The Middle Stone Age After 50,000 Years Ago: New Evidence From the Late Pleistocene Sediments of the Eastern Lake Victoria Basin, Western Kenya

NICK BLEGEN
Max Planck Institute for the Science of Human History, Kahlaische Straße 10, 07745 Jena, GERMANY; and, Department of Anthropology, Harvard University, Peabody Museum of Archaeology and Ethnology, 11 Divinity Avenue, Cambridge, MA 02138, USA; blegen@shh.mpg.de; and, nick_blegen@fas.harvard.edu

J. TYLER FAITH
Natural History Museum of Utah & Department of Anthropology, University of Utah, Salt Lake City, UT 84108, USA; tyler.faith@anthro.utah.edu

ALISON MANT-MELVILLE
Department of Anthropology, University of Connecticut, Storrs, CT 06269, USA; Alison.melville@uconn.edu

DANIEL J. PEPPE
Terrestrial Paleoclimatology Research Group, Department of Geosciences, Baylor University, Waco, TX 76706, USA; daniel_peppe@baylor.edu

CHRISTIAN A. TRYON
Department of Anthropology, Harvard University, Cambridge, MA 02138, USA; christiantryon@fas.harvard.edu

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ABSTRACT

Here we report tephra correlations, lithic artifacts, obsidian sourcing data, and fauna from nine Late Pleistocene localities of the eastern Lake Victoria basin of western Kenya, as well as new excavations from the 49–36 ka site of Nyamita Main on Rusinga Island. The Late Pleistocene of Africa is an important period for the evolution and dispersals of *Homo sapiens*. A conspicuous behavioral feature of this period is the replacement of Middle Stone Age (MSA) technologies by Later Stone Age (LSA) technologies. Current research shows this process is complex with the LSA appearing and the MSA disappearing at different times in different places across Africa. Accounting for this pattern requires a precise chronology, detailed evidence of past human behavior and environmental reconstructions of the appropriate scale. Data presented here provide this detail. Tephra correlations improve the regional chronology and expand the lateral area of Late Pleistocene eastern Lake Victoria basin exposures from ~650km^2 to >2500km^2. Lithic artifacts show MSA technology is present younger than 36 ka in western Kenya, 25–35 kyr younger than the first appearance of early LSA technology elsewhere in equatorial East Africa. Obsidian sourcing data presented here shows the use of the same raw material sources by MSA and LSA populations through long periods of time from >100 ka through <36 ka. The methods employed here provide the temporal resolution and appropriate geographic scale to address modern human behavioral evolution.

INTRODUCTION

Late Pleistocene Africa is an important time period for understanding the evolution and dispersal of *Homo sapiens*. Fossil evidence of *Homo sapiens* is present in East Africa by 195 ka (McDougall et al. 2005). This region also was likely significant to human dispersals across and out of Africa in the Late Pleistocene between 130–50 ka (Beyin 2006; Groucutt et al. 2015; Rito et al. 2013). A conspicuous aspect of hominin behavior in Late Pleistocene Africa is the disappearance of Middle Stone Age (MSA) technologies, defined by points and characterized by prepared disc cores, and the replacement of these stone tool industries by Later Stone Age (LSA) technologies, defined by backed geometric microliths (Ambrose et al. 2002) and often associated with the bipolar core reduction (Diez-Martín et al. 2009), sometime between ~60–30 ka (Ambrose 1998; Tryon and Faith 2013). The longevity and adaptability of MSA technology throughout Africa make the reasons for its replacement by LSA technology a matter of interest and debate.

THE MIDDLE TO LATE STONE AGE TRANSITION ACROSS AFRICA

The latest occurrences of MSA technologies and earliest occurrences of the LSA technologies are staggered through-

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out Africa with aspects of MSA technology occurring <30 ka regardless of broad differences in raw materials, site type, or dating technique employed. In southern Africa, MSA technology persists as late as 28–27 ka at Rose Cottage Cave based on charcoal ^{14}C AMS dates (Wadley 2001), while the MSA/LSA transition is dated between 49–45 ka by AMS ^{14}C methods on charcoal at Border Cave (Villa et al. 2012). In southeastern Africa, cosmogenic nuclide dates on sediments provide an age of ~29 ka for MSA materials in Mozambique (Mercader et al. 2012). In northern Malawi, MSA artifacts at Mwanganda's Village site are OSL dated to between 42–22 ka (Wright et al. 2014) and 47–30 ka at Chaminade II (Wright et al. 2017). In western Africa, MSA technologies are found in Pleistocene sediments of the Senegal River Valley and OSL dated as late as 30–11.5 ka (Chevrier et al. 2016; Scerri et al. 2015) and in the Nile Valley of northern Sudan, OSL dates suggest MSA technology persists until ~15 ka (Osypiński and Osypińska 2016). In the southeastern Ethiopian cave of Goda Buticha, characteristically MSA material is dated to ~34 cal BP by ^{14}C with aspects of MSA technology such as trimmed points and a preferential Levallois core found in a middle Holocene layer dated as late as ~7 ka (Tribolo et al. 2017).

In equatorial East Africa, the MSA/LSA transition is conventionally thought to occur earlier. The Kisele industry (MSA) from Bed VI of Mumba rockshelter in northern Tanzania is dated to >65 ka based on U-series dates on bone from the overlying Bed V and 73.6±3.8–63.4±5.7 ka based on quartz and feldspar OSL dates from Bed VI-A (Gliganic et al. 2012; Mehlman 1989). The Mumba industry from overlying Bed V is variably characterized as "transitional" between MSA and LSA technologies, because of the presence of backed geometric microliths, bifacial points, and prepared disc cores (Marks and Conard 2008; Mehlman 1989), or as an LSA industry because of the presence of backed microliths and bipolar flaking (Diez-Martín et al. 2009; Eren et al. 2013), with the MSA elements incorporated into the assemblage due to the excavation of vertically thick, arbitrary excavation spits (Prendergast et al. 2007). Bed V and the Mumba industry are dated to between 65–45 ka based on amino acid racemization (AAR) of ostrich eggshell fragments and 56.9±4.8–49.1±4.3 ka based on quartz grain OSL dates (Gliganic et al. 2012; McBrearty and Brooks 2000). A similar technological succession is found at Nasera rockshelter in northern Tanzania with strata containing the Kisele industry dated to a minimum age of ~56 ka by U-series on bone (Mehlman 1977, 1989; Tryon and Faith 2016).

The Naisiusiu beds of Olduvai Gorge contain LSA microliths (Leakey et al. 1972). Mehlman (1977, 1989) suggests an age equivalent to the Last Glacial Maximum (LGM) for these deposits based on archaeological similarities with the LSA Lemuta industry at Nasera. Conventional radiocarbon dates on bone from the Naisiusiu beds suggest very late to terminal Pleistocene ages between 17.5±1.0–10.4±0.6 ka (Hay 1976; Leakey et al. 1972), but more recent AAR dates on ostrich eggshell of >42 ka and $^{40}Ar/^{39}Ar$ dates of 42.0±10.0 ka on tephra suggest a considerably older age (Manega 1993, 1995). Recent ages of 62±5 ka are reported based on electron spin resonance (ESR) performed on equid teeth found in an archaeological excavation, although ESR on another tooth from a different location within the Naisiusiu beds produced an age of 39±5 ka (Skinner et al. 2003). Together, these dates suggest LSA artifacts in the Naisiusiu beds date somewhere between 67–34 ka, and thus predate the LGM.

At Enkapune Ya Muto in the central Kenyan rift, the Endingi industry contains facetted platform triangular points and flakes with radial scar patterns characteristic of MSA technologies, as well as three backed microliths characteristic of the LSA (Ambrose 1998). This level has been dated (lab number QL-4259) to 44.9±0.64 ka cal BP (calibrated using IntCal13 in OxCal; (Ramsey 2009; Reimer et al. 2013)). The Nasampolai and Sakutiek industries, both LSA industries containing backed microliths, overlie the Endingi Industry. Radiocarbon ages of the Sakutiek industry, the younger of these two LSA industries, range from 44.24±1.5–19.98±1.2 ka cal BP (Ambrose 1998). Based on a combination of radiocarbon, obsidian hydration, and sedimentation rates, the earliest LSA of Enkapune Ya Muto is considered to have begun by at least ~50 ka and possibly earlier (Ambrose 1998). The LSA materials at several sites of Lukenya Hill in south-central Kenya are considered to be <20 ka based on bone collagen and apatite ^{14}C dates (Kusimba 1999, 2001). The Late Pleistocene cultural layers of GvJm-22 'Occurrence E' and 'Occurrence F' were originally called LSA (Gramly and Rightmire 1973). However, recent work suggests the lower of these two cultural layers, 'Occurrence F,' is MSA with Levallois cores and trimmed points dating between 26 ka and >46 ka (Tryon et al. 2015).

The broad overlap of the MSA and LSA as well as geographic variation in the timing of this transition across Africa does not agree with models of behavioral evolution positing a single, sudden event (Klein 2008). The complex chronological and geographic circumstances of the MSA/LSA transition demand a more detailed archaeological record accompanied by high resolution chronological and paleoenvironmental records on expansive deposits of a geographic scale that reasonably approximate the size of the ancient landscape across which Pleistocene humans would have ranged. In light of this, the Late Pleistocene sediments of the eastern Lake Victoria Basin (eLVB) provide a valuable venue in which to address the MSA/LSA transition. Tephrostratigraphy provides precise chronometric dating and lateral stratigraphic control of geographically expansive deposits. Combined with ongoing environmental reconstructions, this provides the ability to assess the character of past landscapes over 100s to 1000s of square kilometers. The rich history of archaeological research combined with new data from ongoing fieldwork in the eLVB allows us to characterize hominin technologies and behavior in the eLVB and across equatorial Africa. We also examine previous and ongoing obsidian raw material sourcing studies to gauge the scale of past hominin interactions. Finally, we combine new geological and archeological data from the eLVB with previously published research from eastern Africa to provide insights into the MSA-LSA transition in equatorial Africa.

THE EASTERN LAKE VICTORIA BASIN OF EAST AFRICA

GEOLOGY

Tectonic activity in the East African Rift System (EARS) has produced a series of rift basins in which rapid sedimentation buried paleoanthropological materials, with extensional faulting subsequently re-exposing these materials. The Victoria basin is formed in the depression between the eastern and western branches of the EARS, probably within the last few million years (e.g., Danley et al. 2012). During the Late Pleistocene, the eLVB formed a repository for sediments, including volcaniclastic deposits of volcanic eruptions from >200km east in the central Kenyan Rift (Tryon et al. 2016). While no formal geological formation has yet been defined, the Late Pleistocene exposures of the eLVB are currently known to include the Wasiriya beds of Rusinga Island, the Waware beds of Mfangano Island, and the Late Pleistocene exposures of Karungu on the Kenyan mainland (Figure 1c). These sediments were informally named by Pickford (1984) based on previous mapping and descriptions (Kent 1942; Van Couvering 1972). The first measured sections and sedimentary descriptions of the Wasiriya beds were reported by Tryon et al. (2010) and expanded in recent studies (Figure 2; Beverly et al. 2015b; Blegen et al. 2015; Garrett et al. 2015; Van Plantinga 2011). Sediments are exposed in sections up to ~18m thick and are primarily comprised of four distinct lithologies: 1) poorly sorted coarse sand and gravel channels cemented by carbonate representing episodic channel erosion and deposition; 2) fine grained mudstone, siltstone, and silty sandstone preserving evidence of incipient soil development indicating a more stable landscape; 3) tephra preserved as both primary fall-out deposits and tuffs that have undergone varying amounts of reworking and incipient pedogenesis; and, 4) tufa deposits made primarily of calcium carbonate indicating the presence of springs and small ponded areas on the landscape (Figure 3; Beverly et al. 2015b; Tryon et al. 2010). Barrage tufa deriving from the Nyamita Valley spring ceased continuously forming in the Late Pleistocene, but small springs still exist today (see Figure 3) and have likely existed intermittently from the Late Pleistocene through the present, providing a source of fresh water to local fauna.

Laterally discontinuous deposits are connected stratigraphically and chronologically by tephrostratigraphy. Late Pleistocene tephras are correlated over a ~60km north-south transect between Rusinga Island, Mfangano Island, and Karungu (Blegen et al. 2015). This tephrostratigraphy, as well as lithostratigraphic and chemical characterization of the paleosols between the tephras (Beverly et al. 2015a; 2015b; 2017), indicate the same stratigraphic sequence is discontinuously preserved over an area of at least ~120km^2. Thus, the eLVB constitutes a laterally extensive stratigraphic sequence of Late Pleistocene exposures preserving different depositional environments.

CHRONOLOGY AND STRATIGRAPHY

The base of the Late Pleistocene eLVB exposures known so far is estimated to date to ~100 ka (see Figure 2; Beverly et al. 2015b). The phonolitic Wakondo Tuff was hypothesized by Tryon et al. (2010) to derive from Late Pleistocene eruptions of Longonot or Suswa dated to 100±10 ka (Baker et al. 1988). This tuff is near the base of the Nyamita Valley stratigraphic sequence and has been used to correlate these exposures to other deposits of the Wasiriya beds across Rusinga Island and to Karungu on the Kenyan mainland (Blegen et al. 2015; Tryon et al. 2010; Van Plantinga 2011). U-series dates of 94–111 ka on a barrage tufa in the Nyamita Valley into which glass from the Wakondo Tuff is incorporated provide additional support for this ~100 ka age estimate (Beverly et al. 2015). The most common stratigraphic marker in the Nyamita Valley and throughout the eLVB is the Nyamita Tuff (see Figure 2; Beverly et al. 2015a; 2015b). At section Nyamita 2 (see Figure 2), optically stimulated luminescence (OSL) dates on sands bracketing the Nyamita Tuff provide ages of 50±4 ka and 46±4 ka below and above the tuff respectively, indicating this tuff was deposited ~49 ka (Blegen et al. 2015; Tryon et al. 2010; Van Plantinga 2011). At least two stratigraphically higher tuffs are widely encountered throughout the Late Pleistocene exposures of the eLVB (Blegen et al. 2015). The uppermost of these tuffs, originally referred to as the 'Bimodal Trachyphonolitic Tuff' and abbreviated to 'BTPT' (Blegen et al. 2015) has recently been correlated over an area >115,000km^2 across much of Kenya and to its source Menengai Crater where it is $^{40}Ar/^{39}Ar$ dated to 35.62±0.26 ka (Blegen et al. 2016). The BTPT, now properly termed the Menengai Tuff, provides the minimum $^{40}Ar/^{39}Ar$ age for the Late Pleistocene eLVB tephrostratigraphy. This minimum age is corroborated by >35–33 ka AMS ^{14}C dates on gastropod shells that post-depositionally burrowed into the sediments at the Nyamita 2 and Nyamita 3 localities (see Figure 2; Blegen et al. 2015; Tryon et al. 2010; 2012).

