Renewed investigations into the Middle Stone Age of northern Malawi

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ABSTRACT

J. Desmond Clark and his colleagues were first to investigate the rich Middle Stone Age (MSA – from ca. 285 to 30,000 years ago) deposits in the Karonga District of northern Malawi in the 1960s. This work demonstrated the enormous potential of the area to inform about Middle to Late Pleistocene hominin lifeways, but further studies were hindered by difficulties in dating the sites and understanding their fine-scale depositional and paleoenvironmental contexts. With the advances that have been made in the fields of geoarchaeology, lithic analysis, palaeoenvironments, and geochronology over the last fifty years, the time is ideal to renew these investigations. Recent survey and excavation in Karonga, Malawi show that MSA lithic artifacts are preserved in a variety of stratified sedimentary contexts and that they exhibit limited weathering or other indications of post-depositional transport. These deposits are in close proximity to the high-resolution paleoenvironmental records derived from sediments at the bottom of nearby Lake Malawi, which provide context for the human behavior recorded by the artifacts. Results of excavations at one of these stratified sites – the Airport Site – are detailed here. This provides a renewed example of the site formation and behavioral data available in the region.

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1. Introduction

Research on the origins and dispersal of anatomically and behaviorally modern humans has taken a prominent role in multidisciplinary Quaternary studies over the last decade. Genetic work demonstrates that the diversity of modern populations can all be traced to a single point of origin in Africa as recently as 200 ka (Relethford, 2008). Physical anthropologists confirm that modern skeletal anatomy was also established by this time (White et al., 2003; Pearson, 2008). Along with these biological questions, there has been much debate amongst archaeologists regarding the specifics of when, where, and how the transition to behavioral modernity occurred (Henshilwood and Marean, 2003; Mellars, 2007; d'Errico and Stringer, 2011). The sum body of research

indicates that the time period known in Africa as the Middle Stone Age (MSA; from ca. 285 to 30 ka) witnessed important changes in both biology and behavior that led to eventual global colonization by *Homo sapiens*. Investigations of the pressures on and dynamics of these MSA populations are therefore central to understanding these larger questions of our origins.

Two major unresolved problems within MSA research center on the timing of the processes that drove behavioral change. First, it is unclear if important changes took place over a short or a long chronology, and testing hypotheses of the timing of behavioral change is strongly limited by the available empirical record (Klein, 2000; McBrearty and Brooks, 2000; Henshilwood and Marean, 2003; Klein, 2008). Second, across Africa there are only a few detailed reports on MSA response to climatic change. Although technological change and demographic movements can be recorded in the lithic artifact record, high-resolution paleoclimatic datasets that cover the requisite time span are rare.

The Chitimwe Beds of northern Malawi preserve a rich MSA record that is within 45 km of one of the longest and most detailed terrestrial paleoclimatic lake core records available in Africa (Cohen et al., 2007; Scholz et al., 2007, 2011). This record has currently been

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reported in detail back to ca. 145 ka and early age estimates from the long 1B core several km further to the south indicate that an additional record back to ca. 650 ka will be available (McHargue et al., 2011). In the Chitimwe Beds, abundant MSA artifacts are entrained within well-developed paleosols and fluvial facies which provided sources for lithic raw materials. Many of these sites are stratified, have good spatial integrity, and attest to the exploitation of river terrace cobbles as sources of lithic raw materials. Several sites within the Chitimwe Beds were investigated over the course of a six-week field season in Karonga in 2010. The Airport Site (APS), reported here, was the main focus of excavation and provides a renewed example of the site formation and behavioral information available in these deposits (Fig. 1). Reporting sites such as the APS is the first step in a larger project that will embed such localities in their larger landscape and palaeoenvironmental contexts.

2. Regional geological and geomorphological setting

The bedrock geology of the project area consists of Neogene red sandstones, marls and clays known as the Dinosaur Beds (or Lupata Group) resting unconformably above the shale- and sandstone-dominated Mesozoic Karoo Supergroup (Betzler and Ring, 1995; Ring and Betzler, 1995; Catuneanu et al., 2005; Schlüter, 2006). The region is subject to extreme tectonic uplift, which has faulted and tilted the landforms subjecting them to erosion and colluvial sediment translocation (Ring and Betzler, 1995). Littoral, lacustrine and deltaic fluvial processes are defined throughout the Neogene sequence (Betzler and Ring, 1995). Pleistocene and Holocene alluvium has incised and overlies the substrata (Haynes, 1970; Kaufulu, 1990). Extensive paleosols and laterite kandic horizons have developed within this environment, but are variably eroded due to the high topographic relief of the region.

Exposures of the Pleistocene Chitimwe Beds are variable through an overburden of Holocene alluvium in the Karonga District. These deposits unconformably overlie the Pliocene Chiwondo Beds, which have been dated by biostratigraphy to ca. 4.0–2.4 Ma (Schrenk et al., 2002). The Chitimwe–Chiwondo contact has an estimated age of ca. 300 ka based on a single Rb/Sr

age assayed from carbonate deposits at the lower boundary of the Chitimwe Bed at the site of Mwanganda's Village (Kaufulu, 1990; Clark, 1995). Surficial deposits within the Chitimwe Beds are comprised of stratified alluvium ranging from fine sands to large cobbles, indicating variable degrees of erosional and/or depositional energy across the paleolandscape. This suggests that the Chitimwe Beds have variably incised into the softer underlying Chiwondo Beds, and some strata within the Chitimwe Beds are also buried under colluvium originating from tectonically uplifted terraces (Betzler and Ring, 1995).

