

## Late Pleistocene artefacts and fauna from Rusinga and Mfangano islands, Lake Victoria, Kenya

Christian A. Tryon , Daniel J. Peppe , J. Tyler Faith , Alex Van Plantinga , Sheila Nightingale , Julian Ogondo & David L. Fox

To cite this article: Christian A. Tryon , Daniel J. Peppe , J. Tyler Faith , Alex Van Plantinga , Sheila Nightingale , Julian Ogondo & David L. Fox (2012) Late Pleistocene artefacts and fauna from Rusinga and Mfangano islands, Lake Victoria, Kenya, *Azania: Archaeological Research in Africa*, 47:1, 14-38, DOI: [10.1080/0067270X.2011.647946](https://doi.org/10.1080/0067270X.2011.647946)

To link to this article: <https://doi.org/10.1080/0067270X.2011.647946>



Published online: 27 Feb 2012.



Submit your article to this journal [↗](#)



Article views: 360



View related articles [↗](#)



Citing articles: 33 View citing articles [↗](#)

## Late Pleistocene artefacts and fauna from Rusinga and Mfangano islands, Lake Victoria, Kenya

Christian A. Tryon<sup>a\*</sup>, Daniel J. Peppe<sup>b</sup>, J. Tyler Faith<sup>c</sup>, Alex Van Plantinga<sup>d</sup>, Sheila Nightingale<sup>e</sup>, Julian Ogondo<sup>f</sup> and David L. Fox<sup>g</sup>

<sup>a</sup>Center for the Study of Human Origins, Department of Anthropology, New York University, 25 Waverly Place, New York NY 10003, United States of America; <sup>b</sup>Department of Geology, Baylor University, One Bear Place, # 97354, Waco, TX 76798, United States of America; <sup>c</sup>School of Social Science, University of Queensland, Brisbane, QLD 4072, Australia; <sup>d</sup>Department of Geology, Baylor University, One Bear Place, 97354, Waco, TX 76798, United States of America; <sup>e</sup>Department of Anthropology, Graduate School and University Center, City University of New York, 365 Fifth Avenue, New York, NY 10016-4309, United States of America; <sup>f</sup>Earth Sciences Department, Geology Section, National Museums of Kenya, Box 40658-00100, Nairobi, Kenya; <sup>g</sup>Department of Geology and Geophysics, University of Minnesota, 310 Pillsbury Drive SE, Minneapolis, MN 55455-0231, United States of America

Surveys and excavations in 2009–2011 recovered fossil and artefact assemblages from late Pleistocene sediments on Rusinga and Mfangano islands (Lake Victoria, Kenya). Radiometric age estimates suggest that the Rusinga material dates to between 100 and 33 kya, whereas that from Mfangano may date to  $\geq 35$  kya. The preservation of a large and diverse suite of vertebrate fossils is unusual for Pleistocene sites in the Lake Victoria region and the composition of the faunal assemblages from both islands strongly suggest an open, arid, grassland setting very different from that found in western Kenya today. Middle Stone Age (MSA) artefacts from Rusinga and possible Later Stone Age (LSA) or MSA/LSA assemblages from Mfangano are distinct from Lupemban MSA sites characteristic of the Lake Victoria region and instead share a number of typological and technological features with late Pleistocene sites from open grassland settings in the East African Rift System. This highlights the complex roles that shifting environments, as well as temporal change, may have played in the development of regional variation among Equatorial African artefact assemblages in the Pleistocene.

**Keywords:** Middle Stone Age; Later Stone Age; Quaternary; aridity; Lake Victoria

Les prospections et fouilles de 2009–2011 ont mis au jour des ensembles de fossiles et d'artefacts dans des sédiments du Pléistocène tardif sur les îles de Rusinga et Mfangano (Lac Victoria, Kenya). Les datations radiométriques indiquent que le matériel de Rusinga date d'entre 100,000 et 33,000 BP et celui de Mfangano de  $\geq 35,000$  BP. La préservation d'une grande et diverse série de fossiles des vertébrés est exceptionnelle parmi les sites pléistocènes de la région du Lac Victoria. La composition des ensembles fauniques des deux îles suggère fortement un environnement de prairie ouverte aride, très différent de celui que l'on trouve actuellement dans l'ouest du Kenya. Les ensembles lithiques du Middle Stone Age (MSA) de Rusinga et ceux du Mfangano, qui datent soit du Later Stone Age (LSA) ou soit du MSA/LSA sont distincts de ceux des sites Lupemban MSA typiques de la région du Lac Victoria. Par contre, ils partagent

---

\*Email: ct68@nyu.edu

des traits typologiques et technologiques avec les sites des prairies ouvertes du Pléistocène tardif du grand rift est-africain. Cette observation met en évidence les rôles complexes que les environnements changeants, ainsi que l'évolution au cours du temps, ont pu jouer durant le Pléistocène dans le développement des variations régionales au sein des ensembles lithiques de l'Afrique équatoriale.

## **Introduction**

Archaeological, palaeontological and genetic evidence suggests the presence of diverse hominin populations and complex patterns of geographic and temporal variation in the late Pleistocene of Africa (Lahr and Foley 1998; Barham and Mitchell 2008; Gunz *et al.* 2009; Tishkoff *et al.* 2009). The late Pleistocene African record is particularly important in a global context because it encompasses the dispersal of some early populations of *Homo sapiens* to Eurasia and beyond. Middle Stone Age (MSA) and Later Stone Age (LSA) sites provide the only source of behavioural data for African hominin populations from this time interval. MSA sites show spatial and temporal variation, although the underlying causes of this variation remain poorly understood, as do the reasons for the technological and behavioural shifts that characterise the first appearances of LSA sites (cf. McBrearty and Brooks 2000; Klein 2009). Possible causes include improved cognitive capacities through the rapid spread of an advantageous genetic mutation, larger populations or changing environments, the latter leading to novel adaptive niches, new technologies and behavioural differentiation by vicariance.

Equatorial Africa has a complex history of Quaternary environmental change. Spanning the Equator, Lake Victoria is the largest lake in Africa as measured by surface area and is characterised by a dynamic history of fluctuating lake levels and the expansion and contraction of surrounding biotic communities (reviewed in Johnson *et al.* 2000 and Stager and Johnson 2008). This environmental dynamism is known to affect the distribution and function of Holocene archaeological sites in the region (e.g. Robertshaw *et al.* 1983; Lane *et al.* 2006), and it may have also impacted Pleistocene hominin populations (Tryon *et al.* 2010). In turn, the Lake Victoria region is potentially an important place to explore the relationship between climate change and hominin evolution.

Despite the Lake Victoria region's biogeographic and climatic importance in understanding past hominin populations, relatively little is known about its late Pleistocene palaeoanthropological record. The Kenyan islands of Rusinga and Mfangano are located near the eastern shore of Lake Victoria (0°24'S, 34°0'E; Figures 1 and 2) and include Pleistocene exposures yielding artefacts and fossils. The Pleistocene sediments from Rusinga were first described by Kent (1942) and those from Mfangano by Whitworth (1961), although these early investigations focused primarily on the Miocene deposits on the islands. Pickford (Pickford and Thomas 1984; Pickford 1986) collected and described Pleistocene fossils from both islands during the course of his wide-ranging surveys and remapping of the islands. We began the first dedicated geological, palaeontological and archaeological study of the Pleistocene deposits on both islands in 2009 (Tryon *et al.* 2010; Faith *et al.* 2011).

Here, we describe the results of our ongoing fieldwork on Rusinga and Mfangano, emphasising data collected during the 2010 field season on sedimentary and palaeoenvironmental context, fossil fauna and lithic assemblages, including raw material sources. The 2010 season doubled the artefact sample from Rusinga,

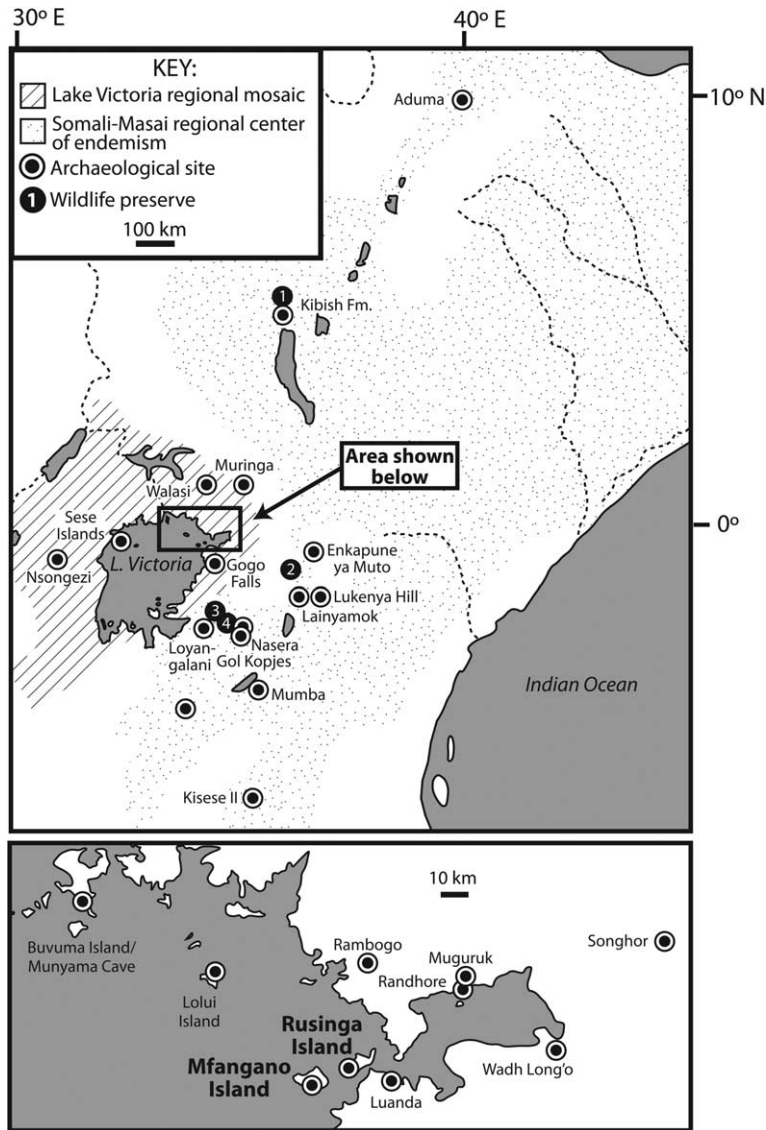


Figure 1. Map of eastern Africa showing archaeological sites discussed in the text in relation to two major phylogeographic zones, the Somali-Masai centre of regional endemism and the Lake Victoria regional mosaic (after White 1983). Also shown are the (1) Omo, (2) Nairobi, (3) Serengeti and (4) Ngorongoro wildlife reserves.

allowing for more robust interpretations of MSA lithic technology than previously possible (cf. Tryon *et al.* 2010). Survey of Mfangano began in 2010 and continued in 2011. We provide here the first description of its Stone Age artefacts, the first radiometric age estimates for the late Pleistocene sediments and a faunal sample considerably larger than that reported by Pickford (1986). These data facilitate comparison of the Rusinga and Mfangano Island assemblages with other East African sites, the results of which emphasise the importance of understanding

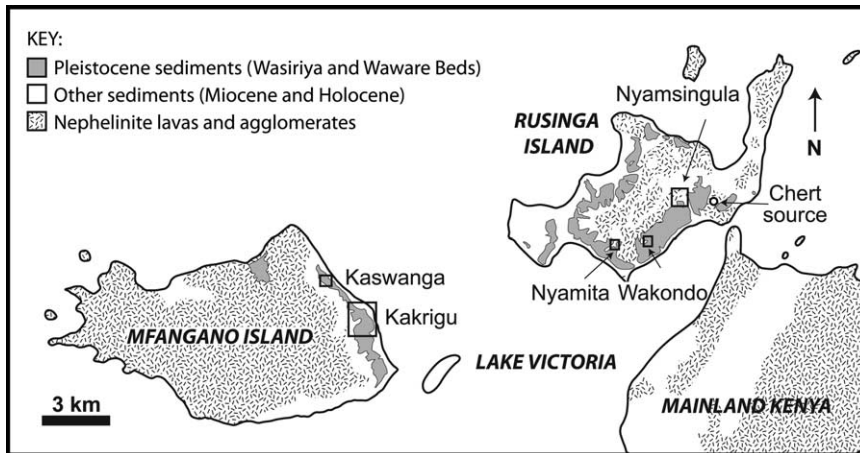


Figure 2. Map of Rusinga and Mfangano islands, showing archaeological and palaeontological localities discussed in the text, as well as outcrops of the Wasiriya Beds, the Waware Beds and nephelinite lavas (after McCall 1958; Whitworth 1961; Van Couvering 1972).

environmental change in mediating temporal and spatial variation among late Pleistocene archaeological assemblages.

