The Last Glacial Maximum and Acceleration of Technological Change in the Lesotho Highlands

by

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Dedication

For all who have taken shelter under Melikane's roof. This dissertation would not exist without you, and I hope I did your story justice.

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Abstract

Between 45,000 and 25,000 years ago, the prepared cores and formally retouched tools of the southern African Middle Stone Age were replaced by idiosyncratic, informal, and miniaturized lithic assemblages. This murky period of prehistory, loosely named the "Middle to Later Stone Age Transition" (MSA/LSA transition), terminated with the appearance of southern Africa's first true Later Stone Age (LSA) industry, the Robberg, and the onset of the Last Glacial Maximum (LGM). The LGM profoundly impacted southern Africa's human occupants by altering the livability of certain environments and the distribution of bioavailable resources. Despite this, the relationships between the MSA/LSA transition, the beginning of the Robberg, and the onset of the LGM are relatively misunderstood. Previous studies have emphasized the differences between final Middle Stone Age (MSA), transitional, and Robberg industries, attributing the slow spread of the poorly defined "Early Later Stone Age" (ELSA) technocomplex to diffusion or migration from other parts of the subcontinent and denying the roots of Robberg technology in the MSA (C. B. Bousman & Brink, 2018; Goodwin & Van Riet Lowe, 1929). This dissertation tests three hypotheses on the MSA/LSA transition through the analysis of lithic assemblages from Melikane Rockshelter, Lesotho: that the transition was precipitated by population replacement, that it was a consequence of changes in mobility and resource distribution due to LGM conditions, and/or that it was prompted by demographic shifts unrelated to large-scale migration.

Melikane, a large sandstone rockshelter in the Maloti-Drakensberg Mountains of highland Lesotho, preserves an 80,000-year-old archaeological sequence including two layers (4 and 5) dated to the onset of the LGM (~24,000 years ago) and previously assigned to the MSA/LSA transition. For this dissertation, I analyzed > 17,000 lithic artifacts from layers 4 and 5 to understand how the MSA/LSA transition at Melikane was related to either external or local mechanisms of change. Although there are some similarities between the lithics at Melikane and other penecontemporary sites, I conclude that there is no evidence to support the hypothesis that the MSA/LSA transition was a population replacement or migration event. In contrast, layer 5’s heavily reduced microlithic assemblage suggests that Melikane’s early LGM foragers were isolated from lowland and interior populations. The microlithic roots of Robberg technology were already established in layer 5 and became entrenched as new challenges to mobility and resource scheduling favored the use of standardized bladelet technologies. However, the introduction of a new core reduction sequence in layer 4 insinuates that some, but not all, Robberg technologies were introduced from outside the highlands. This implies that population connectivity was reestablished in southern Africa following an earlier period of isolation, potentially as changing environmental conditions provided an impetus for movement. This cycle of isolation and connectivity would encourage the development of regionally adapted technological systems while simultaneously allowing for the spread of new elements, potentially leading to the Robberg’s fluorescence following the LGM. Overall, my findings support an indirect role for environmental change in the MSA/LSA transition. Microlithic LSA technologies were rooted in the Middle Stone Age, fully adopted only when the right environmental and demographic conditions were met.

Chapter 1: Introduction

The prepared cores and formal tools of the southern African Middle Stone Age (MSA) are separated from the microlithic Later Stone Age (LSA) Robberg industry by a murky technological phase, loosely termed the "Middle to Later Stone Age transition" (MSA/LSA transition) (C. B. Bousman & Brink, 2018; Loftus, Mitchell, et al., 2019; Lombard et al., 2012). Lithic assemblages from this period are idiosyncratic, informal, and frequently miniaturized, often containing elements of both MSA and LSA industries. The transition resolved with the appearance of Robberg bladelet technology ~24,000 years ago, broadly in conjunction with the onset of the Last Glacial Maximum (LGM), the coldest period of earth's history in the last 130,000 years (P. J. Mitchell, 1988a, 1995; Pargeter et al., 2017, 2018).

Worldwide, microlithization and bladelet technology tend to appear in combination with significant environmental shifts (Clarkson et al., 2018). In southern Africa, ecological models directly implicate composite tool and bladelet technology as LGM adaptations, reducing subsistence risk by combining elements of reliability and maintainability and permitting the use of a wider range of raw materials (P. J. Mitchell, 1988a, 1992, 2000). While this may be true, the LGM could also be more indirectly related to the end of the transition. Hunter-gatherers often respond to environmental change by restructuring themselves on the landscape (Grove, 2010; R. L. Kelly, 1983, 2013; Whallon, 2006). For example, the Siberian "microblade adaptation" is interpreted as an adjustment to a highly mobile lifestyle prompted by changes in resource distribution during the LGM (Goebel, 2002). Foragers also diversify their subsistence bases and engage in a variety of social strategies to mitigate risk (C. B. Bousman, 1993, 2005; Grove, 2010; Halsted & O'Shea, 1989; R. L. Kelly, 1983, 2013; Read, 2008; Stewart et al., 2016; Stewart & Mitchell, 2019; P. Wiessner, 1982; P. W. Wiessner, 1977). All these coping mechanisms affect population connectivity and isolation, and thus innovation and cultural transmission.

However, the study of the MSA/LSA transition is complicated by a tendency to implicate punctuated demographic events rather than more subtle ecological pressures in technological change. The transition was initially conceptualized as an event akin to Middle to Upper Paleolithic transition in Europe – the replacement of Neanderthal-like "Boskopoid" peoples with the modern San (Goodwin, 1929, p. 181; Goodwin & Van Riet Lowe, 1929). New artifact types accompanied this replacement, including beads, pottery, rock art, bone tools, microliths, and flakes with parallel rather than convergent dorsal scars (J. Deacon, 1984b; Goodwin, 1929, 1946). However, a century of research has clarified that MSA peoples were behaviorally and anatomically modern and that many of these LSA "innovations" have roots in the Middle Stone Age (Klein, 1970; McBrearty & Brooks, 2000).

Instead of broadening the definition of the MSA to include sites with these precocious artifacts, some archaeologists have pushed back the dates for the MSA/LSA transition and assigned relevant assemblages to the Early Later Stone Age (ELSA) technocomplex, supplanting the Robberg as the first official LSA industry. Sites in East Africa and KwaZulu-Natal have been allotted to the ELSA >40 ka[1] on the basis of first known datums (FKDs) for artifacts resembling those used by the Kalahari San, including wooden digging sticks, ostrich eggshell beads, and bone awls (c.f. Backwell et al., 2018; d'Errico et al., 2012; Diez-Martín et al., 2009; Solano-Megías et al., 2020; Tryon, 2019; Tryon et al., 2015, 2018; Tryon & Faith, 2016; Villa et al., 2012). The most recent iteration of the population replacement model for the MSA/LSA transition assumes that the microlithic ELSA was a homogenous entity, originating in KwaZulu-Natal before spreading slowly to the rest of southern Africa. A second population replacement event resulted in the diffusion of Robberg bladelet technologies ~25 ka. This model assumes little environmental influence and no innate relationships between the industries – the ELSA and Robberg are unrooted in the MSA and unrelated to each other (C. B. Bousman & Brink, 2018).

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[1] Ka= thousands of years ago (OSL or other non-radiocarbon); kcal BP= thousands of calibrated radiocarbon years ago; ka BP= thousands of uncalibrated radiocarbon years ago; BP= uncalibrated radiocarbon years ago; kya=a span of thousands of years ago (non-radiocarbon).

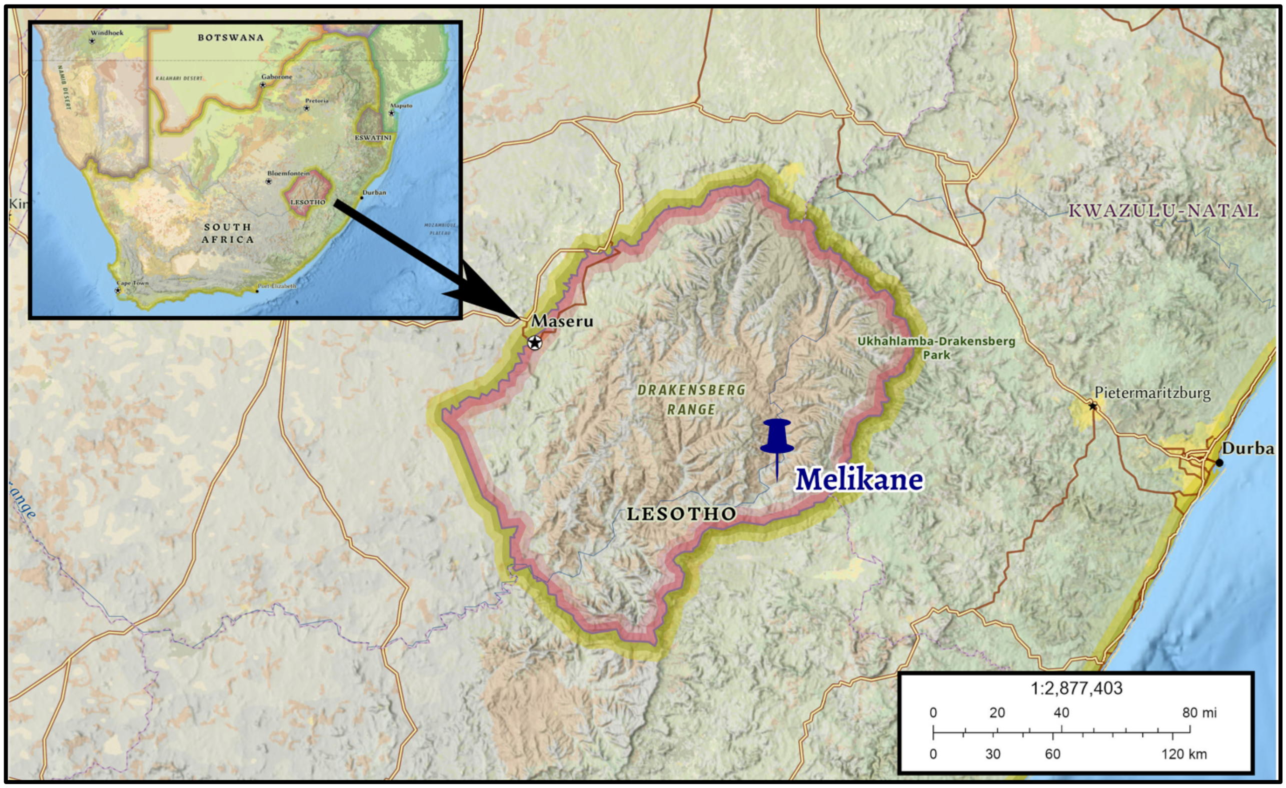


Figure 1 Location of Melikane within Lesotho.

In this dissertation, I evaluate these models of the MSA/LSA transition in southern Africa by studying the lithic assemblages of Melikane Rockshelter in highland Lesotho (Figure 1). Melikane is an ideal environment for this project for several reasons. First, Melikane preserves an unstudied lithic assemblage (layer 5, contexts 6-8) dated to ~24 kcal BP alongside paleoenvironmental proxies including charcoal and phytoliths (Stewart et al., 2012, 2016). This lithic assemblage has been referred to as "transitional" or "ELSA," but there are hints that it may contain or underly a true Robberg technocomplex. Mitchell (1988a, p. 34) found a number of unmodified bladelets and high-backed bladelet cores diagnostic of the Robberg among the materials from Carter's (1978) original excavations, although the relevant layer did not contain enough organic content for radiocarbon dating.

Second, Melikane's assemblages are primed for both intrasite and intersite comparisons. Dates from nearby Sehonghong Rockshelter, ~24 km north as the crow flies, suggest that the two sites may have been occupied more-or-less simultaneously ~24 kcal BP, providing the opportunity to study the transition in a regional context. Sehonghong's deposits ~30-24 kcal BP have been described as "transitional" and are followed by an early expression of the Robberg Industry (P. J.

Mitchell, 1994a, 1995). In the temporal dimension, the Melikane sequence itself also stretches back to ~80 ka. Portions of it have also been studied by the author, providing a consistent means to investigate long-term technological and environmental trends at the same site (Pazan et al., 2022).

Lastly, Melikane's location in the Maloti-Drakensberg Mountains means that the effects of the LGM would have been acutely felt. Highland Lesotho is rugged, and the Cape Drakensberg may have been glaciated as early as ~24 ka (C. A. Lewis & Hanvey, 1993; C. A. Lewis & Illgner, 2001). The logistics of movement and cultural transmission would have been complicated in this terrain. Climate change is usually felt first in mountain systems, meaning that foragers in the Lesotho highlands may have been dealing with new ecological pressures relatively early on (Dobrowski, 2011; Dobrowski & Parks, 2016).

Chapter One of this dissertation begins with an overview of southern African geography and paleoclimates, followed by a summary of southern African culture history from the continent's earliest toolmakers to the Later Stone Age. Chapter Two opens with a historic review of the MSA/LSA transition, covering the earliest hypotheses and the newest research. This review is followed by a summary of archaeological sites with relevant deposits, including Melikane, the subject of my analysis. Chapter Three introduces my hypotheses on the transition alongside a review of relevant archaeological theory. Chapters Four through Six detail my methods and results. In Chapter Seven, I summarize my findings and evaluate my hypotheses. My dissertation concludes with Chapter Eight, in which I discuss Melikane, microlithization, and the LGM in a global context.

Environmental Context

Southern Africa is broadly divided into climatic regions using rainfall zones. It is likely that these rainfall zones existed during the Late Pleistocene (126-14 kya), but possible that they did not encompass the same areas as they do today (Chase & Meadows, 2007). The southwestern Cape is located in the winter rainfall zone (WRZ), receiving most of its precipitation between April and November (Braun et al., 2017; Tyson & Preston-Whyte, 2000). The summer rainfall

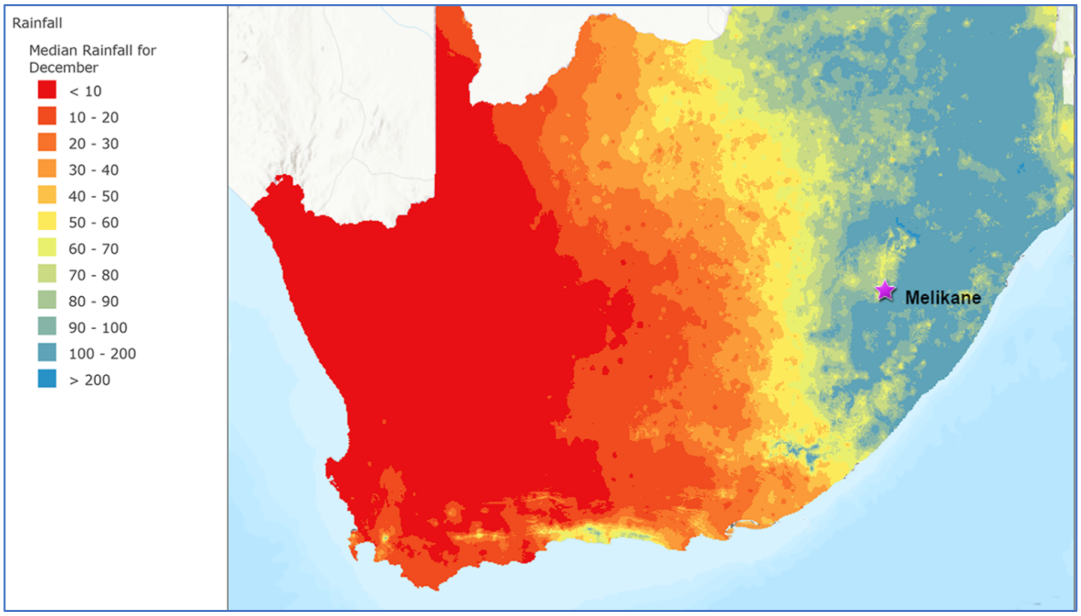


Figure 2 Summer rainfall gradient in southern Africa.

zone (SRZ) envelopes Lesotho (including Melikane) and the interior and eastern portions of South Africa and Swaziland, receiving most of its rainfall between October and March (Roffe et al., 2019). The SRZ receives greater than 66% of its rain in the summer months (Chase & Meadows, 2007; Roffe et al., 2019). The year-round rainfall zone (YRZ), located on the southern Cape, receives rainfall from both the SRZ and WRZ precipitation systems (Engelbrecht & Landman, 2016; Roffe et al., 2019).

These rainfall zones create a diverse assortment of biomes, bioregions, and environments. From the Kalahari Desert in the northern interior to the unique fynbos biome on the southwestern Cape, temperatures, the seasonality and amount of precipitation, and vegetation all vary widely. During the LGM, changes in climate altered the character of southern Africa, altering the lives of hunter-gatherers by influencing their foraging and hunting habits, mobility schemes, and by forcing some to adapt to less-than-ideal conditions. This section seeks to provide an overview of the vegetation and climate of southern Africa (including South Africa, Lesotho, and Swaziland) today, and then dives into research on climate during the LGM.

Biomes and Bioregions

Nine different biomes have been identified in southern Africa. The “biome” concept divides areas based on both plant and animal communities, but often defers to vegetation as the final arbiter of borders (Mucina & Rutherford, 2006). Rutherford and Westfall (1994) posit that a biome must be noteworthy and distinguishable at a continental or subcontinental scale, is defined by combinations of taxa (rather than the presence of singular taxa alone), and must exhibit major climatic similarity across its extent. In contrast to a biome, a “bioregion” is a smaller unit occupying the space between a biome and vegetation type and represents an area often more homogenized in climate than the biome as a whole. Southern Africa’s biomes are not evenly distributed in terms of area. The Savannah, Grassland, and Nama-Karoo biomes are the largest, collectively comprising 80% of the total area. The smaller biomes include the Albany Thicket, Desert, Forests, Fynbos, the Indian Ocean Coastal Belt, and the Succulent Karoo (Mucina & Rutherford, 2006).

This dissertation is primarily concerned with the Grassland biome, but a basic understanding of the characteristics and extent of the other biomes is essential to forming a larger picture of the dynamics of southern African ecosystems. Albany Thicket is sometimes combined with the Savannah biome and comprises small areas of dwarf forest in the Eastern Cape. Desert forms a strip on the Namibian border in the far northwest of the subcontinent. The Forest biome in southern Africa is poorly represented and can be identified only as small patches in the southern Cape, otherwise surrounded by Fynbos or Albany Thicket. The Fynbos biome can be found nowhere else in the world, and is located in the moist winter-rainfall zone of southern and western South Africa, including the city of Cape Town and much of the Western Cape Province (Mucina & Rutherford, 2006). Fynbos is the largest biome other than Savannah, Grassland, and the Nama-Karoo, comprising 6.6% of the area of southern Africa. Fynbos includes wetlands and peat bogs as well as a vast diversity of flora and fauna (Mucina & Rutherford, 2006; Rebelo et al., 2006). It is also sometimes called the Cape Floristic Region or the Cape Floral Kingdom (Rebelo et al., 2006). The Indian Ocean Coastal Belt consists of a strip of subtropical forest along the eastern Cape, and like Albany Thicket, is sometimes designated as Savannah (Mucina & Rutherford, 2006; Rutherford & Westfall, 1994). The Succulent Karoo includes Namaqualand, the Richtersveld, and the Little Karoo, and in the southwest separates the Fynbos of the Western Cape from the Nama-Karoo. The latter is the least diverse biome in terms of vegetation type and

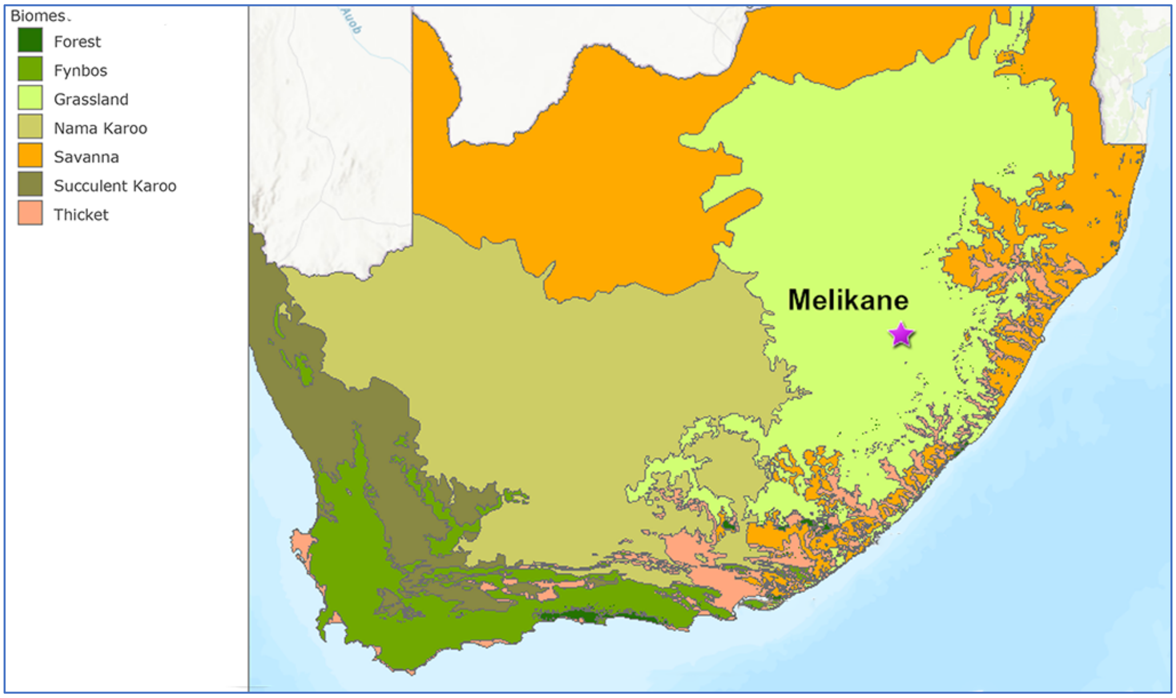


Figure 3 Distribution of biomes in southern Africa. (After Rutherford and Westfall, 1994.)

occupies the bulk of Northern Cape province and the continental interior (Mucina & Rutherford, 2006).

Savannah is concentrated mainly in northeastern and north-central parts of southern Africa, with a small strip in between the grasslands and Indian Ocean Coastal Belt on the eastern Cape. There is generally little frost in this region, with climates either tropical or subtropical (mean annual temperature (MAT)=17-18ºC), and altitudes are accordingly lower at <1500 masl (meters above sea level). Vegetation in the Savannah depends largely on rainfall, which can be highly variable, and on fires (Mucina & Rutherford, 2006). Without fire, most of the area would be woodland (Bond et al., 2003). Drought can devastate Savannah biome grasses, but plants with underground storage organs or woody components tend to survive (Leistner, 1967). Thus, drought and fire can have major short-term effects on vegetation, causing the landscape to vary greatly annually. This can also cause changes to the faunal composition of the landscape with down-the-line effects on human occupation of any given region (Mucina & Rutherford, 2006).

The entire country of Lesotho is situated in the geographic center of the Grassland biome. Grasslands also encompass large chunks of the North-West, Gauteng, Mpumalanga, Eastern Cape, and KwaZulu-Natal Provinces, as well as a strip of western Swaziland and nearly the entire Free State. The southern African grasslands are part of the larger Temperate Grassland Biome, a global entity that also includes the Eurasian steppe and the North American Great Plains (Mucina & Rutherford, 2006). They likely formed during the Late Miocene as temperatures cooled. Despite sharing a summer rainfall pattern, areas of the Grassland biome receive dramatically different amounts of precipitation, ranging from only 400 mm to over 2500 mm annually. Generally, rainfall decreases on a northeast-southwest gradient (Mucina & Rutherford, 2006). Most vegetation growth occurs in the wet summer months, peaking earlier in the temperate east and mountainous areas (Hoare & Frost, 2004). The uKhahlamba-Drakensberg Escarpment is notable for a high frequency of violent thunderstorms, resulting in frequent lightning strikes, and thus, fires. Frost occurs frequently as temperature decreases with altitude (Mucina & Rutherford, 2006).

The three grassland vegetation units covering the area around Melikane Rockshelter are the Lesotho Highland Basalt Grassland, Drakensberg Afroalpine Heathland, and Senqu Montane Shrubland (Mucina & Rutherford, 2006). Within this area, temperature and vegetation are largely controlled by altitude and aspect (Ehleringer et al., 1997; Vogel, 1983). At higher altitudes, lower growing season temperatures and greater moisture favor plants using a C_3 photosynthetic pathway, like woody trees, herbs and shrubs (Vogel, 1983). Lower altitudes favor C_4 tropical grasses, which can tolerate hot and dry climates and low levels of CO_2 (Ehleringer et al., 1997). Data from the 1990s suggest that C_3 plants begin to dominate south-facing slopes at 2100 masl (J. M. Smith et al., 2002), but Patalano et al. (In prep) estimate that the C_3/C_4 boundary may have climbed 200-400 meters since.

The highest altitudes of the Maloti-Drakensberg (>2900 m) belong to the Drakensberg Afroalpine Heathland vegetation unit. This unit includes Matebeng Pass, ~10 miles from Melikane between the modern-day villages of Sehlabathebe and Sehonghong. The heathland sits on the Jurassic basalts of the Drakensberg Group. Soils are generally shallow, but still contain enough organic content to support some grasses and shrubs. The soils are formed by frost action, causing erosion. On average, this area will experience 158 days of frost per year. This unit is the coldest of those discussed here, mostly as a function of its higher altitude. MAT is 4ºC, equivalent to that of Quebec City, Canada. The heathlands have a mean annual precipitation

(MAP) of 737 mm. The landscape is nearly entirely C_3-dominated, including heath and shrublands (Mucina & Rutherford, 2006).

The Lesotho Highland Basalt Grassland lies underneath the heathland between 1900 and 2900 masl. Some of the "basalt" grassland is present on the Clarens Sandstone Formation, which reaches altitudes of 2600 masl in Sehlabathebe National Park. This vegetation unit can be found on plateaus, ridges, and in valleys. Soils are highly organic and moist, supporting robust communities of palatable grasses. MAP is 707 mm, although the distribution of rainfall is highly variable (Mucina & Rutherford, 2006). The Mokhotlong weather station in northeast Lesotho records only 575 mm of precipitation per year, whereas 928 mm/annum falls in the southeast at Qacha's Nek (Killick, 1978; Tyson et al., 1976). Despite a more temperate environment than that of the heathlands, frost and snow are possible in the highland basalt grasslands year-round. MAT is 9.6ºC, comparable to Detroit, Michigan and Erie, Pennsylvania, and the area receives on average 96 days of frost per year. The lower elevations of the basalt grasslands are dominated by nutritious C_4 grasses and shrubs, with few trees present. Above ~2100 m on the southern slopes and ~2700 m on the north-facing slopes, less nutritious and sour C_3 grasses begin to overtake the C_4 component (Mucina & Rutherford, 2006).

The Senqu Montane Shrubland is the lowest-lying vegetation unit discussed here, falling between 1600 and 1900 masl. It forms the slopes of the Lower Senqu Valley and its tributaries, including the Melikane River, and extending upstream towards Thaba-Tseka. The Senqu Montane Shrubland is situated within the Clarens, Elliot, and Molteno sedimentary formations under the Jurassic basalts of the Drakensberg group. Precipitation is generally the lowest of the three vegetation units detailed here, at 687 mm per annum. These shrublands are quite dry and can become "hyper-arid" further upstream on the Senqu. MAT is higher than elsewhere at 13ºC, and frost is present for 52 days of the year on average. MASMS is comparable to that of the other vegetation units at 74%. The vegetation is dominated by C_4 grasses with a smaller C_3 tree and shrub component along the river corridors (Mucina & Rutherford, 2006).

The Last Glacial Maximum

During colder periods of the past, the climate and vegetation belts of the Maloti-Drakensberg mountains fell to lower altitudes, changing the resources available to Pleistocene foragers. Melikane was occupied at the eve of one of these periods, the Last Glacial Maximum. The Last Glacial Maximum (LGM) can be defined as the period of maximum global ice volume during the last glacial period, approximately 24-18 kcal BP (P. U. Clark & Mix, 2002; Mix et al., 2001). The effects and timing of the LGM varied regionally. For example, the Laurentide ice sheet in North America attained its maximum size well before the aforementioned dates, around 29-27 kcal KP (Dyke et al., 2002). Ice volume in the Antarctic may also have peaked earlier at 30-24 kcal BP and actually declined during the LGM (Crosta et al., 2004; Gersonde & Zielinski, 2000; Stuut et al., 2004).

Changing patterns of oceanic and atmospheric circulation paired with colder temperatures have implications for snow accumulation and glacial mass in Lesotho (Kohfeld et al., 2013; Mills et al., 2012). A series of fronts in the southern hemisphere are likely to have moved northward during the LGM, but may have been limited in their movement by topographic constraints like mountains (Gersonde et al., 2003, 2005; Hayward et al., 2008; Neil et al., 2004; Weaver et al., 1998). It is difficult to say how much the movement of these fronts corresponded with climate change. Changes in their locations do not necessarily correlate with temperature, and their latitudes vary seasonally and geographically (Kohfeld et al., 2013). Estimates of the degree of temperature depression during the LGM in southern Africa range from 5-6º C (Holmgren et al., 2003; Kulongoski et al., 2004; Partridge et al., 1999; Stute & Talma, 1998) to at least 10º C (C. A. Lewis & Illgner, 2001) below present-day values. Most recently, noble gas groundwater data from Namibia and Botswana have converged on 6º C, not only in southern Africa, but worldwide (Seltzer et al., 2021).

Most of the WRZ and southern Cape were more humid during the LGM (Meadows & Baxter, 1999). Hyrax middens from the Pella site in the Namib Desert describe fluctuating humidity during marine isotope stage (MIS) 3 (57-29 kya) before a particularly wet phase at 26 kcal BP during early MIS 2 (29-14 kya), and then dry conditions at ~24 kcal BP and during the LGM itself (Chase & Meadows, 2007; Lim et al., 2016). However, sediments from the Richtersveld and further northwest in the desert indicate humid conditions 25-20 kcal BP (Dewar & Stewart, 2017; Lancaster, 1984, 2002, 1986; Scott et al., 1995; Teller & Lancaster, 1986). Other proxies agree that the Namib in general was wetter during late MIS 3 and early MIS 2 (Chase & Meadows, 2007). Interestingly, radiocarbon dates peak in the Namib at this time, concentrated at 35-30 kcal BP and 28-23.5 kcal BP (Lancaster, 2002).

Hyrax middens in the northern Cederberg mountains contain pollen characteristic of higher altitudes and moister climates. A change in the vegetation at 16 kcal BP indicates a drop in moisture following the LGM (Scott, 1994; Scott & Woodborne, 2007a, 2007b). Pollen samples from the LGM levels of Elands Bay Cave contain high proportions of woodland taxa – in fact, the highest values in the entire sequence. Charcoal data from the same site confirm a high percentage of Afromontane taxa with low drought tolerance (J. Parkington et al., 2000). At Apollo 11, the Mean Ungulate Bodymass index is higher in the MIS 2 assemblage, suggesting greater rainfall during that period (Thackeray, 1979). It is also possible that the winter rainfall season in the area was longer, shortening any possible periods of drought (Chase & Meadows, 2007). The faunal assemblages from Boomplaas Cave and the Cango Cave speleothem isotope record suggest similar conditions in the Cape Fold Belt. High frequencies of the Saunder's vlei rat ~26 kcal BP imply a cool and open landscape (Avery, 1982; Pargeter et al., 2018). A high grazer diversity index and increased C_3 isotope signature suggest increased humidity and winter rainfall (Faith, 2013; Pargeter et al., 2018). However, the microfaunal assemblage signals that temperatures were ~6º C lower than the present by ~22 kcal BP, suggesting that even if the environment as productive, it may have been hostile to human occupation in other ways (Pargeter et al., 2018).

The southern African interior experienced alternating pulses of humidity and aridity during MIS 3 and 2. Mollusks from the Western Karoo also show greater moisture over the entire period of 43-17.3 kya (Beaumont, 1986). Preliminary results from a study of Karoo paleolakes during MIS 2 and 3 suggest increased humidity and high lake levels between 50-42, 35-30, 22-18, and 15 kya, with periods of aridity in between (B.A. Stewart, personal communication). Speleothem accumulations in the Kalahari also imply wet periods between 26-21 kya and 19-14 kya (Brook et al., 1998; Karin Holmgren et al., 1995). A speleothem from Wonderwerk Cave indicates warm, dry conditions ~24 ka followed by cooler, wetter conditions from 23-17 kya, likely accompanied by increased winter rainfall (Brook et al., 2010). To the north, conditions were different. The northeast Kalahari experienced overall greater dune activity between 32-19 kya, indicating a long period of increased aridity (Munyikwa et al., 2000; Stokes et al., 1997, 1998). In the northern Kalahari, overall maximum activity is between 48-21 kya (O'Connor & Thomas, 1999; Thomas et al., 2000). Based on precipitation required today for dune activation, these areas may have received as little as 20% of present-day rainfall (Partridge et al., 1999). However, there remains the possibility that dune formation is affected more by wind patterns than moisture conditions (Chase & Brewer, 2009).

Climatic conditions in the summer rainfall zone near Melikane are more difficult to pin down. Carbon and oxygen isotope ratios from the T8 stalagmite at Cold Air Cave in Limpopo Province suggest cold, dry conditions from 23.5-21 kya (Holmgren et al., 2003). Rainfall estimates from the Pretoria saltpan indicate that the region may have received only 50% of present-day precipitation ~21 kcal BP, accompanied by a 5º C temperature depression (Partridge et al., 1997). Total organic carbon (TOC) levels in the Mfabeni peatland deposits of KwaZulu-Natal increase from 26.1-23.1 kcal BP, accompanying water-logged sediments and aquatic plants. TOC levels plunge at 23.1 kcal BP, indicating a drop in moisture conditions (Baker, 2016).