The Chitimwe Beds are restricted to a strip of land about 15 km (from east to west) by 70 km (from north to south) that runs parallel to the long axis of Lake Malawi (Fig. 1). They are provisionally classified as petroferic kandistox Oxisols (Soil Survey Staff, 1999), predominately composed of coarse-grained deposits (sands and cobbles). They exhibit horizontal and vertical variability in clast size, and some occurrences include discontinuous iron pans. Variability in the sediment matrix of the Chitimwe Beds has been defined by Betzler and Ring (1995) as a function of the complex surficial processes that dominated the Pleistocene landscape in this part of Malawi. Deposits bearing MSA artifact assemblages have not been directly dated in this region, but the MSA has been dated to ca. 285–30 ka in eastern Africa (Tryon and McBrearty, 2006) and its technology is well-represented within the Chitimwe Beds (Clark, 1966; Clark et al., 1966, 1970; Clark and Haynes, 1970).

Near the Chaminade Secondary School at least 6 km² of Chitimwe Beds are exposed. Initial investigations in the 1960s (Clark, 1966; Clark et al., 1970) revealed *in situ* sediments with stratified unweathered MSA lithic and ochre materials in low-energy depositional facies. These were recovered from large test excavations extending upslope, which produced nearly 25,000 lithic artifacts from ca. 200 m³ of stratified deposit. Clark (1968) reported later that sealed MSA activity areas had been excavated where reconstruction of the entire spectrum of lithic reduction sequences was possible. Although this statement is also made in later publications (Clark, 1995, 2001), a formal refitting study was never published. The modern landscape at Chaminade is comprised of dozens of tectonically uplifted, high relief hills incised by ephemeral streams.

Fig. 1. Overview of the study area in Karonga, Malawi (SRTM data). The artifact-bearing Chitimwe Beds are restricted to the light, low-lying area adjacent to the western lakeshore.

The slopes of the hills are covered in Chitimwe sands and gravels, and the tops of the hills are frequently capped by erosion-resistant iron pans.

3. Regional paleoenvironmental setting

A high-resolution record of climate change based on cores from Lake Malawi has recently shown that several periods of ‘mega-drought’ occurred in central Africa between ca. 135–75 ka, during which time water volumes in Lake Malawi were reduced by as much as 95% (Cohen et al., 2007; Scholz et al., 2007, 2011). Beuning et al. (2011) report two severe arid episodes occurring between 135 and 127 ka and again from 115 to 95 ka from terrigenous pollen assayed from a lake core drilled near the center of Lake Malawi. In the earlier phases of these dry spells (prior to 105 ka), grasslands and *Podocarpus* arboreal taxa dominate the landscape, whereas total pollen accumulation rates (PAR) between 105 and 95 ka suggest sparsely vegetated, desert-like conditions (Beuning et al., 2011). This variability in the pollen record is concurrent to saline and alkaline conditions within the lake indicating lake levels as low as 125 m in depth (Cohen et al., 2007; Scholz et al., 2007). After 60 ka, lake levels stabilized to their present ~700 m deep bathymetric highs, and the amplitude of vegetation succession is relatively attenuated compared to the early Pleistocene (Cohen et al., 2007; Scholz et al., 2007; Beuning et al., 2011; Scholz et al., 2011).

Profound oscillations in the vegetation and rainfall regime created the environmental backdrop for early modern humans as they made decisions about subsistence and migration strategies. At face value, the paleoenvironment appears to have had suboptimal periods for intensive habitation. However, cultural connections to landscapes cannot be documented in the archaeological record, and the dense MSA artifactual deposits documented in the Chitimwe Beds indicate that early humans did not avoid this area during the Pleistocene. Resource stress in such an environment presents a challenge to survival, but can also provide the impetus for crossing evolutionary milestones associated with the ability to strategically coordinate tasks, for example through the use of language (Ambrose, 2010). This study takes the first steps toward understanding MSA behavior during a time when large-scale climatic perturbations may have caused punctuated habitation and desertion of the region, technological reorganization, or other changes within MSA populations that are detectable archaeologically.

4. Material and methods

The Airport Site is located at the southeastern side of the Chaminade area, and is named for its proximity to the Karonga Airstrip. Its existence has been known at least since the 1970s, when Kaufulu (1983) notes that gravel pits had been dug in the area, and that these provided geological exposures representative of the Chitimwe Beds. APS is characterized by a general sequence of Chiwondo Beds overlain by subplanar, rounded to sub-rounded cobbles within a very poorly-sorted coarse sandy matrix associated with the Chitimwe Beds. The gravelly sediments are slightly deflated with a high concentration of coarse aggregates within the upper 3 cm of the unit. This unit is blanketed by a massive, poorly-sorted medium to coarse sand that is unconformably overlain by a petroferrikan horizon, or iron pan (Fig. 2), that has developed within massive, well-sorted fine sands with rare coarse sand inclusions.

