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ORIGINAL ARTICLE

Sitwe 23, a Complex ESA/MSA Locality in the Northern Luangwa Valley, Zambia

Michael S. Bisson · Ariane Burke · Flora Schilt · Julie Aleman · Matthew C. Peros · Michelle Drapeau · Maggie Katongo · Martha Nchimunya Kayuni · Joseph Mutale Museba · Steve Tolan

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Abstract This paper describes the lithic aggregates from Sitwe 23 (SW23), a Stone Age locality in a previously unstudied region of the northern Luangwa Valley, Zambia. This area yielded two surface lithic scatters containing abundant artifacts derived from Pleistocene sediments on uplifted terrain and exposed by recent erosion on two adjacent terraces. The scatters are time-averaged palimpsests formed by deflation, but most of the lithics lack evidence of significant fluvial transport or post-depositional damage, indicating minimal horizontal displacement. Typological and attribute analyses of samples from both spurs reveal predominantly simple and expedient core and flake technologies, as well as sophisticated biface manufacture and Levallois technique producing flakes and points that are differentially distributed between the terraces. The artifacts identified in this analysis include types conventionally considered diagnostic of the Acheulean, Sangoan, and Middle Stone Age, suggesting that the collections may document one or more temporal windows during the Chibanian age (770–126 ka). Whether artifacts in these samples were originally deposited sequentially or concurrently is not yet known and alternative hypotheses are presented and discussed. The collections are compared to sites in Zambia and

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M. S. Bisson (✉)
Department of Anthropology, McGill University, Montréal, Canada
e-mail: Michael.bisson@mcgill.ca
URL: https://www.McGill.ca

A. Burke · M. Drapeau
Université de Montréal, Anthropologie, Montréal, QC, Canada
e-mail: a.burke@umontreal.ca

M. Drapeau
e-mail: m.drapeau@umontreal.ca

F. Schilt
Interdisciplinary Center for Archaeology and Evolution of Human Behaviour, University of the Algarve, Faro, Portugal
e-mail: fcschilt@gmail.com

J. Aleman · M. C. Peros
Environment and Geography, Bishop's University, Lennoxville, QC, Canada
e-mail: julie.aleman@gmail.com

M. C. Peros
e-mail: mperos@ubishops.ca

M. Katongo
Rice University, Anthropology, Houston, TX, USA
e-mail: katongo17@gmail.com

M. N. Kayuni
Historical and Archaeological Studies, University of Zambia, Lusaka, Zambia
e-mail: martha.kayuni@gmail.com

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the northern Lake Malawi basin and found to be similar technologically but typologically different. Given the paucity of previously known Ston Age archaeological sites in the region, our work now demonstrates that northern Luangwa has significant archaeological potential and deserves further study.

Résumé Cet article décrit les agrégats lithiques de Sitwe 23 (SW23), un site de l'Âge de pierre situé dans une région auparavant non étudiée de la vallée septentrionale de Luangwa en Zambie. Deux dispersions lithiques en surface, sur deux terrasses adjacentes, ont été identifiées sur un terrain surélevé et exposés par une érosion récente, chacune contenant de nombreux artefacts provenant de sédiments pléistocènes. Ces dispersions sont des palimpsestes moyennés dans le temps, formés par déflation, mais la plupart des artefacts lithiques ne montrent pas d'évidences de transport fluvial significatif ou de dommages post-dépositionnels, indiquant un déplacement horizontal minimal. Les analyses typologiques et d'attributs des deux zones révèlent la prédominance d'une technologie d'éclats et de nucleus simple et expéditive, combinée à une fabrication sophistiquée de bifaces ainsi que d'éclats et de pointes de technique Levallois qui sont répartis de manière différentielle entre les terrasses. Les artefacts identifiés dans cette analyse comprennent des types généralement considérés comme diagnostiques de l'Acheuléen, du Sangoan et du Middle Stone Age, suggérant que les collections pourraient documenter une ou plusieurs fenêtres temporelles du Chibanien (770–126 ka). Comme on ignore si ces artéfacts ont été déposés de manière séquentielle ou simultanée, différentes hypothèses sont présentées et discutées. Des comparaisons de ces collections à d'autres sites en Zambie et dans le bassin septentrional du lac Malawi révèlent qu'elles sont technologiquement similaires mais typologiquement différentes. Compte tenu du manque de sites archéologiques de l'Âge de pierre connus dans la région, nos travaux démontrent désormais que le nord de vallée de la Luangwa possède un potentiel archéologique significatif et mérite des recherches supplémentaires.

Keywords Early stone age · Sangoan · Early middle stone age · Zambia · Northern Luangwa Valley · Palimpsest

J. M. Museba
National Heritage Conservation Commission, Northern Region, Kasama, Northern Province, Zambia
e-mail: josephmuseba@yahoo.com

S. Tolan
Chipembele Wildlife Education Centre, Mfuwe, Zambia
e-mail: luangwa@hotmail.com

Introduction

The last half of the Middle Pleistocene, 770–126 ka (thousand years ago), or Chibanian stage (Hornyak, 2020), encompasses the origin of anatomically modern humans (AMH) (Hublin et al., 2017; Scerri et al., 2018), the technological transition from the Early Stone Age (ESA) to the Middle Stone Age (MSA) (Deino et al., 2018), and the appearance of complex behavioral and cognitive traits (Brooks et al., 2018; McBrearty & Brooks, 2000; Shea, 2011). In Central Africa, the archaeology of this period is poorly understood (Taylor, 2014) compared to Southern (Dusseldorp et al., 2013) and Eastern Africa (Tryon & Faith, 2013). Although many ESA and MSA sites have been reported for south-central Africa (Clark, 1967), few are firmly dated and many lack stratigraphic integrity due to long-term bioturbation and other taphonomic issues (Cahen & Moeyersons, 1977; McBrearty, 1990; Moeyersons, 1978; Williams, 2019). These factors, added to the difficulty of access, mean that with a few exceptions (Barham, 2000; Barham et al., 2011, 2015; Colton, 2009; Colton et al., 2021; Thompson et al., 2018), much archaeological coverage in this region remains at the level of basic reconnaissance (Deacon, 2001) and archaeological sequence identification (Taylor, 2016).

Here, we present a newly discovered Stone Age site, Sitwe 23 (SW23), situated in the northern Luangwa drainage system, northeastern Zambia (Figs. 1 and 2). Amateur archaeologists (Macrae & Lancaster, 1937) had collected artifacts later identified as Sangoan (Clark, 1950) near Sitwe village, and the presence of artifacts in surficial gravels was later confirmed by paleontologists (Drysdall & Kitching, 1963). In 2014, Stone Age localities were discovered in the Luwumbu catchment by one of us (S.T.), followed by archaeological surveys in 2016 and 2019 (Burke et al., 2023) which identified many archaeological sites including three localities with large lithic

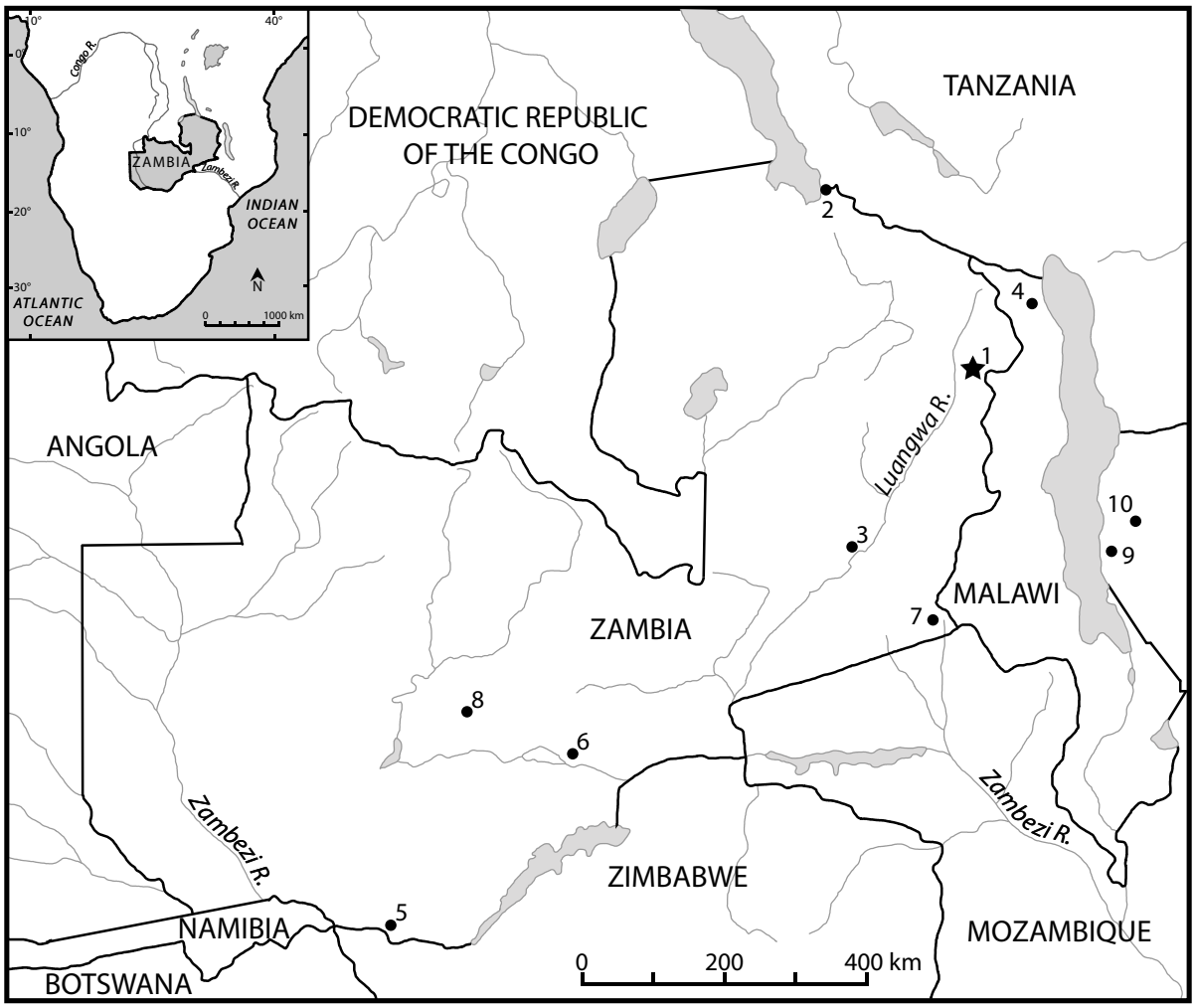

Fig. 1 Map of Zambia. Location of Zambia and the archaeological sites mentioned in the text. 1 Sitwe 23 research area; 2 Kalambo Falls; 3; Central Luangwa Valley research area including Manzi and SL 8; 4 Karonga, Malawi, research area including Chaminade I & II and Mwanganda's Village 1; 5 Zambezi River gravels; 6 Twin Rivers; 7 Kalemba rock-shelter; 8 Mumbwa Caves; 9 Ngalue Cave, Mozambique; 10 Mvumu, Mozambique

concentrations: Sitwe 23, Sitwe 37 (SW37), and Sitwe 60 (SW60).

SW23, divided into two main areas by a deep gully, exemplifies many of the problems that have made Central African open-air sites difficult to date and interpret. Although chronometric dates are currently unavailable, the techno-typological makeup of the SW23 lithic collections described here suggest that the site may have formed some time during the Chibanian. Surveys in areas surrounding SW23 identified similar sites and abundant artifacts in surface lag deposits (Burke et al., 2023).

The northern Luangwa Valley is an understudied region of east-central Africa that has the potential to provide data relevant to currently unanswered questions related to the timing and nature of human physical and behavioral evolution (McBrearty & Brooks, 2000; Bräuer, 2012; Stringer, 2016; Marean, 2015). Because the Congo rainforest is thought to have been uninhabited by early hominins (Barham, 2000; Taylor, 2016), the parallel North–South oriented Luangwa and Lake Malawi Basins provided an over 500-km-long biogeographic corridor that could have enabled hominin dispersals in either direction,

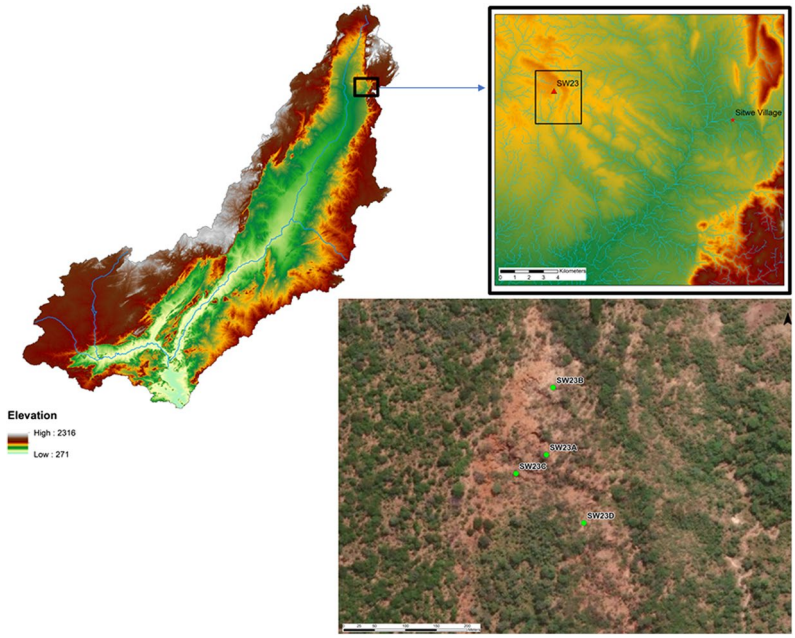

Fig. 2 The Sitwe 23 research area. Left is an elevation profile of the Luangwa River Basin showing the research area to be in the northeastern margin of the basin. Upper right is the locality relative to Sitwe Village and the Mafinga Hills northeast of the village. Bottom right is the SW23 locality with the placement of SW23A–D (image from Google Earth Pro V.7.3.6.9345/January 3, 2023 © 2023 Airbus)

facilitated gene flow between eastern and southern Africa (Thompson et al., 2012), and provided essential refugia with permanent water during the severe climate fluctuations that characterized the Pleistocene in this area (Ivory et al., 2018; Lyons et al., 2015). Climate driven environmental changes may have been an important driver of both physical and cultural evolution (Potts & Faith, 2015). Increasing archaeological knowledge of this region was an important consideration in our decision to undertake this project.

The lithic aggregates from SW23 are typologically diverse. Samples from both parts of the site combine a predominantly simple and expedient core and flake technology with small numbers of shaped tools and debitage strategies often considered markers of the Late Acheulean (ESA), the Sangoan (Early Middle Stone Age, EMSA), and the Later Middle Stone Age (LMSA) (McBrearty & Tryon, 2006) technological traditions. Here, we describe fieldwork conducted at SW23 in 2016 and 2019, outline the stratigraphic context and depositional environment of the locality and present a detailed techno-typological analysis of the lithic aggregates from the two adjacent terraces. This is followed by a discussion of the placement of these aggregates within the regional and continental archaeological context. Our aim is to assess the archaeological potential of this and other localities in the region, to highlight the kinds of data that are present and absent, and to place the SW23 locality in the broader context of the African Stone Age.

The Zambian Middle and Upper Pleistocene Culture-Chronological Sequence

J. Desmond Clark established the Stone Age archaeological succession in Zambia based primarily on the stratified alluvial deposits at Kalambo Falls (Clark, 1969, 1974). This was presented as a developmental sequence of industrial complexes, each being a "cultural entity" within "general developmental or adaptive stages" that was produced by specific "groups of prehistoric people" (Clark et al., 2001:37). The complexes identified by Clark continue to be employed, but their widespread temporal and spatial distribution makes it highly unlikely that they represent cultural groups in the modern ethnographical sense (Kleindienst, 2006; Shea, 2014; Wilkins, 2020). Kalambo Falls remains the most complete and best documented archaeological sequence in Zambia, spanning the later ESA to the Iron Age (Barham et al., 2015; Clark et al., 2001). However, the techno-typological sequence at Kalambo is less complicated than that found elsewhere on the continent (Herries, 2011; McBrearty & Brooks, 2000; Sahle et al., 2014; Scerri, 2017; Tryon & Faith, 2013), a situation with potential implications for our understanding

Table 1 Zambian culture chronological sequence (500 ka–30 ka)

Stage	Industry	Chronology	Diagnostic artifacts	Core technology	Key Zambian sites
Late Early Stone Age	Final Acheulean	Stratigraphically older than the Sangoan[1]; 500–300? ka (OSL)[3]	Handaxes, cleavers, and knives[4] made on giant flakes[5] exceed 50% of formal tools[6]. Some core-axes & picks[7]	Predominantly informal, some radial in Zambia[2,7]. Some Levallois, usually large, in Eastern[8,9] and Southern Africa[10]	Kalambo Falls[1,7]. Zambezi River Gravels[11]
Early Middle Stone Age	Sangoan	Stratigraphically older than the Lupemban[1]; No absolute dates, perhaps ~ 500 to 300 ka[2, 19] or (MIS 9)[12]	Core-axes & picks, often with unflaked butts, outnumber handaxes. "Choppers" and core-scrapers are common. Numerous crudely retouched flakes in some assemblages[1, 7, 12, 13]	Predominately informal and radial. Presence of true Levallois in Zambian Sangoan is debated [2, 7, 15, 16, 17]	Kalambo Falls[1,7]. Zambezi River Gravels[11]. Numerous surface sites across the entire country [18]
	Lupemban	Stratigraphically younger than the Sangoan, older than the LMSA[1]; 265–170 ka[12]	Long lanceolate bifacial points, refined core-axes with parallel sides, picks,[20, 21] blades, Levallois products and large backed elements[12, 17, 22]	Informal and radial cores are common, but blade cores and Levallois cores producing both flakes and points occur in significant numbers [12, 14, 17]	Kalambo Falls[1,7] Twin Rivers[12]
Later Middle Stone Age	MSA (unnamed [12], formerly "Magosian" or "Proto-Stillbay") [11]	Above Lupemban, below Late Stone Age (LSA)[1]; 120–107 ka[12]; 44 ka [2]; > 35 ka[24]	Flake and/or blade-based technology including both unifacial and bifacial points. Backed flakes and blades, some with transverse cutting edges. Numerous scrapers and other flake tools [1]. Core-axes and picks are present but rare[12]. Formal tools are smaller than those of the ESA and EMSA[23]	Informal and radial cores present. Blade and Levallois cores increase in frequency [12, 14, 17]	Kalambo Falls[1,7] Mumbwa Caves[12] Kalemba Rock-shelter[24]

References: 1. Clark, 1974; 2. Barham et al., 2015; 3. Gilbert et al., 2016; 4. Kleindienst, 1962; 5. Sharon et al., 2009; 6. Leakey, 1971; 7. Clark et al., 2001; 8. Tryon & McBrearty, 2006; 9. Lahr & Foley, 2016; 10. Wilkins et al., 2010; 11. Clark, 1950; 12. Barham, 2000; 13. Clark, 1969; 14. Taylor, 2014; 15. Cooke 1962; 16. Cornelissen, 1992; 17. Taylor, 2016; 18. Clark, 1967; 19. Duller et al., 2015; 20. Breuil, 1944; 21. Clark, 1971; 22. Barham, 2002; 23. Clark, 1988; 24. Phillipson, 1976. Ka refers to (thousand years ago)

of SW23. Table 1 summarizes the segment of the Zambian sequence potentially relevant here.