PALEOENVIRONMENTS

Fauna from the Late Pleistocene beds of the eLVB constitute the largest and most diverse Late Pleistocene faunal assemblages in East Africa. The majority of specimens belong to taxa indicating open, semi-arid grasslands (e.g., equids and alcelaphin antelopes) distinct from the evergreen bushlands, woodlands, and forests historically found in the region (Lillesø et al. 2011; Robertshaw et al. 1983; White 1983). Isotopic data from tooth enamel indicate that the majority of the large-bodied mammalian fauna recovered from the Wasiriya and Waware beds consumed a predominantly C_4 diet indicating the presence of an extensive C_4 grassland in the eLVB (Garret et al. 2015). Exceptions to this general trend include the area of Nyamita Main. In addition to taxa with open-habitat preferences such as *Rusingoryx atopocranion*, *Damaliscus hypsodon*, and Grevy's zebra (*Equus grevyi*) found throughout the Nyamita landscape (and elsewhere in eLVB), Nyamita Main has produced taxa associated with dense cover or freestanding water, including reedbuck (*Redunca redunca*), duiker (*Sylvicapra grimmia*), bushbuck

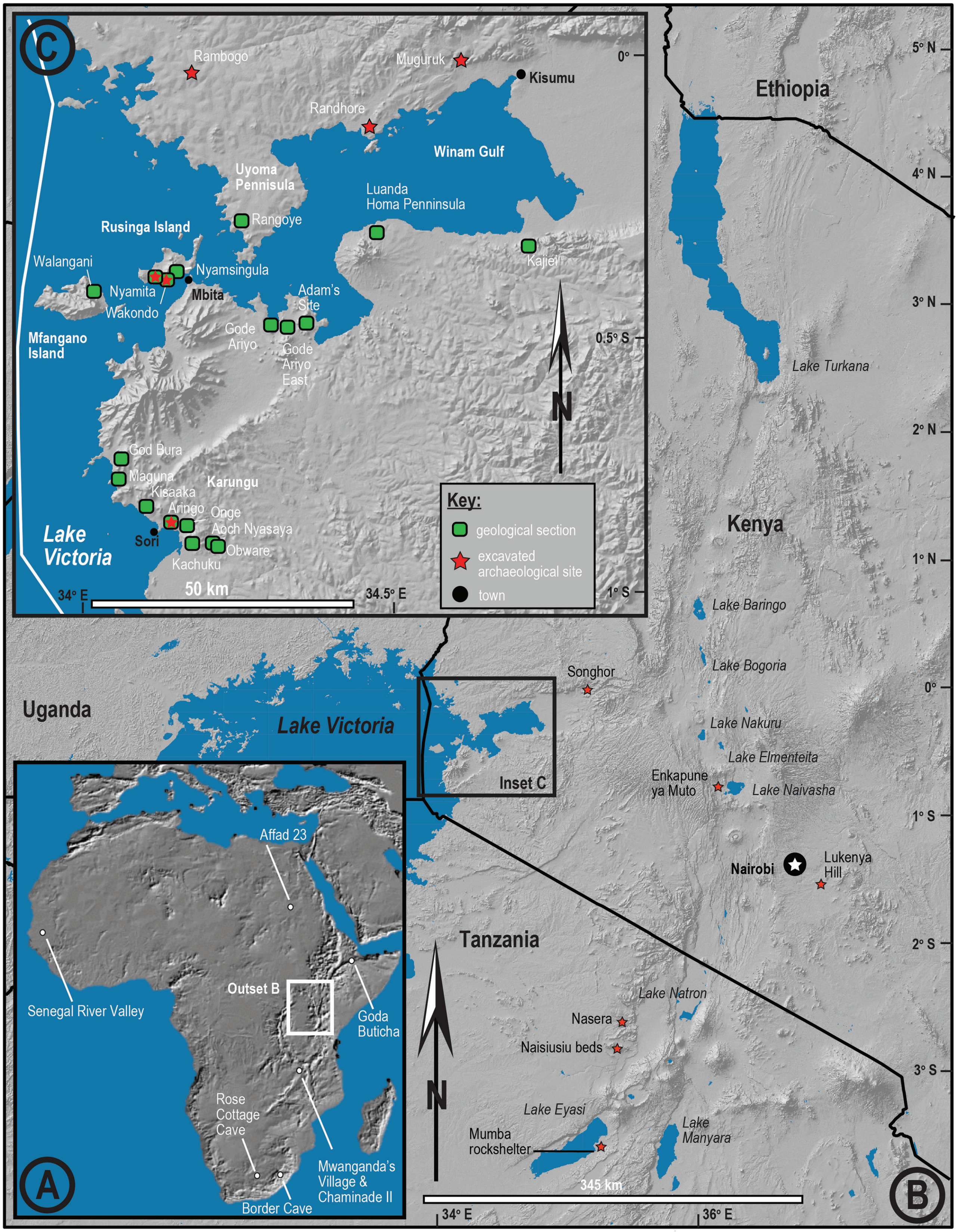

Figure 1. A) Map of Africa showing sites mentioned; B) map of East Africa focused on Lake Victoria and eastern (Kenyan) rift region; C) map of approximate area of the eastern Lake Victoria Basin (eLVB) around Winam Gulf referenced in this study. This includes Rusinga Island, Mfangano Island, and Karungu, the southern shore of the Winam Gulf, and the Uyoma Peninsula on the north shore of the Winam Gulf.

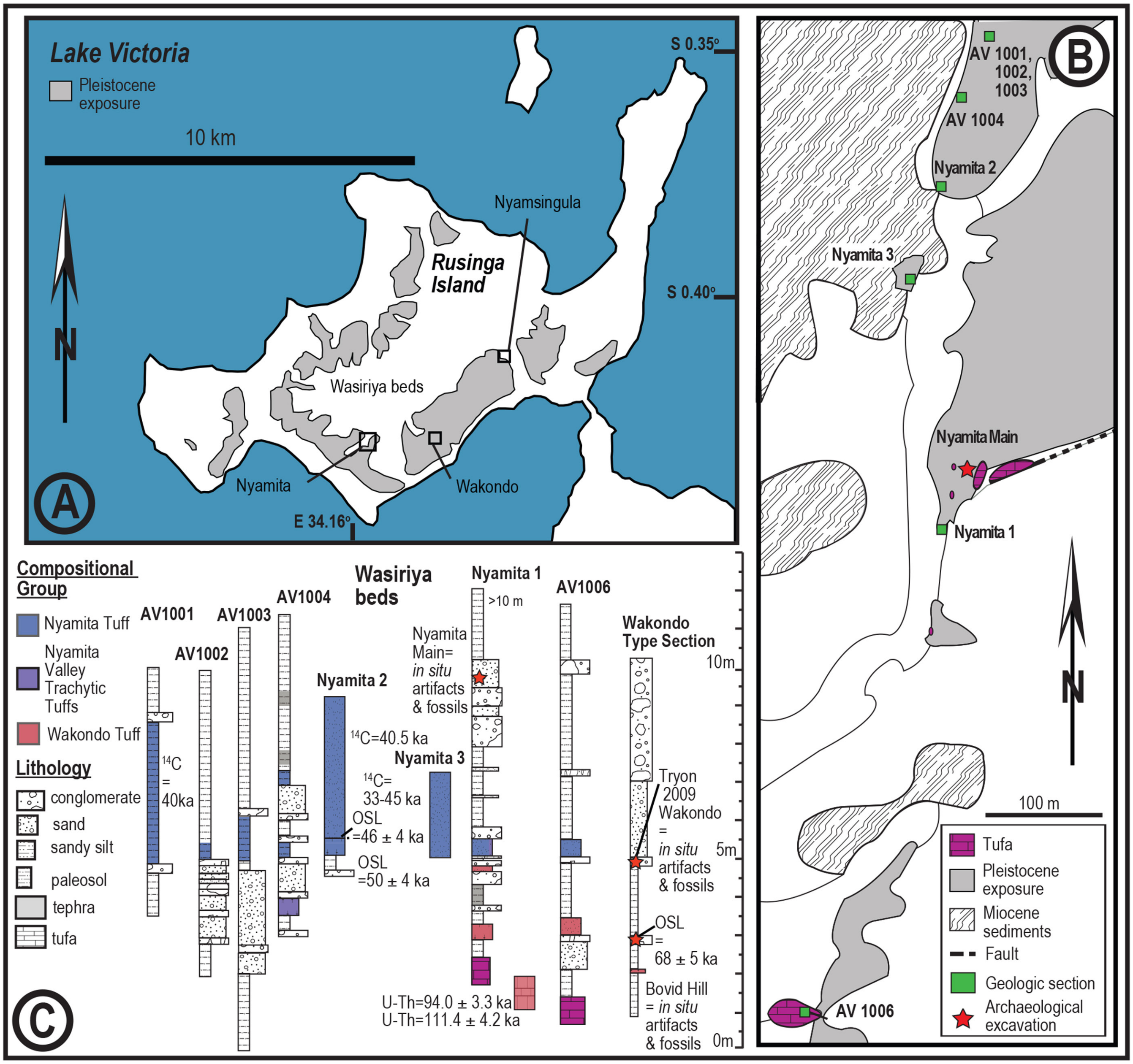

Figure 2. A) Map of Rusinga Island showing the extent of Pleistocene outcrops of the Wasiriya beds as well as archaeological and paleontological localities discussed in the text (after Tryon et al. 2010, 2012); B) map of Nyamita valley indicating relevant archaeological and geological localities (after Beverly et al. 2015; Van Plantinga 2011); C) stratigraphic columns of measured and sampled sections, arranged west (left) to east (right). Lithologies are indicated for all units. Tuffs are color-coded to chemically correlated group (see Blegen et al. 2015). Tuffaceous units not chemically characterized and assigned are shown in grey.

(*Tragelaphus scriptus*), impala (*Aepyceros* sp. nov.), and hippo (*Hippopotamus amphibius*) (Faith 2014; Faith et al. 2012; 2014; 2015; Garrett et al. 2015; O'Brien et al. 2016; Tryon et al. 2012). The presence of *Hippopotamus* indicates standing water, likely related to the spring system that probably served as a magnet for water-dependent grazers and supported dense vegetation cover that favors taxa rarely found in other parts of Nyamita Valley or the eLVB. Additionally, isotopic reconstructions from Wasiriya beds paleosols in the Nyamita Valley indicate this region was characterized by ~46–82 % leafy cover in the Late Pleistocene. This is more dense woody cover than the reconstructions for other parts of the Wasiriya and Waware beds in the same time period (Garrett et al. 2015). Together, the isotopic and mammalian fossil data indicate that the Nyamita Valley probably represented a patch of more dense riverine woodland with standing water within an otherwise dry C_4 grassland ecosystem.

HISTORY OF ARCHAEOLOGY

Archaeological exploration of Late Pleistocene sediments of the eLVB extends to the early twentieth century, with early

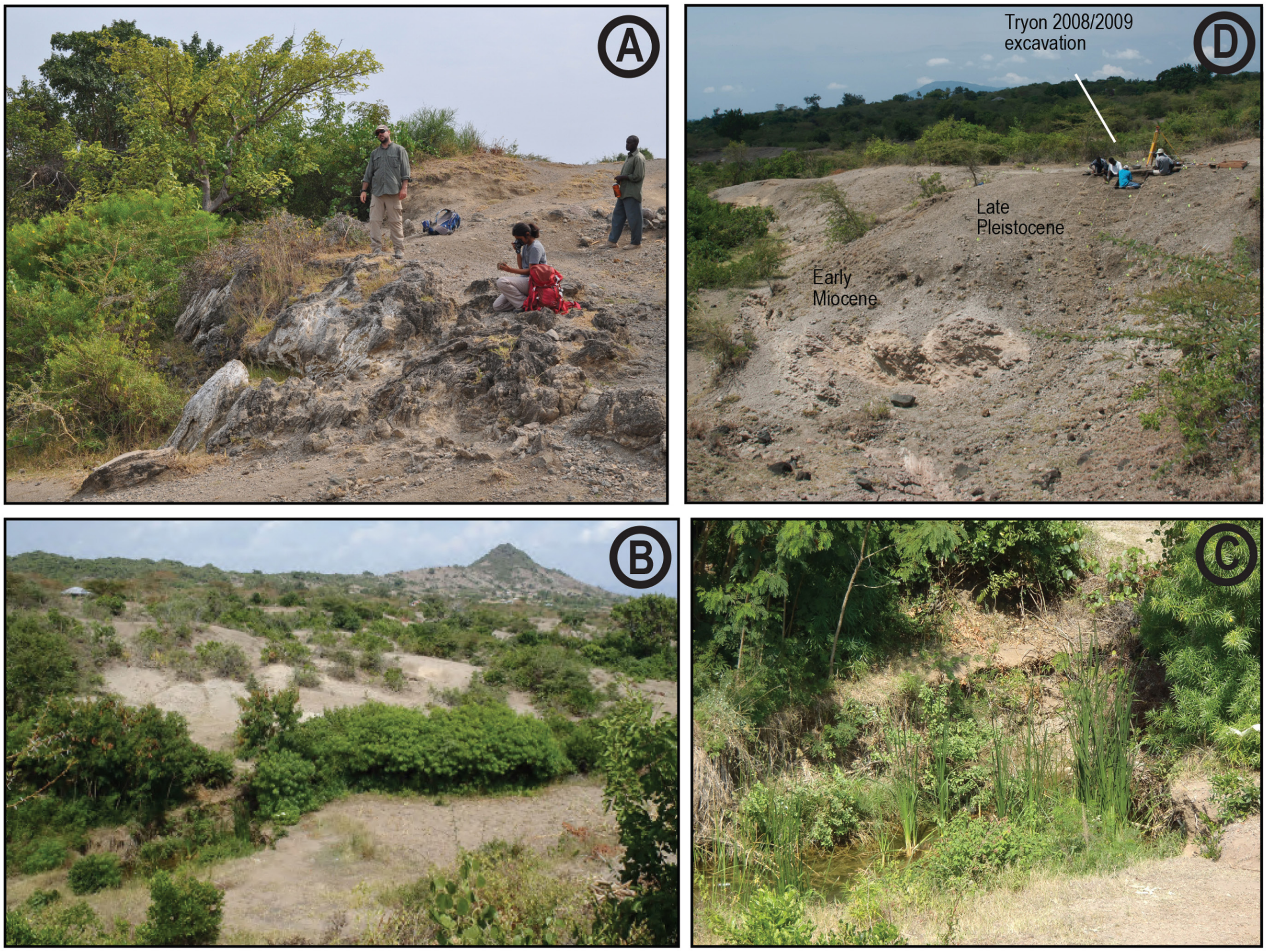

Figure 3: A) Late Pleistocene barrage tufa at base of Nyamita Valley; B) modern spring in Nyamita Valley; C) close-up of spring showing presence of perennial fresh water; D) photograph (looking ~southwest) at 2009 excavations at Nyamita Main. Note the Late Pleistocene fluvial sediments unconformably overlying more consolidated, variegated, and tilted early Miocene sediments.

study of MSA materials by Archdeacon W.E. Owen (Owen 1937, 1938, 1939), at times in collaboration with L.S.B. Leakey (Leakey and Owen 1945). Creighton Gabel (1969) excavated a series of rockshelters along the north of the Winam Gulf, one of which, Randhore, sampled undated strata attributed to the MSA (Tryon et al. 2016). Sally McBrearty conducted excavations of Sangoan-Lupemban and MSA materials at Muguruk (McBrearty 1986) and MSA material in the Pleistocene sediments of Songhor (McBrearty 1981). Laura Basell (2007) conducted work at Rambogo rockshelter as part of a review of Sangoan-Lupemban industries in eastern Africa (see Figure 1c). The authors' current research project began in 2008 as part of collaborative research on the early Miocene and Late Pleistocene sediments of Rusinga Island (Peppe et al. 2009; Tryon et al. 2010).