Excavations focused on two areas separated by ca. 36 m (Fig. 3). The northeastern area was designated as the “Long Section” because previous gravel extraction for road improvement had resulted in a long, exposed section. A total area of 6 m² (total volume 4.42 m³) was excavated in adjacent 1 × 1 m test pits, using the section as a guide. A control square was designated, and this

Fig. 2. Close-up of iron pan nodules. Note artifacts embedded within and below the nodules.

was excavated in arbitrary 10 cm spits until a change in lithostratigraphy was noted. All sediments from this square were screen-washed through a 2 mm screen, and sediments from all other Long Section excavations were dry-screened on site through a 2 mm mesh. Artifacts of any size that were discovered over the course of excavation were piece-plotted, resulting in the recovery of a total of 112 specimens.

The northwestern area is designated as the “Iron Pans” because of the presence of iron nodules eroding from the section left by gravel mining to build the nearby airstrip. This area was selected for excavation because: 1) sharp, unweathered lithic artifacts were abundantly distributed on the surface, suggesting that a large sample could be readily obtained; and 2) artifacts could be seen within and underneath the iron pans in section, indicating that a proportion of the assemblage had remained *in situ* since the iron pan formed (Fig. 2). Because of the abundance of artifacts, a total area of 2 m² (total volume 0.66 m³) was excavated in adjacent 50 × 50 cm quadrants. Arbitrary 5 cm spits were used until a change

Fig. 3. Contour map of the Airport Site indicating excavated areas. Contours are at 0.5 m intervals and labels are placed every 1 m.

in lithostratigraphy became apparent. Artifacts of any size that were discovered over the course of excavation were piece-plotted and all sediments from were screen-washed through a 2 mm screen. As the iron pans were rapidly eroding in the excavated location, all loose surface artifacts within a 1 m buffer of the excavation area were piece-plotted and collected to conserve them and provide a larger sample for analysis. A total of 1665 specimens were piece-plotted from the excavated area and an additional 664 were piece-plotted from the surface in the buffer zone. All site mapping, including piece-plotting, was conducted with a total station following the protocols developed by Marean (2010).

Description of the artifact assemblage involved categorical and metric data. Categorical data focused on classifying systems used in the reduction of cores and the production of flakes at APS, as well as considering the types of retouched artifacts present in the assemblage. Metric data focused on quantification of flake and core size, as well as other aspects of artifact character such as cortical coverage. Representative samples of piece-plotted artifacts from both main excavation areas were included in this analysis to obtain a preliminary characterization of the assemblage. Screen-recovered finds were also included where specified, mainly to augment understanding of site formation processes. This increased the sample by an additional 1544 specimens for which only size data are currently available. Future presentations will examine finer details, such as the spatial distribution of different raw material, size class, and technological types between excavation areas. These will include all the piece-plotted and sieved elements of the assemblage.

The first stage of analysis of flaked stone artifacts from APS is reported here. This had three primary objectives. The first of these was to provide a basic description of the assemblage, such that would allow comparison with other potentially like-aged assemblages from the region. The second was to assess the role and extent of taphonomic agents in the formation of the assemblage. As noted, APS lies in a low-energy drainage zone, making it possible that the composition of the assemblage had been modified since deposition. The third objective, with some consideration of site taphonomy required beforehand, was to explain why artifacts had accumulated at APS and what the assemblage might thus signify.

Clark (1968) and Clark et al. (1970) has asserted that the Chitimwe Beds contain high potential for sites with degrees of spatial preservation suitable for larger interpretations of MSA technology and behavior. Artifact size was thought to be relevant to site taphonomy, given that fluvial and colluvial forces have been observed to winnow assemblages over time (Nash and Petraglia, 1987; Schick, 1992; Fanning et al., 2009) preferentially removing smaller assemblage elements. The nature and extent of site taphonomy were also assessed by considering evidence for post-depositional fluvial transportation of artifacts in the form of edge rounding. Edge rounding was classified into four groups: 0, where no edge rounding was evident; 1, where edge rounding was visible under light magnification; 2, where edge rounding was visible to the eye but where no features of the artifact were obscured; and 3, where edge rounding obscured features of the artifact, including blurring of dorsal scar patterns and possible modification of artifact dimensions.

Explanations for the concentrations of artifacts at APS were expected to derive from an assessment of the relative prevalence of implements, flakes and cores. Specifically, was APS a procurement site, where people exploited existing cobble beds in the manufacture of artifacts? In that case, relatively large numbers of cores and an assemblage wherein both cores and flakes had high proportions of cortex might be expected, and materials could occur in the assemblage in roughly the same proportions as they occur in the local gravels. Alternatively, was APS a site where foragers came to exploit (non-stone) riverine resources? In that case, higher

proportions of implements and fewer cores would be expected. Moreover, if rocks used in the manufacture of the assemblage were not locally derived, little cortex or cortex of a type not found in the local area would be expected.

