Research Article

NOTHING SET IN STONE: *CHAÎNES OPÉRATOIRES* OF LATER STONE AGE SEQUENCES FROM THE LUANGWA VALLEY AND MUCHINGA ESCARPMENT, ZAMBIA

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ABSTRACT

This study applies a hybrid analytical approach that combines chaîne opératoire *analysis with a reduction sequence typology to investigate the organisation of lithic technologies in the mid to late Holocene record of eastern Zambia. Later Stone Age sequences are analysed from two recently excavated sites, Poacher's Cave in the Luangwa Valley and Caterpillar Rock in the Muchinga Escarpment overlooking the Luangwa Valley. Both sequences are discontinuous, quartz-based, lack refits and in the case of Caterpillar Rock, only a small area of the site was sampled. Despite these analytical challenges, the analysis reveals underlying similarities in knapping strategies with the production of bladelets and use of expedient flaking common to both sites. A clear difference emerges with the use of prepared and radial flaking strategies only at Caterpillar Rock. Core preparation features at some Holocene sites in the region, and its occurrence in the escarpment adds to the spatial distribution of this distinctive strategy. The hybrid analytical approach aids the recognition of subtle variability within and between sites locally and regionally, but the underlying cognitive assumptions of the* chaîne opératoire *approach cannot be easily reconciled with the limitations of the archaeological record.*

Keywords: *chaîne opératoire* analysis, Later Stone Age, quartz, Zambia.

INTRODUCTION

Techno-typological analyses based on lithic reduction sequences are widely used in the study of Later Stone Age (LSA) assemblages in southern Africa (Mitchell 2002). This framework provides a common analytical currency for making comparisons within and between sites and is the basis for our current understanding of patterns of change through time. The reduction sequence approach is, however, less explicitly developed to investigate past decision-making when compared with the *chaîne opératoire* (CO) approach (Tostevin 2011). The latter is a concept and method designed to examine planning at each step in the process of making, using and discarding a tool. In essence it is a cognitive approach to analysing technology (Pelegrin 1991). We apply both approaches to the analysis of LSA sequences from two Holocene sites in eastern Zambia.

We briefly review the history of LSA research in Zambia and then introduce the CO approach used before describing the sites, the excavations and the respective chronologies. In the language of a CO analysis, we examine the lithic record in search of patterns of technical choices (Pelegrin 1991). The search starts with raw material selection and moves to informal and more formal blank production strategies and culminates in the analysis of retouched tools in terms of their production pathways and regional typological affiliations. Commonalities are identified between the two sequences and a slight, but a potentially significant difference is highlighted in the choice of formal knapping techniques. We conclude with an assessment of the advantages of using a CO analysis and highlight limitations as well as ways forward.

LATER STONE AGE RESEARCH IN ZAMBIA

The history of LSA research in Zambia during the twentieth century was characterised by a focus on culture-historical sequence building largely based on lithic assemblages, and particularly on the forms of retouched tools (Musonda 2012). Five regional industries were identified including the Zambian Wilton in central and southern Zambia (Clark 1950; Fagan & Van Noten 1971; Savage 1983; Derricourt 1985), the Nachikufan and Kaposwa in northern Zambia (Clark 1950, 1974; Miller 1969; Sampson & Southard 1973; Musonda 1984), the Makwe in eastern Zambia (D. Phillipson 1976), and possibly the Fingiran on the border with Malawi (Savage 1983). L. Phillipson (1977) applied Grahame Clark's (1969) general classification of technological modes and identified several Mode 5 (microlithic) sequences in the Upper Zambezi Valley, which have since been redated, indicating the sequences are discontinuous (Burroughs *et al*. 2019).

The early manifestations of a microlithic LSA in Zambia are not well dated but fall within the latter part of the Last Glacial Maximum ~20 ka and are attributed to the first phase of the Nachikufan Industry (Miller 1971). In parts of eastern and northern Zambia, LSA technologies continued to be made into the late Holocene, overlapping chronologically and spatially with the technologies of farming communities (D. Phillipson 1976; Musonda 1987).

The Zambian Wilton and Nachikufan are the best documented industries in terms of spatial coverage and extent of study. The typological foundation of these industrial groupings has been discussed in terms of how to interpret variability, whether as cultural, functional, ecological, geographical or temporal markers (Sampson 1974; D. Phillipson 1976; Savage 1983; Musonda 1984; Bisson 1990). Others have observed that assemblages assigned to industrial phases often cross-cut technological, chronological and geographical boundaries, suggesting that phase classifications mask high levels of variability (Sampson & Southard 1973; L. Phillipson 1977; Savage 1983). Bisson (1990), in his analysis of the undated Luano Spring sequence in north-western Zambia, attempted to move the culture-historical debate forward by employing a reduction sequence lithic analysis alongside a typological analysis of the retouched component. In a further technological study, Barham (2000) adapted Janette Deacon's (1984) reduction sequence model for the analysis of Middle and Later Stone Age material from Mumbwa Caves, central Zambia. The latter followed a hierarchical approach which separated assemblages into steps of manufacture from cores to flakes, including their by-products, with retouched tools as the final stage in the reduction process.

Retouched tools have been the mainstay of these analyses, in part because their relative abundance and variety provides a means of defining spatial and temporal patterning. Such patterning is valuable for sequence building, but less so for extracting socially constructed processes of decision-making. The analysis below marks an intentional shift in focus towards a CO perspective and is applied to material excavated in the Luangwa Valley and its western margin between 2002 and 2007.

A *CHAÎNE OPÉRATOIRE* APPROACH FOR THE LSA

In its original formulation, a CO analysis is both a method of study and a conceptual approach examining all technologies (Leroi-Gourhan 1964 [1993]). It is a method of studying technological organisation and technical choice *via* the investigation of manufacturing processes. As a concept, it links learned skill (gestures) with a representation or goal of the final product and assumes that by recreating the sequence of production of a prehistoric technology the ideational foundation (goal) of the maker can be revealed (Pelegrin 1991; Sellet 1993; Schlanger 1994; Inizan *et al*. 1995; Soressi & Geneste 2011). In common with other hierarchical sequence models, the CO method examines the succession of steps involved in toolmaking (Bleed 2001; Shott 2003). In relation to stone-tool production, it differs from the concept of a reduction sequence in making an explicit link with decision-making and a representation of the final form (Tostevin 2011). A CO approach typically follows the technical choices made starting with raw material selection through to the final discard of a used or recycled tool (e.g. Edmonds 1990; Hallos 2004, 2005; Tostevin 2011). The process may be represented in linear sequence or contain sub-stages of decision-making linked to the recycling of a tool. More complex artefacts made of multiple materials each with a separate sequence of manufacture may require more nested diagrams to capture interlinked and phased decision-making.

To date, the CO approach has been closely allied with studies of Middle and Upper Palaeolithic lithic technologies (e.g. Audouze 1999, 2002; Bar-Yosef & Van Peer 2009; Akhilesh & Pappu 2015). More recently, and more broadly, archaeologists have been developing analytical methods to examine elements of social learning and cognition involved in toolmaking that build on and move beyond the CO approach (e.g. Stout 2011; Tostevin 2012; Bader *et al*. 2015; Coolidge *et al*. 2016; Fairlie & Barham 2016). In the southern African context, Lombard and Haidle (2012) introduced 'cognigrams' as a methodological tool for illustrating decision-making processes in relation to specific desired end states for producing a generic technology, in this case a Middle Stone Age bow and arrow set. This approach draws on CO analyses but does not aim to capture technological details, such as gestures. These newer variants and the CO approach itself seem to have been avoided by researchers working with LSA quartz-based assemblages.

One reason for this may be the perception of quartz as an unrewarding material for analysis given its naturally occurring cleavage planes and weaknesses within its crystalline structure. Quartz tends to shatter rather than fracture conchoidally in a predicable manner (Bisson 1990: 104; Diez-Martín *et al*. 2011). Quartz knapping also creates significant amounts of largely undiagnostic small debris with non-retouched pieces seeming to retain scant technological information. Bisson (1990: 104) suggests that "There are few things more discouraging for an archaeologist … than to be faced with the analysis of an assemblage that is made on poor quality quartz", while researchers in West Africa have expressed similar frustrations (Casey 2000: 51). Cornelissen (2003: 2) has also noted the poor reputation that quartz assemblages have among workers in Central Africa attempting technological analyses. The challenging nature of quartz analysis does have some bearing on the analytical approaches open to researchers, but this does not eliminate the possibility of applying CO approaches to the LSA material record (Mitchell 2005). In southern Africa, many workers already use classification schemes founded on reduction sequence principles, such as that developed by Deacon (1984), to study quartz-based assemblages. These schemes are, in theory, already largely compatible with CO analyses, but quartz debris can lead to the under-representation of certain core types especially on small flakes which preserve a small proportion of the core face (Orton 2012).

METHODS OF ANALYSIS

To reiterate, a CO-based lithic analyses aims to identify the varying techniques involved in material production, and the learned technical choices they reflect. A CO lithic classification scheme should, ideally, be able to recognise the entire trajectory of lithic production, from raw material collection to final discard (Odell 2000: 87; Soressi & Geneste 2011). In this study, we use a hybrid scheme which combines a CO analysis of the debitage (reduction) process (Inizan *et al*. 1995) with the quantitative classification of reduction sequences and especially for retouched tools as devised by Deacon (1984) and modified by Barham (2000). The combined approaches allow us to examine separate knapping techniques in terms of decision-making steps, and to describe the LSA assemblage within existing, familiar culture-stratigraphic labels. From Inizan *et al*. (1995) we draw on their debitage classification scheme that provides technical variables which distinguish between the following knapping techniques: bladelet flaking, prepared core flaking, radial flaking, bipolar flaking and other more informal knapping strategies. All lithic pieces measuring over 10 mm were assigned to one (or more) of these knapping techniques according to the technical markers evident on each piece. Retouched pieces were also attributed to a knapping technique where possible, based on the technique used to produce the tool blank. Particular attention was given to raw material selection and transport, blank production and selection, core maintenance and tool shaping, to elucidate the technical choices made at each site and through time.

All cores, retouched pieces and pieces measuring over 20 mm were analysed individually. The whole flake class was divided into pieces measuring over 20 mm, termed 'large flakes', and pieces measuring between 20 mm and 10 mm, termed 'small flakes'. All large flakes were analysed individually, and all small flakes sorted according to raw material and flake type (whether informal, bipolar, radial, prepared, etc.), counted and weighed. All whole flakes measuring less than 10 mm were considered debris, as it was felt that these small pieces would not have been viable blanks. Descriptive statistics are produced for each knapping technique to assess continuity and variability within and between the sites.

LUANGWA VALLEY AND MUCHINGA ESCARPMENT SITES

The Luangwa Valley extends over 700 km in a southwesterly orientation, forming an extension of the East African

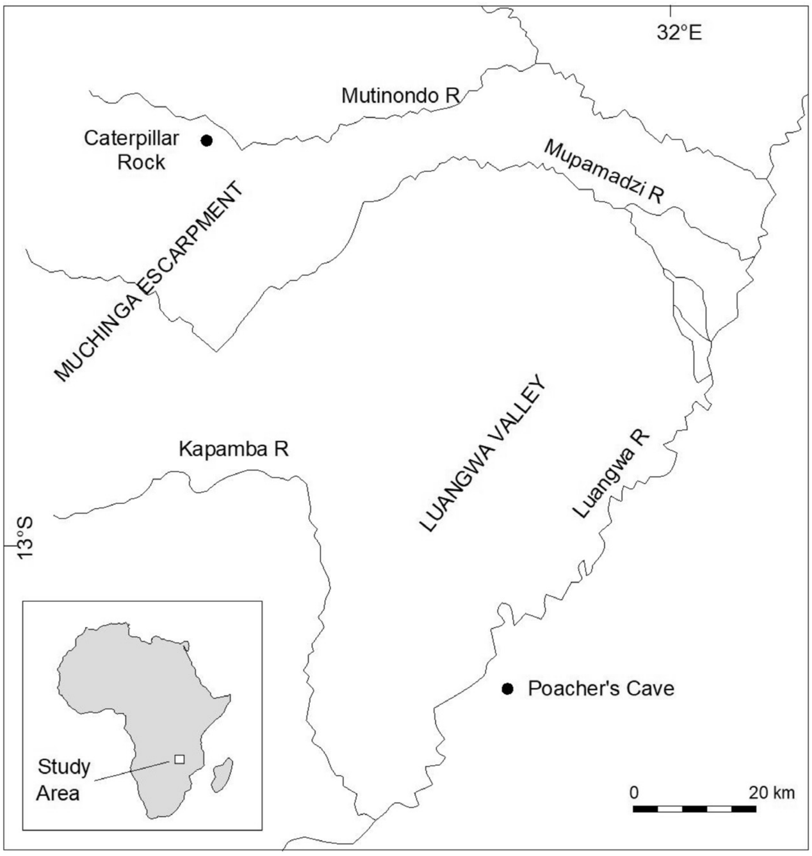

FIG. 1. *Map showing the location of Poacher's Cave in the Luangwa Valley, and Caterpillar Rock in the Muchinga Escarpment.*

Rift Valley system (Colton *et a*l. 2021) (Fig. 1). The valley floor lies at an altitude of between 500 m and 700 m amsl and is bounded to the north-west by the granitic Muchinga Escarpment, and by the lower and discontinuous Nchindeni Hills to the south-east. Rock shelters are relatively common along the escarpment, but rare in the hills.

From the valley floor the Muchinga Escarpment dominates the skyline and at its maximum elevation rises *c*. 1300 metres above the valley (Astle 1995). The escarpment landscape is characterised by large, eroded granite inselbergs which stand hundreds of metres above the surrounding *miombo* woodland. The present Luangwa River is a meandering sand-bed river with a large alluvial floodplain, which has probably flowed consistently throughout the Holocene (Gilvear *et al*. 2000). The river is highly mobile, rapidly creating and eroding the large meanders that eventually form seasonal oxbow lagoons. In low interfluves seasonally wet internally drained depressions (*dambos*) support grassland through the dry season, and along perennial streams draining the escarpment are found riparian vegetation which also characterises the banks of the Luangwa River (Astle 1995). Elsewhere, particularly in the more northerly sections of the Luangwa Valley and along the Muchinga Escarpment, *miombo* woodland is widespread with *mopane* woodland dominant along the valley floor (Smith & Allen 2004).

POACHER'S CAVE AND CATERPILLAR ROCK

Poacher's Cave and Caterpillar Rock are both rock shelters with lithic assemblages typical of the region being largely quartz based and recovered from discontinuous stratigraphic sequences. (Fig. 2). Poacher's Cave (site SL3, S13°12′15.3″; E31°45′13.9″ 561 amsl) is situated in a granite outcrop at the base of the Nchindeni Hills (Fig. 3). The site lies approximately 4 km east of the present course of the Luangwa River, and 200 m east of the Kafunta River, a seasonal tributary of the Luangwa. The site is surrounded by open *mopane* woodland interspersed with dense patches of elephant grass (*Pennistum purpureum*) and scrub grassland. The rock shelter faces north and rises 10 m above the landscape. Much of the interior floor is interrupted by roof fall and boulder tops; the excavated area, though small, covers most of the accessible surface (Fig. 4). Faint traces of dark red geometric imagery survive on the wall behind square 25Z (Fig. 5), partially obscured by a mineral crust, which are attributable to a regional LSA tradition of non-figurative painting (Clark 1959; Musonda 1987; Smith 1997; Barham 1998; but see D. Phillipson 1976; Olivier 2011).

Caterpillar Rock (site MUT-1, S12°24′25.5″; E31°18′23.8″, 1538 amsl), known locally as *Ntuponya mboo* ('buffalo fell down', David Chomba, pers. comm. 2007) is a large exfoliation scar on a north-west facing inselberg in the Muchinga Escarpment (Fig. 6). The site rises ~200 metres above the surrounding *miombo* woodland with the perennial Mutinondo River 2.6 km to the north-west, and its tributary the Musamfushi River 3.5 km to the south-east. Water is also available seasonally in three large *dambos* between 2 and 5 km to the south-west.

The shelter is 16 m long but no more than 4 m wide (Fig. 7), and as at Poacher's Cave, there is poorly preserved geometric imagery on the back wall with elements resembling the red imagery at Poacher's Cave, but also distinctive horizontal lines 2–3 m long, some executed in yellow pigment (Fig. 8). The main excavation took place at the base of a painted 'panel' (Square 1A).

