. Artifacts were not included in the analysis if significant chemical weathering made geochemical and technical analysis of the material impossible. The combined assemblage size of 725 artifacts is the largest assemblage in the KBS Member.

Raw materials in the KBS Mbr.

Although the igneous rocks in the Lake Turkana Basin include both felsic and mafic rocks the majority of artifacts in the Plio-Pleistocene sediments are made from basalts. These basalts can be geochemically divided into alkali and tholeitic basalts. Alkali basalts are distinguished from the more common tholeitic basalts by lower silica levels and higher alkali content. Rhyolitic rocks can also be found around the basin margin. These are mostly peraluminous rhyolites defined by Watkins (1982) as pantellerites. Associated with these rhyolites are large bands of chalcedonic cherts which are the product of hydrothermal activity leaching the silica from underlying silica rich rhyolitic rocks. These rocks outcrop in small patches in the extreme northern end of the sedimentary basin. All archaeological materials were subject to non-destructive ED-XRF testing to determine the trace element signature of the materials. This allowed the designation of different types of basalts (Figure 7). Rhyolitic rocks can easily be distinguished from basaltic rocks based on the presence of quartz and feldspar phenocrysts. However, Zr concentrations were also checked to confirm this distinction (see Braun et al. in press for further description of this analysis). Tables 3 and 4 show the composition of the original KBS Mbr. localities according the previously described raw material categories.

Debitage Products and Reduction Sequences

The stone artifact collections from the KBS Member represent hominin behaviors in diverse settings. New excavations and extensive raw material sourcing allow the technology of the KBS Member to be viewed in a manner which may reflect the uses and selective pressures acting on tool mediated behaviors. Although transport behaviors were not limited to certain portions of the technological system, previous refit studies have suggested that flaked pieces were the primary tool transported from locality to locality (Schick 1987). Whole flake assemblages may be the best example of behaviors that happened "on site." Here we apply a multiple linear regression model that is based on a series of linear measurements of whole flakes and allows for a reasonably accurate description of the position of a whole flake in a reduction sequence (see Braun 2006 for complete description of the multiple regression model technique). The values for the predicted stage in reduction sequence are not intended to actually recreate the actual sequence number of flakes that were removed in antiquity. Rather the model is used to compare across assemblages in a

Table 3. Raw Materials at FxJj 1 (n=164)

Raw Material	Angular Fragment	Core	Snapped Flake	Split Flake	Whole Flake	Total
Asille Basalt	10.06	4.40	1.26	0	8.18	23.89
Chalcedony	0	0	0	0	0	0
Gombe Basalt	25.79	5.03	5.66	1.89	20.12	58.49
Rhyolite (Pantellerite)	1.89	2.51	0	0	5.03	9.44
Jasper	0	0	0	0	0	0
Quartz	0	0	0	0	0	0
Unknown	2.51	1.89	.63	.63	2.51	8.18

Table 4. Raw Materials at FxJj 3 (n=64)

Raw Material	Angular Fragment	Core	Snapped Flake	Split Flake	Whole Flake	Total
Asille Basalt	3.70	0	3.70	0	0	7.40
Chalcedony	0	0	0	0	0	0
Gombe Basalt	44.44	0	1.85	7.40	31.48	85.19
Rhyolite (Pantellerite)	3.70	0	3.70	0	0	7.40
Jasper	0	0	0	0	0	0
Quartz	0	0	0	0	0	0
Unknown	0	0	0	0	0	0

way that allows comparison of flake manufacture strategies at different sites.

Due to the small sample sizes in some assemblages it is necessary to use non-parametric tests to measure the significance of differences between assemblages. The Mann-Whitney test of two independent samples verified if the distribution between two samples is significantly different, but does not assume a normal distribution of the data. Box plots show that there are significant differences between assemblages in the KBS Mbr. (Figure 8). It appears that there is significant variation within the whole flake assemblages from those sites that are from the lower KBS Member (FxJj 1 and FxJj 3). In general all of the whole flake assemblages from FxJj 1 and FxJj 3 are from significantly earlier in an idealized reduction sequence than flakes from the latter part of the KBS Mbr ($p<.05$). This suggests that whole flake assemblages from sites in the older KBS Member sites were removed from cores that were not as extensively reduced. Furthermore it appears that at least for the assemblages at FxJj 1 there are no extreme outliers to suggest that there are cores being brought into these sites that are extensively flaked. The rhyolite assemblage from FxJj 1 does appear to have outliers that are from much later in the reduction sequence. It is possible that some of the rhyolitic material is being transported into this site.

