Renewed Geoarchaeological Investigations of Mwanganda’s Village (Elephant Butchery Site), Karonga, Malawi

David K. Wright, Jessica Thompson, Alex Mackay, Menno Welling, Steven L. Forman, Gilbert Price, Jian-xin Zhao, Andrew S. Cohen, Oris Malijani, and Elizabeth Gomani-Chindebu

Corresponding author; E-mail: msafiri@snu.ac.kr

The site of Mwanganda’s Village, located along a paleochannel in northern Malawi, is one of only a few sites that have characterized the Middle Stone Age (MSA) of Malawi for decades (Clark & Haynes, 1970; Clark et al., 1970; Kaufulu, 1990). The Malawi Earlier-Middle Stone Age Project has re-examined the site using new mapping and chronometric tools in order to reinterpret the site’s significance within the context of current debates surrounding human origins and the potential role the environment played in shaping human behavior. The new data do not support the previous hypothesis that the site was an elephant butchery location (contra Clark & Haynes, 1970; Clark et al., 1970; Kaufulu, 1990). Instead, the evidence shows successive colonization of riparian corridors by MSA hunter-gatherers focused on exploiting localized resources during periods of generally humid climates while other lakes desiccated across Africa. We challenge the hypothesis that stable and intermediately high lake levels within the African Rift Valley System (sensu Trauth et al., 2010) catalyzed the evolution of regional interaction networks between 42 and 22 ka. Instead, we interpret the evidence to suggest that regional variants of technology persist into the late MSA as foragers focused on exploiting resources from local catchments. © 2014 Wiley Periodicals, Inc.
behavior, changes observed in the archaeological record, and profound changes in past ecosystems (Guerin et al., 1996; Basell, 2008; Bar-Matthews et al., 2010; Blome et al., 2012). Such data are essential for understanding if the environment placed greater selective pressures on early modern humans to force a change in cognitive capacity and behavior, or if ancestral human populations experienced independent cultural or demographic expansions unrelated to a change in the environment (e.g., Powell, Shennan, & Thomas, 2009).

Renewed archaeological investigations into MSA deposits near the town of Karonga have yielded sequences from new sites and new data from previously known sites (Thompson et al., 2012; Thompson, Welling, & Gomani-Chindebvu, in press), which can be directly related to the nearby paleoclimate and paleoenvironmental records from Lake Malawi (Scholz et al., 2011). Research by the Malawi Earlier-Middle Stone Age Project (MEMSAP) in northern Malawi has identified stratified archaeological deposits on alluvial fans located in riparian catchments spanning the MSA with a resumption of occupation in the historical period (Thompson et al., 2012; Thompson, Welling, & Gomani-Chindebvu, in press). Successive human occupations of the site of Mwanganda’s Village imply that highly mobile MSA hunter-gatherers exploited fluvial resources within this transitional region between lowland and upland environmental zones. Recent agriculturalists occupied the site at or near the end of a period of alluvial fan deposition and were less mobile and more tethered to the site than their predecessors. Our investigation revises and updates previous site interpretations, using new geoarchaeological and geochronological data obtained by MEMSAP during fieldwork in 2010, 2011, and 2012. Herein, we provide new data about the site itself, with specific reference to how the evolution of human technological behavior occurred within the changing environment of the Late Pleistocene of Africa.

THE LATER MSA OF NORTHERN MALAWI
Paleogeographic Background

For the most part, the transition from the MSA to the LSA can be viewed as a series of technological and behavioral adaptations that occurred within highly variable environments lasting from 40 to 20 ka throughout Africa. Some technological elements of the LSA such as blade production, hafting, and symbolic expression also occur at earlier sites associated with the MSA technology, particularly in the case of the techno-complex known as the Howieson’s Poort (Soriano, Villa, & Wadley, 2007; Backwell, D’Errico, & Wadley, 2008; Henshilwood & Dubreuil, 2011; Charrié-Duhaut et al., 2013), but by 20 ka there are no MSA sites unequivocally documented in the archaeological record (see Lombard, 2012 for a recent review of the evidence). Offshore sediment records and terrestrial pollen records from across the continent demonstrate significant longitudinal and temporal variability in climate regimes throughout the Pleistocene, creating an environmental mosaic rife with both ecologically productive and marginal foraging territories (e.g., Schneider, Müller, & Acheson, 1999; Stuut et al., 2002; Trauth et al., 2003; Dupont, 2011).

Some of the most critical phases of human biological and cultural evolution occurred within the margins of the tectonically active African Rift Valley, and the highly irregular topographic environment combined with extreme climatic gradients within relatively short distances are seen as prime catalysts fostering allopatric speciation (King & Bailey, 2006; Trauth et al., 2010; Bailey, Reynolds, & King, 2011; Winder et al., 2013). Within this environment, small changes in global or regional climatic forcing mechanisms are amplified in Rift Valley lakes because they respond with exceptional sensitivity due to the trough-shaped aspect of the basins in which they sit and contrast between high- and low-precipitation zones within their catchments (Olaka et al., 2010). According to the Hypothesis of Amplifier Lakes, exceptionally high and low lake levels serve to separate hominin populations living on opposite sides of the Rift Valley margin because such events create an impenetrable geographic barrier, whereas intermediate lake levels encourage interactions within the lacustrine margins (Trauth et al., 2010). Thus, constraining lake levels and the chronometry of tectonic activity within the Rift Valley provide critical background for potential drivers of human evolution.

Northern Malawi is a unique landscape to investigate the role of lacustrine systems and topographic variability during periods of profound climatic change. Lake Malawi provides a physical barrier along the eastern margin of the study area, and has contained water for at least the last 145 ka (Scholz et al., 2011), although megadroughts significantly reduced the water balance to ~5% of its present level as recently as 90 ka (Scholz et al., 2007). Less than 100 km to the west the Nyika Plateau rises from 476 masl to nearly 2500 masl, leaving a narrow north-south strip of land between the two major features (Figure 1). The presence of sharp elevational gradients and a stable water body since at least 70 ka facilitates a high endemic biodiversity and there is a wide range of potential ecological niches that could be exploited during harsh environmental conditions (Mercader, Bennett, & Raja, 2008; Mercader et al., 2013).
One of the longest and most detailed terrestrial palaeoclimate records in Africa is derived from cores taken in the northern basin of Lake Malawi (Cohen et al., 2007; Scholz et al., 2007, 2011). These records show that from at least 145 to 70 ka, the climate oscillated between cool/dry and warm/wet intervals with several periods of “megadrought” documented in the core record (Cohen et al., 2007; Scholz et al., 2007; Stone, Westover, & Cohen, 2011). The proxy record reflects extreme low stand events between 135 and 126 ka (~130 ka), 117 and 85 ka (~100 ka), and a less severe episode between 85 and 71 ka (~75 ka) with intervening high stands comparable to present levels (Scholz et al., 2011; but see Lane, Chorn, & Johnson, 2013 for a slight revision in the age model used to anchor the geochronology). During some of these episodes the northern basin of Lake Malawi effectively dried up. After 70 ka, the lake transitioned to generally higher conditions punctuated by slight regressions between 64–62 and 47–30 ka (Scholz et al., 2011; Stone, Westover, & Cohen, 2011).

The so-called “Elephant Butchery Site” in northern Malawi was discovered at Mwanganda’s Village by J. Desmond Clark and C. Vance Haynes in 1965 (Clark & Haynes, 1965; Clark et al., 1970). Excavations ensued in 1966 (Clark & Haynes, 1970; Clark et al., 1970), and the site was later explored by Zefe Kaufulu (1983, 1990). Mwanganda’s Village is located approximately...
10 m above the present-day level of Lake Malawi within the catchment of the Rukuru River, which drains hundreds of kilometers to the west and south along the western wall of the Rift Valley escarpment (Figures 1 and 2). Previous geoarchaeological analyses of Mwanganda’s Village provided evidence of hominin activities from the contact between the Chiwondo and Chitimwe beds demarcated by a paleosol that formed on the margin of a braided stream (Clark & Haynes, 1970; Kafulu, 1990). The majority of artifacts and the elephant fossils were recovered by Clark and Haynes (1970) from an excavated area measuring approximately 11 × 12 m and named “Area 1” (see also Clark et al., 1970). A trench connected to a second large excavation approximately 5 m to the south was named “Area 2,” from which a small number of additional fossils were recovered (Figure 3).