EXCAVATIONS

POACHER'S CAVE

Four 1 m^2 squares were opened in 2003–4 and reached a maximum depth to bedrock of 121 cm below surface level (24Y)

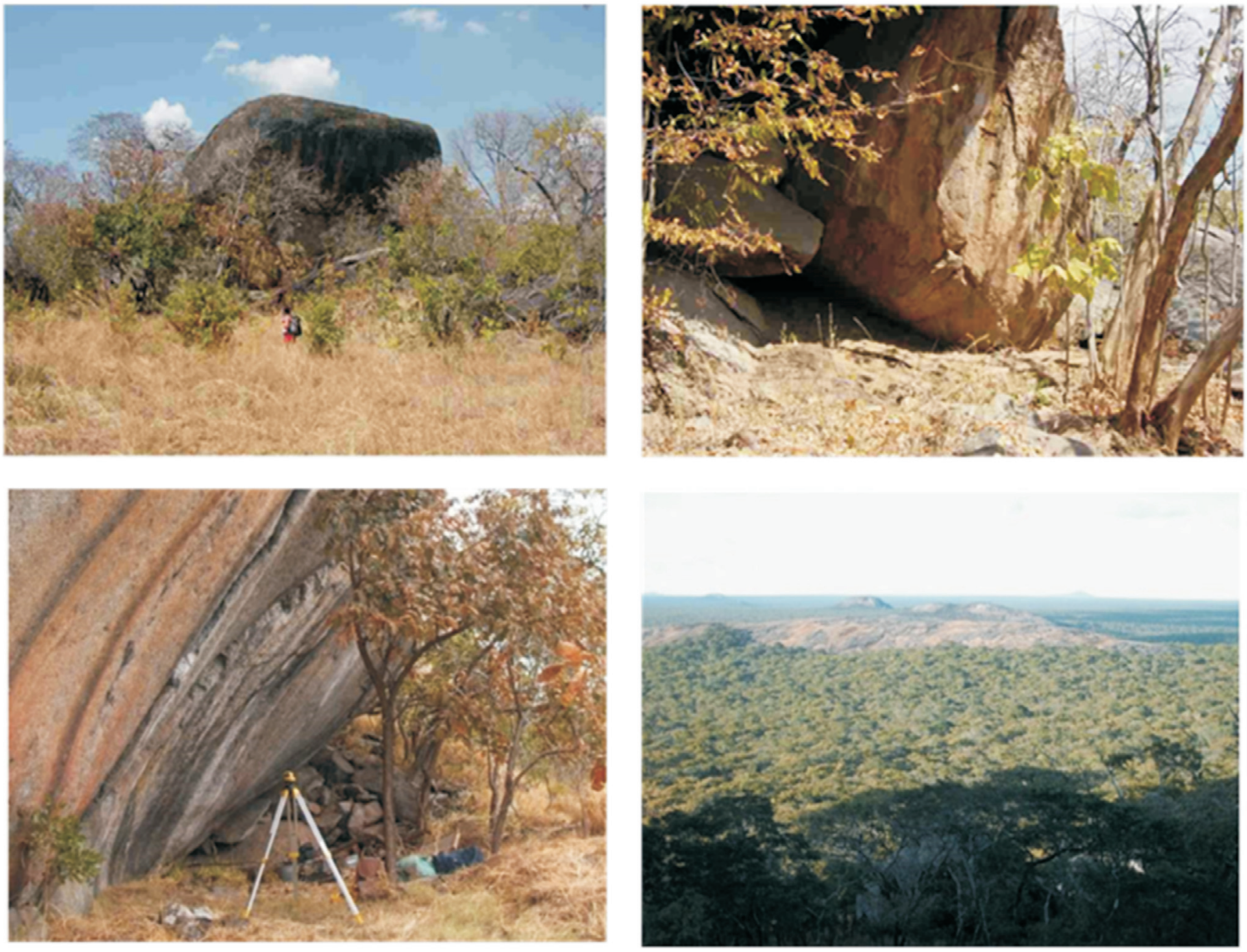

FIG. 2. *Clockwise from top left: Poacher's Cave from the north-west; entrance to Poacher's Cave showing the excavated area; looking north-east from the Caterpillar Rock shelter showing distant inselbergs; northern margin of Caterpillar Rock shelter with square 1A situated underneath the shelter wall.*

(Fig. 4). Excavation took place in arbitrary 5 cm levels where no differentiation in the deposit was observable (Fig. 9). All artefacts were piece plotted (analogue) and all sediments were sieved through a 2 mm mesh. The upper 25 cm were characterised by loosely compacted fine sediment that contained LSA lithics and small amounts of fragmentary pottery. Below 25 cm the sediment became progressively more compacted. Active and old ant nests were found scattered through the compacted deposits causing some mixing. Artefact concentrations increased steadily below 25 cm, and between 54 cm and 69 cm, a change was recorded across all squares, with the sediment becoming more loosely compacted with a higher sand and gravel content. This stratigraphic shift was accompanied by a notable increase in the lithic artefact count. The number of lithics continued to increase until *c*. 95 cm below the surface, after which the frequency of artefacts decreased across the squares. Boulders began to hamper excavation from 100 cm downwards.

Microlithic material was distributed across the site, though concentrations were lower directly beneath the rock overhang. Other artefacts were recovered including haematite, limonite, specularite, quartzite grinding stones, charcoal and some organic material including fragmentary bone and shell (land snail, freshwater mussel), but these are not described here.

The interior of Poacher's Cave appears to have escaped significant post-depositional disturbance as evidenced by the mostly concordant radiocarbon and OSL dates (below), and the localised occurrence of specific raw materials such as purple chert in square 25Z. The presence of small ant nests, however, will have caused localised mixing. In contrast, the area outside the dripline (24A′) appears to have suffered significant post-depositional disturbance, not only due to winnowing associated with runoff (Mercader *et al*. 2002), but also to a large tree root system. Material from this area was excluded from analysis.

DATING

Charcoal is the primary material for dating both sites, but no hearths were identified raising the possibility of the movement of isolated charcoal fragments through the deposits. Ten radiocarbon dates on charcoal are available from Poacher's Cave (Table 1a), and three single grain optically stimulated luminescence (OSL) ages on quartz sand (Table 1b, Supplementary Material). For the latter, Central Age Model (CAM) is the preferred estimate as it best accounts for the variability in dose rates recorded (Supplementary Material, Fig. 1) and is a measure of central tendency. The Maximum Age Model (MAM) assumes all the variability results from bioturbation which seems unlikely given the stratigraphic consistency of the CAM ages and the radiocarbon ages.

The radiocarbon dates indicate some mixing of sediment in the upper 15 cm of deposit in square 25Z (a date of 170 ± 40 bp underlies a date of 2303 ± 32 bp) (Fig. 9) which reflects the current use of the site. Below 25 cm there, the radiocarbon and

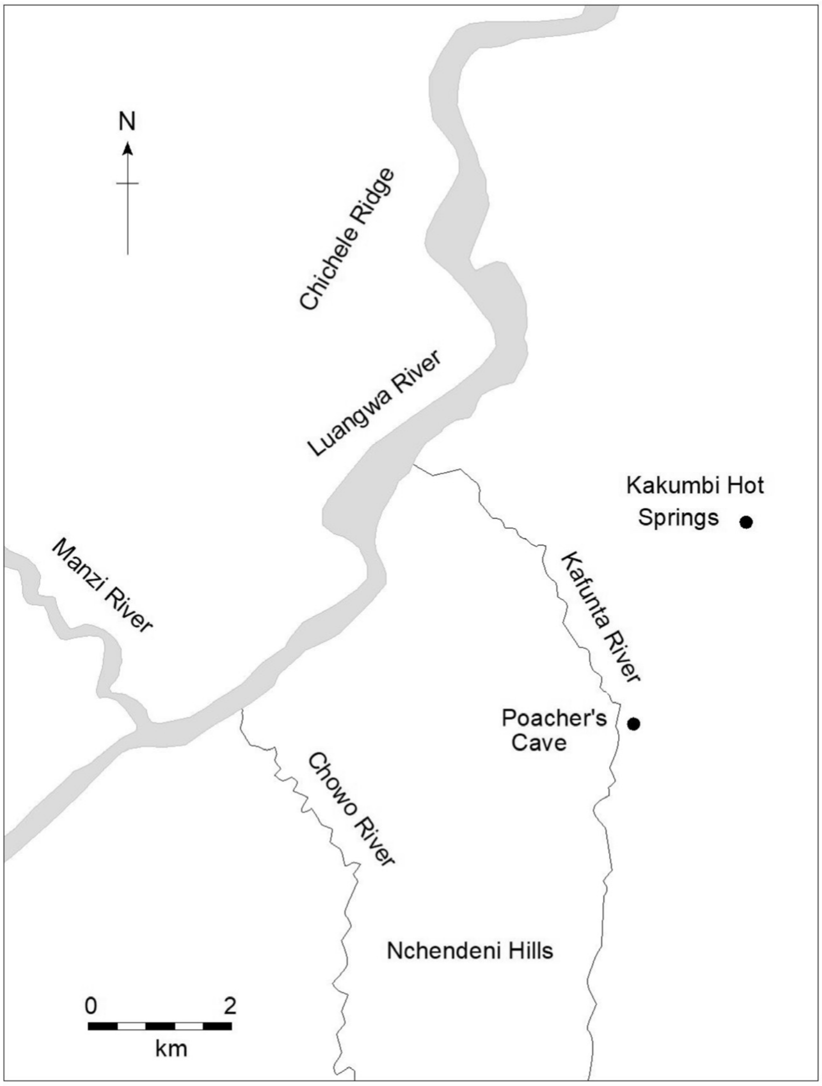

FIG. 3. *Area plan showing the Poacher's Cave site, Luangwa Valley and localities mentioned in the text. Drawn from maps 1331B1 and 1331B2 of the Zambian survey, copyright Zambian Government 1972.*

OSL ages are roughly concordant in showing an increase in age with depth. The OSL CAM dates increase from 1.60 ka (54 cm below datum) to 2.21 ka (85 cm) and 3.88 ka (132 cm). The radiocarbon ages range from 2190 ± 80 bp (68 cm below datum) to 3860 ± 40 bp (135 cm) with the latter very similar in age and depth to the basal OSL age. These two dating methods place the Poacher's Cave sequence in the late to middle Holocene.

CATERPILLAR ROCK

The material analysed here was recovered from a 1 × 1 m^2 test pit (1A) positioned underneath the shelter wall in 2006–7 (square 7B, 1.0 × 0.5 m, 12 cm deep is not included) (Fig. 7). Pottery was found in the upper 5 cm, below which all archaeological material comprised knapped lithics, charcoal and pieces of ochre (haematite, limonite) (Fig. 10). Fourteen levels were excavated (A1-1 to A1-14) and all excavated material was passed through a 2.5 mm sieve. Stratigraphic levels followed the natural stratigraphy where visible and arbitrary 5 cm levels were used where no changes were visible. The full depth of the excavated deposit was 71 cm.

The upper 12 cm was disturbed by rootlets, with fine sand and silt characterising the deposit to a depth of 37 cm below which the sediment become coarser, compacted and the density of lithic artefacts increased noticeably (level A1-7). The compaction became more pronounced at 42 cm (A1-8) with fragments of weathered bedrock and roof spall appearing. The extent of weathered granite increased in subsequent levels to A1-11 associated with dense concentrations of quartz artefacts. Artefact frequency declined from 61 cm below surface to the base at 71 cm below surface.

DATING

Five radiocarbon dates (on piece-plotted charcoal) sample the sequence from just below the surface (MUTI-A1-2) to near the base (MUTI-A1-14) (Table 1a, Fig. 10). A large chronological gap of ~3500 years exists between the dates for level 5 and 10, spanning ~25 cm of sediment, but this may simply reflect insufficient sampling of the sequence. The top 20 cm are, however, consistent in their coverage of a very recent period of occupation (~300–500 bp) including the uppermost LSA and surface Iron Age pottery. Further excavation is needed to develop a full chronology representative of the site.

THE SITES IN A REGIONAL PERSPECTIVE

The two lower radiocarbon dates, from Caterpillar Rock (3910 ± 40 bp, level 10) and Poacher's Cave (3860 ± 40 bp, level 20), correspond closely, indicating that the sites were used at roughly the same time in the middle Holocene. Poacher's Cave appears to have been abandoned about 2000 years ago, while at Caterpillar Rock there is a human presence in the very late

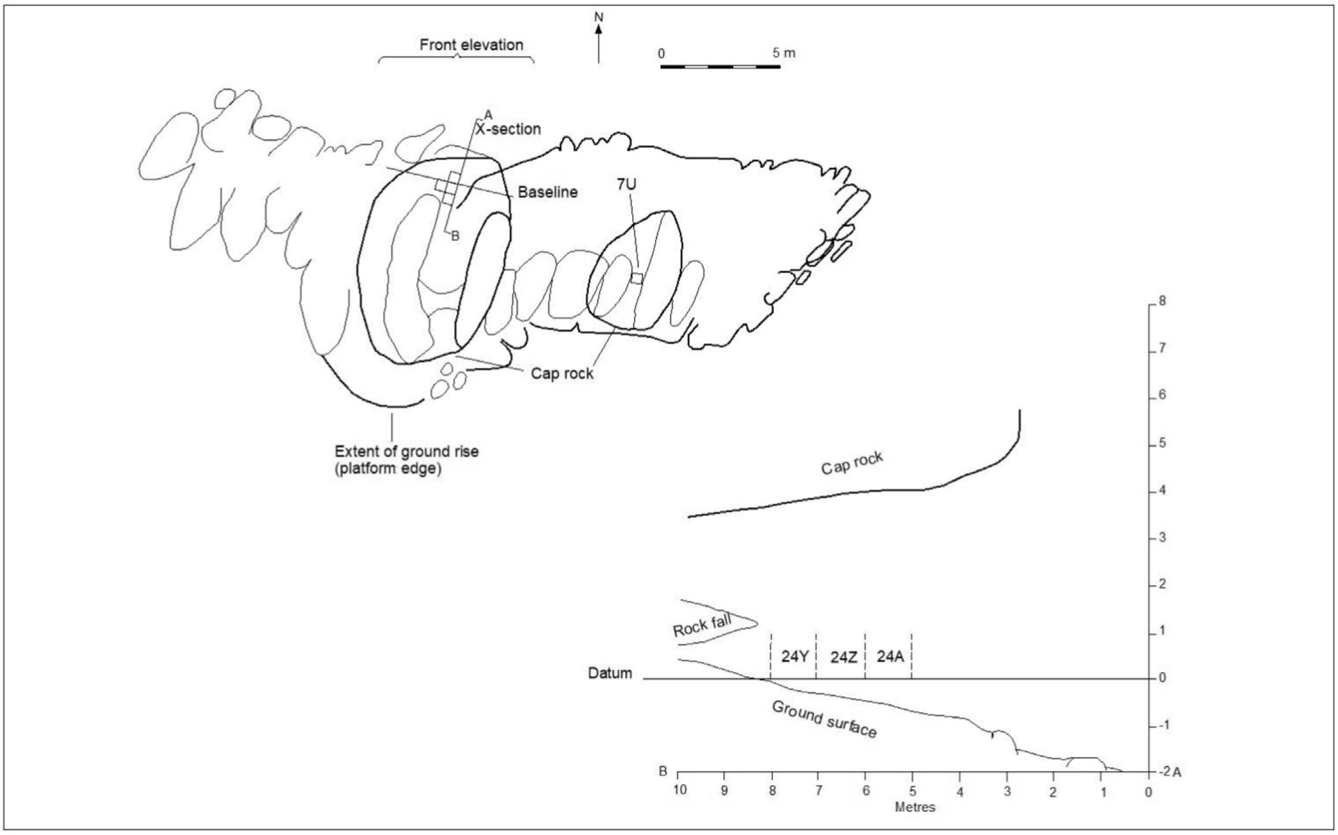

FIG. 4. *Poacher's Cave site plan showing excavation area, and cross-section showing location of squares 24Y, 24Z and 24A in relation to the shelter overhang and ground surface. Square 25Z is located on the baseline adjacent to 24 and towards the back of the shelter.*

Holocene. The chronologies of both sites overlap with the late Holocene Nachikufan III industry, the middle Holocene Wilton and the middle to late Holocene Makwe industry (Miller 1969; Fagan & Van Noten 1971; D. Phillipson 1976; Musonda 1987). The apparent abandonment of Poacher's Cave may reflect the arrival of farming groups locally and the displacement of foragers. The Chowo River site, located 2.2 km to the southwest, records the presence of Early Iron Age farmers by AD 400 (Barham & Lie Jarman 2005), but an unpublished radiocarbon chronology from the site of Kakumbi Hot Springs (3.7 km to the north-east, Fig. 2) records an earlier arrival of farmers before AD 100 (De Filippo *et al*. 2009). Elsewhere in Zambia, particularly in the Central and Southern Provinces, the Early Iron Age dates to ~AD 50 (Roberson 2000). In these areas, LSA sites were often abandoned at the time of the arrival of farmers suggesting that hunter-gatherer communities were displaced by, replaced by or subsumed into farming communities (Miller 1969). In contrast, LSA sites in the