Despite these indications that precipitation may have decreased in the SRZ, glacier formation in the Maloti-Drakensberg mountains as early as 24 kcal BP suggests increased winter rainfall alongside a significant drop in temperatures. Glaciers almost certainly formed in northeastern Lesotho on the cold, south-facing slopes of the Great Escarpment over 3100 masl, evidenced by debris ridges interpreted as moraines (S. W. Grab, 1996; Mills & Grab, 2005). Incidentally, these slopes are the areas today that receive the most snow and are the areas where snow tends to melt last (S. Grab, 2002). Signs of permafrost are found in the form of large circles on the high plateau >3400 masl, otherwise known as "patterned ground development" (S. Grab et al., 2021; Mills & Grab, 2005; Wang & French, 1995).

Evidence for glaciation outside of the high Drakensberg is more tenuous. Lewis and Hanvey (1993) identified debris from rock glaciers as low as ~2100 masl in the Bottlenek valley of the Eastern Cape Drakensberg, dating to 21,000 ± 400 BP (~24 kcal BP). Associated debris suggest that stadial conditions began much earlier, 27,000 BP. Lewis and Illgner (2001) also found evidence of cirque glaciers ~2100 masl at Mount Enterprise 30 km away, requiring a temperature reduction of at least 10ºC. A temperature depression of this magnitude is inconsistent with the generally accepted estimate of 6º C (Holmgren et al., 2003; Mills et al., 2009), but a change in precipitation patterns could have encouraged glacier formation alongside a less severe temperature depression. Assuming a more modest temperature decrease of 6º C, the Leqooa glacier in northeast Lesotho would have required double today's annual precipitation to form (Mills et al., 2009), but shifting the bulk of precipitation to the winter months would increase potential snow accumulation and have the same effect (Mills et al., 2012). Amplified winter precipitation is consistent with the displacement of the westerly winds by greater sea ice volume (Mills et al., 2009).

Cultural Context

Humans and their ancestors have deep antiquity in southern Africa. The prehistoric record is divided into three main stages as defined by Goodwin and Van Riet Lowe (1929): the Early Stone Age (ESA), Middle Stone Age (MSA) and Later Stone Age (LSA). In this section, I present a brief overview of southern African prehistory and technological developments, with the objective of setting the stage for a discussion of the Middle to Later Stone Age Transition.

The First Toolmakers: The Early Stone Age

Prior to 2015, it was believed that the archaeological record began 2.6 ma (millions of years ago) with the Oldowan tool industry (L. Barham & Mitchell, 2008; Kimbel et al., 1996; L. S. B. Leakey, 1934). However, the recent discovery of the Lomekwian tool industry at the site of Lomekwi 3, West Turkana, Kenya pushes this date back into the Pliocene (Harmand et al., 2015). The industry is bracketed by dates of volcanic tuff between 3.44 ± 0.02 ma and 2.53 ± 0.02 ma. Carbon isotope analyses determined that the environment surrounding the site would have been considerably more wooded than the environment surrounding Gona, Ethiopia at 2.6 ma, the site and time of the previously accepted earliest stone tool assemblage (Semaw, 2000; Stout et al., 2005, 2010). These data contradict the narrative that tool use began in tandem with cooling temperatures and desertification in the early Pleistocene (Bobe & Behrensmeyer, 2004; Quinn et al., 2013). The Lomekwian predates the earliest *Homo* fossil site in West Turkana by nearly one million years. The assemblage's dates and location are consistent with the geographic and chronological presence of *Kenyanthropus platyops* and *Australopithecus afarensis* (B. Brown et al., 2001; M. G. Leakey et al., 2001; J. E. Lewis & Harmand, 2016). Assuming it was indeed invented and used by pre-*Homo*, this indicates that important developments in hand-eye coordination, preplanning, and dexterity occurred long before the appearance of the *Homo* lineage (Harmand et al., 2015; J. E. Lewis & Harmand, 2016).

Prior to the discovery of the Lomekwian, the Oldowan was recognized as the first stone tool assemblage present in Africa (L. S. B. Leakey, 1951; M. D. Leakey, 1971; Semaw, 2000). Oldowan tools are sometimes referred to as "Mode 1" tools and are classically defined by worked cobbles, hammerstones, and simple flakes (Barsky et al., 2011; de la Torre et al., 2018; de la Torre & Mora, 2018; Stout et al., 2005, 2010). Despite its association with *Homo habilis*, the Oldowan predates the earliest specimens of the species and is associated with *Australopithecus ghari* (Semaw, 2000). Later assemblages in South Africa at Swartkrans are associated with *Australopithecus robustus* and *Homo erectus* (Caruana, 2017; Kuman et al., 2018). Oldowan technologies persisted in some regions into the Holocene, persisting despite the appearance of later, more complex stone tool assemblages (L. Barham & Mitchell, 2008).

Following the Oldowan, the Acheulean industry appeared ~1.7 ma. The Acheulean is defined by the presence of hand axes and cleavers and can also be referred to as "Mode 2" technology (J. D. Clark, 1959; L. S. B. Leakey, 1951). The bifically worked hand axes typical of the technology were extraordinarily long-lived (Bates et al., 2014), made on a diverse array of raw materials, and increased in craftsmanship over time (Kleindienst, 1961; Lycett et al., 2016; Lycett & von Cramon-Taubadel, 2008; McNabb & Cole, 2015; Shipton, 2020; Shipton & White, 2020; Vaughan, 2001; White & Foulds, 2018; Wynn & Tierson, 1990). The beauty of some later hand axes suggests that they may have been used not only as physical tools, but also for social purposes (Corbey et al., 2016; Hayden & Villeneuve, 2009; Kohn & Mithen, 1999).

Although the appearance of the Achulean is widely associated with the speciation of *Homo erectus*, the presence of Mode 1 tools alongside *H. erectus* at Dmanisi, Georgia shows that speciation and innovation were not concerted events (Ferring et al., 2011; Lordkipanidze et al., 2013; Mgeladze et al., 2011; Rightmire et al., 2019). Different technological modes were in use simultaneously in different geographical regions (Brumm & Moore, 2012; Iovita et al., 2017; Lycett & Bae, 2010; Lycett & Norton, 2010; Norton et al., 2006; M. D. Petraglia & Shipton, 2008). Acheulean tools were also used in Europe by later species *H. antecessor, H. heidelbergensis,* and *H. neanderthalensis* (Álvarez-Alonso, 2014; Moncel et al., 2013, 2016, 2020).

After more than one million years of Achulean technology, new hand axe forms began to appear in southern Africa, marking the beginning of the transition to the Middle Stone Age. The Victoria West is sometimes seen as a natural continuation and component of the Acheulean but is also sometimes associated with later Levallois technology. Although the products of the Victoria West production sequence resemble large hand axes, the production sequence itself bears some resemblance to the prepared core technology typifying later Mode 3 (flake-based) technology (J. D. Clark, 1959; Li et al., 2017; Lycett, 2009). However, 3D morphometric studies (Lycett et al., 2010) suggest that the Victoria West technique was a natural extension of technological trends already present in the Achulean (Sharon, 2009). The Fauresmith industry also presents a challenge to a sharp dichotomy between the Early and Middle Stone Ages (Herries, 2011). It dates to 464 ± 47 ka via OSL or 542 ka using combined U-series dates at Kathu Pan 1 in the Northern Cape Province of South Africa (Porat et al., 2010). It is notable for blade production (Wilkins & Chazan, 2012), which was long considered an indicator of "behavioral modernity" (McBrearty & Brooks, 2000). Artifacts also include small hand axes and convergent flakes (Porat et al., 2010; Underhill, 2011). Like the Victoria West, there is evidence of core preparation before flaking.

Attempts have been made to associate the ESA/MSA transition and the use of prepared core technology with a speciation event (ie. Foley & Lahr, 1997), but to do so oversimplifies the complex fossil and genetic data from the Middle Pleistocene (780-126 kya). Nevertheless, the ESA/MSA transition occurred against a background of dynamic demographic and biological evolution. The most recent genetic data have pushed back the date of divergence between the KhoeSan and non-KhoeSan lineages to 350-260 kya (Gronau et al., 2011; C. Schlebusch et al., 2017; C. M. Schlebusch et al., 2012; C. M. Schlebusch & Jakobsson, 2018; Veeramah et al., 2012; Vicente & Schlebusch, 2020). Fossils from this period show jigsaw-like combinations of modern and archaic features. The Jebel Irhoud fossils from Morocco, recently dated to ~315 and ~286 ka, are associated with Levallois flakes and retouched points (Richter et al., 2017). Hublin et al. (2017) have argued that the two crania should be considered anatomically modern because their cranial shapes fall into the range of variation observed for recent modern humans, yet their endocranial shapes better resemble those of other Middle Pleistocene hominins and Neanderthals. The Florisbad cranium dated to ~259 ka has a similarly confusing conglomeration of traits, with a modern frontal squama but parietal lobes and endocranial vascularity like more archaic species (Bruner & Lombard, 2020; Curnoe & Brink, 2010). Rather than showing that the ESA/MSA transition is associated with the sudden "appearance" of modern humans, the genetic and fossil evidence show that major changes in the archaeological record occurred in tandem with major changes in biology and demography. The fuzzy distinction between the late ESA and the early MSA, as well as a lack of a clear speciation event, foreshadows the MSA/LSA transition.

Flakes and Blades: The Middle Stone Age

Early definitions of MSA technology are definitions of exclusion. Goodwin (1928) and van Riet Lowe (Goodwin & Van Riet Lowe, 1929, p. 28) defined "Middle Stone Age" as a technology "in some ways intermediate between the Earlier and Later Stone Age Methods" that fell stratigraphically between ESA and LSA industries. They identified points with facetted platforms and convergent dorsal scars as the MSA type fossil. Later definitions did not differ significantly, recognizing the MSA as any flake or blade industry chronologically between the ESA and LSA (Mason, 1962, 1967; Sampson, 1968, 1974; T. Volman, 1984; T. P. Volman, 1980). According to Volman (1984), MSA industries are less focused on core tools than ESA industries, preferring flakes and blades to handaxes and cleavers. Cores are usually prepared and can take a variety of forms, from discoid to multidirectional or platform. Carter (1978) described MSA industries as variable in their mode of production, dominated by flakes or blades, having a variety of retouched and/or unmodified tools, and possibly microlithic and backed forms. He agreed, however, that prepared core technology is common, and that handaxes must be absent.

The MSA was long regarded as the African equivalent of the European Middle Paleolithic, lacking refined and standardized tool industries and the sustained artistic behaviors associated with modern humans. The art, sophisticated stone tool industries, long-distance movement of artifacts, and complex use of space shown in the European archaeological record were purported evidence for a neural mutation leading to modern behavioral capacities around 40 ka (Klein, 1992, 1995; P. Mellars, 1991, 2006; P. A. Mellars, 1992). This misconception was partially due to a research bias towards western Europe but was also an artifact of low archaeological visibility in the early MSA and the limits of radiocarbon dating. Sites from the early MSA are rare and difficult to date, and populations at the time were likely small and mobile (L. Barham & Mitchell, 2008; McBrearty & Tryon, 2006).

However, in the past 20 years, advances in dating beyond the radiocarbon ceiling and further excavations have pushed back the FKDs for symbolic expression and complex technologies in Africa (Henshilwood et al., 2009, 2011; Hovers et al., 2003). The 60,000 year-old backed segments of the Howiesons Poort, long suspected as transitional to the Later Stone Age, are now known to significantly predate similar artifacts in Europe (Henshilwood & Dubreuil, 2011). A 100,000 year-old ochre preparation kit from Blombos Bay Cave (BBC) includes an abalone shell, grindstones, hammerstones, ochre, and charcoal (Henshilwood et al., 2011). Ochre has been used ethnographically as sunscreen and as body decoration, possibly implying symbolic capacities and perhaps a sense of group or individual identity. Ochre engravings at BBC dating to MIS 5 may have been intended as art (Henshilwood et al., 2009), and a cluster of *Nassarius* shell beads may have been strung on the same cord like jewelry (d'Errico et al., 2005; Vanhaeren et al., 2013). Similar discoveries at Middle Paleolithic sites in Europe (c.f. Barras, 2013; Bello, 2021; Callaway, 2015; Hardy et al., 2020; Romandini et al., 2014) point to an underestimation of Middle and Late Pleistocene hominin cognition, both in anatomically modern humans and European Neanderthals. It is now widely accepted that humans were behaviorally modern long before the Upper/Middle Paleolithic and MSA/LSA transitions, and that both MSA and Mousterian (Neanderthal) cultures were likely far more complex than previously believed (K. S.

Brown et al., 2012; d'Errico et al., 2005; D'Errico, 2003; Henshilwood et al., 2001, 2001; Henshilwood, 2002; Henshilwood et al., 2009; Henshilwood & Marean, 2003; Högberg & Larsson, 2011; McBrearty & Brooks, 2000; J. Parkington, 2003; Powell et al., 2009; J. J. Shea, 2011; S. Shennan, 2001; Villa & Roebroeks, 2014; Wadley, 2001; Wadley et al., 2009; Zilhão, 2007).

Regardless of the presence of complex behaviors in the southern African archaeological record, their punctuated, discontinuous nature has allowed theories of a later, Upper Paleolithic-aged European origin for behavioral modernity to persist (Klein, 2000; P. Mellars, 2006). The argument is that these expressions of behavior were flukes, and that the extended expression of these behaviors in the European Upper Paleolithic is evidence that humans had finally reached behavioral modernity. However, research on the effects of demography on the development and maintenance of innovations has helped to counter this idea. It has been shown that innovations are more likely to persist in larger, more interconnected, multigenerational populations and are more likely to be imperfectly transmitted and lost in smaller populations with fewer interacting subpopulations (Derex, Beugin, et al., 2013; Henrich, 2004; Powell et al., 2009; Wolpoff & Caspari, 2013). If populations in southern Africa oscillated between interconnected and isolated states during the MSA or never attained a critical population density, the result may have been perceived spottiness of modern behavior in the southern African archaeological record (cf. Mackay et al., 2014).

Sites from the Middle Pleistocene MSA are rare, but Late Pleistocene populations were more visible on the southern African landscape. Chan et al. (2019) suggest that the L0 lineage, basal to KhoeSan populations, emerged in the Makgadikgadi–Okavango palaeo-wetland before increased humidity during MIS 5 (126-75 kya) allowed a series of dispersals to the southwest, ~130-110 kya. This humid period was followed by aridity in the Kalahari, pushing more populations towards the Cape coasts, ~110-80 kya (E. K. Chan et al., 2019; but see Schmidt et al., 2017 for alternate climate interpretations). Dense concentrations of sites along the Cape coasts, including Klasies River Mouth, Pinnacle Point 13b and 5/6, Blombos Bay Cave, Ysterfontein I, Diepkloof rockshelter, Elands Bay Cave, Sibudu, and Hoedijespunt I, suggest that these MIS 5 foragers were highly successful (Brenner & Wurz, 2019; Douze et al., 2015; Esteban et al., 2020; Porraz, Parkington, et al., 2013; Porraz, Texier, et al., 2013; Porraz, Schmid, et al., 2016; Rots et al., 2017; Schmid et al., 2019; Singer & Wymer, 1982; Wilkins et al., 2017; Will et al., 2013; Wurz, 2012). Many MIS 5 sites, including Melikane, appear to have been extensively occupied and revisited into the Holocene (Pazan et al., 2022; Stewart et al., 2012).

MIS 5 technologies in southern Africa are regionally diverse, suggesting population fragmentation, local environmental adaptation, and minimal long distance social networks (Mackay et al., 2014; Pazan et al., 2022). In the Klasies River typology, lithic assemblages from this period are referred to as either MSA 2a or 2b. Attempts to extend this typology and identify similar industries have been largely unsuccessful. The last decade has seen the expansion of MIS 5 research beyond the Cape coasts and into the interior, and technological analyses at sites in different biomes suggest that production methods, tool types, and linked lifeways including mobility were highly site-specific (Pazan et al., 2022).

The idiosyncratic tool industries of MIS 5 were followed by the well-studied and widespread Still Bay (SB) and Howiesons Poort (HP) technocomplexes book-ending MIS 4 (75-59 kya). The two industries have been compared to European Upper Paleolithic and Mesolithic industries, and before improvements in radiometric dating, were believed to be transitional to the LSA. Both technocomplexes were relatively shortlived. The Still Bay perhaps lasted only from 72.2-71.9 kya, and the Howiesons Poort from 66.6-58.3 kya (but see Guérin et al., 2013; Jacobs et al., 2013; Jacobs & Roberts, 2017). Many of the behaviors associated with these industries disappeared after the Howiesons Poort, not to reappear until the Early Later Stone Age.

The Still Bay is characterized by bifacial foliate points (Goodwin & Van Riet Lowe, 1929). It is confined to the perimeter of the subcontinent and does not extend into the Maloti-Drakensburg highlands (Mackay et al., 2014; Stewart et al., 2012). Flaking systems are mainly focused on the production of flakes from radial cores, with the exception of Apollo 11, where blades play a more important role (Vogelsang et al., 2010). Still Bay points may have been hafted and used as spear tips or butchering knives (Minchillo, 2005). Small impact scars on points found at Blombos indicate that the spears were likely thrusted or hand-thrown, and not used with an atlatl like similar Paleoindian points (Villa et al., 2009). Following the end of the Still Bay, many sites were abandoned to be reoccupied a few thousand years later with groups using technologies of the Howiesons Poort industry (Mackay et al., 2014). This has led some anthropologists to question why a highly sophisticated technology should disappear so suddenly, only to be replaced by another very different though equally refined industry.

At some sites, the gap between the Howiesons Poort and Still Bay is nonexistent or greatly reduced. At Diepkloof rockshelter, Still Bay layer Kerry is dated to 70.9 ± 2.3 ka. However, this layer is better characterized by backed artifacts than bifacial foliate points (Porraz, Parkington, et al., 2013; Porraz, Texier, et al., 2013), and Porraz et al. (2013) consider it an early expression of the Howiesons Poort rather than as a terminal manifestation of the Still Bay. This early date for the Howiesons Poort is similar to that seen at Pinnacle Point 5/6, where backed artifacts extend to 71 ka in antiquity (K. S. Brown et al., 2012). The Howiesons Poort's fluorescent period begins ~65 ka around southern Africa (Jacobs & Roberts, 2008). Despite the technocomplex's broad geographic reach, it manifests itself differently in various environments and climates. Mackay et al.'s (2014) study of technological variability between rainfall zones reveals that backed blades are more common in the YRZ, yet backed flakes are more prevalent in the WRZ. In the SRZ, however, there appears to be little regional cohesion and greater intrasite continuity. Backed blades are rarer at Melikane than Rose Cottage Cave despite the sites' proximity, and Melikane's assemblage shows a significant degree of continuity from MIS 5 in both flaking systems and typology (Mackay et al., 2014; Pazan et al., 2022; Soriano et al., 2007; Stewart et al., 2012).

At approximately 58 ka, the beginning of MIS 3, the Howiesons Poort was replaced in the African subcontinent by environmentally and geographically variable technologies known as the "Sibudan," "post-Howiesons Poort," or "MSA 3" (Lombard et al., 2012; Mackay et al., 2014; Singer & Wymer, 1982). The backed artifacts of the Howiesons Poort gave way to regionally diverse larger, thicker unifacial points and scrapers (Conard et al., 2012; Lombard et al., 2012; Mackay, 2011; P. J. Mitchell, 2008). In highland Lesotho, Carter (1978, 1988) noted that hornfels and dyke materials were used more frequently in contrast to the previously extensive use of cryptocrystalline silicates. Southern Africa also went through a series of rapid oscillations in aridity and temperature during MIS 3, prompting changes in landscape and site use (Mackay et al., 2014). At some sites, particularly in the WRZ and YRZ, the Howiesons Poort is followed by an occupational hiatus beginning ~50 ka (Mackay et al., 2014). Where occupation does continue, assemblage size and density decrease (Mackay, 2011; Porraz, Texier, et al., 2013; Singer & Wymer, 1982). Most abandoned sites were not reoccupied until MIS 2. However, MIS 3 sites proliferate in the SRZ and Lesotho highlands (Mackay et al., 2014). At approximately 40 ka, industries termed "final MSA," "late MSA," and "early LSA" mark the potential beginning of the Middle/Later Stone Age transition (Lombard et al., 2012).

The Later Stone Age

Prior to the 1920s, the LSA was viewed as an African variant of the European Upper Paleolithic. All changes and technologies in the African record were studied in parallel to those in the northern hemisphere. However, in 1926, the South African Association for the Advancement of Science decided that European terms and should no longer be directly used or applied, and sub-Saharan African prehistory was split into the Early, Middle, and Later Stone Ages (Astley John Hilary Goodwin & Lowe, 1929). The LSA referred specifically to assemblages with artifacts resembling those used ethnohistorically by African hunter-gatherers, and by extension, thought to be the hallmark of anatomically modern humans (P. J. Mitchell, 1988a).

Twentieth century studies of the LSA emphasized it as a "package" of traits appearing for the first time in the archaeological record. According to Deacon (1984b, p. 277), "the basis for differentiation between the MSA and LSA is the appearance in the archaeological record of a number of innovative items which fulfill the expectation of increasing complexity in technology." These items included ochre, digging stick weights, ostrich eggshell beads, marine shell beads, tortoise shell bowls, and bone tools (J. Deacon, 1984b). However, as MSA research has developed over the last 20 years, it has become clear that many aspects of LSA material culture significantly predate the MSA/LSA transition. Definitions of the LSA based on lithic technology have aged better than Deacon's. Vogel and Beaumont (1972, p. 50) defined the LSA as "the presence of flakes with plain striking platforms, partly produced by means of a punch technique," along with scaled pieces (core reduced pieces), convex scrapers, and bone points. Mitchell's (1988, p. 257-262) definition of the LSA includes three key components: 1.) the presence of microliths, 2.) the disappearance of prepared core technology and faceted platforms, and 3.) the disappearance of retouched points and blades. Mitchell's definition is perhaps the most enduring, yet leaves room for interpretation: for example, are microliths always necessary, and if so, what proportion of the assemblage should they comprise? Are any facetted platforms acceptable?

The term "ELSA" was introduced by Beaumont and Vogel (1972) to refer to assemblages with "large, circular, convex, concave, and informal scraper types, scaled pieces… broad irregular flakes and microblades with preponderantly plain striking platforms," but without geometric microliths (Beaumont & Vogel, 1972, p. 155). At Rose Cottage Cave, Beaumont (1978) included in the ELSA assemblages now assigned to the final MSA, the Robberg, and the Oakhurst. Today, "ELSA" has been coopted to refer to a heterogenous group of East and southern African lithic assemblages dating ~45-20 kya. Assemblages now assigned to the ELSA often have high frequencies of bipolar cores and scaled pieces and show signs of microlithization and bladelet production (C. B. Bousman & Brink, 2018), but some are macrolithic, like those at Buffelskloof in the Western Cape, and others like Umhlatuzana's contain MSA formal tools such as points (Lombard et al., 2012). Due to the considerable heterogeneity of ELSA assemblages, a number of archaeologists (L. S. Barham, 1989; Carter et al., 1988; A. M. B. Clark, 1997b; J. M. Kaplan, 1989; P. J. Mitchell, 1994b) have advocated to abolish the term, instead referring to these assemblages as "transitional." Mitchell (1988a) has also proposed the term "early microlithic" to refer to these and Robberg assemblages from the Late Pleistocene.

Microlithization and Miniaturization

Although considerable disagreement still abounds, most archaeologists agree with Mitchell (1988a) that the true LSA is marked by a distinct increase in microlithization, or lithic miniaturization. Microlithization was a world-wide phenomenon, occurring from Australia to the Arctic circle. Globally, it has been linked to climate change and instability, although the type and severity of climate change is highly variable between regions (Hiscock et al., 2011). "Microlithic" usually refers to artifacts < 25 mm in maximum dimension, but size cut-offs vary widely - microblade cores from Siberia can reach up to 50mm in length, for example (Ambrose, 2002). Bladelets are a typical component of southern Africa microlithic industries. Bladelets are usually defined in southern Africa as flakes less than 12mm in breadth with a length/width ratio of at least two (J. Deacon, 1984b). They can be backed or unretouched, and some have evidence of hafting or use in multi-component tools (Bar-Yosef & Kuhn, 1999; Binneman, 1997; Binneman & Mitchell, 1997; Kuhn & Elston, 2002). However, microlithization was not a sudden switch turned on in the LSA, and not all LSA industries are microlithic. Backed microliths are common in Howiesons Poort assemblages, and Sibudu's even shows evidence of systematic prismatic bladelet reduction (de la Peña & Wadley, 2014). In contrast, the Oakhurst, which follows the microlithic Robberg industry in southern Africa, is characterized by macrolithic, heavy-duty implements (J. Deacon, 1984b). Furthermore, Clarkson et al. (2018) point out that the connection between the backed microliths and bladelets is weak. Backed microliths appear in assemblages without bladelets much earlier in the archaeological record, and bladelet-heavy assemblages often feature little retouch.

Many archaeological studies of microlithization limit the definition of "microliths" to small, backed flakes (Clarkson et al., 2018; Hiscock et al., 2011) and assume that they must have served a social function. Backed microliths have been implicated as a part of an exchange system resembling the Kalahari San's *hxaro* tradition (P. Wiessner, 1982, 1984, 1998, 2002). According to this hypothesis, they convey group identity, permit access to territories, and cement social ties (Ambrose, 2002; H. J. Deacon, 1992, 1995; H. J. Deacon & Wurz, 1996). However, Hiscock et al. (2011) point out that small microliths would be difficult to see when hafted and covered in mastic. They suggest that if microliths were involved in social currency, composite tools were more likely gifted than the individual pieces. Furthermore, if the function of backed microliths was purely social, then the subsequent use of a macrolithic toolkit would imply a loss of social connectivity (Hiscock et al., 2011). Ambrose (2002) adds that frequencies of exotic raw materials actually drop at many East African sites during the LSA, which would be unexpected if the microliths were embedded in long-distance exchange networks. These social explanations fail to explain miniaturization in southern African LSA assemblages, which are better characterized by unretouched bladelets.

Other studies, including this dissertation, view microlithization in its technological context, including irregular, unretouched flakes and bladelets in a more general study of lithic “miniaturization” (Pargeter, 2017; ie. Pargeter & Faith, 2020). Most of these studies hinge on the assumption that microlith production is economical. Muller and Clarkson (2016) found that flaking systems focused on the production of narrow, thin flakes used raw material most efficiently. Other attributes that were associated with increased efficiency were focalized (punctiform) platforms and feather terminations. Microlithization is often associated with bipolar reduction, which is particularly cheap in terms of both time and energy (Pargeter et al., 2019; Pargeter & Eren, 2017). It allows for the exploitation of small cobbles and hard rock types like quartz that are difficult to knap using freehand percussion (Bamforth and Bleed, 1997). Even without the use of bipolar percussion, bladelets can be removed from exhausted cores and oddly shaped nodules (Doelman, 2008). Clarkson et al.’s (2018) experiments found that less time was spent preparing and maintaining bipolar cores than freehand blade cores. While Muller and Clarkson (2016) argue that bipolar percussion is less efficient, producing less cutting edge than freehand percussion per unit of core mass, flakes under 2 cm in maximum dimension were not included in the results of their experiments. This assumes that small blanks were both undesirable and unutilized, neither of which are true for most microlithic assemblages (c.f. Villa et al., 2012).

Besides raw material efficiency, microliths have several other practical advantages over macrolithic tools. For example, retouched microliths are easier to standardize and copy. Clarkson et al. (2018) found that retouched microliths, and especially microblades, were easier to copy than bifacial points. When hafted, they are can be easily and quickly replaced by standardized copies (Bleed, 1986; Hiscock, 2002). Even if microliths fall out of a haft, the tool is often still usable because of the multiple microliths still in place (Clarkson et al., 2018). This makes multicomponent, microlithic tools both extremely reliable *and* extremely maintainable (c.f. Bleed, 1986). Backed microliths do have several advantages over their unretouched counterparts – they are less likely to fall out of their hafts, break, or damage the haft itself (Clarkson et al., 2018). Considering that none of these problems immediately impacts the effectiveness of multicomponent weapons, I hypothesize that backing would only have been selected for when raw materials were scarce and the loss of an individual piece more detrimental, or in the case of strong stylistic preferences.

In southern Africa specifically, environmental and demographic pressures have been implicated in the development of microlithic technologies. Phillipson (1980) hypothesized that backed bladelets were used in composite weaponry as an adaptation to high vegetation density during the warmer and wetter Late Glacial in Zambia. However, Mitchell (1988b) points out that backed bladelets are absent in many early microlithic assemblages in southern Africa, and that microliths were already use in the Pleniglacial. Instead, he hypothesized that in Lesotho, microlithic technology was developed as environmental changes leading up to the LGM put a premium on foragers' time. Miniaturization would take advantage of the abundant, small, oddly-shaped CCS nodules scattered across the highland landscape. The efficient use of these local materials would free up time that would otherwise be spent in its procurement. The composite tools made using the microliths would be easy and faster to repair and modify, as well as being more reliable and effective hunting implements. Retouched points and blades would disappear as they were replaced by composite tools, and prepared cores would disappear as a consequence (P. J. Mitchell, 1988a). Carter et al. (1988) note that if this is correct, then a trend of decreasing artifact size should be visible over time as the climate deteriorated. This pattern does occur at Sehonghong, where blades gradually decreased in length over the 12,000 years leading up to the LGM (Carter et al., 1988).

Demographic factors have also been linked to lithic miniaturization in southern Africa. Tryon and Faith (2016) argue that miniaturization at Nasera Rock Shelter in Tanzania ~40 ka was necessary as a means to use local rocks during a time of increased occupation density and population pressure. At Boomplaas, Pargeter and Faith (2020) suggest that extended periods of site occupation motivated by decreased seasonality would have stressed raw material resources, prompting increased flaking efficiency through miniaturization. Although the authors successfully link decreased rainfall seasonality, increased site use, and bipolar and bladelet technologies, their techniques for calculating both reduction and occupation intensity are problematic. Ambrose (2002) proposed that the full development of microlithic industries in the LSA was due to a need to conserve high-quality raw materials after access to their sources was cut off. As territories expanded during the last glacial in response to resource scarcity, the foragers added non-local raw materials through embedded procurement and exchange. The high quality of these materials may have promoted the early expressions of blade and microlithic technology. If nonutilitarian items replaced raw materials as currency, then microlithization may have continued as an efficient strategy to conserve them (Ambrose, 2002). This hypothesis falls apart in areas of raw material abundance, like Lesotho.

Hypotheses specific to other regions of the world may have some applicability in Lesotho. Petraglia et al. (2009) suggest that microlithization ~35-28 kya in South Asia may have resulted from population packing in small, ecologically rich areas as the rest of the environment declined in productivity. In East Africa, backed microliths are associated with dry conditions, which Clarkson et al. (2018) claim necessitated higher mobility. Hiscock (2002) also linked declining effective precipitation with the increased production of backed artifacts in southeastern Australia, hypothesizing that backing decreased subsistence risk and allowed for greater mobility. The general consensus among archaeologists is that microliths were adopted in different places for different reasons to solve a multitude of problems. The real challenge, according to Torrence (2002), is determining which explanation fits each individual case.

The Robberg

Although there is little agreement about the existence and definition of the Early Later Stone Age, the Robberg is universally accepted as an LSA industry in southern Africa, appearing earliest ~25 kcal BP at Sehonghong, Boomplaas, and Heuningneskrans (Bousman & Brink, 2018; J. Kaplan, 1990; Lombard et al., 2012; Wadley, 1996). The Robberg was first identified by French archaeologist Abbé Breuil during Malan's 1943 and 1944 excavations of Rose Cottage Cave (RCC). Breuil identified a distinct "blade culture" underlying and distinct from the Wilton, recommending that it be officially classified as a new lithic industry (Wadley, 1991a). However, Breuil's recommendation went unheeded by Malan, who assigned all LSA materials underneath the Wilton to the "pre-Wilton" (B. D. Malan, 1952; Sampson, 1974).

The term "Robberg" was introduced thirty years after Breuil's discovery by J. Deacon to describe the bladelet industry found in Nelson Bay Cave (NBC) on the Robberg peninsula (Klein, 1972a, 1972b, 1974). The Robberg was dated to 18.5-11.5 ka BP at NBC and was also recognized at Kangkara and Melkhoutboom caves. It is microlithic by definition, characterized by bladelets, bipolar and bladelet cores, scaled pieces, and infrequent formal tools (Lombard et al., 2012). Artifacts described as “small carinate scrapers or bladelet cores” were identified at all three sites (Klein, 1974, p. 258). These artifacts would later become known as “high-backed” or “wedge-shaped” bladelet cores (J. Deacon, 1978; P. J. Mitchell, 1994a, 1995), and are unknown prior to the Robberg.

One of the earliest expressions of the Robberg appears at Sehonghong rockshelter in level BAS, dated to 24.3-23.1 kcal BP (Pargeter et al., 2017). In BAS, the Robberg takes the form of utilized bladelets, microlithic “high-backed” cores, the occasional use of bipolar percussion, dominance of CCS over coarse-grained materials, and the presence of few formal tools (P. J. Mitchell, 1995; Wadley, 1996). It differs from the later Robberg levels at the site by having lower frequencies of bladelets and bladelet cores (Mitchell, 1994). The Robberg has also been identified relatively early at Boomplaas, where member LPC dates to 26.4-24.3 kcal BP (H. J. Deacon, 1995; J. Deacon, 1984b; Pargeter et al., 2018). However, LPC and overlying member LP are referred to as the “earliest LSA” by Pargeter et al. (2018) and Mitchell (1988b) because of their lesser focus on bladelet production than the overlying layers. As at Sehonghong, the Robberg is long-lived at Boomplaas, lasting until 11.9 kcal BP (Pargeter et al., 2018). The early Boomplaas Robberg has higher bipolar core frequencies (~90% of all cores in member LP) and higher retouched tool frequencies (8% of all artifacts in member LP) than level BAS at Sehonghong (P. J. Mitchell, 1995; Pargeter et al., 2018; Pargeter & Faith, 2020). However, Boomplaas’ greater focus on bipolar technology may simply be an artifact of the greater use of quartz and lesser availability of high-quality chert.