A Rb/Sr age assayed on soil carbonate that overlies the elephant yielded a minimum constraining age of ca. 300 ka associated with artifacts that were tentatively classified as Sangoan (Clark & Haynes, 1970; Kafulu, 1990; Clark, 1995). However, Rb-Sr ages on soil carbonate may be spurious because of open system geochemistry and potential of secondary exchange of carbonate (Bizzarro et al., 2003). The primary focus of hominin activities was described as occurring on a subtly elevated terrace adjacent to a stream with maximum flow rates of 80 cm/s (Kafulu, 1990). Some local fluvial reworking of artifacts as a result of low-energy overbank flooding was interpreted from morphological data, but, overall, artifacts and fossils recovered from archaeological excavations were argued to have been located close to their primary depositional context with little evidence for fluvial winnowing or abrasions resulting from long-distance fluvial transport (Clark & Haynes, 1970; Clark et al., 1970; Kafulu, 1990). Kafulu’s (1983, 1990) description of the sedimentology of the site was based on a series of geological trenches emplaced around the site and adjacent to Clark’s “Area 1” (Table I). He reconstructed a main paleochannel
Table I Comparative lithology of Kaufulu (1990) and Clark and Haynes (1970)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stony soil</td>
<td>Unit 8</td>
<td>Light brownish sand</td>
<td>Qk</td>
</tr>
<tr>
<td>Light red sandstone with basal gravel</td>
<td>Unit 7</td>
<td>Light red sand</td>
<td>Qkt2b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sandy pebble gravel</td>
<td>Qkt2a</td>
</tr>
<tr>
<td>Dark brown muddy sandstone</td>
<td>Unit 6</td>
<td>Dark brown sand</td>
<td>Qkt1b</td>
</tr>
<tr>
<td>Caliche</td>
<td>Unit 5</td>
<td>Caliche pebble gravel</td>
<td>Qkt1a</td>
</tr>
<tr>
<td>Pale grayish orange sandstone</td>
<td>Unit 3</td>
<td>Dark grayish brown sand</td>
<td>Qco1c</td>
</tr>
<tr>
<td>Greenish/brownish gray sandy claystone</td>
<td>Unit 2</td>
<td>Greenish gray clayey sand</td>
<td>Qco1b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenish gray sandy clay</td>
<td>Qco1a</td>
</tr>
</tbody>
</table>

*Units not observed to occur at the site but that occur in the region are not included.*

flowing SE-NW that would have been responsible for minor fluvial reworking of the elephant fossils and artifacts. In actuality, Kaufulu’s trenches were mistakenly placed adjacent to Clark’s “Area 2,” which was approximately 9 m south of the closest elephant fossils. Additionally, the stream he identified (Kaufulu, 1990) was oriented SW-NE, not SE-NW, due to a misplaced north arrow (Thompson, Welling, & Gomani-Chindebvu, in press). Thus, the paleochannel reconstruction cannot apply specifically to the locus of the elephant skeleton.

**METHODS AND TECHNIQUES**

**Archaeological Excavations**

The fact that Mwanganda’s Village was designated as a Sangoan elephant butchery site suggested to MEMSAP researchers that the site had potential to shed light on the transition to modern human behavior during the earlier part of the MSA. The first full MEMSAP season took place in July/August 2010 (Thompson, Mackay, & Welling, 2011) with subsequent field seasons in 2011 and 2012 (Thompson, Mackay, & Welling, 2011; Thompson, Welling, & Gomani-Chindebvu, 2012). Three test pits totaling 4 m² were excavated in 2010, with all deposits sieved through 5-mm mesh, and cultural materials piece-plotted where they were found in situ. In 2011, 13 geologic trenches approximately 1 × 2 m were excavated across the site to document the stratigraphy, and these were not sieved. Optically stimulated luminescence (OSL) samples were collected for analysis from two of these trenches to constrain deposition on the site. In 2011 and 2012, three main areas were subjected to controlled excavation by MEMSAP. These are differentiated from the original Clark excavations by use of a roman numeral. Area I refers to a 5 × 5 m block emplaced in the deposits upslope and approximately 60 m to the south of the “Elephant Butchery Site.” Area II was a 2 × 3 m block approximately 3 m south of Clark’s own Area 2, and Area III was a 4 × 6 m block in the intact deposits under and to the west of the backdirt from Kaufulu’s (1990) “Trench 1” (Figure 3). A total of 59 m² were removed as part of controlled excavations, which proceeded in natural layers. All finds were piece-plotted and screened through 5-mm mesh. An additional 5 m² wet-sieved from Area I, 2 m² from Area II, and all 24 m² from Area III to recover lithic microdebitage and fossil material. A detailed topographic map was generated of the project area using a Nikon© C-series total station and Ashtech© Promark Mobile Mapper differential GPS with elevations based on a local elevation beacon to provide true masl giving centimeter-scale precision topographic maps (Figure 3).

The Area I excavation revealed a lithic assemblage buried under 1.5 m of overburden, which contained modern pottery and bricks in the uppermost plough zone. Rare faunal material and lithic tools were recovered close to the modern ground surface from Areas II and III, closer to the reported “Elephant Butchery Site.” These were likely associated with the originally reported archaeological finds (Clark & Haynes, 1970).

**Dating**

**Optically stimulated luminescence dating**

The geochronology of the site relied primarily on OSL dating of multiple aliquots of buried quartz grains using the single aliquot regeneration (SAR) method. Recent advances in OSL dating (e.g., Rittenour, 2008; Wintle, 2008) on carefully selected fluvial sediments, usually low-energy deposits, can yield absolute ages for the past ca. 100 ka (see also Sitzia et al., 2012). Dating of fluvial sediments in Africa has been ongoing for over a decade (Woodward, Macklin, & Welsby, 2001; Feathers, 2002; Wright et al., 2007; Rittenour, 2008). In large drainage systems, OSL is effective in reconstructing large-scale changes in hydrology and geomorphology related to continental-scale shifts in climate (e.g., Williams et al., 2010), whereas in smaller catchments OSL has proven
effective in identifying localized sources of groundwater (Ashley et al., 2011).

Fourteen samples for OSL dating were taken from nonpedogenically or mildly pedogenically modified sediments to specifically avoid bioturbation. Samples were taken from a freshly cleaned surface using PVC or aluminum tubes 15 cm long and 2.5 cm in diameter driven into the pit face with a rubber mallet. The OSL sampling was accompanied by the collection of associated bulk samples for geochemical analysis. Optical ages are reported in years prior to A.D. 2010.

SAR protocols (Murray & Wintle, 2003) were used in this study to estimate the apparent equivalent dose of the 150–250 μm quartz fraction for 24–30 separate aliquots. Each aliquot contained approximately 100–500 quartz grains corresponding to a 1.5–2.0 mm circular diameter of grains adhered (with silicon) to a 1 cm diameter circular aluminum disc. The quartz fraction was isolated by density separations using the heavy liquid Na–polytungstate, and a 40-minute immersion in HF (40%) was applied to etch the outer ∼10 μm of grains, which is affected by alpha radiation (Mejdahl & Christiansen, 1994). Quartz grains were rinsed finally in HCl (10%) to remove any insoluble fluorides. The purity of the quartz separates was evaluated by petrographic inspection and point counting of representative aliquots; this procedure was repeated if samples contained >1% of nonquartz minerals. The purity of quartz separates was tested by exposing aliquots to infrared excitation (845 ± 4 nm), which preferentially excites feldspar minerals. Samples measured showed weak emissions (<200 counts/s), at or close to background counts with infrared excitation, and ratio of emissions from blue to infrared excitation of >20, indicating a spectrally pure quartz extract (Duller, Bøtter-Jensen, & Murray, 2003).

A series of experiments was performed to evaluate the effect of preheating at 200, 220, 240, and 260°C for isolating the time-sensitive emissions and assessing thermal transfer of the regenerative signal prior to the application of SAR protocols (see Murray & Wintle, 2003). These experiments entailed giving a known dose (20 Gy) and evaluating which preheat resulted in recovery of this dose. There was concordance with the known dose (20 Gy) for preheat temperatures above 220°C with an initial preheat temperature used of 240°C for 10 seconds in the SAR protocols. A “cut heat” at 240°C for 10 seconds was applied prior to the measurement of the test dose and a final heating at 280°C for 40 seconds was applied to minimize carry-over of luminescence to the succession of regenerative doses (Table II). A test for dose reproducibility was also performed following procedures of Murray and Wintle (2003) with the initial and final regenerative dose of ~16 Gy yielding concordant luminescence responses (at 1-σ error).