### Field survey methods

In 2009, our field efforts were primarily restricted to the Nyamita, Wakondo, and Nyamsingula localities on Rusinga (Figure 2) and we focused on demonstrating the presence of *in situ* MSA artefact assemblages and identifying recovered fossil fauna (Tryon *et al.* 2010). In 2010 we completed survey of all exposures of the Pleistocene Wasiriya Beds on Rusinga and began the first archaeological fieldwork in the Pleistocene Waware Beds on Mfangano, completing the survey of all exposures there in 2011. In the 2009–2011 field seasons, artefact collection was generally limited to typologically or technologically distinct specimens, except at Nyamita, Wakondo and Nyamsingula, where controlled surface collections of all visible material were conducted. For fossil fauna, we followed the protocol of Bobe and Eck (2001) and collected all mammalian crania and mandibles or major fragments thereof, isolated teeth, bovid horn cores, astragali and ruminant metapodials, as well as all specimens belonging to the order Carnivora.

### Geological context of Rusinga and Mfangano Islands

#### *Wasiriya Beds of Rusinga Island*

The Pleistocene Wasiriya Beds (following the terminology of Pickford, 1986) represent a complex succession of valley-fill sediments and tephra deposits. They comprise three major lithologies representing different depositional environments (Figure 3): (1) carbonate-cemented, coarse grained, poorly sorted sandstones and conglomerates that likely represent intervals of high-energy erosion and deposition in short-lived or seasonal channels; (2) fine-grained sandstones and siltstones with evidence for pedogenic modification, such as root traces and carbonate nodules,

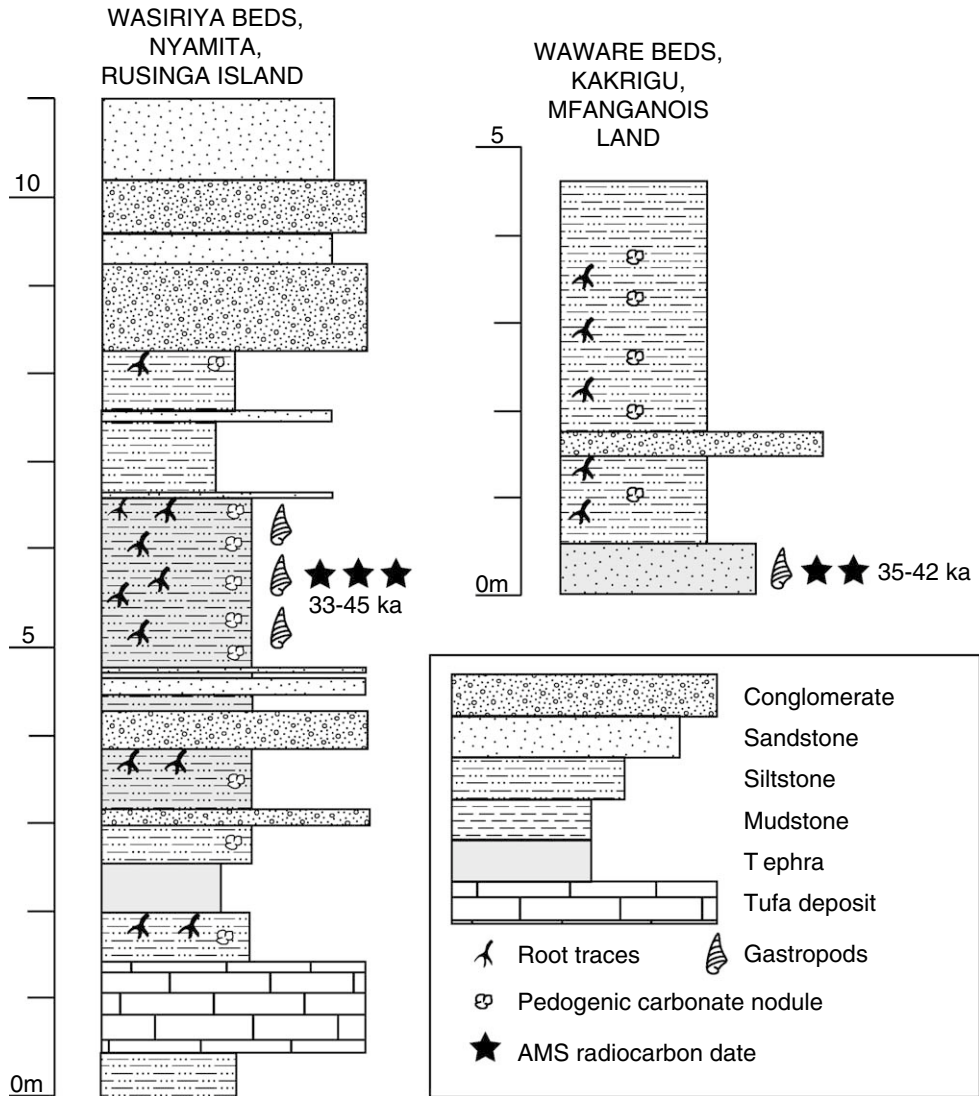


Figure 3. Composite stratigraphic sections for the Wasiryia Beds on Rusinga and the Waware Beds on Mfangano. The Wasiryia Beds composite stratigraphic section is based on tephrostratigraphic correlations across the Nyamita locality (Tryon *et al.* 2010; Van Plantinga *et al.* 2010). Gastropod shells at Nyamita have calibrated AMS radiocarbon age estimates between 33 and 45 kya; fossils and artefacts described here are below the dated levels. The Waware Beds stratigraphic section is based on lithological correlations between the Kakrigu and Kaswanga localities on Mfangano. Gastropod shells from the base of the section have a calibrated AMS age estimates of ~35–42 kya.

deposits that are poorly developed palaeosols and probably represent intervals of landscape stability in an otherwise actively eroding fluvial system; and (3) primary, very fine-grained tephra and variably reworked siltstone- and fine-grained sandstone-sized tuffaceous deposits. Due to the fine-grained nature of the tephra and their geochemical signature, the tuffaceous deposits probably derive from a

distant source in the Rift Valley (Tryon *et al.* 2010). The geochemical signatures of some of these deposits have been used to correlate between fossil and artefact-bearing deposits across Rusinga (Tryon *et al.* 2010; Van Plantinga *et al.* 2010). Several of the reworked tuffaceous beds have clear indications of pedogenic modification, including siliceous rhizoconcretions and carbonate nodules suggesting they are poorly developed palaeosols that also represent intervals of landscape stability. In addition to the tephra and fluvially derived sediments, we have located three discrete tufa deposits at the Nyamita locality within the Wasiriya Beds sediment succession that indicate the presence of Pleistocene spring deposits (Figures 2 and 3).

The age of the Wasiriya Beds is relatively well constrained. Three AMS radiocarbon dates from gastropod shells (ranging from  $\sim 33$  to 45 kya) and tephrostratigraphic age estimates, which are based on comparisons to Pleistocene phonolitic volcanic deposits in Kenya, suggest an age range for them of between 100 and 33 kya (Tryon *et al.* 2010).

#### *Waware Beds of Mfangano Island*

Similar to the Wasiriya Beds on Rusinga, the late Pleistocene Waware Beds on Mfangano Island (following once again the terminology of Pickford 1986) include a succession of fluvial channel deposits, reworked tuffaceous beds, and poorly developed palaeosols. In general, the Waware Beds are poorly exposed and are found only on the eastern side of the island (Figure 2). They are typically represented by less than a metre of sediment, but deposits can be locally thicker (as shown in Figure 3). The Waware Beds comprise: (1) very fine-grained sandstone, siltstones, and mudstone beds that occasionally have evidence of pedogenic modification including root traces and rare carbonate nodules; (2) reworked tuffaceous deposits with common roots traces; and (3) poorly sorted coarse grained sandstones and conglomerates (Figure 3). The sandstones and conglomerates likely represent short-lived, high-energy channel deposits. The reworked tuffaceous deposits and the fine-grained beds both probably represent intervals of landscape stability in an otherwise actively eroding fluvial system.

Two AMS radiocarbon dates (AA-92838 and AA-93998) on the carbonate fraction of shell of the terrestrial gastropod *Limicolaria* cf. *L. martensiana* from the Kakrigu area (Figures 2 and 3) yielded age estimates of  $30,530 \pm 390$  BP and  $37,000 \pm 840$  BP or  $34,788 \pm 423$  and  $41,846 \pm 458$  calibrated years before present when calibrated using the CalPal-2007<sub>Hulu</sub>  $^{14}\text{C}$  calibration curve (Weninger and Jöris 2008). Gastropods often incorporate ingested calcium carbonate into their shells, which can cause radiocarbon ages to be offset up to 3000 years older than the true age of the shells (Goodfriend and Stripp 1983; Goodfriend 1987). One dated sample (AA-92838) is from the base of the measured stratigraphic section at Kakrigu, the thickest exposure of Waware Beds sediments on Mfangano, and therefore provides a reasonable age constraint for these deposits. This maximum age estimate of  $\sim 42$ -35 kya predates the Last Glacial Maximum (LGM) arid interval (26.5-19 kya; Clark *et al.* 2009), which is supported by the presence of extinct fauna from the Waware Beds (discussed below) that also suggests a pre-Holocene minimum age. The combined evidence therefore suggests that the Waware Beds likely sample a relatively arid interval in the late Pleistocene before the LGM.

*Age relationship and depositional setting of the Wasiriya and Waware Beds*

Pickford (1986) suggested that the Wasiriya and Waware Beds were age equivalent. Although our age estimate for the Waware beds is currently limited to two radiocarbon dates, preliminary results suggest that they may represent a sedimentary succession, with the Waware Beds on Mfangano possibly being slightly younger than the fossil- and artefact-bearing strata of the Wasiriya Beds on Rusinga. The dates for the Waware and Wasiriya Beds indicate that we are sampling fauna and artefacts from the Lake Victoria region during the late Pleistocene between 100 and 33 kya.