Increased levels of reduction at FxJj 82 may be the result of increased transport behaviors due to ecological conditions that favor the use of more mobile toolkits. Previous studies have suggested that *H. ergaster* may have had an increased range size (Rogers et al. 1994; Anton and Swisher 2004). Extending the use life of a core by reducing it more exhaustively may have provided the mechanism for the expansion of home and day ranges in these hominins (Braun and Harris 2001, 2003).

Oldowan Technology at Koobi Fora: Synthesis

Oldowan technology represents the first attempt by early hominins to culturally mediate resource acquisition. In that sense it is vital to understand energetic input of technological organization because it should reflect the energetic benefits accrued from stone tool production

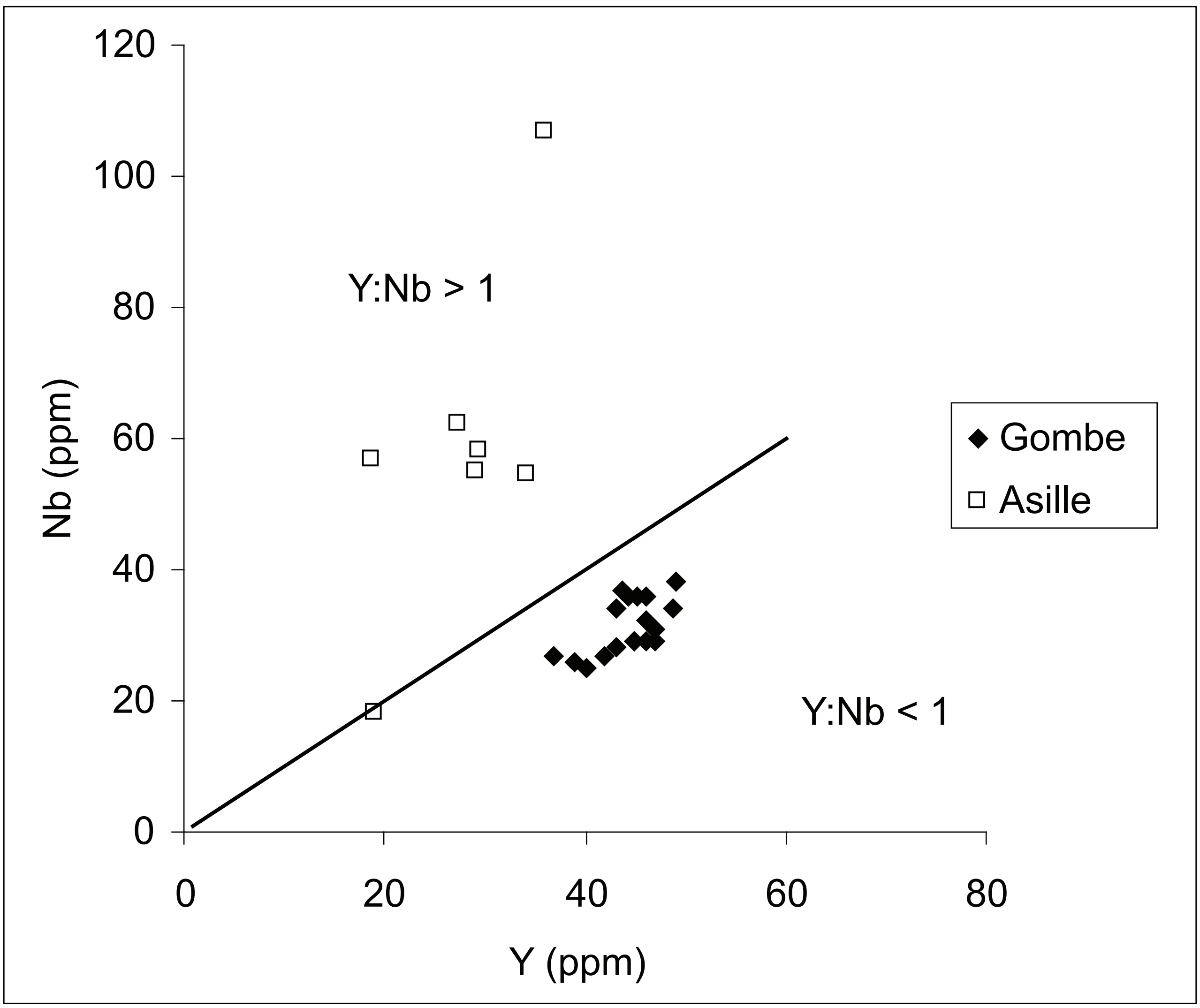

Figure 7. A ratio of Yttrium: Niobium separates the two major basalt groups found in the eastern Turkana Basin.

and use. In this sense the KBS Mbr. assemblages form a very interesting case study because the different factors that affect technological organization are well known (raw material availability and quality). Therefore it is possible to investigate simulate the affects of different ecological settings on patterns of stone tool use and discard. Stone tool technology may represent a method for Oldowan hominins to increase the efficiency of resource acquisition (Bousman 1993). Therefore, increases in the efficiency of stone tool manufacture and use may represent correlative increases in resource acquisition efficiency. Selective pressures acting on stone tool mediated resource acquisition should be directly reflected in attempts by Oldowan hominins to increase the efficiency of their technological organization.