Typical OSL shine-down curves for 150–250 μm quartz grains are shown in Figure 4. The curve shapes show that OSL signal is probably dominated by a fast component, with the OSL emission decreasing by 90–95% during the first 4 seconds of stimulation. The regenerative growth curves are modeled by using the exponential plus linear form. For many aliquots the regenerative growth curves (Figure 4) show that (1) the recuperation is close to zero, (2) the recycling ratio is consistent with unity at 1-σ, and (3) the natural \( L_n / T_n \) ratio is well below 20% of the saturated level. The few aliquots removed were because of unacceptable recycling ratio and \( D_i \) values at or close to saturation with errors of >10%. Error analysis for equivalent dose calculations assumed a measurement error of 1% and Monte Carlo simulation repeats of 2000. Recuperation is lower than 2% for all samples, which indicates insignificant charge transfer during the measurements. These favorable luminescence characteristics for a majority of aliquots indicate that credible equivalent dose values for these sediments can be determined by the SAR protocol.

The SAR protocols yielded individual OSL ages by averaging 24–30 separate, equivalent doses from respective aliquots of quartz grains (Murray & Wintle, 2003). Equivalent dose distributions were usually log normal and the scatter in the data is quantified with overdispersion values (Figure 4). An overdispersion percentage of \( D_i \) distribution is an estimate of the relative standard deviation from a central \( D_i \) value in context of a statistical estimate of errors (Galbraith et al., 1999; Galbraith & Roberts, 2012). A zero overdispersion percentage indicates high internal consistency in \( D_i \) values with 95% of the \( D_i \) values within 2-σ errors. Overdispersion values ≤20% are routinely assessed for quartz grains that are thoroughly reset during exposure to solar rays, like eolian sands (e.g., Olley, Pietsch, & Roberts, 2004; Wright et al., 2011) and this value is considered a threshold metric for calculation of a \( D_i \) value using the central age model of

<table>
<thead>
<tr>
<th>Table II Single aliquot regeneration protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>
Galbraith et al. (1999). Overdispersion values >20% may indicate mixing of grains of various ages or partial solar resetting of grains; the minimum age model (three parameters) may be an appropriate statistical treatment for such data and effectively weights for the youngest $D_e$ distribution. However, some studies have concluded that overdispersion values between 20% and 32% may reflect a single $D_e$ population, particularly if the $D_e$ distribution is symmetrical, with the dispersion related to variability associated with microdosimetry and/or sedimentary processes (e.g., Arnold & Roberts, 2009). Four of the twelve samples (LM2011-03, LM2011-08, LM2011-09, and LM2011-11) have overdispersion values that are >20% (at 2-$\sigma$ errors) with negatively skewed distributions, thus the minimum age model is most appropriate for estimating an equivalent dose (Galbraith et al., 1999; Galbraith & Roberts, 2012).
Multiple aliquot regenerative dose protocols, similar to those used in Londofio et al. (2012) were employed on two samples (UIC3091 and UIC3091) to test the accuracy of the SAR-based ages. The Multiple Aliquot Regeneration (MAR) analyses are predicated on different assumptions than SAR with resetting of naturals under UV light for 2 days prior to regenerative dosing. In turn, each aliquot is used for a single measurement, rather than a series with SAR, which necessitates just one sensitivity correction. The MAR equivalent doses overlap with the corresponding SAR values, which yields greater confidence in the rendered equivalent doses.

The environmental dose rate is a critical measurement for calculating a luminescence age. The dose rate is an estimate of the exposure of quartz grains to ionizing radiation from the decay of the U and Th series, K, and cosmic sources during the burial period. The U, Th, and K concentrations are determined by inductively coupled plasma mass spectrometry (ICP-MS) by Activation Laboratory LTD, Ontario, Canada. The beta and gamma doses were adjusted according to grain diameter to compensate for mass attenuation for the dose rate (Fain et al., 1999). Beta and gamma attenuation coefficients for 150–250 μm are 0.876 and 0.999, respectively. The U, Th, and K2O content was determined for the bulk sediment to calculate the dose rate. A cosmic ray component, taking into account location, elevation, and depth of strata sampled is between 0.17 and 0.20 mGy/yr and is included in the estimated dose rate (Prescott & Hutton, 1994). There is uncertainty in assessing the moisture content of a sample during burial. We estimated moisture contents from present values, particle size characteristics, and in reference to the water table.

In the absence of gamma spectrometry, it is unknown if there is disequilibrium in the U and Th decay series. A number of samples have relatively high Th values (10–25 ppm) with Th to U ratios that exceed 6, which suggests a granitic source (Van Schmus, 1995), though digenetic processes cannot be dismissed for these elevated ratios.

**Uranium-thorium dating**

Uranium-thorium (U-Th) ages were obtained from three fragments of fossil elephant tusk recovered by Clark and Haynes (1970). These samples were loaned from the Stone Age Institute at the University of Indiana-Bloomington to the University of Queensland (UQ). U-Th dating was conducted at the Radiogenic Isotope Facility at UQ. Analysis was performed using a multi-collector inductively-coupled mass spectrometer (MC-ICPMS) following procedures described in Zhou et al. (2011) and Roff et al. (2013).

U-Th dating is a radiometric dating technique commonly used to determine the age of carbonate materials from sources such as speleothems and corals. The U-Th dating method is based on the decay of 238U (with a half-life $T_{1/2} = 4.469 \times 109$ years) to stable 206Pb via intermediate daughters such as $^{234}$U ($T_{1/2} \sim 245,000$ years) and $^{230}$Th ($T_{1/2} \sim 75,400$ years). In this decay series, $^{238}$U-$^{234}$U-$^{230}$Th disequilibrium occurs when U is differentiated from Th during a particular geological or environmental event or process. In the case of natural aqueous systems, for example, in which U is slightly soluble, but Th is highly insoluble, carbonate precipitated from the aqueous system will contain trace amounts of U (usually 0.01–100 ppm), but virtually no Th, leading to excess U in the decay chain (i.e., $^{238}$U and $^{234}$U activities $> > ^{230}$Th activity).

Once disequilibrium is established, it takes about seven times the half-life of $^{230}$Th ($\sim 500$ ka) for the system to return to near secular equilibrium (i.e., when the activities of the parent and daughter nuclides are equal), or to the level where the degree of disequilibrium is below the limit of detection by thermal ionization mass spectrometry or MC-ICPMS.

Unlike speleothems or corals, teeth and bones of living animals contain very little U. Instead, U is taken up from the environment during fossilization processes. Thus, the U-Th date of a fossil tooth or ivory sample records the mean age of the fossilization process or U uptake history. In ideal cases, U uptake may reach saturation level during the early stage of the fossilization process (early uptake mode). In this case, the U-Th date would approximate the deposition age of the fossil material. In most other cases, U uptake modes might be more complex. The U-Th dates of the fossil are variable but theoretically younger than the deposition age of the fossil material. U-Th dates of the fossil may become apparently too old if extensive U loss through leaching occurred (Pike, Hedges, & Van Calsteren, 2002). However, extensive U loss, sufficient to make the apparent U-Th date older than the true age of the fossil, is usually extremely rare. In most cases, as demonstrated in numerous previous studies (e.g., Zhao et al., 2001; Grün et al., 2010; Price et al., 2011, 2013), the ages returned by the U-Th method provide minimum dates for the fossilization of the bone or molar fragments.

**Stone Artifact and Faunal Analysis**

A sample of 2363 stone artifacts and specimens of fossil bone have been studied from the MEMSAP excavations. Attempts have been made to locate the cemetery site of the elephant remains described by Clark and Haynes (1970: 393) both in Malawi and in known places to which materials were exported in the 1960s, but these have proven largely unsuccessful. The Stone Age
Institute in Bloomington, Illinois currently houses the majority of the stone artifacts originally recovered and reported by Clark and Haynes (1970), but only has a small collection of fossils ($N = 156$) most likely representing the fragments found underlying the elephant femur and a small number of fossils from Clark’s Area 2 (Clark & Haynes, 1970).