Setting

The Luangwa Valley is a lateral extension of the East African Rift System (EARS) that forms the eastern margin of the Central African Plateau (Daly et al., 2020). Bedrock geology consists of formations of the Permian and Triassic Karoo Supergroup. Extensive studies of Karoo formations North and West of the village of Sitwe have been carried out due to their paleontological significance (Dixey, 1937; Peecook et al., 2017). Above the Karoo formations are Luangwa Formation sandstones which may date to the Cretaceous or Paleogene (Siefert et al., 2001). Neogene and Quaternary colluvial and alluvial sediments complete the sequence.

Regional vegetation in northern Luangwa is a mosaic of Zambezian Miombo woodland, grasslands (Mayaux et al., 2004) and traditionally farmed cropland. The Miombo zone is subhumid, characterized by short but intense seasonal rainfall (650–1400 mm) from November to March and a long, dry season from April to October/November (Chidumayo, 1999; White, 1983). During the peak rainy season (Jan–Mar) heavy rains result in high-energy stream deposits, sheetwash, and gullying, examples of which were observed in the vicinity of SW23 including "elevated" trees with exposed roots, and pedestals of remnant sediment capped by natural clasts and artifacts.

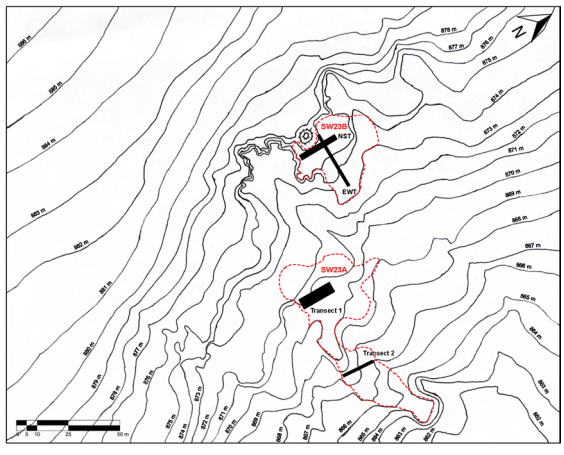

Fig. 3 Contour map showing SW23A and B. The dashed lines indicate the edges of the artifact scatters on each spur, and the black rectangles are the locations of the transects collected in 2019. Contour interval is 1 m

Site Description and Stratigraphic Context

SW23 (33°4′24″ E 10°49′19″ S) is located at the headwaters of the Lutete River, a seasonal tributary of the Luwumbu, on the southern edge of the divide between the Luangwa and Luwumbu drainages, ca. 12 km west of the village of Sitwe at the foot of the Mafinga Mountains (Fig. 2). SW23 comprises four roughly parallel spurs bounded by steep gullies cutting into a plateau that tilts slightly to the southeast. The northernmost spurs, SW23A and SW23B (Fig. 3), slope steeply from the top of the gully system escarpment (ca. 900 m asl) and terminate as partially denuded terraces ca. 870 m asl. The SW23A terrace is c.150 m long. It has two relatively flat lobes on its northwestern end and narrows to a ridge at its eastern end. The area studied measures 490 m^2 and is in the western half of this spur at the base of the escarpment slope. Most of this terrace is slightly domed.

The terrace at SW23B, the northernmost spur, measures ca. 970 m^2. It is the flattest of the terraces, and slopes slightly to the southeast. Both terraces are composed of partly eroded light red lateritic sediment resting on an erosion resistant, imbricated cobble layer. Preliminary survey in 2016 revealed abundant artifacts on the surface of both terraces. Numerous small, raised original sediment pedestals, up to 20 cm high, were observed on the SW23A platform, capped by artifacts or pebbles of varying sizes (Online Appendix 5: Fig. 1). Small trees and bushes with partially exposed roots also occur on the terraces suggesting recent and rapid erosion at the head of this gully system (Stoffel et al., 2013).

A large erosion feature of uncertain origin is located on the southwestern end of the terrace at SW23B, partially cutting into the base of the slope. The feature, possibly a fossil termitary, forms a roughly 12-m-wide circular depression, up to 1 m deep, that contains a fragmented cone of hard, gray mottled clay up to 2.5 m high (Fig. 4).

Two further spurs, SW23C and SW23D, located southwest of SW23A and B, are in the process of eroding and are still covered in vegetation. Time

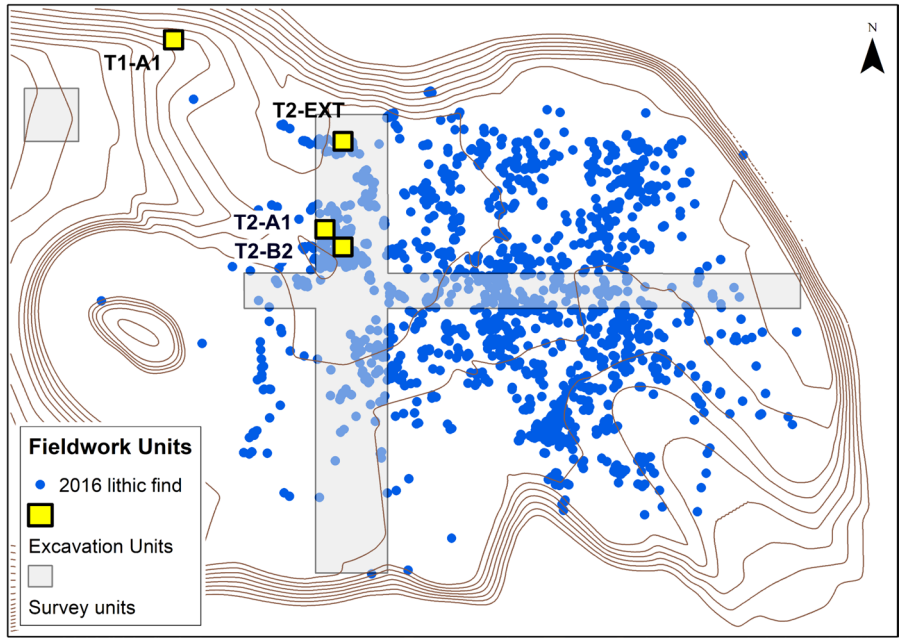

Fig. 4 The SW23B terrace. Shaded areas are transects that were surface collected in 2019. The positions of the four 1 × 1 m excavation units are indicated. Dots are lithics recorded in 2016. Contour interval is 50 cm

constraints prevented a detailed study of these spurs, but artifacts were observed on both.

Field observations of the actively eroding faces of the gully between SW23A and B and geoarchaeological analyses conducted at SW23B in 2019, detailed in Burke et al. (2023), afford an overview of the local depositional sequence (Fig. 5(D)) which consists of four geological units, as follows:

Unit 1: Bedrock consisting of Upper Grit Formation Permian and Early Triassic sandstones (Siefert et al. 2001). These are pale in color, but when weathered oxidize to a dark red. The upper surface of this formation is uneven, suggesting that it was exposed and weathered prior to burial.

Unit 2: A layer of fine sandy clay ca. 1.5 m thick, interpreted to be alluvial in origin, with a mineralogy and grain size resembling the underlying sandstone bedrock of Unit 1. The deposit contains fragments of re-worked Upper Grit sandstone as well as red redox masses formed by fluctuations of the groundwater table. An episode of higher energy deposition created a stringer of pebbles roughly 30 cm below the top of the unit. Above that, cobbles, pebbles, and feldspars become increasingly abundant. Artifacts are present in this unit.

Unit 3: An undulating layer, 15 to 40 cm thick, of subrounded to rounded cobbles (15–20 cm in diameter) and subangular medium pebbles, displaying slight imbrication and likely deposited by a high-energy braided river or alluvial fan. Clasts are primarily gray quartzite, with occasional feldspars, quartz, and fossil wood. In some areas, iron-manganese concretions have cemented the clasts in this layer, increasing its resistance to erosion. There is no evidence of soil formation or buried paleosol horizons in this unit or the underlying sediments, and no observable unconformity between the cobbles and the overlying deposits of Unit 4, suggesting that the exposure of the upper surface of this unit was of relatively short duration. Artifacts occur in this unit.

Unit 4: This layer caps the sedimentary sequence and consists of a ~ 1-cm-thick layer of bedded medium gravel grading up into fine to medium sandy clays with slight variations in grain size. While the unit is thinner at SW23B, less eroded areas upslope may exceed 10 m in thickness. The depositional environment is interpreted as a low energy floodplain with alluviation persisting throughout the formation of this unit (Burke et al., 2023). Where the full thickness of this unit is present, lateritic soil formation is pronounced,

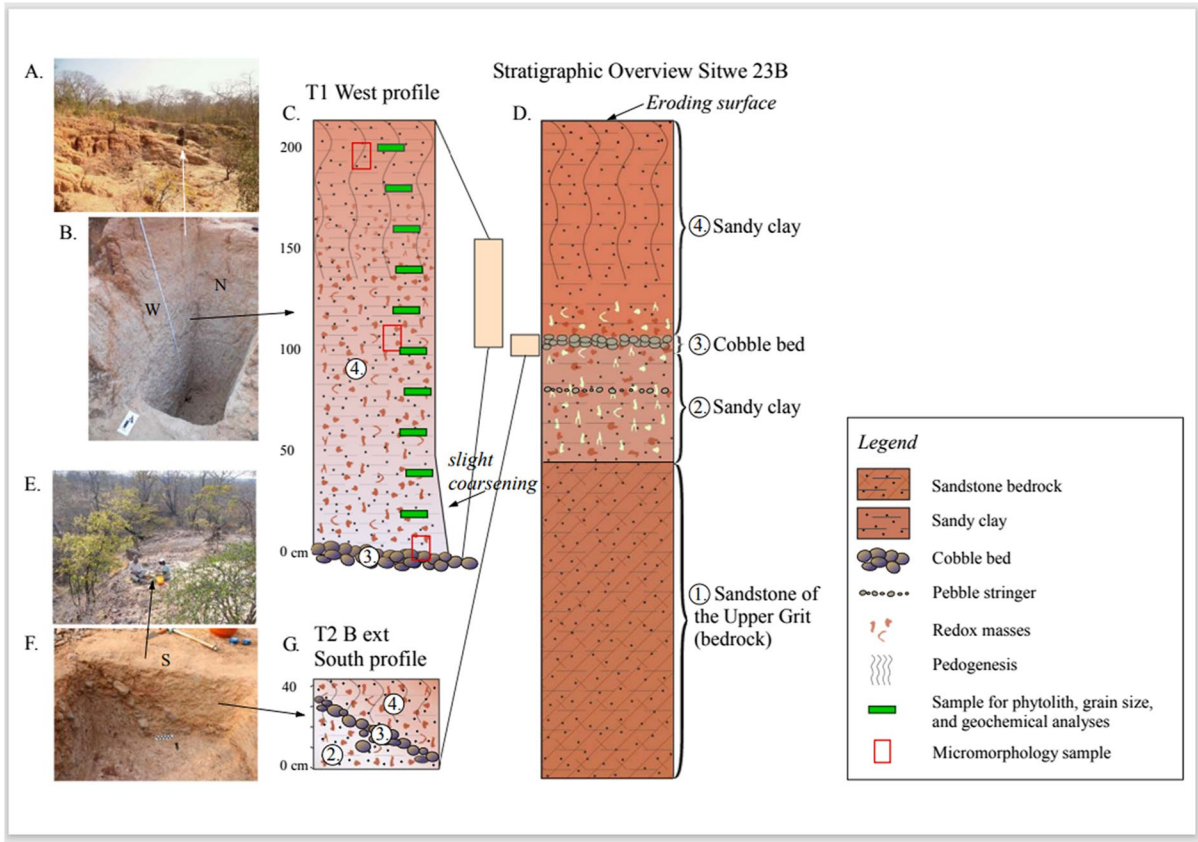

Fig. 5 The sedimentary context of SW23B. **A** A test excavation was placed north of the terrace to sample a remnant of Unit 4 at the foot of the eroding hillslope. The excavation reached down to and just below the cobble bed of Unit 3. The exposed profile was sampled for phytolith, grain size, geochemical, and micromorphology analysis. **B** A profile drawing of the excavation shown in A., with relatively fine sediments (fine to coarse sandy clays) overlying the cobble streambed, only slightly overprinted by recent soil formation (reddening) due to ongoing sheet erosion of surface sediments. The bar next to the profile drawing indicates the approximate position of this excavation relative to (**C**). **C** Schematic stratigraphy of the sedimentary context at SW23B. The bedrock (Unit 1) sandstone is overlain by sandy clay with reworked weathered sandstone fragments (Unit 2). This is capped by an extensive cobble streambed (Unit 3). Artifacts were found within the cobble bed. Most sharp-edged artifacts derive from the lower part of Unit 4, which consists of sediments like Unit 2 and the sandstone bedrock, though slightly more mature in mineralogical composition. **D** View from the west toward the test excavation shown in (**A**). **E** View to the south from the test excavation shown in (**A**), showing work at pit T2-EXT that sampled the cobble bed near the edge of the eroding platform

creating a > 2-m-thick biomantle (Crossley, 1986; McBrearty, 1990) of pinkish red homogenized sediment that grades into a mottled horizon becoming more pallid with depth. Below this horizon, in the area sampled by test excavations, minor differences in sand grain size frequencies are present (Burke et al., 2023), ruling out extensive bioturbation below the modern soil formation horizon. No paleosols are present, suggesting that there were no major environmental changes or depositional hiatuses during its formation. Artifacts occur throughout this unit but are most frequent within 2–3 m of its base.

Materials and Methods (For a Complete Description, See SI Appendix 1)

In 2016, sites originally identified in 2014 were relocated and surveyed to assess their archaeological contents, with SW23 judged to have the greatest potential (Burke et al., 2023). On SW23B, GPS

survey located 1656 lithics. In 2019, lithics from two transects totaling 115 m^2 in SW23A were recorded and collected (Fig. 3). At SW23B, a total station survey and collection was conducted along two transects covering ~ 166 m^2 (Fig. 4 also SI Appendix 5, Fig. 2). Four 1 × 1 m excavations were opened in SW23B in 2019 (Fig. 4). The deepest pit was T1-A1 (~ 2 m), which cut into the base of the slope above the terrace and sampled lower Unit 4 to the top of Unit 3. This pit provided samples for geoarchaeological and paleoenvironmental analysis (Fig. 5). Pits T2-A1 and T2-B2 were excavated into the terrace surface to sample Unit 4, and T2-EXT was placed at the edge of the terrace to sample Unit 3. Surface collections in the transects were necessary to obtain sufficient samples for analysis. All loose specimens were retrieved and imbedded specimens left in place. All visible artifacts were collected and specimens > 2 cm were individually point located.

Geoarchaeological Sampling included a column of 11 loose sediment samples (20 cm spacing) collected in T1-A1 for phytolith and pollen analysis plus five samples for optically stimulated luminescence dating (OSL) (Fig. 5). Micromorphological samples were collected from this unit and squares T2-B2 and T2-EXT. Sediment analyses are described in Burke et al. (2023). The OSL samples were damaged in transit and could not be processed. The Coronavirus pandemic cancelled a return to Zambia in 2020. A revisit to the site to obtain new OSL samples is planned.

Post-Excavation Analysis

Spatial location data from the GPS units was processed using Garmin ©Basecamp software and exported to ESRI ©ArcGIS (10.3). Spatial information from the TOPCON (2019 survey and excavations at SW23B) was processed using Carson ©SurvPC software and exported to ESRI ©ArcGIS (10.7). Nearest neighbor analysis, Ripley's K and Kernel density analyses were carried out using the Spatial Statistics toolbox to assess spatial patterning.

Paleoenvironmental analysis included processing the 11 sediment samples to determine particle grain size of the sandy clay that constituted most of the deposits on and above the terraces. Standard pollen processing protocols (Faegri et al., 1989; Zabenski et al., 2006) were employed, but the samples were sterile. Phytolith extraction (Aleman et al., 2013) was successful and Phytolith shapes were classified according to the international code (Madella et al., 2005). The results of this analysis are fully described in Burke et al., 2023.

In total, 1459 artifacts were collected for study in 2019, and these constitute the main data for the lithic analyses reported here (Table 3). Artifacts > 2 cm maximum dimension were subject to full typological and attribute analysis (209 from SW23A and 1001 from SW23B) whereas specimens measuring < 2 cm (70 from SW23A, 179 from SW23B) were categorized according to type and raw material and individually weighed. Artifacts were separated into three primary samples. These were (1) all specimens collected from SW23A (total 279), (2) all surface collected specimens from SW23B (total 1058), and (3) all specimens from the excavations in SW23B (total 122). These samples were analyzed separately and subsequently compared to assess whether all three samples could be considered as a homogenous aggregate. The lithic analysis included typological identification of each specimen and the recording of technological, metrical and taphonomic attributes appropriate to each of the six broad categories of lithics in each collection. For methods, artifact and attribute definitions see SI Appendices 1.5–2.7.