Previous researchers suggested that the Wasiriya and Waware Beds were lake margin sediments (e.g. Kent 1942; Pickford 1986). However, there is no evidence for lacustrine or lake margin deposits in the Wasiriya or the Waware Beds. Their lithologies and sedimentary structures indicate instead a terrestrial sequence of cut-and-fill channel and flood plain deposits (Figure 3).

**Pleistocene faunas of Rusinga and Mfangano***Rusinga Island faunas*

Consistent with the sedimentological data, the fauna from the Wasiriya Beds of Rusinga Island (Table 1) includes a number of index taxa that suggest the local presence of at least seasonally available water, such as hippopotamus (*Hippopotamus amphibius*) and reduncine bovids. However, 73% of the sample consists of alcelaphine bovids, suggesting that the areas studied represent riparian zones or spring-side settings within a broader open grassland environment (Vrba 1980). The presence of oryx (*Oryx gazella*) and Grevy's zebra (*Equus grevyi*), both of which inhabit relatively arid environments today (Kingdon 1982), suggests an arid grassland setting. The arid character of the grasslands is further supported by the presence of extinct bovids that are often associated with arid and open faunal communities (Klein 1980, 1994; Vrba 1987; Marean and Gifford-Gonzalez 1991; Marean 1992), including the giant wildebeest (*Megalotragus* sp.), the giant buffalo (*Syncerus antiquus*), a small, unnamed, extremely hypsodont alcelaphine best known also from Lukenya Hill (Marean and Gifford-Gonzalez 1991; Marean 1992) and the medium-sized alcelaphine *Rusingoryx atopocranion* (Pickford and Thomas 1984; Faith *et al.* 2011) (Table 1). We follow Gentry (2010) in assigning the extinct giant buffalo to *Syncerus* rather than *Pelorovis* (see also Klein 1994, 731). The extinct bovids may have interacted in an arid-adapted grazing succession (Faith *et al.* 2011), similar to the grazing succession observed in the modern Serengeti (Bell 1971). Initial isotopic analyses of pedogenic carbonates, soil organic matter and ungulate tooth enamel are consistent with the interpretation that the Wasiriya Beds on Rusinga represent wetter (and perhaps more closed) environments within a larger arid grassland setting (Garrett *et al.* 2010).

*Mfangano Island faunas*

Table 1 lists specimen counts (NISP) for the Waware Beds fauna from Mfangano Island. The presence of *Hippopotamus* and of two species of reduncine bovids on Mfangano, likely the same species as those documented in the Wasiriya Beds, is consistent with the fluvial nature of the deposits. The presence of bushpig (*Potamochoerus larvatus*) may also signal dense vegetation along the ancient fluvial



Table 1. Taxonomic list of fossil fauna recovered from the Wasiriya Beds and Waware Beds of Rusinga and Mfangano Islands, Kenya.

Taxon	Common Name	Rusinga NISP	Mfangano NISP
<i>Crocuta crocuta</i>	Spotted hyena	3	0
<i>Procapra</i> sp.	Hyrax	0	1
<i>Orycteropus crassidens</i> †	Aardvark	1	0
<i>Lepus capensis</i>	Cape hare	0	1
Elephantidae cf. <i>Loxodonta africana</i>	Elephant	1	0
Rhinocerotidae	Rhino	0	1
<i>Equus burchelli</i>	Burchell's zebra	4	1
<i>Equus grevyi</i> *	Grevy's zebra	5	0
<i>Equus</i> sp. indet.	Zebra	11	3
<i>Hippopotamus</i> cf. <i>H. amphibius</i>	Hippopotamus	4	1
<i>Phacochoerus</i> sp. indet.	Warthog	9	1
<i>Potamochoerus larvatus</i>	Bushpig	0	1
<i>Taurotragus oryx</i> *	Eland	2	0
<i>Tragelaphus strepsiceros</i> *	Greater kudu	1	0
<i>Oryx gazella</i> *	Oryx	3	0
<i>Redunca</i> cf. <i>R. fulvorufalredunca</i>	Reedbuck	11	2
<i>Reduncini</i> cf. <i>Kobus kob/Redunca arundinum</i>	Kob/Southern reedbuck	5	1
<i>Connochaetes taurinus</i> *	Wildebeest	35	3
<i>Megalotragus</i> sp. indet.†	Giant wildebeest	3	0
Alcelaphini cf. <i>Alcelaphus buselaphus</i>	Hartebeest	11	3
Small Alcelaphine (cf. <i>Damaliscus</i> sp.)†	Small extinct alcelaphine	26	2
<i>Rusingoryx atopocranion</i> †**	Extinct wildebeest	140	13
Alcelaphini indet.	Alcelaphini	34	10
<i>Gazella</i> cf. <i>G. thomsoni</i>	Thomson's gazelle	7	2
<i>Gazella</i> cf. <i>G. granti</i>	Grant's gazelle	7	0
Antilopini indet.	Antilopini	2	0
<i>Ourebia ourebi</i>	Oribi	8	3
<i>Oreotragus/Raphicerus</i>	Klipspringer/Steenbok	0	1
<i>Madoqua</i> sp. indet.	Dik-dik	0	1
<i>Syncerus caffer</i>	Cape buffalo	6	2
<i>Syncerus antiquus</i> †	Giant buffalo	2	3
Bovini indet.	Buffalo	2	1
	TOTAL	343	57

NISP = Number of Identifiable Specimens, \* = outside historic range, † = extinct, \*\* = reported as *Alcelaphini* cf. *Alcelaphus/Damaliscus* in Tryon *et al.* (2010).

system. As is also the case for the Rusinga Island Wasiriya Beds, the Waware Beds faunal assemblage is dominated by alcelaphine bovids, suggesting relatively open environments within a fluvial setting. Oryx and Grevy's zebra are absent from the Waware Beds assemblage, which may suggest a more mesic environment relative to that from the Wasiriya Beds of Rusinga Island. However, considering the small number of identified specimens from the Waware Beds, their absence may also reflect sampling error (Grayson 1981; Lyman 1995, 2007; Faith and Surovell 2009). Given the observed relative abundance of oryx and Grevy's zebra in the Wasiriya Beds assemblage (0.023), the probability of observing no oryx or Grevy's zebra in the Waware Beds assemblage (NISP = 47) can be calculated as  $(1-0.023)^{47}$  (Koch 1987; Lyman 1995; Barry *et al.* 2002). This returns a probability of 0.27, which indicates that we cannot rule out sampling error as an explanation of the absence of these arid-adapted ungulates.

The extinct ungulates in the Waware Beds fauna are indicative of relatively open and xeric environments, similar to those known from the Wasiriya Beds. These include the giant buffalo (*S. antiquus*), the unnamed small alcelaphine best known from Lukenya Hill, and *R. atopocranion*. These taxa suggest that similar environmental conditions may have existed during the late Pleistocene arid intervals sampled on Mfangano as well as on Rusinga. All of these taxa are absent from Holocene deposits in eastern Africa (Marean and Gifford-Gonzalez 1991; Faith *et al.* 2011). Both the small alcelaphine and *R. atopocranion* are poorly known from the region's late Pleistocene record. The small alcelaphine has been reported previously from Lukenya Hill and Rusinga Island's Wasiriya Beds in Kenya, as well as from the sites of Gol Kopjes and Kiseke II rockshelter in Tanzania (Figure 1) (Marean and Gifford-Gonzalez 1991; Tryon *et al.* 2010), whereas *R. atopocranion* is otherwise known only from Rusinga Island (Pickford and Thomas 1984; Faith *et al.* 2011). Their presence on Mfangano Island thus expands the presently small sample of these taxa.

### ***Pleistocene palaeoenvironments of Rusinga and Mfangano Islands***

Previous studies demonstrated that the relative abundances of various bovid tribes can be used to distinguish between open-closed and dry-wet environments (Vrba 1980; Greenacre and Vrba 1984; Shipman and Harris 1988; Alemseged 2003). Here, we employ correspondence analysis (CA) to compare the composition of the Wasiriya and Waware Beds bovid assemblages to those of modern African wildlife reserves (using modern data from Alemseged 2003). The CA plot (Figure 4) reveals three primary clusters of African game reserves, distinguishing among those characterised by closed woodland habitats, wet edaphic grasslands and dry-open grasslands. The fossil assemblages from Rusinga and Mfangano islands both cluster with extant game reserves characterised by open and dry grasslands and dominated by alcelaphine and antilopine bovids, including Nairobi National Park (Kenya), Serengeti and Ngorongoro (Tanzania), Omo (Ethiopia), Kalahari (Botswana) and Etosha (Namibia). These areas are substantially drier and more open than the environment characteristic of the Rusinga and Mfangano area today. The Pleistocene fossil assemblages also differ considerably from Holocene assemblages within the Lake Victoria basin (Gogo Falls, Luanda and Wadh Lang'o) that are characterised by more mesic environments (Figure 4).

The faunal results coupled with the sedimentological evidence suggest that the Wasiriya and Waware Beds record time intervals when the climate of the Lake Victoria region was considerably more arid than at present. Water level in Lake Victoria is primarily driven by rainfall (Nicholson 1998), and there is evidence for substantial late Quaternary fluctuations in lake level, including periodic desiccation of the lake (Johnson *et al.* 1996; Stager and Johnson 2008). The Wasiriya and Waware Beds potentially sample times when lake levels were substantially lower than at present, perhaps even desiccated. As discussed below, several lines of evidence support this hypothesis.

On Rusinga Island, the arid character of the fauna, the presence of abundant pedogenic carbonate in the palaeosols, the carbonate-cemented sandstones and conglomerates and the channel deposits, which suggest seasonal or ephemeral deposition, all indicate the prevalence of arid and highly seasonal conditions during the deposition of the Wasiriya Beds. This arid signal, coupled with the proximity of the

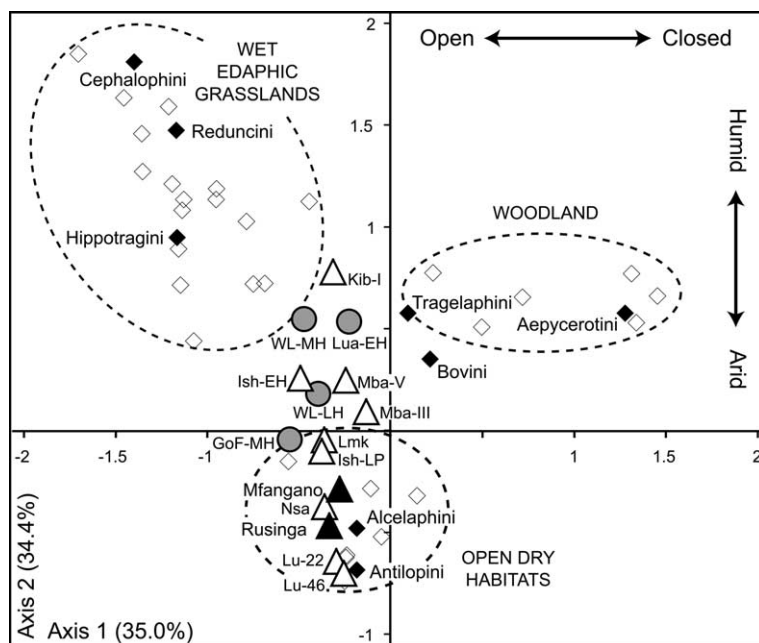


Figure 4. Habitat distinctions from correspondence analyses of bovid abundances in African game parks (diamonds) using data from Alemseged (2003), Pleistocene archaeological sites (triangles; using data from Mehlman 1989; Marean 1992; Potts and Deino 1995; and Assefa *et al.* 2008) and Holocene archaeological sites in the area east of Lake Victoria (grey circles; using data from Robertshaw *et al.* 1983; Robertshaw 1991; Karega-Munene 2002; Lane *et al.* 2007; and Prendergast 2008). Habitat boundaries encircled by dashed lines are arbitrary. The Rusinga Island and Mfangano Island fossil bovid assemblages (black triangles) are consistent with open, dry habitats.

island to the mainland ( $\sim 350$  m) and the shallow depth of the lake between Rusinga and the mainland ( $< 5$  m), suggests that the island was likely part of mainland Kenya during much of the Pleistocene. It is plausible that during the deposition of the Wasiriya Beds, the Lake Victoria region was primarily an open, arid grassland and the lake was considerably smaller than at present.