Analytic techniques for stone artifacts at Mwanganda’s Village followed those previously employed during work at the nearby Airport Site (Thompson et al., 2012). All plotted and sieve-recovered artifacts were analyzed. The analytical focus was on the metric attributes of artifacts, indicators of manufacturing systems, extent of reduction, and indicators of rock source. Metric data included measures of artifact weight, length, width, and thickness. For flakes, platform dimensions were also recorded. Indicators of manufacturing systems included evidence of laminar, disc/discoidal, and Levallois reduction techniques from dorsal and platform scar patterning. Extent of reduction was assessed using artifact size and percentage of cortex coverage, the latter being of particular interest in this case given potential sourcing of toolstone from local gravels. Indicators of rock source included rock type and cortex types, variance in the latter being taken to identify secondary (e.g., cobble) or primary (e.g., outcrop) sources.

An additional component of the analysis concerns evidence for postdepositional fluvial reworking on artifacts—important given the particular interest in site formation at Mwanganda’s Village. Artifact fluvial reworking was assessed mainly through edge rounding. Four classes of edge rounding were used: 0, no edge rounding; 1, rounding discernable by touch but not visually obvious; 2, visually obvious rounding that may obscure some artifact features; and 3, a rock that could still be identified as having been an artifact but which was now so heavily abraded as to be little more than a fluvial clast.

Although small, the sample of fauna from the Stone Age Institute was the largest available sample of fossil fauna from the site. It was examined for taxonomic and taphonomic attributes that could provide information about site formation at the “Elephant Butchery Site” itself, as no faunal remains were recovered from MEM-SAP’s Area I. Each bone surface was examined under a 10–40× binocular zoom microscope with bright incident light shining obliquely across the surface. In this way evidence of smoothing or polishing was identified that might indicate fluvial transport or abrasion. Each specimen was also examined for potential human modification (such as cut marks) or carnivore modification (such as tooth marks).

RESULTS

Geologic Evolution of Mwanganda’s Village

There are four primary sedimentary facies found at Mwanganda’s Village (Figure 5), which correspond with four phases of deposition (Figure 6). Complete descriptions of the sedimentology and pedology of the excavation units are provided in the Supporting Information Table S1.

The basal, nonarchaeological deposits are composed of weakly bedded silty clay within a well-developed paleosol with strong redoximorphic features (Unit 1). These deposits broadly correspond to descriptions of “Chiwondo Beds” or Qco1 made by Clark and Haynes’ (1970; see also Table I and Kaufulu, 1990), although there is no direct evidence to suggest that these actually are Pliocene lake deposits. Instead, Unit 1 is consistent with slackwater or wetland sediments and is a localized phenomenon rather than a regionally distributed bed.

The second depositional unit identified at Mwanganda’s Village is characterized by coarse sands and gravels with unconformities associated with cut-and-fill deposition separated by argillic and calcic paleosols. These deposits were interpreted by Clark and Haynes (1970) and Kaufulu (1990) as braided stream deposits, which eroded into parts of the underlying strata (Table I). Kaufulu (1990) inferred that gentle overbank sedimentation provided a riparian habitat in which prehistoric people butchered an elephant, with some minimal postdepositional movement of the remains. However, our analysis (based on differential Global Positioning System (dGPS) and OSL reconstruction of the site) shows that the site deposition was not as uniform as previously reported. Stream formation and overbank sedimentation was successive and involved multiple cut-and-fill episodes that punctuated periods of argillic carbonate soil (Btk) formation. “Soils on soils” (Bhkm) are identified in Area III, Unit 2 associated with episodic fluvial aggradation with different types of sediments (occurring in different environmental conditions) followed by a period of landform stability (Figure 5). Each channel formation episode eroded the upper portion of the calcic soil and cut at least one terrace into the site. Hiatuses in fluvial deposition likely occurred during arid conditions based on Stage 2 carbonate formation and the accretion of well-developed illuvial lenses of clays (argillans) within the soils. The period of time that it took to form these soils is uncertain, but was likely on the order of 100s to 1000s of years. U-Th analysis of three elephant tusk samples from these deposits returned apparent dates of $228.7 \pm 2.7$, $254.3 \pm 4.1$, and $282.3 \pm 2.4$ ka (Table III). We argue that 282 ka represents the minimum age of the fossilization of
the elephant remains (Price et al., 2013). An OSL sample analyzed from the correlated paleosol yielded an age of 23,613 ± 1900 years (UIC2858) suggesting that the elephant remains were entrained in a lag deposit, only coincidentally and are not functionally related to the archaeological artifacts found on the site.

The third depositional unit recorded at the site consists of poorly sorted coarse sands and gravels within a strongly redoximorphic environment, which fine upward to a massive, well-sorted fine sand capped by a very weak epipedon. This deposit can be correlated with the broader regional emplacement of Chitimwe Beds across northern Malawi. Chitimwe Beds are broadly defined as Pleistocene alluvial fan deposits that occurred concomitant to rotational faulting and uplift (Ring & Betzler, 1995). This likely catalyzed erosion of red sandstones within the

Table III  U-Th ages from elephant tusk at Mwanganda’s Village, Malawi

<table>
<thead>
<tr>
<th>Lab Sample Name</th>
<th>Date and Time</th>
<th>U (ppm) ± 2 seconds</th>
<th>232Th (ppb) ± 2 seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>JT-1 #13</td>
<td>September 7, 2010 at 21:21</td>
<td>2.8027 ± 0.0009</td>
<td>2.43 ± 0.025</td>
</tr>
<tr>
<td>JT-2 #14</td>
<td>September 7, 2010 at 22:39</td>
<td>2.6222 ± 0.0006</td>
<td>11.22 ± 0.034</td>
</tr>
<tr>
<td>JT-3 #15</td>
<td>September 7, 2010 at 23:18</td>
<td>5.2161 ± 0.0019</td>
<td>5.24 ± 0.024</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>JT-1 #13</td>
<td>228.7 ± 2.7</td>
<td>2.782 ± 0.0023</td>
</tr>
<tr>
<td>JT-2 #14</td>
<td>254.3 ± 4.1</td>
<td>1.1863 ± 0.0035</td>
</tr>
<tr>
<td>JT-3 #15</td>
<td>282.3 ± 2.4</td>
<td>1.3356 ± 0.0022</td>
</tr>
</tbody>
</table>
**Table IV**  Optically stimulated luminescence (OSL) ages on quartz grains from Karonga District, Malawi