Results

Stratigraphic Sequence

The stratigraphic sequence (Fig. 5) includes three of the four lithological units described above. The surface of the terrace exposes basal deposits (sandy clays) of Unit 4. Coarse pebble and gravel-rich deposits directly underlie and overlie the cobbles. The cobble deposit (Unit 3) formed in a high-energy environment (On-line Appendix 5 Fig. 3). Abundant fragments of sandstone in the sediments of Unit 2 show that pre-existing sediments were shallow or non-existent and the underlying bedrock (Unit 1) was susceptible to erosion. The cobble horizon may represent an extensive braided river system or alluvial fan with (seasonal) high-energy flash floods; the cobbles may originate in the Mafingi Mountains, where Basement Complex quartzite is exposed. Organic preservation is absent, reflecting the acidic nature of the soils typical of the Miombo zone (Chidumayo, 1999).

Paleoenvironmental and Depositional Context

Phytolith samples suggest an overall picture of alternating cycles of relatively wet/dry conditions associated with Miombo woodland or forest, supported by seasonal rainfall during the formation of the Unit 4 flood plain deposits at SW23B (Burke et al., 2023). The combination of low nutrient soils and woody flora affected overall biomass, which would have been low compared to other African biomes (White, 1983).

When artifact size categories defined by both maximum dimension (over or under 2 cm) and weight as well as the frequencies of surface abrasion were compared to the geological units in which the specimens were found, they yielded significant information on the depositional circumstances of the strata and provided a useful standard by which to evaluate the composition of the surface collections and the post-exposure forces acting on them. In the excavated sample including small specimens, artifact categories were distributed unevenly between the depositional units (SI Appendix 4 Table 27, $\varkappa^2$ $p \leq 0.001$), with less flakes and many more fragments being found in the sandy clay of Unit 4, and more whole flakes and cores in the Unit 3 cobbles. These differences are explicable by the statistically significant (SI Appendix 4 Table 28, $\varkappa^2$ $p \leq 0.001$) differences in artifact surface condition in the sedimentary units. In Unit 4, all specimens were either fresh or sharp, with no visible abrasion, whereas in Unit 3, a total of 51.4% were either moderately abraded, abraded or rolled although a few (4) on the top of the cobbles were fresh. Average artifact size differences were equally pronounced. The mean weight of the 83 specimens from Unit 4 was 12.82 g, the mean weight from Unit 3 and below was 61.81 g. Artifacts from Unit 3 are larger overall, and that unit also yielded larger fragmentary pieces. In Unit 3, flake fragments and angular fragments were much less common. These results agree with the geoarchaeological analysis which identified Unit 4 as the result of low energy alluvial deposition on a flood-plain and Unit 3 as a higher-energy braided river channel or alluvial fan. In those circumstances higher water flow rates differentially removed smaller lithics (Fanning & Holdaway, 2001) from the cobble deposits. Nevertheless, the presence of a few fresh flakes on the top of the cobble layer suggests that when it was exposed prior to burial, it may have served as a raw material source and occasional chipping location.

All artifacts in open-air circumstances are subject to varying degrees of disturbance by geomorphic circumstances and hydrologic processes both before (Rezek et al., 2020) and during burial (Sala, 1986) as well as after subsequent exposure by erosion (Fanning & Holdaway, 2001 and references therein). If the excavated specimens are representative of the depositional circumstances that existed at SW23B and possibly SW23A, then in the surface samples, most specimens originating from Unit 4 should not be abraded, and specimens with visible abrasion are much more likely to have eroded from Unit 3. If winnowing did not remove specimens from the surface, then roughly 40% of the surface samples should be small pieces. Horizontal disturbance by sheet-wash is influenced by the degree of slope, the volume of flowing water, and the presence of obstructions such as rocks and vegetation, in addition to the shape and size of the artifacts themselves (Keay-Bright & Boardman, 2009; Petraglia & Nash, 1987; Poesen et al., 1994; Schick, 1987). On the surface of SW23B, 928 artifacts were > 2 cm, and 130 (12.3%) were smaller. In SW23A, 25.1% were small. Winnowing by sheet flow appears to have removed a significant proportion of small lithics from both terraces, but not to the same degree.

The explanation for the differences in frequencies of small artifacts between the two samples is not yet clear. Although the geological sequences at SW23A and B appear to be the same, the gradient and surface of each terrace differs. The slope above both terraces is steep. At SW23A it is ~ 11.4% over 70 m distance, and at SW23B it is ~ 11.8% over 35 m. Both terrace surfaces are tilted as well. At SW23A, the slope to the arm of the spur where both collections were made has an average gradient of 7.3% over a 110 m transect. Tilt of the SW23B terrace is less pronounced, with a 4.0% gradient over 35 m. The surface of SW23A is less uniform. It is slightly domed and falls away toward both sides of the narrow arm of the spur (SI

Appendix 5 Fig. 4). It is also more vegetated with sapling trees as well as bushes, most having exposed roots. SW23B has a more uniform surface and tilts primarily to the South. Our initial hypothesis was that SW23A was more eroded because it was narrower and more of the Unit 3 cobble layer was exposed on its margins. However, the small artifact data partly contradict this interpretation. SW23B has the lowest percentage of small pieces on the surface (12.3%), yet it also has the lowest gradient. Because of its shape, small specimens near the center of that terrace would need to be moved longer distances before being swept into the surrounding gullies.

In contrast, sediments above the cobble layer at SW23A appear to be undergoing more rapid erosion. Larger artifacts frequently occur on splash pedestals (Poesen et al., 1994) of original sediment to which they are firmly attached, suggesting that they are in their original depositional position since once a pedestal collapses, sheet wash prevents a second pedestal from forming. Many pedestalled artifacts photographed in 2016 (SI Appendix 5, Fig. 1) were loose on the surface with the pedestals missing in 2019. New pedestalled artifacts had appeared elsewhere on the spur. No pedestaled artifacts were observed on SW23B in either year. The current SW23B surface may be more stable and currently eroding more slowly than SW23A, although the greater number of vegetation traps and the larger overall size of both large and small pieces at SW23A may account for the differences in the retention of small artifacts since specimens over 2 cm are less likely to be winnowed on gently sloping terrain (Fanning & Holdaway, 2001). Further research is planned to resolve this issue.

Spatial Analysis SW23B NS and EW Transects

A total of 1656 lithics were recorded on the surface of SW23B in 2016 and 928 artifacts were collected from the surface transects in 2019.Visual inspection of the density plots for lithic data resulting from the 2016 survey indicates some clustering (Fig. 6a) confirmed by NN analysis (NN ratio: 0.41, Z-score: − 31.96, $p = 0.000$) and kernel density mapping (Fig. 6b). These results should be treated with caution, however, given the coarse spatial resolution of the GPS devices and valid criticism of NN as a basis for identifying spatial clustering (Conolly & Lake, 2006). Lithic density is low, with an average of $N = 4$ pieces per m^2 counting only grid units with one or more lithics. In the 2019 surface collections, including small pieces, average lithic density at SW23B was 6.37/m^2, and in the collected transects at SW23A, 2.43/m^2.

Spatial analyses of the material recovered on the surface of the survey transects in 2019 (Fig. 6), including surface lithics from excavation units T2-A1, T2-B2, and T2-EXT, confirms that the lithics are not randomly distributed (NN ratio: 0.83, z-score − 3.97, $p = 0.0000$). Lithic density is low, with only 3% of the grid units yielding > 20 lithics per m^2. A maximum density of 42 lithics per m^2 occurs in a single unit located in the north end of the N/S transect (Fig. 7).

A small lithic scatter eroding out of slope deposits just over 5 m to the SW and ~ 3 m upslope of T1A1 was also documented (Fig. 3). The scatter includes 26 fragments of white quartz in a 2.65 m^2 area and could represent a single lithic reduction event with a density of 9.79 lithics per m^2. The scatter provides a potentially useful metric for the expected density of a discrete lithic reduction sequence (Fig. 8).

Although surface lithics were not randomly distributed on the SW23B terrace, within this overall distribution lithic attributes and type categories showed no spatial patterning. The surface condition of the lithics (Fig. 8a) ranges from fresh/sharp to abraded and rolled. Similarly, patinated and unpatinated lithics (Fig. 8b) co-occur in the surface deposits. Among raw materials (Fig. 8c, d), quartzite is ubiquitous. Grey and brown quartzite are the most common raw materials and are broadly distributed. White quartz is also common. Orange quartzite is less common but widely distributed. Rarer types of raw material include pink/white quartzite, chalcedony and fossil wood. Within individual grid cells and clusters of material identified using kernel density maps, and in the excavated units, raw materials are heterogeneously distributed.

Among lithic categories (Fig. 8e, f), most of the lithics recovered in the surface deposits are angular fragments, followed by flakes and fragmented flakes. Many informal cores were also identified, together

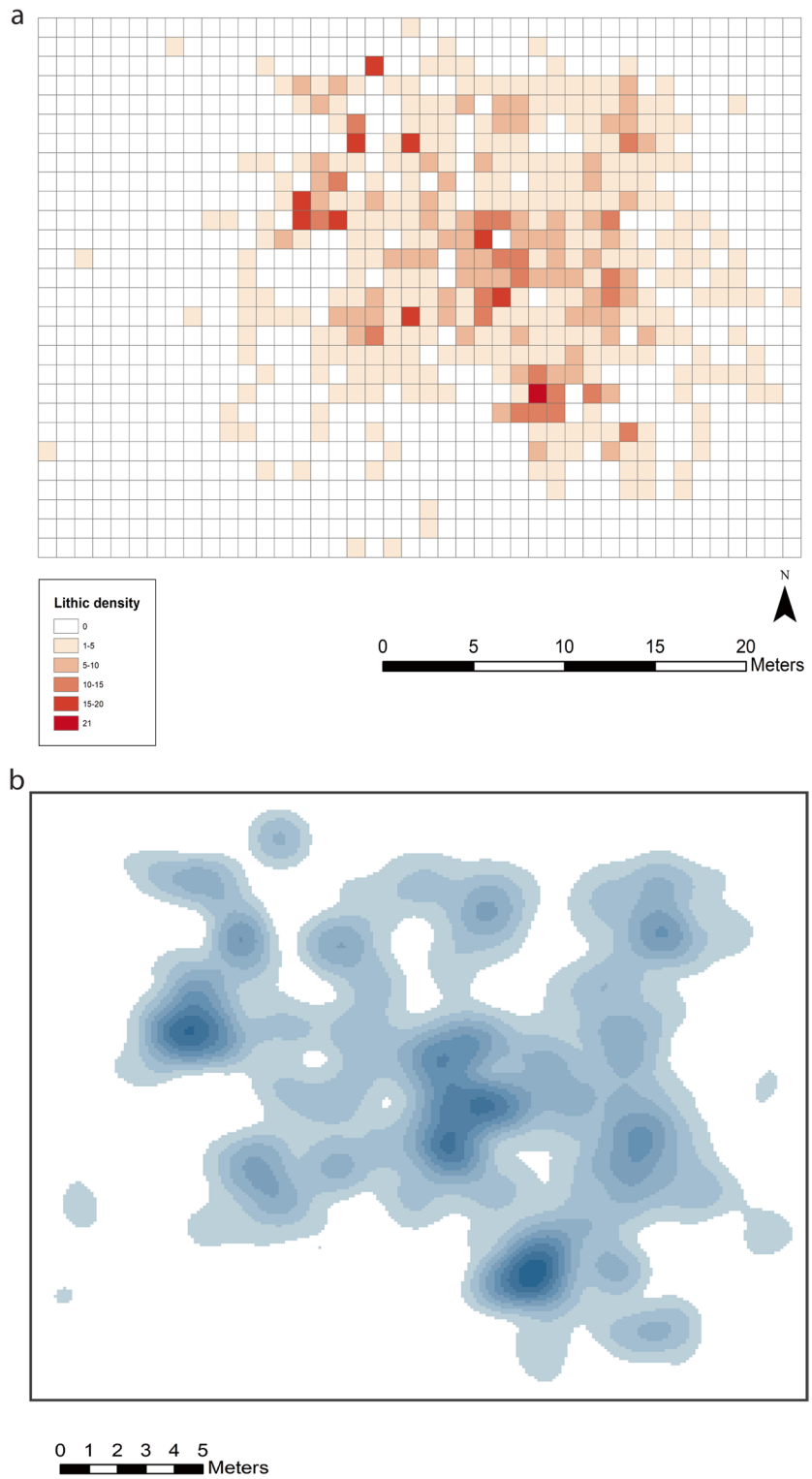

Fig. 6 Spatial distribution of artifacts on SW23B in 2016 showing clustering. **a** nearest neighbor data; **b** kernel density map

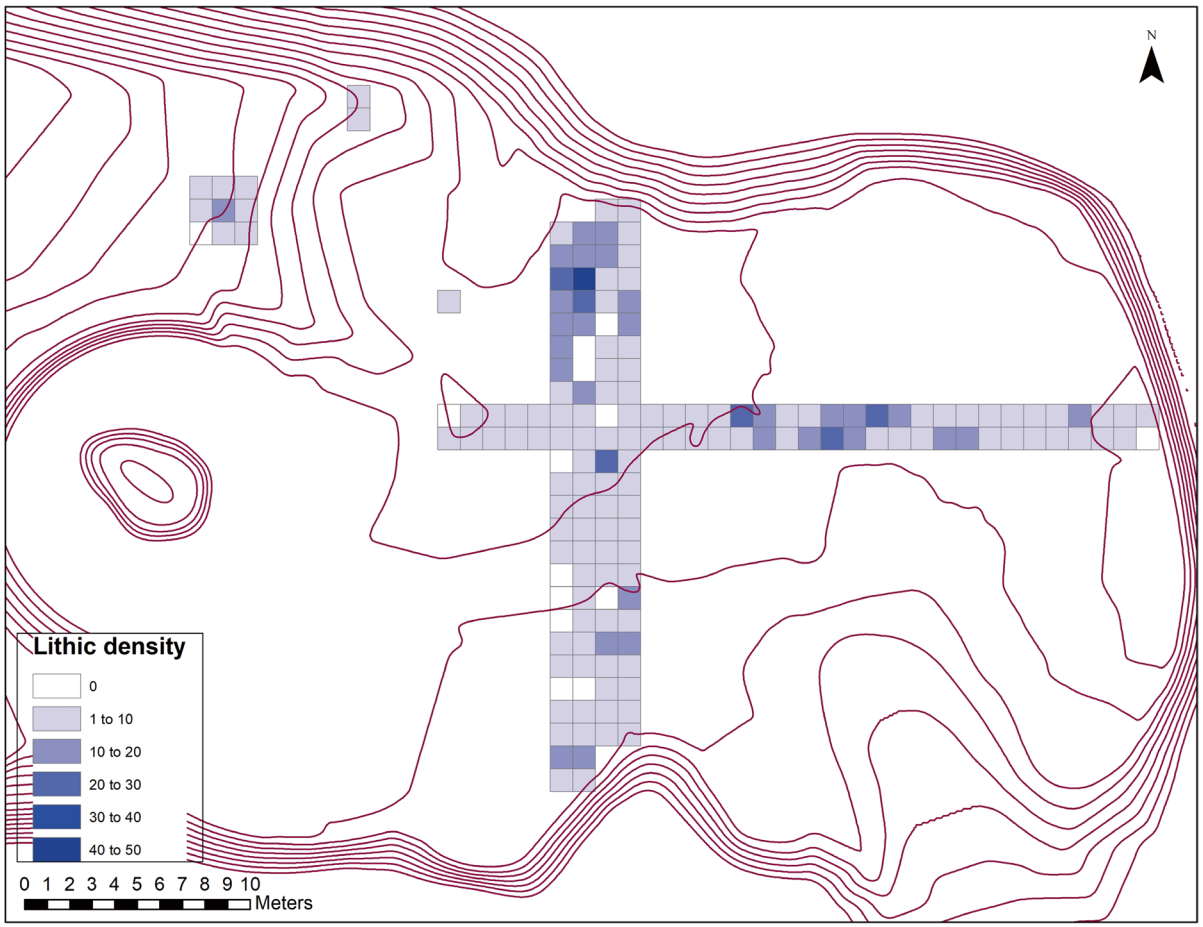

Fig. 7 Surface density of lithics in the transects collected in 2019, SW23B. Contour interval is 50 cm

with a much smaller number of formal cores, tools, Levallois elements and blades. The spatial distribution of these individual lithic categories appears random across the survey transects and the excavation units.

In summary, there is no discernible spatial patterning in the distribution of different raw materials or lithic categories in the surface deposits at SW23 and the surface condition/alteration of the lithics indicates that the material is heterogeneously affected by taphonomic processes. In other words, it likely represents a mix of materials from different initial depositional contexts and/or with different taphonomic histories. The surface material is non-randomly distributed but the small clusters of lithics observable on the surface could reflect the impact of surface topography and/or the presence of clumps of vegetation affecting run-off patterns, rather than discrete depositional events.