5. Depositional context of the reported lithic assemblage

There are some immediately observable differences between the two excavation areas at APS. One has iron pans and a high concentration of artifacts (approximately 2.5 artifacts/l of sediment). The Long Section lacks iron nodule formation and has a concentration of artifacts that is two orders of magnitude lower than observed at the iron pans (approximately 0.025 artifacts/l of sediment). Several smaller geological test pits were excavated primarily along the northern part of the eroding section to correlate the lithostratigraphy between the two excavation areas, and a detailed topographic map was created for context. A summary of the stratigraphy and lithological correlations is provided in Fig. 4. Subtle differences in color, texture, and inclusions between the excavation areas suggest that different surficial processes occur within the Chitimwe Beds across the site. This is consistent with other geomorphic analyses conducted in Karonga province, which detect intercalated fluvial, littoral, lacustrine and eolian deposits preserved within the Chitimwe Beds (Haynes, 1970; Kaufulu, 1990; Betzler and Ring, 1995).

The relationship between the depositional facies and human occupation areas is complex, but follows a general sequence across the APS. This general sequence, including erosional surfaces, has been built from field observations and confirmed by a variety of sedimentary analyses (Fig. 4): 1) Basal cobbles with no artifacts; 2) Cobbles with artifacts only at the top; 3) Coarse sand with a few artifacts; 4) Intermittent formation of an iron pan at the top of the coarse sand, containing many artifacts; 5) A fining-up sequence of sands containing a few artifacts; 6) Intermittent modern organic contribution and formation of an A1 horizon (Table 1). The artifacts reported here are aggregated as the excavated sample is small, but it should be noted that they derive mainly from two different contexts. At the Long Section artifact numbers were highest at the top of and incorporated within the upper 5–10 cm of the cobble horizon, rather than in the overlying sands. The fact that they are mixed into this horizon suggests that they were not deflated onto it and the fact that they are largely unweathered (see below) suggests that they were not transported to the terrace as fluvial clasts.

Hominin habitation of the site appears to have occurred on abandoned channel deposits. Adjacent non-artifact bearing coarse sandy deposits suggest that the stream channel migrated laterally, providing a riparian area for hominin activities. Streambeds are excellent sources of lithic raw materials as well as resource rich foraging locations, particularly during otherwise dry periods. The artifact-bearing units at the Long Section and to a lesser extent at the Iron Pans are overlain by stratified alluvium indicating another episode of channel migration and aggradation, possibly relating to tectonic shifting of the landform aspect or changes in base level of nearby Lake Malawi.

At the Iron Pans, artifacts were concentrated at the top of the deposits, although several were also found *in situ* below the nodules at both the iron pan and geological trench localities. This suggests some post-depositional deflation onto an erosional surface. The erosional unconformity between the coarse sandy and overlying fining up sandy deposits includes mm-scale clayey laminates. This surface may be associated with the formation of a biotic crust resulting from aerial exposure of the surface during an arid interval. This surface appears to have provided a position for illuvial perching and formation of the laterite iron pans in the kandic horizon.

Fig. 4. Stratigraphy of the iron pan (left) and Long Section (right) excavation areas at the Airport Site, showing correlations achieved through a geological trench (center) and PSA analysis (top). PSA data are plotted at the top according to true *m* above sea level and the stratigraphic sections below are scaled vertically and horizontally relative to one another. Vertical distances are correct for all sections, but horizontal distances between sections have been compressed for illustration. The iron pan deposits were capped by iron nodules that tapered and disappeared toward the west. Hence, the iron pan itself is not represented in the west section but its approximate location at the top of the sequence is indicated with black capping. All basal units continue into unexcavated deposits below.

6. Results

6.1. Assemblage composition

A total of 1595 piece-plotted artifacts was analyzed from the present sample. Most of these artifacts (90.7%, $n = 1447$) came from excavations and 1 m buffer zone surface collections in the iron pan area. Only 105 artifacts (6.6%) were recovered from the Long Section, with the remainder coming from the geological trenches. Because of the small sample size from locations other than the iron pans and associated difficulties in comparison between locations, the assemblage is considered in this analysis as a single entity.

The basic composition of the assemblage is detailed in Table 2. As would be expected, flakes dominate, with broken flakes outnumbering complete flakes by ~3:1. Retouched flakes are very rare at APS, accounting for around 0.5% of the artifact total. While cores were by no means abundant, they were still considerably more common than retouched flakes (1.8%, $n = 29$). Artifacts with no positive percussion features or complete negative scars, classified

here as 'other large flaking debris', account for the remainder of the artifacts > 10 mm.

6.2. Materials

Quartzite was the dominant material in the assemblage, accounting for 63.2% of the assemblage ($n = 1038$). The quality of the quartzite varied from relatively coarse to quite fine in crystallinity. Quartz was the next most common rock type, accounting for a further 27.6% ($n = 434$). This includes crystal quartz, which comprised 6.0% of the total ($n = 95$). A diverse array of other materials includes fine-grained and crypto-crystalline silicate rocks, silicified wood, and sandstone. Coarse volcanic and rocks of unknown type account for most of the remainder. Most of these rocks could have been sourced within the local gravels, particularly quartzite and quartz, which are locally abundant. One rock type which could not be located in the gravels was a material tentatively identified as ferricrete. A total of 51 ferricrete artifacts is included in the analysed sample.