<table>
<thead>
<tr>
<th>Sample</th>
<th>Laboratory Number</th>
<th>Aliquots</th>
<th>Equivalent Dose (Gray)</th>
<th>Overdispersion (%)</th>
<th>U (ppm)</th>
<th>Th (ppm)</th>
<th>K (%)</th>
<th>H₂O (%)</th>
<th>Cosmic Dose (mGray/yr)</th>
<th>Dose Rate (mGray/yr)</th>
<th>OSL Age (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S683</td>
<td>UIC2854</td>
<td>30/30</td>
<td>37.99 ± 2.31</td>
<td>25.2 ± 3.4</td>
<td>1.4 ± 0.1</td>
<td>9.4 ± 0.1</td>
<td>1.41 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>2.43 ± 0.12</td>
<td>15,610 ± 1280</td>
</tr>
<tr>
<td>S684</td>
<td>UIC2857</td>
<td>30/30</td>
<td>48.58 ± 2.50</td>
<td>19.7 ± 2.6</td>
<td>1.6 ± 0.1</td>
<td>9.6 ± 0.1</td>
<td>1.54 ± 0.02</td>
<td>20 ± 5</td>
<td>0.18 ± 0.02</td>
<td>2.20 ± 0.11</td>
<td>22,065 ± 1920</td>
</tr>
<tr>
<td>S685</td>
<td>UIC2856</td>
<td>30/30</td>
<td>82.70 ± 4.19</td>
<td>21.4 ± 2.8</td>
<td>1.8 ± 0.1</td>
<td>9.6 ± 0.1</td>
<td>1.39 ± 0.02</td>
<td>30 ± 5</td>
<td>0.17 ± 0.02</td>
<td>1.94 ± 0.10</td>
<td>42,550 ± 3550</td>
</tr>
<tr>
<td>S1865</td>
<td>UIC2858</td>
<td>28/40</td>
<td>59.09 ± 3.53</td>
<td>24.4 ± 3.9</td>
<td>1.5 ± 0.1</td>
<td>11.4 ± 0.1</td>
<td>1.51 ± 0.02</td>
<td>10 ± 3</td>
<td>0.15 ± 0.02</td>
<td>3.97 ± 0.20</td>
<td>23,610 ± 1900</td>
</tr>
<tr>
<td>LM2011–02</td>
<td>UIC3097</td>
<td>28/30</td>
<td>3.22 ± 0.20</td>
<td>27.1 ± 4.0</td>
<td>1.6 ± 0.1</td>
<td>13.2 ± 0.1</td>
<td>1.51 ± 0.02</td>
<td>10 ± 3</td>
<td>0.20 ± 0.02</td>
<td>2.69 ± 0.13</td>
<td>1195 ± 50</td>
</tr>
<tr>
<td>LM2011–03</td>
<td>UIC3095</td>
<td>26/30</td>
<td>15.80 ± 0.79</td>
<td>34.6 ± 4.8</td>
<td>1.1 ± 0.1</td>
<td>9.6 ± 0.1</td>
<td>1.39 ± 0.02</td>
<td>25 ± 5</td>
<td>0.20 ± 0.02</td>
<td>2.80 ± 0.14</td>
<td>2760 ± 230</td>
</tr>
<tr>
<td>LM2011–06</td>
<td>UIC3120</td>
<td>30/30</td>
<td>7.74 ± 0.47</td>
<td>27.3 ± 4.0</td>
<td>1.5 ± 0.1</td>
<td>8.8 ± 0.1</td>
<td>1.85 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>2.80 ± 0.14</td>
<td>7665 ± 550</td>
</tr>
<tr>
<td>LM2011–07</td>
<td>UIC3098</td>
<td>30/30</td>
<td>14.81 ± 0.61</td>
<td>11.0 ± 1.5</td>
<td>1.3 ± 0.1</td>
<td>7.6 ± 0.1</td>
<td>1.64 ± 0.02</td>
<td>7 ± 2</td>
<td>0.18 ± 0.02</td>
<td>2.42 ± 0.12</td>
<td>6130 ± 435</td>
</tr>
<tr>
<td>LM2011–07</td>
<td>UIC3098m²</td>
<td>30/30</td>
<td>14.09 ± 0.71</td>
<td></td>
<td>1.3 ± 0.1</td>
<td>7.6 ± 0.1</td>
<td>1.64 ± 0.02</td>
<td>7 ± 2</td>
<td>0.18 ± 0.02</td>
<td>2.42 ± 0.12</td>
<td>5820 ± 390</td>
</tr>
<tr>
<td>LM2011–08</td>
<td>UIC3119</td>
<td>24/30</td>
<td>4.89 ± 0.17</td>
<td>39.2 ± 5.7</td>
<td>1.4 ± 0.1</td>
<td>10.2 ± 0.1</td>
<td>1.51 ± 0.02</td>
<td>5 ± 2</td>
<td>0.21 ± 0.02</td>
<td>2.62 ± 0.13</td>
<td>1865 ± 120</td>
</tr>
<tr>
<td>LM2011–09</td>
<td>UIC3092</td>
<td>27/30</td>
<td>32.82 ± 2.84</td>
<td>37.7 ± 5.2</td>
<td>1.5 ± 0.1</td>
<td>13.0 ± 0.1</td>
<td>1.60 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>2.88 ± 0.14</td>
<td>11,380 ± 1165</td>
</tr>
<tr>
<td>LM2011–09</td>
<td>UIC3091</td>
<td>25/30</td>
<td>42.93 ± 2.52</td>
<td>23.7 ± 3.5</td>
<td>1.4 ± 0.1</td>
<td>11.0 ± 0.1</td>
<td>1.57 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>2.69 ± 0.13</td>
<td>15,955 ± 1285</td>
</tr>
<tr>
<td>LM2011–10</td>
<td>UIC3091m²</td>
<td>24/30</td>
<td>38.30 ± 3.20</td>
<td></td>
<td>1.4 ± 0.1</td>
<td>11.0 ± 0.1</td>
<td>1.57 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>2.69 ± 0.13</td>
<td>14,245 ± 820</td>
</tr>
<tr>
<td>LM2011–11</td>
<td>UIC3134</td>
<td>29/30</td>
<td>0.31 ± 0.02</td>
<td>59.0 ± 7.8</td>
<td>3.6 ± 0.1</td>
<td>21.4 ± 0.1</td>
<td>2.30 ± 0.02</td>
<td>5 ± 2</td>
<td>0.20 ± 0.02</td>
<td>4.59 ± 0.22</td>
<td>65 ± 5</td>
</tr>
</tbody>
</table>

*One hundred fifty to 250 μm quartz fraction (2 mm plate area) analyzed under blue-light excitation (470 ± 20 nm) by single aliquot regeneration protocol (Murray & Wintle, 2003).*

*Values reflect precision beyond instrumental errors; values of ≤ 20% indicate low spread in equivalent dose values with a unimodal distribution.*

*U, Th, and K₂O content analyzed by inductively coupled plasma mass spectrometry analyzed by Activation Laboratory LTD, Ontario, Canada.*

*From Prescott and Hutton (1994).*

*Ages calculated using the central age model of Galbraith et al. (1999).*

*Ages calculated using the minimum age model of Galbraith et al. (1999) because of elevated overdispersion values (> 20%).

*Equivalent dose determined by multiple aliquot regeneration protocols (Jain et al., 2003).*
Dinosaur Beds, which exist as remnants in the plateau foothills ca. 25 km west of the project area. Deposition of the Chitimwe Beds was not a single event, but rather a series of events with different geologic sources, which is attested by the extremely variable nature of the sediments across the region. At Mwanganda’s Village, basal Chitimwe Bed emplacement occurred ca. 42,550 ± 3550 years (UIC2856; Table IV), which is statistically coeval to the OSL age assayed from Unit 2 from Area III. In Area I of the site, the Chitimwe Beds unconformably overlie depositional Unit 1 and appear to have buried the paleosols in a relatively undisturbed state. MnO and Fe₂O₃ staining of the sediments in the lower 25 cm of the unit is likely a function of the creation of an aquatard in the argillic horizon that subaerially weathered the sediments in situ. An OSL age assayed from GT9 constrains alluvial fan deposition as ceasing after 2760 ± 230 years (UIC3120).

Following the deposition of the youngest sediments at the site, a final geomorphic phase occurred marked by a period of fluvial incision and terrace formation. Four terraces were documented within Mwanganda’s Village and the northwestern edge of the project area was defined as Chirambiru Creek (Figure 3). Thin lenses of alluvium were deposited as the stream downcut. The incision event has exposed paleosols across the sites, and the water table dropped significantly from the periods when redoximorphic features formed. The Area I excavation by MEMSAP was located on Terrace 3 and Areas II and III (and the “Elephant Butchery Site”) were located on Terrace 2.

STONE ARTIFACT ANALYSIS

A sample of 2363 flaked stone artifacts were analyzed from the three excavation areas at Mwanganda’s Village. The assemblage analyzed to date from 2 m² (of the total 24 m²) at Area III is small and heavily reworked, with half of the 12 artifacts showing class 2 edge rounding (the other half show no rounding). Of the flakes with intact platforms, five have dihedral or faceted platforms suggestive of MSA affinity. Two flakes exhibited centripetal
dorsal scar patterning. None of the artifacts in the assemblage could be classified as characteristic Sangoan implements, such as picks, core axes, or core scrapers (Clark & Haynes, 1970; McBrearty, 1988; Tryon & McBrearty, 2002); bifacial tools were generally absent from the Mwanganda’s Village assemblages.

Area II produced a considerably larger and more diverse assemblage \((n = 278)\). The assemblage includes flakes \((78.1\%, n = 224)\), retouched flakes \((2.2\%, n = 6)\), and cores \((2.9\%, n = 8)\), along with other flaking debris. Slightly over half \((50.7\%)\) of the Area II artifacts exhibited cortex, with cobble cortex being the only type present, consistent with sourcing of toolstone from local gravels. As with Area III, the evidence from edge rounding suggests considerable fluvial reworking in the assemblage. Only \(\sim 40\%\) of the 278 artifacts show no evidence of abrasion, with class 1 \((21.6\%)\), class 2 \((21.2\%)\), and class 3 \((14.5\%)\) edge rounding all well represented.