RECENT FIELD ARCHAEOLOGY AND EXCAVATIONS

All the fresh and unweathered stone artifacts found by our project on Rusinga Island, Mfangano Island, and Karungu since 2008 are typologically and technologically characteristic of the Late Pleistocene MSA in East Africa. Levallois cores (recurrent and preferential) and Levallois points, as well as bifacial and unifacial trimmed points, are found in the Wasiriya beds of Rusinga Island (Tryon et al. 2010). Collection of artifacts (n=12) from the surface of the Waware beds on Mfangano Island lack Levallois technology in this small sample, but contain bifacial points and can be also attributed to the MSA (Tryon et al. 2012). The archaeology of Karungu is indistinguishable from that of the Wasiriya beds of Rusinga Island, including Levallois technology, as well as bifacial and unifacial points (Faith et al. 2015; Tryon et al. 2016).

Four excavations have previously been conducted at three localities within our study area in the Late Pleistocene sediments of the eLVB. One of these, Aringo 3, is a small 1x3m^2 test excavation at the locality of Aringo, Karungu (Faith et al. 2015). At Aringo 3, artifacts were recovered from a gravel channel underlain by a tufa-cemented conglomerate indicative of the presence of a paleo-spring and overlain by a ~2m thick paleosol capped by the Nyamita Tuff. Based on its stratigraphic position, the Aringo 3 site is

<100 ka and >49 ka. The excavated sample includes a Levallois point and preferential and recurrent Levallois cores. It also includes a ~2cm obsidian flake.

Two excavations have been conducted at Wakondo (Jenkins et al. 2017; Tryon et al. 2010). A 4m^2 trench dug to an average depth of 0.7m recovered nine artifacts *in situ* (Tryon et al. 2010). At Wakondo Bovid Hill, the larger of the two excavations, a series of trenches totaling 19m^2 with an average depth of 0.50m were excavated into small and shallow braided stream channels cutting into a paleosol overlying the Wakondo Tuff (Jenkins et al. 2017; Tryon et al. 2010). These excavations targeted a bone-bed of the extinct alcelaphin *Rusingoryx atopocranion* deposited in sediments OSL dated to 68 ka (Blegen et al. 2015). Stone artifacts from the Bovid Hill excavation are few (n=78 with 9 *in situ*), but these lithic artifacts are laminar, including those produced by Levallois methods, and are consistent with an MSA attribution. Cut-marked fauna indicates an association between the bones and stone artifacts (Jenkins et al. 2017; Tryon et al. 2010).

Tryon excavated 4m^2 at Nyamita Main in December 2008–January 2009 with the goal of establishing the source of the artifacts found on the surface. Raw material types and technology suggest that the surface and *in situ* material sample the same assemblage. The excavation samples strata ~4–5m above the Nyamita Tuff, and thus is <49 ka.

OBSIDIAN SOURCING: THE VICTORIA BASIN AND EAST AFRICA

Geochemical sourcing data on Pleistocene obsidian artifacts in the eLVB has long been known from the MSA sites of Songhor and Muguruk (Merrick and Brown 1984), and more recently from the sites of Kisaaka and Aringo 3 (Faith et al. 2015). The presence of obsidian chemically sourced to Lake Naivasha at all these sites suggests persistent long distance contact between Late Pleistocene populations making MSA technologies in the eLVB and the central Kenyan Rift 140–250km to the east. Obsidian sourcing from Mumba and Nasera rockshelters in northern Tanzania show MSA and early LSA producing hominins had continued contact with these same Naivasha obsidian sources 240–305km from these sites from at least ~60 ka through the Holocene (Mehlman 1989; Merrick et al. 1994). Obsidian LSA artifacts of the Naisiusiu beds of Olduvai Gorge also derive ~250km away from the Sonanchi and Mundui sources of the Naivasha basin. At Lukenya Hill, proportions of obsidian appear to increase throughout MSA layers at GvJm-16, and at least some of the non-local obsidians of these assemblages appear to derived from Naivasha sources (Merrick and Brown 1984). The same is true of the LSA layer, Occurrence E, of GvJm-22 at Lukenya Hill (Gramly 1976; Merrick and Brown 1984). Thus, not only do the Late Pleistocene eLVB sites attest to the scale of hominin interactions through raw material transport distances, these sites provide important evidence that MSA hominins in western Kenya and LSA hominins in northern Tanzania were using the same resources in the Naivasha basin during the same time periods.

SUMMARY OF PRIOR RESEARCH IN THE LAKE VICTORIA BASIN

Research reviewed above emphasizes that the Late Pleistocene exposures of the eLVB provide the chronological control, geographically expansive deposits, and archaeological materials necessary to address human behavioral evolution in Late Pleistocene Africa.

Original work presented here further provides: 1) refined chronological and stratigraphic control for 50–36 ka deposits through identification and correlation of new tephras; 2) a greatly expanded (>2500km^2) lateral area of known Late Pleistocene eLVB exposures through identification, survey, and tephra-correlation of new geological deposits; and, 3) improved characterization of MSA technology and hominin behavior through systematic surface-collection (following Tryon et al. 2012) and expanded archaeological excavations at the site of Nyamita Main.

MATERIALS AND METHODS

TUFF SAMPLING STRATEGY

All 24 tuff samples analyzed for this study were collected from or can be stratigraphically linked to a series of 12 sections (>0.50m to <10m thick) measured from Late Pleistocene outcrops in the eLVB between 2014 and 2016. The geographic locations of surveyed localities introduced here are provided in Figure 1c and GPS coordinates for tephra samples at each of these localities are provided in Table 1. Schematic stratigraphic sections with lithologies are provided in Figure 4. Whenever possible, tuffs were sampled from sections with multiple tephra deposits exposed in stratigraphic succession. Field correlations were made by walking exposures and by using a Jacob's staff and Abney level to establish the stratigraphic equivalence between exposed tuffs. Both field and laboratory methods of correlation are necessary as exposures are discontinuous and tephra deposits in the eLVB vary widely in their thickness, amount of subsequent soil development, and amount and/ or size of natural glass.

EXCAVATION

Excavations at Nyamita Main were carried out over three weeks in August of 2013. Spatial data was collected in three dimensions using a total station connected to a PC laptop operating EDM for windows excavation software (McPherron and Dibble 2002). Prior to excavation, the topography of the locality was mapped in 0.40m intervals and all artifacts and fossils on the surface or exposed *in situ* were recorded and collected. A 1x1m^2 grid was laid out over the intended area of excavation. Excavations were aligned north-south along the western edge of Tryon's 2009 trench and carried out with arbitrary 10cm levels because of the absence of any natural vertical stratigraphy within the artifact and fossil-bearing matrix. All *in situ* stone material and fossil fauna with a maximum dimension >2cm were piece-plotted. All material with a discernable long axis (a ration of length/ width approximately ≥1.5) was piece-plotted with a point at either end. All excavated sediment was

TABLE 1. LOCATIONAL GPS INFORMATION (decimal degrees in WGS 1984) FOR ALL LOCALITIES WITH TUFF SAMPLES NEWLY REPORTED IN THIS STUDY.

Tuff Sample	Locality	Section	GPS locality (WGS 1984)	Chemical Composition
LVP2014-18	Gode Ariyo	Sec.2015.A	S-0.503500° E34.338417°	Wakondo
LVP2014-30	Homa Peninsula	Luanda	not available	Wakondo
LVP2015-48	Gode Ariyo	Sec.2015.A	S-0.503500° E34.338417°	Wakondo
LVP2015-49	Gode Ariyo	Sec.2015.WPT017	S-0.505267° E34.339600°	Wakondo
LVP2015-51	Gode Ariyo	Sec.2015.WPT018	S-0.506300° E34.339383°	Wakondo
LVP2015-73	Maguna South	near Maguna Point Site #2	S-0.762733° E34.081217°	Wakondo
LVP2014-19	Gode Ariyo	Sec.2015.A	S-0.503500° E34.338417°	Nyamita
LVP2014-20	Gode Ariyo East	Sec.2015.B	S-0.507733° E34.353033°	Nyamita
LVP2014-27	God Bura	Elephant Site	S-0.730117° E34.081717°	Nyamita
LVP2015-50	Gode Ariyo	Sec.2015.WPT017	S-0.505267° E34.339600°	Nyamita
LVP2015-52	Gode Ariyo	Sec.2015.WPT018	S-0.506300° E34.339383°	Wakondo
LVP2015-54	Gode Ariyo	near Sec.2015.WPT018	S-0.506717° E34.339416°	Nyamita
LVP2015-56	Gode Ariyo East	near Gode Ariyo Sec2014.B	S-0.512583° E34.35425°	Nyamita
LVP2015-57	Gode Ariyo East	Sec.2015.B	S-0.507733° E34.353033°	Nyamita
LVP2015-61	Kajiei	WPT029	S-0.38775° E34.74678°	Nyamita
LVP2015-63	Maguna	Maguna Point Site #1	S-0.74628° E34.08945°	Nyamita
LVP2015-65	Maguna	Maguna Point Site #1	S-0.74628° E34.08945°	Nyamita
LVP2015-67	Maguna	Maguna Point Site #1	S-0.74628° E34.08945°	Nyamita
LVP2015-81	God Bura	Molly's Site	S-0.73178° E34.19016°	Nyamita
LVP2015-86	Kachuku	WPT055	S-0.86383° E34.20126°	Nyamita
LVP2014-29	Rangoye	Sec.2014.WPT 312	S-0.334833° E34.294600°	Nyamsingula
LVP2015-55	Adam's Site	WPT021	S-0.494167° E34.412567°	Nyamsingula
LVP2015-58	Gode Ariyo East	Sec.2015.B	S-0.507733° E34.353033°	Nyamsingula
LVP2015-72	Maguna South	WPT 040	S-0.759716° E34.08345°	Other

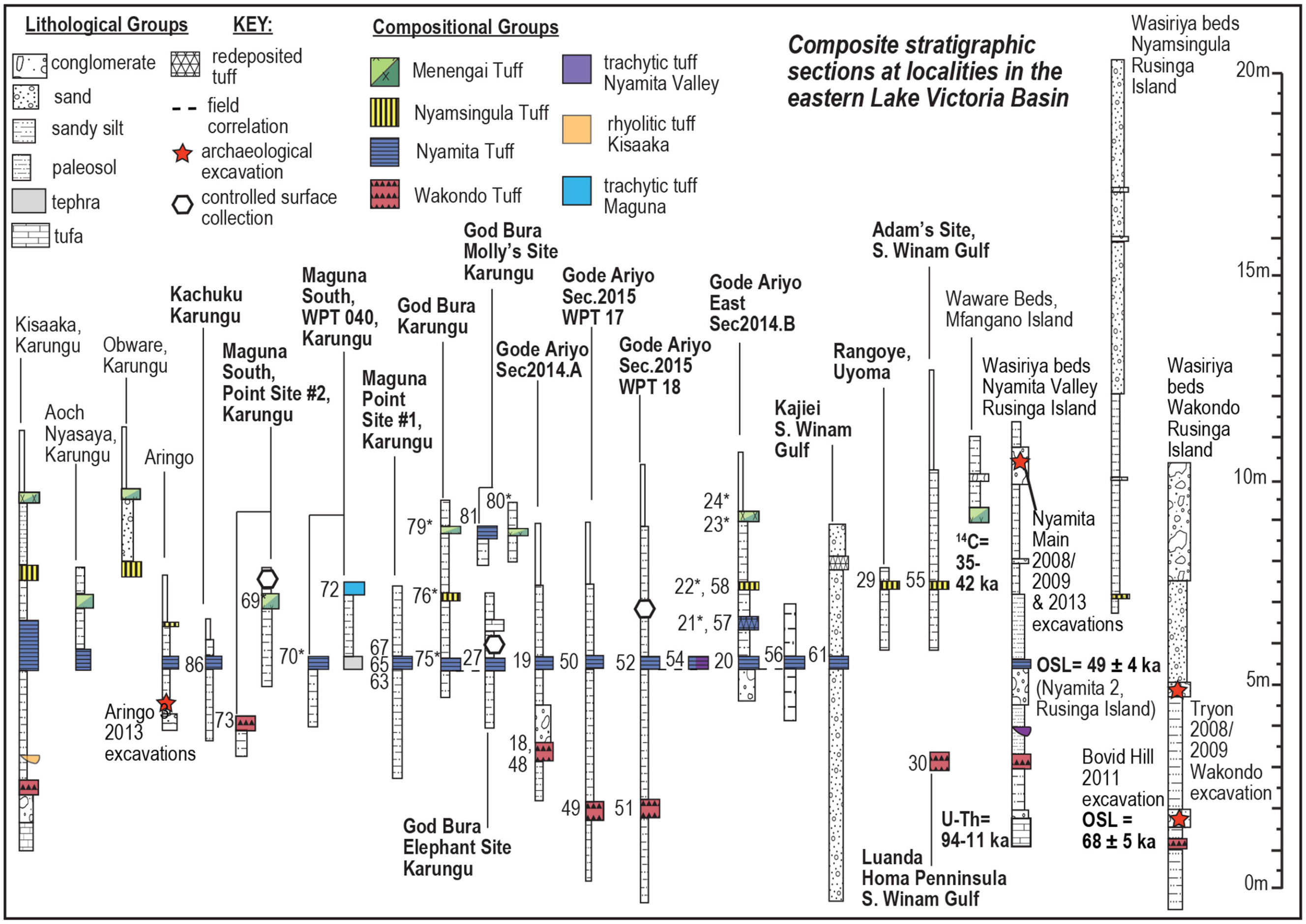

Figure 4. Schematic stratigraphic sections of tephra correlations between localities of the eastern Lake Victoria Basin. Tephra samples with the ID number (example: '72') are those samples newly presented in this study. Samples with an '' after the ID number (example: 76*) are those recently published in a study of the Menengai Tuff (Blegen et al. 2016).*

screened through 1/8″ mesh and sieved material collected in bags specific to date, square and level. All materials are permanently housed in the collections of the Archaeology Department of the National Museums of Kenya, Nairobi.