Table 1

Summary of major stratigraphic units at the APS with site formation and human behavioral interpretations.

Unit	Description	Artifact distributions	Geological interpretation	Archaeological data quality	Behavioral interpretation
6 (surface)	Occasional A1 horizon formation (not present at Iron Pans)	VLD at Long Section	Recent soil formation primarily via organic input	Very limited horizontal or vertical artifact movement within the sequence	Modern land surface
5	Coarse to fine sands fining up not associated with Unit 4 (not present at Iron Pans)	LD at Long Section; EC at Iron Pans	Ephemeral and migratory low-energy channel aggradation	Very limited horizontal or vertical artifact movement within the sequence but potential for palimpsests through (past) deflation at the contact surface with Unit 3 or (recent) deflation where iron pans are currently exposed	Regular human use of riparian areas over an extended time; artifacts not diagnostic to general technological chronology where <i>in situ</i> but Levallois reduction apparent at deflation surfaces
4	Intermittent iron pan formation within lateritic sediments.	C – HC VLD at Long Section;	Iron pan formation processes	Very limited horizontal or vertical artifact movement within the pans but potential for palimpsests via the same processes as Unit 5; pans may have formed around artifacts that were concentrated from a previous deflation event of the top of Unit 3	Regular to intermittent human presence; Levallois reduction apparent
3	Coarse sand fining up	C at Iron Pans	Channel aggradation	Very limited horizontal or vertical artifact movement within the sequence	Regular human use of riparian areas over an extended time; Levallois reduction apparent
2	Large cobbles in red sediment matrix with discrete clay films on ped faces	C at Iron Pans but only on top and within upper 5–10 cm	High energy fluvial deposit followed by terrace formation and bioturbation	Very limited horizontal or vertical artifact movement but potential for palimpsests through extended land surface exposure	Regular human habitation of the top of the terrace over an indeterminate time and production of stone tools from nearby cobbles; Levallois reduction apparent
1 (basal)	Large cobbles in grey, silty sediment matrix with grey precipitates associated with Oxisol soil formation	None	High energy fluvial deposit followed by terrace formation and bioturbation	N/A	None

KEYVery Lightly Dispersed (VLD) = approximately 1 artifact every 1 m³.Lightly Dispersed (LD) = approximately 10 artifacts every 1 m³.Concentrated (C) = approximately 100 artifacts every 1 m³.Heavily Concentrated (HC) = approximately 1000 artifacts every 1 m³.Extremely Concentrated (EC) > 1000 artifacts every 1 m³.

At 90.8%, the prevalence of quartzite and quartz in the assemblage generally reflects their prevalence in rocks found APS. In a sample of 496 cobbles and pebbles greater than 20 mm recovered from the site 53.8% were quartzite and 41.5% were quartz. The remaining 4.6% were of unknown material, but did not include silicified wood, volcanics or ferricrete. The artifactual data suggest some slight over-representation of quartzite relative to quartz in the artifact assemblage when compared with their prevalence in the local cobbles. This may in part be explained by differences in size. Quartzite cobbles were overall slightly but significantly larger than

quartz cobbles ($\bar{x}_{\text{quartzite}} = 51.6$ mm, s.d. = 18.9; $\bar{x}_{\text{quartz}} = 45.7$, s.d. = 17.5; $t = 3.52$, d.f. = 489, $p < 0.001$).

6.3. Cores

Typologically, the range of cores in the APS sample is quite small. Radial forms are the most common type ($n = 9$), followed by cores with fewer than five flake scars and more than 50% cortex, classified here as ‘minimally reduced’ ($n = 8$). Minimally reduced cores may reflect cobble testing on site, but the validity of this inference cannot readily be assessed. Many of the cores ($n = 7$) in the assemblage, including broken pieces and those with an irregular pattern of scar distribution, could not be classified to any particular type. Among the remaining types were three platform cores, defined by preferential removal of flakes from a single platform following Conard et al. (2004), and a single Levallois core. Quartzite and quartz were the only materials identified among cores. Fig. 5 illustrates examples of radial cores on different raw materials.

Assuming that cobbles were locally acquired for flaking, the sizes of cores at APS suggest preferential selection for larger pieces. Fig. 6 plots the sizes of quartz and quartzite cores against the size of unworked cobbles of the same materials from the same excavation units at the site. Most notable is the difference in size range between quartzite cores and unworked cobbles, where there is no

Table 2

Technological classes of lithic artifacts and their proportions in the APS sample.