Quartzite is the dominant material within the total assemblage \((54.7\%)\) followed by quartz \((39.2\%)\) and crystal quartz \((5.8\%)\). With the quartz values combined, these numbers are very similar to those in the Clark and Haynes sample. The frequency of edge rounding does not discriminate the two main rock types. Unrounded pieces accounted for 38.8% of quartzite artifacts and 42.2% of quartz artifacts. Heavily rounded pieces \((\text{classes 2 and 3})\) accounted for 40.1% and 33.9% of quartzite and quartz pieces, respectively. Quartz crystal artifacts have considerably lower rates of edge rounding, with 68.8% unrounded.

Flaking patterns weakly attest to the use of discoidal and Levallois methods at the site \((\text{Figure 7})\), though most flakes appear to be at a relatively early stage of reduction as reflected in the high proportion of cortex noted above. There was no evidence of laminar working in the examined samples. However, there are clear differences in the proportions of platform types in our assemblage compared to the Clark and Haynes sample. Of the 49 complete flakes we recovered from Area II, 24.5% \((n = 12)\) had cortical platforms, 34.7% \((n = 17)\) had simple platforms \((\text{e.g., single scar, no cortex})\), and 10.2% \((n = 5)\) had multiple facets. In the Clark and Haynes \((1970)\) sample of 80 flakes, 59% had cortical platforms, 32.4% had simple platforms \((\text{subsuming both plain and single faceted in the classification published in Clark & Haynes, 1970})\), and none exhibited multiple facets.

The small core assemblage includes two pieces with scar removals to alternating surfaces around a portion of a worked margin. These may have been early stages in the reduction of discoidal cores though notably in both cases the selected packages were small quartz crystal pebbles. Two other more typically discoidal cores also occur and these show some hierarchical arrangement of volumes with scarring patterns unevenly distributed between surfaces. Cortex is in both cases restricted to a single surface, though in one instance flakes were removed from both surfaces while in the other the cortical surface was entirely unworked \((\text{Figure 7})\). This latter piece may conceivably have been classed by Clark and Haynes \((1970:\text{Figure 28})\) as a core axe. The retouched flakes in the assemblage show only minor and generally unstructured marginal flaking: no morphologically regular types were recorded.

The assemblage from Area I is considerably different in composition and degree of fluvial reworking from the Area II and Area III assemblages. The analyzed sample comprises 2073 pieces, and shows similar proportions of quartzite \((59.1\%)\), quartz \((32.6\%)\), and quartz crystal \((7.2\%)\) to Area II. Unlike Areas II and III, however, rounding only occurs on 12.8% of pieces, and heavy rounding \((\text{classes 2 and 3})\) on only 4.2%. That the assemblage is not substantially reworked is supported by conjoin analysis; 61 conjoin sets were identified comprising 161 artifacts, which refit to at least one other artifact or fragment thereof.

The artifacts recovered from Area I include flakes \((72\%)\), retouched flakes \((2\%)\), and cores \((4.5\%)\), as well as other flaking debris. Formal tools are extremely rare, a single scraper and a single denticulate being the only types identified. Cortex is common, occurring on 53.9% of pieces. This value is as high as 73% if restricted to complete flakes. With a single exception, cortex was of cobble/pebble form. Again, it seems probable that the materials for artifact manufacture were sourced from locally available gravels.

Like Areas II and III, the Area I assemblage included MSA markers such as discoidal and Levallois flakes and cores \((\text{Figure 7})\). Though fairly large \((200–900\, \text{g})\) discoidal cores are present in the sample, the cores from Area I were generally quite small. The smallest core in the assemblage had a weight of 2.3 g. The Area I sample included 16 cores characterized by the centripetal reduction of a single surface of a small crystal quartz pebble from a cortical platform \((\text{Figure 7})\). Though this was the single most common core type at Area I, it was not observed in the other assemblages. Its abundance at Area I may account for the elevated proportions of cortical platforms in the flake assemblage, which at 46.5% \((n = 180, \text{complete flakes only})\) is roughly double the proportion at Area II. The proportion of simple platforms \((18.6\%)\) at Area I is approximately half that at Area II.

Bipolar and laminar reduction are also represented at Area I but neither constitutes a significant assemblage component. In spite of the small size of the cores, only two \((2.1\%)\) were worked using bipolar techniques. Indeed, the small size of cores is likely a reflection of the
size of the pebbles selected. Nine of the 10 smallest cores in the sample had cortex coverage of 40% or greater, and more than 92% of all complete cores retained some cortex.

Clark and Haynes (1970: 394) report that 99% of the stone tools from their Area 1 excavation were unabraded, although they also report, “Signs of utilization are very extensive in the form of minute scarring of the edges, crushing, and rubbing” (Clark & Haynes, 1970: 395). Macroscopic signs of tool use were very infrequently observed in the MEMSAP sample. Edge damage (percussive damage as opposed to edge rounding and excluding excavation damage) was noted in 13 cases, all of which occurred in the Area I sample. There are, consequently, few consistencies between our samples from Areas I, II, and III and those recovered from Clark and Haynes’s (1970) “Elephant Butchery Site” (see also Clark et al., 1970). The only clearly in situ occurrence at Area I was not recovered from the same terrace as the “Elephant Butchery Site” and has ages and a composition that mark it as late MSA, not Sangoan. Area III may have contained more robust evidence of Sangoan tools given a larger sample. However, this would not explain the high rate of fluvial reworking in our recovered assemblage. The Area II assemblage exhibits a few potentially Sangoan tools, however the high fluvial reworking rates and the low proportion of cortical platforms render this assemblage an unlikely match for the Clark and Haynes sample.

**FAUNAL ANALYSIS**

Reanalysis of the fossils from Clark and Haynes’ (1970) excavations hosted at Stone Age Institute identified one fragment to be a turtle carapace fragment from the family Pelomedusidae and another was a partial catfish frontal from the genus *Clarias*. Most of the remaining fragments come from a very large animal, suggesting they were part of the original elephant skeleton reported from the site (Clark & Haynes, 1970). Of the 156 specimens in the total collection, 108 (or 69.2%) displayed some evidence of smoothing. The fluvial context of the sediments makes waterborne abrasive particles the most parsimonious
candidates for the cause of the smoothing. Of the fragments remaining at the Institute only 11/135 (8.1%) were less than 2 cm in the maximum dimension, which is in general agreement with the sizes of the stone artifacts and also suggests fluvial size winnowing (Schick, 1992; Panté & Blumenschine, 2010; Sitzia et al., 2012).

In spite of extensive smoothing, many of the bones still preserve clear evidence of carnivore activity (and no evidence of hominin butchery). A total of 13% (n = 13) of the fossils from Clark’s Area 1 and 14.7% (n = 5) from Clark’s Area 2 preserve tooth marks. Most have morphology that involves deep punctures rather than furrows and scores, and several are ovate in shape. In some cases the pits are bisected, possibly produced by the bicarinated teeth of crocodiles rather than mammalian carnivores (Baquedano, Domínguez-Rodrigo, & Musiba, 2012; Njau & Blumenschine, 2012).

**DISCUSSION**

**Archaeological Habitation of Mwanganda’s Village**

Archaeological occupation of Mwanganda’s Village was punctuated, but repeated during the Pleistocene and Holocene. The aggradational sediment sequence from MEMSAP Areas II and III of the site contain MSA artifacts both in situ and in secondary context, along with the remains of turtle, catfish, and elephant faunal remains with a minimum constraining age of fossilization of 282.3 ± 2.4 ka (Table III). However, these remains are entrained in sediments that were last exposed to light 23,613 ± 1900 years. Thus, the archaeological and geologic evidence indicate that the area from which the elephant was derived was a depositional context more closely resembling a channel-lag deposit rather than a channel-fill deposit (sense Behrensmeyer, 1988). The presence of a partial elephant skeleton with few other identified vertebrates in association suggests some degree of spatial integrity, but the amount of abrasion, presence of aquatic fauna in nearby Area 2 (Clark & Haynes, 1970; Clark et al., 1970), modification suggestive of crocodile activity, and the fragment size distribution indicates that the fossil assemblage contains allochthonous elements transported by water and not butchered by people. Thus, there is no current evidence to support the original interpretation of the site as a Sangoan elephant butchery site (Clark & Haynes, 1970; Clark et al., 1970; Kafulfu, 1990).