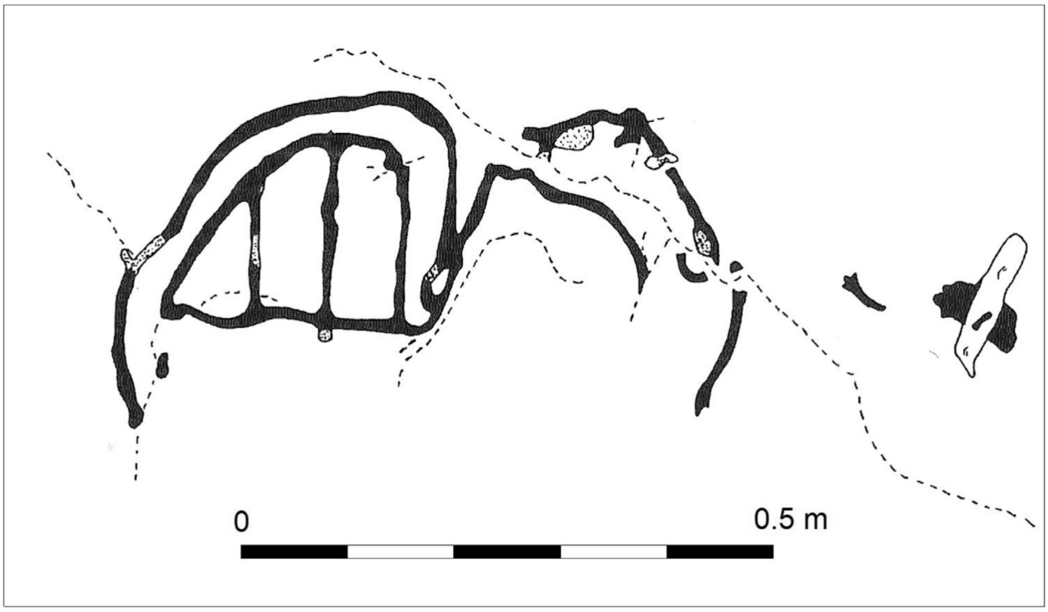

FIG. 5. *A tracing of the geometric imagery preserved on the main vertical surface behind 25Z. The imagery is faded dusky red (Munsell 10R 2.5/2; 10R 3/3) with areas missing.*

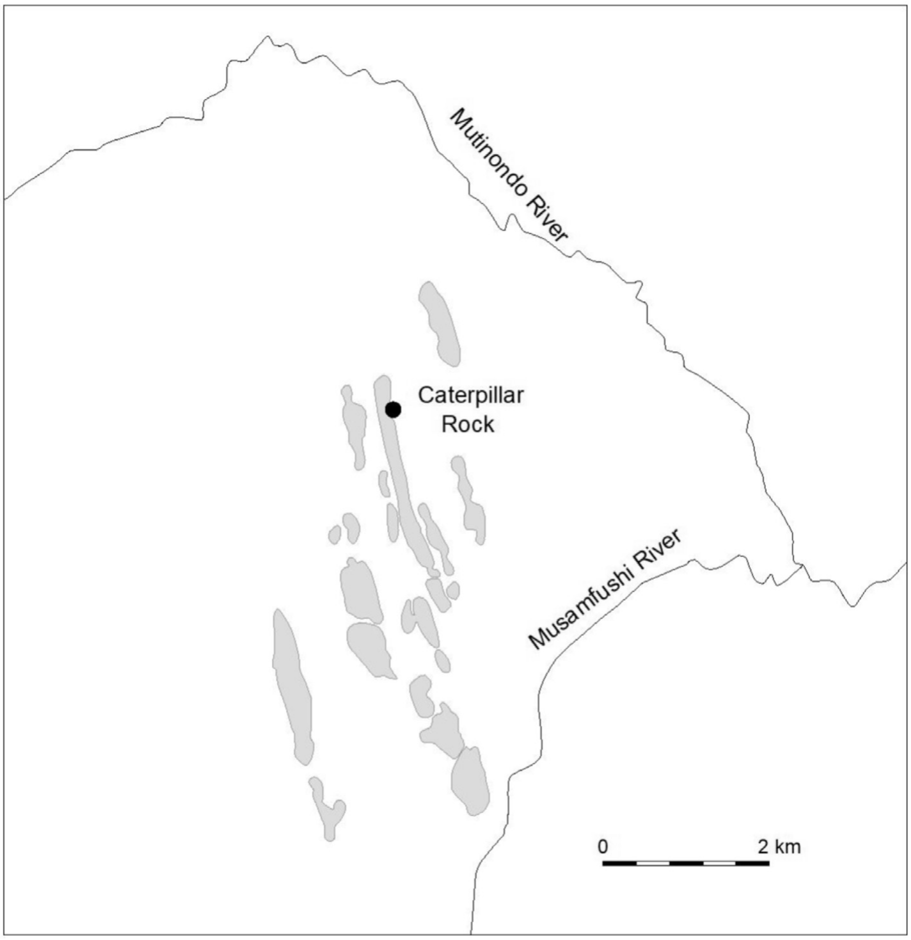

FIG. 6. *Map showing the location of Caterpillar Rock in one of a series of concordant granite inselbergs and in relation to the nearest rivers. The perennial Mutinondo and Musamfushi Rivers drain into the Luangwa River. The map is oriented north–south.*

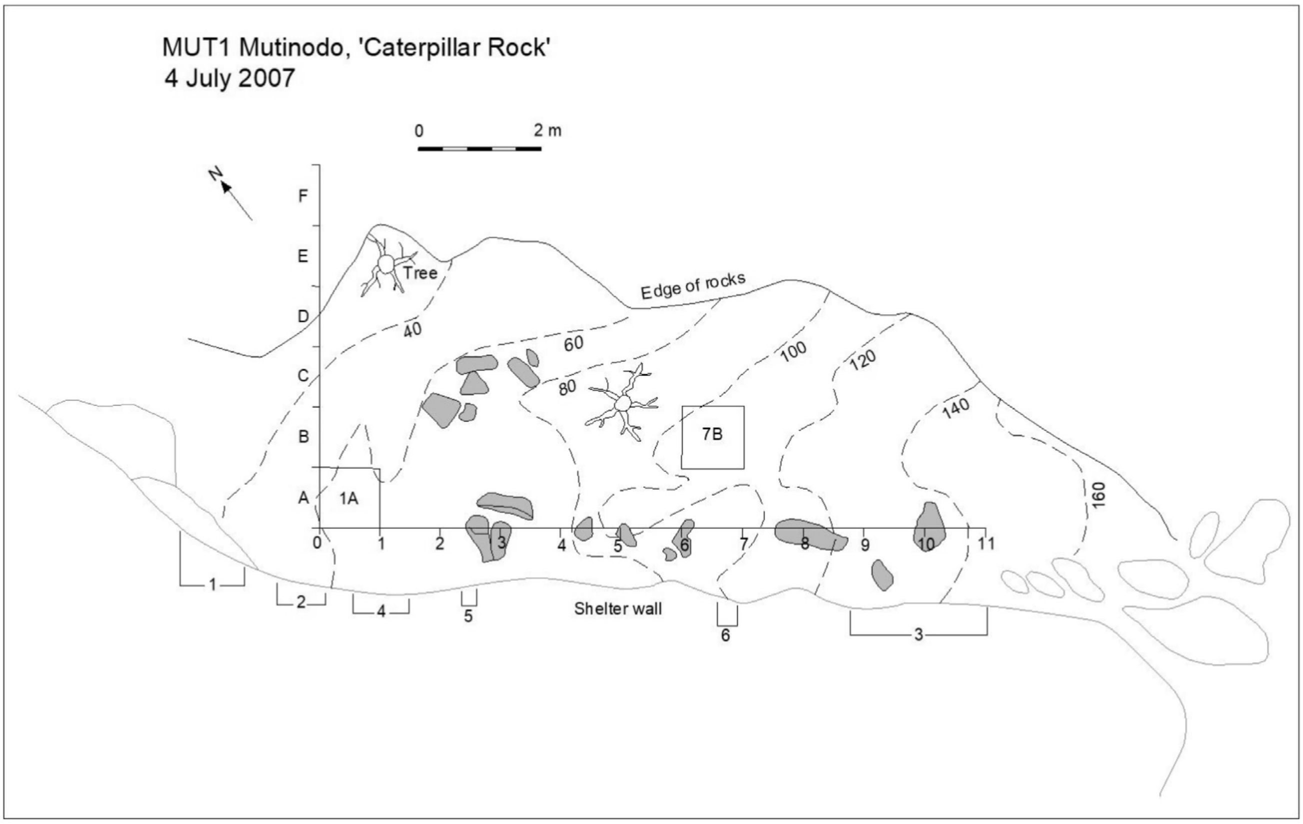

FIG. 7. *Site plan of Caterpillar Rock Shelter, showing the locations of square 1A and rock art panels (numbered) in relation to the shelter wall and rock fall that forms the boundary of the habitable area.*

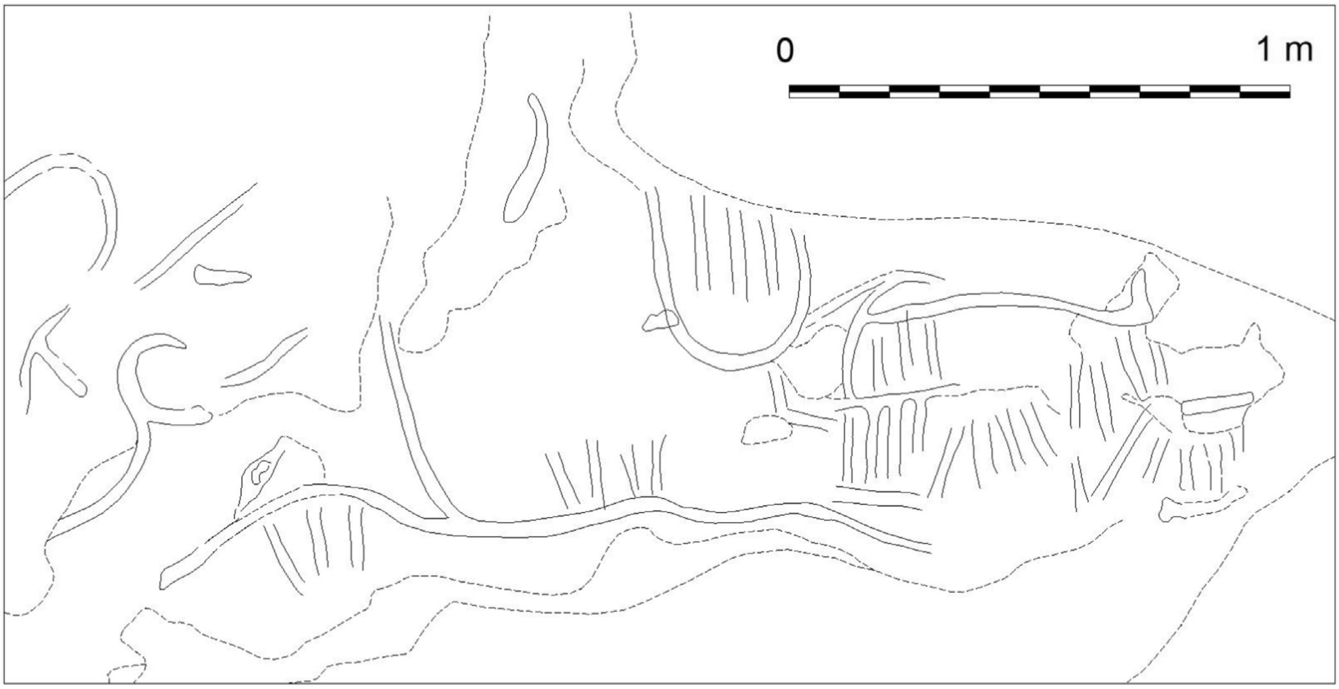

FIG. 8. *A portion of the geometric imagery behind square 1A, Caterpillar Rock. The imagery is shown in outline (faded red 10R 2.5 Munsell and horizontal linear yellow 5Y 8/6), some marks overly thin pale mineral crust, others have flaked away.*

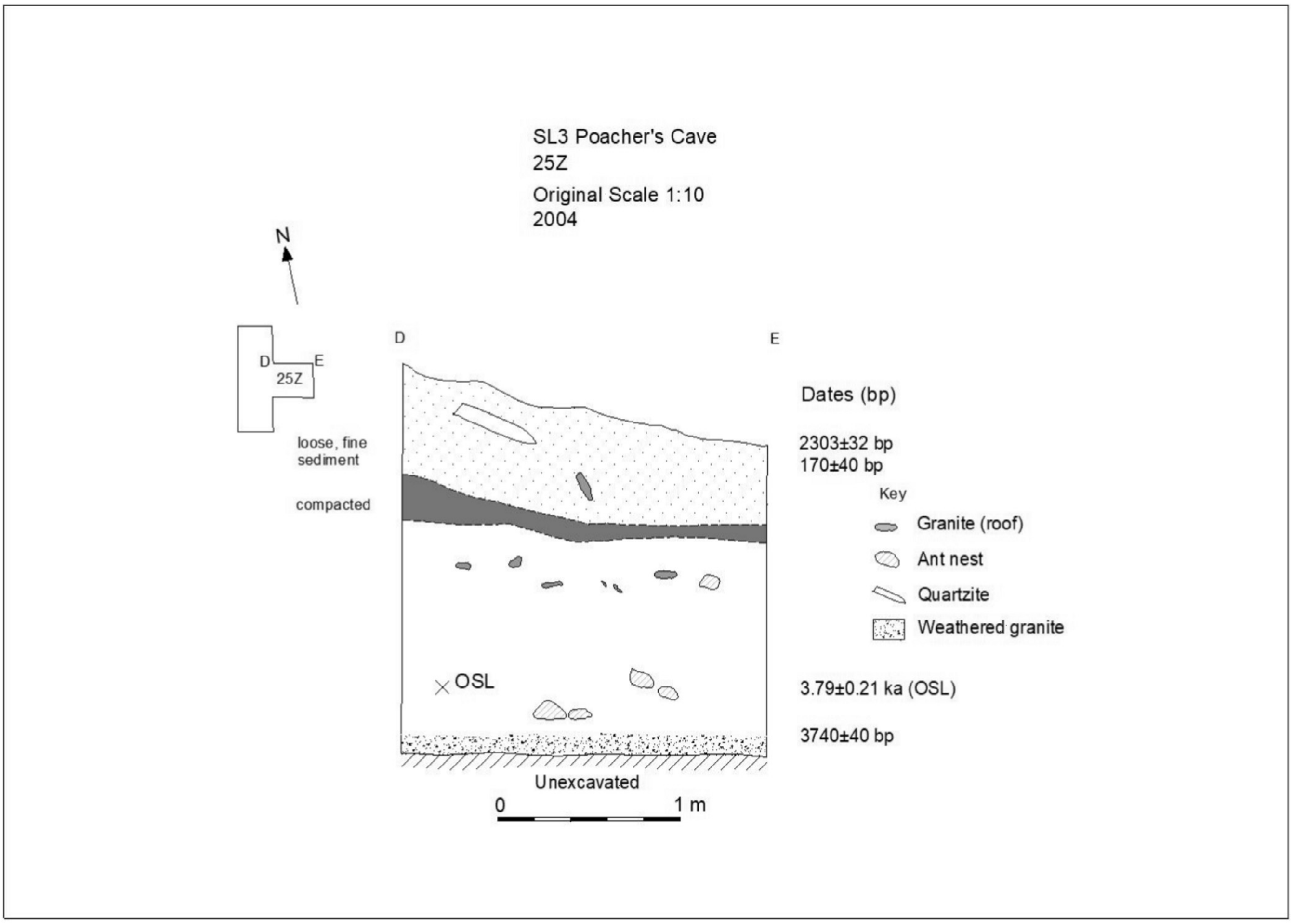

FIG. 9. *Poacher's Cave, square 25Z section, showing general features of the sedimentary profile of the excavations with a loose surface layer with pottery and Later Stone Age artefacts overlying a more compacted layer sealing late to middle Holocene deposits that contain the bulk of the artefact sample. Radiocarbon dates and one OSL date shown in relation to their depth.*