Excavation Units (SW23B)

T1-A1 cuts into the slope deposits (Unit 4) in the northwest quadrant of the terrace and is asymmetrical in area because of the slope angle (Figs. 4 and 5). The unit was excavated until it reached the cobble layer (Unit 3). Isolated lithics occur sporadically throughout the sediment column (Table 2) and could represent either background "noise" or the edges of discrete lithic reduction events. A small collection of lithic material ($n = 8$, including informal cores, flakes, and flake and angular fragments) was encountered at the bottom of Unit 4 in level 10 (above the cobble layer). At this point, T1-A1 has a surface area of 0.24 m^2. Lithic density in level 10, therefore, is comparable to the density recorded in the survey transects. The collection does not represent a discrete

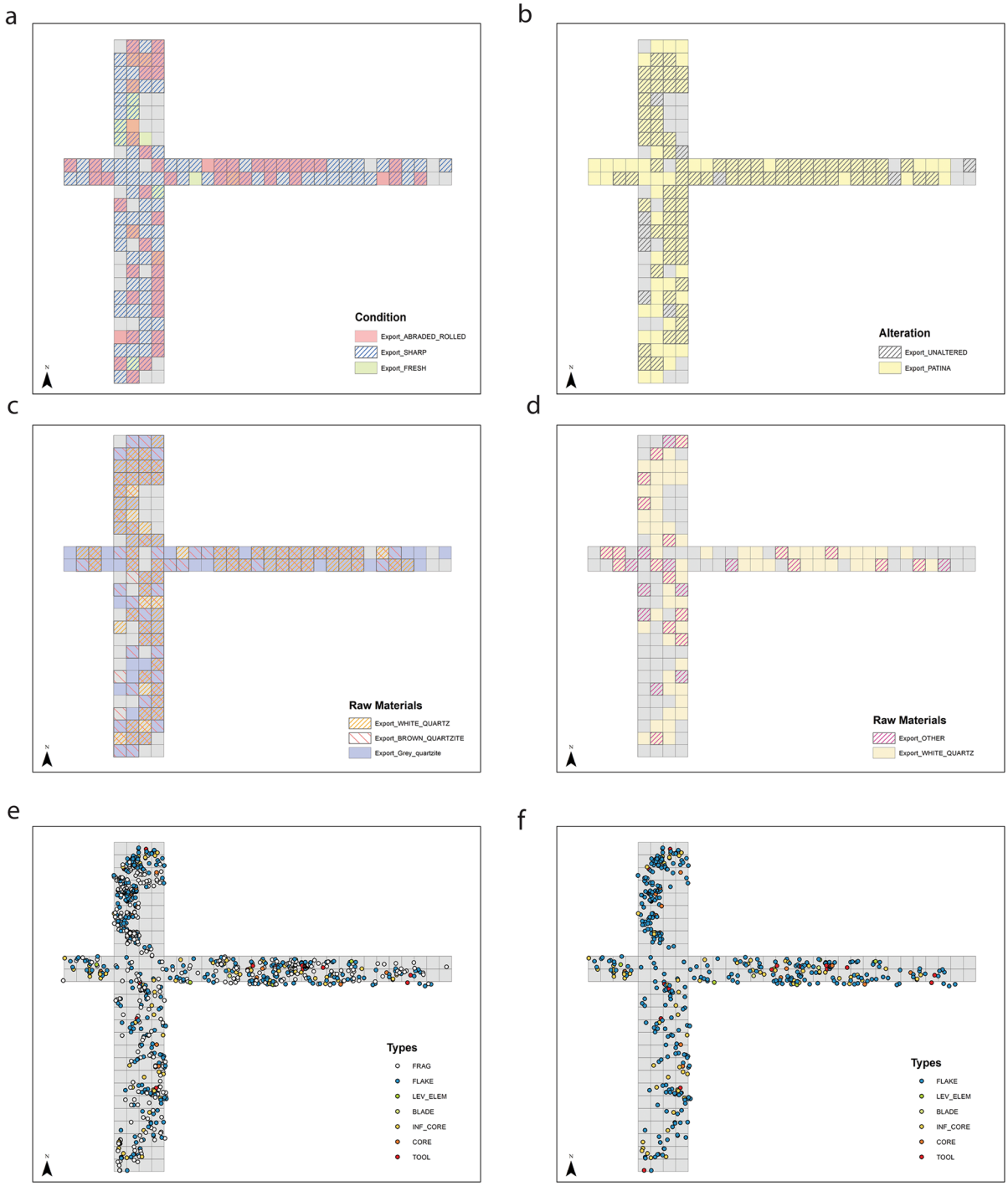

Fig. 8 Distribution of surface lithic attributes and types at SW23B, 2019 sample. Surface condition (**a**) indicates the presence and/or degree of post-depositional abrasion. Alteration (**b**) indicates the presence or absence of patination. Plots (**c** and **d**) illustrate the distribution of lithic raw material types, and categories of artifact morphological types (**e** and **f**)

lithic reduction event since the raw materials are heterogeneous.

T2-A1 yielded $n = 22$ lithics in the top 5 cm of reworked sediment, on the surface of the terrace

(level 1), and $n=3$ lithics excavated in levels 1 and 2, in Unit 4. T2-B2 yielded $n=43$ of which 16 were imbedded in the sediments on the top of level 1. Other lithics ($n=15$) were excavated in levels 2, 5, and 6 (Unit 4), all of which are either flakes, or fragments.

T2-EXT was deliberately positioned on the northern edge of the platform intersecting the cobble layer which tilts E/W toward a depression on the platform edge (Fig. 3). A total of 41 artifacts were recovered from T2-EXT (Table 2). Sub-surface lithics > 2 cm ($n=29$) were found at depths ranging from −0.35 to −0.72 m below the surface, with 8 just above the cobble layer, as well as 19 within the cobble layer, and two below it. Artifacts excavated in T2-EXT include an informal core, flakes, flake fragments, and one scraper.

The taphonomic attributes in the collection of 73 excavated artifacts > 2 cm are mixed. Specimens with Patinated/Unaltered surfaces were randomly distributed between the sedimentary units (χ^2 6.969, df 6, $p=0.324$). This suggests that the chemical environment of the sediments sampled was relatively uniform. Surface condition, however, was clearly linked to the sedimentary unit in which an artifact was found. Combining samples from all the excavations, all 44 specimens from the Unit 4 sandy clay were either fresh or sharp. None had visible abrasion. Among the 29 lithics from the more energetic depositional environment of the Unit 3 cobbles or from the top of Unit 2, 16 (55.2%) were abraded. This association of fresh/sharp lithics with Unit 4, and abraded lithics with the Unit 3 cobbles is statistically significant (χ^2 52.080, df 8, $p \leq 001$).

Table 2 Lithics recovered from SW23B excavation units: Sedimentary Unit; 4 Sandy Clay; Unit 3 Cobble Layer; Unit 2 Sandy Clay with Bedrock Fragments

Excavated unit	Sedimentary unit	Excavation level	*N* Point Loc	N screen	Total > 2 cm	*N* < 2 cm screen	Total all sizes
T1-A1	4	2	2				2
		3	1			1	2
		4				1	1
		5	2			2	4
		6	1	1		1	3
		7	1	2		1	4
		8	1			11	12
		9	1			5	6
		10	6	2		2	10
					20	24	
Total							
T2-A1	4	1	1			3	4
		2	2				2
					3	3	
Total							
T2-B2	4	1	16			4	20
		2	4			3	7
		3				1	1
		4					0
		5	1			2	3
Total					21	10	
T2-Ext	4	2–3	8			12	20
	3	2–5	18	1		0	19
	2	4–5	2			0	2
Total					29	12	
Total					73	49	122

The raw materials are varied but grey and brown quartzite dominate (75.4% total); other materials include white quartz, yellow granular quartz, pink quartzite, chalcedony, and fossil wood (SI Appendix 4, Table 28).

Lithic Analysis

SW23A Lithics

The 2019 SW23A surface collection includes 279 specimens (Table 3) of which 209 > 2 cm maximum dimension were subject to detailed analysis. Following the description of this sample we briefly discuss a few specimens analyzed in 2016 that expand our knowledge of what was present on that spur, but those selected specimens are excluded from the statistical tables or intra-site comparisons presented below. For definitions of artifact types, variables, and attributes, see Appendix 2.

Detached pieces (SI Appendix 3, Tables 1–6) including whole normal flakes, blades, and fragments of both are the most common artifacts in the collection, totaling 62.7%. In the fully analyzed sample of whole detached pieces ($n = 65$), 60 are normal flakes, only two are blades (not prismatic), two are core rejuvenation flakes and one is a typical Levallois flake. None of the whole flakes were recognizable as biface thinning flakes as defined by a diffuse bulb, thin cross section, multi-directional flake negatives on the dorsal face and a narrow, faceted platform (Odell, 2004). Five of the flakes are cobble opening flakes, totally cortical on their dorsal surfaces and platform. Another 7 specimens have totally cortical dorsal faces. Among dorsal scar patterns, unidirectional are more than half of all cases followed by opposed, convergent and radial, all with less than 12%. The most common striking platform patterns are plain (40.0%), followed by cortical (35.4%) and simple facet (15.4%). Detachments (Speth, 1972) are predominantly

Table 3 Artifact categories of all specimens including < 2 cm from the excavated and surface collections at the SW23 locality, 2019 season. In the analysis below, some of these categories (Flake, Informal Core, Handaxe, and Retouched Flake Tool) are further subdivided into specific types

Category	SW23A Surface *N*	%	SW23B excavated *N*	%	SW23B surface *N*	%	Total *N*
Flake	75	26.9	40	32.8	351	33.2	466
Blade	2	0.7	0		7	0.7	9
Flake Fragment	96	34.5	57	46.7	352	33.2	505
Prismatic Blade Frag	0		0		2	0.2	2
Blade Fragment	1	0.3	0		10	1.0	11
Levallois Flake	1	0.3	0		24	2.3	25
Levallois Point	0		0		2	0.2	2
Levallois Flake Frag	0		0		1	0.1	1
Informal Core	18	6.4	4	3.3	74	6.9	96
Levallois Core	0		0		2	0.2	2
Radial Core	5	1.8	0		11	1.0	16
Blade Core	0		0		1	0.1	1
Angular Fragment	58	20.8	20	16.4	182	17.2	260
Handaxe	4	1.4	0		1	0.1	5
Bifacial Cleaver	0		0		1	0.1	1
Core-Axe	1	0.3	0		2	0.2	3
Pick	1	0.3	0		4	0.4	5
Split Cobble	15	6.1	0		15	1.4	30
Hammer Stone	1	0.3	0		2	0.2	3
Pitted Anvil	0		0		1	0.1	1
Retouched Flake Tool	0		1	0.8	13	1.2	14
Other	1	0.3	0		0		1
Total	279	100.0	122	100.0	1058	100.0	1459

Hertzian cones (93.8%) but some lip detachments are present (6.2%). Only 27.7% of detached pieces are non-cortical, 53.8% are partly cortical and 2 are naturally backed. Average length is 40.76 mm, width is 40.44 mm, thickness is 13.12 mm, and platform thickness is 8.33 mm. The length/width ratio is 1.007. Weight is 27.33 g.

The single Levallois flake in the SW23A sample (Fig. 9a) requires special mention. It is fine-grained gray quartzite and the largest Levallois

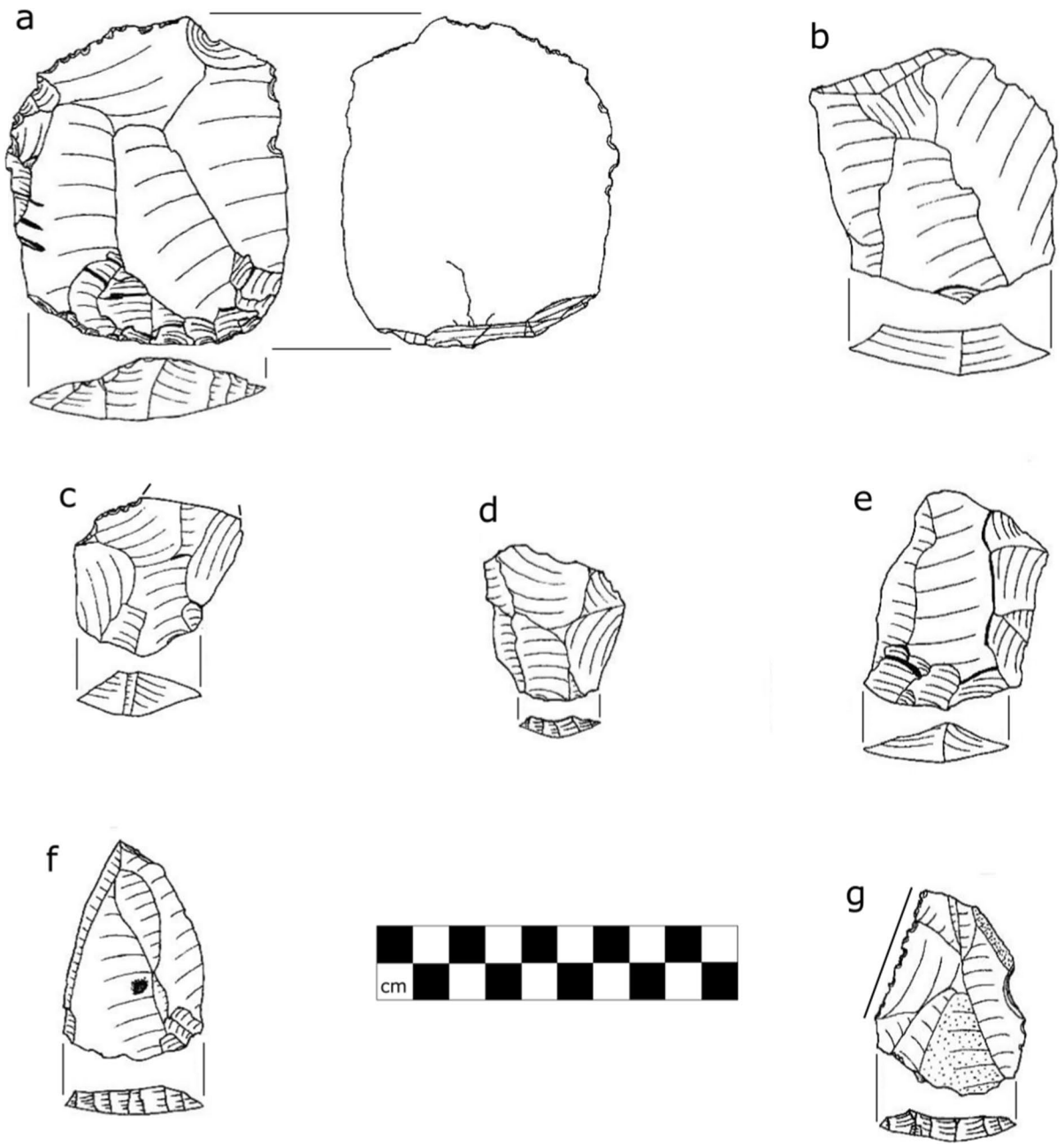

Fig. 9 Levallois products. **a** Levallois flake; **b–e** Levallois flakes; **f** Levallois point found adjacent to specimen; **d**, **g** atypical Levallois point line on left distal edge indicates possible utilization damage. SW23A (**a**). SW23B (**b–g**). Gray quartzite (**a**, **b**, **e**, **g**). Orange quartzite (**d**, **f**). White quartz (**c**)

product in the collections (length = 89.5 mm, weight = 137.8 g). It is extremely well executed, with a broad, thick, slightly convex platform crossed by six facets. Exterior preparation involved five major flake scars originating from three directions. Small scars on the dorsal edge of the platform show careful trimming to prevent overhang. With its blunt platform end, straight sides, and moderately convex distal end this piece resembles a "cleaver flake" (Clark & Kleindienst, 1974:95), defined as a large prepared-core flake with some lateral retouch that was used as a cleaver, but in this case without retouch. There is extensive macroscopic edge damage (flaking) that may represent utilization on the distal and right lateral edges. The specimen rested on a short sandy pedestal of Unit 4 sediment on the terrace surface. A few smaller Levallois flakes were photographed at SW23A but were not within the collected transects.

Cores (Fig. 10; SI Appendix 3, Tables 7–10) and core by-products (core or angular fragments) constitute 26.8% of the SW23A sample of artifacts > 2 cm. No whole cores had maximum dimensions under 2 cm. Including small pieces, the frequency of core or angular fragments is 15.8% of the total collection. The 23 complete cores are primarily simple forms and, in many cases minimally reduced, which is consistent with the high percentage of flakes with cortex. Informal cores are most common (34.8%), followed by single platform (21.7%). Partial radial 13.8%, radial pyramidal (8.7%), 2 platform (8.7%), core on flake (8.7%), and multiple platform (4.3%) cores are also present. Cortex was present on all but two cores (91.3%), and because of the limited number of flake removals in most cases, the initial shape of the raw material clast could be determined in all but one case. Cobbles were the source for 73.9% of cores followed by angular water-abraded chunks (13.0%), and large, thick flakes (8.7%). Raw material was brown (56.5%) and gray (30.5%) quartzite followed by white quartz (13.0%). Mean core debitage face length was 93.49 mm and face width 70.52 mm. The face length/face width ratio was 1.33, more elongated than the 1.007 length/width ratio of the whole detached products. Mean weight was 382.46 g.

Larger tools from SW23A (SI Appendix 3, Table 11) include four handaxes (Fig. 11), one convergent sided core-axe, one pick, one hammerstone, and 15 split cobbles. One is a superbly executed elongated oval handaxe made on a large side-struck flake (Fig. 11a). It has a lenticular cross section and slight S-twist. All the bifacial retouch scars are thin removals. The lateral edges and rounded tip of this specimen are sharp, with edge angles between 20° and 25°. Tiny flake scars around the perimeter may represent utilization, or post-depositional damage (Sala, 1986), but there is no abrasion. The lithic raw material of this specimen, a very dark brown fine-grained quartzite, is rare at this locality. As mentioned above, biface retouch flakes were absent from 2019 SW23A sample. A single specimen, recorded in 2016, was identical to the raw material of this handaxe but did not refit to it.

The other three handaxes are not as well executed, which may be a consequence of the shape of the raw material employed. One is an elongated ovate with a cortical butt (Fig. 11b). This specimen was finished with thin invasive retouch flakes. Two thinning flake scars on the tip are slightly less patinated than all others, showing that this tool was re-sharpened after it had been exposed to weathering for an unknown period. The other two handaxes are lanceolate forms retouched with a combination of short and deep scars and thinner, more invasive scars. One is made on a cobble and has a cortical butt (Fig. 11c). It was found on the surface of Unit 4, roughly one meter above the estimated position of the cobble layer. The other (Fig. 11d) is made on a naturally split abraded chunk of fossil wood. The tip of this specimen is missing due to an ancient break, probably during manufacture. The tip and retouch flakes were not found.