Technological class		<i>n</i>	%	Combined %
Flakes	Complete	338	21.2	84.1
	Broken	1003	62.9	
Retouched flakes	Complete	3	0.2	0.5
	Broken	5	0.3	
Cores	Complete	24	1.5	1.8
	Broken	5	0.3	
Flaked pieces		199		12.5
Small flaking debris (pieces <10 mm)		18		1.1
Total		1595		100

Ferricrete Flakes

Levallois Flake

Radial Cores

Fig. 5. Example artifacts from APS. Ferricrete flakes (top row); Levallois flake on quartzite (middle row); radial cores on quartz (penultimate 2 rows), radial core on quartzite (bottom row). Numbers indicate specimen numbers.

overlap in inter-quartile range. It should also be recalled that all of the cores in the figure have been reduced to some degree, and thus under-represent the sizes of the cobbles on which they were made. Size differences between cores and cobbles for both quartz (mean $\text{rank}_{\text{cobble}} = 110.59$, mean $\text{rank}_{\text{core}} = 165.33$; $M-WU = 662.0$, $\text{sig.} = 0.005$) and quartzite (mean $\text{rank}_{\text{cobble}} = 260.13$, mean $\text{rank}_{\text{core}} = 142.51$; $M-WU = 971.0$, $\text{sig.} < 0.001$) are statistically significant at $\text{sig.} < 0.05$. Mann–Whitney U tests are used in preference to t -tests due to the small sample sizes for cores.

Another interesting point to make is that all of the cores recovered from APS in 2010 had some cortex. The majority (19 of 25) of complete cores had cortical coverage equal to or exceeding 25% of their exterior surface. Only four cores had very minor ($\sim 5\%$) cortical coverage.

Fig. 6. Sizes of unworked APS cobbles relative to cores of the same material.

All of the radial and Levallois cores exhibited preferential reduction of one surface, with cortex present on one hemisphere only. Cortex coverage on the upper or platform surface of these cores ranged between 10% and 100%. This pattern of cortex distribution suggests establishment of a platform on the upper surface of a cobble from which centripetal scars were struck in a radial pattern. In some cases scars were also directed back onto the upper surface and in others they were not. In all cases the upper platform surface was more convex than the lower exploitation surface. The method used for assessment of convexity is shown in Figs. 6 and 7.

6.4. Retouched flakes

As noted earlier, retouch was rare at APS. Of the eight complete and broken retouched flakes in the assemblage, one could be classified as an end scraper and another as a notch. Two further pieces may have been retouched to serve as cores (including the one mentioned earlier). The remaining retouched flakes were not classifiable by type, and indeed one of these pieces may have been modified by incidental damage rather than by retouch *per se*. It is worth specifying that no points, either retouched or Levallois, were observed in the APS assemblage, and nor were any handaxes.

6.5. Unretouched flakes

With respect to flake types, distinctively Levallois products ($n = 8$) were rare, though flakes with faceted ($n = 39$) or 'chapeau de gendarme' platforms ($n = 31$) attest to the use of prepared core reduction methods. Between them these platform types account for 14.5% of all complete platforms in the assemblage. Cortical platforms are also very common in the assemblage (24.1%) – perhaps unsurprising given the presence of cortex on all complete cores. This high prevalence of cortical platforms also supports previous inferences about core reduction whereby a cortical upper cobble surface was preferentially worked in the initial production of flakes. Overall, some cortex was present on most (55.9%) of the complete flakes in the assemblage, with six flakes having 100% cortical coverage. Almost all cortex in the assemblage (98.1%) was of river cobble form.

Fig. 7. Measurement of core surface convexity for cores with two hemispheres (e.g., radial and Levallois cores). Surface heights are measured at two pairs of opposed points around the perimeter. Values are averaged to give an indicative height for each face. As the distances between measurement points are the same for both surfaces, relative convexity of upper to lower surfaces = average height upper surface/average height lower surface. Where this value exceeds 1 the upper surface is more convex.

Sixteen of the flakes recovered from APS in 2010 were classified as being products of laminar reduction. Interestingly, six of these were made from the material tentatively identified as ferricrete (Fig. 5). The high proportion of ferricrete among blades (37.5%) contrasts with its overall infrequency among flakes (3.2%). Pearson's chi-square test suggests that this is unlikely to reflect an even distribution of debitage types between ferricrete and non-ferricrete flakes ($\chi^2 = 53.986$, $df = 1$, $sig. < 0.001$). It might also be noted that while 10 of the ferricrete flakes had cobble cortex, a further three had cortex suggestive of having been sourced at an outcrop. In contrast, only two of 368 cortical quartzite flakes had outcrop cortex, while this was exhibited on none of the 142 cortical quartz flakes. As with laminar working, variation in the prevalence of outcrop cortex differs significantly between ferricrete and non-ferricrete flakes ($\chi^2 = 54.729$, $df = 1$, $sig. < 0.001$).

Differences in reduction tendencies between ferricrete and other materials suggested by the prevalence of laminar products are reinforced by metric data. It was noted during analysis that the ferricrete flakes at APS were relatively thin. Given the large number of transversely broken flakes, thickness relative to length cannot readily be used. Thickness relative to width can be used on transversely broken flakes, so long as they are not longitudinally broken. This measure gives some sense of the proportions of the pieces available for analysis. Boxplots of thickness/width (Fig. 8) confirm

the impression gained during analysis. The ferricrete flakes are not only disproportionately laminar, they are also unusually thin. *T*-tests suggest that the differences between ferricrete and non-ferricrete flakes ($t = -2.422$, $df = 739$, $p = 0.016$), are statistically significant at $p < 0.05$.