Despite the association of the Robberg with bladelet technology, the bladelet frequencies of Robberg assemblages vary widely. Sehonghong and Rose Cottage Cave have comparatively high bladelet frequencies (Wadley, 1996). Sixteen percent of all lithics in layer RBL-CLBRF at Sehonghong are bladelets (Mitchell, 1995). This contrasts strongly with Nelson Bay Cave, where bladelets comprise only 2.4% and 5.4% of blanks in Robberg layers YGL and YSL respectively, and Boomplaas, where 9.2% of blanks in Late Robberg member CL are bladelets (J. Deacon, 1984b). Bladelet frequencies are affected by differential breakage (Wadley, 1996) and the size limits used to define them (Pargeter et al., 2017). H.J. Deacon (1983) also suggested that the

Boomplaas bladelets, which are found in concentrated groups, may have been kept in containers. If Robberg bladelets were stored in containers, only used at specific times, or only produced at certain locales, then sites with otherwise similar assemblages might appear to have very different bladelet frequencies (P. J. Mitchell, 1988a). I also propose that assemblages with high frequencies of bipolar reduction may have falsely depressed bladelet frequencies. Bipolar percussion creates more shatter and chips than freehand percussion, adding more waste to the assemblage per unit of core mass (B. Morgan et al., 2015; Muller & Clarkson, 2016; Pargeter & Eren, 2017).

Bladelets, bladelet cores, and bipolar technology are all important components of Robberg assemblages, but the Robberg is also defined by what it lacks: prepared core technology and formal MSA-type tools. Most, but not all, Robberg assemblages have few retouched artifacts. At Rose Cottage Cave, retouched artifacts make up only 0.3% of the stone from the Robberg levels (Wadley, 1996). Both layers YSL and YGL at NBC are less than 0.1% retouched (J. Deacon, 1984b). Retouch is also rare at Sehonghong, both in the Robberg and in the preceding MSA/LSA transitional levels (Mitchell, 1994, 1995). However, there are exceptions: eight percent of artifacts from member LP at Boomplaas are retouched (H. J. Deacon, 1983). Where retouch does occur, small scrapers, backed tools, and expedient retouch are generally most common (J. Deacon, 1978, 1984b; P. J. Mitchell, 1995; Porraz, Igreja, et al., 2016; Wadley, 1996). Points, denticulates, and MSA-type knives are conspicuously absent, except when collected from the landscape and repurposed (c.f. Wadley, 1996). Mitchell (1988a) suggested that points disappeared as a consequence of their replacement by barbed spears.

Although backed bladelets are more reliable when hafted (Clarkson et al., 2018), the unretouched bladelets of the Robberg were likely used in multicomponent tools. Mitchell (1988a) points out that they were too small to be used individually, and there is no evidence that they were used as blanks for retouched artifacts (Lombard & Parsons, 2008). They may have been components of spears or knives (J. Deacon, 1984b; P. J. Mitchell, 1988a; J. E. Parkington, 1984; Wadley, 1996), or possibly as parts of projectile points (P. J. Mitchell, 1988b). Binneman and Mitchell's (1997) usewear analysis of Sehonghong bladelets concluded that they were hafted parallel to a shaft rather than attached obliquely like barbs. The bladelets from Rose Cottage Cave also appear to have been mounted longitudinally, often exhibiting usewear on the ventral side of a lateral margin (Binneman, 1997; Wadley, 1996). Most of the Sehonghong bladelets were used for cutting a diversity of organic materials like hides and plant parts, and only one had evidence of use in a projectile. Binneman and Mitchell (1997) argue that multiple bladelets were likely mounted in a row to create a long, knife-like edge, and were probably not fixed onto multicomponent weapons.

However, all the bladelets studied from Sehonghong and Rose Cottage Cave are from later Robberg layers. Both Mitchell (1995) and Pargeter and Redondo (2016) suggest that bladelet tasks may have changed after the LGM, and it is likely that foragers' priorities and available resources were different during Early Robberg occupations. Lombard and Parsons' (2008) analysis of 2000 year-old bladelets from the Northern Cape concluded that some were definitely used to make inset points, whose reliability compensated for production costs. They associated higher bladelet frequencies with higher hunting risk. Australian stabbing spears, also known as "death spears" or "dread spears" (Davidson, 1934; Flood, 1995), have similarly been invoked in analogies with the Robberg (Binneman & Mitchell, 1997; J. E. Parkington, 1984). These spears were made by "embedding a series of small jagged stone chips in a gum layer which has been smeared over the head of the spear" (Davidson, 1934, p. 147). The same technique was also applied to the production of knives in southwestern Australia (Davidson, 1934). Ethnohistoric evidence points to the use of the spears both for hunting and for fighting (Davidson, 1934; Flood, 1995). Unlike Robberg bladelets, the inserts used in the death spears were unstandardized. However, this lack of standardization may be relevant to some of the "ELSA" or transitional assemblages just preceding the Robberg, which are sometimes microlithic but bladelet-poor. The death spears show that a technology does not need to be fancy to be functional.

Chapter 2: The MSA/LSA Transition

Although archaeologists agree that the Robberg industry belongs to the LSA, there is little agreement on how or why microlithization began in southern Africa. This chapter begins with a discussion of both historical and existing hypotheses on the MSA/LSA transition in the region. Then, I discuss relevant sites with final MSA, transitional, ELSA, and Robberg assemblages.

A History of Thought

Current hypotheses on the MSA/LSA transition in southern Africa are rooted in early studies of the Smithfield and Wilton industries, the first identified LSA cultures. The Smithfield, divided into letters A through C, was described as comprised of technologies typical of the Eurasian Upper Paleolithic and Epipaleolithic (Goodwin & Van Riet Lowe, 1929). Based on the degree to which different artifacts were patinated, Goodwin (1926) suggested that the larger concavo-convex and D-shaped scrapers were used by earlier Smithfield peoples (Smithfield A). Smithfield B tools were smaller, including duckbill endscrapers, thumbnail scrapers, and bored stones. The Smithfield C was distinguished by the introduction of microliths and represented a transition to the Wilton, a microlithic industry associated with rock art and ostrich eggshell beads and thought to be contemporaneous with much San rock art (Goodwin & Van Riet Lowe, 1929).

Goodwin and Van Riet Lowe (1929, p. 149) tentatively suggested that the Smithfield C and Wilton were the product of human incursions from the north. They suspected that the Smithfield's mixed MSA and LSA traits represented the "fusion" of "Neo-anthropic" elements into local MSA culture, particularly as the newcomers began exploring the knapping properties of hornfels, presumed to be unavailable in the population's source area. These ideas are the earliest expression of a hypothesis explaining the MSA/LSA transition: waves of population movement from North Africa. This hypothesis remained popular for at least the next 30 years. J.

D. Clark (1959) also favored the wave migration theory, explaining the new tool forms and cultural memes appearing throughout the LSA as introductions by new emigrants. However, he did suggest that changes could also be attributed to the movement of ideas rather than that of people (J. D. Clark, 1955).

In the 1970s, radiocarbon dating recalibrated the chronology of southern African prehistory, rendering many of the early assumptions about the MSA/LSA transition inaccurate. Most notably, the Smithfield A was absorbed by the Oakhurst Complex, dating prior to the Wilton, and Smithfield B and C were recognized as *younger* than the Wilton (J. Deacon, 1974; Sampson, 1974). The Robberg was also acknowledged as the first true LSA industry. Today, the Robberg dates to ~25-12 kcal BP, the Oakhurst (Smithfield A) dates to ~12-7 kcal BP, the Wilton dates to ~8-4 kcal BP, and the final LSA (including the Smithfield B and C) dates to ~4-1 kcal BP (Lombard et al., 2012). This new sequence also complicated the prior understanding of the microlithization process. Microliths appeared in the Robberg, disappeared for 5,000 years during the Oakhurst, and reappeared in the Wilton. However, population replacement arguments remained popular. Sampson (1974) hypothesized that people brought microliths to the southern Cape from southern Zambia and Rhodesia. Humphreys (1972) did not see any continuity in the MSA and LSA assemblages of the middle Orange River. Instead, he proposed that a group of foragers with a chert-centric tool tradition moved into the area at the beginning of the LSA. As these foragers came to know their environment more closely, they began to expand their raw material choices to other local options.

Later twentieth century research turned to general environmental models. J. D. Clark (1974) and Phillipson (1976, 1977) claimed that microlithic technology evolved independently in many areas, taking forms most advantageous to the local environment. J. Deacon (1984) pointed out that although this explained regional differences in microlithic technology, the probability of independent invention in so many areas was extremely low. H. J. Deacon (1976) rejected the earlier wave migration theory as the explanation for change during the LSA. Instead, microlithic techniques arrived though diffusion and were then modified to suit environmental conditions (H. J. Deacon, 1976). According to H.J. Deacon (1976), the Robberg, Albany, and Wilton industries represented stable adaptations to periods of environmental constancy. Each transition between these so-called “homeostatic plateaus” was the result of a necessary change in subsistence patterns due to environmental conditions. For instance, the Robberg was an adaptation to the lifestyles of highly mobile, non-territorial big game hunters. J. Deacon (1984b) tested this hypothesis and found that the transition from the Robberg to the Albany was closely corelated with changes in the faunal assemblage. According to Mitchell (1988a), a slight “lag” in the timing of technological change confirms that it was a response to the environmental shifts.

Mitchell (1988a) was the first to directly implicate the Last Glacial Maximum as an impetus for change. Mitchell’s (1988a, 1988b) model rests on Torrence’s (1983) concept of “time-stressed” environments, where resources are mobile and scheduling is unpredictable. According to Mitchell, there are two ways in which hunter-gatherers during the LGM could have saved time in toolmaking: by being less picky about raw materials, or by spending less time making and maintaining tools. He points out that small CCS nodules, like those found in Lesotho, could be used for microlith production. These microliths would then be used in composite tools, which would be quicker to modify and repair. This would save time over longer forays to obtain larger nodules of dyke material. These changes would be reflected in lithic assemblages by increased microlith frequencies and decreased frequencies of retouched points and blades alongside the prepared cores used to make them. Furthermore, the increase in portable art seen during the LSA could be an artifact of free-flowing social networks, expanding to handle the insecurity of environments declining in productivity.

As excavations and dates continued to accumulate, a “gradualist theory” of the MSA/LSA transition also came into vogue. Kaplan (1990, p. 85) identified “no distinct MSA/LSA boundary” at Umhlatuzana Rock Shelter, instead noting *in situ* changes: the gradual disappearance of prepared platforms and radial cores, and a steady increase in bladelet and bead production. Kaplan also rejected Mitchell’s (1988b) model of change, claiming that it would not explain the presence of bladelets in the site’s MSA layers prior to the LGM. Excavations at Rose Cottage Cave also supported the gradualist theory. A.M.B. Clark (1997b, p. 119) identified a “transitional” industry at the site, and like at Umhlatuzana, found no evidence for an abrupt switch in technology. Mitchell’s (1994, 1995) rebranding of Sehonghong’s MSA 6 and MSA 9 assemblages as “transitional,” containing elements of underlying MSA assemblages alongside bladelets and small LSA scrapers, also supported a gradual transition rather than a sudden replacement.

Recently, in a synthesis of final MSA, ELSA, and Robberg sites, Bousman and Brink (2018) have modified the gradual intersite transition hypotheses and returned to earlier models of outside influence. They propose that the ELSA arrived in southern Africa by means of population replacement over a period of 20,000 years, lacking any sort of technological continuity with final MSA assemblages and later Robberg assemblages. This harks back to Goodwin and Van Riet Lowe's (1929) hypothesis that the LSA arrived via population replacement from North Africa, as well as Humphreys' (1972, p. 52) view that there was no "direct evolution via any 'intermediate' industries from the Middle Stone Age to Later Stone Age." According to Bousman and Brink (2018), the MSA/LSA transition consists of two transitions centered around two demographic events at ~43 and ~25 ka. The first transition, from the MSA to the ELSA, is argued to have initiated in the eastern part of southern Africa at Border Cave and slowly spread west. The authors claim that it may have been prompted by an overall population increase in the L0 haplogroups (Behar et al., 2012). The subsequent ELSA/Robberg transition was spurred by a population bifurcation event ~25 ka, and occurred more rapidly, with a locus in the Southern Cape and uKhahlamba-Drakensberg Escarpment. The ~25 ka date aligns with the earliest Robberg at Boomplaas Cave (Behar et al., 2012; C. B. Bousman & Brink, 2018). Bousman and Brink (2018) deny the possibility of cultural continuity at sites and insist on defining the ELSA as a distinct tradition.

Bousman and Brink's (2018) hypothesis rests on three problematic archaeological assumptions. First, it assumes that the final MSA, ELSA, and Robberg are distinct and homogenous entities. As previously discussed, the term "ELSA" is so indiscriminately used and vague that it has become nearly meaningless. Second, it assumes that the cultural designations previously assigned to different sites and assemblages are accurate, but only when convenient. This is particularly problematic in the case of Border Cave. Although Border Cave's ~40 ka assemblages have been allegedly assigned to the ELSA, as Wadley (1993) and A.M.B. Clark (1997b) have pointed out, numerous artifacts *not* associated with the ELSA have been identified in the relevant layers, including prepared cores and flakes with faceted platforms (L. R. Backwell et al., 2018; Beaumont, 1978). Third, Bousman and Brink (2018) assume that certain assemblages belong to the ELSA based solely on time. For example, Rose Cottage Cave's transitional levels were also assigned to the ELSA, despite A.M.B. Clark's (1997b) insistence that they should be ascribed to the MSA/LSA transition and *not* the ELSA. The result of these three assumptions is that Bousman and Brink create the structure they want to see – by sequencing radiocarbon dates and labelling assemblages based on the order of these dates, a perfect diachronic picture emerges.

Bousman and Brink's (2018) hypothesis also oversimplifies the population dynamics of the MSA and LSA and minimizes the dynamism of the LGM itself. The authors ignore the most updated and accurate haplogroup divergence dates, choosing Behar et al.'s (2012) based solely on their sample size. Furthermore, Behar et al.'s (2012) divergence dates were calculated based on the Reconstructed Sapiens Reference Sequence (RSRS) rather than the revised Cambridge Reference Sequence (rCRS). Certain nucleotide gaps in the RSRS, left empty in the rCRS because they were "extreme mutational hotspots," were filled with estimated sequences rather than actual sequences (Bandelt et al., 2014, p. 70). These estimated sequences are not always the most parsimonious, and result in a reconstructed, hypothetical reference (Bandelt et al., 2014). Lastly, instead of focusing on key haplogroup bifurcations, Bousman and Brink (2018) looked at the density of Behar et al.'s (2012) dates, divided them into two clusters, and calculated mean ages for each cluster. This has the effect of minimizing the importance of the divergence of main haplogroups and overemphasizing the divergence of subclades.

Despite the drawbacks of Bousman and Brink's model, significant genomic evidence has accumulated over the last decade to suggest that the period covering the MSA/LSA transition does contain a series of significant population divergences. Chan et al.'s (2015) genetic study incorporated 67 novel genomes from modern KhoeSan peoples and 115 from non-Khoesan (primarily Bantu-speaking) peoples from South Africa and Namibia into the existing mtDNA collections. The authors identified several population bifurcations within main haplogroups. Haplogroup L0a, which is restricted to Bantu-speakers, bifurcated at 41.7, 38.2, and 15.3 ka, although these dates may be irrelevant given that the "Bantu expansion" into southern Africa did not occur until the late Holocene (E. K. F. Chan et al., 2015; C. M. Schlebusch & Jakobsson, 2018). Haplogroup L0k, which is restricted to the modern KhoeSan, split at ~48 ka. One of the subclades created, L0k1a, is confined to the Kalahari region, and split again ~14.8 ka. Haplogroup L0d1 is the second-most-common haplogroup in modern southern African populations. It emerged ~61 ka, and shows evidence of further divergence at ~48, ~39, and ~21 ka. Haplogroup L0d2, today's most common haplogroup, emerged at 71 ka, and bifurcated multiple times during the LGM. The rare subclade L0d2b likely split ~20 ka, followed by the more common L0d2a at ~17 ka. Additional divergences within L0d2 occurred at 29.6 and 19.5 ka. Chan et al. (2015) point out that the African skeletal record also begins to reflect modern KhoeSan morphology around the time of the LGM (also see Morris, 2002). Although there are multiple population divergences around the ~43 and ~25 ka dates proposed by Bousman and Brink (2018), therefore, there are others at times equally relevant to the MSA/LSA transition, and at times irrelevant to it. However, Bousman and Brink (2018) are correct to suggest that period ~45-20 kya, during which the MSA/LSA transition takes place, was an overall dynamic period of demographic change.

Transitional Sites in South Africa and Lesotho

In the following section, I provide an overview of southern African sites (Table 1, Figure 4) in which final MSA, transitional, ELSA, and Early Robberg assemblages exist, providing a backdrop against which to study the analogous assemblages of Melikane Rockshelter. Many of the assemblages discussed below significantly predate Melikane's, and their statuses as transitional or ELSA are often debated. If Bousman and Brink's (2018) gradual replacement hypothesis is correct, many of these assemblages should share characteristics with Melikane's, and a gradual spread of transitional technologies should be seen over a period of 20,000 years from a source region into the Lesotho highlands. If the changes at Melikane immediately prior to the LGM were not due to a population replacement or migration, these assemblages may not necessarily share characteristics, and no pattern of temporal spread should be visible.

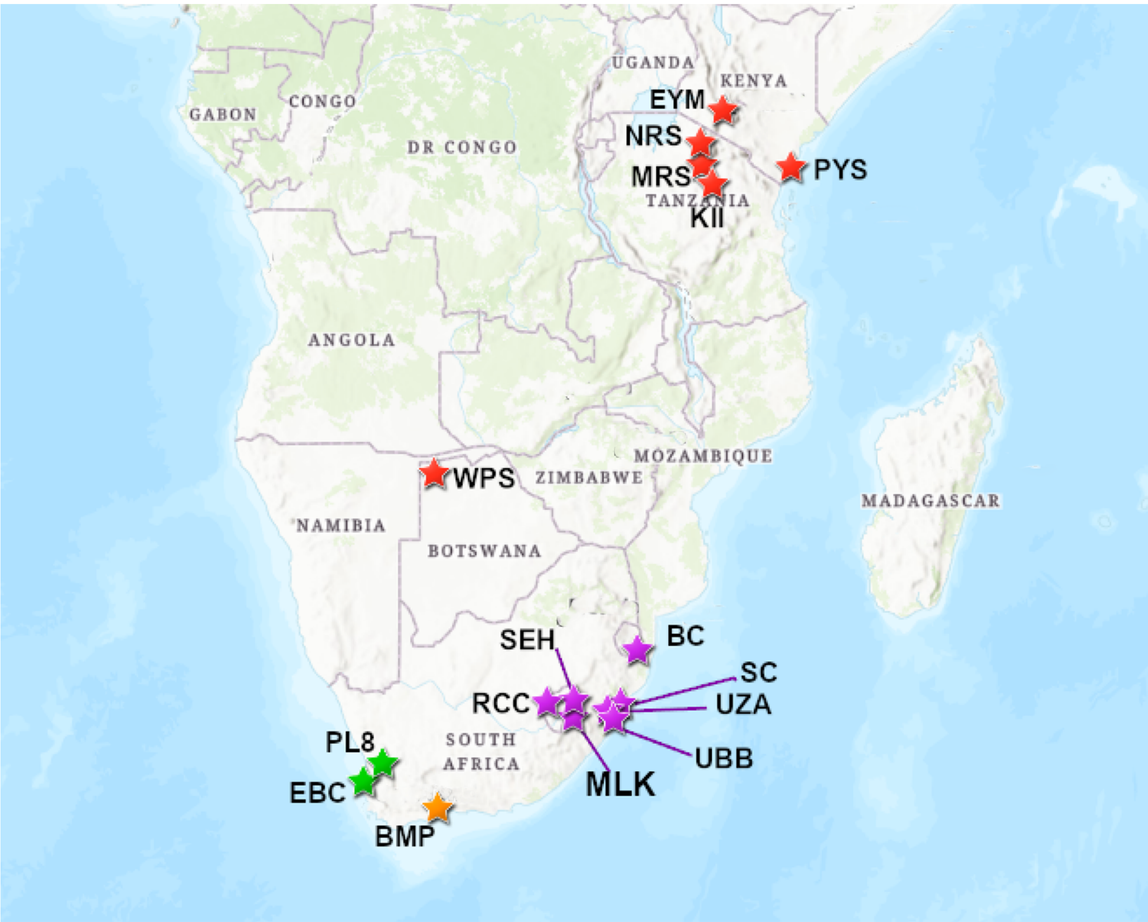


Figure 4 Sites discussed in the text. WRZ = green, YRZ = yellow, SRZ = purple, greater Africa = red. Elands Bay Cave (EBC), Putslaagte 8 (PL8), Boomplaas (BMP), White Paintings Shelter (WPS), Rose Cottage Cave (RCC), Sehonghong (SEH), Melikane (MLK), Border Cave (BC), Sibudu Cave (SC), Umhlatuzana (UZA), Umbeli Belli (UBB), Kisese II (KII), Enkapune ya Muto (EYM), Nasera Rockshelter (NRS), Mumba Rockshelter (MRS), Panga ya Saidi (PYS).

Border Cave

The ~40 kcal BP assemblages of Border Cave in KwaZulu-Natal are nearly analogous with the term "Early Later Stone Age" (ELSA). According to Villa et al. (2012), the "MSA/LSA transition" at Border Cave occurs in the post-Howiesons Poort levels ~45-49 kcal BP. In these layers (2BS LR A+B and 2BS UP), blades decline in frequency, unifacial points disappear, bipolar technology increases in frequency, and the percentage of formal tools falls. These technological trends continue into the ELSA layers, dating to ~44-42 kcal BP. These layers are differentiated from the above post-Howiesons Poort layers by an increasingly expedient style of flake production, the "systematic production of microliths," and the presence of organic materials including digging sticks, ostrich eggshell beads, engraved bone, bone points, and wooden artifacts (Villa et al., 2012, p. 13210). Except for bored stones, the ELSA is not marked by the sudden appearance of new lithic forms at the site.

However, Villa et al.'s (2012) assignment of these layers to the ELSA is questionable. Backwell et al. (2018) noted the presence of large flakes in the ELSA levels. Beaumont (1978) also described "very crude radial prepared cores" and flakes with faceted butts. Large flakes and radial cores are more frequently associated with the MSA than the LSA. Furthermore, I argue that it is inappropriate to use the presence or absence of organic technologies to classify a site. In the absence of organic remains at Border Cave, the ELSA assemblages largely resemble other post-Howiesons Poort occurrences. Even Villa et al. (2012, p. 13212) admit that "their assessment as MSA or transitional MSA/LSA seems to rest mainly on the absence of Robberg components, such as thin prismatic cores, "punch-struck" bladelets, and the retention of a few "MSA" pieces." In short, there is no evidence that the ELSA layers at Border Cave were innovative or different from other post-Howiesons Poort assemblages in any other aspect except outstanding organic preservation. Both the conflicting descriptions of the Border Cave ELSA lithics and the current knowledge that organic technologies and personal ornamentation were in use earlier in the MSA should prompt a reassessment of whether these layers deserve their status as the source of all LSA innovations.

Umbeli Belli

Sites with late or final MSA assemblages are abundant on the eastern side of the uKhahlamba-Drakensberg Escarpment in KwaZulu-Natal, although many of these sites were abandoned at the time of Melikane's occupation ~24 kcal BP. Wadley (2005) has gone as far as to identify these final MSA assemblages as a distinct cultural tradition, distinguished by hollow-based points, the use of hornfels, and the presence of quartz cores. Umbeli Belli, located ~7 km from the coast and ~300 km south of Border Cave, was first excavated by Cable (1984) in 1978. Cable only analyzed artifacts from the upper two layers, dating to the late Holocene. Recently, Bader et al. (2016, 2018) reexcavated the site, clarifying the stratigraphy and dating the older deposits. Only results from the MSA layers have been published. The final MSA, Layer 7 (GH7), is dated to 29 ± 2 ka on OSL (Bader et al., 2018). The raw materials used derive from local river cobbles and include different variations of hornfels and smaller contributions of quartzite and quartz. Towards the end of GH7 hornfels falls from 76.1% to 62.6% of the assemblage as quartz becomes more prominent. 7.7% of the assemblage is modified, with about 2/3 of all tools exhibiting bifacial retouch. Pointed forms are common (39.3%) and are found at the site in two varieties – broad (~18%) and narrow (21.4%). Some have hollow bases. Backed tools do occur at Umbeli Belli, comprising 4.8% of retouched forms (n=13). Umbeli Belli has asymmetric convergent tools (ACTs), with one convex backed edge and one unmodified straight edge (Bader et al., 2018). These ACTs were first identified at Sibudu (Will et al., 2014). Few cores are present, but most are platform types. Bipolar bladelet cores are represented in small numbers, and are exclusively associated with quartz (Bader et al., 2018). According to Bader et al. (2016, 2018), an increase in the prevalence of these cores is the only significant technological marker separating GH7 from the earlier MSA layers at the site, dating to 40.3 ±3.5 ka.

Umbeli Belli's LSA layers (GH5-GH3) are separated from GH7 and the MSA by GH6, a layer of "naturally accumulated rocks" (Bader et al., 2018, p. 735). GH5 is dated to 27.2 ± 2.3 ka and 24.9 ± 2.3 ka on quartz OSL and 21.0 ± 1.4 ka and 22.7 ± 1.8 ka on feldspar. GH3 dates to 17.8 ± 1.5 ka (quartz). The artifacts from these layers have not been formally analyzed, but Bader et al. (2016, p. 610) briefly describe them as "characterized by microlithic bladelet production from bipolar quartz cores and the almost complete absence of typical MSA-like retouched forms, prepared cores and platforms," and tentatively assign them to the Robberg on a profile drawing. However, until additional analyses are complete, it is unclear whether these layers represent a fully developed Robberg industry, an early LSA, or an *in situ* development. Importantly, the OSL dates from GH5 are comparable with the OSL date from contexts 6-8 at Melikane. Future analyses of the Umbeli Belli lithics will be critical to the interpretation of the Melikane assemblages.

Sibudu

The site of Sibudu, also in KwaZulu-Natal, has a rich archaeological sequence spanning from MIS 5 until the Iron Age. Wadley (2005) classifies the post-Howiesons Poort levels dating to 60-50 ka as "late MSA" and uses "final MSA" to refer to anything younger than 42 ka. Layer Co is the youngest of the final MSA layers, dating to ~33 ka via OSL. It is underlain by layer Bu, with a date of 35.2 ± 1.8 ka. However, radiocarbon dates point to much earlier occupation ~42 kcal BP. Hornfels and dolerite are the most commonly used materials in the final MSA at Sibudu. Common final MSA tools include hollow-based points like those at Umbeli Belli and sidescrapers or "knives." A few scaled pieces are present, as are notches. Backing is present but extremely uncommon. The percentage of retouched artifacts in the final MSA of Sibudu is very low compared to that of Umbeli Belli – only 3% excluding chips. Cores are relatively uncommon at Sibudu and are restricted primarily to minimal and bipolar cores, including core-reduced pieces. Prepared cores and blade cores are rare, consistent with the low frequency of blades and bladelets (4% of all flakes) at the site. Despite the high frequencies of hornfels and dolerite in the assemblage as a whole, quartz is more common among cores, pointing to a degree of differential provisioning between materials (Wadley, 2005). Following its final MSA deposits, Sibudu was abandoned until the Iron Age (Jacobs, Wintle, et al., 2008).

Umhlatuzana

Umhlatuzana is located just east of the Great Escarpment in KwaZulu-Natal, approximately 90 km southwest of Sibudu (Wadley, 2005). The shelter overlooks the Umhlatuzana River – a relatively similar geographic setting to Melikane, despite an elevation of only 531 masl (J. Kaplan, 1990; Lombard et al., 2010). It has deposits assigned to the late MSA, the transition, the early Robberg, and the late Robberg, as well as earlier deposits reaching back to MIS 5 and later Holocene deposits (J. Kaplan, 1990; Sifogeorgaki et al., 2020). It was initially believed that the site was occupied continuously from MIS 3 to MIS 2, and thus that the MSA/LSA transition was smooth and gradual (J. Kaplan, 1990), but recalibration of radiocarbon dates has shown that gaps in occupation do exist (Sifogeorgaki et al., 2020).

The late MSA (Kaplan's layers 19-21) dates to ~48-41 kcal BP (Sifogeorgaki et al., 2020). Hornfels is the primary raw material in the assemblage and is also most commonly used for formal tools including points, scrapers, and MRPs (miscellaneous retouched pieces). Segments are also present, with pieces >30 mm usually on hornfels and pieces <30 mm usually on quartz (J. M. Kaplan, 1989). The MSA/LSA transitional layers date to 33.7-30.8 kcal BP (Kaplan layer 15, context P6). Both bladelets and hollow-based points like those at Umbeli Belli are present (Sifogeorgaki et al., 2020). Formal tools are uncommon, but still include unifacial and bifacial points, MRPs, and occasional scrapers (J. M. Kaplan, 1989).

Kaplan (1990) identified an Early and a Late Robberg at Umhlatuzana. The Early Robberg comprises Kaplan's layers 13-9 and Sifogeorgaki et al.'s (2020) units P3-P5. It is not directly dated, but must fall between the dates of 33.7-30.8 and 16.4-15.7 kcal BP for the surrounding layers. Sifogeorgaki et al. (2020) excavated bladelet products as well as larger flakes and blades. Kaplan's (1990) excavations described *outils éscaillés,* scrapers, adzes, MRPs, unifacial points, two segments, a backed point, a backed blade, and three miscellaneous backed pieces in the assemblage. Although the most common raw material in the assemblage is quartz, 80% of the Early Robberg retouched artifacts were made of hornfels. Bipolar technology was rarely used at Umhlatuzana. Some bipolar cores do exist among the platform cores in both the transitional layers and the Robberg, but they are secondary to other percussion methods (J. Kaplan, 1990). This is possibly because it was unnecessary due to the large size of the vein quartz nodules available locally, which could be knapped free-handedly (L. S. Barham, 1987).

Rose Cottage Cave

Rose Cottage Cave (RCC), a rock shelter located in the Free State ~10 km northwest of Maseru and the Lesotho border, has a long MSA and LSA sequence including the Howiesons Poort, the MSA/LSA transition, the Robberg, and the Wilton (Wadley, 1991a). The final MSA (level Ru) and MSA/LSA transition (level G) were previously dated to ~32 kcal BP and ~23 kcal BP respectively (A. M. B. Clark, 1997b; Wadley, 1997). However, newer dates confine both layers to a period between 30 and 35 kcal BP (Loftus, Pargeter, et al., 2019). If layer Ru is indeed final MSA and layer G is transitional, then the technological changes that occurred did so over a relatively short period.

Levels Ru and G are characterized by irregular cores, declining in frequency from 61% to 40-50%. This decrease in irregular cores was accompanied by an increase in bladelet cores from 4% to 17%. The constant presence of bipolar technology in layers Ru and G at RCC is important to note. Core-reduced pieces (CRPs, 19-27% of all cores) and less commonly, bipolar cores, are also found in these layers. Retouched tools are relatively infrequent in layers Ru and G, comprising only 1% of the assemblages. The most common tools, however, are knives. Layer G also contains a few retouched points and denticulates. All of these trends from the late MIS 3 layers at RCC – an increase in bladelet technology, the persistence of bipolar technology, the phasing out of irregular cores – continued in level DB, assigned to the Robberg by Wadley (1991) and newly dated to ~11 kcal BP (Loftus, Pargeter, et al., 2019). Despite a long occupation hiatus, the microlithic Robberg was foreshadowed in final MSA at RCC, showing that the basic components of LSA technology were already well-formed before its fluorescence (A. M. B. Clark, 1997b, 1997a).