Split cobbles and pebbles (SI Appendix 3, Tables 12–15) constitute 15 (5.4%) of the SW23A collection, and more than half of the large artifacts excluding cores. In this group, only one is a split pebble (< 64 mm). Two are white quartz, 13 are brown or gray quartzite. At least 12 began as elongated water-smoothed clasts with cylindrical or oval cross sections (Fig. 12f). In most cases a single perpendicular (possibly bipolar) blow initiated a shear fracture that detached the end of the cobble creating a flat facet rather than a negative flake-scar. This facet is usually transverse,

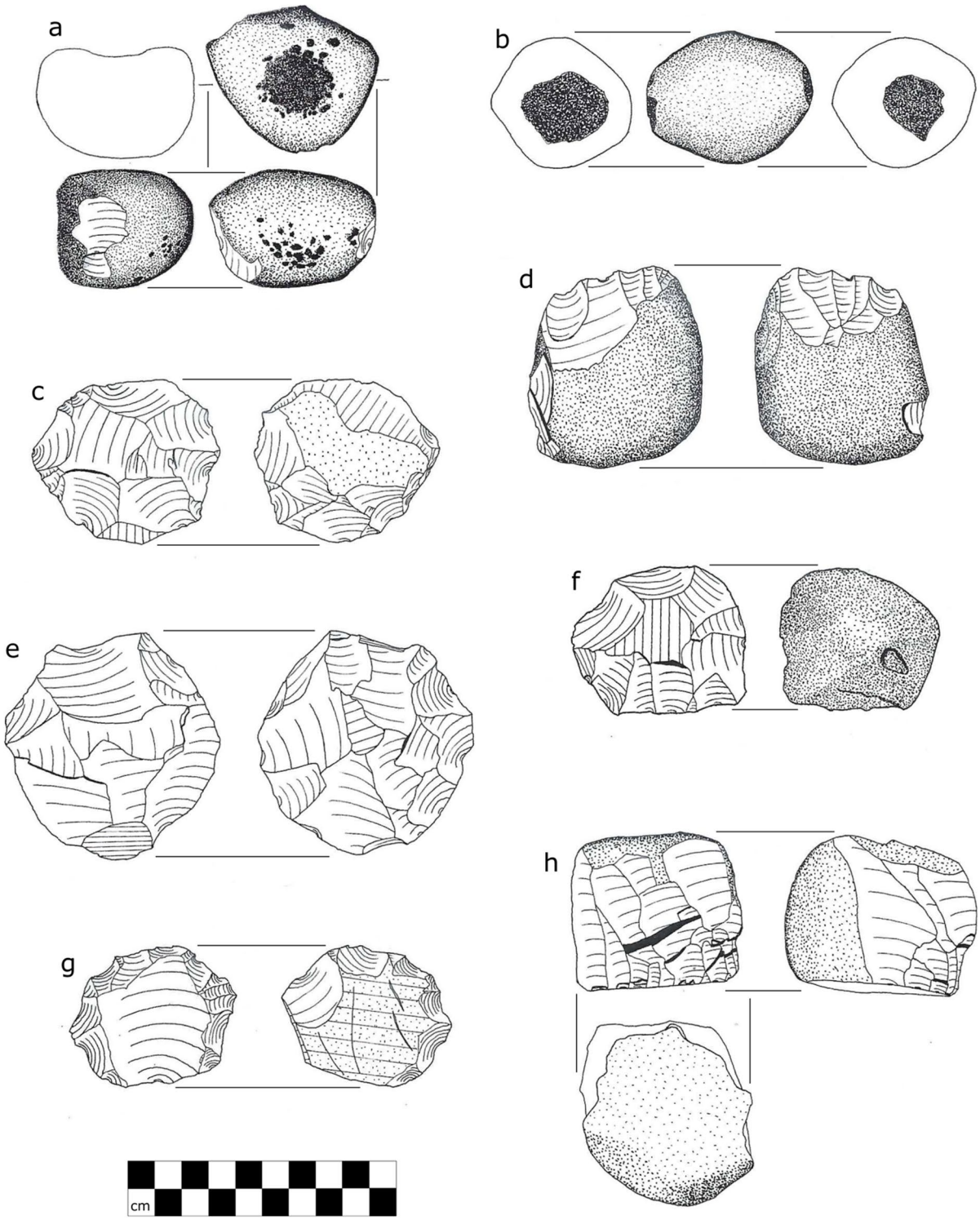

Fig. 10 Cores and Hammerstones; **a** "dimpled" anvil with battering showing occasional use as a hammerstone; **b** hammerstone with battering on both ends; **c** radial core, bifacial; **d** bifacial single platform core ("chopping tool"); **e** radial core, bifacial; **f** unifacial radial core made on a split cobble spall; **g** Levallois flake core; **h** single platform core. SW23A (**b**, **d**, **e**). SW23B (**a**, **c**, **f**–**h**). Quartzite (**a**–**c**, **e**, **f**, **h**). White quartz (**d**, **g**)

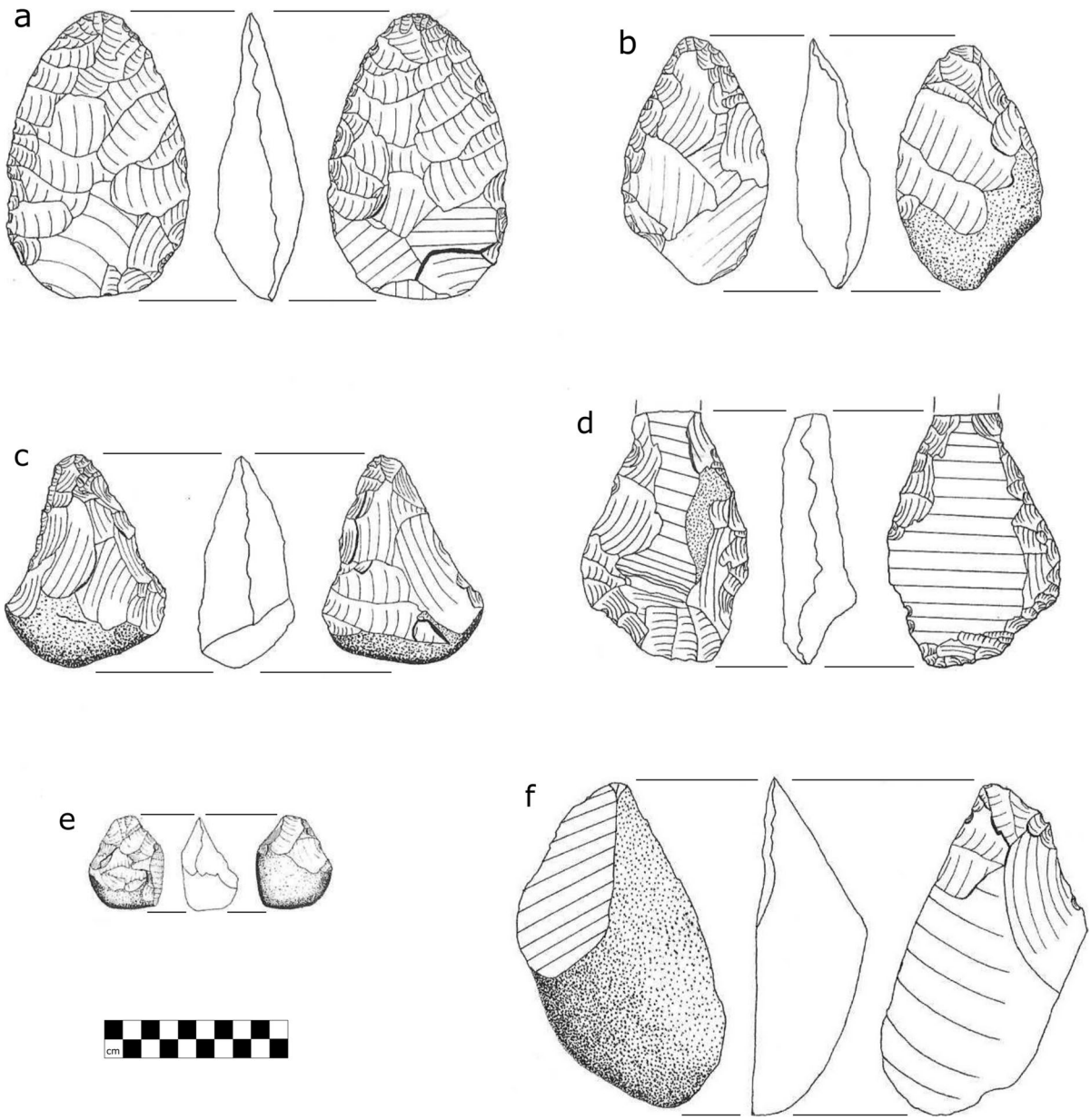

Fig. 11 Large cutting tools: **a** Handaxe made on a giant flake; **b** Handaxe made on a split cobble; **c** handaxe made on a cobble; **d** handaxe (tip missing) made on a naturally split flat spall; **e** bifacial cleaver, diminutive, made on a small cobble or large pebble. **f** Unifacial handaxe on a split cobble spall. SW23A (**a**–**d**). SW23B (**e**–**f**). Quartzite (**a**–**c**, **e**–**f**). Fossil wood (**d**)

but sometimes slightly oblique to the long axis of the piece. In a few cases, multiple bipolar blows created this facet, which appears to be the desired feature of these artifacts. In no cases was the facet used as a platform to strike flakes from the side of the piece as has been observed in other Zambian and Malawian Stone Age contexts (Clark et al., 2001; Colton et al., 2021; Thompson et al., 2014), Most are elongated, with a mean length/width ratio of 1.51, and only three specimens had a length/width ratio under 1.3. Lengths averaged 100.2 mm and weights ranged from 64.3 g to 1355.8 g (avg. = 541.9 g).

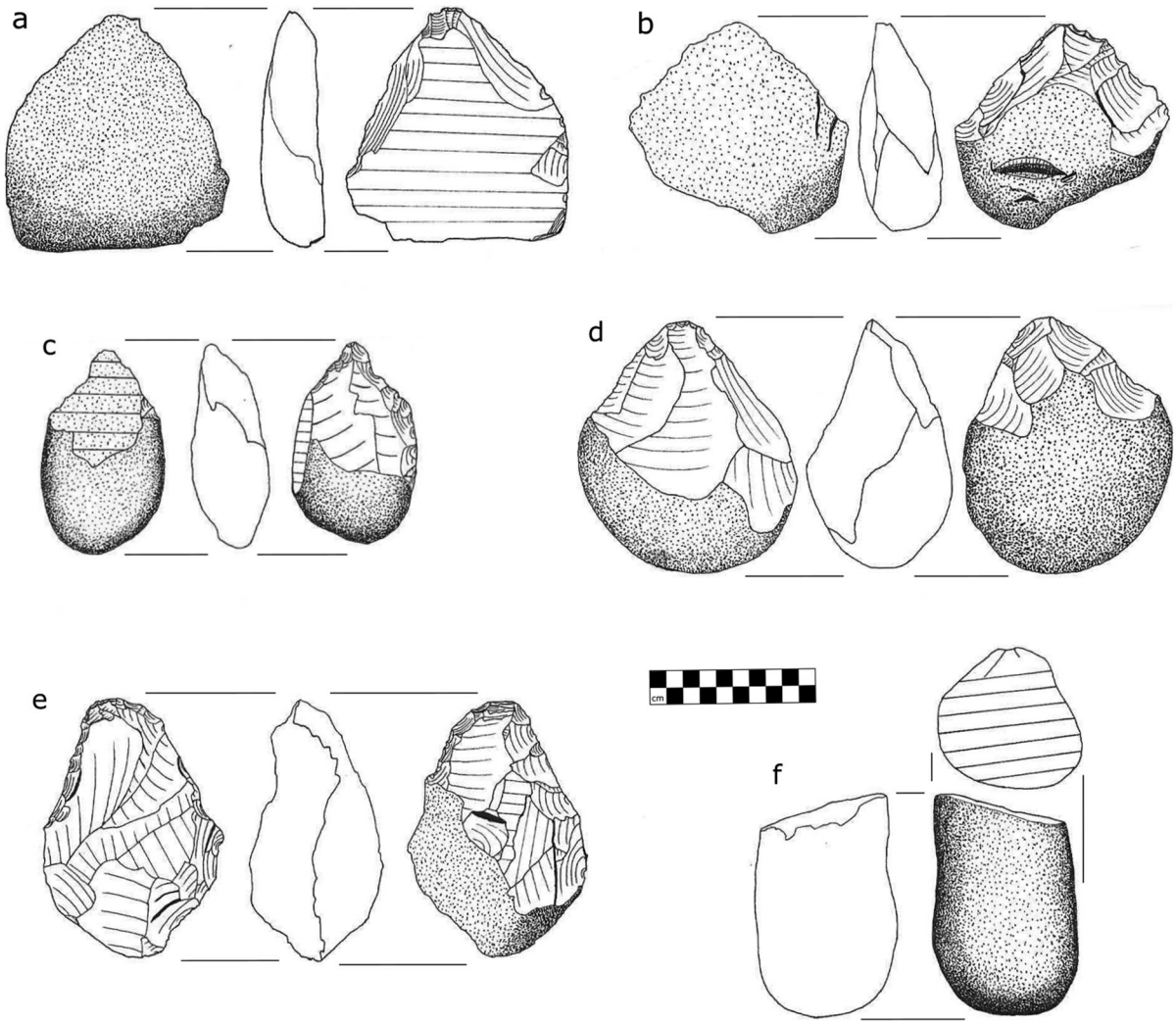

Fig. 12 Heavy-duty tools. **a**–**c** Picks; **d**, **e** Core-axes; **f** elongated transversely split cobble. SW23A (**b**, **d**, **f**). SW23B (**a**, **c**, **e**). Quartzite (**a**–**f**)

SW23B Lithics

There are two samples from SW23B. An excavation sample includes 122 imbedded specimens found in the four test pits. Of these, 49 were < 2 cm maximum dimension, and 73 exceeded 2 cm. The larger sample includes 1058 specimens that were loose on the surface of the test pits and on the two collected survey transects. These included 928 large enough for full analysis, and 130 < 2 cm. These two samples were initially treated separately because the surface specimens are a winnowed lag deposit of material in which each specimen could have originated from any part of the ~ 10-m thickness of Unit 4 sediments above the terraces as well as the upper portion of Unit 3 that was exposed on the edges of the terrace and at isolated places near the center of the terrace. The excavated sample included a majority (68.1%) from the Unit 4 sandy clay, with specimens from Unit 3 (30.3%) only being from the bottom of pit T1-A1, and from T2-EXT (Table 2).

The smaller excavated sample is less typologically diverse (Premo, 2014). It includes only 5 artifact categories as opposed to 20 in the surface collection (Table 3). Flake fragments are most common (46.7%), followed by whole detached

pieces (32.8%), and angular fragments (16.4%). Four cores and one scraper complete the inventory. Among the 40 whole detached pieces, there are 39 normal flakes and one pointed flake. Platforms are 71% plain, 19.4% cortical, and 3.2% simple facet. Excluding the 13.9% fully cortical dorsal faces, most scar patterns are unidirectional (71.0%) or two directions irregular (19.3%). Cortex was present on 72.2% of flakes, one of which was a cobble opening flake. Quartzite constituted 90% of the sample, with the rest being quartz. Identifiable detachments are predominantly hertzian cones. Average flake length is 43.4 mm, width 37.5 mm (L/W ratio 1.16), and weight 40.6 g.

The four cores from the excavations (SI Appendix 3: Tables 7–10) all come from the deepest levels of pits T1-A1, T2-B2, and T2-EXT. All are made of quartzite. Two were in Unit 3, and one was in the coarse sandy clay immediately above Unit 3. They are all simple and three are minimally reduced. Types include two single platform specimens made on small cobbles, one double platform and one multiple platforms, both made on water abraded angular chunks. Surface condition reflects their sedimentary origin. Of the three cores from the cobble layer, one was worn, and another rolled. The specimen from Unit 4 was fresh. All cores were found in layers that had higher numbers of artifacts, but they were not surrounded by enough smaller debris to demonstrate chipping at that location. The two abraded cores had probably been fluvially transported from their original place of discard. Lack of small debris around the specimen from Unit 4 shows that either it had been moved from its last point of use, or that fluvial winnowing had displaced any associated chipping debris.

The single excavated formal tool (Fig. 13(i)) was recovered from within the cobble layer. It is a large (< 30 mm) lateral scraper made on a thick pink-white quartzite partially cortical flake blank. Although found in depositional Unit 3, the surface condition of this piece was sharp.

The surface sample from SW23B totals 1058 specimens including small pieces (Table 3, SI Appendix 3, Tables 1–21). Whole and fragmentary detached pieces are the most common (72.1%), followed by cores and angular fragments (24.5%), split cobbles (1.2%), retouched flake tools (1.2%), shaped large tools including core-axes, picks and two unusual large cutting tools (LCTs) (0.6%). Other implements include hammerstones and a dimpled anvil (0.3%). There are 65 specimens (5.5%) that are potentially techno-typologically and/or temporally diagnostic. Few of the surface specimens were abraded. Fresh and sharp specimens totaled 88.0%. Most of the remainder were only moderately worn, while less than 3% were worn or rolled. Chemical alteration of artifact surfaces was absent on 36.8% of the collection. Most were patinated (50.6%), and a few (0.3%) were double patinated. The most common raw material was quartzite (62.1%) followed by quartz (34.3%), fossil wood, and chalcedony (3.6%).