A later Pleistocene occupation on T-3 of the site is interpreted as having intact, in situ artifactual deposits and a range of lithic reduction strategies were undertaken within a riparian setting. Diagnostic MSA artifacts are present at MEMSAP Area I from 42,550 ± 3550 years (UIC2856) and are stratified through to 22,065 ± 1920 years (UIC2857) with a resumption in occupations occurring by the Iron Working period (>2760 ± 230 years, UIC3120) and continuing through the present day (Table IV). The relatively late age for MSA technology at Mwanganda’s Village is consistent with data from most sites in southern and eastern Africa but differs from recent arguments for an MSA/LSA transition before 49 ka at Mumba in eastern Africa (Eren, Diez-Martín, & Domínguez-Rodrigo, 2013). That said, the late MSA at Mwanganda’s Village appears compositionally different from comparably aged assemblages on the other side of Lake Malawi at Mvumu and Ngalue Cave (Mercader et al., 2012). Those assemblages are overwhelmingly quartz dominant (~95% at Mvumu vs. ~40% at Mwanganda’s Village Area I) and contain numerous unifacially and bifacially worked flake tools such as scrapers and awls that are effectively absent at Area I. Mercader et al. (2012) report that retouch occurs on 10% of the Mvumu assemblage; at Area I the value is 1.8%. More strikingly, formal tools account for 11% of the Mvumu assemblage whereas the value is two orders of magnitude lower at >0.1% in the Mwanganda’s Village Area I sample. While classificatory differences might conceivably drive some portion of the typological variability it seems unlikely to account for all of it and would not explain the discrepancy in retouched flake proportions.

Similarly the most common mode of reduction at Area I, which features unifacial centripetal reduction of small crystal quartz pebbles, is not described in the published samples from Niassa (Mercader et al., 2012). While there is no doubt that the size of the quartz crystal pebbles selected influenced the reduction system used, raw materials of sizes up to and exceeding 10 cm diameter were also available in the gravels at Area I and adjacent drainage ways. Therefore, preferential selection of small quartz crystal pebbles was a choice not dictated by geological constraints. Overall, while the Mozambican assemblages and those described here share similarities—notably the persistence of MSA technologies and the paucity of bipolar reduction—the differences at this stage seem considerable despite the fact that the radiometric ages for the occupations of the sites overlap at 1–σ (Mercader et al., 2012).

All phases of occupation at Mwanganda’s Village include artifacts that are likely to have been discarded either at or near the point of manufacture. This inference is based on the presence of local cobble/pebble beds and the high prevalence of cortex in assemblages recovered from our excavation areas. To that extent the richness of the area with respect to archaeological material is likely in part a reflection of persistent if perhaps opportunistic use of locally abundant sources of flakeable rock in the
form of gravel beds. These beds would have produced a reliable source of toolstone that would have acted to minimize pressures on curation of transported artifact material, particularly for foragers moving along or in proximity to small watercourses as a means of exploiting riparian resources. That these cobble sources are widely distributed in the Karonga area may go some way to explaining the surface and subsurface richness of the region’s Pleistocene archaeological landscape.

A surface collection of Kisii pottery indicates habitation in historical times. This occupation of agriculturalists appears to have been concentrated on T-3, and postdated the onset of fluvial incision. It is impossible to estimate the distance of the water source to the historical occupation, but pot irrigation and water extraction for consumption would have been manage able even from its present distance from the locus of historical residence (~150 m). The ability to store water in vessels and cultivate cassava (*Manihot esculenta*) for off-season consumption is a cultural practice that extends to the present day. Mwanganda’s Village is currently settled and under cultivation by Ngonde and Tumbuka-speaking people with deep cultural connections to the land.

**Environmental Context of Occupations at Mwanganda’s Village**

Basal wetland and soil formation detected from Unit 1 of Areas I and III do not conform *sensu stricto* to Pliocene Chiwondo Beds as described by Betzler and Ring (1995), but appear to be part of a broader pluvial period preceding Chitimwe Fan activation. There are no archaeological artifacts entrained in these sediments, nor has OSL dating been successful in determining an age due to saturation of luminescence traps within the assayed quartz minerals. This phase of site deposition was likely occurring prior to the activation of fault-induced and/or climatically induced alluvial fans, and the landscape was more geologically stable and more topographically regular than during the Late Pleistocene (Ebing er et al., 1989).

There is an erosional unconformity at the site, which compromises the archaeological record until ca. 40 ka, when the emplacement of Chitimwe alluvial fan deposits occur within a landscape of braided streams (Kaufulu, 1990). Initial formation of Chitimwe Beds at Mwanganda’s Village are in close chronological agreement with the formation of depositionally analogous Luchamange Beds on the east side of the basin (Mercader et al., 2012). Mwanganda’s Village hosts high-energy channel deposits with 2–5 cm rounded to subrounded cobbles as well as lower energy channel deposits composed of sandy clay loam. The diatom assemblage from the Lake Malawi sediment core suggests a slight regression in lake levels between 47 and 30 ka (see also Finney et al., 1996; Scholz et al., 2011; Stone, Westover, & Cohen, 2011). There is a transition to deeper lake conditions (>400 m deep) between 31 and 16 ka with great variability in lake levels ca. 17 ka (Scholz et al., 2011; Stone, Westover, & Cohen, 2011). The in situ archaeological occupations documented at Mwanganda’s Village begin at Area 1 ~40–42 ka with the deposition of a sandy facies that contains minimally reworked MSA artifacts that retain at least two instances of flake-to-flake refitting. A fluvial layer truncates this facies and contains heavily rounded artifacts that attest to a separate occupation elsewhere in the catchment that is unlikely be contemporaneous with the material in the sandy facies. This is overlain by an in situ late, and possibly terminal, MSA assemblage in fine-grained sediments that date to ~22 ka (Figure 5: Area I). The majority of artifacts were recovered from this layer, including at least 54 instances of knapping refits (e.g., flake-to-flake or flake-to-core). Thus, all lithic debris is located within or on the margins of fluvial deposits separated by erosional unconformities. Deposition is discontinuous with numerous cut-and-fill episodes documented across the broader site as well as Area I.

Between 22 and 7 ka, alluvial fan deposition intensifies on the site, while human activity is poorly represented. There are fluvial deposits identified on T-3 (514 masl) at 11 ka, while fluvial deposits also occur on T-1 (507 masl) at 7 ka. A low stand in lake levels centered around the Last Glacial Maximum (LGM, ca. 22–17 ka) inferred from diatoms (Gasse, Barker, & Johnson, 2002) is supported by newer data derived from the 2005 Lake Malawi Scientific Drilling Project, indicating that lake levels fell by much as 100 m of its preceding and succeeding 700 m deep level (Scholz et al., 2011; Stone, Westover, & Cohen, 2011). Beuning et al. (2011) argue that grasses and afro montane vegetation are reflected in the terrigenous pollen assemblages recovered from the drill core during the LGM, which is concurrent with drier winters (see also Ivory et al., 2012). On the other hand, phytolith data from the east-central portion of the basin suggest that the lowlands were wooded including high water-consuming panicoids and bam busoids (Mercader et al., 2013). These data suggest a mosaic landscape of woodlands and grasslands, and hominins were likely focused on exploiting resources from within the catchment regions where the biodiversity potential would have been at its highest (Mercader et al., 2013).

Site level reconstructions of the paleohydrology at Mwanganda’s Village suggests that the site was terraced with meandering streams descending into the paleo-Rukuru River catchment between 22 and 7 ka (see also Kaufulu, 1990). Until at least 11 ka, the landform was generally aggrading within active alluvial fan deposition,
but there are carbonate-rich paleosols that developed during periods of landform stability. After 11 ka, there appears to have been significant fluvial downcutting concurrent to continuing Chitimwe fan activity in the southeast aspect of the site.