TABLE 1a. *Radiocarbon dates (uncalibrated and calibrated) for Square 1A Caterpillar Rock (MUT-1) and for the Poacher's Cave (SL3) sequence.*

Site/square, level, depth (cm) below surface/datum	Lab number	$^{13}C/^{12}C$ ratio	**2 σ Calibration**[†]	Conventional radiocarbon age
MUTI-A1-2 7.5–12/60–73.5	Beta-227449*	–24.8 ‰	**Cal AD 1326 to 1455**	550 ± 40 bp
MUTI-A1-3 12–18.5/73.5–80	Beta-227450*	–23.4 ‰	**Cal AD 1465 to 1650**	350 ± 40 bp
MUTI-A1-5 18.5–23.5/80–85	Beta-244466*	–22.7 ‰	**Cal AD 1481 to 1664**	330 ± 40 bp
MUTI-A1-10 48–53/110–115	Beta-244467*	–25.2 ‰	**Cal BC 2468 to 2206**	3910 ± 40 bp
MUTI-A1-14 65–70/127–132	Beta-244468*	–27.6 ‰	**Cal BC 4594 to 4353**	5680 ± 50 bp
SL3-25Z-2 5–14/68–77	UB-6894	Unknown	**Cal BC 400 to 210**	2303 ± 32 bp
SL3-25Z-3 14–21/77–84	Beta-197050*	–25.2 ‰	Cal AD 1670 to 1953 (95.3%)	170 ± 40 bp
SL3-24Y-6 50–55/72–77	Beta-182947***	–25.0 ‰	**Cal BC 391 to AD 16**	2190 ± 80 bp
SL3-24Y-8 60–65/82–87	Beta-182948***	–25.0 ‰	**Cal BC 778 to 393**	2490 ± 80 bp
SL3-24Y-10 70/91	Beta-182950***	–25.0 ‰	**Cal BC 729 to 102**	2310 ± 80 bp
SL3-24Z-11 42–47/88–93	Beta-197052***	–24.6 ‰	**Cal BC 792 to 412**	2530 ± 80 bp
SL3-24Y-12 76–81/97–102	Beta-197051**	–25.2 ‰	**Cal BC 1188 to 808**	2840 ± 70 bp
SL3-24Z-18 78–82/123–127	Beta-197053*	–25.8 ‰	**Cal BC 2289 to 1985**	3780 ± 40 bp
SL3-25Z-18 85–90/148–156	Beta-197054*	–26.1 ‰	**Cal BC 2206 to 1948**	3740 ± 40 bp
SL3-24Z-20 88–93/134–139	Beta-197055*	–25.1 ‰	**Cal BC 2457 to 2140**	3860 ± 40 bp

[†]95.4% probability.
*AMS-Standard delivery.
**Radiometric-Standard delivery.
***Radiometric-Standard delivery with extended counting.
Dates calibrated using OxCal4.2 Bronk Ramsey (2009) with calibration curve SHCal13 for the southern hemisphere (Hogg *et al*. 2013). All dates on charred material with acid/alkali/acid pre-treatment.

Muchinga Escarpment continue to be occupied into the late second millennium AD, as is the case at Caterpillar Rock. Miller (1969) and Musonda (1984) argue that farming communities settled this mountainous region much later, and at lower densities because of the poor plateau soils. Forager communities continued to live in these areas until relatively recently and are remembered in local oral history (David Chomba, pers. comm. 2007).

RAW MATERIAL SOURCES AND SELECTION

At both Poacher's Cave and Caterpillar Rock, the most used lithic raw materials were those available locally. Quartz, chert and quartzite occur near Poacher's Cave as cobbles eroding from a palaeochannel underlying Kakumbi Hot Springs and in gravel ridges located approximately 8 km to the north-west (quartz, quartzite) (Colton *et al*. 2021). Quartzite occurs within 1 km as boulders and blocks at the base of the Nchindeni Hills. 'Chert' is common at Kakumbi Hot Springs and at Chichele Ridge, 6 km to the north-west (Colton 2009) (Fig. 2). This material has subsequently been reclassified as silcrete, but we retain the original attribution of chert given its use in the field records and in the analyses.

TABLE 1b. *Dosimetry information for the three OSL samples (S31, S32 from 24Z and S33 25Z with location shown in Fig. 9). A grain size of 90–150 µm was used for all samples. Supporting analytical detail for the Central and Maximum Age Model is provided in Supplementary Material. The Central Age Module is the preferred option.*

Sample (Aber90/)	Depth (cm)*	Water content (%)	Alpha count rate (cts/ks/cm²)	Beta dose (Gy/ka)	Calculated concentrations			Total dose (Gy/ka)
					K (%)	U (ppm)	Th (ppm)	
SL31	31/54	5 ± 2	1.52 ± 0.02	3.70 ± 0.12	2.74 ± 0.23	5.99 ± 0.79	22.98 ± 2.65	5.70 ± 0.21
SL32	62/85	8 ± 2	1.70 ± 0.02	3.75 ± 0.12	2.57 ± 0.20	6.95 ± 0.62	24.71 ± 2.08	5.68 ± 0.18
SL33	109/132	10 ± 5	1.39 ± 0.02	2.97 ± 0.10	1.94 ± 0.16	6.37 ± 0.52	17.71 ± 1.74	4.41 ± 0.21

Sample (Aber90/)	Number of grains		Central Age Model		Max. Age Model	
	Measured	Accepted	D_e (Gy)	Age (ka)	D_e (Gy)	Age (ka)
SL31	1000	406	8.86 ± 0.28	1.55 ± 0.08	22.6 ± 0.98	3.97 ± 0.22
SL32	1000	331	12.3 ± 0.27	2.17 ± 0.08	20.9 ± 0.79	3.67 ± 0.18
SL33	1000	209	16.7 ± 0.52	3.79 ± 0.21	29.6 ± 1.41	6.71 ± 0.45

*Depths recorded as below surface/below site datum T3.

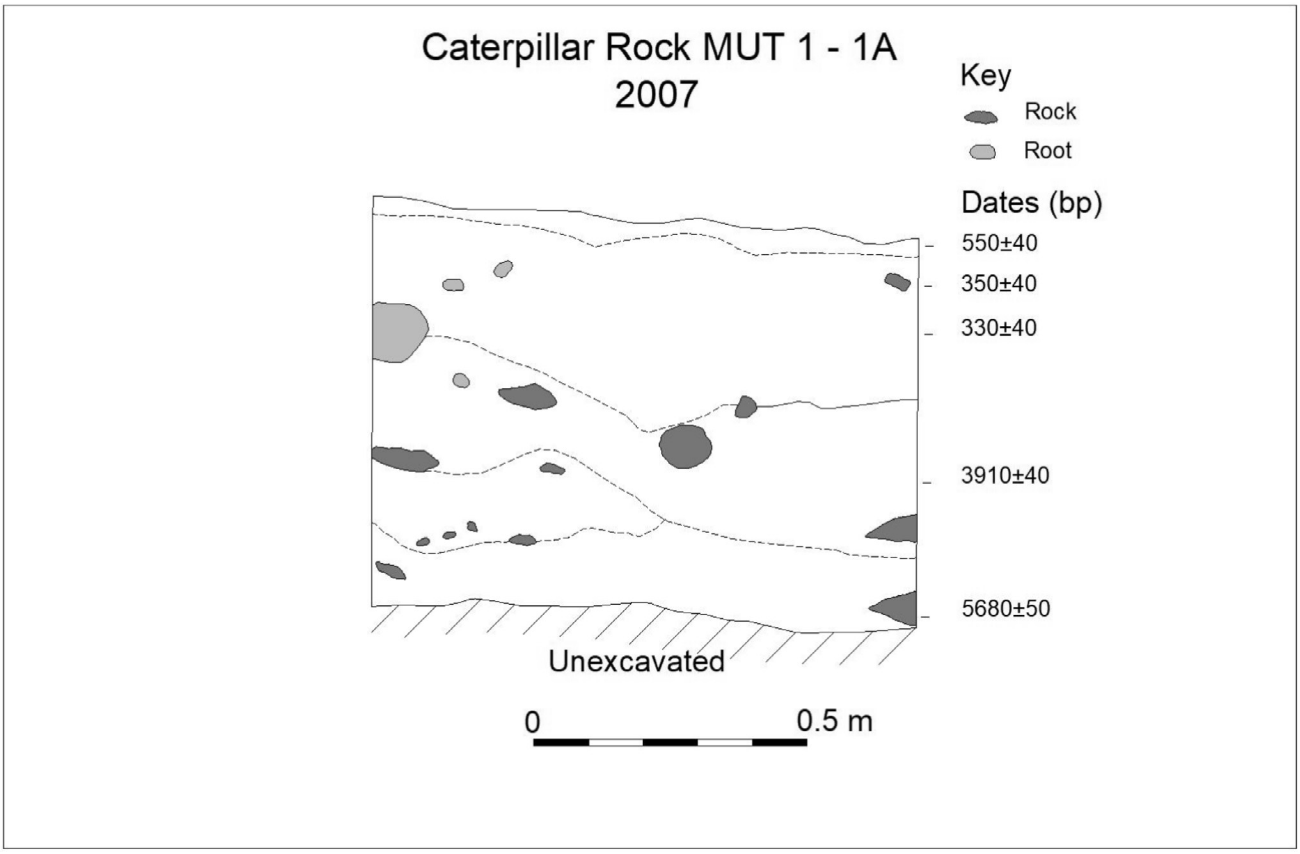

FIG. 10. *Section drawing of 1A, Caterpillar Rock showing the location of dated samples.*

At Caterpillar Rock, limited survey work was conducted, and fewer raw material sources have been identified. In the immediate vicinity of the shelter, the granite inselberg contains veins of opaque quartz below which lie surface scatters of usable quartz blocks. The gneiss/quartzite basement complex of the escarpment zone also provides a source of coarse-grained quartzite in the form of weathered cobbles on the land surface. River-rolled quartz cobbles are found in the beds of nearby perennial rivers, such as the Mutinondo. Chert sources have yet to be located near Caterpillar Rock, and the only site locally with chert is Nachikufu Cave, 53 km to the north-east, where it occurs rarely, and the source is also unknown (Miller 1969).

At Poacher's Cave, quartz represents the dominant material (opaque vein quartz 57.8%, *n* = 6188; clear quartz 25.1%, *n* = 2692) with chert a small but consistent component (10.9%, *n* = 1165). Quartzite was also knapped (6.2%, *n* = 664). Other lithologies are rare. Raw material frequencies remain largely constant throughout the sequence with Table 3 showing a gradual but not significant increase in the exploitation of opaque quartz from the base to the top of the sequence, and a decrease in the frequency of quartzite and chert use.

At Caterpillar Rock, by contrast, clear quartz represents the most selected raw material (71.3%, *n* = 21 466) followed by opaque vein quartz (27.9%, *n* = 8407, Table 2). Quartzite and chert are rare materials (chert = 0.2%, *n* = 67; quartzite = 0.4%, *n* = 129). The frequency of clear quartz increases gradually from the base to the top (Table 3). The rarity of chert reflects its local scarcity and the fact that some of it was retouched (6%) indicates it had a value that transcended the (unknown) distance involved in acquiring the material.

At Poacher's Cave, chert was knapped on site, as evidenced by the recovery of chert cores, flakes, debris and retouched pieces. The very high ratio of chert flakes to cores, 18:1, compared to 6.2:1 for clear and opaque vein quartz combined (Table 4), suggests that chert cores may have been transported from the site after blank production. This may also reflect the greater availability of quartz nodules in the landscape compared to chert, and potentially the increased core utility of chert whereby more flakes could be knapped per core. The recovery of 22 chert core shaping and maintenance pieces (crested blades, core rejuvenation flakes) also reflects efforts to manage and prolong the utility of chert cores. A similar pattern of core transportation is evident at Caterpillar Rock, where the ratio of chert flakes to cores is also 18:1 in comparison to 8.2:1 for quartz cores (opaque/clear quartz combined). A pattern emerges of chert cores as managed and curated elements of the toolkit at both sites.

The number of manuports documented at each site which fall within the size, morphology and raw material types of knapped cores, offers insights into raw material collection strategies. We consider these manuports to be unknapped raw material packages. At Poacher's Cave, 58 manuports were recovered, the majority of which are opaque vein quartz (67.2%, *n* = 41), followed by quartzite (16.4%, *n* = 10), clear quartz (8.2%, *n* = 5) and chert (3.3%, *n* = 2). The small number of unknapped chert raw material packages, indicates that these nodules were almost always reduced when brought to the site, or that initial reduction took place off-site. In contrast, opaque vein quartz packages appear to have been over-collected and abandoned unknapped at the site, perhaps reflecting the local abundance of this material. The number of split quartz cobbles (opaque quartz, *n* = 114; clear quartz, *n* = 77) is further evidence that these nodules were transported to the site and tested. Split cobbles comprise 25.3% of the core and core by-product category at Poacher's Cave.

Manuports are infrequent at Caterpillar Rock and only three pieces fall within the size parameters of cores. Split

TABLE 2. *Raw material frequencies and reduction techniques documented at Poacher's Cave and Caterpillar Rock.*

Poacher's Cave

Knapping technique	Type class	Raw material										Total	
		Milky quartz		Clear quartz		Quartzite		Chert		Other			
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Informal	Cores and core by-products	368	3.4%	143	1.3%	68	0.6%	32	0.3%			611	5.7%
	Whole flakes > 20 mm	363	3.4%	88	0.8%	133	1.2%	170	1.6%	3	0.0%	757	7.1%
	Whole flakes < 20 mm	1211	11.3%	483	4.5%	123	1.1%	298	2.8%	1	0.0%	2116	19.7%
	Retouched pieces	140	1.3%	76	0.7%	8	0.1%	42	0.4%			266	2.5%
	Total	2082	19.4%	790	7.4%	332	3.1%	542	5.1%	4	0.0%	3750	35.0%
Bladelet	Cores and core by-products	24	0.2%	14	0.1%			3	0.0%			41	0.4%
	Whole flakes > 20 mm	35	0.3%	13	0.1%	4	0.0%	10	0.1%			62	0.6%
	Whole flakes < 20 mm	96	0.9%	63	0.6%			20	0.2%			179	1.7%
	Retouched pieces	111	1.0%	69	0.6%			11	0.1%			191	1.8%
	Total	266	2.5%	159	1.5%	4	0.0%	44	0.4%			473	4.4%
Bipolar	Cores and core by-products	68	0.6%	22	0.2%	15	0.1%	1	0.0%			106	1.0%
	Whole flakes > 20 mm	70	0.7%	19	0.2%	12	0.1%	1	0.0%			102	1.0%
	Whole flakes < 20 mm	59	0.6%	36	0.3%	2	0.0%	3	0.0%			100	0.9%
	Retouched pieces	10	0.1%	8	0.1%	2	0.0%	3	0.0%			23	0.2%
	Total	207	1.9%	85	0.8%	31	0.3%	8	0.1%			331	3.1%
Radial	Cores and core by-products	9	0.1%	1	0.0%	3	0.0%	3	0.0%			16	0.1%
	Whole flakes > 20 mm											0	0.0%
	Whole flakes < 20 mm	1	0.0%	1	0.0%							2	0.0%
	Retouched pieces	1	0.0%									1	0.0%
	Total	11	0.1%	2	0.0%	3	0.0%	3	0.0%			19	0.2%
Prepared	Cores and core by-products					1	0.0%	1	0.0%			2	0.0%
	Whole flakes > 20 mm	3	0.0%					2	0.0%			5	0.0%
	Whole flakes < 20 mm											0	0.0%
	Retouched pieces											0	0.0%
	Total	3	0.0%			1	0.0%	3	0.0%			7	0.1%
Debris	Informal/undiagnostic	3231	30.2%	1446	13.5%	272	2.5%	500	4.7%	2	0.0%	5451	50.9%
	Bladelet	280	2.6%	176	1.6%	5	0.0%	37	0.3%			498	4.6%
	Bipolar	34	0.3%	8	0.1%	7	0.1%	1	0.0%			50	0.5%
	Radial											0	0.0%
	Prepared											0	0.0%
	Total	3545	33.1%	1630	15.2%	284	2.7%	538	5.0%	2	0.0%	5999	56.0%
Combined	Cores and core by-products	5	0.0%	3	0.0%	3	0.0%					11	0.1%
	Total	5	0.0%	3	0.0%	3	0.0%					11	0.1%
Maintenance	Cores and core by-products	41	0.4%	9	0.1%	5	0.0%	22	0.2%			77	0.7%
	Total	41	0.4%	9	0.1%	5	0.0%	22	0.2%			77	0.7%
Indeterminate	Retouched pieces	28	0.3%	14	0.1%	1	0.0%	5	0.0%			48	0.4%
	Total	28	0.3%	14	0.1%	1	0.0%	5	0.0%			48	0.4%
	Grand total	**6188**	**57.8%**	**2692**	**25.1%**	**664**	**6.2%**	**1165**	**10.9%**	**6**	**0.1%**	**10715**	**100.0%**