Among the 397 whole detached pieces in the SW23B surface sample of specimens > 2 cm (SI Appendix 3, Tables 1–6), most were normal flakes (86.9%) followed distantly by Levallois products (6.0%, 25 flakes and 2 points). Pointed flakes (3.0%), blades (none prismatic), and core rejuvenation flakes (1.8% each) are present. A bipolar flake and a Kombewa flake complete the inventory. Striking platforms are plain (53.5%), cortical (24.1%), with simple facet and multiple faceted platforms combining for 21.0%. Dorsal scar patterns were predominantly unidirectional (47.4%), two directions irregular (19.6%), and radial (13.7%). Cortex was present on 63.8% of the sample of which 10.2% were totally cortical, 41.9% partially cortical, and 11.7% naturally backed. Fourteen were cobble-opening flakes (3.7%). Detachments were hertzian cones (91.8%) and a few lip forms. Other than the few blades, most flakes were short. Length averaged 40.59 mm, width 36.80 mm (L/W = 1.10), and thickness 12.4 mm. Mean weight was 29.4 g.

Like SW23A, the core types in the SW23B surface sample ($N = 88$) were the results of simple reduction sequences (SI Appendix 3 Table 7). Single platform cores were the most common (29.6%) followed closely by informal (28.4%) and two platform (22.7%). Radial pyramidal and partial radial together total 10.2%. No other types are represented by more than two specimens. These include opposed platform, Levallois, core on flake, multiple platform, and blade cores. Combined, all types defined by the number of platforms (Tryon, 2006) total 55.7%. Cortex was present on 95.5% of cores.

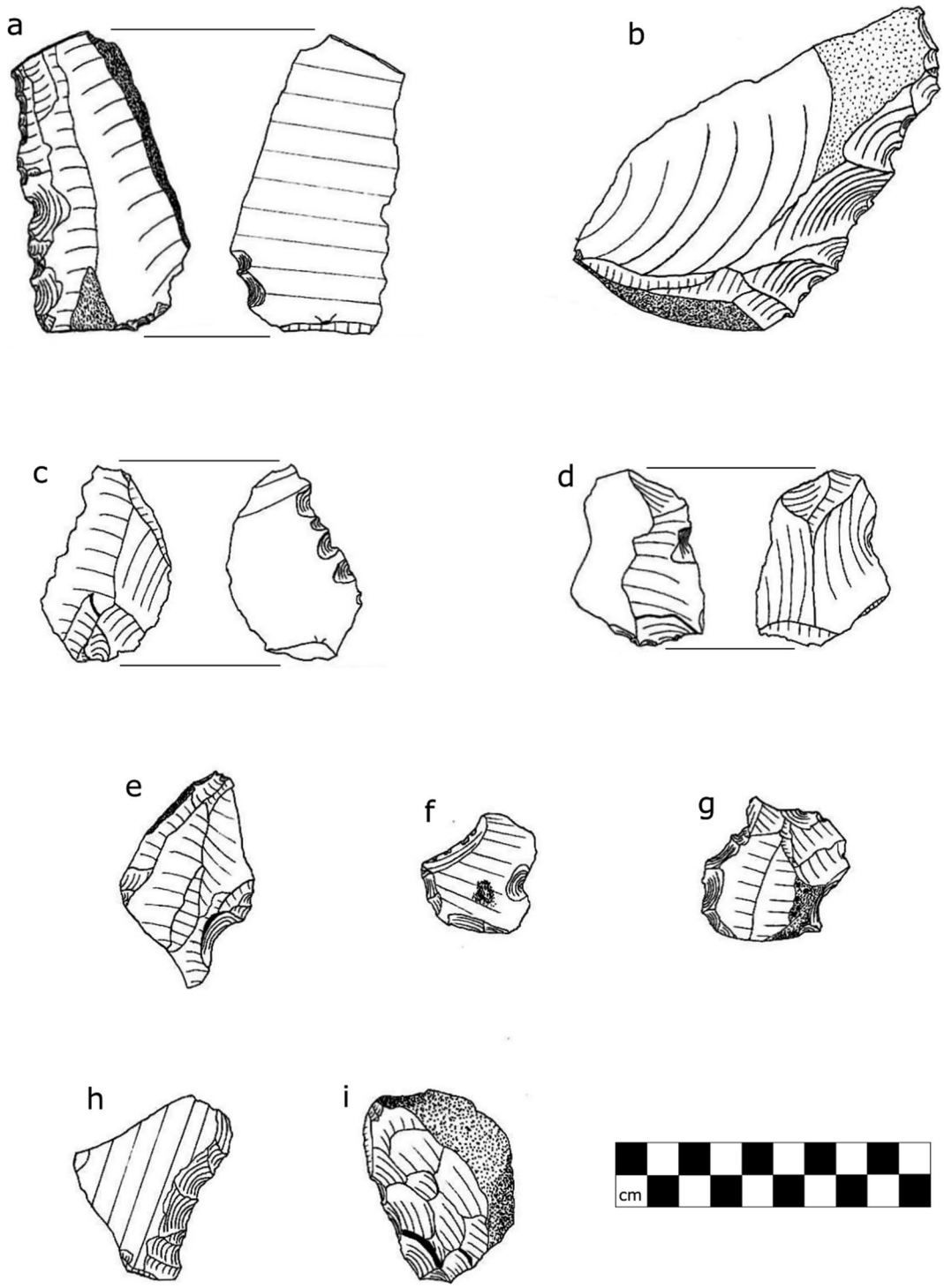

Fig. 13 Retouched flake tools: **a**–**c** Denticulates, **c** is on the interior face; **d**, **e** notch tools; **f** double notch tool; **g** double borer; **h** concave scraper; **i** straight scraper, SW23B (**a**–**i**). Quartzite (**b**–**i**). Fossil wood (**a**)

Because many cores were minimally reduced, the original form of the raw material clasts could be inferred in 96.6% of specimens. Most cores began as cobbles or pebbles (76.5%) or water abraded angular clasts (21.2%). Only one was a unifacial radial form made on a hemispherical split cobble spall (Fig. 10(f)). Eight kinds of raw materials were employed of which gray and brown quartzite plus white quartz were most common. Core face length averaged 72.93 mm and width was 66.28 mm. The face length/width ratio of 1.10 was identical to the L/W ratio of detached pieces. Thickness was 41.15 mm and weight averaged 276.99 g. Taken together, these flake and core data show that the expedient exploitation of water-worn clasts using direct percussion was the dominant technology at the SW23B locality and created normal flakes from simple and often minimally reduced cores.

Retouched flake tools (Fig. 13, SI Appendix 3 Tables 16–19) were classified using the typology employed by Barham (2000) to describe Zambian MSA artifacts. All specimens in the SW23B surface collection are unifacial and include regularized scraper edges, single notches, denticulates, and a double borer. All are large (>3 cm) in the context of the MSA typology. However, only one, a denticulate, would qualify as large (>10 cm) in an ESA context (Clark et al., 2001). Six are convex side forms including the excavated specimen. The two other scrapers include one concave form, and a convex form retouched on the ventral face. There are two single notch tools and three denticulates. Retouch is located on the dorsal face on 12 specimens, ventral face on one and both faces on one. Blanks are predominantly whole flakes, but two of the denticulates were made on large, elongated pieces, one a fossil wood blade, and the other a very broad side-struck flake. Average dimensions for flake tools are length 58.9 mm; width 44.8 mm; thickness 17.4 mm; and weight 59.7 g. The more elongated nature (length/width = 1.31) of the retouched tools compared to whole flakes is a consequence of the two elongated denticulates, which were much larger than the other retouched tools. Cortex was present on only 42.9% of retouched tools, the lowest frequency of all the lithic categories.

There were 11 shaped large tools in the SW23B surface collection (SI Appendix 3, Table 11) including four picks, two core-axes, two hammerstones, a pitted anvil and two LCTs, both unusual in a Zambian context (Clark et al., 2001). Heavy-duty types include the four picks and two core-axes. The picks (Fig. 12(a–c)) are made on tabular quartzite cobbles or longitudinally split cobbles/boulders. They average 122.8 mm in length and 720 g in weight. All have triangular cross sections and converging retouched sides ending in a pointed tip in three cases and a narrow-rounded tip in the other. Three are unifacially retouched, and one is bifacial. All are made on water worn quartzite clasts including two on artificially split cobbles. Most of the perimeter of these specimens is unworked. Retouch is large flake scars with deep negative bulbs and restricted to creating the tip. On one unifacial specimen (Fig. 12a) the retouch flakes are struck from the ventral surface of the large and flat split cobble blank. The thick, rounded, and cortical butts of all four are ideal for manual prehension and are impossible to haft. On the largest specimen, there is a single expanding flake removal originating at the tip that may be use damage from a powerful perpendicular blow on a resistant material. The tips of two other picks bear crushing that may also represent utilization damage.

One of the core-axes is made on a thick oval quartzite cobble, with bifacial flaking on roughly half of the perimeter creating converging straight edges and a narrow, rounded tip opposite a thick, cortical butt (Fig. 12d). The other (Fig. 12e) is made on an abraded angular chunk of quartzite. It is bifacially flaked over all of one face and roughly 60% of the other. The sides taper to a broad, rounded tip. There is extensive primarily unifacial crushing on the bit of this specimen consistent with oblique impacts on a resistant material. On both core-axes, deep flake scars produce a sinuous edge, and the cross section of the flaked portion is biconvex. These are massive tools, with an average length of 150.1 mm and weight of 1288.4 g. Like the picks, the thick cross sections and cortical butts would prevent hafting.

The two other cutting tools from SW23B are atypical. One is a small bifacially flaked quartzite cobble shaped into a cutting tool with converging sides and a sharp, slightly convex canted bit (Fig. 11e). This tool is only 62.6 mm in length and weighs 117.8 g. There is no macroscopic damage on the bit or edges. Morphologically, the flaked portion of this tool is a bifacial cleaver that resembles those common in the Late Lower Paleolithic of the Levant (Shimelmitz & Kuhn, 2017 and references therein). In an African context, it

is unusual because of its small size, unfinished butt, and the cobble from which it was made. Most African cleavers are made on giant flakes (Sharon et al., 2009). The other LCT (Fig. 11f) was made on a large plano-convex spall (173 mm long) split from an elongated cobble or boulder. There is a single large flake scar, removed prior to the cobble being split, on the convex cortical face of the spall. This scar extends along half of one edge, creating a canted point on the thinner end of the piece. The rest of the dorsal face is smooth abraded cortex. The pointed end has been unifacially thinned by seven invasive flakes all struck from the ventral face creating two sharp cutting edges converging at the point. The edges of this tool are undamaged. This specimen is classified as an atypical unifacial handaxe, and it does not match any of the common African handaxe categories (Kleindienst, 1962) since unifacial handaxes in both East and South Africa are usually shaped by retouch on the dorsal rather than the ventral surface of the flake or split cobble spall (Beyene et al., 2013; Kuman et al., 2020; Li et al., 2016). Other handaxes made by this novel technique were recorded at both SW23A and a nearby site (SW60) in 2016 and are described elsewhere (Burke et al., 2023).

Two hammerstones were collected, small quartzite cobbles with battering on one or more narrow surfaces (Fig. 10b). One had two flake removals as well as a battered area and may be a re-purposed casual core, but the flake removals could have been intended to adjust the weight of the hammer and/or to accommodate easy manual prehension. The battered area was opposite the flake removals. The weight of the hammerstones averaged 319.8 g. A pitted (dimpled) anvil (Fig. 10a) was also found. This was a large quartzite pebble with one natural flat surface that has a 3-cm-diameter pecked depression in the center. There are three other areas on this pebble with impact marks suggesting its occasional use as a hammer. A dimple can be formed by use as the anvil in bipolar production of small flakes (Clark, 1974; Odell, 2004), but little other potential evidence of bipolar technology exists in this collection except for the split cobbles, which are too large to have created this feature. This specimen differs from pitted anvils found in Sangoan and Lupemban contexts at Kalambo Falls because the dimpled face at those sites was also abraded, showing that those artifacts were also used as grinding stones (Clark et al., 2001).

Like SW23A, data gathering during both seasons the surface sample from SW23B included 15 split clasts of which 14 were cobbles and one was a pebble (Appendix 3, Tables 17–20). Quartzite (86.7%) was the raw material in all but two cases, which were white quartz. Surface condition was sharp (80%) or only slightly abraded. Like the SW23A sample, almost all are elongated, with an average length/width ratio of 1.42. Also, like SW23A, these split cobbles showed no signs of subsequent flaking, although one probable end-spall from a split cobble was transformed into a unifacial radial core (Fig. 10f). Split cobbles at SW23B were significantly smaller than those from SW23A. Mean weight was 251.6 g at SW23B, and 447.6 g at SW23A (*T* test p 0.037).

It is important to differentiate split cobbles as an artifact type from the technique of cobble splitting as part of the manufacture of other artifact categories. Split cobbles as a type have been considered a defining trait of the Early Acheulean (Biberson, 1961), but they occur in other contexts including the EMSA, possibly linked to testing the suitability of clasts for subsequent exploitation as a lithic resource (Cornelissen, 1992; Thompson et al., 2014; Tryon, 2006). Cobble splitting as a first stage in the production of single platform or radial cores occurs in the ESA and continues into later periods in variable frequencies (McBrearty & Tryon, 2006). This was undoubtedly influenced by the nature of the available raw material. If local stone is restricted to thick water-rounded clasts, then breaking them to create a platform surface would be an essential first step in most manufacture sequences. For cores, this strategy was absent at SW23A and barely present at SW23B. However, some handaxes and picks were made on large spalls from longitudinally split cobbles. Given the pattern of selecting elongated raw material clasts and creating a flat transverse split with no subsequent modification, it is likely that this form was a deliberate product. No evidence of battering or other damage indicative of use as either an anvil or hammer (Cornelissen, 1992) was found on the surface or edge of the facets, so the use of these artifacts remains unknown.

Small Lithics

Seventy small lithics were recovered in SW23A and 179 in SW23B, of which 49 were from the excavations (Table 4, SI Appendix 3 Tables 20–21).

Table 4 Frequencies of small (<2 cm) lithics in the 2019 collections. These were excluded from the detailed techno-typological analysis

Category	SW23A		SW23B excavated		SW23B surface		Total	
	N	%	*N*	%	*N*	%	*N*	%
Flake	14	20.0	4	8.2	13	10.0	31	12.5
Flake fragment	29	41.5	31	63.2	82	63.1	142	57.0
Blade	1	1.4	0	0	0	0	1	0.4
Angular fragment	25	35.7	14	28.6	35	26.9	74	29.7
Split pebble	1	1.4	0	0	0	0	1	0.4
Total	70	100.0	49	100.0	130	100.0	249	100.0

Each specimen was categorized, weighed and the raw material was recorded. The three samples are primarily debris (flake and angular fragments), which range from 77.2% in SW23A to 91.8% of specimens in the SW23B excavated sample. The remainder are whole flakes and a single split pebble. There are no retouched microliths. Average weight of small pieces at SW23A is 2.99 g, in the SW23B excavated sample, 1.01 g, and in the surface sample 1.92 g. White quartz was the most common raw material in the surface collections from SW23A (42.9%) and SW23B (68.5%) followed by brown and gray quartzite, but in the excavations, white quartz was only 6.1% and quartzite totaled nearly 90%. The samples from SW23A and B differ significantly in a similar way to differences evident in the samples of larger artifacts. Whole small flakes and angular fragments are proportionally more common at SW23A, and flake fragments more common in SW23B (χ^2 15.660, df 4, $p=0.004$). Lithic raw materials also differ significantly but only when the surface small specimens are included, with SW23A having proportionally more quartzite and SW23B having more white quartz (χ^2 18.604, df 5, $p=0.002$). When the excavated specimens are included in the SW23B sample, these raw material differences are no longer significant (χ^2 6.960, df 5, $p=0.224$). These two variables are interdependent. White quartz is more prone to breakage (Luedtke, 1992), resulting in the higher frequency of flake fragments in SW23B. In addition to providing clues to site formation processes and the degree of post-exposure disturbance discussed earlier, when combined with frequency of cortex and striking platform morphology, the relative numbers and characteristics of small lithic specimens are potentially relevant to understanding stages of lithic reduction, as well as site function and provisioning strategies. These issues are covered in the discussion below.

Comparing SW23A and SW23B

The stratigraphic context, sediment similarities, and close physical proximity of the SW23A and B spurs raise the possibility that the artifacts exposed on them may be two parts of a single widely distributed time-averaged palimpsest (Bailey, 2007; Rezek et al., 2020) separated only by the accident of gully erosion. However, comparison of the aggregates shows that the situation is more complex and ambiguous. In the statistical comparisons that follow, we use both the surface collections and excavated artifacts. Although each surface artifact could derive from anywhere in the full thickness of the sediments overlying the terraces, a crosstabulation of the surface and excavated samples from SW23B revealed no statistically significant differences in artifact category frequencies (χ^2 17.371, df 19, $p=0.565$) and both excavation data and field observations suggest that most artifacts on the surface of SW23B were derived from a horizon ~ 2 to 3-m thick at the bottom of sedimentary Unit 4 and top of Unit 3, the same portion of the stratigraphic sequence sampled by the excavations.

A cross-tabulation (SI Appendix 4, Table 22) of the inventories of the two collections ($n=1459$) revealed significant differences in typological content (χ^2 52.223, df 20, $p \leq 0.001$). The artifact categories that contributed most to this result were tools often considered technological "index fossils" for named stone tool industries in the region (see Table 1). For SW23A, these include split cobbles, handaxes and, to a lesser degree, radial cores. For SW23B, it is Levallois pieces (flakes, points, and cores), normal flakes

and retouched flake tools that account for the differences. Retouched flake tools consisting of large scrapers, denticulates and notches are not common and in 2019 were only recovered in the SW23B collection. Lithic raw materials (SI Appendix 4, Table 23) also differed (χ^2 22.282, df 7, $p \leq 0.001$). In SW23A, brown and gray quartzite exceeded expected frequencies, and in SW23B white quartz and fine-grained orange quartzite were the largest contributors to the differences.