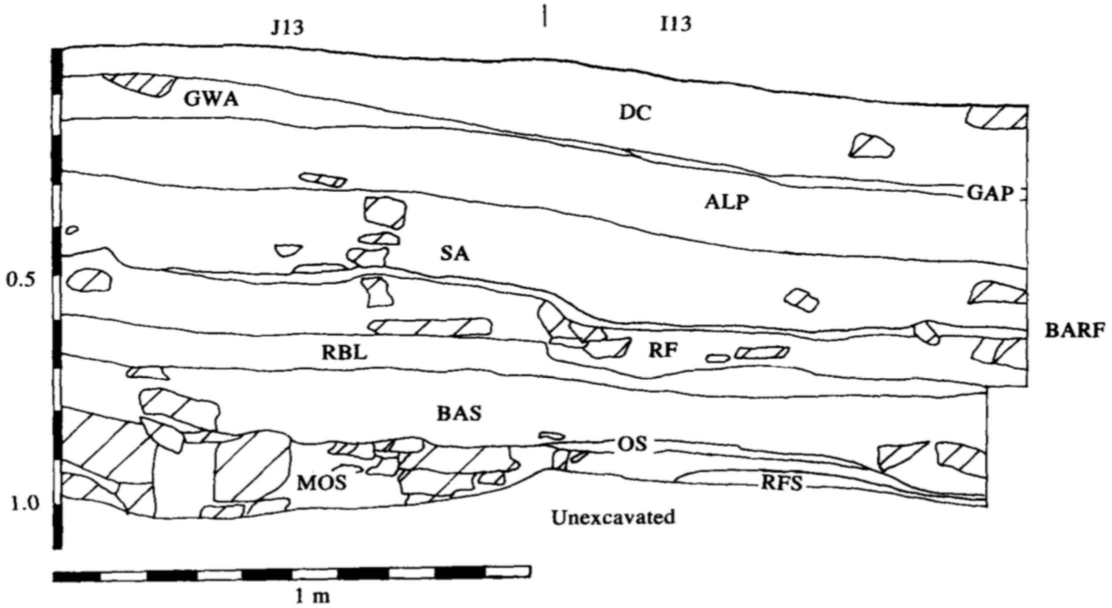
Sehonghong

Sehonghong rockshelter, like Melikane, is located in the Lesotho highlands on a tributary of the Senqu River (Figure 5). Like at Rose Cottage Cave, newly calibrated radiocarbon dates have revised the pre-LGM chronology of the site. Carter's initial excavations (Carter et al., 1988) identified a Holocene LSA, a "bladelet industry," and MSA 9, MSA 6, MSA 5, and MSA 3 assemblages at the site. The bladelet industry was dated at 12,000-18,000 BP, with the underlying MSA 9 assemblage dating to ~20 kcal BP and MSA 6 dating to ~31 kcal BP. These designations were limited by Carter's excavation approach, which used arbitrary spits. The MSA 6 assemblage was grouped with the earlier MSA industries during analysis, characterized by a lower frequency of CCS and few bladelet cores. Carter et al. (1988) found no utilized bladelets in their analysis of the MSA 6 material. Formally retouched artifacts were rare and limited to side and endscrapers. The MSA 9 assemblage differed from the bladelet industry by less frequent use of CCS (<60% of the assemblage), greater use of hornfels and quartzite, and less focus on bladelet technology. Fewer than one third of the MSA 9 blades were under 25mm in length in contrast to ~80% in the bladelet industry. However, MSA core types like Levallois and radial cores were absent, and some bladelet cores were present. The bladelet industry was defined by a heavy focus on CCS and a higher frequency of single-platform blade/bladelet cores. Bipolar flaking and retouch were less common.

These designations and dates were revised after additional excavations by Peter Mitchell in 1992. Mitchell (1994) excavated in natural stratigraphic layers rather than in arbitrary spits. The bottom four layers of his excavations, BAS, OS, MOS, and RFS, were all initially assigned to the period 26-20 kcal BP (Figure 6) (Mitchell, 1994). Newer radiocarbon dates and Bayesian modelling have refined this sequence (Pargeter et al., 2017). RFS belongs to an earlier occupation pulse ~30 kcal BP and was followed by a hiatus from ~28-25 kcal BP. MOS, OS, and BAS date to 24.9-24.1 kcal BP, 24.5-24.0 kcal BP, and 24.3-23.1 kcal BP respectively (Pargeter et al., 2017). Mitchell (1994) also significantly revised previous interpretations of the Sehonghong cultural sequence. RFS, MOS, and OS had been included in Carter et al.'s (1988) MSA 6, and BAS included in the MSA 9. Mitchell (1994, p. 21), however, denied that the term MSA could be "meaningfully applied" to any of these assemblages. He differentiated them from the rest of the MSA by their microlithic character, the presence of bipolar technology, a definite bladelet component, a lack of prepared core technology, and a high frequency of CCS use. Mitchell (1994a, 1995) eventually reassigned RFS, MOS, and OS (MSA 6) to the MSA/LSA transition and BAS (MSA 9) to the Robberg.

Figure 5 View of Sehonghong Rockshelter from the southeast. Photo by Brian Stewart.

Figure 6 Mitchell's (1996) Sehonghong section drawing.



Mitchell (1994) recognized the transitional assemblages of OS, MOS, and RFS as "microlithic," with mean flake lengths on CCS artifacts of <25 mm and mean blade lengths of 25-30 mm. CCS is the most frequently used raw material, although hornfels is more common in RFS than the upper layers. Formal tools are rare and include mostly MSA-type knives. Bipolar cores are present throughout the sequence, but higher frequencies actually occur in layers with lower occupation density, which is the opposite of what should be expected (Parry & Kelly, 1987). Pargeter et al. (2017) hypothesize that something other than raw material constraints and population density was driving bipolar reduction at the time – perhaps time pressure during ephemeral site occupation.

Mitchell (1994a, 1995) grouped BAS (MSA 9) into the Robberg along with the other layers from Carter et al.'s (1988) bladelet industry. According to Mitchell, BAS' heavier focus on bladelet technology and particularly the presence of high-backed bladelet cores distinguished it enough to mark the beginning of a new technocomplex. BAS is also characterized by a unique tool type, the "truncated flake," and a lesser focus on bipolar percussion than the transitional layers. Fish contribute a large component to BAS' faunal assemblage, consistent with Binford's (2001) model showing increased use of aquatic resources during periods of cold (Stewart & Mitchell, 2019). Mitchell's later Robberg layers (RBL-CLRBF, RF, and BARF) postdate the LGM at 16.2-14.6, 15.2-13.4, and 13.9-11.9 kcal BP respectively (Carter et al., 1988; P. J. Mitchell, 1995; Pargeter et al., 2017). However, Sehonghong may not have been completely abandoned between 23.1 and 16.2 kcal BP. Two radiocarbon dates of 22.3-20.8 and 19.8-18.5 kcal BP were taken from ephemeral occupation horizons towards the top of BAS, suggesting that the site may have been revisited periodically during the LGM (Pargeter et al., 2017).

The main importance of the Sehonghong assemblage is that it shows evidence of *in situ* change from the MSA/LSA transition to the Robberg. Carter et al.'s (1988) arbitrary spits masked the continuity between RFS and the Robberg and downplayed the presence of bladelets and microliths in the earlier assemblages. The Sehonghong transitional layers and layer BAS are the closest to Melikane's ~24 ka assemblages in both time and space and provide key context for the MSA/LSA transition in the region.

Heuningneskrans

Heuningneskrans Shelter (HNK) is located in the SRZ in Limpopo Province, South Africa on the edge of the Great Escarpment. It was first excavated in three layers by Peter Beaumont in 1968 and reopened in 2018 by Guillaume Porraz and Aurore Val (Porraz & Val, 2019). There are two primary occupation phases at HNK. The first begins >35 kcal BP and ends ~23 kcal BP. The second phase picks up at the end of the LGM, ~16 kcal BP and lasts until 8 kcal BP. An ephemeral Iron Age occupation caps the sequence. The cultural affiliation of the 35-23 kcal BP layers is questionable. Initially, Beaumont assigned the bottom-most layer of the sequence (3h) to the final MSA and the rest of the sequence to the ELSA. When he later reevaluated the sequence, he identified a more complex sequence including Howiesons Poort-like MSA, Robberg-like, Robberg/Oakhurst intermediate, and Oakhurst industries (Klein, 1984; Porraz & Val, 2019).The "Robberg-like" industry includes materials from layers 3b-3h, with dates ranging from 28.6-13.8 kcal BP (Porraz & Val, 2019).

Other than a brief description of by Beaumont (1981), these materials have never been studied. Lombard et al. (2012) assign the materials to the ELSA, whereas Mitchell (1988a, 1995) and Wadley (1993) recognize them as an early occurrence of the Robberg. In all likelihood, the assemblage is far more complex than Beaumont (1981) originally thought. The layers cover a large swathe of time as well as an occupational hiatus during the LGM. The radiocarbon date of 24.5-23.1 kcal BP from layer 3c is the last before the site's abandonment. It was then reoccupied ~16 ka (Porraz & Val, 2019). To put this in perspective, the "Robberg-like" industry at HNK would be the equivalent of combining RFS, MOS, OS, BAS, and all of the post-LGM Robberg industries at Sehonghong. However, the fact that Beaumont combined layers 3b-3h into one industry is itself tentative evidence for a gradual and early transition to the Robberg at the site.

Putslaagte 8

Puutslaagte 8 (PL8), located in the Cederberg Mountains of the Western Cape, is one of the few sites in the WRZ with an ELSA assemblage. Mackay et al. (2015) identified a pre-Robberg microlithic industry dating to ~25-22 kcal BP, which is followed by a Robberg assemblage dated ~21-18 kcal BP. The pre-Robberg is associated with hornfels blades and flakes with unidirectional scars, bipolar cores, and minimal core and platform preparation. The ELSA core reduction strategy revolved around unidirectional freehand reduction of hornfels cores. Low and Mackay (2016) suggest that this strategy was designed to take advantage of the natural shapes of local hornfels river cobbles. Unlike other WRZ ELSA industries, PL8's does not concentrate on bipolar quartz reduction. Instead, its ELSA is "best distinguished by the expedient production of small blades and the broad absence of prepared core systems" (Low & Mackay, 2016, p. 158). Low and Mackay (2016) compare the PL8 ELSA to quartz-poor ELSA assemblages in the SRZ rather than to other WRZ sites, where quartz is dominant and bladelets are rare.

There is significant continuity between the PL 8 ELSA and Robberg assemblages. The overall frequency of blades does not change, although the Robberg blades show more evidence of standardization and are smaller. Linear, crushed, and lipped platforms are more frequent. Marginal, soft-hammer percussion and bipolar percussion increase in the PL 8 Robberg levels. The frequency of bipolar percussion is positively correlated with the frequency of quartz in the assemblage. Cores are smaller, have more flake scars, more blade removals, and more frequent step and hinge terminations (Low & Mackay, 2016). Low and Mackay (2016) divide the Robberg and ELSA only on the basis of the latter's earlier age and clear differences from the later Robberg. However, the continuity between the two industries raises the question of whether the PL8 ELSA should be considered an “Early Robberg” industry like layer BAS at Sehonghong.

Table 1 Sites in southern Africa with late MSA, transitional, ELSA, or Robberg assemblages.

Site name	Location	Dates	Designation?	Artifacts	Technologies	Citations
Putslaagte 8	WRZ, Cederberg, Western Cape	25-22 ka	ELSA, microlithic pre-Robberg	Unidirectional hornfels blades, quartz bipolar cores.	Unidirectional cores, some bipolar, minimal core preparation	(Low & Mackay, 2016; Mackay et al., 2015)
		21-18 ka	Robberg	Smaller bladelets than in the ELSA, increase in silcrete over hornfels. More intense core reduction.	More core preparation, marginal and soft-hammer percussion, more bipolar.	
Boomplaas Cave	YRZ, Cape Fold Mountains	~35 kcal BP	Final MSA (member BP)	Larger flakes and blades, formal tools.	Centripetal core reduction.	(Pargeter et al., 2018)
		26.4-24.3 kcal BP	Robberg (member LPC)	Quartz microliths, few retouched artifacts	High-backed cores.	
		23.5-21.4 kcal BP	Robberg (member LP)	Quartz microblades, OES, irregular cores.	Bipolar percussion.	
		21.9-20.5 kcal BP	Robberg (member GWA/HCA)	Increase in bladelets, fewer retouched tools.	Less bipolar percussion. Increase in high-backed cores.	
Border Cave	SRZ, KwaZulu-Natal	45-49 kcal BP	Transitional	Fewer blades and formal tools	Bipolar percussion	(L. R. Backwell et al., 2018; Villa et al., 2012)
		42-44 kcal BP	ELSA	Hafted microliths, some large flakes, digging sticks, OES, bored stones.	Radial prepared cores, hafting.	
Sehonghong	SRZ, Lesotho	~30 kcal BP	Transitional (layer RFS)	Bladelets present in small amounts. CCS and dolerite. Some knives.	Microlithic. Bipolar technology. Lack of PCT.	(P. J. " Mitchell, 1994; P. J. Mitchell, 1995)
		25-24 kcal BP	Transitional (layers OS & MOS)	More bladelets, few knives and MRPs. CCS, some dolerite. Heavy presence of fish remains in BAS.	Microlithic. Bipolar present, though less common. Lack of PCT.	
		24.3-23.1 kcal BP	Early Robberg (BAS)	More bladelets, little retouch except truncated pieces.	Microlithic. High-backed bladelet cores present.	
Rose Cottage Cave	SRZ, Free State	30-35 kcal BP	Final MSA and transitional(?). (Levels Ru and G)	Irregular cores, increase in bladelet cores over time, bladelets, microliths, core-reduced pieces, bipolar cores, infrequent retouch (knives, denticulates).	Irregular cores, BP technology.	(A. M. B. Clark, 1997c, 1997a; Loftus et al., 2015; Loftus, Pargeter, et al., 2019; Wadley, 1991b)

Sibudu	SRZ, KwaZulu-Natal	33 ka (OSL), 35.2 ± 1.8 kcal BP.	Final MSA (layers Co and Bu).	Hornfels, dolerite, hollow-based points, knives, scaled pieces, notches. Infrequent retouch. Few blades and bladelets.	Minimal and bipolar cores. Rare blade cores and PCT.	(Wadley, 2005)
Umbeli Belli	SRZ, KwaZulu-Natal	29.3 ± 2 ka	Final MSA (layer GH7)	Hornfels, hollow-based points, quartz cores, bifacial retouch, broad and narrow points, backed tools, asymmetric convergent tools.	Platform cores, some BP bladelet cores.	(Bader et al., 2016, 2018)
		27.2 ± 2.3 – 17.8 ± 1.5 ka (quartz OSL)	Robberg? (layers GH5-GH3)	Absence of retouched tools	Microlithic bipolar bladelet cores on quartz	
Umhlatuzana	SRZ, KwaZulu-Natal	41.9 ± 2.6 ka	Late MSA	Hornfels, quartz, points, scrapers, segments, MRPs.	Platform cores	(J. M. Kaplan, 1989, 1989; Lombard et al., 2010; Sifogeorgaki et al., 2020)
		33.7-30.8 kcal BP (context P6).	MSA/LSA transition	Bladelets, hollow-based points, backed segments, hollow-based points, scrapers. Hornfels and quartz.	Platform cores	
		Between 33.7-30.8 and 16.4-15.7 kcal BP	Early Robberg	Bladelets, unifacial points, scrapers, adzes, some larger blades and flakes, MRPs, backed artifacts, outils éscaillés.	Platform cores, minimal BP technology.	
Elands Bay Cave	WRZ, Western Cape	~35 ka	Late MSA	Bifacial retouch, knives, blades. Quartz.	Decrease in discoidal production	(Porraz, Igreja, et al., 2016; Porraz, Schmid, et al., 2016; Tribolo et al., 2016)
		~24-22 ka	ELSA	Smaller flakes, bladelets, denticulates. Quartz.	Bipolar technology, no PCT.	
Heuningneskrans	SRZ, Limpopo	28.6-23.1 kcal BP, ~16-13.8 kcal BP	"Robberg-like," Robberg, or ELSA	Bladelets and pyramidal bladelet cores.	Not described.	(Beaumont, 1981; Klein, 1984; Porraz & Val, 2019)

Boomplaas

Boomplaas Cave is located in the YRZ in the Western Cape Province of southern Africa. Boomplaas is distinct in that it contains both a defined Robberg element as well as earlier transitional industries. The final MSA (member BP) at Boomplaas dates to ~35 kcal BP, after which the site is abandoned until ~26 kcal BP (member LPC). Member YOL separates these two layers and contains very few artifacts. It remains undated, but may represent the MSA/LSA transition at the site (Pargeter et al., 2018). Member BP contains larger flakes and blades than those later in the sequence and is also characterized by the presence of extensively retouched formal tools and centripetal core reduction. Bladelets and bipolar reduction are relatively rare.

As previously discussed, member LPC is assigned either to the Robberg or an early microlithic LSA (J. Deacon, 1982; P. J. Mitchell, 1988b; Pargeter et al., 2018). Faunal evidence suggests that the local environment was cool and moist with open vegetation during this time. Member LP (23.5-21.4 kcal BP), also assigned to the LSA, follows LPC. Quartz microblades increase in frequency, as does the use of ostrich eggshell. Irregular and bipolar cores are both common, and bladelet cores nearly double in frequency. In LPC, 12.9% of all quartz cores have bladelet removals, compared to 23.9% in member LP. Member GWA/HCA (21.9-20.5 kcal BP) overlies LP, and was likely at least partially contemporary (Pargeter et al., 2018; Pargeter & Faith, 2020). Robberg member CL follows the LGM members, with dates as late as 11.9 kcal BP (Pargeter et al., 2018).

Members LPC and LP differ from the later Robberg members in their lesser focus on bladelet production and higher frequencies of bipolar cores and core reduced pieces. Bipolar core frequency peaks at 90% in member LP, falling to 62% in member GWA/HCA at the height of the LGM. Although a few high-backed bladelet cores are present in LPC, they disappear in LP before becoming increasingly common in GWA/HCA (P. J. Mitchell, 1988a; Pargeter, 2017). Raw material preferences also change, with silcrete use rising during GWA/HCA (Pargeter & Faith, 2020). This coincides with a drop in bipolar core frequency and quartz use, and is consistent with Mitchell's (1988a) observation that high frequencies of bipolar bladelet cores are associated with quartz-dominant assemblages.

Elands Bay Cave

Elands Bay Cave (EBC) is located on the Western Cape. Its deposits range from the Holocene until MIS 6. It is somewhat remarkable in that it preserves deposits assigned to the late MSA (~35 ka), early LSA (29-22 ka), and the Robberg (~19 ka) (Tribolo et al., 2016). The final MSA deposits from phases J-I are dated to ~35 ka. They are characterized by bifacial retouch, truncated knives, blades, and a decrease in discoidal reduction (Porraz, Schmid, et al., 2016). These final MSA phases are followed by phases H-F, assigned to the ELSA and dated to 24-22 kcal BP. The ELSA is characterized by a heavy emphasis on bipolar flaking and a trend towards the production of smaller flakes and bladelets. Core preparation is extremely rare, and the only formal tools present are denticulates. The dominant raw material in both the final MSA and the ELSA is quartz (Porraz, Schmid, et al., 2016).

The ELSA at EBC was followed by a hiatus of ~2500 years, after which phase D (the Robberg) dates to 19.4-18.8 kcal BP (Porraz, Igreja, et al., 2016; Porraz, Schmid, et al., 2016). Quartz remains a common raw material, and heat-treated silcrete becomes more prevalent. Bladelets and bladelet cores, microflakes, single platform cores, and bipolar cores are all present (Porraz, Schmid, et al., 2016). The heat-treated silcrete is non-local, with sources greater than 30 km from the site, and a higher proportion of formal tools are made of silcrete than quartz. Full-sized blades and flakes are restricted to local quartzites. Only three retouched pieces are found in phase D – two modified bladelets and one modified silcrete flake (Porraz, Igreja, et al., 2016).

Sites in Greater Africa

Although some archaeologists place the MSA/LSA transition in East Africa as early as 50,000 years ago (Ambrose, 2002; Tryon, 2019), many East African sites (Table 2) are plagued by old, uncalibrated, and sometimes infinite radiocarbon dates that cast doubt on the antiquity of the LSA in the region (Tryon et al., 2018). There is also a tendency to assign sites to the LSA based on the presence of organic technologies, like bone tools and ostrich eggshell beads. If beads were used to define the LSA in southern Africa, then the MSA/LSA transition would have occurred

>35 ka at Sehonghong, but only 3,000 years ago at Melikane (Tryon, 2019; Tryon et al., 2018). Furthermore, some of the lithic technologies used to define the LSA in East Africa resemble and are penecontemporary with technologies in the southern African Howiesons Poort, including backed segments and reduced artifact size (ie. Ambrose, 2002). Because the Robberg Industry did not develop in East Africa, tracing the ending of the MSA/LSA transition is more challenging, but an understanding of its beginning may be key to understanding the transition at Melikane.

The transition to the LSA in East Africa has sometimes been attributed to a rise in territoriality and subsequent stresses on human populations in that macroregion. It has been argued that there was a dramatic upsurge in population density ~60 ka (Basell, 2008; Bird & O'Connell, 2006; Faith, 2008; McBrearty & Brooks, 2000; P. Mellars, 2006), and Eren et al. (2013) believe increased population densities contributed to escalating territoriality. Groups were required to spend more time defending their territories, necessitating a shift in the amount of time spent on technology. The solution to this problem may have been to balance reliability and efficiency in tool making.

Limited paleoenvironmental data for East Africa during this time also complicates the transition's relationship to environmental change. At some sites, including Lukenya Hill, Mumba, and Panga ya Saidi, the transition occurs independently of any environmental changes, or during a period of relative stability (Gliganic et al., 2012; Marean, 1992; Robinson, 2017; Tryon et al., 2015). At Nasera, however, fauna suggests that moderately moist and temperate conditions are associated with an increase in bipolar cores, and that more open environments correlate with an increase in backed microliths and decrease in Levallois technology. Throughout the transition, however, occupational intensity increases at Nasera, regardless of the environmental conditions (Tryon & Faith, 2016). The sites discussed below represent some of the earliest possible dates for the MSA/LSA transition. If the hypothesis that the transition was the result of population movement or diffusion from other parts of the African continent is correct, these sites may be the source of the technological changes occurring at Melikane Rockshelter.

White Paintings Shelter

White Paintings Shelter (WPS) is located in the northwest Kalahari Desert of Botswana. If the dates associated with the MSA/LSA transition at WPS are correct, then the transition occurred much earlier, ~65-48 ka, than in the southern subcontinent. A microlithic assemblage (Lower Fish deposits) is present at WPS as early as ~48 ka. A more likely date of 36 ka was obtained from OSL, but even the more recent date makes this microlithic assemblage one of the first recorded. The deposit contains abundant fish remains, microliths, and worked bone including harpoon points (Robbins et al., 2000). Some of the raw materials associated with this assemblage are non-local, including varieties of CCS and silcrete. Local quartz and quartzite are also present. Common stone artifacts include backed bladelets, segments, backed points, notches, burins, equal proportions of side and endscrapers, unretouched bladelets, drills, and awls. Blades become larger deeper in the assemblage. There is a large diversity in core types, including bipolar cores on quartz and quartzite, flat bladelet cores, multidirectional cores, and core-reduced pieces. Underneath the Lower Fish deposits, the "Large Blade, Early MSA/Transitional LSA" industry dating to 65-48 kya is marked by large blades and prepared core technology. It is essentially similar to the microlithic assemblage, but with up-sized artifacts and large MSA blades and some prepared cores (Robbins et al., 2000).

Although WPS has been referenced as showing evidence for an early, slow MSA/LSA transition, refitting studies have unveiled significant postdepositional disturbances mixing the MSA and LSA levels (Staurset & Coulson, 2014). These studies are foreshadowed in Robbins et al.'s (2000) description of radial cores and backed blades in the "Low Density LSA" levels overlying the Lower Fish deposits. For this reason, none of the WPS deposits can be securely assigned to the LSA or MSA/LSA transition, but future dating and excavations have the potential to redefine the site's sequence.

Enkapune ya Muto

At Enkapune ya Muto, a rock shelter in Kenya, the final MSA/early LSA Endingi industry is dated to >41 ka. This industry shares many "typical" characteristics with MSA industries, including prepared platforms, radial cores, points, and sidescrapers, and but also includes *outils éscaillés*, burins, and backed microliths. Blades and blade cores are uncommon. Exotic raw materials also spike in this industry, occurring at the highest frequencies in the entire sequence (Ambrose, 1998, 2002). This is followed by the Nasampolai industry, dated to ~50-40 kya. Ambrose (2002) suggests that this may be the world's earliest LSA or Upper Paleolithic industry, marked by large backed tools and the appearance of OES beads. The following microlithic Sakutiek industry dates from 40-35 kya (Ambrose, 1998). Thumbnail scrapers and *outils éscaillés* are prolific in this LSA industry, but many MSA elements are still present in small numbers – knives, points (sometimes bifacial), and discoid and radial cores – and it lacks blade technology (Ambrose, 2002). However, Ambrose (2002) maintains that that the Sakutiek belongs to the LSA because it postdates the Nasampolai and the introduction of OES beads. Tryon (2019) cautions against the integrity of this stratigraphic sequence, suggesting that a more complicated relationship exists between the industries.

Table 2 Sites in East Africa with final MSA, transitional, or ELSA assemblages.

Site name	**Location**	**Dates**	**Designation?**	**Artifacts**	**Technologies**	**Citations**
Enkapune ya Muto **disturbed, affiliations questionable**	Kenya	>41 ka	Transitional (Endingi industry)	Side scrapers, *outils éscailles,* burins, backed microliths, points.	Prepared platforms, radial cores	(Ambrose, 1998, 2002)
		~50-40 kya	Earliest LSA (Nasampolai)	Large backed tools, ostrich eggshell bead ~40 ka.	Blades	
		40-35 kya	LSA (Sakutiek)	Thumbnail scrapers, *outils éscailles,* some knives and points.	Some discoid and radial cores, NO blade technology.	
Nasera Rock Shelter	Tanzania	56-50 ka, 37-25 ka, 24-16 ka	Transitional and LSA	Trends: decrease in artifact size, increase in proportion of BP cores, appearance of backed blades and bladelets.	Heavy emphasis on bipolar. Laminar methods also present.	(Solano-Megías et al., 2020; Tryon & Faith, 2016)
White Paintings Shelter **disturbed, affiliations questionable**	Botswana	~36 ka (Lower Fish deposits)	LSA?	Microliths, worked bone, non-local raw materials, backed segments and notches, side and end scrapers, burins, bladelets, and awls.	Bipolar, flat bladelet cores, multiddirectional cores, core-reduced pieces.	(Robbins et al., 2000; Staurset & Coulson, 2014)
		65-48 ka	Early LSA/transitional	Microliths, longer blades, burins, awls, scrapers, unretouched bladelets.	Prepared core technology, bipolar, flat bladelet cores, core-reduced pieces.	
Kisese II	Tanzania	39.6-34.3 kcal BP	Transitional	Informal flakes, points, OES beads, grindstones, bladelets.	Bladelet cores, centripetal cores, and bipolar cores.	(Tryon et al., 2018)
Mumba Rockshelter	Tanzania	65-45 ka	LSA?	Scrapers, backed tools, geometric microliths in upper levels.	Bipolar dominant, also discoid, radial, and Levallois. Some single platform cores.	(Diez-Martín et al., 2009; Mehlman, 1989)
Panga ya Saidi	Kenya	~67 ka	MSA/LSA	Rise in use of chert and CCS, OES beads peak ~25 ka,	Levallois, bipolar, some Levallois blade production. Technologies come and go.	(d'Errico et al., 2020; Roberts et al., 2020; Shipton et al., 2018)

Nasera Rock Shelter

Like Enkapune ya Muto, Nasera is poorly dated, with old radiocarbon dates, a few amino acid racemization dates, and some U-series dates. The Mumba industry (levels 8/9-11), the first of two transitional industries at the site, dates to 56-50 ka. After an occupational hiatus, the Nasera industry (levels 6/7) lasted from 37-25 ka, and the ELSA Lemuta industry (4/5) from 24-16 ka. Throughout this sequence, the frequency of Levallois cores drops, and the mean size of all nonbipolar cores decreases (Tryon & Faith, 2016). Bipolar cores are prevalent throughout the sequence, first appearing in the final MSA Kisele industry and then reaching their peak in the Mumba levels, increasing in their proportion to other cores throughout time (Solano-Megías et al., 2020; Tryon et al., 2018; Tryon & Faith, 2016). In general, artifacts, particularly endscrapers, become smaller, and standardized backed blades and bladelets become common, although backed microliths are infrequent until the ELSA (Tryon & Faith, 2016). One major problem with the Nasera industries is small sample size – only 254 lithics were analyzed in the most recent MSA/LSA transition study (Solano-Megías et al., 2020).

Kisese II

Kisese II, unlike the aforementioned sites, does have relatively new and calibrated radiocarbon dates. It is notable for its assemblage of >5000 OES beads, which appear as early as 46.2-42.7 kcal BP, and persist throughout the entire sequence at the site. Backed microliths also appear >45 kcal BP. Despite these early dates, Tryon et al. (2018, p. 16) assigns the relevant layers to the MSA and cautions against using first appearance datums (FADs) as markers of the MSA/LSA transition at any of the East African sites:

> “While useful, an emphasis on FADs tends to downplay evolution within technical systems, and obscure the processes by which innovations are spread from their point of origin; they also mask the potential to examine the loss and reinvention of technology and to detect convergent evolution among disparate groups.”

Tryon et al. (2018) maintain that the transition at Kisese II was slow, beginning with changes in social structure followed by changes in subsistence and lithic technology. The actual MSA/LSA transition dates to 39.6-34.3 kcal BP. Changes included the gradual fade of Levallois technology and the beginnings of bladelet and grindstone production. Some technologies remained stable however – persistence in point production until ~33 kcal BP, casual flake production, bipolar technology, and centripetal flaking. Bladelet cores are consistently present alongside centripetal cores. The transitional layers are followed by layer X, dating to the early LGM at 23.7-23.1 kcal BP. This layer contains numerous backed microliths, and is followed by a resurgence in point production from 22-18 kcal BP.

Mumba Rockshelter

Like Kisese, Mumba rock shelter has recently been redated. The eponymous Mumba industry (bed V) was originally assigned to the MSA/LSA transition on the basis of a combination of typical MSA and LSA forms – knives, geometric microliths, OES beads, and points (Mehlman, 1989). New OSL dates place the earliest Mumba industry at 56.9 ± 4.8 ka and the latest at 49.1 ± 4.3 ka (Gliganic et al., 2012). These are roughly in line with the earlier amino acid racemization (AAR) dates of 65-45 ka (McBrearty & Brooks, 2000). Diez-Martín et al. (2009) and Tryon (2019), however, argue that bed V should be designated as LSA. H. J. Deacon & Deacon (1999) point out that AAR dates of 65-45 ka could be contemporaneous with the Howiesons Poort, and that the Mumba industry might represent an East African variant of the former.

Overall, the technological organization of bed V remains relatively stable through time. It is dominated by bipolar percussion, characterizing 50% of cores overall and increasing in frequency towards the top of the bed (Diez-Martín et al., 2009). "Peripherally worked cores," which include discoid, radial, and Levallois types, are the most common of the freehanded cores throughout the sequence. Single-platform cores occur in small numbers. Formal tools occur throughout the sequence, decreasing in terms of length, width, thickness, and weight from the lower Mumba up. In the lower Mumba, scrapers (including notches and denticulates) are slightly more common than backed forms (47.61 vs. 42.85 %). The trend reverses in the middle and upper levels, where backed tools comprise 70 and 62.79% of retouched artifacts, respectively. The backed tools in the upper Mumba are often microlithic and sometimes crescent-shaped. Geometric microliths, however, only appear in the upper levels. Notably, blades do not form a significant portion of bed V, and their frequency does not vary through time (Diez-Martín et al., 2009).

Panga ya Saidi

Located in Kenya, Panga ya Saidi (PYS) demonstrates gradual technological change in the MSA and LSA. MIS 5 occupations are followed by another occupation ~67 ka, during which cryptocrystalline quartz and chert become more common than the fine-grained limestones characterizing the earlier assemblages. Artifacts begin to decrease in size independent of changes in raw materials, and bipolar technology rises in significance. Although these changes are generally considered "LSA," typical MSA characteristics remain. Levallois technology is present even in the Holocene. Technologies come and go throughout time – blade production, backed tools, and bipolar technology, once present at the site, do not necessarily persist, appearing sporadically in different layers. In short, the LSA does not arrive at PYS as a "package," and does not necessarily "stick." The most noticeable and persistent trends throughout the Pleistocene at PYS begin at ~67 ka, with the use of cryptocrystalline quartz and chert and a decrease in artifact size (Shipton et al., 2018). It is notable that these changes are also seen in southern Africa in the Howiesons Poort, like those seen in the Mumba industry.

Chapter 3: Theory

This chapter reviews the theory on hunter-gatherer technology. I break down this body of theory into two domains, environment and culture. I begin with the environment and a basic summary of hunter-gatherer mobility patterns, tying them to the toolkit form and provisioning systems. Then, I transition into a discussion of culture, discussing the mechanics of flaking system transmission, the effects of population density, and hunter-gatherer territoriality. Lastly, I present three hypotheses that I will test in this dissertation.

Environment

Mobility

Early studies of hunter-gatherer mobility focused on the relationship between movement and food availability. Binford (1980) distinguished two idealized types of hunter-gatherers: foragers and collectors. The two types are not mutually exclusive, and most hunter-gatherer societies fall on a "spectrum" between the two poles (R. L. Kelly, 2013). Foragers are often described as "mov[ing] consumers to goods," and collectors as "mov[ing] goods to consumers" (Binford, 1980, p. 15). On one end of the spectrum, foragers have high residential mobility. They move their residential bases often and do not store food. The distance of each residential move is contingent on resource distribution. When food is homogenously distributed across the landscape, foragers will move shorter distances than when it is patchily distributed. Generally, foragers adapt by either moving or changing the size of their group.

Conversely, collectors move their residential bases less frequently. They are more likely to store food and have higher logistical mobility, sending out small task groups to "field camps", "stations", and "caches" to undertake specific activities (Binford, 1980). Binford hypothesized that a collector strategy would be preferable when resources were patchy, allowing access to multiple types of resources from a central place. Logistical mobility would play a larger role in areas with greater seasonality and contribute to larger variation in the form of archaeological assemblages (Binford, 1980). Although residential and logistical mobility are often conceptualized as opposite ends of a continuum, it is also possible for hunter-gatherers to have high residential *and* high logistical mobility, or low mobility overall (Barton & Riel-Salvatore, 2014; Marean, 2016; Schoville et al., 2021).

The frequency of residential movement is tied both to resource distribution and the costs of movement. Dense vegetation, or high primary biomass, decreases resource availability by increasing search and pursuit costs. This correlates with more frequent movement for groups relying on terrestrial resources. However, the inverse is true for groups relying on aquatic resources. For these groups, lower primary biomass is associated with more frequent movement (R. L. Kelly, 1983; Yesner et al., 1980). Residential moves will be less frequent when moving entails significant costs such as the need to build structures, move a large number of goods, or empty goods from storage (R. L. Kelly, 2013). However, the use of persistent places can counter these costs (C. Morgan et al., 2018). The presence or absence of firewood, lithic raw materials, or social and political factors also encourage and discourage movement (R. L. Kelly, 2013).