LITHIC ANALYSIS

No single, standardized framework of lithic analysis exists in the study of MSA archaeology in Africa. Lithic analysis and terminology follow Tryon et al. (2005). For data reporting, we use tables similar in format to Shea (2008), but depart slightly from his scheme in classifying 'debris' as flake fragments and angular waste (flaked material that cannot be oriented).

GEOCHEMICAL CHARARTERIZATION OF VOLCANIC GLASS

The geochemical analysis of tephras and obsidians focuses on electron probe microanalysis (EPMA) of eleven major element oxide proportions in volcanic glass from tuffaceous deposits, sediments, and obsidian artifacts. Preparation protocols for microprobe analysis of tephra and obsidian follow University of Utah Microprobe facilities equipment and methodologies outlined in Blegen et al. (2015) for tephra analysis and Brown et al. (2013) for obsidian analysis. EPMA of major element oxides on volcanic glass is the favored method of obsidian sourcing because this methodology has been tested and proven valid for obsidians from Stone Age assemblages in East Africa. A large comparative dataset of geological obsidian sources characterized by EPMA is available (Brown et al. 2013; Merrick and Brown 1984).

TEPHRA CORRELATION

Correlations rely on glass composition and are based on overlap of major element oxides following Brown and Nash (2014). Samples in this study include both fresh vitric tephra deposits, as well as tuffs subsequently reworked by fluvial processes or variably overprinted by pedogenesis. Lithic and crystal phases from an eruption cannot always be reliably distinguished from those found in detrital sediments, and thus our correlations rely on chemical composition of the glass component for all samples following Brown and Nash (2014). All correlations are supported by similarity coefficients (SCs) to quantify similarity between means of glass analyses from samples after which a tephra is named the 'type sample' and the mean value of all other modes in our dataset following the methodology of Blegen et al. (2015). We use ten elements and/or element oxides: SiO_2, TiO_2, Al_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, and Cl in computation of SCs. In this methodology, for any two-tephra comparison, SCs are the ratios obtained by dividing pairs of sample means (with the larger value of the two samples always the denominator such that the ratio is always ≤1.0) element by element as defined by Borchardt et al. (1972). Resulting SCs range between 0 (complete dissimilarity) to 1 (perfect similarity). Previous studies have proposed arbitrary cutoffs for interpreting SCs in terms of potential correlation. Kuehn and Foit (2006) proposed a value of ≥0.95 for definitive correlation, and Froggatt (1992) recognizes that values ≥0.92 are typically accepted for correlations. As in Blegen et al (2015), this study employs randomization procedures to develop empirically informed SC cutoffs for accepting or rejecting potential correlations. In this methodology, for each of the tephra type samples published in Blegen et al. (2015), the means and standard deviations of each element oxide are used to generate 5000 random, normally–distributed samples using Microsoft Excel statistical package (Rochowicz, Jr. 2010); this effectively represents 5000 replicates of the type tephra. We then calculate SCs between each of the 5000 replicates and the type sample that are used to generate a frequency distribution of expected SC values when comparing two samples of the same tuff. From this distribution, we determine the lower SC limit that encompasses the upper 95% of observations. We use this value as the lower limit cutoff for rejecting potential correlations. For example, an SC value between an unknown tuff and a type sample that falls below the 95% cutoff is excluded for consideration as a potential correlate. To increase the stringency of our protocol, we also require that the ten element oxides of the unknown tuff considered in our analysis overlap within two standard deviations of the mean of the type sample. This is because an unknown sample that is very similar in composition for most element oxides (e.g., 9 of 10) to a type sample will record a relatively high SC value, even if one oxide is distinct and outside the range of expected values. The SCs included in this analysis were used as a data exploration and confirmation technique. All correlations were investigated in more detail utilizing the known stratigraphy of a site and visual inspection of the tephra datasets.

RESULTS

TEPHROSTRATIGRAPHY AND GEOLOGY OF LATE PLEISTOCENE SITES

Tephra Correlations

Chemical characterizations of 328 individual shards from 24 tuff samples (Tables 2 and 3) incorporate nine new localities into the Late Pleistocene tephrostratigraphic framework of the eLVB: God Bura, Maguna, and Kachuku in the region of Karungu, Gode Ariyo, Gode Ariyo East, Adam's Site, Luanda Homa Peninsula, and Kajiei on the south shore of the Winam Gulf, and Rangoye on the Uyoma Peninsula north of the Winam Gulf (see Figures 1c, 4). These tephra correlations roughly quadruple the area over which Late Pleistocene eLVB exposures are known, from ~650km^2 to >2500km^2, and show that they occur both north and south of the Winam Gulf (see Figure 1c).

Geology of Pleistocene Localities

In the three new Karungu localities, the sedimentary packages and depositional environment above, below, and between the tephras appear similar in thickness and character to the paleosols described for nearby stratigraphically equivalent sites of Karungu (Beverly et al. 2015a). The sedimentary sequences Gode Ariyo and Gode Ariyo East on the south shore of the Winam Gulf (see Figure 1c) also preserve a sequence of paleosols between known tephra. The exposures at Gode Ariyo are unique in the Late Pleistocene beds of the eLVB in preserving a >2m thick and well-developed paleo-Vertisol below the Wakondo Tuff (see Figure 4; Figure 5a). This lower stratigraphic interval is very poorly exposed in the Late Pleistocene beds of the eLVB, and indicates the presence of lower stratigraphic intervals within the same Late Pleistocene eLVB tephra sequence further northeast up the Winam Gulf and Nyanza Rift. The sedimentary sequence at Kajiei near the southeast corner of the Winam Gulf is distinctive. The character of the Nyamita Tuff here is typical, but there are no paleosols. Instead the strata found above and below the Nyamita Tuff at Kajiei are comprised of coarse sands locally derived from fluvially redeposited weathered granitic basement rock.

ARCHAEOLOGY OF LATE PLEISTOCENE SITES

Much of the archaeological material collected at the new eLVB localities is typologically and technologically attributable to the MSA, characterized by Levallois points as well as uni- and bifacially trimmed pointed pieces (Figure 6). Prepared cores spanning a wide range of sizes, raw materials, and styles of preparation have also been recovered (Table 4; Figures 6–9) similar to what has been observed on Rusinga Island, Mfangano Island, and Karungu in the eLVB (Tryon et al. 2016).

A few localities offer archaeological materials typologically or stratigraphically different from what has been previously observed. At Maguna Point Site #2 at the locality of Maguna South in the Karungu area, MSA bifacial trimmed points (see Figure 6d, e) and Levallois cores (see Figure 8a, c) are found associated with and directly above primary air-fall exposures of the 35.62±0.26 ka Menengai Tuff (see Figures 4, 5b). The MSA material collected above the Menengai Tuff at Maguna South makes this material demonstrably the youngest MSA material in the eLVB. The exposures at God Bura also provide an assemblage of lithic artifacts from a controlled surface collection conducted above the Nyamita Tuff at the God Bura Elephant Site. MSA material collected in association with bones and a tufa deposit consists of three Levallois points (see Figures 6j and

TABLE 2. MEAN MAJOR AND MINOR ELEMENT OXIDES AND ELEMENTS BY WEIGHT PERCENT.*

Sample	M,N	No.	SiO_2	TiO_2	ZrO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	F	Cl	Sum	O	Sum less O	H_2O	TOTAL
LVP2014-18	1,1	20	59.96	0.53	0.12	15.42	7.91	0.35	0.33	1.02	8.71	4.85	0.51	0.30	100.00	0.28	99.72	1.68	100.52
			1.47	0.03	0.04	0.30	0.18	0.03	0.01	0.04	0.33	0.19	0.04	0.02	2.21	0.02	2.21	1.00	1.76
LVP2014-30	1,1	25	59.23	0.54	0.11	15.25	7.79	0.35	0.32	0.99	8.46	4.76	0.55	0.31	98.65	0.30	98.35	2.41	99.89
			1.77	0.04	0.05	0.49	0.25	0.03	0.01	0.07	0.82	0.26	0.15	0.02	3.34	0.07	3.33	1.76	2.24
LVP2015-48	1,1	14	60.80	0.59	0.12	15.27	7.91	0.36	0.26	0.99	8.75	4.93	0.30	0.30	100.58	0.19	100.39	1.46	100.96
			0.98	0.03	0.06	0.25	0.17	0.03	0.02	0.03	0.56	0.17	0.04	0.02	1.91	0.02	1.92	1.13	1.18
LVP2015-49	1,1	6	60.75	0.58	0.12	15.20	7.90	0.35	0.32	1.01	8.59	5.07	0.36	0.29	100.54	0.22	100.33	1.57	101.02
			0.56	0.01	0.03	0.12	0.12	0.02	0.02	0.02	0.38	0.19	0.04	0.02	1.01	0.02	1.01	1.14	0.37
LVP2015-51	1,1	15	60.89	0.59	0.11	15.28	7.85	0.35	0.40	0.99	8.68	5.02	0.35	0.30	100.82	0.21	100.60	1.56	101.29
			0.57	0.02	0.05	0.14	0.10	0.03	0.02	0.02	0.48	0.13	0.05	0.02	1.22	0.02	1.22	1.23	0.41
LVP2015-73	1,1	15	60.37	0.61	0.10	15.53	7.55	0.34	0.29	1.10	8.05	4.92	0.29	0.27	99.43	0.18	99.24	2.30	100.70
			0.42	0.06	0.05	0.26	0.62	0.04	0.05	0.20	0.84	0.15	0.08	0.06	1.47	0.05	1.43	0.73	1.28
LVP2014-19	1,1	20	61.12	0.57	0.09	15.56	6.55	0.28	0.32	1.04	7.33	4.67	0.37	0.16	98.34	0.19	98.15	3.54	100.97
			1.42	0.15	0.05	1.61	1.66	0.07	0.09	0.29	1.81	1.21	0.15	0.05	2.55	0.07	2.55	2.33	1.31
LVP2014-20	1,1	18	61.26	0.58	0.10	15.55	6.63	0.30	0.34	1.11	7.47	4.99	0.39	0.17	98.89	0.20	98.68	2.91	100.86
			0.97	0.04	0.03	0.23	0.13	0.02	0.01	0.03	0.25	0.26	0.04	0.01	1.63	0.02	1.64	1.10	0.81
LVP2014-27	1,1	8	58.81	0.56	0.11	15.10	6.65	0.29	0.41	1.11	7.06	4.86	0.40	0.18	95.54	0.21	95.33	2.78	97.37
			2.42	0.05	0.04	0.60	0.41	0.03	0.11	0.08	0.57	0.44	0.09	0.03	4.08	0.04	4.08	1.10	4.41
LVP2015-50	1,1	15	61.78	0.64	0.10	15.25	6.64	0.28	0.41	1.12	7.34	5.13	0.13	0.16	98.99	0.09	98.90	2.72	100.89
			0.85	0.04	0.04	0.29	0.16	0.04	0.03	0.07	0.39	0.26	0.08	0.01	1.53	0.03	1.53	1.34	0.66
LVP2015-52	1,1	15	62.02	0.64	0.10	15.53	6.66	0.28	0.31	1.11	7.36	5.34	0.20	0.16	99.72	0.12	99.59	2.96	101.81
			0.63	0.02	0.04	0.18	0.12	0.02	0.03	0.05	0.32	0.29	0.05	0.02	1.19	0.02	1.17	1.24	0.71
LVP2015-54	1,2	8	61.85	0.64	0.09	15.31	6.65	0.28	0.38	1.12	7.55	5.16	0.22	0.16	99.42	0.13	99.29	3.07	101.62
			0.89	0.04	0.05	0.17	0.17	0.01	0.01	0.04	0.47	0.30	0.04	0.01	1.54	0.02	1.54	1.41	0.70

TABLE 2. MEAN MAJOR AND MINOR ELEMENT OXIDES AND ELEMENTS BY WEIGHT PERCENT (continued).*

Sample	M,N	No.	SiO_2	TiO_2	ZrO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	F	Cl	Sum	O	Sum less O	H_2O	TOTAL
LVP2015-54	2,2	2	64.95	0.59	0.18	10.22	9.06	0.43	0.17	0.64	5.86	4.49	0.54	0.32	97.44	0.30	97.14	2.77	98.90
			0.94	0.03	0.01	0.16	0.09	0.01	0.01	0.01	1.57	0.18	0.03	0.00	0.26	0.01	0.24	0.48	0.73
LVP2015-56	1,1	15	62.58	0.65	0.08	15.39	6.77	0.30	0.35	1.10	7.76	5.32	0.19	0.16	100.67	0.12	100.55	1.20	101.00
			0.42	0.03	0.03	0.18	0.08	0.02	0.03	0.03	0.17	0.19	0.04	0.01	0.67	0.01	0.67	0.74	0.41
LVP2015-57	1,1	14	62.28	0.66	0.08	15.36	6.76	0.31	0.34	1.09	7.54	5.34	0.19	0.16	100.10	0.12	99.98	1.79	101.02
			0.69	0.05	0.04	0.18	0.16	0.04	0.02	0.06	0.27	0.26	0.06	0.01	1.18	0.03	1.18	1.21	0.76
LVP2015-61	1,1	14	62.03	0.67	0.08	15.67	6.73	0.29	0.33	1.12	7.70	5.11	0.19	0.16	100.36	0.12	100.25	0.19	99.68
			0.40	0.04	0.03	0.06	0.08	0.02	0.02	0.01	0.15	0.04	0.06	0.01	0.33	0.03	0.33	0.28	0.58
LVP2015-63	1,1	5	61.57	0.67	0.11	15.74	6.67	0.31	0.33	1.11	7.57	5.07	0.15	0.17	99.45	0.10	99.35	1.59	100.21
			1.01	0.05	0.04	0.30	0.10	0.03	0.02	0.03	0.23	0.32	0.04	0.01	1.48	0.01	1.49	0.97	0.63
LVP2015-65	1,1	14	61.31	0.66	0.07	15.69	6.61	0.32	0.33	1.10	7.34	5.03	0.21	0.17	98.92	0.12	98.79	1.66	99.72
			0.68	0.04	0.02	0.18	0.07	0.02	0.02	0.03	0.40	0.23	0.04	0.00	1.39	0.02	1.40	1.21	0.49
LVP2015-67	1,1	2	62.26	0.68	0.10	15.84	6.77	0.29	0.33	1.11	7.65	5.15	0.23	0.17	100.57	0.13	100.43	0.02	99.66
			0.48	0.01	0.07	0.16	0.10	0.02	0.03	0.02	0.02	0.19	0.02	0.00	0.66	0.01	0.65	1.01	0.37
LVP2015-81	1,1	15	61.55	0.64	0.08	15.86	6.29	0.27	0.35	1.07	7.43	5.18	0.21	0.16	99.08	0.12	98.96	2.33	100.59
			1.17	0.10	0.03	0.49	0.91	0.05	0.06	0.11	0.31	0.27	0.07	0.03	1.83	0.03	1.82	1.32	1.04
LVP2015-86	1,1	15	61.33	0.67	0.11	15.63	6.59	0.30	0.40	1.12	7.35	5.10	0.20	0.17	98.97	0.12	98.84	2.70	100.81
			1.12	0.03	0.05	0.26	0.15	0.02	0.03	0.03	0.31	0.21	0.04	0.01	1.89	0.02	1.89	1.38	1.79
LVP2014-29	1,1	14	58.44	0.41	0.19	15.48	7.20	0.33	0.22	0.77	7.83	4.63	0.61	0.41	96.51	0.35	96.16	3.97	99.33
			1.71	0.11	0.05	0.69	0.77	0.06	0.07	0.12	1.10	0.27	0.10	0.09	3.16	0.06	3.20	1.76	2.06
LVP2015-55	1,1	13	60.77	0.52	0.22	16.10	6.54	0.29	0.37	1.03	8.28	5.32	0.46	0.35	100.24	0.27	99.97	2.30	101.55
			0.92	0.05	0.05	0.23	0.30	0.02	0.03	0.06	0.55	0.18	0.10	0.05	1.89	0.05	1.86	1.24	0.86
LVP2015-58	1,1	15	60.78	0.44	0.23	15.52	7.27	0.33	0.19	0.98	8.77	4.96	0.58	0.41	100.46	0.34	100.13	1.79	101.11
			0.99	0.04	0.05	0.28	0.12	0.02	0.02	0.07	0.70	0.22	0.09	0.06	1.93	0.05	1.94	1.45	0.91
LVP2015-72	1,1	11	61.44	0.58	0.11	14.35	7.55	0.31	0.15	1.06	7.33	4.75	0.25	0.23	98.12	0.16	97.96	2.64	99.76
			1.04	0.05	0.04	0.43	0.13	0.03	0.10	0.13	0.42	0.23	0.07	0.05	1.54	0.04	1.54	0.99	1.00

*Sample listed on left (M,N=mode number, number of modes; No.=number of analyses). One standard deviation from the mean listed below each element oxide mean. Voltage=10keV, beam current=25nA, spot size=10mm.