It is also possible that Mfangano Island was connected to the mainland during the deposition of the Waware Beds. It is unlikely that an island the size of Mfangano ( $\sim 65$  km<sup>2</sup>) could support minimal viable populations of large gregarious grazers including wildebeest (*Connochaetes taurinus*), Cape buffalo (*Syncerus caffer*) and their oversized extinct relatives (e.g. *S. antiquus*). Furthermore, the presence of an open grassland fauna and the primarily fluvial deposits on Mfangano Island also imply a connection to mainland Kenya. Maximum lake depth between Mfangano and the mainland is approximately 30 m (Whitehouse and Hunter 1955), potentially implying a substantial drop in lake levels relative to the present.

Taken together, our results suggest that the Wasiriya and Waware Beds on Rusinga and Mfangano sample mainland, rather than insular, faunal communities and human activities during a period of diminished Lake Victoria lake levels in the Pleistocene. In contrast to the surrounding environment, the artefact- and fossil-bearing deposits on Rusinga and Mfangano islands are likely sampling locally wet environments within a broader open/arid grassland setting.

## The stone artefact assemblages of Rusinga and Mfangano Islands

### *Artefact assemblages from Rusinga Island*

The artefact assemblages from the Wasiriya Beds are derived from controlled surface collections of lithic artefacts at Nyamita, Wakondo, and Nyamsingula (Figure 2), collections of *in situ* material recovered from test excavations at Nyamita and Wakondo (Tryon *et al.* 2010) and material collected during our survey of all Wasiriya Beds sediment exposures (Figure 2). The frequency of different artefact types is summarised in Table 2. The Rusinga artefacts are from sites that are separated by short distances (Figure 2), are technologically and typologically similar and include comparable raw material types. Given these similarities and our small sample size, our discussion of lithic technology treats the Wasiriya Beds assemblage as a single aggregate.

### *Stone raw materials of the Wasiriya Beds assemblages*

Wasiriya Beds artefacts are made of a variety of stone raw materials including chert, quartz, and 35 different varieties of lava distinguished on the basis of colour, texture and the type, size and abundance of phenocrysts. Despite this variety, the bulk of the artefacts likely derive from locally available stone sources, but, as detailed below, certain artefact classes are preferentially associated with materials that are not known to be locally available. This may indicate hominin selection of particular rock types for their physical properties (e.g. ease of fracture, durability or colour) and/or may indicate use of distant or unknown sources.

Chert comprises 29% of the Wasiriya Beds sample. The majority of the chert artefacts are white with distinctive localised areas of red or occasionally yellow colouration. These are an excellent visual match for material from a chert source on Rusinga (0°24'16"S, 34°11'38"S; Figure 2), <4.5 km from the sites on the island. The source, described as a dike by Van Couvering (1972, 149), consists of irregularly shaped >1 m thick deposits that discontinuously crop out over an area of 0.3 km<sup>2</sup>.

A variety of sources of Miocene (primarily nephelinite) lavas are available on the island and the adjacent mainland (Figure 2). These sources include the various Lunene Lava flows that cap the hills on Rusinga, lava flows within the Miocene Rusinga Agglomerate, numerous dikes that crop out on the island and clasts in Pleistocene conglomerates (Shackleton 1950; Van Couvering 1972). Although Van Couvering (1972) provides detailed petrographic descriptions for some geological specimens from each of these units, comparable work has not yet been done for the artefacts. Based on visual comparison with specimens collected from outcrops, most of the lava artefacts can be reasonably attributed to these various nephelinite lava sources, particularly the Lunene Lavas (N = 114 out of 219 lava artefacts). However, descriptions by Van Couvering (1972) and our own field observations document substantial variability within some of the Lunene Lava flows, meaning that we cannot yet determine the source of most of the Wasiriya Beds lava artefacts with any precision.

Other rock types used for tool manufacture have no known sources on the island today, although nearby now-submerged sources remain a possibility. They include quartz (N = 7), chert with distinctive green, orange, or dark grey colouring unlike that from the Rusinga source, and a single piece of obsidian from Wakondo, the nearest source of which occurs in the Kenyan Rift Valley >200 km away (Merrick and Brown 1984; Merrick *et al.* 1994).

Table 2. Summary of the recovered lithic artefacts from Rusinga and Mfangano Islands, Kenya, listed by locality as shown in Figure 2. Excavated artefacts are shown in parentheses.

Artefact Type	Wasiriya Beds, Rusinga Island					Waware Beds, Mfangano Island		
	Nyamita	Wakondo	Nyamsingula	Other	Total	Kakrigu	Kaswanga	Total
Complete flakes								
Levallois	2	0	1	0	3	1	0	1
Levallois-related	3	1 (1)	2	0	7	0	0	0
Non-Levallois flake	20 (3)	15 (2)	12	0	52	3	0	3
Blade	0	1	0	0	1	0	0	0
Proximal flake fragments								
Levallois flake	2	0	1	1	4	0	0	0
Levallois blade	0	1	0	0	1	0	0	0
Levallois related	6 (1)	1	0	0	8	0	0	0
Non-Levallois flake	48 (6)	21	17	0	91	2	0	2
Non-Levallois blade	0 (1)	0	0	0	1	0	0	0
Flaking debris	55 (13)	25 (6)	14	1	124	1	0	1
Cores and core fragments								
Levallois	2 (1)	0	4	3	10	0	0	0
Multiplatform	3	0	2	0	5	0	0	0
Casual	2 (1)	1	1	0	5	0	0	0
Discoidal	5	1	5	0	11	2	1	3
Single platform	0	0	1	0	1	0	0	0
Indeterminate	0	0	1	0	1	0	0	0
Shaped and retouched pieces								
Biface	0	0	1	1	2	1	0	1
Point	3	0	1	0	4	1	0	1
Retouched Levallois flake or fragment	1	1 (1a)	0	0	3	0	0	0
Retouched non-Levallois flake or fragment	5	0	0	0	5	0	0	0
Total	193	78	63	6	339	11	1	12

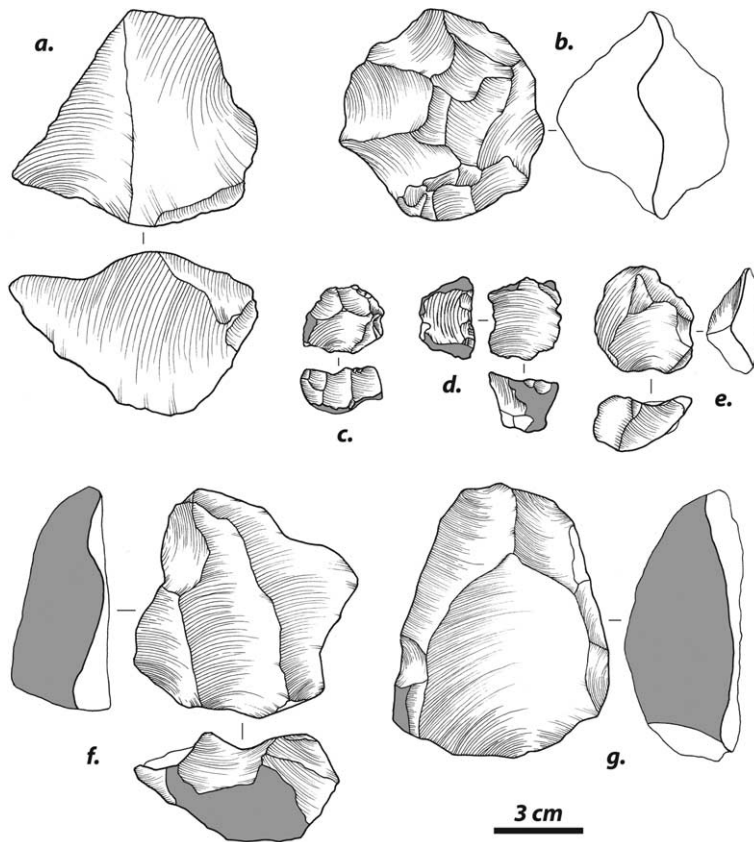


Figure 5. Selected sample of cores from the Wasiriya Beds of Rusinga Island collected in 2009–2010. Cortex is shown in grey. All were found on the surface: (a) lava multiplatform core, Nyamita; (b) lava discoidal core, Nyamita; (c–e) chert Levallois cores, Nyamsingula; (f) lava Levallois core, general survey; (g) lava Nubian 1 core, Nyamsingula. Artefact illustrations by S. Nightingale and C. Tryon.