Caterpillar Rock

Knapping technique	Type class	Raw material										Total	
		Milky quartz		Clear quartz		Quartzite		Chert		Other			
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Informal	Cores and core by-products	549	1.8%	544	1.8%	12	0.0%	2	0.0%			1107	3.7%
	Whole flakes > 20 mm	258	0.9%	332	1.1%	53	0.2%	8	0.0%	8	0.0%	659	2.2%
	Whole flakes < 20 mm	3149	10.5%	5993	19.9%	30	0.1%	27	0.1%	19	0.1%	9218	30.6%
	Retouched pieces	48	0.2%	375	1.2%			4	0.0%			427	1.4%
	Total	4004	13.3%	7244	24.1%	95	0.3%	41	0.1%	27	0.1%	11411	37.9%
Bladelet	Cores and core by-products	39	0.4%	59	0.6%				0.0%			98	0.9%
	Whole flakes > 20 mm	3	0.0%	7	0.0%			1	0.0%			11	0.0%
	Whole flakes < 20 mm	38	0.1%	290	1.0%							328	1.1%
	Retouched pieces	18	0.1%	143	0.5%							161	0.5%
	Total	98	0.3%	499	1.7%			1	0.0%			598	2.0%
Bipolar	Cores and core by-products	38	0.1%	48	0.2%							86	0.3%
	Whole flakes > 20 mm	17	0.1%	9	0.0%							26	0.1%
	Whole flakes < 20 mm	10	0.0%	27	0.1%							37	0.1%
	Retouched pieces			2	0.0%							2	0.0%
	Total	65	0.2%	86	0.3%							151	0.5%

Continued on p. 100

Table 2 (continued)

Knapping technique	Type class	Milky quartz		Clear quartz		Quartzite		Chert		Other		Grand total	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Radial	Cores and core by-products	29	0.1%	85	0.3%							114	0.4%
	Whole flakes > 20 mm	1	0.0%	2	0.0%							3	0.0%
	Whole flakes < 20 mm	2	0.0%	32	0.1%							34	0.1%
	Retouched pieces			9	0.0%							9	0.0%
	Total	32	0.1%	128	0.4%							160	0.5%
Prepared	Cores and core by-products	1	0.0%	30	0.1%							31	0.1%
	Whole flakes > 20 mm	2	0.0%	8	0.0%							10	0.0%
	Whole flakes < 20 mm	2	0.0%	29	0.1%							31	0.1%
	Retouched pieces			15	0.0%							15	0.0%
	Total	5	0.0%	82	0.3%							87	0.3%
Debris	Informal/undiagnostic	4101	13.6%	13072	43.4%	34	0.1%	24	0.1%	7	0.0%	17238	57.3%
	Bladelet	33	0.1%	200	0.7%			1	0.0%			234	0.8%
	Bipolar											0	0.0%
	Radial											0	0.0%
	Prepared											0	0.0%
	Total	4134	13.7%	13272	44.1%	34	0.1%	25	0.1%	7	0.0%	17472	58.0%
Combined	Cores and core by-products	6	0.0%	10	0.0%							16	0.1%
	Total	6	0.0%	10	0.0%							16	0.1%
Maintenance	Cores and core by-products	58	0.2%	106	0.4%							164	0.5%
	Total	58	0.2%	106	0.4%							164	0.5%
Indeterminate	Retouched pieces	5	0.0%	39	0.1%							44	0.1%
	Total	5	0.0%	39	0.1%							44	0.1%
	Grand total	**8407**	**27.9%**	**21466**	**71.3%**	**129**	**0.4%**	**67**	**0.2%**	**34**	**0.1%**	**30103**	**100.0%**

cobbles are also rare (2.7% of the core and core by-product category, *n* = 43), suggesting that raw material packages were not commonly brought to the site for testing (or at least not to the back of the shelter). The relatively low frequency of whole cores that retain >50% cortex supports this observation (21.6%, *n* = 346), while only 5.2% (*n* = 37) of whole flakes measuring >20 mm are fully cortical. The extremely low ratio 0.031:1 of fully cortical flakes per whole core further suggests that raw materials were routinely tested before being transported into the site. This may demonstrate a possible geographical discontinuity between core testing and tool blank production activities, but the very limited area of the excavation means this is a working hypothesis pending further excavation.

BLANK PRODUCTION

Informal and formal blank production techniques were documented at both sites, but differences in the frequency and nature with which these techniques were employed reflect varying technical choices. Informal knapping techniques are considered generalised blank production strategies, which did not require specific platform preparation, or the deliberate shaping of flaking surfaces for useful tool blanks to be detached. The informal attribution encompasses any technique that cannot be confidently ascribed to a blade/bladelet, radial or prepared core technique. Bipolar flaking is also considered an informal technique and is discussed separately after formal core strategies. Formal knapping techniques required the careful management of the core form, including deliberate core shaping, platform preparation, and the removal of specific flake forms.

INFORMAL: EXPEDIENT CORES

Informal or irregular cores have one, two or multiple platforms that follow an opportunistic flaking strategy based on available angles. Core platforms are usually plain or cortical. The flakes removed tend to be informal in morphology and technique of production with minimal butt faceting. Dorsal flake scar patterns may be uni-, bi-, or multidirectional, with dorsal surfaces often displaying some degree of cortical coverage.

Both the Poacher's Cave and Caterpillar Rock core and flake assemblages are dominated by informal knapping techniques (Poacher's Cave, 85.9%, *n* = 9201; Caterpillar Rock 95.2%, *n* = 28 649, Table 2). At Caterpillar Rock, informal cores are uniformly small, with mean core length just 22 ± 8 mm, whereas at Poacher's Cave, irregular cores are larger and more variable in size with mean length 33 ± 16 mm. At both sites, the most common irregular core types are single platform cores, chunk cores (with one or two removals) and cores with two platforms at right angles (Table 5, Fig. 11).

Very few irregular cores at either site show platform preparation. Varying levels of decortication are evident, demonstrating that cores were discarded in both the early and late stages of COs. At Poacher's Cave, plain and cortical platforms (with two or more platforms) account for 93.5% (*n* = 316) of all irregular core. There appear to have been few attempts to prepare flaking platforms beyond the removal of an initial flake to provide a non-cortical striking surface. The utility of informal knapping techniques for blank production is seen in the number of informal flakes that were retouched at both sites (below).

The large quantity of irregular debris and unretouched irregular flakes at both sites is consistent with generalised core reduction. The low percentage of heavily reduced and exhausted irregular cores suggests this flaking strategy was a frequent initial stage in sequences leading to more formal core types (Table 5).

FORMAL: PREPARED CORES

Prepared core techniques (Levallois) are often thought to be synonymous with Middle Stone Age and Middle Palaeolithic technologies, although their appearance in Holocene lithic assemblages has been documented in African contexts (Gutherz *et al*. 2014; Leplongeon *et al*. 2017). In Zambia,

TABLE 3. *Raw material frequencies by level.*

Poacher's Cave

	Milky/vein quartz		Clear quartz		Quartzite		Chert		Other		Total	
Level	Count	Weight	Count	Weight	Count	Weight	Count	Weight	Count	Weight	Count	Weight
1	16	12.0	2	1.0	1	0.3	2	0.5	0	0.0	21	13.8
2	6	4.0	1	0.5	4	50.0	3	18.0	0	0.0	14	72.5
3	11	24.0	0	0.0	2	20.0	1	8.0	0	0.0	14	52.0
4	15	24.8	2	0.3	1	1.0	5	40.5	0	0.0	23	66.5
5	21	13.8	7	2.8	3	2.0	3	0.8	0	0.0	34	19.3
6	48	86.0	17	9.8	4	2.0	4	45.0	0	0.0	73	142.8
7	64	101.3	19	19.8	3	12.5	3	8.0	0	0.0	89	141.5
8	154	245.5	55	47.8	8	54.0	11	7.0	0	0.0	228	354.3
9	119	152.0	66	89.8	8	67.5	12	14.3	0	0.0	205	323.5
10	152	377.5	94	131.8	33	386.5	34	52.0	1	0.5	314	948.3
11	229	486.3	124	87.8	41	691.8	22	46.3	2	4.5	418	1316.5
12	146	247.5	32	5.1	20	82.1	17	5.7	0	0.0	215	340.3
13	273	106.1	57	12.8	10	30.4	35	70.4	0	0.0	375	219.6
14	498	459.5	291	54.8	30	286.6	44	9.1	2	0.1	865	810.1
15	428	310.5	241	42.9	34	184.6	69	3.4	0	0.0	772	541.3
16	611	444.0	266	83.9	50	159.6	104	150.8	0	0.0	1031	838.2
17	930	661.7	428	58.9	78	331.3	198	664.0	1	0.1	1635	1716.0
18	924	702.8	422	149.1	62	143.9	182	79.2	0	0.0	1590	1074.9
19	529	67.0	201	69.5	74	678.5	129	10.0	0	0.0	933	825.0
20	676	421.1	224	74.1	117	972.1	208	181.5	0	0.0	1225	1648.7
21	190	135.9	94	8.3	47	582.3	57	13.5	0	0.0	388	739.9
22	94	33.4	29	11.4	16	33.7	9	0.5	0	0.0	148	78.9
23	21	7.9	11	0.6	4	0.2	3	0.2	0	0.0	39	8.8
24	28	1.4	7	6.3	10	67.4	7	0.3	0	0.0	52	75.3
25	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
26	5	0.3	2	0.1	4	0.2	3	0.2	0	0.0	14	0.7
Total	**6188**	**5125.9**	**2692**	**968.5**	**664**	**4840.1**	**1165**	**1428.6**	**6**	**5.15**	**10715**	**12368.2**

Caterpillar Rock

	Milky/vein quartz		Clear quartz		Quartzite		Chert		Other		Total	
Level	Count	Weight	Count	Weight	Count	Weight	Count	Weight	Count	Weight	Count	Weight
1	86	175.4	183	60.3	0	0.0	0	0.0	0	0.0	269	235.7
2	78	108.8	324	114.6	0	0.0	0	0.0	0	0.0	402	223.4
3	185	167.6	769	258.6	3	0.2	0	0.0	1	0.0	958	426.3
4	158	162.5	579	97.6	3	0.2	1	0.1	0	0.0	741	260.3
5	127	111.3	563	111.2	2	38.1	0	0.0	2	0.0	694	260.5
6	278	241.8	825	326.1	7	28.3	1	0.1	0	0.0	1111	596.1
7	111	132.6	226	155.7	1	0.1	0	0.0	6	0.0	344	288.3
8	1285	701.0	2939	569.2	24	181.2	7	2.3	4	0.0	4259	1453.6
9	1879	913.7	5588	1109.3	42	1413.9	24	5.2	0	0.0	7533	3441.9
10	2029	1209.3	5083	666.4	26	51.2	21	1.1	13	0.7	7172	1928.6
11	2191	672.6	4387	452.6	21	1.1	13	0.7	8	0.4	6620	1127.3
Total	**8407**	**4596.4**	**21466**	**3921.2**	**129**	**1713.9**	**67**	**9.3**	**34**	**1.1**	**30103**	**10241.7**

TABLE 4. *Ratios of whole or complete flakes to whole cores at Poacher's Cave and Caterpillar Rock.*

	Poacher's Cave			**Caterpillar Rock**		
Raw material	Whole cores (*n*)	Whole flakes >10 mm (*n*)	Ratio of flakes to cores	Whole cores (*n*)	Whole flakes >10 mm (*n*)	Ratio of flakes to cores
Opaque quartz	315	1837	5.8	571	3482	6.1
Clear quartz	91	702	7.7	669	6729	10.1
Quartzite	67	274	4.1	11	83	7.5
Chert	28	504	18.0	2	36	18.0
Other	0	4	N/A	0	27	N/A
Total	501	3321	6.6	1253	10357	8.3

TABLE 5. *Irregular core type data for the full assemblage at Poacher's Cave and Caterpillar Rock.*

Poacher's Cave	*n*	%	**Caterpillar Rock**	*n*	%
Chunk with one or two removals	50	14.8%	Chunk with one or two removals	198	17.9%
Two platforms at right angles	36	10.7%	Two platforms at right angles	104	9.4%
Single platform	118	34.9%	Single platform	388	35.0%
Multiple platforms, irregular	35	10.4%	Multiple platforms, irregular	46	4.2%
Flake as core	34	10.1%	Flake as core	30	2.7%
Opposed platform	28	8.3%	Opposed platform	84	7.6%
Two platforms, irregular	19	5.6%	Two platforms, irregular	28	2.5%
Alternative flaking	16	4.7%	Alternative flaking	32	2.9%
Polyhedral core	2	0.6%	Polyhedral core	1	0.1%
Total	338	100	Total	1107	100

prepared cores are found in Holocene Later Stone Age assemblages in the Upper Zambezi Valley (L. Phillipson 1977; Burroughs *et al*. 2019), and in the Lunsemfwa Basin on the southern margins of the Muchinga Escarpment (Musonda 1983). Technologically, the prepared core technique is distinguished by a hierarchical volumetric conception of the core, and its execution (Inizan *et al*. 1995: 48–56) to produce flakes of predetermined size, thickness and shape (Eren & Lycett 2012). The resulting flakes typically display multifaceted butts and convergent dorsal flake scar patterns and are generally thin in profile.

Prepared core techniques are not common at Poacher's Cave with only seven pieces recovered; five convergent prepared flakes and two prepared cores (Table 2). At Caterpillar Rock, however, small (~20 mm) but recognisably prepared cores occur throughout the sequence in low frequencies and are consistent in their dimensions and minimal cortex (Fig. 12). Convergent flakes and points, presumed to be the product of core preparation, are also small and almost exclusively made on clear quartz (92.8%, $n = 52$, opaque quartz 7.2%, $n = 4$). Prepared flakes were shaped into backed flakes, points or awls (Fig. 13). These very constrained COs offer an insight into a seemingly well-defined and persistent technical tradition including raw material selection, blank production to tool manufacture.

FORMAL: RADIAL FLAKING

Radial cores are pieces from which flakes are removed centripetally and bifacially around the perimeter. Striking platforms can be plain or may demonstrate simple faceting. The removal of successive flakes inwards around the core facilitates the removal of thin, rounded flakes that are generally free of cortex. Disc cores are interpreted as the later stage of radial flaking, as successive flake removals have gradually reduced the thickness of the core resulting in a flattened profile. In common with prepared core flaking, radial flaking is considered a more formal strategy, as the sequence of operations and actions are specifically directed at producing end-products of predetermined form and dimensions. Radial flaking features in the Middle Stone Age record of Zambia (Barham 2000), and it is present, though less common, in the Later Stone Age locally (Miller 1969; Fagan & Van Noten 1971; Musonda 1984).

At Poacher's Cave only 19 radial pieces were recovered from the basal levels, making it a very short-lived phenomenon, but the low ratio of flakes to cores may be an artefact of the limited preservation of the core face on small quartz flakes (Orton 2012). Of the 16 radial cores recovered, only one was produced on clear quartz, and all radial cores measure <50 mm in maximum dimension.

Radial flaking is also rare at Caterpillar Rock (Table 2). In contrast to Poacher's Cave, clear quartz was the most frequently utilised raw material for radial knapping (80.0%, $n = 128$). Radial flake blanks were modified into a wider range of tools than those produced *via* a prepared core technique, including backed flakes, and scrapers (Figs 12, 13).

FORMAL: BLADES AND BLADELETS

Blade and bladelet techniques are used to produce elongated flakes that are characterised by their parallel margins and 2:1 length/width ratio. Removals are distinguished by length with blades >25 mm and bladelets <25 mm long. The entire circumference of a blade/bladelet core may be flaked, and occasionally with two opposing platforms worked (Inizan *et al*. 1995: 60–63). Common to both techniques is the need to create and maintain a series of adjacent parallel scars on the flaking surface, and a striking platform at right angles to the flaking surface. Initial removals can be created by shaping the core surface (crested blade) or selecting an existing ridge. The presence of crested blades is a useful indicator of *in situ* production. Bipolar flaking can also be used to produce bladelets though with less control over the dimensions of the flake (Barham 1987). Bladelet production is rare in the regional Middle Stone Age (Barham 2000) and is a distinctive feature of the LSA industries of the region (Miller 1969; D. Phillipson 1976; Musonda 1984).