Distance per residential move is often inversely related to the frequency of movement. However, nomadic hunters require large territories (R. L. Kelly, 2013). They move long distances on a frequent basis, having both high residential and logistical mobility (Grove, 2010). For groups relying on aquatic resources, distance per residential move is also associated effective temperature (ET) and rainfall. Tropical fishers (high ET and high rainfall), for example, make frequent but short moves, and temperate/arctic fishers (low ET, low rainfall) make longer, further moves (Grove, 2009).

Risk

Technology has been conceptualized as a means of responding to risk. Risk refers to both the probability of loss and the severity of its consequences (Torrence, 1989). According to Bousman

(1993), risk also includes lack of knowledge about either of these situations. Wiessner (1982) identifies four general strategies for reducing risk: (1) transfer of loss, (2) prevention of loss, (3) food storage, and (4) storage through social obligation. Technology can be used in all four of these strategies. There is also a fifth possible response to risk – moving away from the risky environment (Butzer, 1988; Rowley-Conwy & Zvelebil, 1989). Technology is not necessarily used in the process of movement but can be greatly affected by it.

Foragers can mitigate risk by making their technologies more efficient (Bleed, 1986). Efficiency is the ratio between the time it takes to make a tool and the time the tool is actually used (Binford, 1979b). A toolmaker can increase efficiency by reducing production time, making it more durable, making it more effective, or using raw material more economically (C. B. Bousman, 2005). One way to reduce production time is to use local raw materials. Even if local raw materials are of substandard quality, they are often preferred to non-local materials for formalized tool production (Gould, 1980; O'Connell & Wright, 1977). The two most basic functional tool types are extractive and maintenance tools. Extractive tools are used in order to procure resources, and maintenance tools are used to fix or craft other tools (Binford & Binford, 1966). Tools also fall on a spectrum between expedient or curated (L.R. Binford, 1973, 1977, 1979). Expedient tools are used for short periods of time and are generally not modified/retouched. This is only possible when raw material is abundant (Bamforth, 1986; Nelson, 1991). In contrast, curated tools are made in anticipation of needs and remain in a toolkit for a long period of time. They show signs of maintenance, recycling, and reuse (L.R. Binford, 1973, 1977, 1979).

Extractive tools fall on a spectrum between reliability and maintainability. Reliable tools should be over-designed, sturdy, and should always work when necessary (Bleed, 1986; Torrence, 1989). However, they are often cumbersome and time-consuming to make. Maintainable tools are multifunctional and versatile, easy to repair and modify, easy to transport, and always ready for use (Bleed, 1986; but see Torrence, 1989). They are not as fail-safe as reliable tools, but are advantageous in situations of unpredictable resource scheduling because they are ready to use at any moment (Bleed, 1986; Torrence, 1989). Reliable tools, although bulky and less versatile, are advantageous when resource scheduling is predictable, but the cost of loss is high. Determining a tool's degree of "reliability" or "maintainability" is relative (Kuhn, 1994), and tools can have elements of both attributes. For example, multicomponent weapons using unretouched microflakes and bladelets are both reliable *and* easy to repair (P. J. Mitchell, 1992, 2000). The use of multiple barbs ensures that if one or a few flakes fall out of the haft, the tool can still function reliably. Afterwards, premade flakes can be quickly slotted in where the others fell out. These flakes can be easily brought along on hunting forays or even knapped on-the-spot from a small core. This system would be highly advantageous in a high-stakes environment.

Traditionally, maintainable and reliable tools have been associated with foragers and collectors, respectively. Kuhn (1994) claims that for a highly mobile forager, the "optimal" design of a toolkit is one that maximizes utility in relation to transport costs. This often includes maintainable tools (C. B. Bousman, 1993), but can also include carrying cores or blanks (Kuhn, 1994). Cores can be used as tools and for blank production, but according to Kuhn (1994), a number of moderately-sized blanks hold more potential utility than a large blank or a core because of the time saved. Transport costs matter less to collectors, who can keep spare parts and repair kits in a central location. Collectors can fix their tools during "gearing up" sessions, storing their maintenance tools where they will be needed (L.R. Binford, 1980).

Bousman (1993) differentiates the treatment of extractive and maintenance tools. In his view, foragers, or those with a high degree of residential mobility, will carry highly maintained extractive tools but expedient maintenance tools. They will use and repair their extractive tools to the point of exhaustion. Conversely, collectors schedule repairs ahead of time, so their maintenance tools are likely to be specialized and curated. Collectors will frequently discard tools long before their utility is expended, lessening the possibility of failure. The caveat to this dichotomy, Bousman says, is short-term food scarcity. Under these conditions, no matter if a group trends towards a forager or collector strategy, they will replace extractive tools frequently, but repair maintenance tools. Bousman suggests that this pattern, or the ratio of residual to expended utility, is a proxy for short-term resource scarcity.

Toolkit complexity and diversity are also impacted by mobility and resource distribution. According to Schott (1986), toolkit diversity, or the number of tools in a toolkit, should increase as mobility decreases because the practical limitations imposed by frequent movement disappear. Read (2006, 2008) found that hunter-gatherers with the most complex toolkits were those who lived in areas with the shortest growing seasons and moved the fewest number of times per year, and that effective temperature was negatively correlated with the number of technounits per tool. He hypothesized that when population growth results in increased population density, foragers should shift to a collector strategy and create a more complex toolkit to reduce risk in resource intensification (Read, 2008). However, Read (2008) also hypothesized that resource uncertainty can shrink toolkit size. If a resource is unreliable, then it may not be worth investing in technology to exploit it.

Based on the above, we can make the following generalizations about the form of hunter-gatherer toolkits:

Maintainable tools will be favored when…

- Foragers have a high degree of residential mobility.
- Resource scheduling is unpredictable.
- A wide variety of resources, including raw materials, are available.
- The costs of implement failure are outweighed by the probability of encountering another resource.

Reliable tools will be favored when…

- Residential mobility is lower.
- Resource scheduling is predictable.
- There is a low diversity of resource types.
- The cost of implement failure is high.

Short term resource scarcity will lead to…

- A high “droppage rate” for extractive tools.
- Repair of maintenance tools.

Toolkit complexity and diversity increase when…

- Residential mobility is low.
- Population density rises.

Provisioning Systems

Technological provisioning, or the "depth of planning in artifact production, transport, and maintenance, and the strategies by which potential needs are met" (Grove, 2009, p. 200), has been studied in detail in the European Paleolithic but less discussed in the archaeological literature of Lesotho (but see Mackay et al., 2014; Pazan et al., 2020). It is a means of handling what Kuhn (1995) sees as the two main obstacles for foragers: design, or making a tool that can complete the task at hand, and supply, or having the tool when you actually need it. Two idealized types of provisioning exist – individual and place. Foragers using an individual provisioning strategy always carry toolkits. These toolkits will usually be small and maintainable. Place provisioning, on the opposite end of the spectrum, means that tools and raw materials will be stored at the places where they will be needed. As noted by Mackay et al. (2014), provisioning systems are highly contingent on resource distribution. They cannot be transferred between dissimilar environments, and thus always represent a local adaptation.

Individual provisioning is advantageous when resource scheduling is unpredictable. A forager will always have a tool on-hand, never be caught off-guard or missing an opportunity to exploit a resource. However, this type of provisioning limits toolkit size. Foragers will be unable to take back-up tools, spare parts, or a variety of specialized implements. Generally, high residential mobility is associated with individual provisioning and maintainable tools (Gould, 1969; Kuhn, 1995; Lee, 1979; Nelson, 1991). Sites visited by individual provisioners will not be occupied for long, and tools will be multifunctional, heavily maintained, and reworked. There will be lower proportions of cores and unworked materials (Kuhn, 1995).

When resources are predictable in time and space, foragers have the luxury of choosing when and where to use particular tools. They will "provision places" by storing tools and raw materials at the locations where they will be needed. Place provisioning, therefore, is usually associated with high logistical mobility. Tools can be large, bulky, highly specialized, and perhaps used to a lesser degree than tools used by residentially mobile individual provisioners. Foragers can also provision sites with raw materials, meeting their needs as they change without having to consider transport costs (Gould, 1969; Kuhn, 1995; Lee, 1979; Nelson, 1991).

Although individual and place provisioning are usually associated with high residential and logistical mobility respectively, the relationship is not always straightforward. Low residential mobility can accompany an individual provisioning strategy if resources are locally abundant. High residential mobility can still accompany a place provisioning strategy if there is significant logistical input (Marean, 2016; Schoville et al., 2021). These combinations of mobility and provisioning strategies will produce archaeological assemblages with different signatures. Individual provisioning and low residential mobility produce assemblages with high artifact densities and high retouch frequencies. Individual provisioning and high residential mobility will produce low artifact densities and low retouch frequencies. Place provisioning and low residential mobility produce high artifact densities and low retouch frequencies, and place provisioning and high residential mobility produce low artifact densities and high retouch frequencies (Barton & Riel-Salvatore, 2014; Marean, 2016; Schoville et al., 2021).

Culture

Flaking Systems

Certain attributes of lithic technology are more likely to be socially negotiated than others. The environment heavily influences mobility patterns and provisioning systems (de la Torre, 2011). These aspects of lithic assemblages, therefore, do not transfer well between different environments. Instead, cultural ties are more apparent in elements of technology that humans control most directly, particularly flaking systems (Tostevin, 2012). Flaking systems are defined as “the means by which cores were reduced” (Mackay et al., 2014, p. 3), and include the technological choices a knapper makes, but not what happens after blank production (Tostevin, 2012). This approach differs from the French *chaîne opératoire*, which involves all stages of lithic manufacture, beginning with raw material selection and including any maintenance, re-purposing, use, and eventually discard (Boëda, 1995, p. 43).

The advantages of studying flaking systems include not only the neutralization of environmental factors, but also that flaking systems are difficult to learn except through “process copying”

(Derex, Godelle, et al., 2013; Hiscock, 2014; Tostevin, 2012). Process copying is a social form of learning unique to humans, where instead of focusing on *what* is produced, learners focus on *how* things are produced (Tennie et al., 2009; Tomasello, 1990, 1996; Tomasello & Call, 1997). It is sometimes called "imitation" (Schillinger et al., 2015). This requires direct observation, often over long periods of time, and usually occurs alongside genetic exchange (Mace & Jordan, 2011; Tehrani & Collard, 2009; Tostevin, 2012). Copying errors, or mutations, are more likely to occur during "reductive" processes like knapping (Schillinger et al., 2014). The consequence of this is that stone tool technology may be particularly sensitive to inaccurate transmission, and therefore that similarities in flaking systems should be indicative of extremely close interaction and contact.

When flaking systems transfer between populations, toolkits are likely to transfer as well (Tostevin, 2012). However, toolkits can also transfer without flaking systems. It has been argued (Hiscock, 2014; Högberg & Larsson, 2011; Mackay et al., 2014) that it is possible to replicate the shape of basic stone tools (ie. denticulates, scrapers, unifacial points, backed artifacts) without seeing the manufacturing sequence. This process is called "product copying," or "emulation" (Boyd & Richerson, 1985; Schillinger et al., 2015; N. Shea, 2009; Tennie et al., 2009). Tool form can therefore be transmitted through more casual population contact (Tostevin, 2012). However, Schillinger et al. (2015) found that participants who watched a video of how to make a basic foam hand axe produced more faithful copies than participants who only saw a finished model. This suggests that even continuity in basic tool shape may benefit from process copying and population interaction, and that typology should not be entirely discarded as an indicator of cultural ties.

Although similarities in flaking systems can arise independently, the likelihood of transmission between adjacent areas increases with the number of "shared choices" made (Tostevin, 2012, p. 153). Tostevin (2012) recognized the need to define units of choice in flaking systems in order to quantify this principle. He identifies four "knapping domains defined for blank production behaviors (core modification, platform maintenance, direction of core exploitation, and the dorsal surface convexity)" (Tostevin, 2012, p. 148). Within each of these domains are a number of possible "changes," or units of transmission (Tostevin, 2012, p. 149, see table 4.3). In general, the more units two assemblages share, the more likely cultural transmission was involved in their formation. However, if these similarities had precursors in earlier assemblages, then independent invention becomes increasingly probable (Tostevin, 2012). For example, if sites A and B are both characterized by flakes with plain platforms, twisted profiles, and trapezoidal cross sections, but plain platforms and twisted profiles were already present in A's earlier assemblage and trapezoidal cross-sections and plain platforms were already present in B's prior assemblage, it is less likely that transmission occurred than if none of the traits had been present before.

However, environmental factors still play into the transferability of flaking systems. There is significant debate on how much raw material choice actually constrains the character of lithic assemblages (Andrefsky, 1994; Eren et al., 2014; Kuhn, 1991). According to the natural forces hypothesis (de la Torre, 2011), it is impossible to make some shapes on certain raw materials. Therefore, the absence of particular tool forms and reduction sequences in different geographic areas does not necessarily indicate a lack of cultural transmission or an attempt at process copying, but rather the failure of transmission due to external factors outside of humans' control. The second hypothesis, or the artificial forces hypothesis, posits that the skill of the knapper in relation to raw material dictates artifact form. In other words, a knapper may not know *how* to work with a certain material, so reduction sequences and toolkits may not be passed on. De la Torre (2011, p. 788) describes this as "technical incompetence." If the knapper is skillful, however, it is theoretically possible to make any form on any material. In this case, process copying and skill can overcome any difficulties imposed by raw material limitations.

Population Structure

Initial research on the survival and proliferation of cultural traits has emphasized that larger, more interconnected populations are buffered against the effects of errors in process copying and will develop more complex solutions to problems. These solutions compound upon one another, accelerating the pace of cultural evolution – the so-called "ratcheting effect" (Derex, Beugin, et al., 2013; Henrich, 2001, 2004; Powell et al., 2009; S. Shennan, 2001; S. J. Shennan et al., 2009; Tennie et al., 2009). Population growth has been employed to explain the development of complex behaviors, particularly as observed in the Still Bay and Howiesons Poort industries (Henshilwood, 2002; Henshilwood & Marean, 2003; Powell et al., 2009). The theory was that a larger population creates more opportunities for innovation, increasing the chance that skills can be passed on faithfully to the next generation. On the other hand, population contraction has been linked to the loss of cultural complexity. For example, in Tasmania toolkit variety shrank during the Holocene as effective population size dropped (Henrich, 2004).

Newer research has found that large, connected populations tend to be less diverse, and thus may have less potential to build on existing innovations (Creanza et al., 2017; Derex et al., 2018). Instead, an intermediate degree of population fragmentation may actually encourage innovation (Creanza et al., 2017; Derex et al., 2018; Derex & Boyd, 2016; Derex & Mesoudi, 2020). Fragmented populations tend to be more diverse, bringing together many different skills, adaptations, and prior knowledge, fueling the ability to innovate and combine technologies to create more complex ones. Copying errors in small populations can also give rise to new technologies and promote behavioral flexibility. Trial-and-error during the copying process leads to exploratory learning, as learners may acquire new skills and information while experimenting (Truskanov & Prat, 2018). However, fragmented populations are prone to cultural loss, and connected populations are better at retaining innovations. Populations intermediate between these two extremes, therefore, are the most likely both to invent complex technologies and maintain them for longer periods of time (Creanza et al., 2017; Derex et al., 2018).

Population connectivity has both risks and benefits. Information exchange is highly valuable in stochastic environments. If a change in resource availability forces a group to move, people need to know both where to go and that they will be well-received (Whallon, 2006, p. 261). Exotic, “non-utilitarian” goods have been interpreted as a form of communication, cementing relationships and ensuring future cooperation (Kuhn & Stiner, 2007; Whallon, 2006). Travelling to visit other groups also gives an individual knowledge of his physical environment. Stewart et al. (2020) identified the presence of social networks extending from the Lesotho highlands into the subcontinental interior at least as early as ~33 ka. The strontium signatures of the ostrich eggshell (OES) beads found at Melikane and Sehonghong match those of the lowland interior grasslands, sometimes greater than 300km away from the shelter. The authors suggest that by facilitating social connections with highland groups in more stable environments like those of Melikane and Sehonghong, the interior foragers were building a safety net for times of scarcity. Interestingly, although ostrich eggshell beads were moving through this network, lithic technologies remained regional (Mackay et al., 2014). It is thus likely that although these populations were in remote contact, they were not interacting enough to exchange skills and ideas, especially flaking systems.

Territoriality

Population connectivity is affected by the type and degree of territoriality. Territoriality is defined as the "maintenance of a bounded range by a group the boundaries of which the group defends" (Guenther, 1981, p. 115). Ecological models based on non-human animals emphasize that territoriality will only occur when resources are defensible and predictable (J. L. Brown, 1964). However, these models are limited when applied to hunter-gatherers. Instead, territoriality is most advantageous among humans when resources are scarce (Cashdan, 1983). Cashdan (1983, p. 49) identifies two types of territoriality in hunter-gatherer societies: "perimeter defense" and "social boundary defense." Groups using the perimeter defense strategy typically have smaller territories with dense, predictable resources. These groups defend a physical border. In contrast, foragers using social boundary defense defend access to their social group. Access is granted with the expectation that it will be reciprocated. Social boundary defense reduces the costs of defending a large territory, which is necessary when resources are sparsely distributed.

The ethnographic study of territoriality, particularly among the Bushmen, has been complicated by colonial influence and the imposition of western ideas of property ownership (for review, see Guenther, 1981). Cashdan's (1983) study of four Bushman groups found that territoriality was the highest when resources were both rare and unpredictable. Out of the four groups considered, the !Ko were the most territorial, and lived in the area of lowest annual rainfall and highest annual rainfall variability. They had no staple food resources, lacked social ties outside of their group, and rarely left their territories. According to Cashdan (1983), the !Ko's social isolation was an adaptive response to regional resource scarcity. Social connectivity, often viewed as a means of decreasing risk, is only adaptive when resources are scarce locally.

Territoriality is often accompanied by intergroup violence, leading to intensification and isolation within individual territories. Allen et al. (2016) showed that sharp-force trauma among Holocene hunter-gatherers in California was most frequent in the least productive environments. Allen et al. (2016) hypothesize that resource scarcity is likely to prompt theft or territorial incursions, which may result in lethal violence. Even if theft does not increase in frequency, scarcity might make theft less tolerable, and thus more severely punished. The nineteenth century Andaman islanders, who lived in geographically restricted territories with scarce resources, had higher rates of intergroup violence than hunter-gatherers in more resource-rich territories. Paradoxically, violence tends to produce buffer zones between territories where resources are not exploited. This leads to an underutilization of resources in an already resource-scarce environment and additional territorial contraction (R. C. Kelly, 2005).

Lesotho's geography may have increased the feasibility of territorial defense as well as provided natural "buffer zones" between territories. Rock shelters, which are often hundreds of feet above the valley floor, provide ideal locations from which to spot intruders. Rivers, along with possible glacial features and permanent snowlines, may have provided natural boundaries and created neutral zones without exploitable resources. These natural features could have made perimeter defense a viable strategy for highland populations, especially when landscape productivity fell. If resource scarcity was local, the populations of highland Lesotho were likely both territorial and connected. Social boundary defense would encourage travel between neighboring territories and sharing of resources. However, regional resource scarcity may have led to the isolation of individual groups and a loss of population connectivity.

Hypotheses

In this section, I present three different hypotheses for technological change at the onset of the LGM in highland Lesotho. I will test these hypotheses through an analysis of the "transitional" lithic assemblages at Melikane Rockshelter, Lesotho. A difficulty I encounter here is disagreement in the archaeological literature on whether I am looking for one transition (MSA/Robberg), or two (MSA/ELSA and ELSA/Robberg) transitions. To simplify my hypotheses, when I refer to the “MSA/LSA transition,” I am referring to all the technological changes that occurred in southern Africa between the final MSA and the fluorescent, post-LGM Robberg. The exception is hypothesis A, which directly tests Bousman and Brink’s (2018) hypothesis and refers to the transition with a bit more specificity.

The three hypotheses I present in this section are not mutually exclusive, and each assesses technological change at a different scale and from a different perspective. Hypothesis A, the population replacement hypothesis, works at the macro scale, assessing change in flaking systems over a period of 20,000 years and across a large swathe of the African continent. Hypothesis B, resource distribution and mobility, works on the local scale and asks how changes in the resource distribution of the highlands may have impacted the day-to-day movements and technological choices made by the Melikane foragers. Hypothesis C, social networks, connects the first two hypotheses by investigating how meso-scale connectivity between the highlands and interior impacted population density and information exchange.

Hypothesis A: Migration/Replacement

My first objective is to test the prevailing hypothesis that the ELSA arrived via population replacement, a hypothesis that has endured nearly 100 years of archaeological research (C. B. Bousman & Brink, 2018; Goodwin & Van Riet Lowe, 1929; Humphreys, 1972). While older theories attribute this migration to peoples arriving from Northern Africa (Goodwin & Van Riet Lowe, 1929), Bousman and Brink (2018) have suggested that a population replacement occurred over a longer period of 20,000 years, and that the appearance of the ELSA and subsequently the Robberg are the consequence of two population divergence events. There is no “transition” at individual sites, but instead a series of “dynamic and punctuated events” (C. B. Bousman & Brink, 2018, p. 130). Bousman and Brink (2018) claim that the ELSA originated at Border Cave, but early dates for the ELSA elsewhere in East Africa necessitate that I consider them here as well.

If the ELSA arrived from Border Cave or East Africa, then the Melikane transitional assemblages should show no technological continuity with each other, the Melikane MSA, or the

Robberg. Considering the low likelihood of flaking system transmission without genetic exchange, migration or population replacement may be the only explanation for convergence that cannot be attributed to natural intrasite evolution (Tostevin, 2012). Certain technological trends prevail at Melikane from MIS 5-3, including the use of multidirectional, bipolar, and parallel core reduction sequences (Pazan et al., 2022; Stewart et al., 2012). If there was a population replacement or migration event, then these trends would be abruptly interrupted. New flaking systems should suddenly appear out of nowhere. However, the Melikane toolkit may not have been replaced if it was highly adapted to the local environment (Tostevin, 2012). A population replacement event would also result in shared flaking systems at Melikane, penecontemporary sites, and at the ELSA source sites. We would also expect to see similar toolkits where environments were the same. If the ELSA/Robberg transition was a rapid and near-synchronous event beginning on the southern Cape, then we would not expect to see any in-situ development of Robberg technology in the Melikane assemblages.

Hypothesis B: Resource Distribution and Mobility

Environmental changes greatly affect lithic assemblages by forcing shifts in resource exploitation strategies and landscape use. It is therefore possible that the Melikane assemblages are the product of changing mobility patterns leading up to the LGM. There are two ways in which the Melikane foragers may have responded to these changes – moving more frequently to follow resources or moving less frequently and intensifying resource use.

High residential mobility was a globally common response to the LGM, particularly in high latitude environments like Siberia, where foragers became increasingly dependent on hunting (Graf, 2010; Grove, 2009; Pitulko et al., 2017). The Melikane foragers may likewise have decided to concentrate on game, moving more frequently, and likely adopting an individual provisioning strategy. High residential mobility is also favorable in extreme environments where resources are unpredictable, yet homogenously distributed – for example, above the snowline in mountainous regions (C. Morgan, 2008). Foragers may have been able to move up and down river corridors in the Lesotho highlands, exploiting the same resources at each basecamp and moving when the local environment became exhausted. Movement would become more frequent as the environment declined and resources became scarcer, but only if population densities remained low (C. Morgan, 2008). The use of persistent places including rock shelters would offset the costs of building facilities (R. L. Kelly, 2013; C. Morgan et al., 2018). If the Melikane foragers adopted a highly residentially mobile strategy and provisioned individuals, the resulting toolkit would include (Bamforth & Bleed, 1997; Barton & Riel-Salvatore, 2014; Bleed, 1986; C. B. Bousman, 1993, 2005; Kuhn, 1994, 1995; Marean, 2016; Schoville et al., 2021):

- A relatively small repertoire of tool types,
- Artifacts that balance use potential with portability (ie. mid-sized blanks),
- Highly curated extractive tools with evidence of re-working, repurposing, and maintenance,
- Expedient maintenance tools and heavily curated extractive tools (until resource scarcity became critical, after which this pattern would reverse), and
- Low artifact density and low retouch frequency.

Instead of increasing the frequency of residential movement, the Melikane foragers may have chosen to intensify their use of local resources. High residential mobility may not have been an option if population density was high (C. Morgan, 2008), or may not have been necessary at first. Initially, the downslope movement of C^3 grasses may have brought faunal resources within close range of the shelter, allowing for less residential mobility. Foragers would have increased their diet breadth to include more aquatic resources, further contributing to sedentariness. At a certain point, movement would have become restricted not only by topography, but also by the social composition of the landscape as regional resource scarcity encouraged territoriality. Unpredictable resource scheduling and limited logistical mobility due to small territory size would encourage individual provisioning despite low residential mobility. The resulting archaeological assemblage would show (Binford, 2001; Kuhn, 1994; Marean, 2016; Read, 2006, 2008; Schoville et al., 2021):

- Greater diversity and more specialization in tool types,
- Tools combining elements of both reliability and portability,
- Raw material conservation (smaller implement and core sizes, possibly bipolar reduction),
- An increase in the use of local raw materials,
- The frequent disposal of extractive tools and intense curation of maintenance tools, and
- High artifact densities and high retouch frequencies.

If territoriality was less severe and populations were less dense, place provisioning and increased logistical mobility would allow foragers to access more distant resource patches. In this case, high artifact density would be accompanied by low retouch frequency, and there would be greater proportions of cores and minimally worked materials at the site. This hypothesis does not preclude the validity of the migration/replacement hypothesis. It is entirely plausible that two groups produced blanks using the same flaking system, but used different provisioning and mobility systems because of environmental constraints (Tostevin, 2012).

Hypothesis C: Social Networks

Changes in social connectivity unrelated to large-scale migration also may have influenced technological change across the MSA/LSA transition. As previously discussed, Stewart et al. (2020) identified an OES bead exchange network connecting the Lesotho highlands with the southern African interior. During MIS 3, movement along this network was not strong enough to facilitate the transfer of flaking systems or toolkits, and lithic technologies remained regional (Mackay et al., 2014; Stewart et al., 2020) Hypothesis C1 implicates the growth of this and other social networks in the MSA/LSA transition. If the movement of people and ideas between the highlands and interior increased in intensity, perhaps as a reaction to a deteriorating climate (Stewart et al., 2020), then the meta-population of southern Africa may have reached the ideal balance of fragmentation and connectivity to both create complex innovations and sustain them through time (Derex & Boyd, 2016). In this case, we would expect that new, more complex elements spread quickly across the subcontinent as innovations collided and built upon one another. No two industries would be exactly alike, but all industries would include bits and pieces of others. Eventually, the population would become too connected and homogenized and reach a point of technological stasis – potentially a unified ELSA or the Robberg.

The transfer of flaking systems through this network would require intense movement of people, and likely genes (Tostevin, 2012). This makes hypothesis C1 difficult to separate from Hypothesis A. However, the timing of change could determine whether cultural transmission occurred between pre-existing populations or from a novel population. If migration is implicated, then technologies should appear first in a source area, and then spread later to other areas. If two-way connectivity between preexisting populations is responsible, then technologies should appear simultaneously at all sites as ideas and skills are transferred back and forth. The expectations of hypothesis C1 are:

- Shared flaking systems in the highlands and lowlands,
- Shared toolkits where environments are the same,
- Innovations appearing simultaneously across the subcontinent,
- No evidence for the restriction of population movement, and
- An eventually homogenous and unchanging lithic industry.

Hypothesis C2 implicates the breakdown of this network in the MSA/LSA transition. Stewart et al. (2016) suggested that during rapid-onset aridity events, including those leading up to the LGM, interior foragers would disperse into the Lesotho highlands via the Senqu River corridor. Evidence from Karoo paleolakes suggests that the period 30-22 kya was relatively arid in the interior (B.A. Stewart, personal communication). The highlands would not only provide a secure supply of fresh water, but also a more stable micro-refuge (Dobrowski, 2011; Stewart et al., 2016). Melikane foragers, as a function of topographic relief, had access to a variety of environments in a contained area. Changes in temperature would first merely affect the altitudinal gradient of vegetation, allowing groups to make smaller movements either into the foothills or further into the escarpment to exploit flora and fauna. In contrast, foragers would need to move further in the flat interior to access different resources (Dobrowski & Parks, 2016; Mucina & Rutherford, 2006).

If the interior grasslands were abandoned during the dry period of 30-22 kya, then the interregional network linking the Lesotho highlands with the rest of southern Africa would disintegrate, but population densities in the highlands would increase. Some MSA technologies might be lost, but tight packing into highland river valleys may also have spurred unique innovations. Higher population densities would also encourage lower residential mobility, resource intensification, and the development of a more complex toolkit to reduce risk, as detailed in hypothesis B (Read, 2008).

Even if populations from the southern African interior did not disperse into the highlands, extreme environmental instability could have prevented the maintenance of large-scale social networks. In rugged mountains like the Maloti-Drakensberg, movement is more energetically expensive than in areas of less relief, and can expose an individual to unpredictable weather events within a relatively small area in a short period of time (Dobrowski & Parks, 2016). This effect could be magnified at the beginning of the LGM, as the mountains cooled and snowfall increased. In this case, it is likely that the foragers were confined to river valleys, where resources were the most concentrated (Stewart & Mitchell, 2019).

Regardless of the reasons for the highlanders' isolation, any technologies they developed would not have spread immediately or with great fidelity to the rest of the subcontinent. Flaking systems would be even less likely to transfer than toolkits, but even toolkits would be unlikely to transfer if environments differed. If the highland populations became isolated, we would expect to see:

- The disappearance of MSA traits,
- No new shared elements with the flaking systems or toolkits of the lowlands,
- Evidence for high occupation density,
- The potential for new forms (possibly the Robberg) in the highlands before their appearance elsewhere.

It is unclear whether the Lesotho highlands were ever completely abandoned during the LGM. Although Carter (1976) believed that the highlands would have been depopulated, ephemeral occupation horizons at Sehonghong dating to 22.3-20.8 and 19.3-18.5 kcal BP suggest that the highlands were at least occasionally revisited during this period (Pargeter et al., 2017). Stewart and Mitchell (2019) have suggested that the Sehonghong foragers spent winters during cold phases across the escarpment in the Eastern Cape or in the KwaZulu-Natal midlands. The Karoo paleolakes also experienced a period of increased humidity 22-18 kya, potentially encouraging dispersal back into the interior from the mountains (B.A. Stewart, personal communication). If the Melikane foragers did eventually disperse to these areas, either seasonally or semi-permanently, any flaking systems developed *in situ* would follow.

Chapter 4: Materials and Methods

To evaluate my hypotheses, I conducted a detailed attribute and morphometric analysis of the lithic assemblages from contexts 5-8 (layers 4 and 5) of Melikane Rockshelter. This chapter introduces Melikane and describes my methods for all levels of this analysis, from identifying raw materials, to recording measurements and attributes, to analyzing data.

Melikane Rockshelter

Setting

Melikane Rockshelter is located on the Melikane River, a tributary of the Senqu, in the Qacha's Nek district of eastern Lesotho (Figure 7). It faces northeast at an altitude of ~1860 meters (Carter, 1978). This places it near the boundary of the Senqu Montane Shrublands and the overlying Lesotho Highland Basalt Grasslands (Mucina & Rutherford, 2006). The shelter itself lies within the Clarens Sandstone Formation, which directly underlies the Jurassic basalts of the Drakensburg group. Its location at this interface results in a plethora of available raw materials, from river-rolled CCS cobbles to high quality sandstones and large chunks of volcanic rock from dykes and sills (Carter, 1978; Stewart et al., 2012, 2016). Today, the valley is canyon-like, deep, and lush with vegetation in the summer (Stewart et al.,

Figure 7 Interior of Melikane Rockshelter. Pictured are K. Pazan and B.A. Stewart.

Figure 8 View of Melikane Rockshelter from the north (Stewart et al., 2012)

2016). The shelter itself is notably large – it measures 44 meters long and 21 meters deep, with an average roof height of 7.7 meters (Carter, 1978).

During his 1974 excavations, (Carter, 1978) noted that the shelter remained a popular stop for overnight travelers, and was located approximately a 3 days' walk down the river valley from Sehonghong. Today, the site receives less precipitation than the uKhahlamba-Drakensberg Escarpment to the east. It is likely that the average annual rainfall at Sehonghong, 578mm, is similar to that at Melikane (Stewart et al., 2012). The local environment is typical for the Senqu Montane Shrublands – mean annual temperatures around 13° C, with warm, wet summers and dry, cold winters. The site can receive snow at any time of year, but particularly between May and September. Frost occurs ~150 days per year (S. Grab, 1997). Daily temperatures can fluctuate wildly, and temperature inversions in the valley are not uncommon (Mitchell, 1992).