#### *Typology and technology of the Wasiriya Beds artefacts from Rusinga*

Our 2010 survey doubled the sample size of recovered cores, flakes, and shaped implements from Rusinga, substantially improving our understanding of various hominin stone tool production strategies. All artefacts from the Wasiriya Beds sediments are consistent with a Middle Stone Age (MSA) attribution. Among the Wasiriya Beds artefacts, core reduction is by Levallois, discoidal (Figure 5, b) and a variety of *ad hoc* or informal methods, the latter producing single and multiple platform cores (Figure 5, a), as well as casual cores with <5 removals (definitions after Isaac 1977; Boëda 1994; Inizan *et al.* 1999; Conard *et al.* 2004). We include as Levallois cores those bifacial specimens flaked about their perimeter that have asymmetrical cross-sections, with a relatively thin, flat upper surface with removals parallel to the plane dividing the two core faces and a thicker, often cortical lower surface that has fewer removals. Among the Levallois cores, larger specimens are made of locally available nephelinite lava (N = 3 with a maximum dimension of 93–110 mm). The lava Levallois cores include a recurrent Levallois core (Figure 5, f)

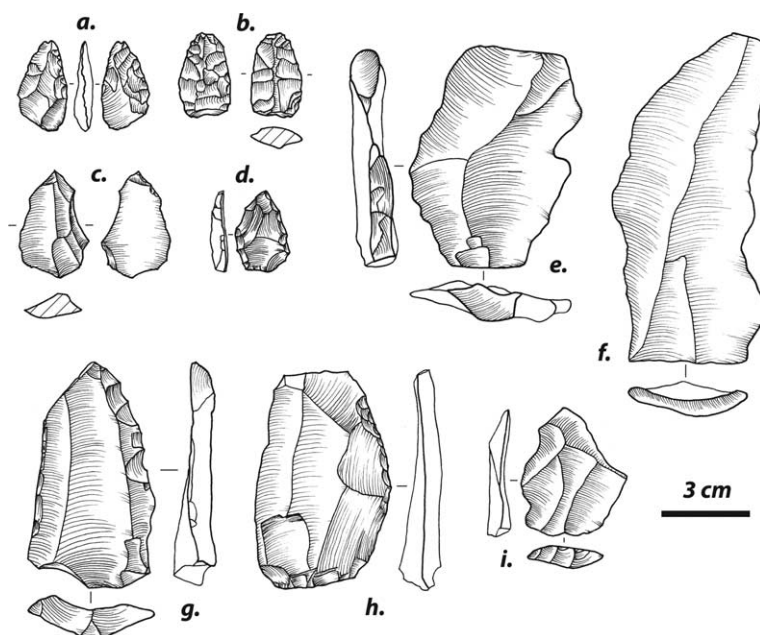


Figure 6. Selected sample of flakes and retouched artefacts from the Wasiriya Beds of Rusinga Island collected in 2009–2010. All were found on the surface unless otherwise noted: (a) chert bifacial point, Nyamita; (b) quartz bifacial point, Nyamita; (c) chert point with bifacially retouched tip, Nyamsingula; (d) lava uniaxially retouched point, Nyamita; (e) lava Levallois *éclat débordant* (edge of core or core trimming flake), Nyamita; (f) lava blade, Nyamita; (g) lava laterally retouched elongated Levallois flake fragment, *in situ*, Wakondo; (h) lava laterally retouched elongated Levallois flake fragment, Nyamita; (i) lava Levallois flake fragment, Nyamita. Artefact illustrations by S. Nightingale and C. Tryon.

and a Nubian Type 1 core (Figure 5, g) for the production of Levallois flakes and/or points, the latter type better represented from sites in the Nile Valley and Ethiopia (Guichard and Guichard 1965; Clark 1988; Van Peer 1992; Vermeersch *et al.* 2002). Flakes of a variety of different shapes and sizes were recovered, including Levallois flakes (Figure 6, i), *éclats débordants* (flakes from core edges the removal of which maintains Levallois core convexity; Beyries and Boëda 1983) (Figure 6, e) and lava blades and other blade fragments (N = 3) (Figure 6, f). These blades may derive from the elongated removals from the distal end of a Nubian Type 1 core that are characteristic of this method (see Figure 5, g), although we lack refits to test this hypothesis.

By comparison with the lava cores, the chert Levallois cores are considerably smaller (N = 4, 30–38 mm maximum dimension) and show use of the preferential (or lineal) method for the production of a single, small Levallois flake prior to core discard (Figure 5, c–e). The small size of the chert cores is striking and could be the result of several related factors, including the availability of only small pieces at the source, intensive reduction prior to discard, deliberate production of small flakes or preferential use of small pieces among highly mobile foragers for whom weight was a major consideration (Kuhn 1994; Dibble and McPherron 2006; Shea 2008). We are unable to exclude any of these possibilities at the moment. Three of the chert

cores are lithologically similar to the nearby chert outcrop on Rusinga (Figure 2). Although this source includes relatively massive chert deposits, our own limited experiments highlight the difficulty in obtaining large inclusion-free pieces from this locality, suggesting that small core size may be due to physical limitations imposed by the source material. At least one of the chert cores (Figure 5, e) was made on a flake as the original ventral surface and hinge termination are still preserved on the upper flake removal surface. The largest chert flake encountered on our survey had a maximum dimension of 75 mm, a maximum thickness of 12 mm and was riddled with inclusions that would have hampered flake propagation. If flakes of this source were the starting form for cores then final core size would have largely been dictated by mechanical rather than cultural factors. However, one of the chert Levallois cores (Figure 5, d) is distinct from those likely from the Rusinga source; it is orange with the pale yellow reticulate cortex typical of eastern African lacustrine chert deposits (Hay 1968) and may derive from more distant areas.

Retouched pieces (N=8) include Levallois flakes with scraper-like removals along one or more margins (Figure 6, g–h) and four small points with unifacial and bifacial retouch (Figure 6, a–d). In this context, we use ‘point’ as a typological category. The function of these particular implements remains uncertain. One of these points is made of nephelinite lava (Figure 6, d), one is of quartz (Figure 6, b), and two are of chert, one a distinctive green (Figure 6, a) and the other dark grey (Figure 6, c); both are very different from the Rusinga source. This suggests a hominin preference for uncommon, and perhaps non-local, sources of stone for the manufacture of points.

#### *Artefact assemblages of Mfangano Island*

Stone artefacts on Mfangano are sparse and often show edge rounding. This is consistent with their transport within, and recent erosion from, sediments that suggest higher energy fluvial regimes relative to those found on Rusinga, likely a result of the steeper topographic gradient on Mfangano. Nearly all artefacts were recovered from the Kakrigu locality (Figure 2 and Table 2). The Miocene bedrock on Mfangano and Rusinga is geologically similar, and the same lavas are found on both islands (Whitworth 1961; Pickford 1986). Sources of chert or quartz have not been reported on Mfangano; however, detailed survey for potential source materials on the island has not been conducted, and some sources could be submerged. The sources of the various stone artefacts we recovered are currently unknown. Artefacts from these sediments include specimens made of chert, including small (< 38 mm) discoidal cores, and a split flake fragment demonstrating the use of the bipolar method of core reduction (Figure 7, b). It is possible that the chert derives from the source on Rusinga, but this possibility has not yet been tested through petrographic or geochemical analysis. Figure 6, a shows a small quartz bifacially flaked point with traces of pebble cortex. None of these artefact types are unique to the Middle or Later Stone Age (LSA), making industrial diagnosis on typological grounds difficult (cf. Marks and Conard 2007; Diez-Martín *et al.* 2009). However, the ~35–42 kya age estimate for the Wawere Beds would be consistent with either a MSA, LSA or some sort of intermediate MSA/LSA attribution based on comparison with relevant well-dated sequences from Rift Valley sites at Enkapune ya Muto in Kenya and Nasera and Mumba rockshelters in Tanzania (Mehlman 1989, 1991; Ambrose, 1998;



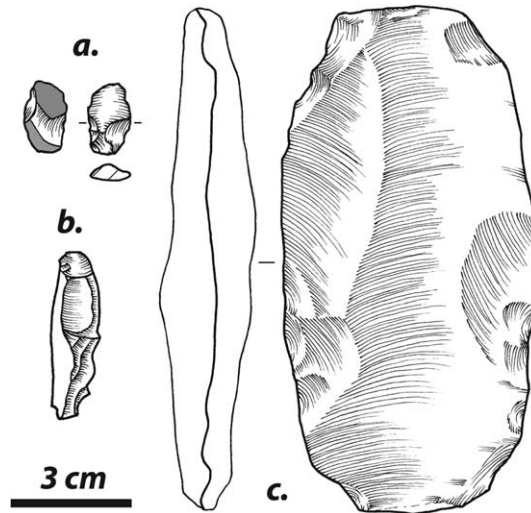


Figure 7. Selected sample of flakes and retouched artefacts from the Waware Beds of Mfangano Island collected in 2009–2010. Cortex is shown in grey. All were found on the surface from the Kakrigu locality: (a) bifacially flaked quartz point on pebble fragment (flaking direction could not be reliably inferred for unshaded portion); (b) chert split flake fragment produced during bipolar percussion (unshaded portion denotes split); (c) weathered lava biface. Artefact illustrations by S. Nightingale and C. Tryon.

Diez-Martín *et al.* 2009) (Figure 1). Figure 7, c shows a large lava biface that resembles some of the lanceolates recovered from Lupemban sites in western Kenya that may date to the middle Pleistocene (e.g. Leakey and Owen 1945; McBrearty 1988; Barham 2000). However, unlike the other illustrated specimens, it is very weathered, was found within a cultivated field in uncertain stratigraphic context and may derive from sediments that predate the Waware Beds.

### Regional comparisons

The appearance of regionally and temporally distinct traditions of artefact manufacture is an important feature of the African MSA and LSA archaeological records (e.g. McBrearty and Brooks 2000; Barham and Mitchell 2008). For the Pleistocene period, most of the discussion of regionally specific archaeological variation in the Lake Victoria region has focused on Lupemban MSA sites. The Lake Victoria region marks the easternmost limit of the Lupemban, with sites characterised by large, elongated, bifacially flaked lanceolate points ~15–30 cm in length. These lanceolate points make the Lupemban the most distinctive MSA variant in equatorial Africa. Available stratigraphic and chronological evidence, some from areas well beyond the margins of Lake Victoria, suggests that Lupemban assemblages represent the basal MSA in the region and likely date to the later part of the middle Pleistocene, in the range of  $\leq 230$ –130 kya, associated with variable, but often relatively wooded habitats (Leakey and Owen 1945; McBrearty 1988, 1992; McBrearty and Brooks 2000; Barham 2000, 2001; Clark 2001; Mercader 2002).

Points such as the Lupemban lanceolates have been used as the basis for exploring regional variation among MSA sites in Africa (e.g. McBrearty and Brooks

2000). However, small point size (<5 cm), late Pleistocene age of ~33–100 kya, and an arid grassland environment distinguish the Wasiriya Beds and, to a lesser extent, the Waware Beds artefact assemblages from Lupemban ones in the Lake Victoria region. This serves to emphasise the fact there is variation among MSA sites within a single area and highlights temporal and environmental factors as possible causal factors for these differences.

Although chronological control is poor, a number of other MSA sites in the Lake Victoria region can be described using the informal terms ‘post-Lupemban’ and ‘non-Lupemban’. These sites have lithic assemblages that include Levallois and other core forms, and many have stone points small ( $\leq 7$  cm) by comparison with the Lupemban lanceolates. McBrearty’s (1986, 1988, 1991) excavations at Muguruk in Kenya (Figure 1) provide the best documentation of a stratified sequence of Lupemban-point-bearing assemblages and ‘post-Lupemban’ MSA artefacts. The site is undated, no fauna was preserved and the ‘post-Lupemban’ artefacts likely represent a ‘stone-line’ concentrated by the action of termites over an estimated 90–60,000 year long period (McBrearty 1990). Stratified deposits bearing possible Lupemban lanceolates at Rambogo rockshelter in Kenya (Figure 1) are unconformably overlain by probable Holocene LSA deposits (Basell 2007).