Bladelet knapping is documented at both Poacher's Cave and Caterpillar Rock and is the second most common core technique in the Poacher's Cave assemblage (9.1%, $n = 971$). Of this total, retouched pieces comprise almost a fifth of all blade/bladelets pieces (19.7%, $n = 191$). A total of 241 whole blade/bladelets were recovered from Poacher's Cave, giving a ratio of 1.26:1 of unretouched to retouched blanks, strongly suggesting a preferential selection of bladelets for tools.

Most whole bladelet cores and unretouched bladelets recovered from Poacher's Cave have plain platforms (cores 73.2%, $n = 31$; flakes 70.7%, $n = 70$), suggesting that platform preparation was not a priority although cortex removal may have been. Opaque quartz is the preferred material for bladelet production (58.5% of bladelet cores, $n = 24$), although clear quartz was also frequently used (34.1% of bladelet cores, $n = 14$). Of the seven crested bladelets recovered, two retain cortex from the initial preparation of the flaking surface, and the remaining five are cortex-free, indicating a later stage of core shaping (Inizan *et al*. 1995). Six of the seven crested blades are chert, suggesting a deliberate strategy for managing this material in contrast to quartz. Only three chert bladelet cores were recovered, indicating that chert may have been a carefully maintained material.

The objective of producing bladelet blanks for retouch may

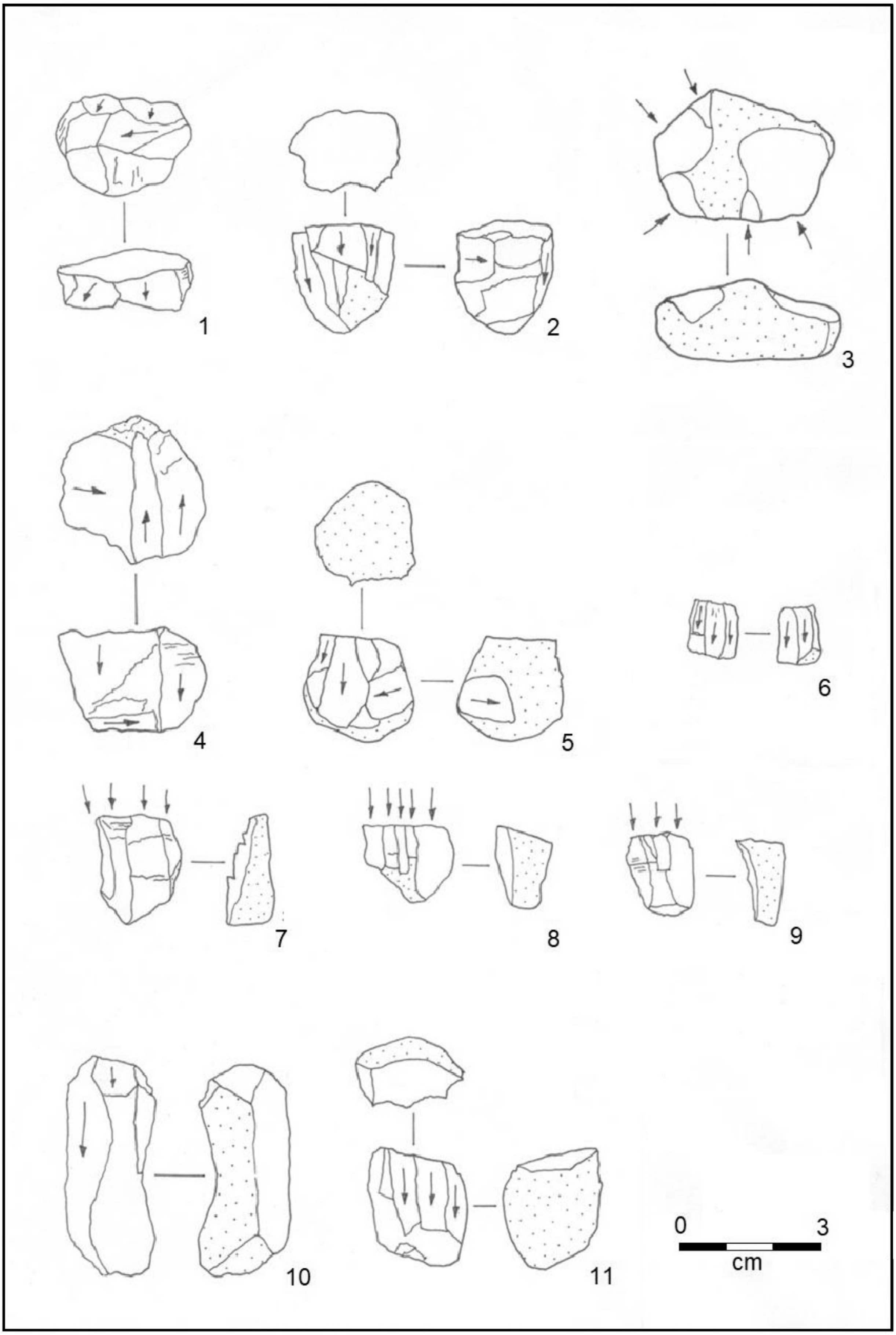

FIG. 11. *Poacher's Cave: Irregular, bladelet and radial cores. All from levels 1–13. Milky/vein quartz; 1, 3, 4, 10; Clear quartz; 2, 5, 6, 7, 8, 9, 11. Two platforms at right angles; 1, 2: Multiple platform; 4, 5: Radial; 3: Bladelet; 6, 7, 8, 9, 10, 11. Numbers 1–4 and 6–11 are from square 24A'. The lithics from 24A' are not included in this analysis, but these pieces are illustrated as they are characteristic of single platform cores recovered from the site.*

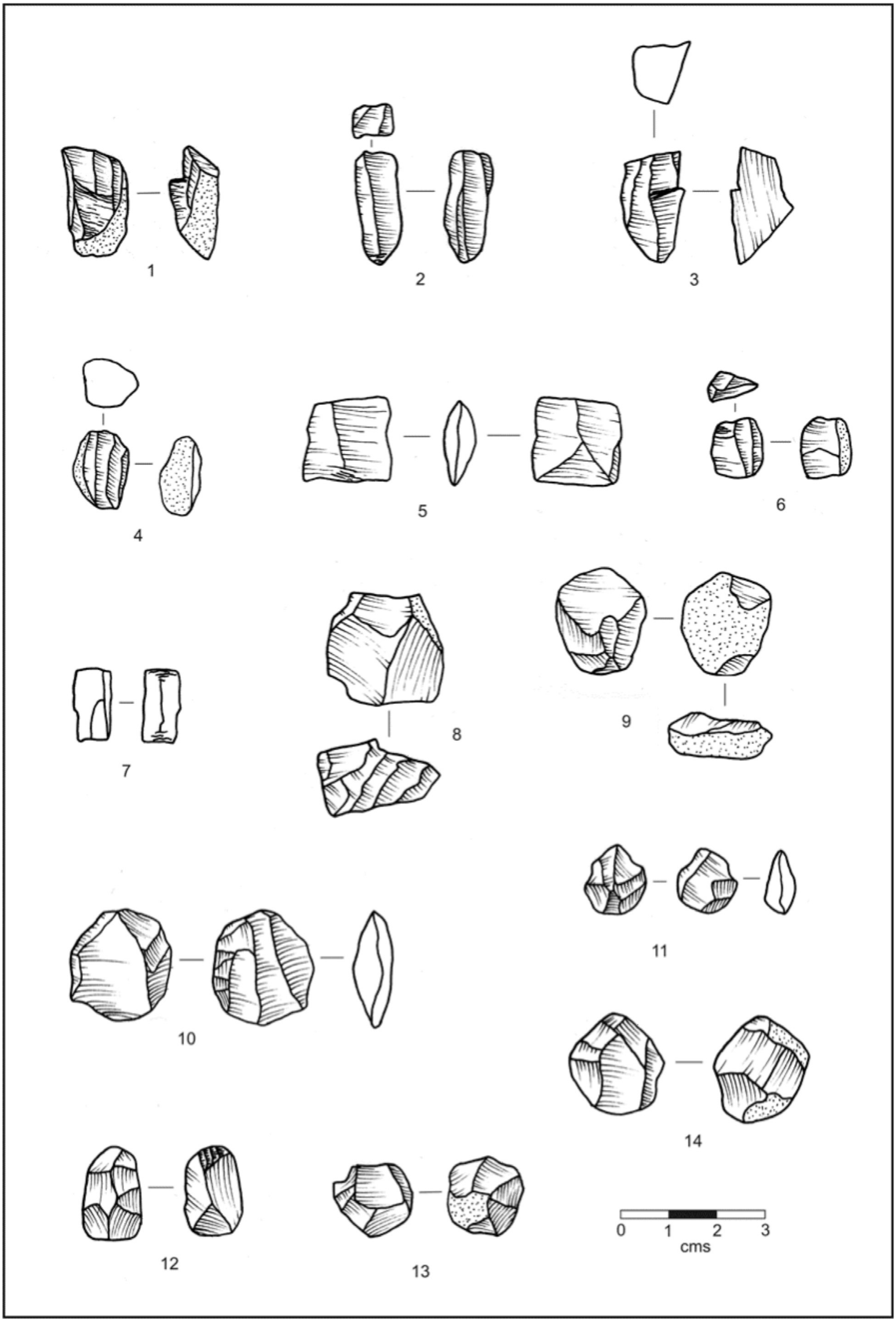

FIG. 12. *Caterpillar Rock: Bladelet, bipolar, radial and prepared cores from Caterpillar Rock, Levels 1–12; artefacts 1–4, 6–8, 12–14; Levels 5, 9–11. Bladelet: 2, 4; exhausted bladelet: 1, 3; bipolar: 5–7; radial: 8–11; prepared: 12–14. Clear quartz: 1, 5–13; milky/vein quartz: 2–4, 14.*

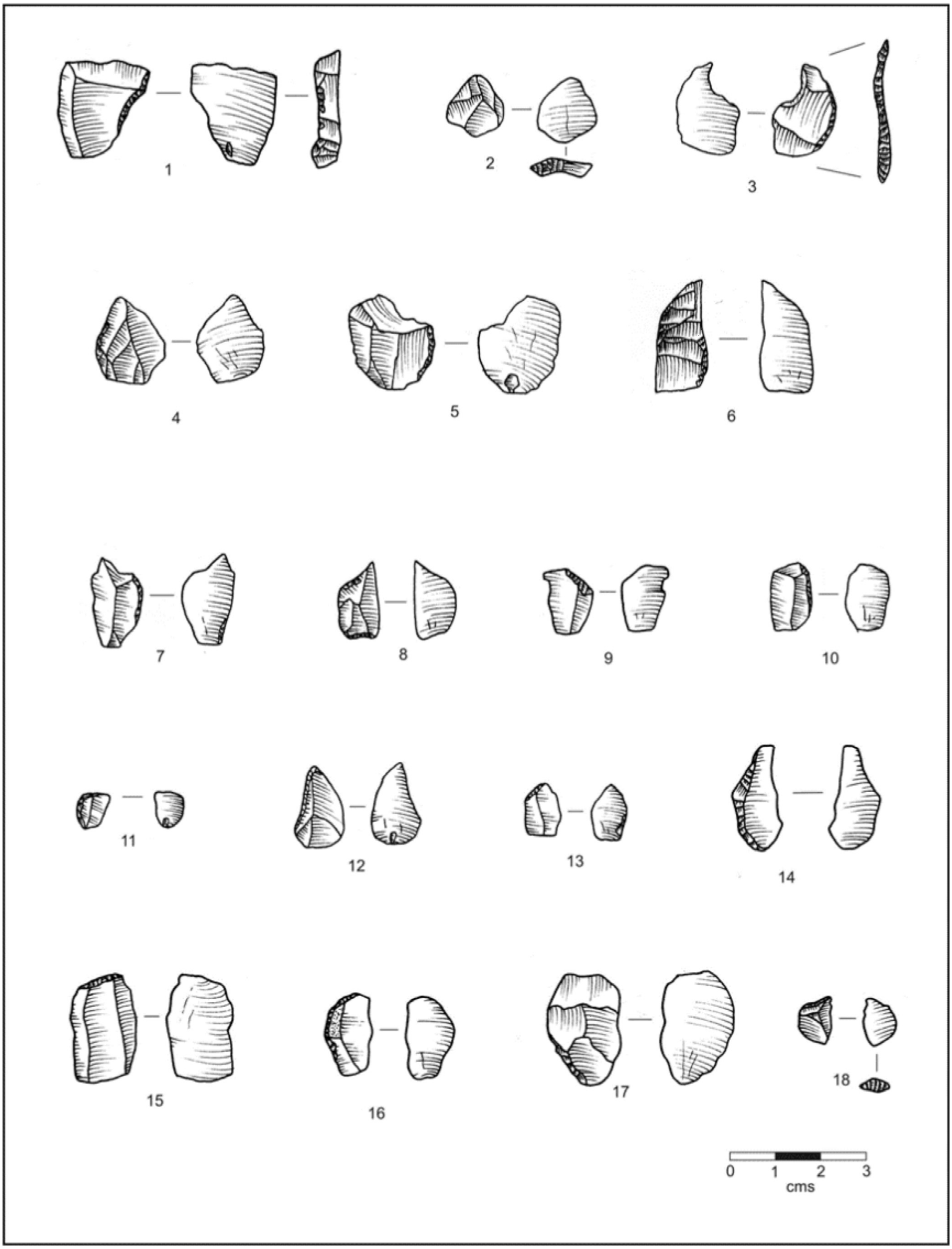

FIG. 13. *Caterpillar Rock: Backed flakes and backed blade/bladelets from Levels 2–18. Clear quartz; 2–18 milky/vein quartz 1. Backed flake; 1, 3, 4, 7–17: Faceted radial flake/point; 2, 5: Backed flake with faceted butt; 18. The backed edge profile of number 3 is enlarged to show the backed margin in its entirety.*

have been chronologically circumscribed at Poacher's Cave as there is a marked decline in the frequency of bladelets in the later levels (from 12 above, 2840 ± 70 bp and younger), perhaps signalling a changing use of the site as indicated by an increase in more informal knapping strategies.

At Caterpillar Rock, the blade/bladelet technique is also the second most common blank production strategy (2.8%, *n* = 832). Bladelet cores are typically small (<25 mm) with plain platforms. In contrast to Poacher's Cave, clear quartz was the most utilised material for bladelet production (60.2% of bladelet cores, *n* = 59), although opaque vein quartz was also used commonly (34.0% of bladelet cores, *n* = 39). A total of 339 whole bladelets were recorded, 87.6% of which are clear quartz (*n* = 297), with only a single chert bladelet recovered. Few bladelets retain cortical surfaces or cortical butts; of the five crested blades recovered, all display non-cortical butts, demonstrating that in each case the core platform was cleared before the removal of the crested blade. As at Poacher's Cave, bladelets appear to have also been preferentially selected for tool manufacture indicated by the ratio of 1:2.3 retouched to unmodified bladelets as compared to the ratio of 1:27.3 for retouched to unmodified irregular flakes.

INFORMAL: BIPOLAR FLAKING

Bipolar knapping involves the use of an anvil to generate flakes. A core is placed on an anvil and struck from above with a hammer, along the vertical or horizontal axis, or at an oblique angle (Diez-Martín *et al*. 2011). Flakes can be removed from the top of the core *via* the direct force from the hammer strike, or from the bottom *via* indirect force from the anvil, and from one or both planes (Barham 1987; Casey 2000). The bipolar force exerted can result in crushing to core platforms and flake butts, and often produces relatively shorter, thicker flakes with few demonstrable Hertzian characteristics (Diez-Martín *et al*. 2011). Bipolar cores may display removals at one or both ends, can be pillow-shaped (biconvex) or flat in profile, or occasionally rounded. Platform/flaking surface angles tend not to be very acute, approximating 90° in many cases, and a large amount of blocky debitage can be produced during knapping (Diez-Martín *et al*. 2011). Bipolar reduction is not specific to any period in Zambia and is one strategy for working small raw materials.

Bipolar reduction is most prevalent at Poacher's Cave, where it comprises 3.1% (*n* = 331) of the lithic assemblage compared with only 0.5% (*n* = 151) at Caterpillar Rock. At Poacher's Cave, the technique was used to open small raw material packages, as evidenced by the high number of split cobbles, but also late in COs, seemingly to extend the viability of an otherwise unusable core. Bipolar cores overlap in size with bladelet cores, demonstrating that both strategies were used to reduce small raw material packages. This is also true at Caterpillar Rock, where bipolar cores and bladelet cores overlap in all dimensions except thickness. The possibility remains that bipolar cores represent the end stage of blade/bladelet COs, as argued by David Phillipson (1976) and Carla Savage (1983) but given the high degree of overlap in the mean dimensions of bipolar and blade/bladelet cores, it is clear that small piece exploitation was not the exclusive province of the bipolar technique.