When subsamples of individual artifact categories were considered, differences were also evident. The largest category was whole detached pieces (n 448), and when detached piece type frequencies are compared across the two terrace samples, paradoxically, no statistically significant differences are evident (χ^2 6.067, df 7, $p = 0.532$). Levallois flakes and points were above expected frequencies in the SW23B collection, but the differences were insufficiently large. However, significant differences between the samples did occur when some detached piece attributes were tested. Dorsal scar pattern (SI Appendix 4, Table 24) is perhaps the most sensitive indicator of flake production strategy other than cores themselves (Debénath & Dibble, 1994; Clarkson et al., 2006), and the two collections differ significantly for this attribute (χ^2 12.32, df 5, $p = 0.031$). For SW23A, unidirectional scars which can be the products of single platform cores contributed most to this statistic, and for SW23B, radial, and irregular two directions patterns were most important. Radial patterns can be produced by both radial and Levallois cores, and irregular two directions patterns are produced by flaking from multiple platforms (Barham, 2000). Cortex on dorsal surfaces (SI Appendix 4, Table 30) also differed significantly (χ^2 8.391, df 3, $p = 0.035$), with fully cortical and partially cortical being proportionally more common at SW23A, and naturally backed and non-cortical at SW23B. Frequencies of striking platform types, detachment characteristics and lithic raw materials did not differ between the samples. Weight is the best measure of relative size of lihics, and the mean weight of detached pieces in the two collections was very similar (SW23A = 27.3 g, SW23B = 29.4 g, t test, df 454, $p = 0.812$).

Although flake scar patterns differed significantly between the two samples, a full breakdown of core types did not (SI Appendix 3 Table 8). Levallois cores were too infrequent to make a difference. Nor were there significant differences in the types of raw materials or in the shapes of clasts selected for reduction. Cores were larger in the SW23A sample. Mean weight of SW23A cores was 290.9 g and of SW23B was 221.3 g. However, these differences are not significant at the 0.05 probability level (t test $p = 0.067$).

Among larger tools including handaxes, core-axes and picks, only split cobbles were common enough to permit meaningful statistical comparison (SI Appendix 3 Tables 11–12). The raw materials employed for split cobbles did not differ between collections, but metrics did differ significantly. Split cobbles at SW23A (L/W = 1.52) are somewhat more elongated than at SW23B (L/W = 1.40) and are much larger (541.9 g to 249.5 g, t test $p = 0.037$). Combining all specimens including small finds, artifact weight averages for both aggregates did differ significantly. The average for SW23A artifacts was 96.1 g, and for SW23B, 49.8 g (t test $p \leq 001$).

To summarize, lithic aggregates from SW23A and B share many aspects of both technology and typology but differ significantly in overall typological makeup with many differences being in artifact categories considered potentially important as culture-historical and/or chronological markers. In addition, the two aggregates differ in some attributes related to lithic technological processes including important indicators of core reduction strategy such as dorsal scar pattern and frequency of cortex. For dorsal scars, the unidirectional patterns that exceed 2/3 of the SW23A whole flake sample are consistent with the informal and single platform core types that are most common in that collection. At SW23B, irregular scar patterns, which contribute most to differentiating that flake sample, are consistent with the two platform, opposed platform and multiple platform cores that together comprise over 1/4 of that sample. Both collections have very high frequencies of whole flakes with cortex, with SW23A being more cortical than SW23B. Although whole detached pieces are essentially the same size in both samples, in the collections, SW23A has significantly larger artifacts than SW23B, and the primary contributors to that difference are the shaped large tools and split cobbles from SW23A. Taken together, these data show that the aggregates from the two spurs share many technological similarities but may be considered different typological entities.

Discussion

The lithic analysis raised many questions that are not yet answered. The contents of SW23A are consistent with an Upper or Final Acheulean attribution (Clark et al., 2001; Gilbert et al., 2016). The inventory of LCTs includes handaxes with one made on a giant flake, as well as a cleaver flake, although LCTs are only 1.9% of the SW23A collection. Split cobbles, considered a marker of the Early Acheulean (Biberson, 1961), comprise 5.6% of the collection. These show none of the modifications to convert them into hammers or anvils that are present on many split cobbles from the Lupemban aggregates at Kalambo Falls (Clark et al., 2001). The thin and invasive flake scars found on all the handaxes match those on Acheulean specimens that have been attributed to soft hammer percussion flaking (Clark, 1970; Sheppard & Kleindienst, 1996), although subsequent research has shown that identification of hammer type from the attributes of flakes or flake scars is not reliable (Driscoll & Garcia-Rojas, 2014; Clément, 2022). In the small SW23A core sample, types were primarily informal, single platform and radial, reduction strategies common in the Acheulean (de la Torre, 2011; Klein, 2000). Although the parent core was not found, the cleaver flake was Levallois, like Acheulean specimens recorded in East Africa (Kleindienst, 1962; Leakey et al., 1970). Other Acheulean markers photographed and analysed on SW23A in 2016, but not recovered in the 2019 sample, included an elongated and sharply pointed handaxe and a large polyhedron. Heavy-duty types (core-axes and picks) were present but outnumbered by LCTs, an important characteristic separating Acheulean from Sangoan aggregates at Kalambo Falls (Clark et al., 2001).

The SW23B aggregate is more difficult to characterize. It includes many more Levallois products, which would be consistent with all phases of the Zambian MSA (Barham, 2000) as well as more heavy-duty core-axes and picks than LCTs. The form of the two LCTs was highly unusual for either an Acheulean or MSA attribution in Africa. The unifacial handaxe was made by a reduction strategy that, although also recorded in SW23A and another site near Sitwe (SW60) in 2016 (Burke et al., 2023), is undocumented elsewhere in Africa. Likewise, the small bifacial cleaver is not a common African Acheulean form (Kleindienst, 1962). The core-axes are less reduced than the core-axes from the well-documented Sangoan assemblages at Kalambo Falls and none have the flaked parallel sides that characterize the Lupemban (Taylor, 2014, 2016). The picks at SW23B are also less reduced than those at Kalambo Falls (Clark et al., 2001). Core types resemble the SW23A collection with the addition of a few Levallois cores, and match the types reported for both the ESA and MSA at Kalambo Falls (Sheppard & Kleindienst, 1996).

However, many common Zambian MSA types are rare or absent at SW23B. Other than the two unretouched Levallois points, there are no bifacial or unifacial flaked points often considered African MSA markers (Barham, 2000; Clark, 1988; Lombard, 2012; McBrearty & Brooks, 2000). Blades, a common element of Zambian MSA technologies are infrequent in SW23B, being only 1.8% of whole detached pieces. None are prismatic. Backed tools that occur in both the Early and Later MSA (Barham, 2002; Phillipson, 1976) are also absent. The shapes of scrapers, notches, and denticulates commonly define archaeological industries in Eurasia (Bordes, 1961), but in Sub-Saharan Africa their forms do not seem to pattern either chronologically or geographically (Barham, 2000). The occurrence of retouched flake tools (1.2% at SW23B) is highly variable when equatorial ESA and MSA assemblages are compared. For open-air sites like Kalambo Falls, the largest Final Acheulean assemblage included 3.5% flake tools, and flake tools are 1.7% of the EMSA Sangoan assemblages (Clark et al., 2001). For sheltered sites, in the Lupemban assemblage from A Block at Twin Rivers (Lupemban, > 170 ka), retouched tools total only 0.11% of the sample. At Mumbwa Caves, in Unit VII (LMSA c.130–105 ka), retouched tools were only 0.36% of the collection, and in Unit II (LMSA, c 15/12 to 8 ka) tools were 0.67% (Barham, 2000). At Kalemba Rock-shelter, in the two LMSA horizons, H (c. 25 ka) and G (> 35 ka), retouched tools were also rare, 0.2% in horizon H, and 0.6% in horizon G. At Kalemba, LMSA flaked tools were primarily simple scrapers made on whole flakes and unifacially or bifacially retouched points (Phillipson, 1976).

Our provisional interpretation is that the SW23B aggregate most closely matches the EMSA Sangoan. Sangoan markers such as crude core-axes and picks are present and outnumber LCTs but are only a small portion of the entire aggregate. Lupemban markers such as long lanceolate bifaces (Breuil, 1944; Clark, 1971; Taylor, 2014, 2016), refined core-axes and

backed tools made on blades or flakes are missing. The Levallois flakes and points could be consistent with an EMSA or LMSA attribution, but other LMSA types are either rare or absent. Unifacial and bifacial points, an important part of LMSA assemblages were also not part of the collection and were not recognized in any of the surveys in both 2016 and 2019. Nevertheless, because core-axes and picks continue in small numbers into some LMSA assemblages (Barham, 2000; Clark, 1988), it is possible although less likely that the SW23B aggregate fits within the LMSA or is a mixture of both EMSA and LMSA material. None of the diagnostic material other than two small cores from the 2016 sample, which could equally be attributed to the EMSA or LMSA (Brooks et al., 2018; Marean et al., 2007; Wendorf & Schild, 1974; Yellen et al., 2005), point to an LSA presence.

Chronostratigraphic Hypotheses

The possible identification of an Acheulean aggregate at SW23A and either or both EMSA and LMSA aggregates at SW23B presents us with a conundrum. How could two nearby terraces with what appear to be identical geological and topographic settings have archaeological components that appear to be originating from the same limited horizon yet based on their techno-typological contents could date from as early as 800 ka or as late as 30 ka? Our team disagrees about the most likely answer to this question, and the following hypotheses are currently being considered.

Hypothesis 1: The Unit 3 cobbles and Unit 4 sandy clays were deposited over a long period of time, at least 500,000 years. Deposition of artifacts throughout the full thickness of Unit 4 included a stratified Acheulean through LMSA sequence that has been concentrated as lag deposits (cumulative palimpsests) on the SW23A and B terraces. Spatial differences in the horizontal distribution of Acheulean and MSA activities resulted in the differences in archaeological contents of the two terraces.

Implications:

A. If this is true, then numerous artifacts should be visible on the slopes above the terraces, with LMSA types being found higher, EMSA types beginning to appear lower, and ESA types occurring only near the bottom of the slopes and on the edges of the terraces where Unit 3 is exposed. Because erosion would expose the upper parts of Unit 4 first, then the MSA artifacts may have a greater chance of post-exposure weathering.
B. These implications are only partially supported by field observations and contradicted by the taphonomic attribute data from the collections. ESA types are indeed restricted to the lowest parts of the slopes and are more common on the parts of SW23A that are eroded down to close to the Unit 3–Unit 4 boundary. However, artifact density on the slopes is low. Other than the discrete cluster of white quartz flake and angular fragments found ~ two meters above the SW23B terrace, the slope above SW23B is remarkably bare, notwithstanding the many small terraces on this slope that would catch both small and large artifacts moving down-slope after exposure (SI Appendix 5 Fig. 5).
C. Sediment micromorphology shows fluctuations in grain size indicating different degrees of inundation flow on the flood plain during the formation of Unit 4 in the ~ 2 vertical meters sampled by the excavations. The phytolith data from the sampled section reveal shifts in the density of the Miombo woodland cover probably related to overall changes in vegetation (Burke et al., 2023). Numerous and often abrupt shifts from wet to dry conditions over the past 1.3 million years are recorded in sediment cores from northern Lake Malawi, c. 150 km to the East (Lyons et al., 2015). Accompanying vegetation fluctuations from Miombo woodland to Afromontane Forest are also documented in pollen from those cores (Ivory et al., 2018). At present it is impossible to link the SW23 paleo-environmental data to those records, although doing so will be an important focus of future research.

Hypothesis 2: The Unit 3 cobbles and Unit 4 clays were deposited over a shorter period, perhaps as little as < 30,000 years. Hominin activity was concentrated during the formation of Unit 3 and continued primarily during the initial deposition of Unit 4, perhaps attracted by a water course that exposed the Unit 3 cobbles as an exploitable lithic resource. The

differences in typological contents between SW23A and SW23B are accounted for by the deposition of Units 3 and 4 happening to coincide with the last of the Acheulean and the beginning of the EMSA, with the SW23A sediments being deposited somewhat earlier than those at SW23B.

Implications:

A. No sedimentary evidence should be present for temporal hiatuses during the formation of Units 3 and 4, although a brief temporal gap at the interface between those units would not reject this hypothesis. Artifacts should be observed eroding out of the sediments that currently form the surfaces of the two platforms and the lowest parts of the slopes above them but should be infrequent above that. There should be clear typological differences between artifacts from within Unit 3 and the lowest 50 cm of coarser sandy clay at the bottom of Unit 4 on the one hand, and artifacts from the finer sandy clay of Unit 4 above that. Taphonomic attributes, particularly the presence or absence of abrasive wear on artifacts, should be clearly linked to the typological categories that define each aggregate. Artifacts characterizing the Acheulean component should exhibit more abrasion because of their hypothesized derivation from the higher energy depositional environments of Unit 3 and the bottom of Unit 4. Artifacts characterizing the EMSA or MSA should exhibit less abrasion if they are derived from the finer-grained levels of Unit 4.
B. Evidence supporting this hypothesis of a shorter duration for the formation of these sediments is the apparent lack of paleosols within and between Units 3 and 4. Other than the change in depositional environment represented by the probably drier conditions represented by Unit 3, and the more mesic environments represented by the flood-plain and Miombo woodlands extant during the formation of Unit 4, no other major climate shifts are evident in the geological sequence. If that sequence covered over 500,000 years, more changes would probably be observable given the record for dramatic fluctuations in regional precipitation and vegetation cover recorded in Lake Malawi. At SW23A, the discovery of numerous artifacts on original sediment pillars of coarse sandy clay shows that they are in their original depositional position near the bottom of Unit 4 as predicted by this hypothesis; however, one handaxe was loose on the surface of Unit 4 well above that horizon. The taphonomic data on artifacts thought to be temporally relevant are statistically significant but ambiguous (SI Appendix 4, Table 26). Abrasion is absent on LCTs, the primary markers for the Acheulean, yet many of the split cobbles are abraded. Overall, abrasion is significantly more frequent in the SW23A sample, which supports this hypothesis. All but three of the Levallois flakes on SW23B bear no abrasion. The heavy-duty core-axes and picks, potential markers of the EMSA are more abraded than both the handaxes and the Levallois flakes.

Hypothesis 3: Like hypothesis 2, this proposes that Units 3 and 4 were deposited over a limited period probably near the ESA-MSA transition; however, it differs in that it does not assume that the Acheulean artifacts at SW23A were deposited earlier than the possible EMSA or LMSA material at SW23B. Instead, it proposes that the two typologically different aggregates are geologically contemporary.

Implications:

A. The geological implications of this hypothesis are similar to those of hypothesis 2. The sedimentary sequences at both spurs should be identical as should the vertical distribution of artifacts in Unit 3 and the lowest part of Unit 4. There should be no evidence for depositional breaks in sedimentation that might extend the time represented by the aggregates. Although the collections from the spurs differ, there should be no stratigraphic or taphonomic evidence that conclusively demonstrates that one is significantly older than the other.
B. Fully assessing this hypothesis relies on geoarchaeological evidence that we do not yet have. Although we cannot automatically assume that there are no discontinuities between the depositional sequences at both spurs, we also cannot assume that discontinuities must exist solely because of the different typological makeup of the two collections. Field observations of both plat-

forms and repeated searches of the slope connecting them as well as the gully between them failed to identify any differences, although this will require confirmation by geological trenching and chronometric dating on both spurs. The taphonomic data summarized above are more consistent with this hypothesis, although they will also require further refinement and confirmation.

Does the possible chronology of artifact types aid in assessing these hypotheses? Using artifacts considered to be chronologically diagnostic (Table 1) to date, the Sitwe aggregates is problematic. It has long been recognized that stone tool types deemed diagnostic of specific industrial complexes may be time transgressive (Shea, 2020). The established culture-chronological sequence in Zambia is based on Kalambo Falls, where a sequential but discontinuous change from handaxes to core-axes and picks to Levallois technology was present (Barham et al., 2015; Clark et al., 2001). However, the temporal distribution of ESA (Gilbert et al., 2016) and MSA tool forms such as the ones identified as SW23 varies across Africa. Handaxes and cleavers first appear more than 1.7 Ma (Beyene et al., 2013) and continue to be reasonably common in some assemblages identified as Sangoan (Clark et al., 2001). In Zambia, they effectively disappear by the Lupemban and are absent in the LMSA (Barham, 2000). The heavy-duty tool types considered "index fossils" of the Sangoan occur in ESA as well as occasional LMSA assemblages (Tryon, 2006). Levallois technique is widely considered to be a defining characteristic of the MSA (Lombard, 2012 and references therein) but it extends back into the late Acheulian in both eastern and southern Africa (Clark, 2001; Lahr & Foley, 2016; McBrearty, 2001; Wilkins et al., 2010). Acheulean Levallois technique was sometimes employed to produce large blanks for LCTs (Sharon et al., 2009), but smaller Levallois flakes also occur in Acheulean contexts (Van Riet Lowe, 1945). Assemblages attributed to the Acheulean, Sangoan, and MSA are known to interstratify in Northern Sudan, (Van Peer et al., 2003), East Africa (McBrearty, 2005; McBrearty & Tryon, 2006) and Republic of South Africa (Kuman et al., 2020 and references therein). This may also be the case at SW23 if hypothesis 3 is correct.

The handaxes from SW23 include specimens made by Acheulean giant flake and cobble-opening techniques (Sharon et al., 2009). Although handaxes persist until ~ 160 ka in Ethiopia (Clark et al., 2003), in Kenya and Tanzania they disappear before ~ 250 ka if only securely dated sites are considered. In East Africa, the known temporal ranges of handaxes, crude core-axes, picks, and Levallois technology producing both flakes and points overlap from ~ 320 ka to 200 ka (Deino et al., 2018; McBrearty & Tryon, 2006), a timeframe within the latter half of the Chibanian. In the absence of OSL dates, linking the SW23 aggregates to this specific span is speculative. Identification of this possible temporal window does not necessarily imply that the SW23 deposits formed during the entire period, only that their formation may fall within those boundaries. In addition, it does not resolve the important question of whether the "diagnostic" artifacts were deposited in the expected chronological order, as proposed in hypotheses 1 and 2, or not. A depositional sequence of Upper Acheulean, Sangoan, and MSA could fit within this span. Only new dating and extensive geoarchaeological research at SW23 and surrounding areas can resolve these issues.