Excavation History and Sedimentary Sequence

Melikane was first excavated by Pat Carter in 1974. Carter ultimately removed 36m^3 of sediment, dividing major layers by perceived depositional differences, but otherwise excavating in 10 cm spits that crosscut the stratigraphy. He identified 7 layers, originally dating layer 1 to ~1500 BP and layer 5 to ~43.2 kcal BP, with the site's oldest levels falling beyond the radiocarbon boundary. Carter never published the results of his lithic analysis at Melikane. His trench was reopened in 2007 for new radiocarbon and OSL dating, significantly revising the site's chronology (Jacobs, Roberts, et al., 2008; Jacobs & Roberts, 2008). In 2008, the Adaptations to Marginal Environments in the Middle Stone Age project (AMEMSA) led by B.A. Stewart and G. Dewar opened a new 2 x 3 meter trench, 1 meter to the east of Carter's trench. The purpose of this was to use Carter's section drawings as a guide and to align new layers with old. Ultimately Stewart and Dewar identified 30 layers, which loosely correlate with individual contexts due to considerable postdepositional transformations conflating finer stratigraphy. Excavations concluded in 2009 upon reaching bedrock. The team used a single-context recording system, using 5 cm spits within contexts if necessary. Artifacts were sieved using 1.5mm mesh for the upper contexts and 3mm mesh for the lower contexts, where the sediment was moist (Stewart et al., 2012). Four "facies," or layers of sediment with similar deposition processes, were identified during the AMEMSA excavations (Figure 9, Table 3). Micromorphology samples were taken from facies A, C, and D. Facies A, which comprises portions of layers 3, 4, 6

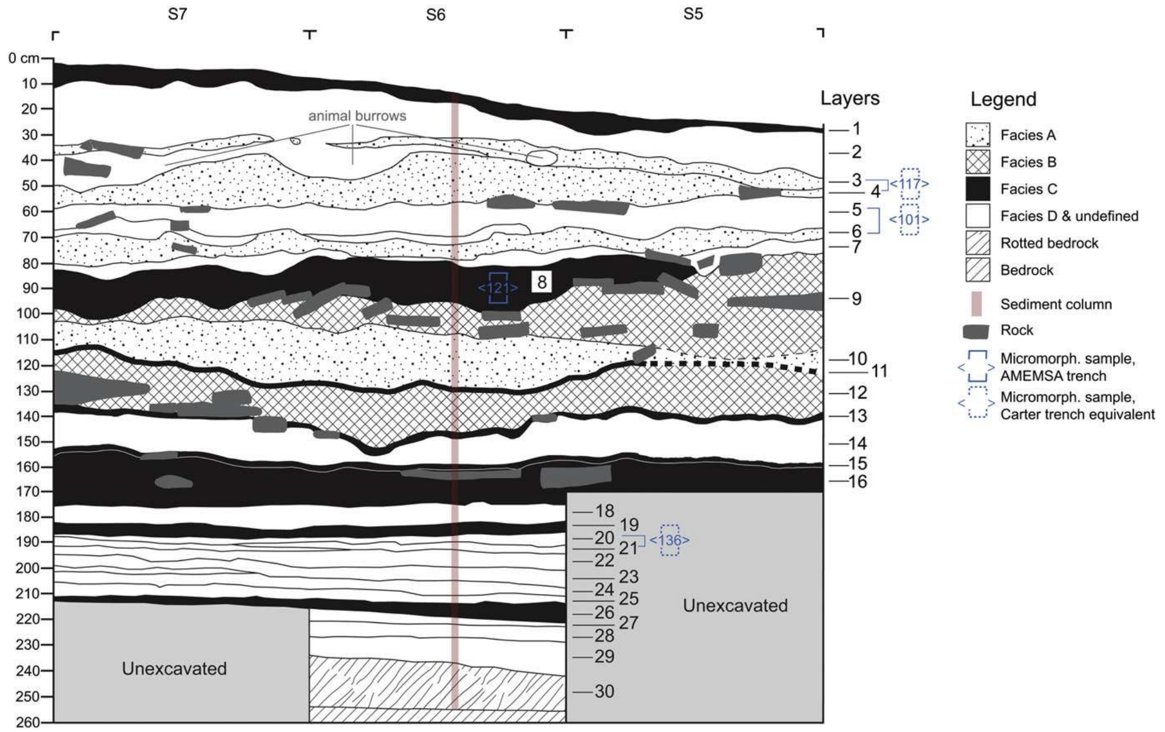


Figure 9 West section of Melikane Rock shelter after the 2009 AMEMSA excavations. Of interest to this dissertation are Layers 4 and 5, equivalent to contexts 5-8 (Stewart et al., 2012).

and 10, is primarily sandstone gravel, likely formed as water leaking through a fissure in the rear of the shelter corroded the shelter walls and existing deposits. Fine sediment within facies A may represent Aeolian deposition from a dry, cold landscape (Stewart et al., 2012). Facies A is consistent with Clarke et al.'s (2003) observations at Voordrag in KwaZulu-Natal, where extensive colluvial deposition occurred during the LGM. Facies C^1 is mottled and banded with charcoal and organic matter, likely from burning. The banding is likely the result of hydrologic taphonomic processes, derived from leakage through the shelter fissure. Facies C^2 is also the result of extreme burning processes, but is ashier and less organic than facies C^1. Stewart et al. (2012) suggest that this thick, burnt deposit may represent either an increase in shelter use or the reorganization of activities within the shelter in layer 8. Facies D^1 (layer 5) is essentially a combination of facies A and C, formed by the process of facies A's colluvial gravel wearing at facies C's occupation horizons, likely because of intense precipitation. Facies D^2 is a combination of facies B and C, formed by roof-fall aligning with a period of increased occupation intensity (Stewart et al., 2012).

Table 3 Description of facies identified at Melikane Rockshelter (data from Stewart et al., 2012).

Facies	Appearance	Interpretation	Layers
A	Sandstone gravel, fine/medium coarse sand, fine yellowish silt.	Gravel formed from breakdown of sandstone via water leaking through the fissure, fine sediments from Aeolian deposition in a cold, arid environment.	4, 10
B	Sandstone slabs and gravel clasts.	Roof-fall.	9, 12
C^1	Organic, dark sandy silt, mottled, banded with charcoal and organic material	Banding from water leaking through fissure, mottling from burning episodes.	15-16, 19
C^2	Thick, burnt, charcoal-rich and ashy silt.	Increase in shelter use, heavy burning.	8
D^1	Combination of A and C. Anthropogenic material and gravel.	Heavy precipitation causing gravel from facies A to wear down occupation horizons in facies C.	5, 7
D^2	Combination of B and C. Sandstone slabs.	Roof-fall and increased occupation intensity mixing facies B and C.	7, 8

This dissertation is primarily interested in layers 4 and 5, which belong to facies A and D^1 respectively. Layer 4, which contains context 5, is described in excavation notes as containing 10YR 5/4 to 5/8 yellowish-brown sediment, silt, and cobbles. The top of the layer (context 5, spit 1) includes pebbles with silty sand. The pebbles in layer 4 were often concreted and difficult to remove, and organic remains and bone were extremely rare. Sediment micromorphology results indicate a high percentage of sand particles and little carbon (Stewart et al., 2012). Decomposed bedrock and sandstone slabs also characterize this layer. Combined with its membership in facies

A, which indicates dry conditions with occasionally violent precipitation events, all evidence points to a date for layer 4 within the Last Glacial Maximum.

Underlying layer 4, layer 5 is composed of darker sediment, described as 10YR 3/4 dark yellowish brown mixed with 7.5YR 4/6 strong brown. Layer 5 contains pebbles and silty sand or sandy silt. Other than lithics, small pieces of bone were recovered in layer 5 as well as a bone needle. Layer 5 is comprised of three contexts – 6, 7, and 8 – which were combined during excavation into "contexts 6-8" upon the discovery that they were identical. Intense colluvial inwash after the deposition of layer 5 may also have disturbed the stratigraphy, churning and mixing the three contexts. Layer 5 is more carbon-rich, siltier, and less sandy than layer 4.

Radiocarbon and OSL Dating

Organic preservation at Melikane is poor, as also noted by Carter (1978). Bone is only preserved in the upper layers, and charcoal often contains too little carbon to be dated. Because of this, only 14 of 45 charcoal samples from Stewart and Dewar's layers 6-20 survived pre-treatment and yielded radiocarbon dates. Samples were not obtained from below layer 20 because the underlying deposits were believed to be >50 ka. All new radiocarbon dates were processed at the Oxford Radiocarbon Accelerator Unit. Samples that were expected to date >25 ka were processed using rigorous ABOx-SC pretreatment, when possible (layers 6-14). The younger samples were processed using the standard ABA pretreatment. Carter's (1978) dates were also recalibrated for comparison. Nine single-grain OSL dates were obtained from Carter's trench, spanning the entire Melikane sequence. After Bayesian modelling and consideration of the OSL dates, occupations at Melikane appear to cluster around pulses at ~80, 60, 50, 46-41, 27-23, 9, and 3 ka (Table 4).

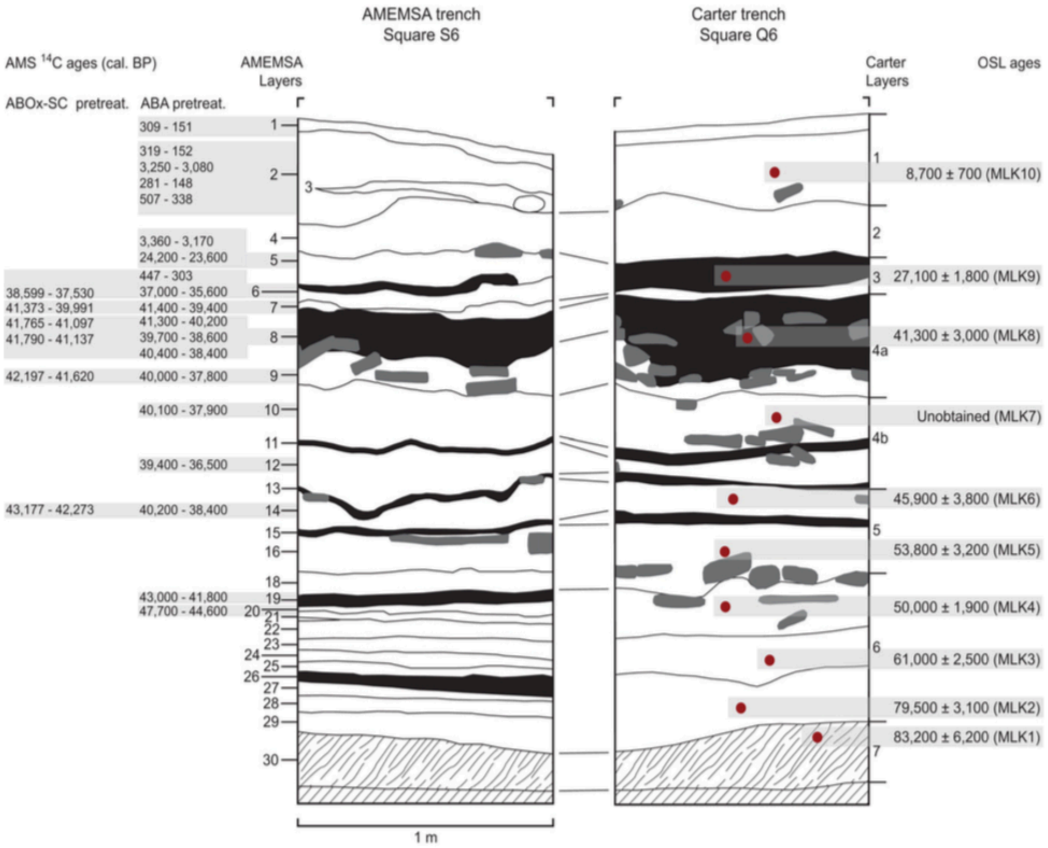


Figure 10 Correlation of AMEMSA's and Carter's stratigraphic layers. AMEMSA radiocarbon dates listed on the left; OSL dates listed on the right.

Table 4 New dates for Melikane Rockshelter. ABOx-SC dates are marked with an asterisk (Dates from Stewart et al., 2012).*

Occupation pulse (ka)	**Marine isotope stage**	**AMEMSA Layers**	**^{14}C dates (cal BP)**	**OSL dates (ka)**	**Industry**
80	5a	27-30	-	79.5 ± 3.1 83.2 ± 6.2	Local variant of MSA II (Pazan et al., 2022)
60	Late 4	23-26	-	61 ± 2.5	Howieson's Poort
50	3	15-22	-	50 ± 1.9 53.8 ± 3.2	Sibidua or MSA III
46-41	3	6-14	43.2-42.3 ka* 42.2-41.6 ka* 41.8-41.1 ka* 41.4-40 ka* 38.6-37.5 ka*	45.9 ± 3.8 41.3 ± 3	Late MSA or MSA 4
27-23	Late 3/early 2	5	24.2-23.6 ka	27.1 ± 1.8	Transitional MSA/LSA?
9	1	2	-	8.7 ± 0.7	LSA
3	1	2	3.34-3.17 ka	-	LSA

Occupation History

MIS 5a

The lithics from layers 30-27 were recently published in Pazan et al. (2020). The assemblage is the oldest radiometrically dated lithic assemblage in Lesotho. Stewart et al. (2016) argue that relative aridity in the interior and coastal regions may have been the impetus pushing foragers into the mountains during MIS 5a. Phytoliths and sediment organic matter (SOM) from layer 29 depict a landscape dominated by C_3 grasses in a humid, cool, and relatively predictable environment.

The Melikane MIS 5a assemblage consists of 2930 artifacts ≥10 cm in maximum dimension. The assemblage is characterized by multidirectional and bipolar core reduction strategies, an emphasis on blade production, and very few convergent flakes. Sandstone was the most commonly used raw material, comprising 51% of all artifacts, followed by CCS (35.9%), quartzite (10.1%), and minute quantities of volcanics, quartz, and other sedimentary varieties such as mudstone. There is a high degree of retouch and use, with a focus on boring and scraping forms and very few notches, denticulates, and points. Both the reduction sequence and typological characteristics of Melikane's MIS 5a assemblage are consistent with Mackay et al.'s (2014) suggestion that the period was a phase of population fragmentation and local environmental adaptation. The assemblage does not appear to fit into any existing typology (ie. Klasies River or Mossel Bay) and points towards a strongly regionally adapted system with limited connectivity to other territories. The toolmakers' focus was a time-minimizing strategy with the goal of creating a multipurpose, maintainable toolkit facilitating frequent residential moves (Pazan et al., 2022).

MIS 4

Melikane's chronology is murky during MIS 4. An OSL date of 61 ± 2.5 ka taken from Carter's trench broadly maps on to AMEMSA layers 25-23 (Stewart et al., 2012). These layers are associated with the Howiesons Poort. Layer 26 is undated, but phytoliths and carbon isotope ratios indicate warm, humid conditions similar to those of layer 24 and unlike those from the MIS 5a layers, 27-30 (Stewart et al., 2016). Because southern Africa was cold and dry between ~70-62 kya, it is likely that layer 26 belongs either to an isolated warm pulse, or to the Howiesons Poort along with layers 25-23.

I previously analyzed all lithics > 10 mm from context 28 within layer 26 (n=872). The assemblage signifies a departure from the informal core reduction sequences of MIS 5a. CCS becomes the dominant raw material, comprising 62.8% of the assemblage. Parallel cores make up the bulk of the cores (58.8%, n=20) as multidirectional cores become rare (8.8%, n=3). Only one core with evidence of bipolar percussion is present. Although borers remain the most common retouched tool type (n=15), unretouched and utilized points are nearly as common (n=12). Backed segments, the type-fossil of the Howiesons Poort, are absent. Only one naturally backed artifact is present.

I have also analyzed a subset of context 27 (layer 25, n=469), which clearly represents the fluorescence of the Howiesons Poort. CCS becomes even more common, making up 82.7% of the assemblage. Context 27 has a much higher rate of retouch than context 28 (24.9% versus 5.0%). A variety of scrapers, borers, MRPs, and backed segments comprise the tool assemblage. Core reduction strategies revert to those from MIS 5a, with multidirectional cores (46.4%, n=13) dominating smaller contributions from bipolar, parallel, platform, and inclined varieties. The percentage of prepared platforms drops slightly, from 30.7% in context 28 to 25.7% in context 27. Contexts 28 clearly differs from context 27 in significant ways and does not belong to the fluorescent Howiesons Poort. However, its heavy emphases on CCS, prepared core technology, and point production draw a stark contrast with the MIS 5a assemblages. It is possible that it belongs to a pulse in early MIS 4 prior to the onset of cold conditions ~71 ka, but I believe that the similarities between the paleoenvironmental records of layers 26 and 24 support a late MIS 4 age just prior to the fluorescence of the Howiesons Poort, 65-60 kya.

MIS 2

Following two occupation pules during MIS 3, Melikane was reoccupied just preceding the LGM. Contexts 6-8 (AMEMSA layer 5, Carter layer 3) comprise a single archaeological unit and are divided into three spits (Figure 11). Contexts 6-8, spit 1 (contexts 6-8:1) were directly dated by Stewart et al. (2012) to 24.2-23.6 kcal BP. A sediment sample (MLK 9) from Carter's trench corresponding the interface of spits 2 and 3 in contexts 6-8 produced a single-grain OSL date of 27.1 ± 1.8 ka. Another, less probabilistically likely date of 15.7 ± 1.1 ka was obtained from a different grain in the same sample. Aberrant dates of 22.7 ± 2.9 ka and 22.8 ± 2.5 ka were also obtained from OSL samples MLK 10 and MLK 8, in layers 2 and 8 respectively.

Context 5 (AMEMSA layer 4, Carter layer 2) directly overlies contexts 6-8 and is comprised of five spits. It did not contain sufficient organic material for a radiocarbon date. In 2018, B.A. Stewart, P. Roberts, S. Challis and I requested and were denied a permit from the Lesotho government to take an additional OSL date from this layer. However, Carter's original excavations produced three additional radiocarbon dates of 24.2-23.6, 24.3-23.8, and 23.8-23.3 kcal BP (Carter, 1978). Stewart et al. (2012) list these under layer 3 (AMEMSA layer 5), but Vogel et al. (1986, p. 1144) assign them to layers 2/3 (the interface of AMEMSA layers 4/5), associated with a "microlithic (?) early LSA assemblage." Multiple additional indicators also support an LGM age for context 5. As previously discussed, it belongs to facies A, whose sediments likely formed during a period of scant vegetation and aridity. Some parts of context 5 are separated from contexts 6-8 by flat sandstone slabs (Carter, 1978; Stewart et al., 2012). These slabs may be contemporary with sandstone roof spall in Sehonghong member OS (~24 kcal BP), interpreted as frost-shattering from colder temperatures just before the LGM (P. J. Mitchell, 1994a; Pargeter et al., 2017).

Paleoenvironmental indicators from contexts 5-8 suggest that Melikane during MIS 2 was surrounded by a cold, C_3 grassland with few trees (Table 5). Stewart et al. (2016) tested phytoliths and carbon isotope ratios ($\delta^{13}C$ values) from sediment organic matter (SOM) from each occupation pulse at Melikane. The SOM samples were taken at depth intervals of 10 cm and were roughly correlated (from deepest to shallowest) with spits 3 and 1 from contexts 6-8 and spits 3 and 1 from context 5. The $\delta^{13}C$ values from the SOM in contexts 6-8 are -23.1 ‰ and -22.5 ‰ in the lower and upper samples respectively. The lower context 5 sample has a value of

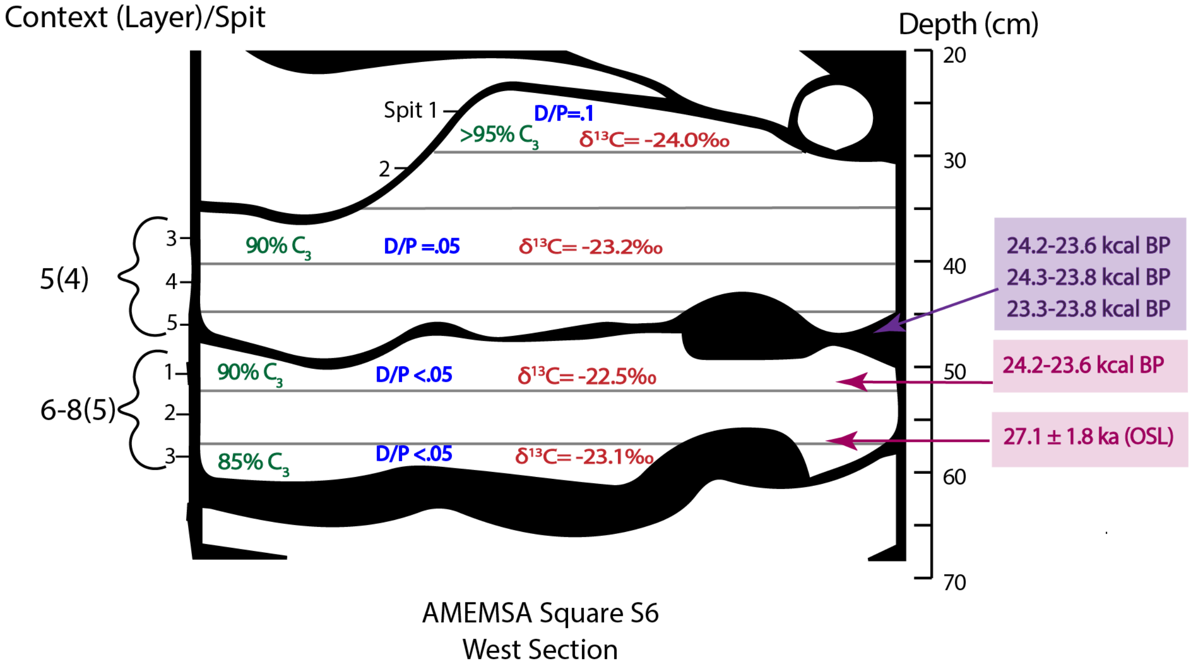


Figure 11 Diagram of layers 4 and 5 showing locations of Carter's original ^{14}C dates (purple), AMEMSA's ^{14}C and OSL dates (pink), Bousman Index values (% C_3, green), tree cover density ratio values (D/P, blue), and $\delta^{13}C$ carbon isotope ratios (red). Spits within contexts are designated by tick marks on the left.

-23.2 ‰, comparable to the values from contexts 6-8, and the upper context 5 sample is the most negative in the entire Melikane sequence at -24.0 ‰. Bousman (1991) developed an index specifically for use in the uKhahlamba-Drakensberg Escarpment to predict the proportion of C_3 grasses on the landscape based on the results of bulk SOM $\delta^{13}C$ values. His index indicates a C_3 plant component of ~85% for the bottom of contexts 6-8, rising to ~90% in the top of contexts 6-8 and the bottom of context 5. Stewart et al. (2016) argue that the presence of any C_4 vegetation in these contexts is a likely consequence of lower CO_2 levels during the LGM, favoring plants using the C_4 photosynthetic pathway. The top sample in context 5 produced the highest Bousman Index values of the sequence, representing an environment with >95% C_3 grasses. The C_4 grasses that remained were drought-tolerant chloridoids (Stewart et al., 2016; Twiss, 1992). The tree cover density ratio (D/P ratio), defined as the proportion of woody to grassy phytolith morphotypes, hits its lowest point in the Melikane sequence in contexts 6-8 and rises slightly in context 5 (Stewart et al., 2016). This suggests a barren landscape on the eve of the LGM, with tree cover increasing incrementally alongside the expansion of C_3 grasses over time.

Charcoal samples were also obtained from contexts 6-8. *Erica drakensbergensis, Leucosidea sericea*, and *Olea europea* were common species represented in the assemblage from early MIS 2 (Stewart et al., 2016). Today, *E. drakensbergensis* is found in moist areas, but is also able to withstand dry conditions. *Leucosidea sericea* thrives in disturbed moist grasslands. It cannot, however, survive extreme cold (Mucina & Rutherford, 2006). *Olea europaea* (the wild olive) is a highly successful and hardy plant that can survive some frost but tends to thrive in warmer areas today where MATs are over 15ºC. Its presence around Melikane, therefore, is likely dependent on the frequency and depth of cold snaps (Mucina & Rutherford, 2006). However, olives can still germinate in cold environments provided that there is a sufficient difference between winter and spring temperatures and frost risk is relatively low (Orlandi et al., 2005). If Melikane was colder during early MIS 2, olives may still have survived so long as frosts were not unpredictable. However, charcoal assemblages are inherently biased towards preferred sources of fuel and thus may not accurately reflect the vegetation, or exact proportions thereof, immediately surrounding the site.

Table 5 Phytolith and SOM data for MIS 2 at Melikane Rockshelter. Bousman Index = proportion of C_3 grasses based on $\delta^{13}C$ values (Bousman, 1991), climatic index = proportion of C_3 pooids in short grass phytolith sample, D/P ratio = proportion of woody taxa to grasses in phytolith sample (data from Stewart et al., 2016).

Context	**Spit**	**Depth**	**Date**	**$\delta^{13}C$**	**Bousman Index (%C_3)**	**Tree cover density (D/P)**	**Climatic index (Ic%)**	**Charcoal**
5	1	30 cm	N/A	-24.0	>95%	.1	50%	N/A
5	3	40 cm	N/A	-23.2	90%	~.05	70%	N/A
6-8	1	50 cm	24.2-23.6 kcal BP	-22.5	90%	<.05	70%	*E. drakensbergensis, Leucosidea sericea,Olea europea*
6-8	3	60 cm	27.1 ± 8 ka	-23.1	85%	<.05	50%	

Overall, the phytolith and SOM samples from contexts 5-8 at Melikane indicate that the site was surrounded by a cool, open C_3 grassland which became even colder after 24 kcal BP. Carter (1976) hypothesized that during particularly harsh periods such as the LGM, the highlands may have been abandoned altogether. However, the landscape was clearly still productive enough to support populations at the onset of glacial conditions. Future attempts to date layer 4 will hopefully clarify the timing of Melikane's abandonment during the LGM, but paleoenvironmental indicators from the layer are consistent with the coldest conditions ever experienced by humans in the Lesotho highlands. It is unclear whether the site was occupied in pulses during milder periods of the LGM or whether context 5 represents a last attempt to occupy the highlands before the onset of glaciation and long-term abandonment. Stratigraphic mixing in Melikane's upper layers makes pinning down the site's date of reoccupation in the Holocene difficult. Stewart et al. (2012) dated AMEMSA layer 2 to 3.25-3.08 kcal BP. However, a sediment sample also taken from this layer produced a single-grain OSL date of 8.7 ± 0.7 ka, showing that the chronology is imprecise.

Methods

Because of the poor organic preservation at Melikane, my analysis is restricted to the site's lithic assemblages. The little bone at the site is fragmentary, and the only non-lithic artifact found in either layer 4 or 5 is a single bone needle from contexts 6-8. This section describes my methods for identifying raw materials, classifying and measuring lithics, and analyzing data.

Raw Material Identification and Classification

Melikane Rockshelter is part of the Clarens Formation, or "Cave Sandstones" (Stewart et al., 2012; Visser, 1984). The thermal transformations that occurred during the deposition of the overlying volcanic Drakensberg Formation produced a wide variety of high-quality raw materials in the immediate vicinity of the site (Visser, 1984). The Melikane foragers used a wide variety of cryptocrystalline silicates (CCS), but also hornfels, sandstone, quartzite, quartz, and very rarely quartz crystal. No exotic raw materials were identified in Melikane's assemblage.

The Clarens Formation itself is comprised almost entirely of fine-grained sandstones, with smaller contributions from siltstone, mudstone, and quarzitic sandstone (S. W. Grab et al., 2011; Visser, 1984). The relative hardness of the Clarens sandstones makes them suitable for stone tool production. The mean Schmidt hammer R-value on the sandstones of the uKhahlamba-Drakensberg Escarpment is 48.91, much harder than the values for similar rock formations in Utah and Wadi Rum, Jordan. The Elliot Sandstones under the Clarens Formation are even harder, with an R value of 58.12 (S. W. Grab et al., 2011). The interface between the Elliot and Clarens Sandstones is blended and transitional, comprised of mudstones and medium-grained sandstones, generally coarser-grained than the sandstones of the upper Clarens Formation (Visser, 1984). A study of the raw materials in the Melikane 80k assemblage revealed that many of the materials designated as "quartzite" were partially silicified sandstones (Pazan et al., 2022). Because of the difficult distinguishing the two rock types, I combine them under the term "sandstone/quartzite."

The igneous Drakensberg Formation overlies the Clarens Formation. Its surface rocks (including basalt) are fine-grained, having cooled quickly upon magma deposition (Fritzen, 1959). Its intrusive rocks, which are coarser-grained, include the dolerite (diabase) dykes and sills in the Clarens Formation around Melikane (Carter, 1978; Fritzen, 1959). The dyke material is hard and suitable for tool production, with an R-value of 55.92. Intrusions are particularly common near rockshelters, and likely influenced the macroscale forms of the surrounding sandstones, creating a variety of caverns, arches, and "honeycombs" (S. W. Grab et al., 2011). Dolerite is usually gray, dark gray, or green.

Near Melikane, contact metamorphism of shale between the dolerite dykes and surrounding sandstones created hornfels. "Contact metamorphism" is the process by which magma enters an existing rock formation (such as the Clarens) and alters the rock around it. The rocks in the contact zone are often harder than their parent rocks (Fritzen, 1959). Carter et al. (1988) recognized two extremes of hornfels – the aforementioned dolerite dyke material, and lydianite. Dyke material is not completely metamorphosed and is usually greyish black and slightly granular. Lydianite is cryptocrystalline, greyish-black, and "flint-like" (Carter et al., 1988). It is high-quality, fractures predictably, and is ubiquitous on the landscape. It can be obtained in large chunks, enabling the production of larger artifacts (Humphreys, 1972), and has been called "the best available raw material anywhere in Southern Africa during the Stone Age" (Sampson & Sampson, 1967, p. 12). Because of the gradation of dyke material into lydianite, I do not separate the varieties, and place both in the parent category "hornfels."

Most of the cryptocrystalline silicates (CCS) used by the Melikane foragers derive from amygdales (intrusive layers) at the base of the Drakensberg Formation. These amygdales include a wide variety of agates, chalcedony, quartz, calcite, zeolite, olivine basalts, andesite, and trachyte. Some of these materials differ chemically, but are difficult to distinguish with the naked eye (Pazan et al., 2022; Visser, 1984). Nodules of these fine-grained materials are found in small pebble form along the banks of rivers in the Lesotho highlands (Humphreys, 1972). These pebbles are usually <4 inches in diameter, preventing the creation of large flakes and setting an upper limit on the size of CCS artifacts in the highlands (Sampson & Sampson, 1967). Sampson and Sampson (1967) remark that some of these pebbles, especially agates, have an outer crust of quartz crystals. I have personally observed this phenomenon in the Melikane agates and chalcedonies and believe that some of the smaller quartz artifacts are isolated chunks of this material. These rocks also tend to fracture less predictably than other varieties of CCS. In this dissertation, I differentiated varieties of CCS by opacity, color and banding. "Chalcedony" is defined as translucent cryptocrystalline material of one color. "Agate" is translucent, multicolored CCS, often with a waxy finish. "Jasper" is opaque, banded CCS. A variety of opaque, solid-colored CCS varieties exist. Olive, brown, grey, and greyish-blue are all common, but pink, purple, blue, light blue, white, beige, black and white, yellow, and maroon CCS are all represented in the assemblage. Quartz is distinguished from chalcedonies by its fracture mechanics and waxier texture. Quartz crystal is rare.

Attributes and Measurements

All lithics >10 mm in maximum dimension from contexts 5-8 were sorted by typology and raw material. Lithics <10 mm with retouch, use, or flake attributes were also sorted. A subsample of artifacts was chosen from squares S5 and S6 for attribute analysis (see Appendix A for full list of attributes). Square S6 was chosen because it is the only square excavated at the base of the Melikane sequence. Square S5 nearly reaches the base of the site, and its position immediately next to S6 ensures maximal continuity of the contexts and spits. Artifacts were measured using digital calipers and a digital scale. An engineering protractor was used to determine platform and edge angles. Cores were identified using the core classification scheme described in Conard et al. (2004) (Table 6). Conard's scheme avoids local and arbitrary categories like "Levallois" and "prismatic bladelet" and instead describes cores by their reduction sequences. Considering my interest in reconstructing flaking systems as well as the conflicting and confusing typologies sometimes used in southern African archaeology, Conard's scheme is best for comparing artifacts over time and space. Retouched artifacts were classified based on the typology outlined in P. Carter (1978) with modifications to allow for comparison to more recently excavated sites (Table 7). Types are consistent with those used in Pazan et al. (2020). Photographs of artifacts are located in Appendix C.

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Table 6 Core types and subtypes recorded at Melikane.

Core type	Subtypes	Characteristics
Parallel	Unidirectional, bidirectional, centripetal	2 hierarchical surfaces. Main flaking surface is angled at <30º from the plane of the surfaces' intersection. Ie. preferential Levallois core.
Inclined		2 hierarchical surfaces. Flaking surfaces are angled ~45º from the plane of the surfaces' intersection. Ie. discoid core.
Platform	Single, opposed	1 or 2 (opposed) striking platforms. All removals originate from these platforms. The angle between the platform and removal is ~90º. Removals are parallel. Ie. prismatic blade core.
Multidirectional		Multiple striking platforms. Usually nebulous in shape. Removals can originate from anywhere.
Bipolar		Result of hammer-on-anvil percussion. Usually crushing on both ends, sometimes intersecting, opposed flake scars.
Core-reduced piece		Interpreted as a maximally reduced bipolar core. Usually <30mm in greatest dimension. Many intersecting flake scars. The number of scars is often undiscernible and thus not recorded.
Initial		A core with a maximum of 5 disorganized removals not falling under another core type. Minimally prepared.
Core-on-flake	Levallois-on-flake. (Parallel core-on-flake).	A flake repurposed as a core. Removals are significant and clearly not meant to modify the flake itself for further use.
Flaked piece		A chunk with <3 removals.
Core fragment		Blocky shatter interpreted as a broken piece of core.

Table 7 Tool typology used at Melikane.

Typology	Description
Borer	Artifact with a thin, pointed tip that has NOT been created solely through burination. Evidence of twisting-type use is usually present.
Backed	An artifact with at least one steeply retouched "backed" margin. Retouch is usually bimarginal, and the edge angle is usually ~90º. The opposing margin is usually unretouched and sometimes utilized, typically with an edge angle <60º.
Burin	An artifact with a pointed tip created by one or two removals originating from the flake's distal margin, or by "burination."
Denticulate	An artifact with 3+ continuous notches.
Miscellaneous retouched piece (MRP)	An artifact that either does not fall into one of the listed categories, or is too fragmented to categorize.
Naturally backed	A backed artifact, except with either a ground or unmodified steep margin.
Notched	An artifact with 1 or 2 retouched notches.
Point	A convergent flake intended for use as a projectile or spear tip. Can be either unretouched, utilized, or unimarginal. Bimarginally retouched points are not found at Melikane. Edge angles are shallow.
Convergent scraper	A convergent flake with retouched lateral margins converging to a retouched tip. Edge angles are steeper than those of a unifacial point, usually >45º.
Nosed scraper	An artifact with a small scraping tip. This tip is only unifacially retouched and does not show signs of twisting.