Bipolar flaking at Poacher's Cave was applied to a wider range of raw material packages than at Caterpillar Rock where chert was not reduced using this strategy (Table 2). A chi-square test performed to investigate any relationships between the four most frequent raw materials (opaque vein quartz, clear quartz, chert and quartzite) and the three most frequent blank production techniques (irregular, blade/bladelet and bipolar) at Poacher's Cave returned a statistically significant result (χ^2 (6) = 126.21, $p < 0.001$) (Tables 6 and 7). The adjusted standard residuals demonstrate that the overall chi-square statistic is driven by the positive associations between clear quartz and the blade/bladelet technique, and between quartzite and chert and irregular knapping (all significant at $p < 0.001$) and the negative associations between chert and bipolar flaking, quartzite and blade/bladelet knapping and clear quartz and irregular knapping (all significant at $p < 0.001$). These statistics reflect the preferential selection of clear quartz, and the eschewal of quartzite, for blade/bladelet knapping at Poacher's Cave, and the routine exclusion of chert from bipolar reduction.

TABLE 6. *Poacher's Cave: actual and expected frequencies of raw material by knapping technique.*

Raw material		Knapping technique			Total
		Irregular	Blade/ bladelet	Bipolar	
Milky/vein quartz	Count	5313	546	241	6100
	Expected	5318.05	561.59	220.36	0.58
	Row %	87.1%	9.0%	4.0%	100.0%
	Column %	57.8%	56.2%	63.3%	57.8%
	Total %	50.4%	5.2%	2.3%	57.8
	Adjusted residual	–0.30	–1.06	2.18	
Clear quartz	Count	2236	335	93	2664
	Expected	2322.51	245.26	96.23	0.25
	Row %	83.9%	12.6%	3.5%	100.0%
	Column %	24.3%	34.5%	24.4%	25.3%
	Total %	21.2%	3.2%	0.9%	25.3%
	Adjusted residual	–5.80	6.96	–0.39	
Quartzite	Count	604	9	38	651
	Expected	567.55	59.93	23.52	0.06
	Row %	92.8%	1.4%	5.8%	100.0%
	Column %	6.6%	0.9%	10.0%	6.2%
	Total %	5.7%	0.1%	0.4%	6.2%
	Adjusted residual	4.41	–7.13	3.14	
Chert	Count	1042	81	9	1132
	Expected	986.89	104.22	40.89	0.11
	Row %	92.0%	7.2%	0.8%	100.0%
	Column %	11.3%	8.3%	2.4%	10.7%
	Total %	9.9%	0.8%	0.1%	10.7%
	Adjusted residual	5.19	–2.53	–5.38	
Total	Count	9195	971	381	10547
	Expected	0.87	0.09	0.04	1.00
	Row %	87.2%	9.2%	3.6%	100.0%
	Column %	100.0%	100.0%	100.0%	100.0%
	Total %	87.20%	9.20%	3.60%	100.00%

TABLE 7. *Poacher's Cave: chi-square test results for relationship between raw material and knapping technique. For a 4 × 3 table, the effect sizes for the Cramer's V statistic are as follows: small = 0.07, medium = 0.21, large = 0.35. (Pallant 2007: 217). The effect size is therefore significant, but small. Analysis performed using PSPP 1.6.2.*

	Value	df	Asymp. sig. (2-tailed)
Pearson chi-square	126.21	6	0.000
Likelihood ratio	157.83	6	0.000
Linear-by-linear association	22.72	1	0.000
No. of valid cases	10547		
Cramer's V	0.08		

RETOUCHED PIECES

Whole retouched pieces make up 3.8% (*n* = 402) of the Poacher's Cave assemblage and 1.9% (*n* = 558) of the Caterpillar Rock assemblage (Table 8). Backed tools are the most common group at each site, comprising over half of the retouched fraction (Fig. 14). Scrapers are the second most numerous tool group at both sites, followed by awls, becs and borers. Notched pieces are infrequent in the Poacher's Cave assemblage, and rarer at Caterpillar Rock, while denticulates and points are extremely rare at both sites. Points are invasively retouched, commonly along a single lateral margin, with bifacial points extremely rare (Fig. 14). At Poacher's Cave, opaque quartz was the most frequently selected raw material for retouching followed by clear quartz, and at Caterpillar Rock clear quartz was the most common raw material. An exception to the preference for quartz occurs at Poacher's Cave where, in the upper levels, chert was more commonly used to make awls, becs, borers and notched pieces.

At both sites the most frequent backed tool types are segments, backed flakes and backed blade/bladelets with trapeze or tranchets, truncated pieces and miscellaneous backed pieces comparatively rare (Figs 15, 16). The frequency of segments and backed flakes varies between the sites, with backed flakes more common at Caterpillar Rock, and segments the most frequent type at Poacher's Cave (Fig. 14). Backed bladelets appear throughout the Caterpillar Rock sequence, and in the earlier levels at Poacher's Cave. Their disappearance above level 14 at Poacher's Cave is not due to a hiatus in bladelet use; bladelet blanks continued to be selected but were only shaped into segments and trapeze/tranchet forms.

Scrapers comprise less than 20% of the retouched fraction at each site. Scrapers are uniformly small, with the majority measuring <20 mm. Chert scrapers are only found at Poacher's Cave. End and side scrapers produced on informal flake blanks are the dominant types at each site, with concave and chunk scrapers very rare.

BLANK SELECTION

At both Poacher's Cave and Caterpillar Rock, irregular flakes and blade/bladelets provided most tool blanks (Table 7). Ten backed pieces produced on bipolar flakes were documented at Poacher's Cave, with the use of bipolar blanks all but restricted to the upper 13 levels of the sequence, and almost exclusively to the production of segments. A bipolar blank production technique, while less controllable in terms of producing uniform flakes, often results in blanks that possess naturally crescent-like dimensions for use as segments without retouch and have the added advantage of sheared or flattened platforms that do not require removal (Barham 1987).

Natural backing describes instances where the cortical margin of a tool blank was incorporated into the backed portion of the tool. The phenomenon occurs most commonly at Poacher's Cave, where 21.1% (*n* = 25) of segments display natural backing. In some cases, the naturally backed edge extends almost the entire length of the blunt margin, with only a few small flakes removed from one or both ends apparently to standardise the symmetry of the piece. Natural backing is most prevalent in upper levels (1–13) with 35% (*n* = 14) of backed pieces having some form of cortical margin, in contrast to the lower levels (14–26) (16%, *n* = 26). This difference coincides with the increased use of bipolar blanks in the upper levels as part of a wider strategy of expedient knapping. In contrast, natural backing is rare at Caterpillar Rock (3.9%, *n* = 13) with most backed pieces free of cortex altogether (79.2%, *n* = 267; Poacher's Cave 61.1%, *n* = 124). These data point to blanks chosen from later in the CO.

SUMMARY

Technical choices shared at both sites include the preference for isotropic raw materials, such as clear quartz, to produce retouched pieces, and for the pursuit of more prolonged COs (e.g. bladelet knapping). Bladelets were the blank of choice for backed tool manufacture, with chert a valued material at both sites for making retouched tools. Informal knapping strategies predominate over formal strategies, with clear and opaque vein quartz the preferred materials for informal reduction. At both sites, informal techniques include plain single or double platform cores with fewer than four removals. At Poacher's

TABLE 8. *Tool types by blank manufacture technique at Poacher's Cave and Caterpillar Rock as assemblage totals.*

	Poacher's Cave											
	Scrapers		Backed		Edge retouched		Points		Flakes >20 mm		Flakes <20 mm	
Blank technique	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Irregular	47	67.1%	83	40.9%	89	73.0%	6	85.7%	757	81.7%	2116	88.4%
Bladelet	20	28.6%	96	47.3%	29	23.8%	1	14.3%	62	6.7%	179	7.5%
Bipolar	3	4.3%	10	4.9%	3	2.5%	0	0.0%	102	11.0%	100	4.2%
Radial	0	0.0%	0	0.0%	1	0.8%	0	0.0%	0	0.0%	0	0.0%
Prepared	0	0.0%	0	0.0%	0	0.0%	0	0.0%	5	0.5%	0	0.0%
Indeterminate	0	0.0%	14	6.9%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	70	100%	203	100%	122	100%	7	100%	926	100%	2395	100%

	Caterpillar Rock											
	Scrapers		Backed		Edge retouched		Points		Flakes >20 mm		Flakes <20 mm	
Blank technique	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Irregular	55	69.6%	209	62.0%	94	74.0%	5	33.3%	659	92.9%	9218	95.5%
Bladelet	17	21.5%	109	32.3%	23	18.1%	1	6.7%	11	1.6%	328	3.4%
Bipolar	1	1.3%	0	0.0%	1	0.8%	0	0.0%	26	3.7%	37	0.4%
Radial	4	5.1%	2	0.6%	2	1.6%	1	6.7%	3	0.4%	34	0.4%
Prepared	0	0.0%	7	2.1%	2	1.6%	6	40.0%	10	1.4%	31	0.3%
Indeterminate	2	2.5%	10	3.0%	5	3.9%	2	13.3%	0	0.0%	0	0.0%
Total	79	100%	337	100%	127	100%	15	100%	709	100%	9648	100%

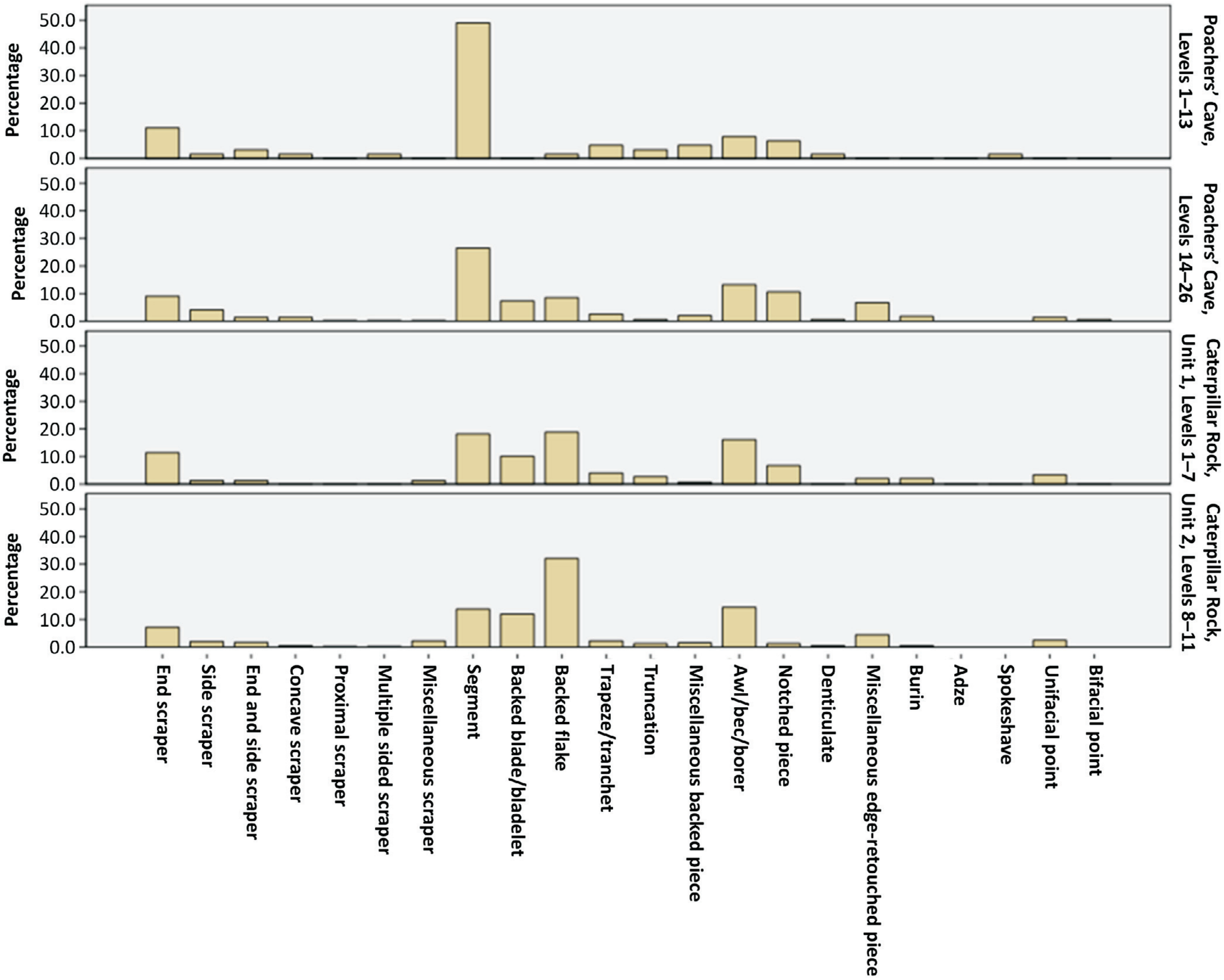

FIG. 14. *Tool type frequencies for Poacher's Cave and Caterpillar Rock by grouped levels (units).*

Cave, bipolar flaking falls into this category. It appears that although communities on the escarpment, and in the valley, viewed bipolar flaking as a useful reduction for working quartz cobbles, it was used only in the later phase of occupation at Poacher's Cave (~2200 BP) to produce retouched tools.

There are other distinct differences between the two sites starting with approaches to specialised/formal blank production. The occupants of Caterpillar Rock applied prepared core and radial flaking strategies to produce blanks for making a narrow range of retouched tools. Knappers at Poacher's Cave, however, rarely used these strategies. Differences are also evident in the approach to the making of backed tools, with backed flakes more common at Caterpillar Rock, and segments more common at Poacher's Cave. Backed bladelets feature throughout the Caterpillar Rock record, but at Poacher's Cave they cease to be made towards the end of the sequence in preference to segments and trapeze/tranchets.

REGIONAL CONTEXT RECONSIDERED

Geographically, the Luangwa Valley lies between the range of the Nachikufan and Makwe industries, while Caterpillar Rock is situated in the heartland of the Nachikufan. In terms of technological and typological similarity, the Makwe lithics do not closely resemble either of the assemblages described here. The clearest dissimilarity lies in the frequencies of single and double platform cores which are common at Poacher's Cave but not in the Zambian Makwe sites to the south (Thandwe, Kalemba, Makwe) (D. Phillipson 1976). In this respect, the Poacher's Cave sequence more closely resembles that of the Makwe assemblage from Chencherere situated in the Malawian highlands where these core strategies are well represented (Crader 1984). There is also variation between localities in the frequency of bipolar reduction. Frequencies are low in Makwe assemblages despite the predominant exploitation of small river-rolled and weathered quartz raw material packages (D. Phillipson 1976: 52, 73, 128, table 38). In terms of retouched tool patterning, the Makwe industry is distinctive in relation to sequences at Poacher's Cave and Caterpillar Rock for the high proportion of angle-backed geometrics (trapezes and *petits tranchets*) relative to the frequency of backed flakes and segments (D. Phillipson 1976: 191).