Other ‘non-Lupemban’ MSA assemblages from the Lake Victoria region are found in Kenya, as well as in Uganda and Tanzania (Figure 1). From Kenya these sites include Songhor (McBrearty 1981) and Randhore (Gabel 1969), from Uganda those on Buvuma Island (Nenquin 1971), Lolui Island (Posnansky *et al.* 2005), the Sese Islands (Fagan and Lofgren 1966), Walasi Hill (O’Brien 1939) and collections from the Nsongezi area (O’Brien 1939; see also Reid and Njau 1994), and from Tanzania the site of Loyangalani in the Serengeti (Bower and Grogan-Porter 1981; Bower *et al.* 1985; Thompson *et al.* 2004; Thompson 2005). All of these sites are poorly dated and only Loyangalani and Songhor have associated fauna. Although published sample size is small for both sites, the faunas suggest local river- or stream-side settings within grassland environments and include waterbuck (*Kobus ellipsiprymnus*) and wildebeest- and buffalo-sized bovids at Songhor (McBrearty 1981), and, among other taxa, catfish (*Clariidae sp.*), crocodile (*Crocodylus niloticus*), blue wildebeest (*Connochaetes taurinus*), hartebeest (*Alcelaphus buselaphus*) and Grant’s gazelle (*Gazella granti*) at Loyangalani (Bower *et al.* 1985).

Pleistocene LSA sites that could provide relevant regional comparisons for the Waware Beds artefacts are sparse (Figure 1), and the sample size from Mfangano is presently too small for meaningful comparison. These sites include the undated but well-described material from Muringa rockshelter in Kenya (Sutton 1973; Nelson 1976) and the few illustrations of material from the ~11–18 kya sequence from Munyama Cave on Buvuma Island, Uganda (Van Noten 1971). No fauna or other palaeoenvironmental evidence is reported from these sites.

#### *East African Rift Valley System comparisons*

Middle Stone Age sites from the East African Rift Valley System (EARS) provide an important comparison from an area adjacent to the Lake Victoria region. There are more stratified sequences in the EARS that in some cases have better chronological control and palaeoenvironmental evidence than is available for the ‘non-Lupemban’

sites of the Lake Victoria region. That this is an appropriate comparison is further supported by stone raw material provenance data that indicate some degree of contact among Pleistocene hominin populations in the EARS and the Lake Victoria region. The ‘post-Lupemban’ levels at Muguruk, as well as the ‘non-Lupemban’ Songhor assemblage, contain obsidian flakes or tools from sources in the EARS > 150 km distant (Merrick and Brown 1984), while the single piece of obsidian from Wakondo on Rusinga Island, one flaked obsidian piece from Lolui Island (Posnansky *et al.* 2005), rare obsidian flakes and flake fragments from Muringa rockshelter (Sutton 1973) and the lower strata at Randhore rockshelter (Gabel 1969) all suggest connections with areas in the Rift Valley, where the nearest obsidian sources occur.

Figure 8 summarises the age, stratigraphy and variation in unifacially and bifacially flaked point size from three sites from the EARS dated to between > 16 and > 80 kya that have multiple MSA and MSA/LSA (e.g. the Nasera Industry) point-bearing strata: Nasera rockshelter (Tanzania), Lukenya Hill (Kenya) and Aduma (Ethiopia) (Merrick 1975; Mehlman 1989; Yellen *et al.* 2005; see Figure 1). Points were measured along the axis of symmetry, based on published illustrations. Figure 8 shows a progressive reduction in point size (and variation) over time at Nasera, Lukenya Hill and Aduma. This suggests that the decreased point size relative to Lupemban lanceolates is likely a function of temporal differences. Importantly, points from the Wasiriya Beds and the Waware Beds show the same sequence and fall within

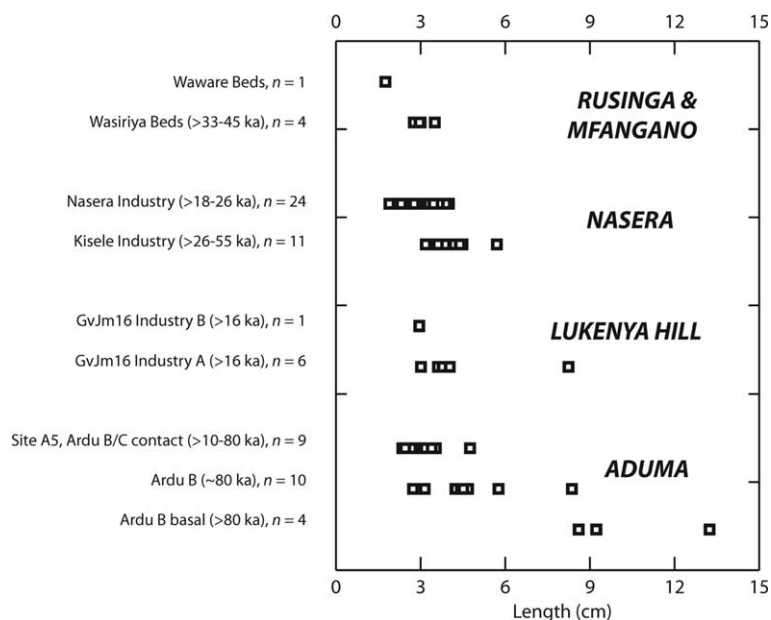


Figure 8. Plot showing point size, measured from illustrations along the axis of symmetry, comparing data from Rusinga and Mfangano islands to three stratified late Pleistocene sites from the Rift Valley. Each square represents a single measured point. Assemblages at Nasera rockshelter, Lukenya Hill site GvJm16 and Aduma are shown in stratigraphic order, along with radiometric age estimates and sample size. The point from GvJm16 Industry B derives from below the 99 cm datum. Data and age estimates are taken from Merrick (1975), Mehlman (1977, 1989, 1991), Manega (1993), Skinner *et al.* (2003), Yellen *et al.* (2005) and Brooks *et al.* (2006).

the range of point sizes from the Rift Valley sites, suggesting comparable patterns among late Pleistocene sites in the EARS and the Lake Victoria region.

Available palaeoenvironmental evidence indicates comparable environments between the two regions during certain intervals of the Pleistocene, suggesting another possible causal factor for explaining comparable patterns in point morphology. Faunal assemblages from Nasera and Lukenya Hill are very similar to these from the Wasiriya and Waware Beds (Figure 4) and suggest the presence of similar arid grassland environments. Although the Aduma faunal assemblage is small and not included in Figure 4, similar arid grasslands there are suggested by the presence of the water-independent oryx (*Oryx gazella*) and isotopic analyses of pedogenic carbonates that suggest 80–85% C<sub>4</sub> plant biomass in the area (Yellen *et al.* 2005). These sites, and indeed all of those with fauna comparable to those of the Wasiriya and Waware Beds (Figure 4), occur within White's (1983, 110–130) Somalia-Masai regional centre of endemism (Figure 1). This faunal similarity suggests that the Lake Victoria regional vegetation mosaic (White 1983, 179–183) within which the 'post-Lupemban' and 'non-Lupemban' MSA sites of the Lake Victoria region occur (Figure 1) may have contracted during periods of increased aridity. The vegetation mosaic of the Lake Victoria region is today composed of a variety of taxa endemic to neighbouring areas the range of which likely expanded with climate change, a model also consistent with the distribution of modern faunas (Kingdon 1974, 1989; Grubb *et al.* 1999; Wronski and Hausdorf 2008).

These palaeoenvironmental data thus suggest that boundary of the Somali-Masai regional centre of endemism may have shifted westward during portions of the Pleistocene, likely as a result of increased aridity. Our archaeological comparisons of point size suggest that shared trends among sites in the EARS and the Lake Victoria region could result from comparable adaptations to similar environments, although, as the function of most points is assumed rather than demonstrated, the nature of these adaptations is uncertain. Our comparisons serve to underscore some of the variation among MSA sites in eastern Africa and highlight the need for increased chronological control and detailed palaeoenvironmental reconstructions to better understand some of the causes of this variation.

## Conclusions

Ongoing fieldwork on Rusinga and Mfangano islands represents an important contribution to the Middle Stone Age (MSA) and perhaps also the Later Stone Age (LSA) archaeological records of this region. Sites from the Wasiriya Beds of Rusinga Island date from ~100 to 33 kya and include typologically MSA stone artefact assemblages. These assemblages show multiple methods of core reduction as shown by the presence of platform, discoidal and Levallois cores of various sizes, but, as is the case with many MSA sites, have a limited number of retouched tools. However, among those that are present are four small unifacially and bifacially worked points. The sample of artefacts from the Waware Beds of Mfangano island is too small to attribute them securely to either the MSA or LSA, but age estimates and the presence of extinct fauna suggest that they may be as old as ~35–42 kya.

The MSA artefacts found on Rusinga and Mfangano islands are associated with a diverse and well-preserved fossil fauna that is exceptional for the region, where high rainfall often produces conditions not conducive to preservation. The faunal

assemblages from both islands suggest arid grassland environments different from that found in the area today. Particularly notable is the presence of extant species well beyond their historic range (e.g. *Equus grevyi* and *Oryx gazella*), as well as a number of extinct bovids (e.g. *Megalotragus sp.*, *Syncerus antiquus* and *Rusingoryx atopocranion*). Fossils and artefacts occur in stream and spring deposits that likely reflect locally more wet (and possibly more closed) settings within the broader grassland environment, a hypothesis supported by initial (Garrett *et al.* 2010) and ongoing stable isotopic analyses of pedogenic carbonates, soil organic matter and fossil tooth enamel.

The lithic assemblages from Rusinga and, to a lesser extent, Mfangano are more similar to late Pleistocene sites in arid grassland settings from the East African Rift System than they are to other, older Lupemban MSA assemblages from the Lake Victoria region. Our comparison of point size supports our hypothesis that shared environments possibly contributed to shared adaptations and similar archaeological records. A more rigorous test of this hypothesis requires extensive comparisons of a broad range of behavioural signals, including methods of stone artefact production among sites in the Lake Victoria region and the East African Rift System. We look forward to such analyses, as well as to a renewed research emphasis on ‘post-Lupemban’ Pleistocene archaeological sites in the Lake Victoria region and their palaeoenvironmental contexts.

### **Acknowledgements**

This research was conducted under research permit NCST/5/002/R/576 issued to Tryon and an exploration and excavation license issued by the National Museums of Kenya (NMK). Our fieldwork in Kenya is made possible through the support of the NMK (particularly Dr Emma Mbuia and Mr Stephen Munge Longoria) and the British Institute in Eastern Africa. Funding was provided by the National Science Foundation (BCS-1013199 and BCS-1013108), the Leakey Foundation, the National Geographic Society’s Committee for Research and Exploration (8762-10), a graduate research grant from the Geological Society of America, Baylor University and New York University. Kieran McNulty, Holly Dunsworth, Will Harcourt-Smith and Tom Lehmann provided a number of valuable contributions to our research, Stanley Ambrose made some key observations about our artefacts while at the NMK and our fieldwork could never have been completed on time without the help of Cornel Faith. Editor Peter Robertshaw and three anonymous reviewers provided excellent comments and suggestions that substantially improved (and shortened!) the manuscript. Claire Heckel and Randall White kindly provided the French translation of the abstract.

### **Notes on contributors**

Christian Tryon is an Assistant Professor of Anthropology at New York University with research interests in the origins of modern human diversity, lithic technology and geoarchaeology, particularly the use of volcanic ashes for stratigraphic correlation. In addition to Kenya, he also conducts fieldwork at sites in Turkey and France.

Daniel Peppe is an Assistant Professor of Geology at Baylor University. His research focuses on integrating palaeoclimatology, geology, palaeobotany and palaeomagnetism to reconstruct Cenozoic climates and palaeoenvironments. He conducts his research primarily in East Africa and North America.