Endscraper	An artifact with continuous retouch on either/both ends.
Sidescraper	An artifact with continuous retouch on either or both lateral margins.
Side/endscraper	An artifact with at least one retouched end and one retouched lateral margin. Often all 4 margins will be retouched.

Statistics and Data Visualization

RStudio (version 4.0.5; R Core Team, 2021) was used for both statistical analyses and data visualization (for frequently used functions and citations, see Table 8). For all tests, a p-value of <0.05 was considered significant. Initial data exploration confirmed that most metric data collected was nonparametric, making commonly used parametric tests like t-tests inappropriate. More robust equivalent rank-sum tests were chosen instead. Frequently used tests in this dissertation include Mann Whitney U-Tests (nonparametric t-test equivalent for comparing the means of 2 groups), Kruskal-Wallis Tests (nonparametric ANOVA equivalent for 3 or more groups), and posthoc Dunn Tests using the Bonferroni correction (for pairwise comparisons when Kruskal-Wallis p-values were significant). Lastly, Fligner-Killeen Tests for Homogeneity of Variances were used to compare group medians. All of these tests are preferred for nonparametric data and are robust alternatives to parametric tests when data is not normally distributed.

For contingency tables, I used G-tests, Fisher's exact tests, and z-tests for the equality of proportions (based on the Pearson's chi-squared statistic). Fisher's exact tests were preferred when the total sample size was under 1000. G-tests were chosen for sample sizes of 1000 or greater. Posthoc tests for the significance of residuals were conducted as necessary using the Bonferroni correction for multiple comparisons, and Cramer's V was used to quantify significant associations. For ordered contingency tables, chi-squared tests for trends, linear-by-linear association tests, and Kendall's Tau-B were preferably used. Correlations between continuous variables or between one continuous and one ordinal variable were assessed using Spearman's Rank Correlation Coefficient. Unlike Pearson's Correlation Coefficient, Spearman's is safely used with nonparametric data and does not assume a linear relationship. Kendall's Tau-B was used in place of Spearman when sample sizes were small or ranks were "tied." I always specify which test I am using in the text or tables. Additional statistical transformations and tests are explained and cited throughout.

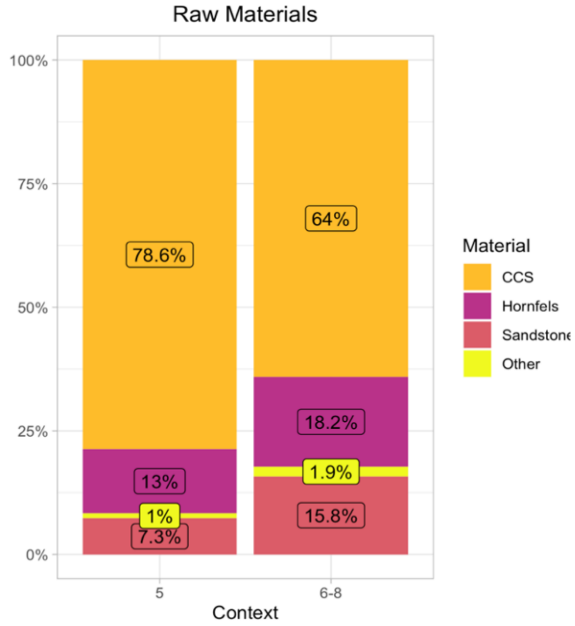
Table 8 Frequently used R packages and functions.

Test	**R Package**	**Function**	**Citation**
Mann-Whitney U-Test (Wilcox test)	stats	wilcox.test	(R Core Team, 2021)
Kruskal-Wallis Test	stats	kruskal.test	(R Core Team, 2021)
Dunn Test	Dunn.test	dunn.test	(Dinno, 2017)
Fligner-Killeen Test	stats	fligner.test	(R Core Team, 2021)
G-Test	RVAideMemoire	G.test	(Hervé, 2021)
Fisher's Exact Test	stats	fisher.test	(R Core Team, 2021)
Posthoc Chi-squared test	chisq.posthoc.test	chisq.posthoc.test	(Ebbert, 2019)
Z-test	stats	prop.test	(R Core Team, 2021)
Cramer's V	RVAideMemoire	cramer.test	(Hervé, 2021)
Linear-by-linear association test	coin	lbl_test	(Hothorn et al., 2008)
Spearman's correlation coefficient	stats	cor.test(method="spearman")	(R Core Team, 2021)
Kendall's Tau-B	stats	cor.test(method="kendall")	(R Core Team, 2021)
Stargazer regression and summary statistics tables	stargazer	stargazer	(Hlavac, 2018)
Ggplot graphics	ggplot2	various functions	(Wickham, 2016)
Partitioning around medoids (PAM)	cluster	pam	(Maechler et al., 2021)
Kmeans	stats	kmeans	(R Core Team, 2021)
Chi-squared test for trend	stats	prop.trend.test	(R Core Team, 2021)
Pearson's chi-squared test	stats	chisq.test	(R Core Team, 2021)
Cochran–Mantel–Haenszel test	stats	mantelhaen.test	(R Core Team, 2021)
Likelihood Ratio test	lmtest	lrtest	(Zeileis & Hothorn, 2002)
Cluster selection	clValid	clValid	(Brock et al., 2008)
Cluster selection	NbClust	NbClust	(Charrad et al., 2014)

Chapter 5: Reconstructing the Melikane Flaking System

Assemblage Description

Figure 12 Raw materials by context.



In total, 17,555 lithic artifacts >1cm in were analyzed from contexts 5 and 6-8 at Melikane (for counts, see Appendix B). Of these, a subsample of 5,916 artifacts from squares S5 and S6 were selected for measurement and attribute analysis. Contexts 6-8 have significantly greater proportions of tools and shatter, whereas the proportions of unretouched flakes and cores rise in context 5 (Table 9). Artifact density is nearly twice as dense in contexts 6-8, indicating greater occupation intensity (Table 10).

CCS (cryptocrystalline silicates) were the most represented raw material in Melikane's assemblage, totaling 78.6% of context 5 and 64% of contexts 6-8 (Figure 12, Table 11). Hornfels is the second most common material (13% and 18.2%), followed by sandstone (7.3% and 15.8%), and minute quantities of quartz, mudstone, and unknown materials (1% and 1.9%). Significant differences in the overall proportions of raw materials exist between contexts ($p<.001$). The proportion of CCS rises in context 5, whereas the proportions of hornfels, sandstone, and quartz fall. Other than opaque, un-banded varieties, the most common type of CCS in both contexts was jasper, totaling 8.2% of all CCS in context 5 and 6.4% in contexts 6-8. Chalcedony comprised 5.8% of all CCS in both assemblages, whereas agate was less prevalent at

~3% (Figure 13). The prevalence of these varieties differs significantly between contexts ($p<0.002$). A posthoc test of residuals suggests that this significant result is accounted for by the increase in jasper use in context 5.

Table 9 Artifact counts by class and context.

Context	**5**		**6-8**		**Total**
	N	*%*	*N*	*%*	
Flakes	4246	*50.8*	3681	*40.0*	**7927**
Cores	983	*11.8*	925	*10.1*	**1908**
Tools	2430	*29.1*	3436	*37.4*	**5866**
Flaked pieces	96	*1.1*	120	*1.3*	**216**
Shatter	598	*7.2*	1006	*10.9*	**1604**
Heat spall	4	*0.05*	30	*0.3*	
G-test: $p<0.001$. Posthoc test for residuals: all <0.05 except flaked pieces.					

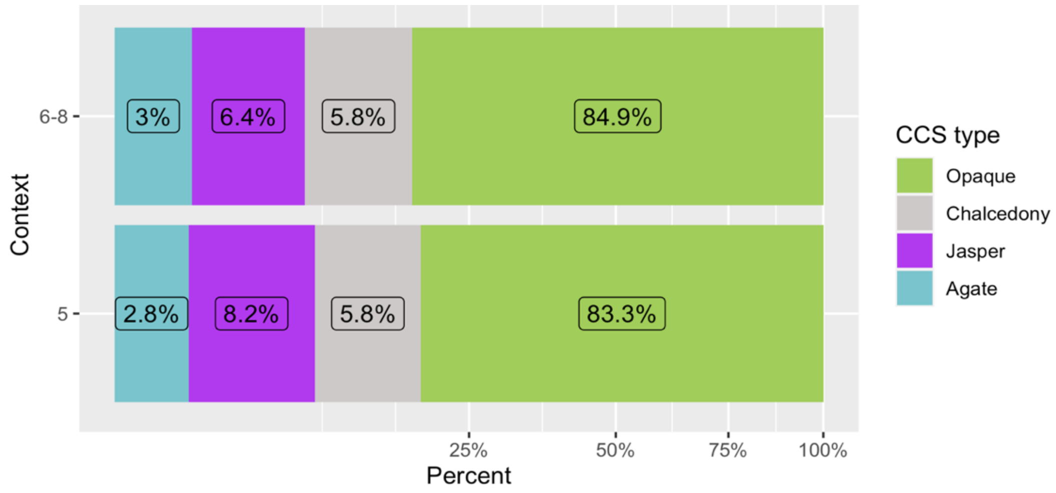
Table 10 Occupation density (artifacts per bucket and artifacts/m^3).

Layer	**Contexts**	**Total artifacts**	**Total buckets**	**Volume (M^3)**	**Artifacts/bucket**	**Artifacts/m^3**
4	5	8357	80.1	0.801	104.33	10,433.2
5	6-8	9198	48.7	0.487	188.9	18,887.1

Table 11 Raw materials by context.

	5		**6-8**		**Total**	
	N	*%*	*N*	*%*	*N*	*%*
CCS	6572	78.6	5891	64	12463	71.0
Hornfels	1086	13	1674	18.2	2760	15.7
S/Q	611	7.3	1454	15.8	2065	11.8
Quartz	61	0.7	134	1.5	195	1.1
Other	27	0.3	45	0.5	72	0.4
Total	**8357**		**9198**		**17,555**	
G-test: $p<0.001$. Posthoc test for residuals: all <0.05 except "other."						

Figure 13 CCS type by context.

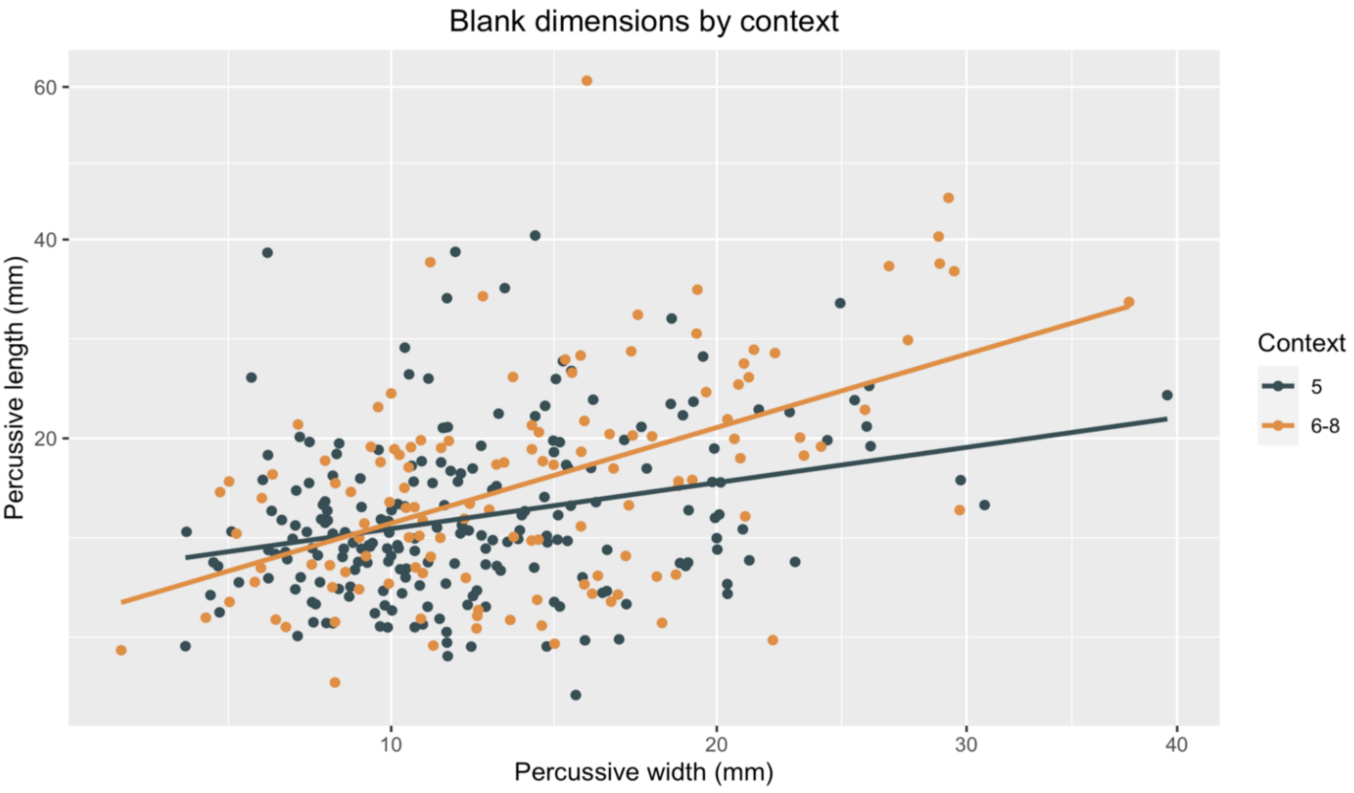


Blanks

Dimensions

Blanks in the Melikane assemblage are small and irregular. Most are endstruck (length/width ratio >1), but 37.3% of blanks in context 5 and 34.3% of blanks in contexts 6-8 are sidestruck. Average blanks in both contexts 5 and 6-8 qualify as "microliths," with mean absolute lengths of 16.66mm and 19.42mm respectively (Table 12). The Melikane blanks are substantially smaller than potentially contemporary CCS blanks from neighboring Sehonghong, which average 23.34, 20.35, and 22.03 mm in length in levels OS, MOS, and RFS (Mitchell, 1995). They are closer in mean length to the "bladelet industry" blanks at Sehonghong (the later Robberg), which average 19.8mm in maximum length and 17.0mm in width (Carter et al. (1988). All recorded lengths, widths, and thicknesses are significantly smaller in context 5 than in 6-8, but these differences are only significant when all raw materials are combined. When broken down by raw material,

Figure 14 Blank dimensions by context.



the only significant differences are for the percussive and absolute length of CCS blanks. This suggests that for all dimensions except length, increased microlithization in context 5 is not driven by any single raw material. Instead, overall decreases in blank size are due to subtler changes throughout the assemblage.

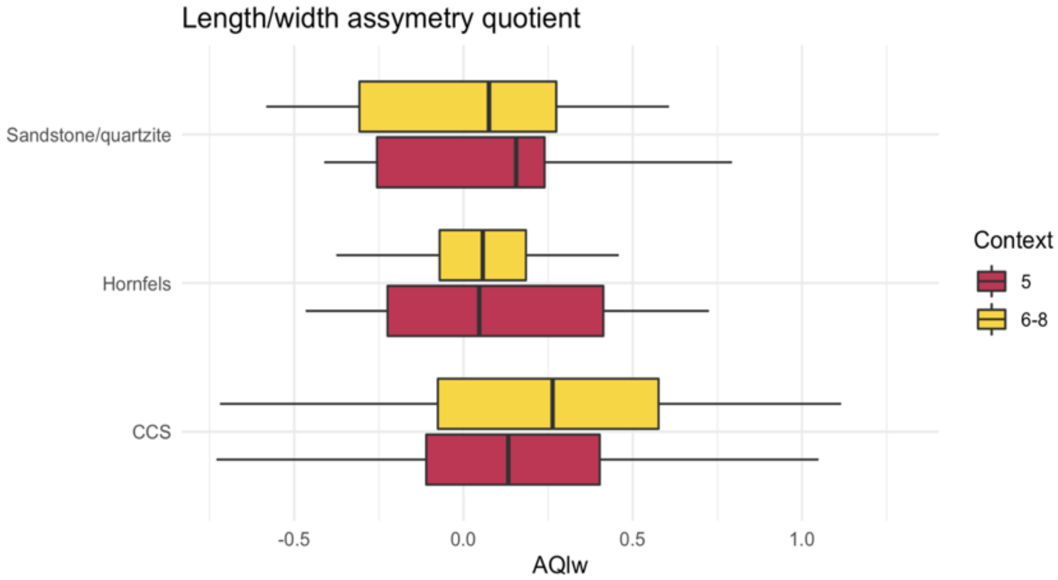
Table 12 Blank dimensions (mm) by context and raw material. (M=Mean, Me=median, SD=standard deviation, N=count, SQ=sandstone/quartzite, H=hornfels, P=p-value. Significant p-values in red.)

Blank dimensions (mm)	**Context 5**					**Contexts 6-8**					**Kruskal Wallis p-values for differences in means, 5 vs. 6-8**			
	CCS	*H*	*SQ*	*P*	*Context (all)*	*CCS*	*H*	*SQ*	*P*	*Context (all)*	*CCS*	*H*	*SQ*	*All*
Absolute length	M: 16.71 Me: 14.91 SD: 6.87 N: 546	17.16 18.24 5.44 108	16.20 15.69 5.96 102	0.8	16.66 14.95 6.59	19.88 19.25 9.85	19.33 17.25 8.69	19.62 17.03 8.67	1	19.42 17.71 9.22	**.02**	.5	.24	**.013**
Percussive length	M: 14.69 Me: 12.94 SD: 6.52	14.65 13.43 6.04	14.04 12.23 5.69	0.9	14.57 16.16 9.12	18.24 18.05 9.83	16.46 14.03 8.28	17.92 16.52 8.30	0.7	17.51 16.16 9.12	**.005**	.6	.119	**.005**
Absolute width at midpoint	M: 12.02 Me: 11.15 SD: 4.55	13.39 12.27 4.83	13.43 11.79 5.98	0.3	12.39 11.34 4.91	13.70 12.04 6.46	15.18 14.06 5.26	15.63 14.79 6.03	0.13	14.22 12.93 6.09	0.12	.4	.142	**.006**
Percussive width at midpoint	M: 12.26 Me: 11.08 SD: 4.97	13.94 14.00 4.76	13.53 11.42 5.52	0.2	12.64 11.42 5.14	13.69 12.13 6.93	16.31 15.52 6.20	15.69 15.27 5.63	0.06	14.42 13.3 6.13	0.12	.2	.177	**.006**
Absolute maximum width	M: 14.02 Me: 12.45 SD: 5.63	15.80 14.33 6.09	15.04 13.79 6.275	0.4	14.37 12.69 5.83	15.21 13.6 6.91	17.69 18.04 6.46	18.27 17.47 7.02	**0.04** *(pairwise >0.05)*	16.11 14.38 6.83	0.2	.4	.072	**.013**
Maximum thickness	M: 5.99 Me: 5.7 SD: 2.75	7.35 6.85 3.21	6.46 6.4 2.48	0.2	6.21 5.84 2.80	6.64 6.15 3.58	8.02 7.33 3.35	7.51 6.79 3.49	0.15	7.04 6.48 3.50	0.3	.4	.344	**.035**
Bulb thickness	4.59	5.66	5.31	**<.001** **CCS/H:.02**	4.89	4.68	6.04	5.63	**<.001** **C/H: .003**	5.15				0.2
Length/width ratio	1.30	1.18	1.18	0.60	1.26	1.42	1.13	1.12	**0.05** (pairwise >0.05)	1.30	0.2	0.7	0.6	0.7

Compared to the earlier Middle Stone Age contexts at Melikane, contexts 5 and 6-8 are less "bladey," with length/width ratios of 1.26 and 1.3 respectively. Maximum length and width were recorded for 212 blanks in context 5 and 129 in contexts 6-8. Only 17 blanks from context 5 (8%) and 16 blanks (12.4%) from contexts 6-8 have length/width ratios greater than two, in contrast to 31% of whole flakes from the MIS 5a assemblage (Pazan et al., 2020). High blade frequencies have also been observed in Melikane's Howiesons Poort contexts. This departure from "bladiness" is a substantial shift in flake morphology away from the long-standing MSA traditions at the site. This is not simply a result of changing raw material frequencies. Although sandstone/quartzite and hornfels cores tend to be larger and were frequently used for blade production in MIS 5a, the sandstone/quartzite flakes that are present in contexts 5 and 6-8 actually have smaller length/width ratios than CCS flakes.

Asymmetry quotients were used to better understand blank dimensions in contexts 5 and 6-8. The asymmetry quotient, or AQ, of two dimensions is defined as $(x-y)/((x+y)/2)$. When two dimensions are equal, the AQ will equal 0. When the first dimension is the larger of the two, AQ will be positive. When the second is larger, AQ will be negative. In terms of lithic dimensions, AQ holds a distinct advantage over ratios as it scales the data, allowing a more accurate depiction of variance that is less affected by outliers (cf. Pargeter & Redondo, 2016).

Figure 15 Length/width asymmetry quotients for blanks.



An asymmetry quotient comparing absolute length to maximum width (AQlw) was used to better understand "bladiness." Although length/width ratios were also calculated for blank dimensions, no significant pairwise differences existed between raw materials or contexts. Like length/width ratio, the interpretation of AQlw is relatively straightforward – a higher AQlw implies a "bladier" blank. There were no significant differences in AQlw between contexts (Table 14). The only significant differences were found within contexts 6-8, between CCS and the other materials (Dunn Test, $p<0.05$). CCS blanks from contexts 6-8 have a higher mean AQlw, and are thus bladier, than contemporary hornfels or sandstone/quartzite blanks (Table 13). This discrepancy in AQlw values disappears in context 5, in which none of the raw materials differ significantly from each other. This is explained by the significant decrease in mean blank length without a proportional decrease in blank width for CCS (Table 12). A decrease in the interquartile range (IQR) for CCS blanks in context 5 also indicates greater standardization in length/width morphology, whereas an increase in IQR for hornfels blanks suggests the reverse.

Table 13 Asymmetry quotients.

	AQlw	AQwt
CCS, 5	0.163	0.806
CCS, 6-8	0.239	0.790
Hornfels, 5	0.098	0.721
Hornfels, 6-8	0.065	0.740
S/Q, 5	0.093	0.772
S/Q, 6-8	0.049	0.846
All 5	0.144	0.793
All 6-8	0.164	0.789

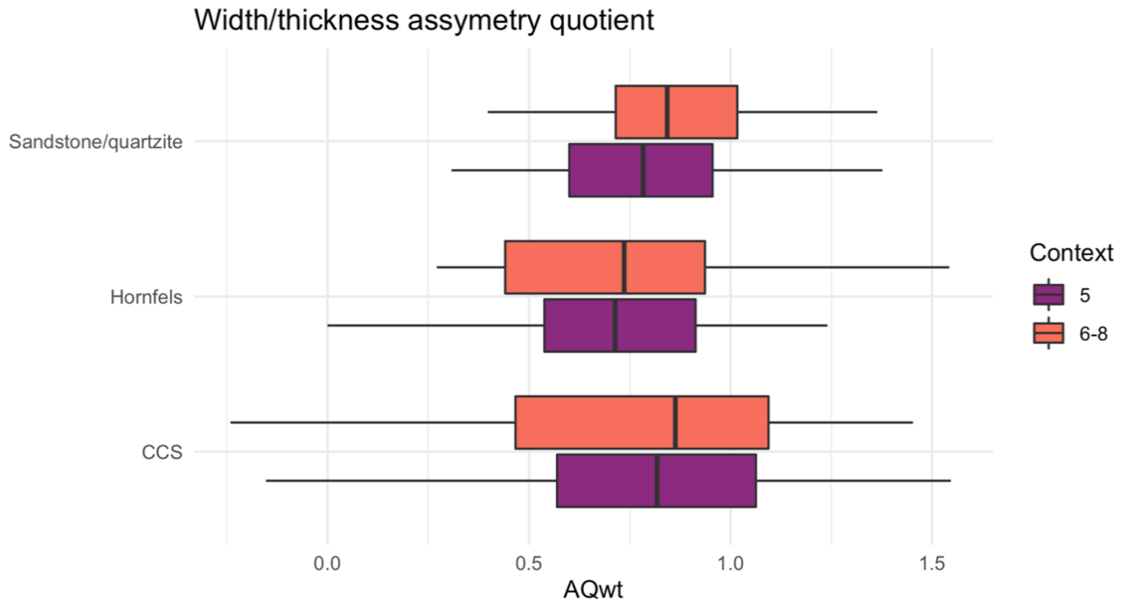
The width/thickness asymmetry quotient (AQwt) quantifies the relationship between the maximum width and maximum thickness of a blank. AQwt, like the width/thickness ratio, is a proxy for the degree to which knappers were focusing on tall ridges (prismatic blade reduction) or flatter surfaces (Tostevin, 2012). A high AQwt implies a wide, thin flake, whereas a low AQwt represents a narrower, thicker flake more likely produced through prismatic reduction. The AQwt values do not vary significantly between contexts, both overall and when broken down by raw material. Thus, there is no evidence to suggest that knappers changed their flaking systems either in favor of or against prismatic reduction. However, inferences can be made based on the distribution of values (Figure 16). Sandstone/quartzite blanks have the smallest interquartile range (IQR), suggesting greater standardization in width/thickness ratio and in flaking strategies than other materials. This likely reflects the non-use of bipolar percussion on these coarse-grained materials. Bipolar percussion tends to produce irregular and unstandardized blanks. The IQRs for both CCS and hornfels shrink in context 5, indicating increased standardization over time, and possibly a decrease in the intensity of bipolar percussion.

Table 14 P-values for asymmetry quotients (Mann-Whitney U Tests).

	AQlw	**AQwt**
CCS	>0.05	>0.05
Hornfels	>0.05	>0.05
S/Q	>0.05	>0.05
All 5 vs all 6-8	>0.05	>0.05
CCS/H, 5	>0.05	>0.05
CCS/SQ, 5	>0.05	>0.05
H/SQ, 5	>0.05	>0.05
CCS/H 6-8	**<0.05**	>0.05
CCS/SQ, 6-8	**<0.05**	>0.05
HSQ, 6-8	>0.05	>0.05

Overall, the asymmetry quotients for length/width and width/thickness show minimal changes in blank morphology between contexts 5 and 6-8. CCS blanks in contexts 6-8 were “bladier” than the other contemporary blanks, but a slight drop in mean CCS blank length in context 5, possibly due to increased reduction intensity or bipolar percussion, makes the context 5 blanks indistinguishable from one another. Based on the AQwt values, there is no evidence for a major change in flaking systems in context 5. Higher IQRs for CCS indicate that a variety of cross-sectional morphologies and reduction techniques were used in blank production, but smaller IQRs for sandstone and quartzite indicate that strategies for knapping coarse-grained materials may have been less diverse.

Figure 16 Width/thickness asymmetry quotients for blanks.



Platform Attributes

Blanks from contexts 5 and 6-8 typically have unprepared platforms (plain, punctiform, or thin) and exterior platform angles (EPAs) ~90º (Table 15). Small shifts are visible from context 6-8 to context 5. Platform thickness, width, and associated standard deviations for platforms >3mm in greatest dimension are slightly greater in contexts 6-8, although not significantly so. However, platforms <3mm are significantly more common in context 5 (p=0.002). Prepared platforms (dihedral and faceted) become slightly less common in context 5, while punctiform platforms increase slightly as a proportion of all unprepared platforms. These changes in platform morphology may reflect a shift in reduction strategies to one aligned with deliberate bladelet and microflake production (see examples of Robberg bladelets in Cochrane, 2008; Porraz, Igreja, et al., 2016).

Table 15 Proximal attributes (based on Tostevin, 2012).

Attribute	**Context 5**	**Contexts 6-8**	**Significance**
Platform treatment	Unprepared: 72.9% Prepared: 13.7% Crushed/undiscernible: 10.4% Cortical: 3.1% N= 424	Unprepared: 69.5% Prepared: 16.4% Crushed/undiscernible: 10.3% Cortical: 3.9% N=311	P=0.7 (Fisher's exact)
Unprepared platform types	Plain: 79.3% Punctiform: 12.6% Thin: 8.1% N=309	Plain: 82.4% Punctiform: 8.3% Thin: 9.3% N=216	P=0.286 (Fisher's exact)

EPA	>120: 2.1% 91-120: 11.9% ~90: 51.8% 61-90: 29.8% ≤60: 4.5% N= 336	>120: 3.1% 91-120: 7.4% ~90: 46% 61-90: 40.7% ≤60: 2.7% N=258	P=0.122 (X^2 test for trend in proportions)
Platform thickness (>3mm only)	Mean: 4.42mm SD: 2.40mm N=338	Mean: 4.61mm SD: 2.48mm N=261	Mann Whitney: p=0.2. Fligner-Killeen: p=0.9
Platform width (>3mm only)	Mean: 9.82mm SD: 4.41mm N=338	Mean: 9.95mm SD: 4.79mm N=261	Mann Whitney: p=0.93 Fligner-Killeen: p=0.60
Platforms <3mm	13.9% of whole and proximal flakes N=381	5.9% of whole and proximal flakes N=322	**P=0.002** (z-test)
Bulb type	Diffuse: 51.5% Moderate: 17.7% Prominent: 11.3% Point:10.9% Sheared: 8.5% N= 423	Diffuse: 57.5% Moderate: 16.3% Prominent: 9.8% Point: 8.3% Sheared: 8.0% N=325	P=0.545 (Fisher's exact)

Dorsal Surface Attributes

Most blanks in contexts 5 and 6-8 have multidirectional or parallel flake scars. Convergent scars are less common, although slightly more prevalent in context 5. Most blanks have straight profiles, although this proportion drops slightly in context 5 as curved profiles become more prevalent. Blank cross-sections are nearly identical in both contexts, with just over half of all blanks having triangular cross-sections. The only significant difference in dorsal surface attributes between contexts 5 and 6-8 is a greater percentage of step terminations in contexts 6-8. A corresponding increase in hinge terminations is observed in context 5.

Table 16 Dorsal surface attributes (based on Tostevin, 2012).

Attribute	**Context 5**	**Contexts 6-8**	**Significance**
Directionality of flake scars *(excluding indeterminates)*	Parallel: 39% Convergent: 10.1%% Multidirectional: 50.1% N: 159	Parallel: 41.3% Convergent: 5.2% Multidirectional: 53.5% N: 235	Fisher's exact: p=0.3
Profile *(excluding indeterminates)*	Straight: 55% Curved: 37.3% Twisted: 7.7% N: 209	Straight: 62.2% Curved: 27.8% Twisted: 10.0% N: 209	Fisher's exact: p= 0.10
Cross-section	Triangular: 52.8% Trapezoidal: 16.0% Irregular: 21.7% Oval: 9.4% N: 212	Triangular: 54.7% Trapezoidal: 19.8% Irregular: 17.9% Oval: 7.5% N: 212	Fisher's exact: p=0.5
Termination (includes distal blanks)	Feather: 34.6% Hinge: 31.1% Natural: 31.9% Plunging: 0.7% Step: 1.8%	Feather: 33.4% Hinge: 26.4% Natural: 28.7% Plunging: 1.5% Step: 10.0%	Fisher's exact: p<.001. (Eliminated plunging due to low numbers.) **Only significant residuals are for step terminations.**

	N: 461	N: 341	

Utilized Flakes

In contexts 6-8, there were 604 whole utilized flakes and 458 whole blanks. Use becomes less common on whole flakes in context 5, with 803 whole utilized flakes and 811 whole blanks (G-test, $p<0.001$). Utilized hornfels flake dimensions change significantly between contexts, decreasing in length and width in context 5. CCS flakes do not change in length and width but do decrease significantly in thickness. In some instances, utilized flakes and blanks differ significantly in size, but not as expected. It would be expected that if they differed in length at all, utilized flakes should be shorter. However, utilized sandstone/quartzite flakes in context 5 and utilized hornfels flakes in contexts 6-8 are significantly longer than their blank counterparts ($p=0.032$, $p=0.022$). Utilized hornfels flakes in contexts 6-8 are also significantly “bladier” than hornfels blanks ($p=0.03$). This contrasts with utilized CCS flakes, which overall are less bladey than CCS blanks ($p=0.03$). Thus, it appears that for coarser-grained raw materials, longer and often bladier flakes were preferentially utilized. Shorter and smaller flakes were less likely to be used and were frequently discarded.

When all raw materials are combined, changes in the dimensions of utilized flakes are exaggerated and drop significantly in context 5. This mirrors the pattern seen in blanks (Table 17), where dimensions change slightly within raw material categories, but differences are more obvious when all materials are considered together. A decrease in overall length/width ratio in context 5 is borderline-significant ($p=0.059$), suggesting an overall decrease in bladiness of utilized flakes (Figure 17). This is consistent with the changes seen in the unmodified blank assemblage.

Figure 17 Density plot for length/width ratio of utilized flakes.