As Oldowan tool kits are simple, modeling increases in efficiency is rather simplistic. Oldowan hominins can increase efficiency by increasing the use life of an artifact, thereby decreasing the time needed to procure new sources of raw material. There are two ways that Oldowan hominins can increase the use life of their technological system. They can increase the use life of a core by simply reducing it more extensively. Exhaustive reduction can be seen as a method of increasing the use life of a flaked piece. The predicted stage in reduction sequence values of whole flakes are a proxy for this behavior. These values record the intensity of core reduction when the detached piece was removed from it. Therefore it is possible that assemblages that exhibit flakes later in the reduction sequence represent cores that are nearing exhaustive reduction levels.

In the KBS Mbr. there are significant differences in the extent of flaked piece reduction between the earlier KBS Member assemblages and the assemblages from the later part of the KBS Mbr. The whole flake assemblage at FxJj 3 represents the least amount of reduction with median values close to 12 or 13, whereas FxJj 82 has median values closer to 24 or 29. Increased levels of reduction at sites later in the KBS Mbr. require further inquiry. One possible explanation may be variation in the requirement of stone artifacts in the behavioral repertoire across various ecological conditions in time and space

The extensive reduction that occurs at FxJj 82 may be the result of a greater need for artifacts and a subsequent attempt by early hominins to preserve their sources of raw material by extensively reducing them. The ability for hominins from the latter part of the KBS