Tyler Faith is a Post-doctoral Research Fellow in the Archaeology program at the University of Queensland. He is a palaeoecologist specialising in zooarchaeology and vertebrate

palaeontology, with research interests in Quaternary paleoecology, megafaunal extinctions, modern human origins and taphonomy.

Alexander Van Plantinga is an alumnus of the Koobi Fora Field School and a Master's of Science student at Baylor University in Waco, Texas. His thesis applies sedimentology and tephrostratigraphic analysis to palaeoenvironmental reconstruction in the Wasiriya Beds.

Sheila Nightingale is an Archaeology PhD candidate in the Department of Anthropology at the City University of New York Graduate Centre. Her research interests include modern human origins, palaeodemography, technological and population diffusion and lithic technology.

Julian Ogondo received her Master's degree from the University of Nairobi and is currently head of the Geology Division, Earth Sciences Department, National Museums of Kenya.

David Fox is an Associate Professor in the Department of Geology and Geophysics at the University of Minnesota. His research focuses on isotopic, stratigraphic and phylogenetic analyses in palaeoecology, applied particularly to Miocene-Pleistocene field sites in North America, Asia and Africa.

## References

- Alemseged, Z. 2003. An integrated approach to taphonomy and faunal change in the Shungura Formation (Ethiopia) and its implications for hominid evolution. *Journal of Human Evolution* 44: 451–478.
- Ambrose, S.H. 1998. Chronology of the Later Stone Age and food production in East Africa. *Journal of Archaeological Science* 25: 377–392.
- Assefa, Z., S. Yirga and K.E. Reed. 2008. The large-mammal fauna from the Kibish Formation. *Journal of Human Evolution* 55: 486–500.
- Barham, L.S. 2000. *The Middle Stone Age of Zambia, south-central Africa*. Bristol: Western Academic and Specialist Press.
- Barham, L.S. 2001. Central Africa and the emergence of regional identity in the Middle Pleistocene. In *Human roots: Africa and Asia in the Middle Pleistocene*, ed. L.S. Barham and K. Robson-Brown, 65–80. Bristol: Western Academic and Specialist Press.
- Barham, L.S. and P.J. Mitchell. 2008. *The first Africans: African archaeology from the earliest toolmakers to most recent foragers*. Cambridge: Cambridge University Press.
- Barry, J.C., M.E. Morgan, L.J. Flynn, D. Pilbeam, A.K. Behrensmeyer, S.M. Raza, I.A. Khan, C. Badgley, J. Hicks and J. Kelley. 2002. Faunal and environmental change in the late Miocene Siwaliks of northern Pakistan. *Paleobiology* 28: 1–71.
- Basell, L. 2007. An exploration of the Middle Stone Age of eastern Africa and excavations at Rambogo Rock Shelter, Kenya. PhD diss., University of Cambridge.
- Bell, R.H.V. 1971. A grazing ecosystem in the Serengeti. *Scientific American* 225: 86–93.
- Beyries, S. and E. Boëda. 1983. Etude technologique et traces d'utilisation des 'éclats débordants' de Corbehem (Pas-de-Calais). *Bulletin de la Société Préhistorique Française* 80: 275–279.
- Bobe, R. and G.G. Eck. 2001. Responses of African bovids to Pliocene climatic change. *Paleobiology Memoirs* 2: 1–47.
- Boëda, E. 1994. *Le concept Levallois: variabilité des méthodes*. Paris: Centre National de la Recherche Scientifique Éditions.
- Bower, J.R.F., D.P. Gifford and D. Livingstone. 1985. Excavations at the Loiyangalani Site, Serengeti National Park, Tanzania. *National Geographic Society Research Reports (1979 Projects)* 20: 41–56.
- Bower, J.R.F. and P. Grogan-Porter. 1981. *Prehistoric cultures of the Serengeti National Park, Tanzania*. Ames: Iowa State University Press.
- Brooks, A.S., J.E. Yellen, L. Nevell and G. Hartman. 2006. Projectile technologies of the African MSA: Implications for modern human origins. In *Transitions before the transition:*

- evolution and stability in the Middle Palaeolithic and Middle Stone Age, ed. E. Hovers and S.L. Kuhn, 233–256. New York: Springer.
- Clark, J.D. 1988. The Middle Stone Age of East Africa and the beginnings of regional identity. *Journal of World Prehistory* 2: 235–305.
- Clark, J.D. 2001. *Kalambo Falls prehistoric site, volume III: the earlier cultures: Middle and Earlier Stone Age*. Cambridge: Cambridge University Press.
- Clark, P.U., A.S. Dyke, J.D. Shakun, A.E. Carlson, J. Clark, B. Wohlfarth, J.X. Mitrovica, S.W. Hostetler and A.M. McCabe. 2009. The Last Glacial Maximum. *Science* 325: 710–714.
- Conard, N.J., M. Soressi, J.E. Parkington, S. Wurz and R. Yates. 2004. A unified lithic taxonomy based on patterns of core reduction. *South African Archaeological Bulletin* 59: 13–17.
- Dibble, H.L. and S.P. McPherron. 2006. The missing Mousterian. *Current Anthropology* 47: 777–803.
- Diez-Martín, F., M. Domínguez-Rodrigo, P. Sánchez, A.Z.P. Mabulla, A. Tarriño, R. Barba, M.E. Prendergast and L. de Luque. 2009. The Middle to Later Stone Age technological transition in East Africa. New data from Mumba Rockshelter Bed V (Tanzania) and their implications for the origin of modern human behaviour. *Journal of African Archaeology* 7: 147–173.
- Fagan, B.M. and L. Lofgren. 1966. Archaeological reconnaissance on the Sese Islands. *Uganda Journal* 30: 81–86.
- Faith, J.T., J.N. Choiniere, C.A. Tryon, D.J. Peppe and D.L. Fox. 2011. Taxonomic status and palaeoecology of *Rusingoryx atopocranion* (Mammalia, Artiodactyla), an extinct Pleistocene bovid from Rusinga Island, Kenya. *Quaternary Research* 75: 697–707.
- Faith, J.T. and T.A. Surovell. 2009. Synchronous extinction of North America's Pleistocene mammals. *Proceedings of the National Academy of Sciences (USA)* 106: 20641–20645.
- Gabel, C. 1969. Six rockshelters in the northern Kavirondo shore of Lake Victoria. *African Historical Studies* 2: 205–254.
- Garrett, N., K.P. McNulty, D.L. Fox, D.J. Peppe and C.A. Tryon. 2010. Isotope palaeoecology of the Pleistocene Wasiriya Beds of Rusinga Island, Kenya. *Programme and Abstracts of the Annual Meetings of the Society of Vertebrate Palaeontology*: 94A.
- Gentry, A.W. 2010. Bovidae. In *Cenozoic mammals of Africa*, ed. L. Werdelin and W.J. Sanders, 741–796. Berkeley: University of California Press.
- Goodfriend, G.A. 1987. Radiocarbon age anomalies in shell carbonate of land snails from semi-arid areas. *Radiocarbon* 29: 159–167.
- Goodfriend, G.A. and J.J. Stipp. 1983. Limestone and the problem of radiocarbon dating of land-snail shell carbonate. *Geology* 11: 575–577.
- Grayson, D.K. 1981. A critical view of the use of archaeological vertebrates in palaeoenvironmental reconstruction. *Journal of Ethnobiology* 1: 28–38.
- Greenacre, M.J. and E.S. Vrba. 1984. Graphical display and interpretation of antelope census data in African wildlife areas using correspondence analysis. *Ecology* 65: 984–997.
- Grubb, P., O. Sandrock, O. Kullmer, T.M. Kaiser and F. Schrenk. 1999. Relationships between eastern and southern African mammal faunas. In *African biogeography, climate change and early hominid evolution*, ed. T. Bromage and F. Schrenk, 253–267. Oxford: Oxford University Press.
- Guichard, J. and G. Guichard. 1965. The Early and Middle Palaeolithic of Nubia: a preliminary report. In *Contributions to the prehistory of Nubia*, ed. F. Wendorf, 57–116. Taos: Fort Burgwin Research Centre.
- Gunz, P., F.L. Bookstein, P. Mitteroecker, A. Stadlmayr, H. Seidler and G.W. Weber. 2009. Early modern human diversity suggests subdivided population structure and a complex Out-of-Africa scenario. *Proceedings of the National Academy of Sciences (USA)* 106: 6094–6098.
- Hay, R.L. 1968. Chert and its sodium-silicate precursors in sodium-carbonate lakes of East Africa. *Contributions to Mineralogy and Petrology* 17: 255–274.
- Inizan, M.-L., M. Reduron-Ballinger, H. Roche and J. Tixier. 1999. *Technology and terminology of knapped stone*. Nanterre: CREP.
- Isaac, G.L. 1977. *Ologesailie: archaeological studies of a Middle Pleistocene lake basin in Kenya*. Chicago: University of Chicago Press.

- Johnson, T.C., K. Kelts and E. Odada. 2000. The Holocene history of Lake Victoria. *Ambio* 29: 2–11.
- Karega-Munene 2002. *Holocene foragers, fishers and herders of western Kenya*. Oxford: Archaeopress.
- Kent, P.E. 1942. The country round the Kavirondo Gulf of Victoria Nyanza. *Geographical Journal* 100: 22–31.
- Kingdon, J. 1974. *East African mammals: an atlas of evolution in Africa. Volume I*. Chicago: University of Chicago Press.
- Kingdon, J. 1982. *East African mammals: an atlas of evolution in Africa. Volume IIID: bovids*. Chicago: University of Chicago Press.
- Kingdon, J. 1989. *Island Africa: the evolution of Africa's rare animals and plants*. Princeton: Princeton University Press.
- Klein, R.G. 1980. Environmental and ecological implications of large mammals from Upper Pleistocene and Holocene sites in southern Africa. *Annals of the South African Museum* 81: 223–283.
- Klein, R.G. 1994. The long-horned African buffalo (*Pelorovis antiquus*) is an extinct species. *Journal of Archaeological Science* 21: 725–733.
- Klein, R.G. 2009. *The human career*. Chicago: University of Chicago Press.
- Koch, C.F. 1987. Prediction of sample size effects on the measured temporal and geographic distribution patterns of species. *Palaeobiology* 13: 100–107.
- Kuhn, S.L. 1994. A formal approach to the design and assembly of mobile toolkits. *American Antiquity* 59: 426–442.
- Lahr, M.M. and R. Foley. 1998. Towards a theory of modern human origins: geography, demography and diversity in recent human evolution. *Yearbook of Physical Anthropology* 41: 137–176.
- Lane, P.J., C. Ashley and G. Oteyo. 2006. New dates for Kansyore and Urewe wares from northern Nyanza, Kenya. *Azania* 41: 123–138.
- Lane, P.J., C. Ashley, O. Seitsonen, P. Harvey, S. Mire and F. Odede. 2007. The transition to farming in eastern Africa: new faunal and dating evidence from Wadh Lang'o and Usenge, Kenya. *Antiquity* 81: 62–81.
- Leakey, L.S.B. and W.E. Owen. 1945. *A contribution to the study of the Tumbian culture in East Africa*. Nairobi: Coryndon Memorial Museum.
- Lyman, R.L. 1995. Determining when rare (zoo-)archaeological phenomena are truly absent. *Journal of Archaeological Method and Theory* 2: 369–424.
- Lyman, R.L. 2007. Estimating the magnitude of data asymmetry in palaeozoological biogeography. *International Journal of Osteoarchaeology* 18: 85–94.
- Manega, P.C. 1993. Geochronology, geochemistry and isotopic study of the Plio-Pleistocene hominid sites and the Ngorongoro volcanic highland in northern Tanzania. PhD diss., University of Colorado, Boulder.
- Marean, C.W. 1992. Implications of late Quaternary mammalian fauna from Lukenya Hill (south-central Kenya) for palaeoenvironmental change and faunal extinctions. *Quaternary Research* 37: 239–255.
- Marean, C.W. and D. Gifford-Gonzalez. 1991. Late Quaternary extinct ungulates of East Africa and palaeoenvironmental implications. *Nature* 350: 418–420.
- Marks, A. and N. Conard. 2007. Technology vs. typology: the case for and against a transition from the MSA to the LSA at Mumba Cave, Tanzania. In *Space and time: which diachronies, which synchronies, which scales? Typology vs. technology*, ed. T. Aubry, F. Almeida, A.C. Araújo and M. Tiffagom, 123–131. Oxford: Archaeopress.
- McBrearty, S. 1981. Songhor: a Middle Stone Age site in western Kenya. *Quaternaria* 23: 171–190.
- McBrearty, S. 1986. The archaeology of the Muguruk site, western Kenya. PhD diss., University of Illinois, Urbana-Champaign.
- McBrearty, S. 1988. The Sangoan-Lupemban and Middle Stone Age sequence at the Muguruk site, western Kenya. *World Archaeology* 19: 379–420.
- McBrearty, S. 1990. Consider the humble termite: termites as agents of post-depositional disturbance at African archaeological sites. *Journal of Archaeological Science* 17: 111–143.