In the Lunsemfwa Drainage Basin, four Nachikufan III sites have been documented (Musonda 1985). These assemblages are typified by a dominance of backed flakes, varying frequencies of segments, and a decreasing frequency of backed bladelets over time (Musonda 1985: 323, 330). Single platform irregular cores occur most frequently, followed by discoid cores and blade/bladelet cores. No bipolar cores were recovered from the excavations, a pattern like that documented at the Nachikufan site of Luando, where only one bipolar core was documented (*n* = 1, 0.1%) (Bisson 1990). Unlike Caterpillar Rock, there appears to have been no specific association

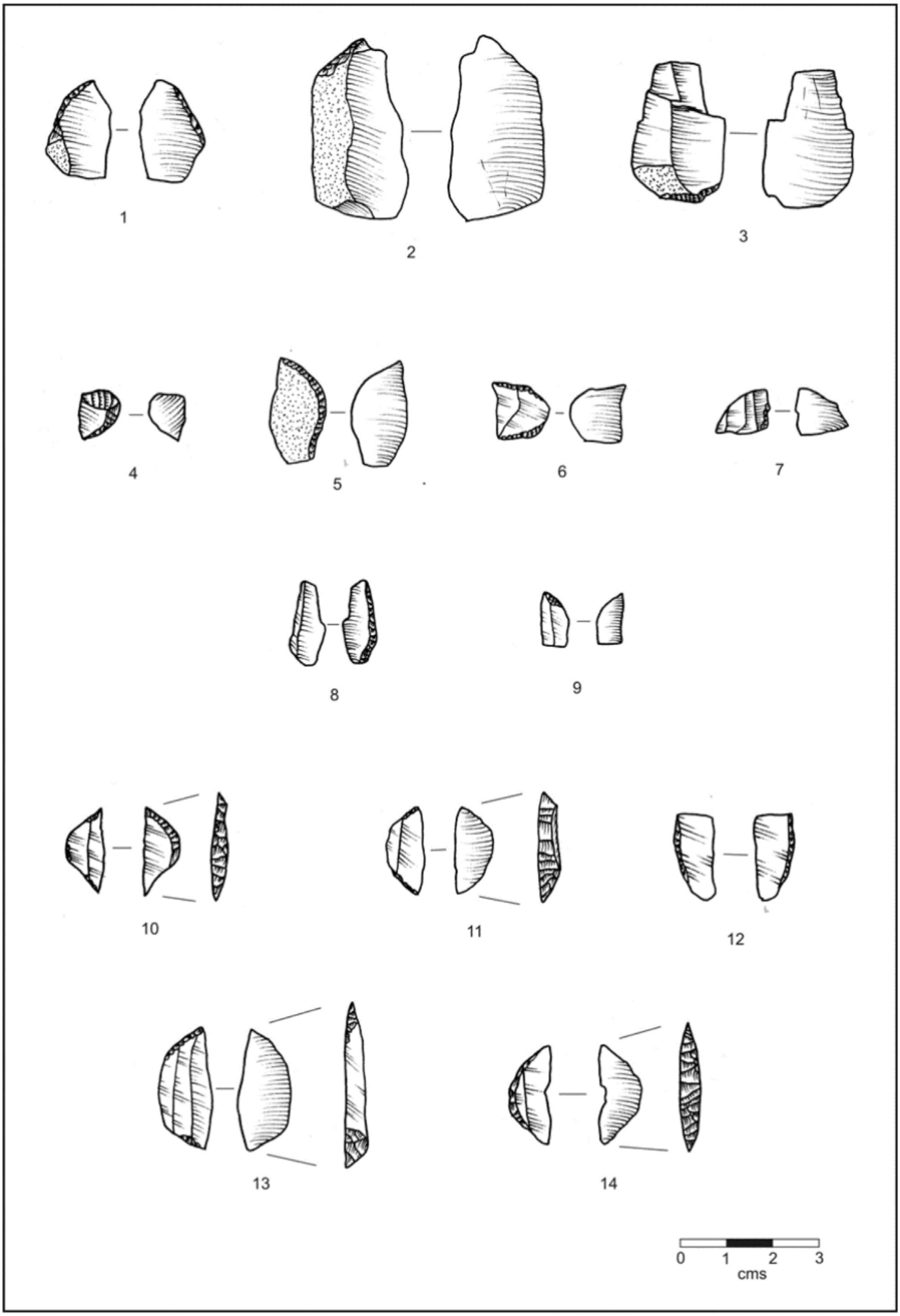

FIG. 15. *Poacher's Cave: Backed pieces. Levels 1–13; 10: Levels 14–26; 1–9, 11–14. Milky/vein quartz; 1–3, 8–14: Clear quartz; 4–7. Backed flakes; 1–7: Backed blade/bladelets; 8, 9: Segments; 10–14 (12 is broken).*

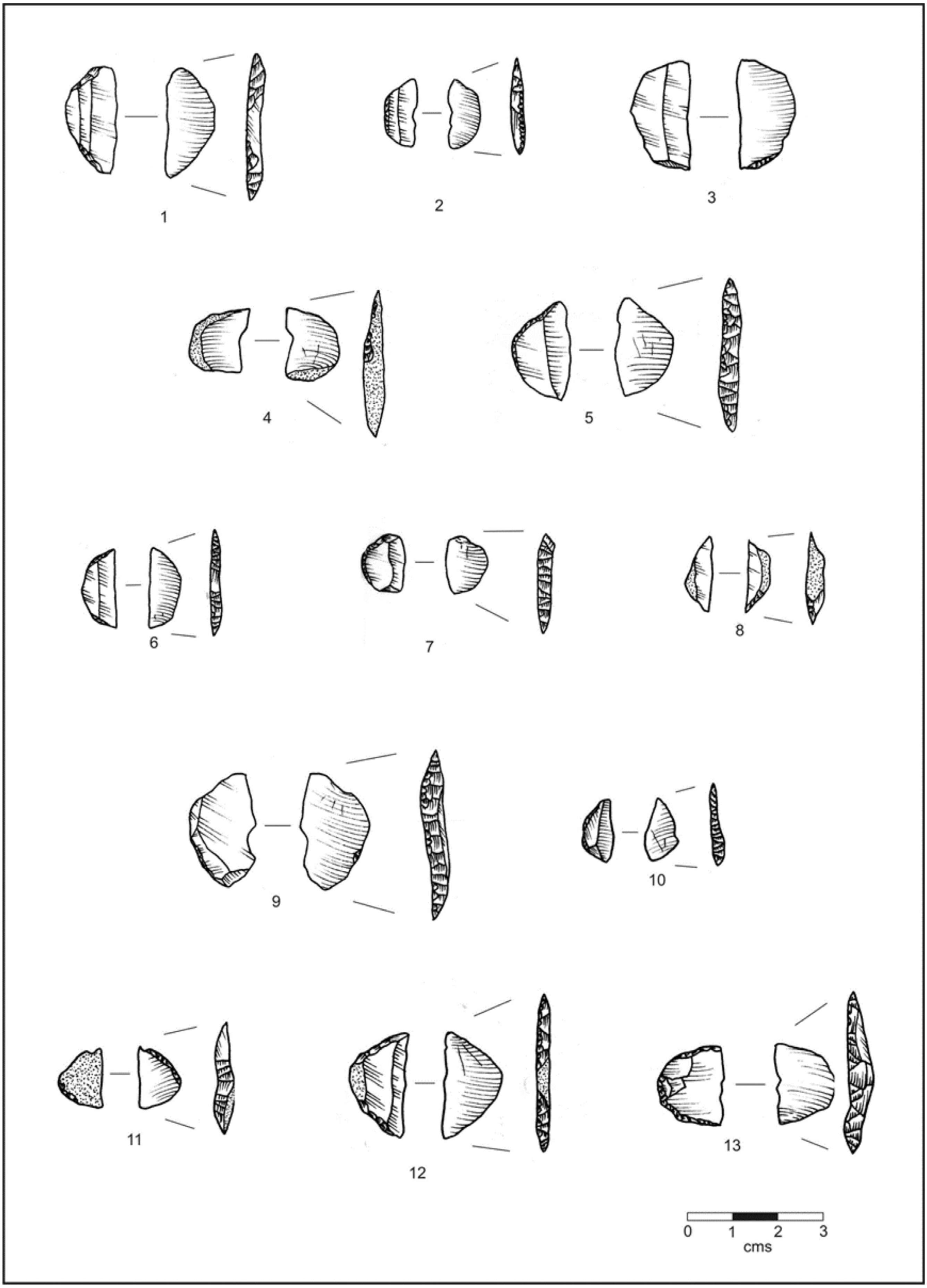

FIG. 16. *Caterpillar Rock: Segments. Unit 1; 1, 2, 4–9: Unit 2; 3, 10–13. Clear quartz; 4–12: Milky/vein quartz; 1–3: Chert; 13. Segments; 1–13. Backed edge profiles are enlarged to show the backed margins in their entirety.*

between clear quartz and radial flaking in the Lunsemfwa Drainage Basin, except perhaps at Mufulwe (Musonda 1985: table 5.14), though blade/bladelet cores do appear to have been preferentially based on clear quartz pieces at each site. Typologically, the microlithic collections from the late Holocene levels at Mufulwe and Mwambacimo resemble that from the later occupation phase at Caterpillar Rock; high relative frequencies of backed flakes and segments, compared to lesser counts of backed bladelets. This resemblance needs assessing with a larger sample from Caterpillar Rock. The backed blade/bladelet element at the Lunsemfwa sites contrasts with the absence of this tool type in the later phase of Poacher's Cave.

The Zambian Wilton assemblage from Mumbwa Caves in central Zambia is characterised by high frequencies of microliths and convex scrapers and is dominated by single and double platform core types (Savage 1983). Bipolar and radial cores occur in low frequencies (Savage 1983: 304–320, fig. 5-43). It is difficult to assess the presence of blade/bladelet flaking as these cores are included in the bipolar core designation. An increase in the frequency of backed flakes over segments possibly occurred during the late Holocene, but low overall retouched piece counts make this pattern difficult to confirm (Savage 1983: 258).

Following her excavations at Mumbwa, and an extensive reassessment of Zambian Later Stone Age material, Savage has rejected the use of separate industrial designations in Zambia, instead arguing that all microlithic assemblages postdating Nachikufan I should be subsumed within a regional 'Nachikufan Industrial Complex' (Savage 1983: 383–385; see also Sampson & Southard 1973). In both typological and technical terms, the Caterpillar Rock and Poacher's Cave assemblages cluster with Wilton assemblages as much as they do with Nachikufan collections, an observation which reinforces the widespread intersection of middle to late Holocene assemblages across the central plateau of Zambia. Typological and technological discontinuities become clearer to the east and south with the distinctive patterning in core and retouched tool frequencies seen in Makwe industry assemblages. A CO approach to lithic variability has also helped to highlight similarities which may reflect local communities of practice within larger regional networks of shared behaviours that transcend industry boundaries. Small but potentially significant differences also become evident, such as the presence of prepared cores at Caterpillar Rock compared with their rarity at Poacher's Cave. These observations raise important implications for assessing the behavioural significance of lithic variability as outlined in our conclusion.

DISCUSSION

In recent years, critiques have emerged that highlight epistemological and methodological shortcomings of the CO approach to lithic analysis (Bleed 2001; Shott 2003; Bar-Yosef & Van Peer 2009; Tostevin 2011; Fairlie & Barham 2016). These analyses converge on its underlying assumption that it can reveal cognitive processes in its treatment of variability in the archaeological record. That some degree of planning is a prerequisite of any manufacturing event is a fact generally acknowledged among lithic analysts (Gibson & Ingold 1993; Andrefsky 2005), but the extent to which knapping is goal driven is being questioned. Bleed (2001) suggests that the way CO analysts conceptualise the role of planning divides them into two broad categories. One group adopts a teleological approach that views the stages in a production sequence as the imposition of a preconceived procedural series aimed at producing specific design forms. This approach offers limited scope for opportunistic deviation from procedural norms, as each action is required before the next can take place. The end-product, in this view, is a genuine reflection of an original design target (Leroi-Gourhan 1964 [1993]). Teleological models tend towards linearity because they emphasise routine, patterned actions that produce predictable, recognisable results. Alternatively, Bleed (2001: 121) elucidates an evolutionary approach which conceptualises steps within a manufacture process as situational, subject to alteration according to immediate circumstances, with action viewed as very much contextual and responsive rather than fixed. Engagement with the material in this embodied perspective recognises that successful results require a degree of planning, but also give room for flexibility in choices in the face of situational constraints (Malafouris 2013; Fairlie & Barham 2016).

In this study, both perspectives coexist with some COs reflecting a greater degree of predetermination than others, and within individual assemblages. Predetermination is evident in the formal strategies, in particular prepared and radial core flaking. The flake blanks from these were selected for a narrow range of tool types, but with variability in the choice of blank to achieve similar outcomes, as in the case of flake and bladelet based segments. Greater flexibility and expediency are seen in the range of informal knapping techniques which produced a variety of blanks for less standardised tool forms, and for formal tools in the case of segments at Poacher's Cave. Bipolar flakes and naturally backed flakes were selected for segments, indicating flexibility in the imposition of form. In an early edge damage analysis of unretouched flakes from the LSA levels at Chiwemupula, Phillipson and Phillipson (1970) demonstrated that a wide variety of unretouched flake forms were utilised for several different tasks. This observation, as supported by ethnographic evidence (Holdaway & Douglass 2012; Dibble *et al.* 2017), demonstrates that many COs were fluid concepts governed less by the need to create a deliberate end-product, than to produce variable flake forms that could be selected for a range of uses. There is room here for seeing a more embodied or situated cognition with the knapper responding actively to the materials as well as intended tasks (Malafouris 2013).

Finally, it is important to acknowledge that debitage analyses such as those undertaken in this study fundamentally limit the potential of a CO approach to reconstruct full sequences of decision-making within the archaeological record. Attempts to recognise patterns in core reduction from dorsal scar signatures on flakes, which only preserve a small portion of the core face, may significantly misrepresent the frequency of core forms within the record. In the present study, this constraint may be affecting radial flake counts which are notably lower than other flake classes, possibly owing to difficulties in recognising radial scar patterning on diminutive dorsal surfaces. These challenges are magnified when attempting to identify tool blanks from which retouched pieces were manufactured as the process of retouch further reduces the evidence of dorsal scar patterning from which inferences regarding knapping strategies can be made. Addressing these limitations in debitage analyses is an ongoing challenge for all lithic studies which incorporate a CO approach.

CONCLUSION

This study addresses the fundamental question of whether a CO approach can be profitably used to analyse LSA quartz-based lithic assemblages. It has been demonstrated that a hybrid analytical scheme based on those developed by Inizan *et al*. (1995) and Deacon (1984) generates detailed information about raw material selection, transport, core reduction, blank production, blank selection, core rejuvenation, tool manufacture and, to a certain degree, discard. We see common strategies between the two sites (bladelet flaking, expedient flaking) and site-specific differences with prepared and radial flaking found at Caterpillar Rock, but almost absent at Poacher's Cave even though they are roughly contemporary sites. An examination of the end-products alone (retouched tools) would have overlooked this significant difference in planning and execution of learned skills.

What is missing from this study, and most studies of quartz assemblages, is the opportunity to use refitting to identify spatially and temporally discrete COs. Instead, it is important to acknowledge that diacritical approaches, such as the one used here, inevitably conflate knapping activities spanning hundreds of years into a single analytical unit and can make it extremely difficult to trace which technical processes genuinely co-occur at a given site (Soressi & Geneste 2011). Ancillary to this problem has been one of interpretation: alongside all lithic analysts, CO workers look for broad-scale patterns in data to identify traditions of production that characterise past technologies. These studies inevitably suppress variability, as well as raising questions over how we interpret techniques that occur infrequently: are these significant in their rarity, a sign of possible innovation events and a window onto individual behaviour, or insignificant in their scarcity, a sign that a community eschewed these techniques as extraneous or inappropriate? These questions are relevant to the current study where more specialised techniques such as prepared core flaking and radial flaking occur as low-level phenomena against an almost overwhelming background of informal knapping strategies and formal bladelet flaking.

The fracture properties of quartz present a further challenge for CO studies, as its tendency to shatter during flaking may result in assemblages with fewer classic core types and formal tools than those based on CCS materials including chert. Quartz and CCS can respond very differently to conchoidal fracture and may therefore produce divergent COs, which analyses emphasising secondary working to mark formal tools and cores may underestimate. The methodology for formal tool analysis used in this study is based on that developed by Deacon (1984) with CCS materials and it is possible that elements of this approach are inappropriate for quartz-based assemblages (Orton 2012: 105). We have retained Deacon's methodology here as we believe that it improves the legibility of analyses across the southern African LSA, but a regional approach which offers more nuanced insights into Holocene technology, such as that developed by Orton (2012) for Namaqualand, South Africa, may also be useful in a Zambian context.

Although the CO methodology used here has offered insights into technical organisation that take us beyond typological classification, limitations in the economic and stratigraphic records at both sites mean that the approach has not reached its full potential. Where the methodology may begin to illuminate LSA hunter-gatherer lifeways more fully is through the analysis of other non-lithic technologies for which we have material evidence in Zambia. Organic technologies offer significant scope for further research (Miller *et al* 2021), especially the well preserved organic middle Holocene record from Gwisho (Fagan & Van Noten 1971). Ground stone technologies, such as axe heads, have also undergone limited investigation in Zambia despite their relative importance in the Nachikufan (Miller 1969) and occurrence at Gwisho, Mumbwa Caves and at Makwe. A complementary but unrealised use of the CO approach exists in the analysis of Zambian rock art. Holl (2002) has demonstrated the potential for studying processes of image creation using this approach, and it is an analytical strategy which would seem particularly relevant to Zambian geometric painting (Smith 1997). By bringing together different strands of CO analyses we will find ourselves in a stronger position to investigate questions of cognition and social identity in the LSA of south-central Africa.

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