Behavioral Implications of the Sitwe 23 Aggregates

Although there are significant typological and technological differences between SW23A and B, the two aggregates share several features suggesting that they represent similar behavior patterns in tool manufacture, site or landscape-use and provisioning strategies. The morphology of cores, frequency of small chipping debris on a site, degree to which cortex is present on detached pieces, and the characteristics of striking platforms have all been cited as indicative of the stage of lithic reduction represented by an assemblage (Magne, 1985; Reher, 1991; Dibble et al., 2005). At SW23, core type frequencies (SI Appendix 3, Table 7) did not differ significantly between the two aggregates (χ^2 9.599, df 10, $p = 0.476$). A majority of both, 56.5% in each case, are simple and lightly reduced forms (informal and single platform), and core types involving more extensive preparation and reduction (radial pyramidal, Levallois, multiple platform) are less common, 13% in SW23A, 14.1% in SW23B. The ratio of cores to whole products (flakes, blades, and points) is low, 2.83 for SW23A, 3.77 for

SW23B. This compares to 6.58 for the Upper Acheulean, and an unusually high 75.85 for the channel deposit Sangoan aggregate at Kalambo Falls (Clark et al., 2001). In LMSA probable base camp sites such as Mwanganda's Village, Karonga, Malawi, the products to core ratio is 28.71 (Wright et al., 2014), and 12.6 in the LMSA Horizon G at Kalemba Rock-shelter, southeastern Zambia (Phillipson, 1976). In open-air sites like SW23, the low ratios for both aggregates could be a consequence of not only the degree of core reduction, but also hominin mobility and provisioning behavior, as well as post-discard taphonomic processes such as fluvial winnowing (Fanning & Holdaway, 2001). In the central Luangwa Valley, in sites known to have been subject to extensive fluvial transport and winnowing the core to product ratio is likely to be reduced, and this is the case of the ESA layers (flake/core ratio of 3.79) and LMSA layers (ratio of 2.50) at Manzi (Barham et al., 2011) and LMSA layers at site SL8 (ratio 1.22) (Colton et al., 2021).

The number of striking platform facets may be better predictors of the stage of reduction represented by a collection, with simple platforms (cortical and single facet) resulting from early stages of reduction (Magne, 1985; Wilson & Andrefsky, 2008). Cortical and single facet platforms are large proportions of both Sitwe aggregates (SI Appendix 3, Table 8). In SW23A, they total 80.4%. In the surface sample from SW23B, they are 77.6% and in the excavated sample they total 90.4%.

The percentage of detached pieces bearing cortex is frequently used to estimate the degree of core reduction (Dibble et al., 2005 and references therein). The collections from SW23A and B had high frequencies of this variable on both whole detached pieces (SI Appendix 3, Table 5) and cores. There are statistically significant differences between the two surface collections for this variable (χ^2 8.391, df. 3, $p = 0.039$), and pieces bearing cortex are more common in SW23A, but at both spurs artifacts with cortex exceeded 63%. This suggests that similar behavioral patterns were operating in both cases. Common interpretations of high cortex frequencies as well as the product to core ratios and simple striking platform types summarized above are that they represent early stages of lithic reduction, often associated with quarrying or nodule resource locations (Odell, 1989), with finished tools, preforms and/or prepared cores transported elsewhere for subsequent use (Reher, 1991) in a provisioning of individuals strategy employed by mobile hunter-foragers (Kuhn, 1995). The high cortex percentages in the Sitwe aggregates combined with the number of cores bearing cortex (95.5% at SW23A, 88.0% at SW23B) shows that short, expedient reduction sequences were the norm. Because most artifacts probably derived from a horizon stratigraphically close to the cobble layer, it is possible that the cobbles were exposed in a nearby riverbed and were being sporadically exploited, resulting in the dispersed distribution of artifacts across the landscape observed in surveys of the region (Burke et al., 2023).

If base camps can be identified by high densities of artifacts (Riel-Salvatore & Barton, 2004; Schoville et al., 2022 and references therein), then by the traditionally used criteria (Bicho & Cascalheira, 2020), the SW23 aggregates do not appear to qualify as long-term or intensive occupations. We did not find evidence for a single occupational surface at either SW23 A or B and artifacts are too dispersed throughout the sediments. Even the horizon immediately above Unit 3, where artifacts were most common, does not yield more than a few artifacts per m^2. The aggregates found on the terraces are palimpsests concentrating what were ephemeral and low-density activity episodes involving the occasional production of flakes and minimally reduced heavy-duty tools from locally available riverine clasts. Some artifacts produced elsewhere such as the handaxes at SW23A and possibly the Levallois flakes at SW23B were occasionally discarded. It is possible that the shortage of Levallois cores relative to finished products at SW23B represents the export of Levallois cores from the site, but the more intensive reduction required to make Levallois cores would probably leave greater amounts of medium to small debris than were recovered. Moreover, transport of cores across the landscape was not observed in the LMSA in northwestern Malawi (Thompson et al., 2014). To date, no high-density artifact concentrations such as those that occur in at Karonga, Malawi (Thompson et al., 2021 and references therein) have been located in the Sitwe region (Burke et al., 2023). The most likely interpretation of these data is that the Sitwe 23 locality was produced by mobile hunter-foragers employing individual provisioning strategies. Although provisioning of individuals is usually associated with larger amounts of retouch on tools, this may have

been mitigated by the local abundance of lithic raw materials (Riel-Salvatore & Barton, 2004; Schoville et al., 2022; Varoner et al., 2022).

Much work remains to be done to test the hypotheses presented here. More extensive excavation data are needed from SW23 and other sites throughout the region. A better understanding of Pleistocene landscape evolution in the region is also essential and can only come from extensive geoarchaeological fieldwork.

Sitwe 23 in the Regional ESA to MSA Context

To place the Sitwe 23 aggregates within the regional archaeological context, technological and typological comparisons were made to the only other excavated open-air sites in the Luangwa Valley and to sites near Karonga, Malawi, in the western Lake Malawi Rift. Dated Early and Later MSA cave and rock-shelter sites in Eastern, Central, and Lusaka Provinces are also included. Previous archaeological research in the Luangwa basin was restricted to the central part of the valley 300 km southwest of SW23 (Barham et al., 2011; Colton et al., 2021). Excavations at a natural exposure on the Manzi River tributary of the Luangwa sampled a ~ 4.5 m sediment column consisting of fluvial cobble layers containing artifacts separated by sterile sands. The top of the sequence produced an OSL date of ~ 78 ka and paleomagnetic correlation placed the bottom of the sequence below an unconformity at slightly over 1 ma (million years ago). Artifacts excavated above the unconformity are attributed to the LMSA, and those recovered below it to an ESA facies characterized by large flakes rather than bifaces (Barham et al., 2011). A systematic geoarchaeological survey of 224 km^2 in the same area (Colton, 2009) followed by excavations above the Luangwa floodplain (Colton et al., 2021) revealed a coherent archaeological sequence ranging from the LSA through possibly the ESA preserved in alluvial fans. The best-preserved site, SL8, yielded abundant microlithic quartz LSA in the top 10–15 cm of the ~ 1 m sequence, underlain by larger quartzite artifacts attributed to the LMSA (levels 3–8) and possible ESA (levels 9–10) based on typological traits, and greater degree of abrasive wear. The ESA component rests on Karoo bedrock. An OSL date from the LMSA layers was 77 ± 7.9 ka, almost identical to the LMSA date from Manzi.

The Karonga region, Malawi, 130 km northeast of SW23 has been systematically investigated (Thompson et al., 2018 and references therein). Prior archaeological surveys reported possible ESA artifacts (Clark, 1966), and one excavated site was incorrectly attributed to the EMSA Sangoan (Clark & Haynes, 1970; Wright et al., 2014). Subsequent research has established that the many sites within the Upper Pleistocene portion of the Chitimwe Formation are LMSA (Thompson et al., 2018). These sites also contain abundant LSA artifacts, which are always confined to the top few cm of deposits. The Karonga LMSA dates to ~ 92 to 20 ka and is characterized by quartzite and quartz lithics manufactured from locally available cobbles (Thompson et al., 2014; Wright et al., 2014, 2017). LSA artifacts are much smaller and predominantly quartz. Sites discussed here occur near Lake Malawi rather than on the rift escarpment. In the following comparisons, three of the largest late MSA excavated assemblages are here combined into a time-averaged aggregate; Chaminade I, 43 ka (Nightingale et al., 2019), Chaminade II, 51–29 ka (Wright et al., 2017), and Mwanganda's Village 1, 46–20 ka (Wright et al., 2014).

The sheltered samples employed here include Twin Rivers Hill A Block in Lusaka province. This was a narrow, enclosed passage that filled with breccia including both artifacts and bone. The A Block deposits produced a Lupemban assemblage including backed tools and evidence of pigment use. The date of ~ 266–170 ka makes it the earliest and one of the only securely dated Lupemban sites. The second sample is Mumbwa Caves Unit VII. This was the richest of the Mumbwa MSA levels and dated to > 120–107 ka, just after the transition from the EMSA to the LMSA (Barham, 2000). The final sample is from Horizon G in Kalemba Rock-shelter in Eastern Province. This was the bottom of the deepest sounding at the site where less than one square meter yielded over 7700 artifacts over a depth of ~ 40 cm. A radiocarbon sample exceeded the effective range of the technique at the time making the date > 35 ka (Phillipson, 1976).

The central Luangwa Valley and Karonga sites are noteworthy for the scarcity, or in some cases complete absence, of shaped tools conventionally considered temporally or behaviorally diagnostic. Therefore, the

numerical comparison presented here is restricted to core types, which are the best indicators of the lithic technologies employed at each site (Barham et al., 2011; Thompson et al., 2018). Table 5 illustrates core type frequencies from the sites arranged in probable chronological order, with the SL8 and Manzi collections being divided into LMSA and possible ESA components as defined by the respective authors. Because of subtle differences in core type definitions between these studies, some types have been condensed into more inclusive categories. Informal/Platform includes all cores defined by their number of platforms (Tryon, 2006) combined with all cores with less than five flake removals. Radial/Disc includes all cores with centripetal removals except Levallois cores as defined by Boëda (1994) which are listed here as prepared cores.

These data reveal a clear pattern. In all samples except Kalemba Horizon H, informal/platform cores constitute a majority or plurality, but are more common in the four potentially earliest samples. Radial/discoid cores vary, but the highest frequencies are in the most recent LMSA samples, the aggregate from Karonga and Kalemba Horizon H. Prepared (Levallois) cores are more numerous in the LMSA collections but present in small numbers in the proposed EMSA component of SL8 and at SW23. Among other core types, bipolar cores are common (19.4%) in Twin Rivers A Block and present in the LMSA components of Mumbwa Caves VII, SL8, Manzi and Mwanganda's Village I. None of these core types are present in the 2019 sample at SW23B, although two bipolar cores were recorded in the 2016 sample. Other core types were core-on-flake (Twin Rivers A Block, Mumbwa VII, Manzi ESA and SW23A and B), micro-flake cores that were identified at SW23B in 2016, and split cobbles flaked peripherally which only occur at SL8 LMSA and contribute to the high frequency of other core types in that collection. One Karonga assemblage, the possibly terminal MSA of Mwanganda's Village I, includes a distinctive variant of the radial reduction strategy using deliberately selected small (<3 cm) split crystal quartz pebbles as raw materials (Wright et al., 2014). Farther south, the Mozambiquan MSA sites of Mvumu and Ngalue Cave on the eastern side of Lake Malawi (Niassa) have more varied core technologies almost exclusively employing quartz rather than quartzite as well as much higher frequencies of retouched formal tools (Bicho et al., 2018; Mercader et al., 2009, 2012) than do the Karonga sites, suggesting that the lake was a barrier to hominin interaction during the Upper Pleistocene (Wright et al., 2014).

The picture that emerges from the cores is one of a broadly similar technology characterized by a moderate increase in the use of more specialized core reduction strategies in the most recent assemblages. Levallois strategies, which are present at both SL8 and SW23B, may have a long history in the region, however. This

Table 5 Core type percentages for selected sites in Central, Lusaka, Eastern, and Muchinga Provinces of Zambia including the Luangwa Valley and Karonga District, Malawi

Site and Age		Core	Type		*N*	Abrasion
Sites in possible chron. order	*Informal*/platform	*Radial*/disc	Prepared/ Levallois	*Other* types		% Abraded (sample n)
Karonga–LMSA[1]	44.1	39.2	7.7	9.0	365	9.3% to 17.0%
Kalemba G–LMSA[2]	36.2	55.3	2.1	4.3	47	na
Mumbwa VII–LMSA[3]	65.0	20.1	5.9	9.0	680	na
SL8–LMSA[4]	50.0	23.5	3.0	23.5	34	65.5% (107)
Manzi–LMSA[5]	53.8	7.7	23.1	15.4	13	31.3% (48)
Twin Rivers–EMSA[3]	50.0	10.1	6.3	33.5	158	na
SW23B– (EMSA?)	84.1	12.5	2.3	1.0	88	11.2% (928)
SL8–ESA[4]	71.0	22.6	0.2	0	31	58.3% (126)
SW23A–(ESA?)	69.6	21.7	0	8.7	23	24.9% (209)
Manzi–ESA[5]	66.7	20.8	0	12.5	24	61.0% (77)

The order is based on published chronometric dates. The SW23 figures are the core samples from the 2019 collections, and their positions are estimates based on their techno-typological characteristics as discussed above. Sources: 1. Thompson et al., 2018; 2. Phillipson, 1976; 3. Barham, 2000; 4. Colton et al., 2021; 5. Barham et al., 2011). *na* not available

would match the pattern of technological continuity between the Late Acheulean and the EMSA at Kalambo Falls (Clark et al., 2001), where a small number of Levallois cores occur in the Acheulean component (Sheppard & Kleindienst, 1996). The Manzi LMSA data are also consistent with the overall technological simplicity identified in the LMSA core technology near Karonga, Malawi. One pattern shared by all these sites is the preferential use of readily available water-worn clasts of fine-grained quartzite and quartz and the lack of evidence of the transport of un-worked lithic raw material across the landscape (Barham et al., 2011; Colton et al., 2021; Nightingale et al., 2019; Thompson et al., 2014, 2018).

The major difference between SW23A and B and the central Luangwa Valley and Karonga sites is the presence and greater variety of larger tools at SW23. LCTs including both bifacial and unifacial handaxes as well as a cleaver and Levallois cleaver flake are present at SW23A and B but absent at Manzi and SL8. LCTs were not found in the extensive survey near Manzi (Colton, 2009) and are either rare or absent in central Luangwa Valley surface sites recognized during paleontological reconnaissance (Barham et al., 2011). In addition, Levallois products (flakes & points) were present in appreciable numbers at SW23B but rarer in Manzi and SL8. However, heavy-duty tools are present in both areas. Core-axes and picks were some of the most common shaped artifacts in both SW23 aggregates. The LMSA levels at SL8 yielded two picks, and a core-axe was recovered on the adjacent hillslope (Colton et al., 2021). At Manzi, the ESA cobble layers produced two specimens described as pick-like cores (Barham et al., 2011). In the case of Manzi, the difference in the incidence of shaped tools may be partly due to sample size, as that collection totaled 205 artifacts compared to the 1180 at SW23B. This is not the case for the combined MSA and ESA samples from SL8, which total 1218. In sharp contrast, all these artifact categories were completely absent in the large assemblages from the Karonga sites (Thompson et al., 2018).

The very limited evidence we now have for the ESA through MSA in the Luangwa Valley and the western Malawi rift suggests a continuing reliance on simple and expedient core-reduction techniques employing informal/platform and radial/discoid cores to produce flakes that were often used without subsequent retouch. More complex core reduction strategies like Levallois are documented in a few cases in the ESA but increase in frequency in the MSA. Regional differences do exist, primarily in the extent to which large shaped tools were employed. At SW23 and two smaller sites surveyed in 2016, SW37 and SW60 (Burke et al., 2023), we have evidence that, in the northern Luangwa Valley, the full range of LCTs and heavy-duty tools occur with Levallois technology but not blade technology in collections tentatively assigned to the Acheulean and EMSA. At present, the record from the northern Luangwa Valley resembles that of East Africa (McBrearty & Tryon, 2006 and references therein), while the central Luangwa valley sites resemble the record in the rest of Zambia (Barham, 2000) and the western Lake Malawi basin (Thompson et al., 2018 and references therein). Further research throughout the Luangwa Valley is needed to assess these tentative conclusions.

Conclusion and Prospects

Our primary goal was to investigate a new Stone Age locality in the Northern Luangwa Basin, a region whose archaeological potential remains largely unexplored. After two seasons of fieldwork at this remote location, we have been able to reconstruct site formation processes at SW23, characterize the paleoenvironmental context and provide evidence for a hominin presence possibly within the second half of the Chibanian.

The locality consists of parallel spurs on the border of a deeply incised piedmont zone where terraces formed because of the stabilisation of erosion by an underlying cobble layer. The erosion of sediments overlying the terraces has resulted in the formation of a deflation horizon containing concentrations of lithic artifacts. The analysis of the lithic aggregates, which are time-averaged, provides the first detailed typological description of what we tentatively attribute to the Acheulean at SW23A and possibly EMSA at the SW23B. Chronometric dating is not yet available, and artifact types and technologies thought to be temporally significant produced ambiguous age estimates. The aggregates are either the product of a sequential presence in the area by makers of separate Acheulean, Sangoan and/or MSA industries, or episodes of activity by hominins capable of producing any of those technologies simultaneously. For the moment, we lack the chronostratigraphic evidence required to test these hypotheses. Resolving this issue can only be achieved

by further geological and archaeological research in the area combined with accurate absolute dating. Gaining more evidence from in situ archaeological deposits is essential. The preliminary results presented here show that the region has archaeological potential and that it could yield critical information relevant to understanding a key period in hominin evolution in an area that may be an important biogeographic corridor for hominin dispersals.

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Data Availability All data used in this analysis are presented in the appendices. Additional information may be obtained from the corresponding author.

Declarations

Competing Interest The authors declare no competing interests regarding the data published here.

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