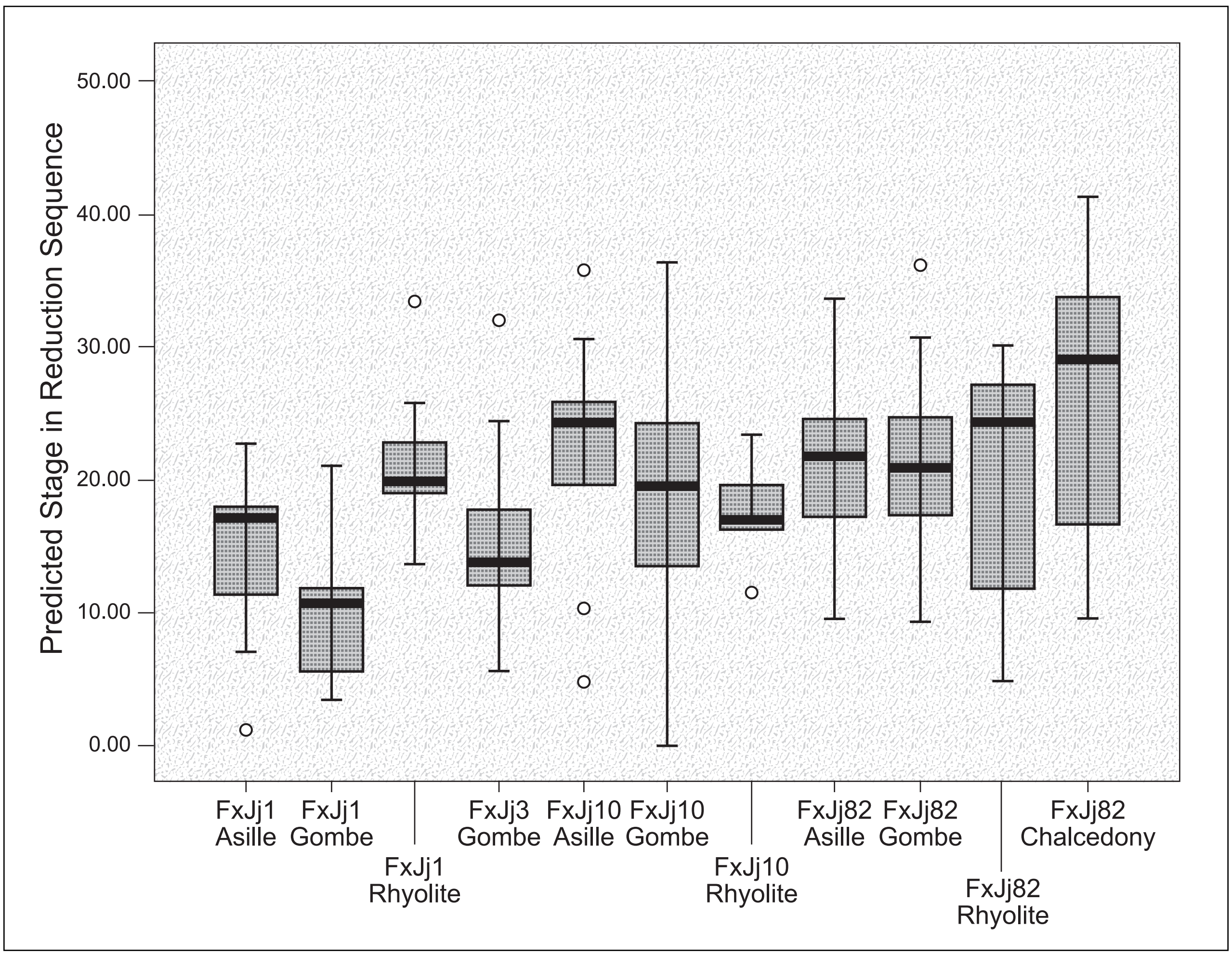

Figure 8. Box plots of predicted place in reduction sequence values for raw material specific assemblages of whole flakes from KBS Mbr. assemblages.

Mbr. to increase the length of time that a flaked piece stayed operable in a technological system may reflect the increased selection pressures for a conservative technological organization in later times in the KBS Member.

The greater effort made by hominins at FxJ10 and especially FxJj82 to conserve raw material sources and extend the use life of their sources of raw material may be a reflection of ecological differences. Although differences in raw material availability could explain the patterns seen in these assemblages, it is an unlikely explanation. FxJj10 and FxJj82 are both located near sources of raw material (Braun et al. in press). During the latter half of KBS Mbr. the basin margin drainage system would have had a higher competence due to increased uplift in the Lake Stephanie basin (Feibel 1988; Lepre 2001). The result would have been a higher incidence of clasts large enough to make artifacts during this time. Since raw material availability cannot explain this pattern, ecological differences may be the cause of variation. Paleoenvironmental data records an increase in xeric conditions towards the end of the KBS Mbr. At FxJj82 and FxJj10 there is proximate evidence to suggest xeric conditions in the form of carbonate horizons associated with soil horizons that were likely subject to intense seasonal variation. Wynn's (2004) analysis of soils during this time interval suggests a drastic drop in rainfall during this time. Macrofaunal evidence at FxJj82 in the form of hyposodont suids (*Metridiochoerus*) and arid adapted bovid species (Alcelaphini and Antilopini) suggest this site was surrounded by arid environments.

Discussion and Conclusion

Water stressed environments have a very different biological structure than more mesic environments. In Africa drier environments tend to have a significant grassland component. In these types of environments the biomass available for hominin consumption is shifted towards large mammals (Leonard and Robertson 2000). Hominins that lived in these environments would have had a limited selection of resources. It is possible that hominin occupation of grasslands required an increased reliance on mammal tissue. Ethnographic and experimental data suggests that certain butchery activities do not place intense raw material requirements on stone tool technologies (Shott and Sillitoe 2005). However, experimental data does suggest that skinning and disarticulation of even small sized animals can drastically reduce the utility of stone edges (Pobiner and Braun 2005). Therefore a technological organization that is focused on intense butchery activity would increase the need for stone artifacts in the behavioral repertoire of these early toolmakers. The potentially drier grassland environments of the later KBS Mbr. may have forced hominins to adapt more conservative tool use strategies. Alternatively, FxJj82 and FxJj10 may represent a greater reliance on stone tool technology because of the physiological requirements of a later hominin species (*H. erectus*). Increased density of artifacts at FxJj82 and FxJj10 may be signaling a more intense reliance on stone tool technology. The expected technological response to such conditions would be an increase in reduction of flaked pieces. The paleoenvironmental reconstruction of FxJj 1 and FxJj 3 in a back-delta swamp indicates that resources that did not require intensive stone tool use were more abundant (e.g. fruiting trees). It is possible that stone artifacts were not a vital resource for hominins in this environment. This may also explain the low density of pieces at FxJj1 and FxJj3 (Rogers et al. 1994).

Conclusions

The Oldowan assemblages in the KBS Mbr. of the Koobi Fora Fm. provide an interesting perspective on variation in the stone tool technology at the Plio-Pleistocene boundary. This study has provided a new perspective on the technology of the KBS Mbr. The earliest record of hominin behaviors on the eastern shores of Lake Turkana may be more complex than originally modeled by Isaac and Harris (1997a). Paleoenvironmental data indicators suggest that major changes occurred during the course of the KBS Mbr. that caused a change in the behavior of stone tool using hominins in the Turkana Basin at this time. Landscape scale variation in technological strategies allowed hominins to increase the use life of their toolkit in accordance with their requirement for stone tool mediated resources. This suggests that Oldowan technology reflects technological capabilities that allowed Plio-Pleistocene hominins to overcome variability in ecological conditions.

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