TABLE 3. SIMILARITY COEFFICIENTS (SCs) FOR ALL DISTINCT MODES OF SAMPLES BASED ON TEN MAJOR-ELEMENT LIST (samples reported here listed vertically [left] and compared with the type samples [top])*.

Sample	Wakondo Tuff CAT09-05 (0.92)	Nyamita Tuff CAT09-21 (0.93)	Nyamsingula Tuff CAT10-03 (0.91)
LVP2014-18	0.98	0.87	0.89
LVP2014-30	0.98	0.87	0.90
LVP2015-48	0.95	0.86	0.90
LVP2015-49	0.96	0.88	0.88
LVP2015-51	0.95	0.88	0.87
LVP2015-73	0.93	0.90	0.88
LVP2014-19	0.88	0.95	0.85
LVP2014-20	0.88	0.98	0.86
LVP2014-27	0.86	0.95	0.84
LVP2015-50	0.84	0.96	0.82
LVP2015-52	0.86	0.95	0.84
LVP2015-54	0.85	0.96	0.83
LVP2015-54	0.79	0.73	0.73
LVP2015-56	0.86	0.97	0.84
LVP2015-57	0.86	0.96	0.84
LVP2015-61	0.86	0.97	0.85
LVP2015-63	0.87	0.96	0.85
LVP2015-65	0.87	0.96	0.84
LVP2015-67	0.86	0.96	0.84
LVP2015-81	0.85	0.95	0.83
LVP2015-86	0.85	0.96	0.83
LVP2014-29	0.86	0.80	0.91
LVP2015-55	0.91	0.90	0.92
LVP2015-58	0.89	0.82	0.94
LVP2015-72	0.86	0.87	0.82

*Type samples from Blegen et al. (2015) and Lower 95% confidence limit for 10 element SCs (in parentheses) for each type sample/mode in top row.

6n for examples) as well as a large bifacial pointed tool (see Figure 9c). Previously, the only large bifacial artifacts (n=2) collected by our team from the Pleistocene exposures of the eLVB are heavily weathered, rolled, and clearly redeposited (Faith et al. 2015; Tryon et al. 2012). The large bifacial tool at God Bura Elephant Site could also have been reworked from (currently unknown) sediments much older than the Nyamita Tuff (49 ka), but the artifact is not heavily rolled or weathered. The locality of Kajiei on the southeast extremity of the Winam Gulf preserves Levallois points (see Figure 6k, l) and a very small (1.9cm) Levallois core (see Figure 6c) collected above the Nyamita Tuff. Exposures above the Nyamita Tuff at Kajiei included a backed piece (see Figure 6h), the only LSA artifact recovered in our surveys of Late Pleistocene eLVB exposures. The artifact in question was found on a deflation surface in association with pottery, implying that it is not likely derived from the Pleistocene sediments at the site.

OBSIDIAN

A ~3cm obsidian medial blade fragment from the 68 ka site of Wakondo Bovid Hill (Jenkins et al. 2017) was recovered in 2011 and analyzed for this study (see Figure 6i). It is chemically indistinguishable from the source of Sonanchi crater in the Naivasha basin of the central Kenyan rift valley, ~250km east of the Wakondo Bovid Hill site. Another obsidian core fragment (~3cm) collected from above a unit attributed to the Nyamita Tuff at Onge, Karungu and analyzed for this study is from this same Sonanchi source. A single piece of obsidian angular waste (~1cm) surface collected from above the Nyamita Tuff at Kajiei is sourced to south Naivasha basin (Table 5).

Figure 5. Photographs of Gode Ariyo and Maguna South sites sampled for tephra analysis in July 2015: A) photograph of Gode Ariyo near measured section 'Sec.2015WPT 017' showing the large paleo-Vertisol exposed beneath the Wakondo Tuff at this locality. This lower stratigraphic interval is very poorly exposed at other known localities in the Late Pleistocene beds of the eLVB; B) photograph of Maguna Point Site #2 collection at Maguna South. Note MSA artifacts are coming from above the Menengai Tuff at Maguna Point Site #2; this upper stratigraphic interval is not exposed at other known localities in the Late Pleistocene beds of the eLVB. Artifacts collected from Maguna South: Maguna Point Site #2 are pictured in Figures 6 and 7.

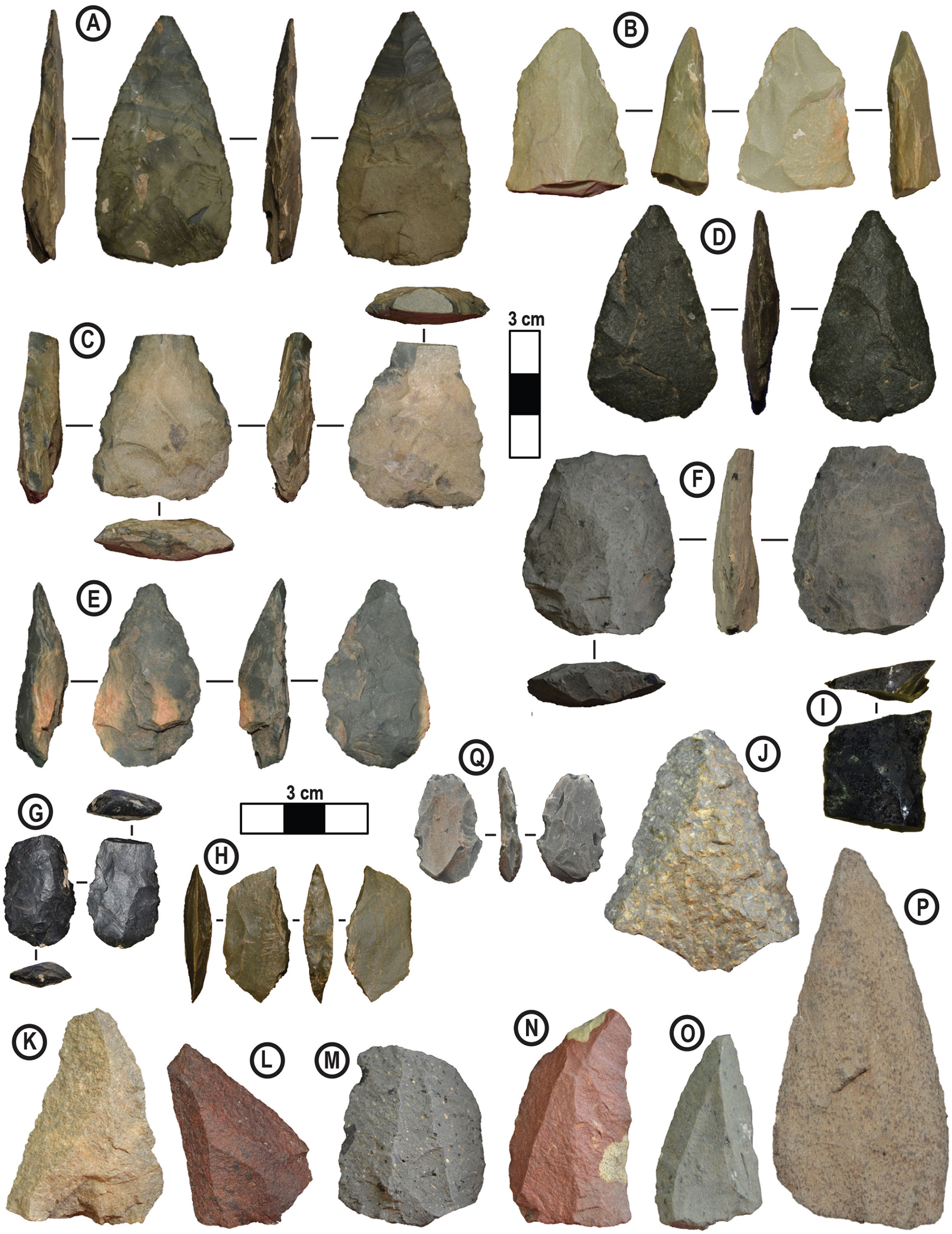

Figure 6. Selection of pointed pieces and technologically diagnostic flakes from new localities in the eLVB: A) bifacial point, chert Maguna Point Site #1; B) tip (broken) of a thick biface, chert, Aringo; C) bifacial point (tip broken), chert, Aringo; D) bifacial point, fine-grained lava, Magana South WPT 040; E) bifacial point, chert Maguna Point Site #2; F) Levallois flake, retouched distally and ventrally fine-grained lava, Kisaaka; G) bifacial point (tip broken) black chert, Maguna Point Site #1; H) backed microlith, chert, Kajiei above Nyamita Tuff; I) medial blade fragment, obsidian, Wakondo Bovid Hill; J) Levallois point, coarse-grained lava, God Bura Elephant Site above Nyamita Tuff; K) Levallois point, lava, Kajiei above the Nyamita Tuff; L) Levallois point, red lava, Kajiei above the Nyamita Tuff; M) Levallois point (tip broken), lava, Maguna Point Site #1; N) Levallois point, red lava, God Bura Elephant Site above Nyamita Tuff; O) Levallois point, lava, Gode Ariyo, above Nyamita Tuff; P) Levallois point, lava, Maguna South; Q) bifacial worked piece, (point?), obsidian with matte patina, Kisaaka.

TABLE 4. SURFACE COLLECTED ARTIFACTS FROM EASTERN LAKE VICTORIA BASIN SITES IN 2015.

Artifact Type	Nyamita	Rangoye	Kajiei	Kachuku	Wakondo-Bovid Hill	Aringo	God Bura	God Bura Elephant site	God Bura Molly Site	Gode Ariyo	Gode Ariyo East	Gode Ariyo West	Kisaaka	Maguna	Maguna Point Site 1	Maguna Point Site 2	Maguna South	Obware	Onge	Total
Complete flakes																				
Initial cortical flake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Residual cortical flake	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	3	0	0	0	**6**
Levallois	0	0	0	0	0	1	2	2	0	1	0	0	0	0	0	0	0	1	0	**7**
Levallois point	1	1	0	0	0	0	3	3	0	2	1	0	0	0	1	0	2	0	0	**14**
Non-cortical flake	1	9	3	0	0	4	3	3	0	1	0	2	1	2	9	27	3	0	2	**70**
Blade	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	**4**
Proximal flake fragments																				
Levallois flake	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0		0	1	0	**3**
Non-Levallois flake	0	0	0	0	0	1	1	2	0	2	0	0	0	2	3	17	0	0	1	**29**
Non-Levallois blade	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	1	**6**
Flake fragment other	0	0	1	0	0	0	0	0	1	0	0	0	0	0	8	24	4	2	1	**41**
Angular waste	0	0	0	0	0	1	0	0	1	1	0	0	0	1	18	50	0	0	0	**72**
Tools																				
Biface	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Bifacial point	0	0	0	0	0	6	0	0	0	0	0	0	1	1	1	1	1	1	0	**12**
Point	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
End scraper	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Retouched flake or flake frag	0	0	0	1	0	4	0	0	0	2	0	1	0	0	1	1	0	0	1	**11**
Retouched blade or blade frag	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**
Microlith	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**

TABLE 4. SURFACE COLLECTED ARTIFACTS FROM EASTERN LAKE VICTORIA BASIN SITES IN 2015 (continued).