6.6. Evidence of taphonomy

The habitation areas of APS are situated adjacent to paleodrainages, which transported rounded cobbles into the site. As Schick (1992) has noted, artifact concentrations associated with drainage features may be subject both to redistribution of artifacts, and in some cases removal of small assemblage components. Schick (1992) considered a range of data types in order to assess the movement and winnowing of the Acheulean assemblage at Kalambo Falls B5, including refitting, patterns of artifact concentration in the piece-plotted fraction, artifact size distributions and edge rounding. Discussion concentrates on two: artifact size distributions and edge rounding. For the former analysis the sieved component, which has been sorted and size-classed but not studied in detail, is included.

Schick (1992) compared the size distributions of archaeological artifacts from Kalambo Falls B5 with those derived from experimental production of handaxes. The experimentally derived artifacts exhibited a strongly right-skewed mode, with a peak in artifact numbers in the size class from 10 to 20 mm. Artifacts were increasingly less numerous as size classes increased. In contrast the archaeological assemblages showed a modal peak from 40 to 80 mm, suggesting that the smaller assemblage elements had been removed, presumably by fluvial processes.

Fig. 9 presents artifacts by size classes, using 10 mm increments. All plotted and sieved artifacts are included. The figure demonstrates a clearly right-skewed distribution, with a peak in artifact frequency in the 10–20 mm class and rapid decay in the larger classes. To that extent the size distribution at APS matches the pattern in Schick's experimental data better than the winnowed archaeological set. The only anomaly is the lack of artifacts in the class from 0 to 10 mm which may indicate some winnowing of the smallest assemblage elements. Overall the results from APS suggest that if the site has been subject to winnowing, the forces involved are likely to have been much lower energy, or to have persisted over much shorter durations than those at Kalambo Falls. Whether there have been some fluvial effects on the assemblage at APS can be established by considering evidence for edge rounding.

The proportions of artifacts with differing degrees of edge rounding at APS are presented in Table 3. The overwhelming bulk of

Fig. 8. Boxplots showing thickness/width for quartz, quartzite, and ferricrete.

Fig. 9. Artifact frequency by size class (10 mm increments) for all artifacts from APS.

artifacts in the assemblage display no evidence of edge rounding, such as might have been caused by fluvial redeposition. Approximately 1 in 11 artifacts display some very minor edge rounding, visible under light (10× hand-lens) magnification. It seems probable that this degree of modification could have been produced by minor redistribution of artifacts within the assemblage, rather than their redeposition at APS from some other starting location. The proportions of artifacts at the site which may have been introduced from elsewhere (edge rounding classes 2 and 3) is very small overall (2%). These data suggest that most of the APS assemblage was probably not subject to extensive transport. Although it is as yet unclear to what extent the site can be considered *in situ*, the stone artifact assemblage shows great integrity.

7. Discussion

Accepting for the moment that APS is, as it appears to be, a largely coherent assemblage representative of activities in the local area, then it is reasonable to interpret the site in behavioral terms. Two applicable caveats here are: 1) that not all of the artifacts necessarily derive precisely from their point of recovery; and 2) that because all of the contexts of recovery have been conflated for this analysis, it is best to consider these interpretations as time-averaged. Time-averaging limits the specificity of behavioral explanations (Stern, 1994), but leaves open the possibility of interpretation at the broadest scale (Bailey, 2007), albeit with the understanding that multiple, potentially conflicting explanations may have validity.

Two potential general explanations for the accumulation at APS were posited in the methods section. One of these was that the site reflected the discard of artifacts brought in from other locations by foragers exploiting non-stone riverine resources. The other was that the site accumulated as the result of the local manufacture of

artifacts from available cobbles. Both explanations receive some support from the available data, although support for the latter is stronger.

There is considerable evidence that reduction of locally available stone (most likely from abandoned river terrace deposits) accounts for much of the assemblage. Material prevalence among artifacts is consistent with availability in the local cobbles, and cobble cortex is by far the dominant form. Cortex occurs on the majority of flakes and on all cores, and primary cortical flakes are present. The prevalence of cortical platforms in particular is consistent with inferences about the mode of reduction for the cobbles from which the cores were made. That at least some of these cobbles were locally procured is reinforced by the presence of cobbles with small numbers of flake scars, classified here as ‘minimally reduced’. While cores were not abundant in the assemblage, they were still far more common than retouched flakes. This reduction may have been opportunistic in pursuit of other resource acquisition, rather than APS representing a defined ‘source’ site specifically visited to procure new toolstones. This also leaves open the possibility that a portion of the artifacts manufactured at APS were transported away from the site after completion of foraging tasks (Schick, 1987).