During the late Holocene, the rate of Chitimwe fan deposition slowed significantly, and there is a laterite soil that developed on the site. Colonization of the site by iron working farmers is recorded from the northeast portion of the site, and it is believed that significant erosion of the site concurrent to the introduction of increasingly intensive and modern agricultural techniques has impacted the integrity of the MSA archaeological occupations. However, the results show a continuation of an ancient practice of riparian resource exploitation even into modern times. Although the means of exploitation are different and the intensity of settlement is significantly higher than during the MSA and later phases, the motivation for selecting this area appears to have the common denominator of seeking a predictable source of water and possibly readily available lithic materials.

**Amplifying?**

During the Late Pleistocene, Lake Malawi appears to have been an attractive environmental feature possibly serving to connect southern and eastern Africa within highly variable regional climatic conditions (Beuning et al., 2011; Mercader et al., 2013) and heterogeneously distributed human (Salas et al., 2002), animal (Cohen et al., 2007), and plant (Cowling et al., 2008) population centers across the African continent. Correlations between tropical oceanic warming and polar glacial isotopic data suggest that the latitudinal extents of the intertropical convergence zone (ITCZ), which governs the distribution of rainfall on the African continent, is generally in sync with high-latitude glacial activity, albeit in lag time (Bard, Rostek, & Sonzogni, 1997; Brown et al., 2007; Schefuß et al., 2011). The ITCZ is the point of convergence of northeasterly and southeasterly monsoons, bringing tropical rain where it is located, while adjoining areas receive little or no moisture (Waliser & Gautier, 1993). The ITCZ is believed to have displaced significantly southward during the LGM and Younger Dryas (12.8–11.5 ka), which had profound effects on the distribution of rainfall and vegetation biomes across the African continent (Adams & Faure, 1997; Garcin et al., 2007; Tierney & Russell, 2007; Gasse et al., 2008; Tierney & deMenocal, 2013). Although Lake Malawi desiccated severely during the Middle Pleistocene, lake levels (reflecting rainfall within the catchment) remained relatively high (≥600 m) during the Late Pleistocene (Scholz et al., 2011) compared to proxy data in southeastern Africa, the Tanzanianika Basin, Congo Basin, and East African Rift Valley lakes (Opperman & Heydenrych, 1990; Maley & Brenac, 1998; Gibert et al., 2002; Johnson et al., 2002; Schefuß, Schouten, & Schneider, 2005; Gasse et al., 2008; Tierney et al., 2008). Thus, as many other landscapes in southern and eastern Africa were becoming increasingly xeric, mosaic woodland environments favored by MSA foragers remained in the Malawi Basin (Mercader et al., 2013) and in southwestern Africa (Gasse, 2000; Gasse et al., 2008).

Later MSA technology found at the site between ~42 and 22 ka would have occurred during a period of relatively stable lake levels and local soil formation, when different MSA technocomplexes are documented from the Ngalue Cave and Niassa sites, east side of Lake Malawi (Mercader & Fogelman, 2006; Mercader, Bennett, & Raja, 2008; Mercader et al., 2009, 2012, 2013). The limited data suggest that intermediate-high lake levels did not foster regional interactions (contra Trauth et al., 2010). If toolkits can be interpreted as culturally mediated responses to ecological conditions (Boyd & Richerson, 1985: 290), the available data here suggest a focus on localized exploitation of resources without a tremendous degree of sharing technology across the basin. We recognize that there is a potential lag in occupation between the sites on the east side of the lake and that of Mwanganda’s Village on the basis of inherent imprecision of the dating methods used. However, there is a focus on localized raw material exploitation at the two locales, the lithic tool production and core reduction systems employed appear considerably different, and the temporal overlap of ages overlaps within 1σ; therefore, we propose that late MSA technological systems in the Malawi Basin were probably geographically restricted and the degree of interregional technology sharing concomitantly low. The persistence of MSA foragers in portions of the Lake Malawi Basin in spite of expanding LSA populations elsewhere across continental Africa may partially explain apparent restricted foraging ranges. Additionally, the extreme topographic variability of the Rift Valley created a resource mosaic during this critical phase of human evolution, and MSA populations seem focused on exploiting local riparian resources.

**CONCLUSION**

The site of Mwanganda’s Village in northern Malawi demonstrates recurrent hominin occupation of riparian corridors dating from the Late Pleistocene through the Holocene. MSA archaeological assemblages (~42–22 ka) were deposited during periods of relatively high lake levels in the Malawi Basin (Scholz et al., 2011), which
contrasts with relatively dry conditions throughout much of southern Africa (Maley & Brenac, 1998; Schefuß, Schouten, & Schneider, 2005; Gasse et al., 2008; Tierney et al., 2008). Use of riparian corridors by hunter-gatherers is unsurprising (Lourandos, 1997; Stafford, Richards, & Anslinger, 2000; Jayaswal, 2002), and comes during a period of active alluvial fan deposition across the western (Ring & Betzler, 1995) and eastern (Mercader et al., 2012) sides of Lake Malawi catalyzed by tectonic activity, more pronounced intra-annual wet-dry cycles associated with the movement of the ITCZ (see also Ivory et al., 2012). Within this environment, fluvial catchments represented resource deposits that could be accessed periodically as part of a residentially mobile foraging strategy.

Reanalysis of Mwanganda’s Village has yielded a different set of interpretations regarding the timing and nature of the archaeological deposits (cf., Clark & Haynes, 1970; Clark et al., 1970; Kafulu, 1990). Presently, there is little evidence to support a significant Sangoan occupation of the site. Artifacts recovered from a paleosol interpreted to be the same as that from the Clark Area 1 excavation are highly abraded, deposits are consistent with a channel lag, and the fauna from the original assemblage suggests the same. The minimum constraining U-Th age from elephant tusk assayed from the site is 282 ka, demonstrating the antiquity of the fossils relative to the dated human occupation of the site.

However, repeated use of riparian channels ~42 ka and until some point after 22 ka coincides with other late MSA occupations known elsewhere from the Malawi Basin (Mercader & Fogelman, 2006; Mercader, Bennett, & Raja, 2008; Mercader et al., 2009, 2012, 2013), suggesting that hominins were inhabiting predictably resource-rich areas as climates changed toward colder and drier conditions across Africa. The preliminary evidence shows regionalism in the MSA toolkits utilized between the east and west sides of Lake Malawi, suggesting fragmentation and lack of interaction between populations across the basin. Although more dated archaeological horizons are needed to test these hypotheses, the density of MSA archaeological deposits across northern Malawi currently being documented by the MEMSAP team will yield the data needed to understand the complex connections between landscape change, resource use, and human techno-behavioral evolution.

We thank our collaborators at the Malawi Ministry of Tourism, Wildlife and Culture for their assistance and permission in facilitating this research. Fieldwork and analysis were funded by National Geographic-Waitt Foundation grant W115-10 (JT), Australian Research Council Discovery Project DP110101305 (JT), Korean Research Foundation Global Research Network Grant 2012032907 (DW), the UQ Field School, and a generous donation from Thomas Jones. An outstanding team of local crew worked on the Mwanganda excavations, with special thanks owed to Liton Adhikari and Gervasio Ngumbira. The 2011 and 2012 excavations were partially conducted by students from the University of Queensland and the Catholic University of Malawi. Julia Maskell, Jessica McNeil, Tierney Lu, Casey Frewen-Lord, and Kristina Lee devoted many hours to refitting artifacts from Area I. Scott Robinson and Marina Bravo Foster were instrumental in obtaining the dGPS data of the site. Kathy Schick and Nicholas Toth facilitated JT’s access to the assemblages from Malawi curated at the Stone Age Institute, as well as permission to sample the three tusk fragments for U-Th analysis. Kathy Stewart identified the catfish fragments and Arun Banerjee and Jürg Tuckermann provided the identification of the three fossil samples from the Stone Age Institute as being derived from fossil elephant ivory. U-Th dating of the elephant tusk was supported by Australian Research Council LIEF grant LE0989067 to JZ and Discovery grant DP0881279 to GP. AC thanks the Lake Malawi Drilling Project, NSF-EAR-0602404, DOESECC Inc., and LacCore for support. Two anonymous reviewers and comments from Jamie Woodward were of invaluable assistance in producing this manuscript and we offer our heartfelt appreciation for their time and insights.

REFERENCES