- McBrearty, S. 1991. Recent research in western Kenya and its implications for the status of the Sangoan Industry. In *Cultural beginnings: approaches to understanding early hominid lifeways in the African savanna*, ed. J.D. Clark, 159–176. Bonn: Römisch-Germanisches Zentralmuseum, Forschungsinstitut für Vor- und Frühgeschichte.
- McBrearty, S. and A.S. Brooks. 2000. The revolution that wasn't: a new interpretation of the origin of modern human behaviour. *Journal of Human Evolution* 39: 453–563.
- McCall, G.H.G. 1958. *Geology of the Gwasi area*. Nairobi: Geological Survey of Kenya.
- Mehlman, M.J. 1977. Excavations at Nasera Rock. *Azania* 12: 111–118.
- Mehlman, M.J., 1989: Late Quaternary archaeological sequences in northern Tanzania. PhD diss., University of Illinois, Urbana.
- Mehlman, M.J. 1991. Context for the emergence of modern man in Eastern Africa: Some new Tanzanian evidence. In *Cultural beginnings: approaches to understanding early hominid lifeways in the African savanna*, ed. J.D. Clark, 177–196. Bonn: Römisch-Germanisches Zentralmuseum, Forschungsinstitut für Vor- und Frühgeschichte.
- Mercader, J. 2002. Forest people: the role of African rainforests in human evolution and dispersal. *Evolutionary Anthropology* 11: 117–124.
- Merrick, H.V. 1975. Change in later Pleistocene lithic industries in eastern Africa. PhD diss., University of California, Berkeley.
- Merrick, H.V. and F.H. Brown. 1984. Obsidian sources and patterns of source utilization in Kenya and northern Tanzania: some initial findings. *African Archaeological Review* 2: 129–152.
- Merrick, H.V., F.H. Brown and W.P. Nash. 1994. Use and movement of obsidian in the Early and Middle Stone Ages of Kenya and northern Tanzania. In *Society, culture, and technology in Africa*, ed. S.T. Childs, 29–44. Philadelphia: MASCA.
- Nelson, C.M. 1976. Flaked stone variations in the Later Stone Age of eastern and southern Africa. In *Proceedings of the Panafrican Congress of Prehistory and Quaternary Studies, VIIIth Session, 1971*, ed. B. Abebe, J. Chavaillon and J.E.G. Sutton, 131–152. Addis Ababa: Provisional Military Government of Socialist Ethiopia Ministry of Culture.
- Nenquin, J. 1971. Archaeological prospections on the islands of Buvuma and Bugaia, Lake Victoria Nyanza (Uganda). *Proceedings of the Prehistoric Society* 37: 381–418.
- Nicholson, S.E. 1998. Historical fluctuations of Lake Victoria and other lakes in the northern rift valley of East Africa. In *Environmental change and response in East African lakes*, ed. J.T. Lehman, 7–35. Dordrecht: Kluwer Academic Publishers.
- O'Brien, T.P. 1939. *The prehistory of Uganda Protectorate*. Cambridge: Cambridge University Press.
- Pickford, M. 1986. Cainozoic palaeontological sites of Western Kenya. *Münchener Geowissenschaftlich Abhandlungen* 8: 1–151.
- Pickford, M. and H. Thomas. 1984. An aberrant new bovid (Mammalia) in subrecent deposits from Rusinga island, Kenya. *Proceedings of the Koninklijke Akademie des Wetenschappen B* 87: 441–452.
- Posnansky, M., D.A.M. Reid and C. Ashley. 2005. Archaeology on Lolui Island, Uganda 1964–5. *Azania* 40: 73–100.
- Potts, R. and A. Deino. 1995. Mid-Pleistocene change in large mammal faunas of East Africa. *Quaternary Research* 43: 106–113.
- Prendergast, M.E. 2008. Forager variability and transitions to food production in secondary settings: Kansyore and Pastoral Neolithic economies in East Africa. PhD diss., Harvard University.
- Reid, D.A.M. and J.E.K. Njau. 1994. Archaeological research in the Karagwe District. *Nyame Akuma* 41: 68–73.
- Robertshaw, P.T. 1991. Gogo Falls: a complex site east of Lake Victoria. *Azania* 26: 63–196.
- Robertshaw, P.T., D. Collett, D. Gifford and N.B. Mbae. 1983. Shell middens on the shores of Lake Victoria. *Azania* 18: 1–44.
- Shackleton, R.M. 1950. A contribution to the geology of the Kavirondo Rift Valley. *Quarterly Journal of the Geological Society* 106: 345–392.

- Shea, J.J. 2008. The Middle Stone Age archaeology of the Lower Omo Valley Kibish Formation: excavations, lithic assemblages, and inferred patterns of early *Homo sapiens* behaviour. *Journal of Human Evolution* 55: 448–485.
- Shipman, P. and J.M. Harris. 1988. Habitat preference and palaeoecology of *Australopithecus boisei* in eastern Africa. In *Evolutionary history of the "robust" australopithecines*, ed. F.E. Grine, 343–381. New York: Aldine De Gruyter.
- Skinner, A.R., R.L. Hay, F. Masao and B.A.B. Blackwell. 2003. Dating the Naisiusiu Beds, Olduvai Gorge, by electron spin resonance. *Quaternary Science Reviews* 22: 1361–1366.
- Stager, J.C. and T.C. Johnson. 2008. The Late Pleistocene desiccation of Lake Victoria and the origin of its endemic fauna. *Hydrobiologia* 596: 5–16.
- Sutton, J.E.G. 1973. *The archaeology of the Western Highlands of Kenya*. Nairobi: British Institute in Eastern Africa.
- Thompson, J.C. 2005. The impact of post-depositional processes on bone surface modification frequencies: a corrective strategy and its application to the Loiyangalani site, Serengeti Plain, Tanzania. *Journal of Taphonomy* 3: 67–89.
- Thompson, J.C., J.R.F. Bower, E.C. Fisher, A.Z.P. Mabulla, C.W. Marean, K. Stewart and C.F. Vondra. 2004. Loiyangalani: behavioural and taphonomic aspects of a Middle Stone Age site in the Serengeti Plain, Tanzania. *PaleoAnthropology* 2004: A56.
- Tishkoff, S.A., F.A. Reed, F.O.R. Friedlaender, C. Ehret, A. Ranciaro, A. Froment, J.B. Hirbo, A.A. Awomoyi, J.-M. Bodo, O. Doumbo, M. Ibrahim, A.T. Juma, M.J. Kotze, G. Lema, J.H. Moore, H. Mortensen, T.B. Nyambo, S.A. Omar, K. Powell, G.S. Pretorius, M.W. Smith, M.A. Thera, C. Wambebe, J.L. Weber and S.M. Williams. 2009. The genetic structure and history of Africans and African Americans. *Science* 324: 1035–1044.
- Tryon, C.A., J.T. Faith, D.J. Peppe, D.L. Fox, K.P. McNulty, K. Jenkins, H. Dunsworth and W. Harcourt-Smith. 2010. The Pleistocene archaeology and environments of the Wasiriya Beds, Rusinga Island, Kenya. *Journal of Human Evolution* 59: 657–671.
- Van Couvering, J. 1972. Geology of Rusinga Island and correlation of the Kenya mid-Tertiary fauna. PhD diss., University of Cambridge.
- Van Noten, F. 1971. Excavations at Munyama Cave. *Antiquity* 45: 56–58.
- Van Peer, P. 1992. *The Levallois reduction strategy*. Madison: Prehistory Press.
- Van Plantinga, A., D.J. Peppe, C.A. Tryon and J.T. Faith. 2010. Geoarchaeology of the Pleistocene Wasiriya Beds, Rusinga Island, Kenya. *Geological Society of America 2010 Annual Meeting Abstracts with Programs*, 42(5).
- Vermeersch, P.M. 2002. *Palaeolithic quarrying sites in Upper and Middle Egypt*. Leuven: Leuven University Press.
- Vrba, E.S. 1980. The significance of bovid remains as an indicator of environment and predation patterns. In *Fossils in the making*, ed. A.K. Behrensmeyer and A.P. Hill, 247–272. Chicago: University of Chicago Press.
- Vrba, E.S. 1987. A revision of the Bovini (Bovidae) and a preliminary revised checklist of Bovidae from Makapansgat. *Palaeontologia Africana* 26: 33–46.
- Weninger, B. and O. Jöris. 2008. A <sup>14</sup>C age calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Palaeolithic transition in western Eurasia. *Journal of Human Evolution* 55: 772–781.
- White, F. 1983. *The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. Paris: UNESCO.
- Whitehouse, B. and C.S. Hunter. 1955. Central Africa, Victoria Nyanza (Northern Portion), Uganda Railway Surveys, 1900–01. Corrections and additions to 1955 Admiralty Chart No. 3252. London: Hydrographer of the Royal Navy.
- Whitworth, T. 1961. The geology of Mfwanganu island, western Kenya. *Overseas Geology and Mineral Resources* 8: 150–192.
- Wronski, T. and B. Hausdorf. 2008. Distribution patterns of land snails in Ugandan rain forests support the existence of Pleistocene forest refugia. *Journal of Biogeography* 35: 1759–1768.
- Yellen, J.E., A.S. Brooks, D.M. Helgren, M. Tappen, S.H. Ambrose, R. Bonnefille, J.K. Feathers, K. Ludwig, P. Renne and K. Stewart. 2005. The archaeology of Aduma Middle Stone Age sites in the Awash Valley, Ethiopia. *PaleoAnthropology* 10: 25–100.