Comparison of core size with a sample of unmodified cobbles from the same deposits suggests that larger cobbles were preferentially selected and perhaps even brought to the site from elsewhere (particularly quartzite). The former observation replicates a pattern noted by Schick (1987) at Koobi Fora. Further evidence of the transport of lithic artifacts to the site (as opposed to restricting flaking activities to cobbles present in the immediate vicinity), is found most notably in the presence of ferricrete artifacts. Ferricrete was not observed among the local cobbles, and a reasonable percentage of the ferricrete flakes in the assemblage exhibited cortex that was suggestive of procurement from outcrops rather than from cobble beds. Perhaps the most interesting aspect of the ferricrete artifacts at APS was that many of them appear to have been produced by reduction methods that were not otherwise common at APS. Specifically, there is some evidence for the preferential use of laminar reduction in the manufacture of ferricrete flakes, expressed in the prevalence of blades and in the relative thinness of the flakes.

There is a general lack of evidence of curation in the form of very heavily reduced cores and extensive retouch, which may be expected in a landscape where raw materials are abundant and sources (in this case in the form of cobbles) are distributed at relatively regular intervals (Bamforth, 1986). However, in spite of this abundance some lithic elements were clearly carried across the landscape and introduced from elsewhere.

At the Long Section, artifacts are almost exclusively distributed upon and within the first 5–10 cm of the uppermost cobble horizon, and artifacts are relatively sparse. This implies a general ‘background scatter’ of lithic distribution upon a cobble surface that was probably directly exploited for new raw material packages. However, at the nearby iron pans the artifact abundances increase dramatically. Further work is required to understand if this is because of post-depositional factors (i.e.: different sedimentation and/or deflation rates) or if the site captures two different activity areas, perhaps mediated by the presence of particular resources that encouraged groups to return frequently as part of their foraging round.

A final consideration that can be made with respect to APS is the question of where the site fits in the regional technological/temporal context. The presence of radial and some Levallois reduction and the absence of handaxes allows the site to be classified as MSA, suggesting a lower age of probably less than 285 ka based on east and central African data (Barham and Smart, 1996; Tryon et al., 2005). Assignment of the APS assemblage to industries

Table 3
Edge rounding classes and proportions in the APS sample.

Edge-rounding class	n cases	Assemblage proportion (%)
0	1419	89
1	144	9
2	23	1.4
3	9	0.6

within the MSA is largely hampered by the absence of distinctive *fossiles directeurs*. For example, points and backed pieces are associated with Lupemban or Sangoan assemblages noted nearby at Mwanganda's Village and in Zambian sites to the west (Clark and Haynes, 1970; Clark and Brown, 2001; Barham, 2002), yet no such implements occur at APS. Recently presented stratified sequences from Mozambique lack distinctive elements that would allow ready comparison with APS (Mercader et al., 2009). As such, a better understanding of the place of the APS site in the local and broader regional contexts awaits radiometric dating of the site and the development of a more detailed local technological sequence.

Regional paleoclimatic datasets provide the basis for hypotheses about when people are expected to have occupied the Airport Site, which lies only 32 km from the Site 2 drill core. Cohen et al. (2007) propose that periods of megadrought during the Late Pleistocene of central Africa would have driven human populations into ephemeral refugia or out of the region Africa entirely. Scholz et al. (2007) suggest further that subsequent amelioration into wetter conditions ca. 70 ka positioned early modern human populations for expansion and dispersal out of Africa. Beuning et al. (2011) argue that the period between 109 and 90 ka was particularly inhospitable to human habitation based on low PAR of terrigenous genera from the central Malawian lake core (Scholz et al., 2011). If climatic conditions were acutely poor in the uplands as the proxy data suggest, early humans would have aggregated within riparian areas to buffer their resource base, assuming that they did not abandon the area altogether.

The paleoclimatic data provide a temporal framework for major changes in regional mobility patterns and/or technological adaptation. Harsh conditions fragment and increase selective pressures on populations surviving in refugia, and this may have underpinned biological and behavioral evolution during the MSA (Basell, 2008). These hypotheses about the impacts of such climatic fluctuations and the timing of human movements within and out of central Africa can only be tested using archaeological data from intact/minimally disturbed sites in the same region that yielded the paleoclimatic data. The Airport Site demonstrates the potential of the Chitimwe Beds to contain those data, and to become the first in a series of sites upon which a regional chronology of MSA behaviour can be built.

8. Conclusions

The Chitimwe Beds of northern Malawi have been described by Clark (Clark, 1968; Clark et al., 1970) as excellent repositories for evidence of human technological adaptations during the Middle – Late Pleistocene. Recent excavations at the Airport Site near the Karonga airstrip confirm that this is the case. The Airport Site contains a lithic assemblage that fits comfortably within the definition of MSA technology. Taken together, the available evidence suggests that APS was a location where people exploited locally available cobbles to make artifacts. Reduction of local rocks involved removal of flakes from a cortical platform in a centripetal pattern, with some more developed radial and Levallois reduction occurring later in the process. At least some lithic reduction took place on site, and it would appear that few of the artifacts have not been secondarily transported. Some of the flake production occurred on cobbles while some involved the reduction of large cortical flakes. An alternative pattern of flake production may have been pursued in exploitation of ferricrete cobbles which were probably not procured on site, but which were transported there by foragers.

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