Artifact Type	Nyamita	Rangoye	Kajiei	Kachuku	Wakondo-Bovid Hill	Aringo	God Bura	God Bura Elephant site	God Bura Molly Site	Gode Ariyo	Gode Ariyo East	Gode Ariyo West	Kisaaka	Maguna	Maguna Point Site 1	Maguna Point Site 2	Maguna South	Obware	Onge	Total
Cores, core fragments																				
Casual	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	**2**
Multiplatform	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	**4**
Levallois preferential	0	1	0	0	1	2	0	1	0	1	2	0	0	0	0	0	0	0	0	**8**
Levallois recurrent	0	2	1	0	0	4	1	0	0	2	2	0	2	0	0	1	1	0	1	**17**
Blade	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Discoidal	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	1	0	0	0	**5**
Core on flake	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Core frag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	**3**
Indeterminate	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	**6**
Total	**3**	**17**	**9**	**1**	**1**	**32**	**12**	**13**	**2**	**16**	**6**	**3**	**5**	**7**	**46**	**130**	**13**	**6**	**9**	**331**
Raw Material (all artifacts)																				
Lava	1	15	3	1	1	14	10	12	1	11	4	2	4	3	39	105	9	3	3	**241**
Chert-White/Red	2	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	**5**
Chert- Brown/Tan	0	1	0	0	0	5	0	0	0	1	2	0	0	0	1	3	0	0	0	**13**
Chert - Black	0	0	2	0	0	2	0	0	0	0	0	0	0	1	0	8	0	0	0	**13**
Chert (type not specified)	0	1	2	0	0	5	1	1	1	2	0	0	0	2	1	4	3	2	2	**27**
Chert - other	0	0	0	0	0	3	0	0	0	1	0	1	1	1	1	3	0	0	1	**12**
Obsidian	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**2**
Quartz	0	0	0	0	0	1	1	0	0	0	0	0	0	0	3	7	1	1	1	**15**
Quartzite	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	**3**
Total	**3**	**17**	**9**	**1**	**1**	**32**	**12**	**13**	**2**	**16**	**6**	**3**	**5**	**7**	**46**	**130**	**13**	**6**	**9**	**331**

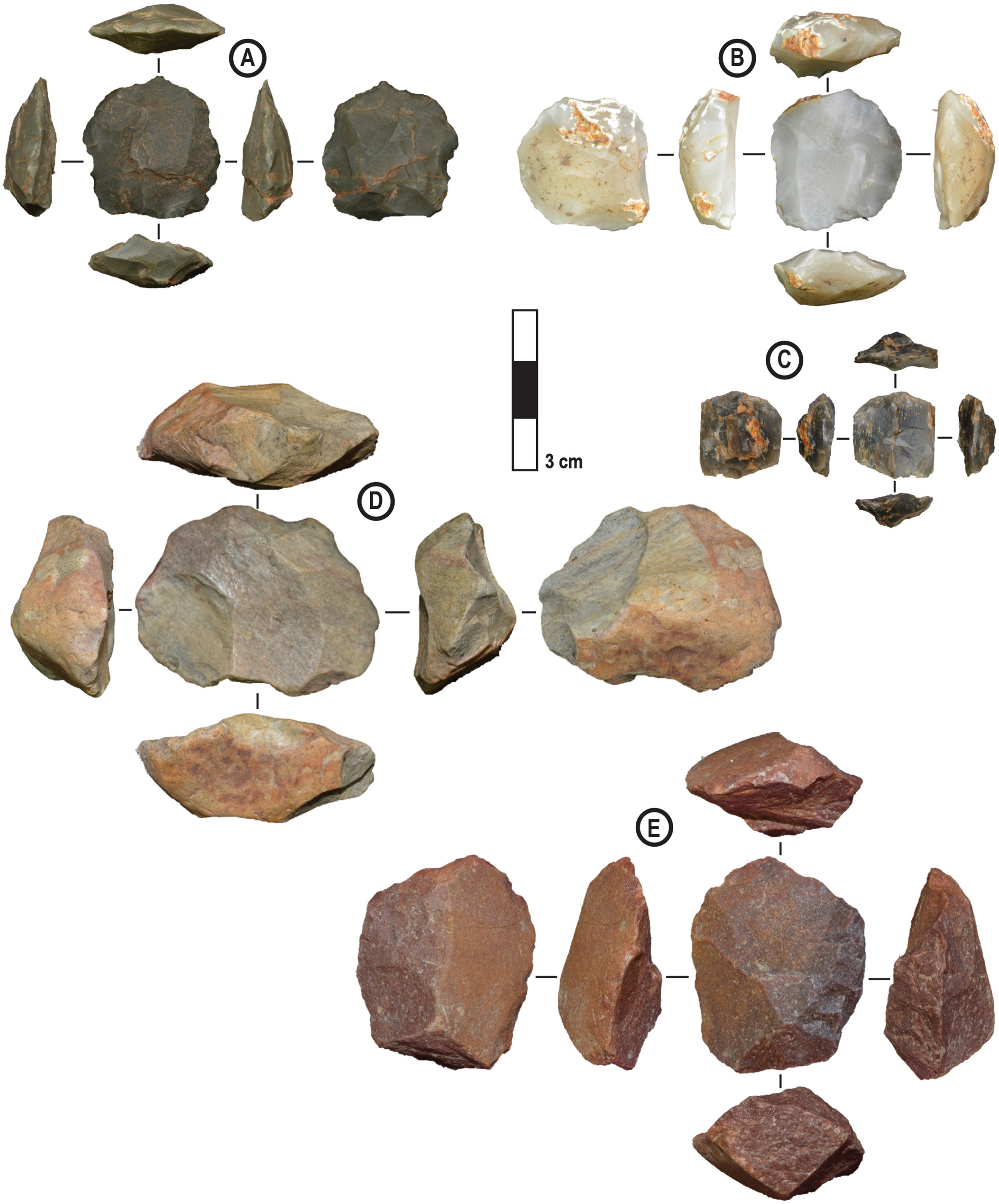

Figure 7. Selection of small cores from new localities in the eLVB: A) Levallois core, green chert, above Nyamita, Kisaaka; B) Levallois preferential flake core, white chert, Gode Ariyo; C) Levallois core, chert, Kajiei, above Nyamita Tuff; D) Levallois core, lava, Kisaaka; E) discoid core, red quartzite, Onge, above Nyamita tuff.

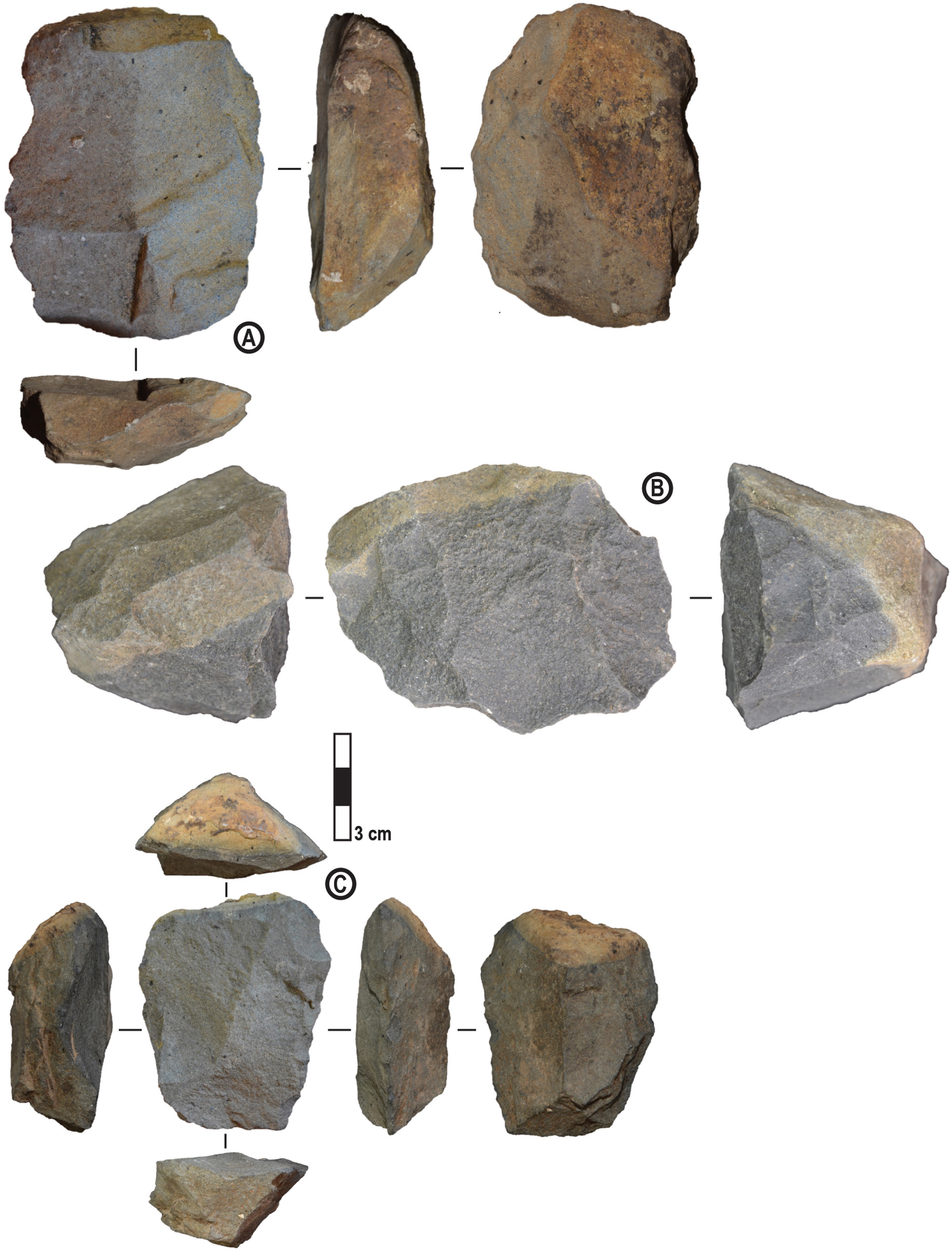

Figure 8: Selection of medium sized cores from new localities in the eLVB: A) Levallois core, lava Maguna Point Site #2, Maguna South above Menengai Tuff; B) Levallois core, coarse-grained two-toned brown lava, Rangoye, near Nyamsingula Tuff; C) Levallois core, lava, God Bura above Nyamita Tuff.

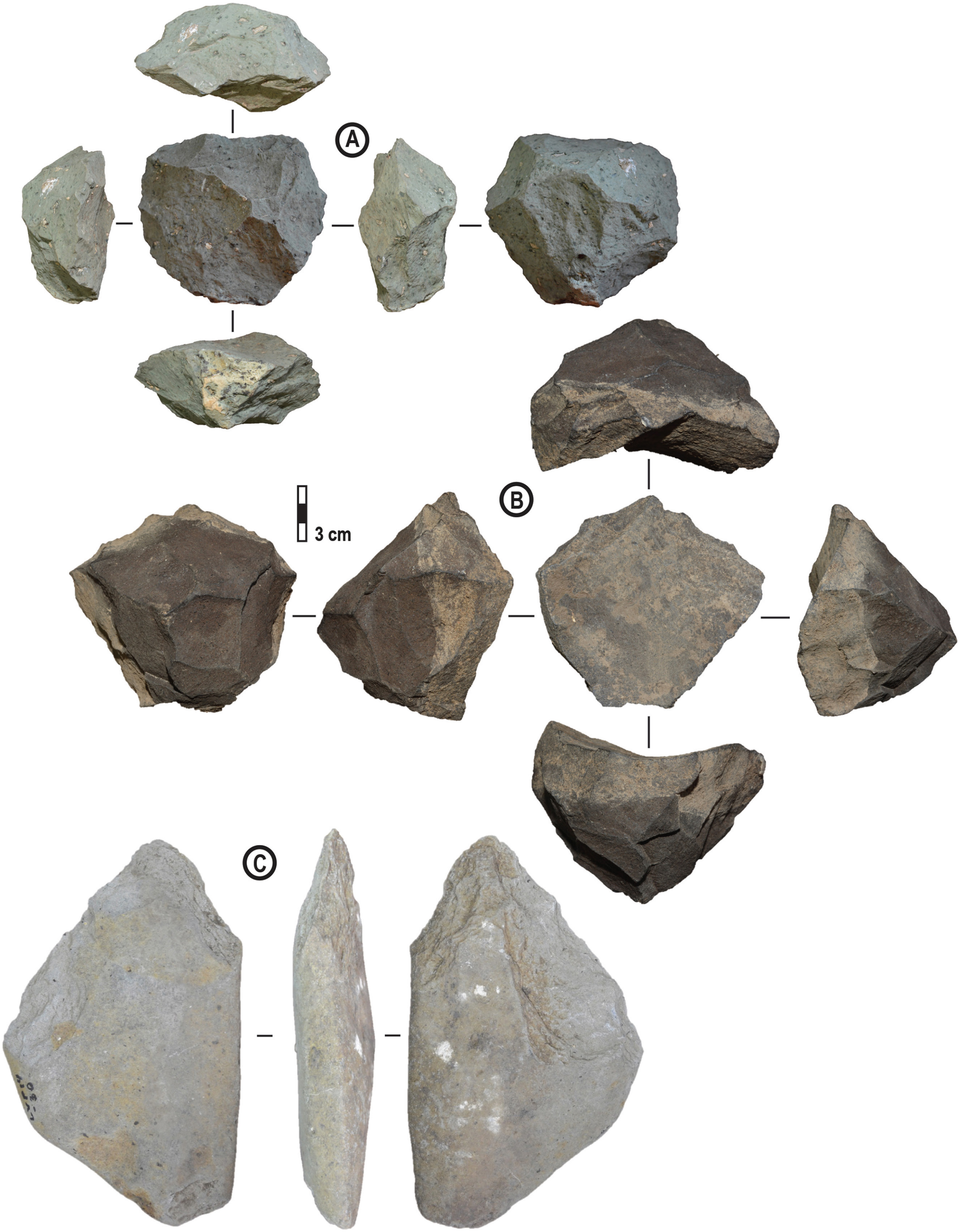

Figure 9. Selection of large sized cores from new localities in the eLVB: A) Levallois core, coarse-grained green lava, Gode Ariyo above Nyamita Tuff; B) Levallois core, coarse-grained two-toned brown lava, Aringo; C) large bifacial pointed tool, lava, God Bura Elephant Site, above Nyamita Tuff.

TABLE 5. INDIVIDUAL OBSIDIAN ARTIFACTS ANALYZED FOR SOURCING.*

Sample	No.	SiO_2	TiO_2	ZrO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	F	Cl	Sum
LVP2015-89	7	75.68	0.12	0.05	12.18	1.89	0.05	0.08	0.39	4.70	5.03	0.43	0.15	100.53
Wakondo														
Bovid Hill		0.28	0.03	0.04	0.15	0.07	0.01	0.01	0.03	0.21	0.09	0.10	0.01	0.39
LVP2015-90	7	70.44	0.31	0.24	8.49	7.83	0.26	0.06	0.39	7.08	4.63	0.54	0.39	99.78
Kajiei		0.30	0.04	0.05	0.08	0.10	0.04	0.01	0.06	0.26	0.12	0.22	0.01	0.74
LVP2015-91	7	75.96	0.11	0.04	12.10	1.79	0.03	0.06	0.35	4.70	5.18	0.51	0.17	100.53
Onge		0.20	0.04	0.06	0.09	0.05	0.01	0.01	0.05	0.22	0.07	0.21	0.01	0.75

*Mean major and minor element oxides by weight percent. Sample listed on left (No.=number of analyses). One standard deviation from the mean listed below each element oxide mean.

EXCAVATIONS OF NYAMITA MAIN

In August 2013, an excavation area of $52m^2$ was opened on the crest and eastern slope of a small hill forming the locality of Nyamita Main. The excavations uncovered sand-to-gravel-bearing channels cross-cutting a silt-to-clay-rich paleosol unit (Figures 10 and 11).

The main trench of the 2013 excavation was oriented approximately east–west and covered an area of $26m^2$ to an average depth of 0.70m below surface. It extended to Tryon's 2009 $4m^2$ trench to recover a larger sample of lithic artifact material *in situ* (see Figure 10). The north trench was oriented north–south along the crest of the hill and an area of $26m^2$ was excavated to an average depth of 0.85m to recover faunal material *in situ* and establish its context.

Sediments encountered in the Nyamita Main excavations are variants of the first two general lithological categories found in the Wasiriya beds. These are: 1) dark brown clay paleosols with varying amounts of silt and sand; and, 2) moderately well-sorted medium to coarse sand with sub-round to angular lava and carbonate grains (see Figure 11a-c).

Lithic Assemblage of Nyamita Main

A total of 449 surface and *in situ* artifacts were recovered in 2008/2009 and 2013 at Nyamita Main (Table 6). Tryon's excavations recovered 26 of the *in situ* pieces and 95 of the surface collected pieces. The 2013 excavations recovered an additional 295 artifacts *in situ* (133 were piece-plotted and 162 were recovered from the sieve) and 33 from the surface, for a total of 321 *in situ* pieces and 128 from controlled surface collections. Most of the *in situ* artifacts were recovered from a small sand-gravel-filled channel in the main trench of the excavation.

Lithic Raw Materials at Nyamita Main

Eight raw materials are recognized from the Nyamita Main excavations: 1) a red and white mottled chert; 2) a fine-grained (aphanitic) lava; 3) a coarse-grained lava; 4) quartz; 5) quartzite; 6) a green chert; 7) a black chert; and, 8) 'other' small pieces of angular debris that cannot be confidently attributed to any of the above categories (see Table 6). The vast majority of all artifacts from the 2008/2009 and 2013 excavations (n=388) are made of the mottled chert (n=204) or lava (n=184) and whole flake measurements by raw material group are provided in Table 7. The mottled chert source is found on the eastern side of Rusinga Island and the aphanitic lava likely is derived from the Lunene Lavas, or similarly aged lavas from Kisingiri, which are found in place at the top of the ridges on Rusinga Island and as cobbles in drainages off of the ridges (Tryon et al. 2014). The quartz and quartzite have been observed in Pleistocene gravels at Nyamita, and as large clasts within granodiorite volcanic bombs in the early Miocene Kiahera Formation. All of these raw materials are local. The source of the green and black cherts has not been observed on Rusinga Island and these materials are likely non-local.

Taphonomic Context of Lithic Materials from Nyamita Main

Lithic artifacts excavated from the site represent the products of on-site knapping in a minimally winnowed context. Both the mottled chert and the lava raw materials, the only raw materials represented by sufficiently large numbers to assess their taphonomic integrity, conform to experimental models for stone tools produced on-site and preserved in a primary context (Schick 1986). Size class analysis of piece-plotted and sieve-recovered mottled chert artifacts shows that 80.0% of all artifacts are ≤ 2cm in maximum dimension (Figure 12). The lava raw material is in a slightly winnowed context, as lava pieces recovered from the excavation show slightly lower proportions of size class 1 flakes (< 1cm in maximum dimension). Accordingly, higher proportions of the flakes are from larger size classes 3–5, indicating some fluvial action sorted and removed smaller pieces. However, the presence of both lava cores and flakes in the same part of the site, suggests the material was knapped on-site and has been subject to minimal winnowing removing some of the smaller pieces.

Technology of Lithic Materials

Like all lithic artifacts known from the eLVB, lithic artifacts from Nyamita Main are typologically and technologically characteristic of the MSA (Figure 13). Flaked pieces include bifacial points (n=2) and unifacial points (n=1) collected

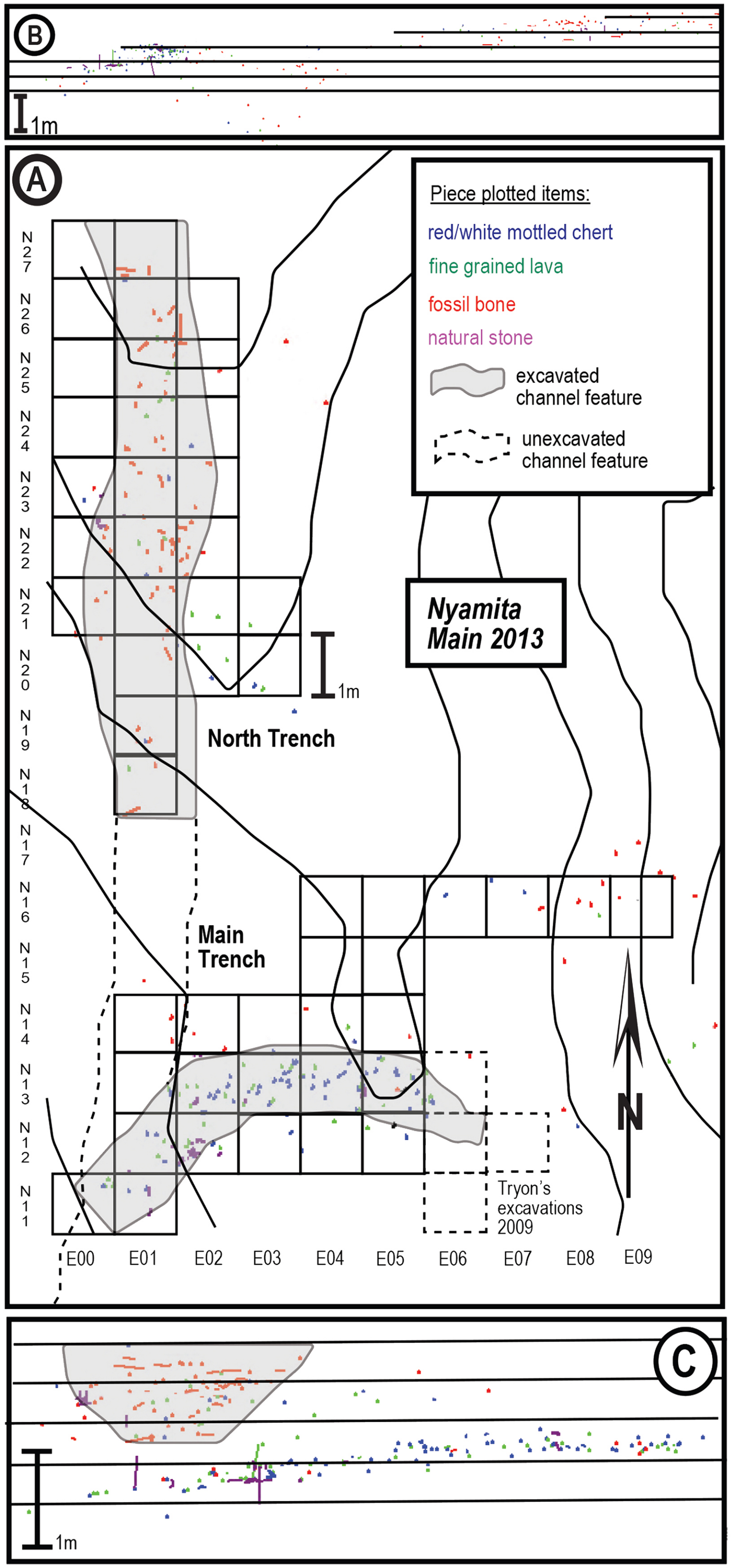

Figure 10. A) Plan map of Nyamita Main 2013 excavation with piece-plotted lithic artifacts sorted by raw materials, fossil bones/teeth, and natural rock color-coded by category. B) Side cross-section of Nyamita Main 2013 excavation (looking west) with piece-plotted lithic artifacts sorted as before. C) Front cross-section (looking north) of Nyamita Main 2013 excavation with piece-plotted lithic artifacts sorted as before.

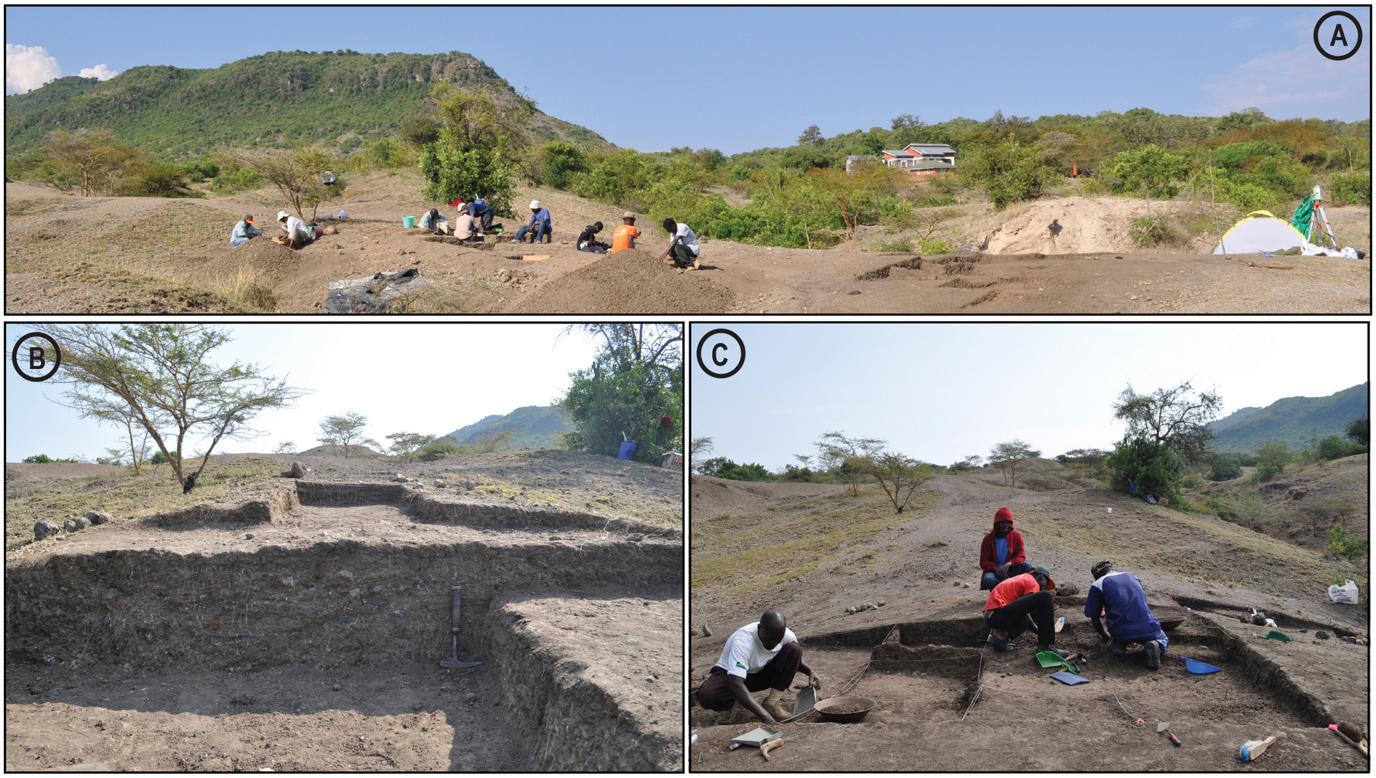

Figure 11. Photographs of Nyamita Main excavations in August of 2013: A) wide-angle photograph (looking east) of excavations showing North trench on left and Main Trench to the right with total station set up to far right; B) photograph of north wall profile of North trench showing the stream channel in cross section; C) main trench under excavation viewed looking north.

from the surface in 2008/2009 (Tryon et al. 2010; 2014) as well as Levallois points (n=2) made in the red and white mottled chert and lava raw materials that dominate the lithic assemblage from the 2013 excavations (see Figure 13). Cores exhibit both the preferential and recurrent Levallois methods of flake production (see Figure 13).

Fauna of Nyamita Main

Fossil fauna at Nyamita Main derives from and immediately adjacent to a single ~2m wide by ~1m deep channel feature encountered along the north–south long axis of the north trench (see Figure 10). The general shape of this channel can be observed in the north facing cross-sectional profile of piece-plotted material in the north trench (red dots in Figure 10c). The channels appear to drain south and west, similar to the trend of the modern Nyamita Valley. Faunal material comprised the majority of plotted material in this trench and was relatively complete with many specimens comprising entire elements such as hemi-mandibles. No cutmarks or percussion marks were observed, but surface preservation is poor. Very little faunal material was recovered in the Main Trench and what was recovered consisted mostly of isolated tooth or bone fragments.

All of the vertebrate remains identifiable below family level are cranio-dental specimens. The taxonomically identifiable sample based on teeth consisted of 16 specimens identifiable to the level of tribe or lower (Table 8, NISP=16, MNI=11). There are a minimum number of eleven individuals and all but one of these, a carnassial attributed to *Canis*, are bovids (Table 8). The bovids represent at least seven taxa from four tribes. Alcelaphin antelopes are most common (62.5% of all large mammal specimens by NISP) and include the extinct medium alcelaphin related to wildebeest (*Rusingoryx atopocranion*), the extinct small alcelaphin similar to modern blesbok (*Damaliscus hypsodon*), extant hartebeest (*Alcelaphus buselaphus*), and at least two individuals that could not be diagnosed to a more specific taxonomic level. The presence of bushbuck in the excavated sample is consistent with the same taxon and other taxa indicative of closed vegetation (common duiker) recovered from the surface collections.

Although sample sizes are small, the relative abundance of alcelaphin specimens among the bovids from the Nyamita excavation is similar to large samples of faunal material from the eLVB (Tryon et al. 2010, 2012, 2014), and is matched in contemporary arid to semi-arid grassland environments (Alemseged 2003; Vrba 1980). The extinct bovids at Nyamita Main, *R. atopocranion* and *D. hypsodon*, are characterized by exceptional hypsodonty (Faith et al. 2011; 2012). This adaptation is interpreted as suited to consuming grasses in dry and gritty environments (Damuth and Janis 2011; Faith et al. 2012; Marean 1992). However, the presence of bushbuck (*Tragelaphus scriptus*) and reedbuck (*Redunca redunca* and *Redunca* cf. *arundinum*), as well as hippopotamus fossils surface collected from the site (Tryon et al. 2010; 2012; 2014) suggest a local component of closed

TABLE 6. SUMMARY OF ASSEMBLAGE COMPOSITION FOR NYAMITA MAIN LITHIC ARTIFACTS.

		n (subtotal)	% Without debris	Red/ White Chert	Lava	Coarse Lava	Quartz	Quartzite	Black Chert	Other
Core										
	Casual	5	1.85	1	2	1	-	1	-	-
	Multiplatform	1	0.37	-	1	-	-	-	-	-
	Levallois preferential	2	0.74	-	2	-	-	-	-	-
	Levallois point	0	0.00	-	-	-	-	-	-	-
	Levallois recurrent	2	0.74	1	1	-	-	-	-	-
	Blade	0	0.00	-	-	-	-	-	-	-
	Core on flake	0	0.00	-	-	-	-	-	-	-
	Core fragment	1	0.37	1	-	-	-	-	-	-
	Core subtotal	**11**	**4.07**							
Debitage										
	Initial coritcal flake	0	0.00	-	-	-	-	-	-	-
	Residual cortical flake	0	0.00	-	-	-	-	-	-	-
	Levallois flake	2	0.74	-	2	-	-	-	-	-
	Levallois point	3	1.11	-	2	-	-	-	1	-
	non- cortical flake	71	26.30	32	32	-	-	4	3	-
	Flake fragment proximal	81	30.00	38	40	-	1	1	1	-
	Flake fragment other	98	36.30	47	46	-	1	4	-	-
	Flake subtotal	**255**	94.44							
Debris										
	Debris and subtotal	**179**		83	55	1	6	4	1	29
Tool										
	point	2	0.74	1	1	-	-	-	-	-
	side scraper	1	0.37	1	-	-	-	-	-	-
	bifacial point	1	0.37	-	1	-	-	-	-	-
	Tool subtotal	**4**	1.48							
TOTAL		**449**		205	185	2	8	14	6	29
	n, % without debris	**270**	**100.00**							

habitats and standing water respectively. This agrees with evidence from tufa and isotopic analyses of paleosol carbonates and organic material from the Nyamita Valley (Beverly et al. 2015a; 2015b; Garrett et al. 2015).

The sand-to-gravel-filled channel from which fossil fauna was recovered is variably cemented by carbonate and is more resistant to erosion then the surrounding silt-clay paleosols. The fauna cannot be directly related to the artifacts at Nyamita Main. The majority of artifacts occur in the main trench while almost all fauna was encountered in the small channel feature in the north trench (see Figures 10a, c; 11b). Further, the fauna on the site cannot be confidently shown to be archaeological as no obvious cutmarks or percussion marks were observed.

TABLE 7. SUMMARY STATISTICS OF DIMENSIONS (mm) OF WHOLE FLAKES FOR THE TWO MOST COMMON RAW MATERIAL TYPES FROM NYAMITA MAIN.

	Whole Flakes	Mean Flake Length (mm)	Mean Flake Width (mm)	Mean Flake Thickness (mm)	Mean Flake Platform Width (mm)	Mean Flake Platform Thickness (mm)	Flake Frags + AW	Total Number of Pieces	Total Weight (g)
Lava	27	37.30	27.69	9.11	18.46	7.38	101	**128**	746.89
±1 sd		22.33	12.36	4.95	9.48	4.99			
Red/White Mottled Chert	27	18.01	17.10	4.68	10.65	3.79	134	**161**	306.67
±1 sd		9.98	8.50	3.96	5.44	2.17			

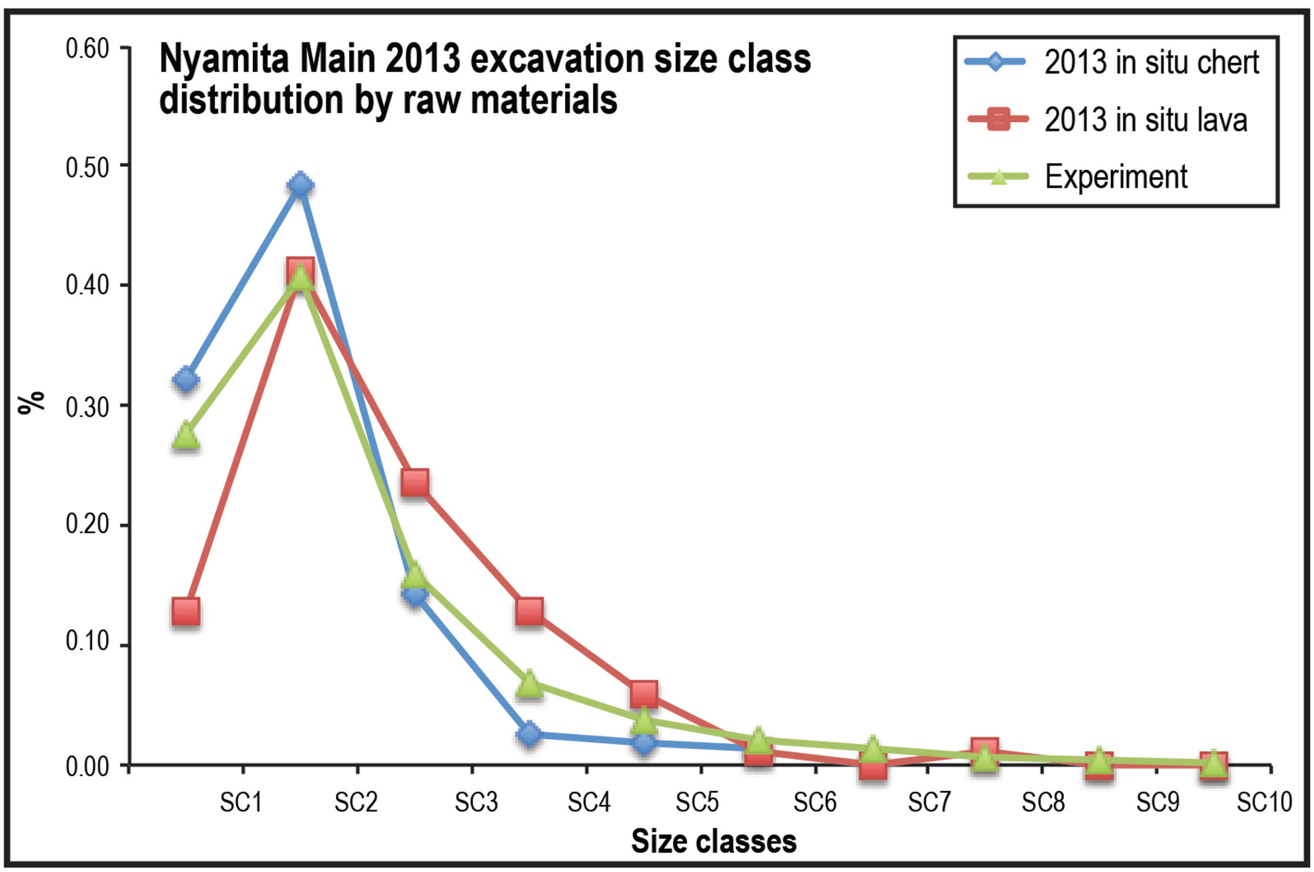

Figure 12. Size class distributions of artifacts by raw material category. Experiment totals from Schick (1986).

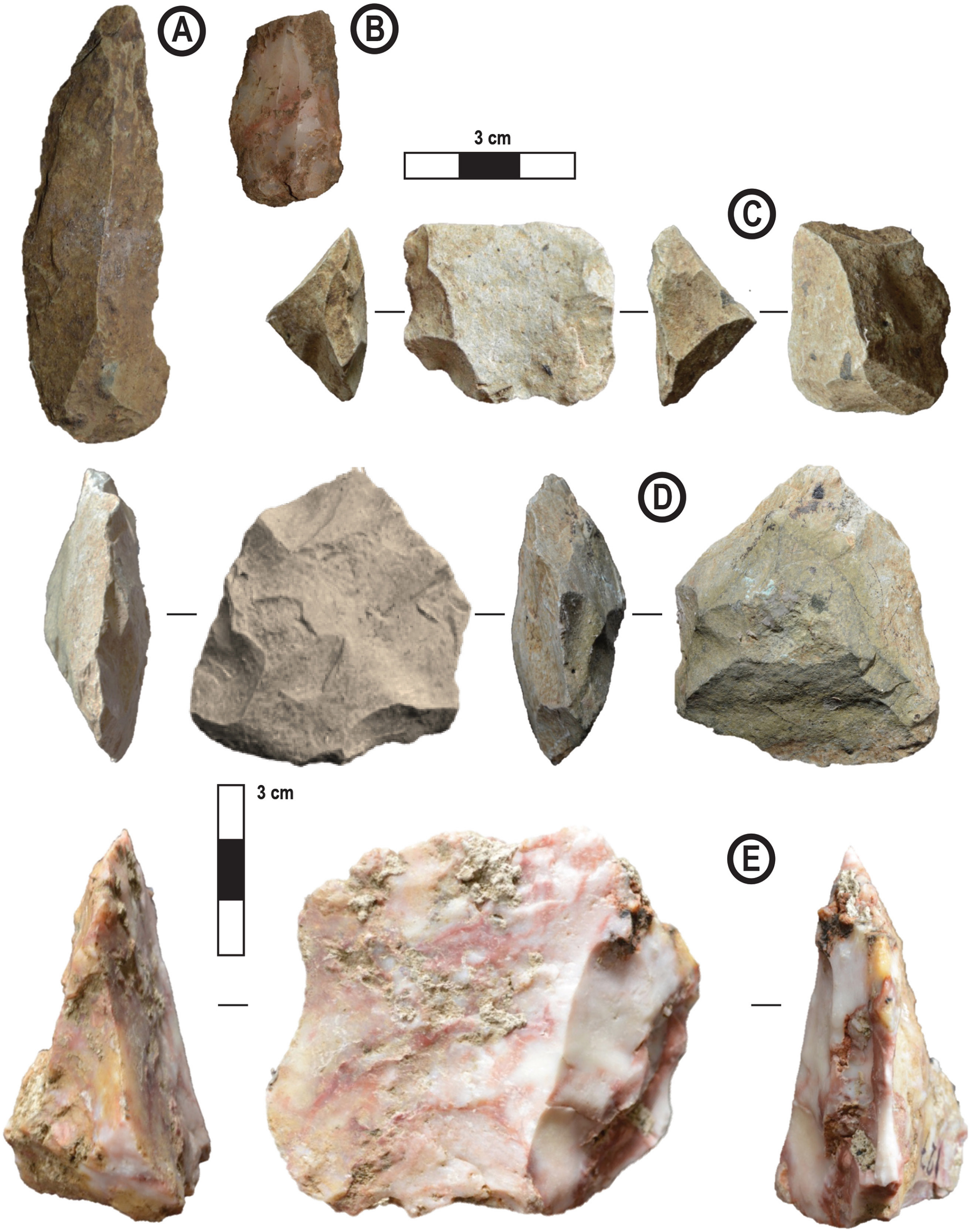

Figure 13. Artifacts: A) elongated Levallois point (lava) retouched on both dorsal margins; B) proximal convergent flake or blade (Levallois point?) made on red/white mottled chert; C) Levallois core with overshot preferential flake made on lava (found on surface on main trench 2013; D) recurrent Levallois or discoid core from Tryon's 2009 excavation (also see illustration in Tryon et al. 2010); E) red/ white mottled chert Levallois core with recurrent unidirectional removals on debitage surface from Tryon's 2009 excavations on surface of main trench.

TABLE 8. NYAMITA MAIN FAUNAL LIST INCLUDING NISP AND MNI COUNTS.

Taxon	NISP	MNI
Canis sp.	1	1
Tragelaphus scriptus	1	1
Redunca cf. *redunca*	1	1
Redunca cf. *arundinum*	2	1
Alcelaphus buselaphus	2	2
Damaliscus hypsodon	1	1
Rusingoryx atopocranion	1	1
Alcelaphini indet.	6	2
Ourebia ourebi	1	1
TOTAL	**16**	**11**

DISCUSSION

THE LATE PLEISTOCENE ELVB AND THE MSA/LSA TRANSISTION

Data presented here showing MSA technology persisted over a wide area in the Victoria basin as late as <36 ka agrees with all prior evidence from these Late Pleistocene exposures. In seven continuous seasons of survey and excavation, only a single diagnostic LSA artifact (see Figure 6h) has been recovered and this surface find is probably younger than the associated Pleistocene deposits. In contrast, hundreds of characteristically MSA tools have been recovered on the surface and *in situ* from all chronostratigraphically defined intervals between ~100 and 36 ka (Tryon et al. 2016).

While temporal variation in the end of the MSA and appearance of the LSA is a phenomenon increasingly recognized across Africa, East Africa provides a unique venue in which to study this phenomenon. The late persistence of the MSA in western Kenya after 50 ka contrasts markedly with the earliest appearances of LSA or MSA/LSA transitional materials at Mumba and Nasera rock shelters and the Naisiusiu beds of northern Tanzania as well as Enkapune Ya Muto in the central Kenyan rift (Ambrose 1998; Leakey et al. 1972; Mehlman 1977, 1979, 1989). Additionally, the obsidian sourcing evidence presented here from after 50 ka suggests MSA-making hominins of the eLVB and the early LSA-making hominins of northern Tanzania and Enkapune Ya Muto all shared access to at least one common area between 100 ka and 36 ka—the Naivasha basin of the central Kenyan Rift. This is despite the presence of high-quality obsidian sources closer to sites of the Victoria basin and northern Tanzania (Brown et al. 2013).

Obsidians could have been transported by trade or through direct procurement of highly mobile hunter-gatherer populations (Ambrose 2012). Regardless, the humans making MSA or LSA assemblages from different parts of equatorial East Africa would likely have had knowledge of, or contact with, one another because they were procuring raw materials from the same sources at the same times. This does not preclude the possibility that different hominin populations maintained different technological traditions in spite of knowledge of alternatives. Such behavior is ethnographically attested (Wiessner 1983), though on a much smaller geographical and temporal scale. The data presented here does suggest that, whatever the reason for the persistence of the MSA in the eLVB, it was a choice hominin populations made with likely knowledge of alternatives, and not because of ignorance due to geographic isolation.

Our sample size of archaeological materials in the Late Pleistocene eLVB remains small. However, it is noteworthy that all lithic artifacts from excavated contexts in several time intervals throughout the eLVB are characteristically MSA. Also, while the sample of sourced obsidians presented in this and recent studies remains small, all sourcing studies of Pleistocene obsidians from the eLVB over the past 30 years including the sites of Muguruk, Songhor, Aringo 3, Kisaaka, Wakondo Bovid Hill, Onge, and Kajiei unilaterally show the source of archaeological obsidians in the eLVB was the Naivasha basin (Brown et al. 2013; Faith et al. 2015; Merrick and Brown 1984; Merrick et al. 1994).

At the very least, our assertion that MSA technologies in the eLVB persist very late despite consistent contact with early LSA-making populations, constitutes a reasonable hypothesis, and one that can be tested by building on work presented here.

Our research also shows the Late Pleistocene eLVB stratigraphic sequence can be expanded laterally across an area >2500km^2 and extended chronologically to deposits older than 100 ka and younger than 36 ka. The geographic area incorporated by this expanded tephrostratigraphic framework, encompassing most of the Winam Gulf, also suggests that this framework will eventually subsume some or all of the known nearby stratified Late Pleistocene MSA sites including Rambogo, Randhore, and Muguruk north of the Winam Gulf, as well as Late Pleistocene and possibly Middle Pleistocene exposures of Simbi and Songhor in the Nyanza Rift for which tephras are reported (see Figure 1; McBrearty 1981, 1986, 1991, 1992; Pickford 1982, 1986a, 1986b; Pickford and Thomas 1984). Establishing chronostratigraphic context and ages for these sites will provide a larger lateral area, longer timeframe, and larger sample sizes of archaeological, paleontological, and geological material. Both the lateral and chronological expansion of the Late Pleistocene eLVB provide improved control and increased potential for investigating human behavior though time and across space.

Tephrostratigraphy combined with archaeology has been used to investigate the Acheulean to MSA transition in the Middle Pleistocene of equatorial East Africa (Tryon and McBrearty 2002, 2006), but similar programs either within or between depositional basins have yet to be instituted for the MSA/LSA transition in the Late Pleistocene of the same region. The combination of excavations of open-air, low-density sites situated in a well-resolved tephro and chronostratigraphic framework, presented here, suggests a methodology to further improve our understanding of this transition.

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