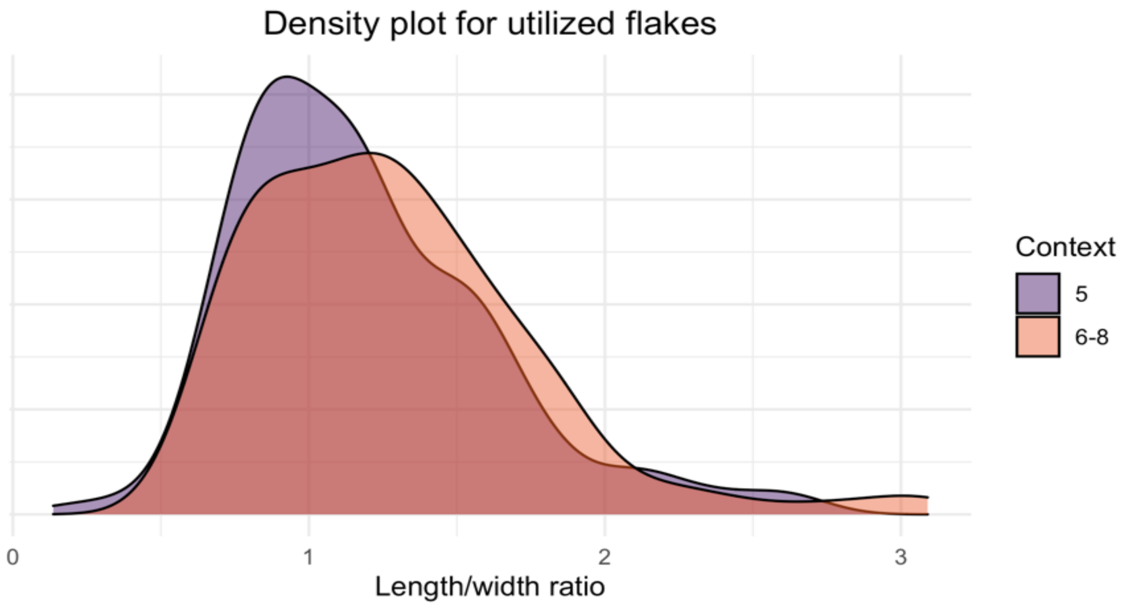


Table 17 Dimensions of utilized blanks. (Mean, standard deviation (SD), count (N), H=hornfels, SQ=sandstone/quartzite.)

Utilized flakes *Mean:* *SD:* *N:*	**Context 5**				**Contexts 6-8**				**All contexts**			
	CCS	*H*	*S/Q*	*All*	*CCS*	*H*	*S/Q*	*All*	*CCS*	*H*	*S/Q*	*5 vs. 6-8*
Length	M: 15.92 SD: 5.43 N: 488	18.18 8.48 89	21.06 7.83 54	16.62 6.26	17.21 6.49 225	25.91 11.32 80	24.31 16.15 106	20.28 10.85	16.24 5.73 P=0.21	20.8 10.14 **P=0.002**	22.92 13.23 P=0.46	**P<0.001**
Percussive length	14.47 SD:5.03	16.45 8.05	19.37 7.83	15.12 5.88	15.64 6.60	24.27 10.75	22.62 16.77	18.74 10.98	14.74 5.45 P=0.36	19.15 9.73 **P=0.002**	21.16 13.5 P=0.58	**P<.001**
Width at midpoint	12.47 SD: 4.55	14.28 4.65	18.09 5.54	13.14 5.49	12.90 4.46	18.90 7.83	16.63 7.11	14.72 6.21	12.58 4.53 P=0.34	15.87 6.28 **P=0.017**	17.26 8.91 p=0.98	**P=.01**
Maximum width	14.36 SD: 5.23	16.87 5.59	17.74 5.97	14.9 5.40	14.52 4.75	20.4 7.66	18.87 7.34	16.49 6.39	14.39 5.11 p=0.51	17.83 6.50 **P=0.039**	18.39 6.74 P=0.86	**P=0.015**
Percussive width	12.68 SD: 4.68	14.32 4.84	15.9 5.54	13.15 4.85	13.09 4.79	19.00 7.22	16.71 7.20	14.93 6.25	12.78 4.70 P=0.44	15.94 9.73 **P=0.003**	16.35 6.46 P=0.79	**P=0.007**
Maximum thickness	5.79 SD: 2.06	7.69 3.69	8.90 3.63	6.29 2.65	6.67 3.33	8.16 2.88	7.10 2.75	7.01 3.13	6.01 2.45 **P=0.03**	7.85 3.41 P=0.29	7.87 3.25 P=0.49	**P=0.007**
L/W ratio	1.19	1.14	1.27	1.19	1.25	1.29	1.35	1.28	1.20	1.19	1.32	**P=0.059**
Utilized vs. blank length	P=0.80	P=0.70	**P=0.03**	P=0.58	P=0.12	**P=0.02**	P=0.13	P=0.42	P=0.23	P=0.16	**P=0.004**	
Utilized vs. blank lwr	p=.10	p=.92	p=.19	P=0.41	p=.19	**p=.03**	p=.75	P=0.66	**p=.03**	p=.13	p=.30	P=0.57

Bipolar Flakes

Experimentation with bipolar percussion has produced a large body of contradictory data. Bipolar flake attributes are frequently different depending on the raw material used, the size of the cobble, the type of the hammerstone, and the individual knapper. Chalcedony and quartz flakes from Barham's (1987, p. 48) experiment frequently had "crushed butts and sheared bulbs." The flakes were frequently broad and irregularly shaped, and associated chips frequently lacked bulbs of percussion. Pargeter et al. (2019) confirmed Barham's association between crushed platforms and bipolar percussion, particularly for quartz flakes, and to a lesser degree with flint. de la Peña's (2015) experiment produced flint bipolar flakes with broken or linear ("thin") platforms, often without a distinguishable point of percussion ("undiscernible" platform) and sometimes accompanied by a hinge bulb. Ahler (1989, p. 210) defined bipolar flakes by a set of attributes including "shattered or pointed platforms with little or no surface area; evidence of force having been applied at opposite ends of the flake; an angular, polyhedral transverse cross section with steep lateral edge angles; the lack of a definite positive bulb of force; very pronounced ripple marks; and the lack of distinction between dorsal and ventral flaked faces," but acknowledged that flakes with these attributes are frequently produced as biproducts of freehand flaking strategies as well.

Other approaches have used metric data or overall assemblage composition to isolate bipolar flakes and cores. Pargeter and Eren (2017) found that their flint bipolar flakes had thinner cross-sections, lower platform width/thickness ratios, were lighter, and less "bladey" in comparison to their freehand flakes. Their bipolar assemblage was characterized by a lower frequency of distal fragments and a higher frequency of unidentifiable fragments, indeterminate flake scar orientations, a higher frequency of twisted profiles, higher frequencies of axial (natural), bipolar (step), crushed, and hinge terminations, crushed or sheared platforms and bulbs, and acute exterior platform angles. Some of these assemblage-level observations contradict previous studies; for example, Kuijt et al.'s (1995) experiment showing higher frequencies of distal and medial fragments in bipolar assemblages and lower frequencies of complete flakes. Diez-Martin et al. (2011), although experimenting on quartz, found that bipolar flakes were thinner in cross-section proximally, but thicker than freehand flakes towards the distal end, and had greater thickness/width ratios. Jeske and Lurie's (1993) experiment, in which the first author attempted to blindly separate bipolar and freehand assemblages based on attributes, emphasizes the importance of an assemblage-level approach. Although Jeske was able to correctly identify assemblages as either entirely bipolar or entirely freehand, when assemblages were mixed, he was unable to categorize individual flakes as the product of one method or the other. Jeske and Lurie associated the bipolar flakes in their sample with flat, diffuse, or invisible bulbs of percussion, and noted that bipolar debitage included higher frequencies fragments lacking flake attributes (unorientable fragments and shatter).

Because of the difficulty of positively identifying a "bipolar flake" onsight, a better approach at Melikane is to look for attribute patterning in the data. If certain "bipolar" attributes tend to cluster together, then trends in bipolar production could be isolated and studied. I was also interested in finding bladelets and microflakes. A study of Robberg bladelets from Rose Cottage Cave (Cochrane, 2008) found that compared to Howiesons Poort bladelets of the same length, Robberg bladelets had higher frequencies of platforms under 3mm in width, thin platforms, and missing platforms. The bladelets from the Elands Bay Cave Robberg level MOS1 also exhibit point-type bulbs (Porraz, Igreja, et al., 2016). I wanted to know if these attributes clustered together at Melikane and if their frequency as a "package" varied over time. I used a three-step approach to identify clusters of attributes, beginning with measuring the strength of association between attributes, followed by Multiple Correspondence Analysis, and lastly K-means clustering based on the results of the MCA.

Cramér's V Associations

Cramér's V, a value between 0 and 1, is a measure of the strength of association or effect size between variables in a contingency table. It is based on Pearson's chi-squared statistic and is equivalent to *Phi* (used only for 2x2 contingency tables). A value of 1 indicates a total association between variables, where one variable is completely determined by the other, whereas a value of 0 indicates no association whatsoever. Cramér's V was calculated for contingency tables for the attributes of platform type, bulb type, EPA, and termination (see Table 18 for an example). Results are summarized in Table 19. Fisher's exact tests produced insignificant p-values for contingency tables comparing platform type to either EPA or termination, so no Cramér's V values are provided in those cells.

Table 18 Contingency table for termination and EPA.

	c90	**Acute**	**Obtuse**
Feather	45	9	41
Hinge	21	7	25
Natural end	68	19	16

Table 19 Cramer's V results for blank attributes.

	Bulb type	**Platform type**	**EPA**
Platform type	**V=0.230, p<.001**	-	-
EPA	**V= 0.194, p<.001**	p>0.05	-
Termination	**V=0.107, P=0.02**	p>0.05	**V=.202, P<.001**

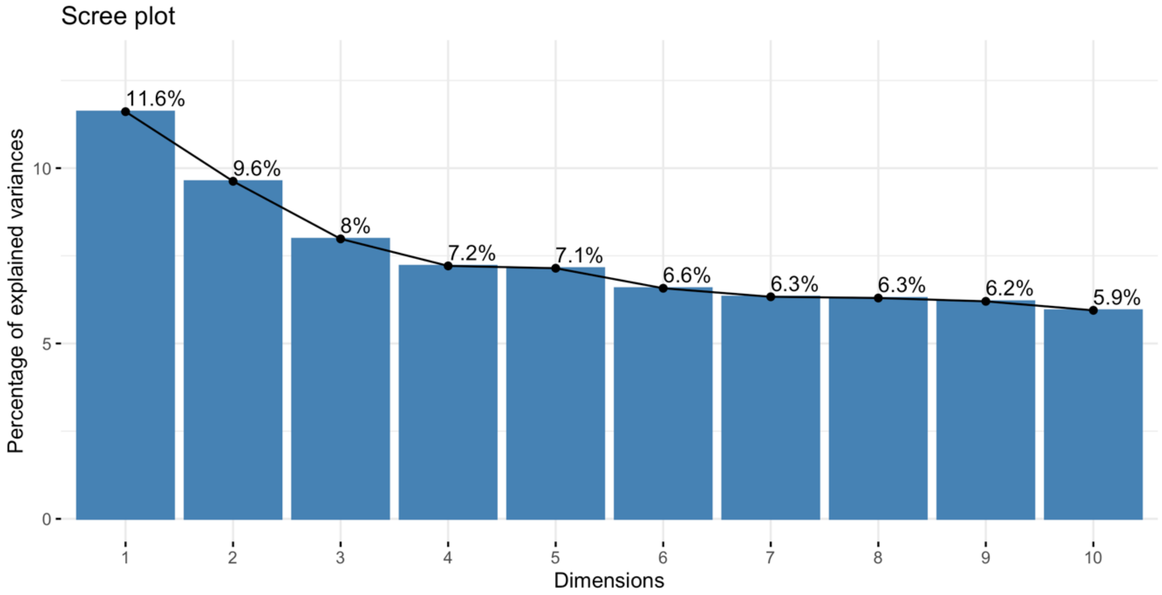
Bulb/platform type is the most closely associated variable pair, with a significant weak-to-moderate association. The relationship between bulb and platform type is complex, but a posthoc test of residuals suggests associations between plain platforms and diffuse bulbs, punctiform platforms and point-type or moderate/prominent bulbs, and between crushed/undiscernible platforms and sheared bulbs. Associations between the other variable pairs are weaker, but natural terminations may be more associated with EPAs ~90º, and less so with obtuse angles, which are disproportionately distributed among feather and hinge terminations. Significant residuals also suggest associations between diffuse bulbs and EPAs ~90º, and moderate/prominent bulbs and more obtuse EPAs.

Multiple Correspondence Analysis for Blank Attributes

Having established that the nominal blank attributes above were interrelated, even if effect sizes showed only weak to moderate association, multiple correspondence analysis (MCA) was conducted using all four attributes (bulb type, platform type, termination, and EPA) as input variables. MCA is a means of uncovering structure in data comprised of multiple nominal variables, working like principal component analysis but with categorical data (Hair et al., 2009). The goals of conducting MCA on blank attributes were to better understand the relationships between variables and to use the individual coordinates obtained from the MCA dimensions in cluster analysis, identifying groups of blanks sharing similar characteristics (ie. Costa et al., 2013; Hwang et al., 2006).

Because all attributes were not recorded for all blanks, the imputeMCA() function from the R package *missMDA* was used prior to analysis in order to probabilistically assign values to incomplete cases (Josse & Husson, 2016). The MCA() function from *FactoMineR* was then used on the imputed dataset (1472 cases, 4 variables with a total of 20 categories) (Lê et al., 2008).

Figure 18 Screeplot for first 10 dimensions of MCA on blank attributes.



The total number of MCA dimensions possible for this dataset is 16, equivalent to the sum of all variable categories (20) minus the number of variables (4). The number of possible dimensions divided by the number of variables (16/4) equals the total inertia (4). The results of MCA are traditionally depicted on a biplot, where the x-axis represents one dimension and the y-axis represents a second dimension. The first two dimensions of the blank attributes MCA account for 21.2% of the total inertia in the data, or 21.2% of the cumulative variance. The dimdesc() function (package FactoMineR; Lê et al., 2008), was used to determine how associated each variable category was with the first 2 dimensions (Table 20). Platform angle, bulb type, and platform type were correlated more

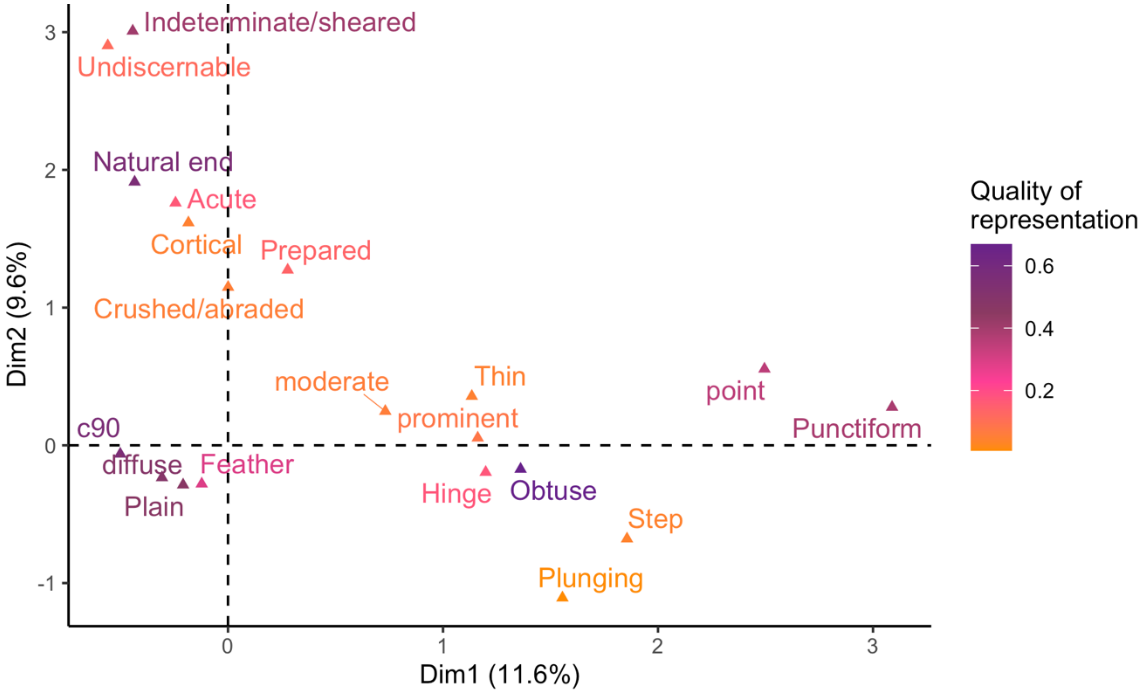
Table 20 Correlation between variables and MCA dimensions.

	(R^2)	
	Dimension 1	**Dimension 2**
Platform angle	0.661	0.166
Bulb type	0.518	0.444
Platform type	0.453	0.397
Termination	0.225	0.533

with the first dimension than the second, whereas termination was correlated more with the second than the first.

Table 20 shows the blank attributes plotted in two-dimensional space. MCA calculates an "object score" from each dimension for each individual and variable. These object scores are used as coordinates when depicting the results of MCA. Variables that are plotted closely together are more closely associated than those that are plotted further apart. The results of the Cramér's V analyses and posthoc tests of the chi-squared residuals are reflected in the MCA plot. Point bulbs and punctiform platforms are plotted closely together, as are plain platforms, diffuse bulbs, and EPAs ~90º, and indeterminate/sheared bulbs with undiscernible platforms. Attributes are colored according to how well they are accounted for by the first two dimensions combined, or their quality of representation (cos2). Variables with higher cos2 values are dark purple and better explained by the first two dimensions than the lighter-colored variables.

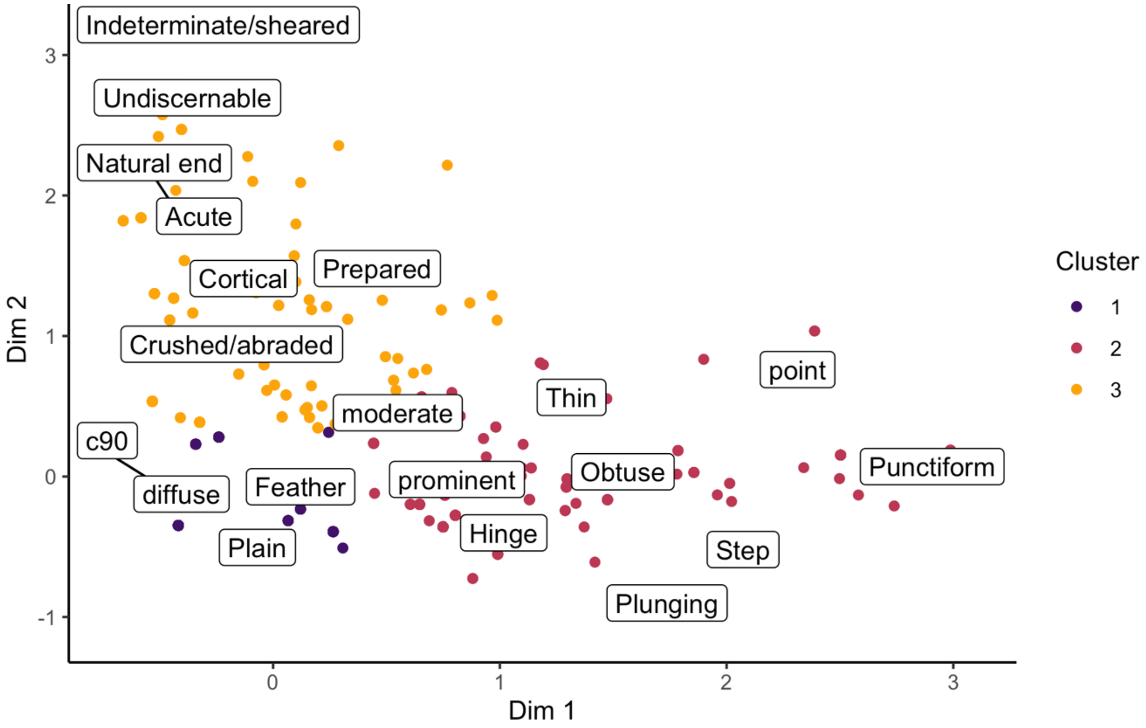
Figure 19 Quality of representation for blank attributes in MCA results.



The Three-Cluster Solution

Like each variable, each individual case in an MCA is assigned an "object score" for each dimension and can also be plotted. The function tuneclus() in the *clustrd* package (Markos et al., 2019) identifies the most parsimonious numbers of clusters and dimensions for solutions based on the results of MCA or PCA analyses. Two solutions of nearly equal parsimony were identified using the highest average silhouette width criteria: a three-cluster and a five-cluster solution, with average silhouette widths of 0.475 and 0.476 respectively, both using KMeans clustering. The three-cluster solution produced clusters of sizes 857, 322, and 293. Each case in the original MCA dataset was assigned to its cluster and then plotted on the first two dimensions.

Figure 20 Kmeans clusters based on results of MCA.



Points closer in space to particular variables should have a greater chance of exhibiting those characteristics and should be more alike than points from a different cluster. Contingency tables comparing cluster number to attribute characteristics confirmed that this was true. Table 21 lists the characteristic attributes of each cluster.

Table 21 Attributes for the three-cluster solution.

	Platform type	**EPA**	**Bulb type**	**Termination**	**Within-cluster sum of squares**
1	Plain	~90º	Diffuse	Feather	0.0154
2	Plain, punctiform, thin	Obtuse	Moderate, point	Hinge, step, plunging	0.0214
3	Plain, prepared, crushed/abraded/undiscernible, cortical	~90º, acute	Diffuse, sheared	Natural	0.0387

The original results of the MCA must also be considered when interpreting cluster composition. Not all variables were well-represented by the first two dimensions. Cortical and crushed/abraded platforms, thin, moderate, and prominent bulbs, and step and plunging terminations were not as well-represented as indeterminate/sheared and diffuse bulbs, natural and feather terminations, and point, punctiform and plain platforms. These variables should be given more weight, whereas the presence/absence of the others should be interpreted carefully.

The blanks in cluster one exhibit feather terminations and plain platforms, which are not associated with bipolar technology in any of the previously discussed studies (Jeske & Lurie, 1993; Pargeter & Eren, 2017). Sheared bulbs (L. S. Barham, 1987; Pargeter & Eren, 2017), associated with bipolar knapping, are not found in cluster one. The other attributes associated with Melikane's cluster one flakes are characteristic of typical blanks from Melikane's MIS 5a assemblage (Pazan et al., 2022), and likely produced through the same freehand reduction strategy using soft hammer percussion. Cluster one could thus be named "MSA-type flakes." Cluster two, with punctiform and thin platforms and point-type bulbs, may consist of microflakes and/or bladelets. The combination of crushed and undiscernible platforms in cluster three along with sheared bulbs and natural terminations is highly suggestive of bipolar percussion.

It was hypothesized that if the blanks in cluster three were the result of bipolar percussion, then they should also exhibit other attributes associated with bipolar technology: lower platform width (length)/thickness ratios, lower length/width ratios (AQlw), shorter length, greater width, lighter weight, twisted profiles, thinner cross-sections, and a higher percentage of fine-grained raw material (Table 22). Because platforms <3mm were not measured, platform width/thickness ratio would not be a viable measurement for comparison, as it would exclude most blanks with punctiform, undiscernible, and crushed platforms. Instead, the percentages of unclear platforms and platforms <3mm were compared across clusters.

Table 22 Ancillary attributes for the three-cluster solution.

	Cluster 1 (n=857)	**Cluster 2 (n=322)**	**Cluster 3 (n=293)**	**P-value**
% platforms <3mm (for whole and proximal only)	5/285 (1.7%)	50/232 (21.6%)	17/258 (6.6%)	**Z-test: p<0.001.**
% unclear platforms (whole and proximal only)	9/285 (3.2%)	3/232 (1.3%)	17/258 (6.6%)	**Z-test: p=0.006.**
Absolute length	16.76mm	17.60mm	18.23mm	KW: p=0.66.
Maximum width	15.05mm	14.09mm	15.61mm	KW: p=0.33.
AQlw	0.022	0.052	0.028	KW: p=0.08.
Weight	1.86 g.	1.33 g.	2.95 g.	**KW: p<0.001.** Dunn: insignificant p-value for 1 vs. 2.
% twisted profiles	13/145 (9.0%)	14/130 (10.8%)	10/176 (5.7%)	Z-test: p=0.255.
Maximum thickness	6.20	4.87	7.73	**KW: p<0.001. Dunn: all p-values <0.05.**
Raw materials (% CCS or quartz)	525/857 (61.3%)	239/322 (74.2%)	199/293 (67.9%)	**Z-test p<0.001.**
Context	5: 408/769 (53%) 6-8: 449/703 (63.9%)	5: 185 (24.1%) 6-8: 137 (19.5%)	5: 176 (22.9%) 6-8: 117 (16.6%)	G-test: p<0.001

Cluster three shows minimal evidence for bipolar technology. The only "bipolar" attribute that is significant for cluster three is the percentage of unclear platforms. Length, width, and length/width ratio do not vary between the clusters. In some cases, the cluster 3 flakes exhibit the exact opposite attributes of what would be expected. They are significantly heavier and thicker than the flakes in clusters one and two. This is contradicted by the fact that blanks with crushed platforms, many of which belong to cluster three, are significantly lighter than those with uncrushed platforms (p=0.023). It is worth noting cluster three had the highest within-cluster sum of squares (0.0387) out of all three clusters, indicating that the Euclidean distance between points within it is greater than the distances between points in clusters one and two. This suggests that cluster three is the least cohesive of all the clusters and may represent a throw-away category for blanks that did not fit either cluster one or two properly. The cluster two flakes, however, do show patterning consistent with freehand bladelet and microflake production. They have a significantly greater percentage of platforms <3mm, the highest length/width asymmetry quotient, the greatest percentage of flakes made from fine-grained raw materials and are slightly narrower than flakes from the other clusters.

Cluster assignments differ significantly by context. A greater proportion of flakes from contexts 6-8 belongs to cluster one, the "MSA-type" cluster. Accordingly, more flakes from context 5 were assigned to clusters two and three (g-test, $p<0.001$). A conservative interpretation of this result would be that the frequency of soft-hammer freehand percussion that characterized the MSA assemblages at Melikane becomes less common in context 5. An increase in cluster two flakes is also consistent with an increase in bladelet and microflake production. The increase in cluster three flakes is ambiguous, considering that the cluster is incohesive unindicative of any particular type of percussion. With this in mind, the five-cluster solution was analyzed in order to bring more resolution to the data.

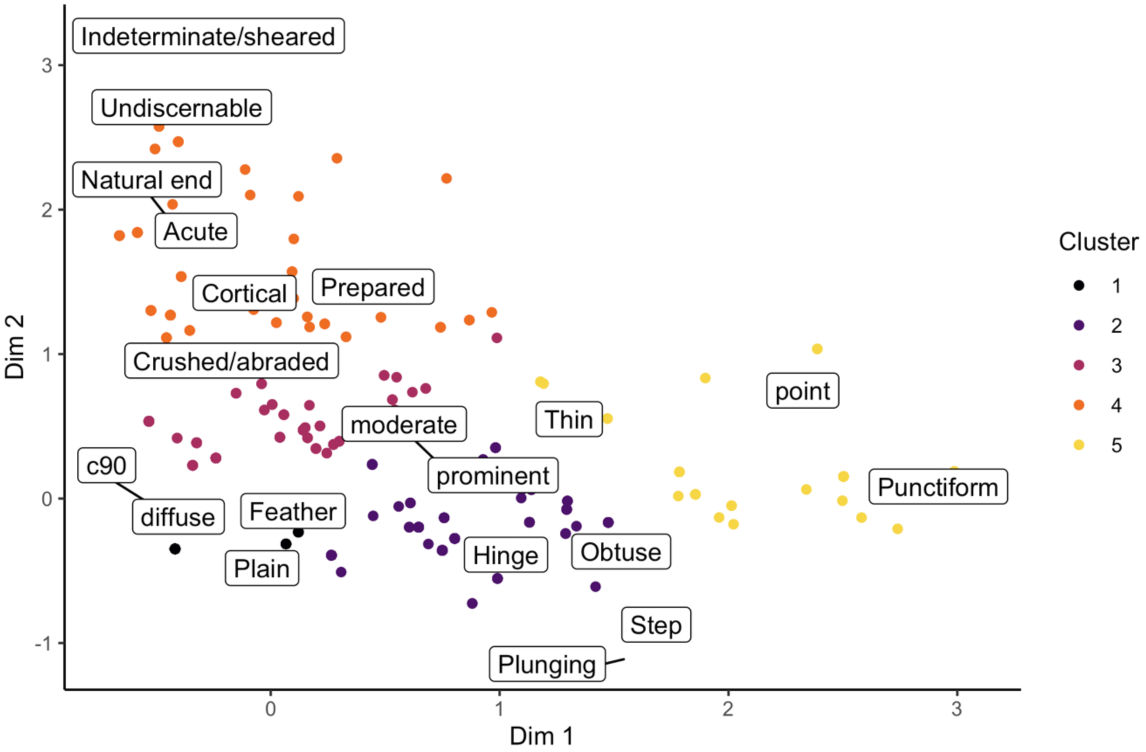
The Five-Cluster Solution

The five-cluster solution, although more complicated by virtue of a greater number of clusters and less even cluster sizes, produced a slightly higher average silhouette width than the three-cluster solution (0.476, versus 0.475 for three clusters). Clusters were of sizes 746, 324, 223, 120, and 59.

Table 23 Attributes for the five-cluster solution.

	Platform type	EPA	Bulb type	Termination	Within-cluster SS
1	94% Plain	~90º	78% diffuse, some moderate/prominent.	92% feather	0.0021
2	72% plain, small amounts of prepared or thin	Obtuse	46% diffuse, 26% moderate, 19% prominent.	65% hinge, 26% feather, 7% step.	0.0100
3	Diverse. 48% plain, 24% prepared, 17% crushed.	~90º	69% diffuse, 17% moderate.	66% natural, 26% feather.	0.0064
4	Diverse. Plain and prepared (26% each), remainder is mostly cortical (13%), undiscernible (13%), and crushed (15%).	~90º/acute	45% sheared, 42% diffuse.	79% natural.	0.0106
5	Punctiform (68%), crushed (14%) or thin (12%).	Obtuse	74% point, 14% prominent, 11% moderate.	39% hinge, 35% feather, 16% natural, 10% step.	0.0050

Figure 21 The five-cluster solution.



The increased resolution provided by the five-cluster solution reopens the possibility that distinctly bipolar flakes could be identified. Cluster one remains nearly identical to cluster one in the three-cluster solution, but cluster two is split into clusters two and five, and cluster three becomes clusters three and four. Cluster four appears to be more associated with typically bipolar attributes, and cluster five appears to consist of the freehand bladelet/microblade flakes identified in the three-cluster solution.

Table 24 Ancillary attributes for the five-cluster solution.

	Cluster 1 (n=746)	**Cluster 2 (n=324)**	**Cluster 3 (n=223)**	**Cluster 4 (n=120)**	**Cluster 5 (n=59)**	**P-value**
% platforms <3mm (for whole and proximal only)	2/177 (1.1%)	15/232 (6.5%)	7/191 (3.7%)	12/117 (10.3%)	36/58 (62.1%)	**Z-test: P<0.001** (5 is different from all, 4 is different from 1-3)
% unclear platforms (whole and proximal only)	3/177	1/232	13/191	10/117	2/58	*#s too small for valid comparison*
Absolute length (mm)	17.71	17.37	17.91	17.89	17.55	KW: P=0.88
Maximum width (mm)	15.37	14.67	16.09	14.48	13.45	KW: P=0.20
AQlw	0.035	0.031	0.021	0.037	0.072	KW: P=0.22
Weight	2.02	1.55	2.76	2.85	1.11	**KW: P<0.001** (Dunn: 5 and 2 are different from 3 and 4, 1 is not different from anything).
% twisted profiles	4/46 (8.7%)	8/87 (9.2%)	4/99 (4.0%)	7/75 (9.3%)	4/31 (12.9%)	Z-test: P=0.48

Maximum thickness (mm)	6.21mm	5.42mm	7.38mm	7.68mm	4.62mm	**KW: P<0.001.** (Dunn: 2 is different than 3 and 4, and 5 is different from 1, 3, and 4.)
Raw materials (% CCS or quartz)	463/746 (62.1%)	220/324 (67.9%)	141/223 (63.2%)	86/120 (71.7%)	53/59 (89.8%)	**Z-test: P<0.001**. 5 is different from 1, 2, and 3.
Context **5: n=769** **6-8: n=703**	5: 355 (46.2%) 6-8: 391 (55.6%)	5: 167 (21.7%) 6-8: 157 (22.3%)	5:134 (17.4%) 6-8:89 (12.7%)	5:72 (9.4%) 6-8: 48 (6.8%)	5: 41 (5.3%) 6-8: 18 (2.6%)	**Z-test:** p<0.001. 3 and 5 are different from 1.

Many of the issues with interpretation of the three-cluster solution still exist with the five-cluster solution. The cluster four blanks have the sheared bulbs, acute platform angles, and natural terminations associated with bipolar flakes, as well as healthy proportions of undiscernible and crushed platforms. The frequencies of CCS and quartz in cluster four are relatively high. However, cluster four flakes are still heavier and thicker than flakes from other clusters. There are two possible explanations for this discrepancy. The first is simply that the cluster four flakes are not bipolar. The second potential explanation is that bipolar reduction at Melikane did not necessarily produce smaller flakes than freehand percussion. Knappers may have chosen to use bipolar percussion on larger cobbles, possibly to save time or simply out of convenience. Strict control over flake shape may have been unnecessary.

If the cluster four flakes are bipolar, then there is inconsistency between the number of bipolar flakes and cores. Cluster four flakes are slightly more common in context 5 than contexts 6-8, but insignificantly so (z-test, p=0.093). However, as will be discussed later in this dissertation, bipolar cores and CRPs are far more common in contexts 6-8. This implies that the frequency of “bipolar flakes” may not accurately reflect the prevalence of bipolar percussion. An explanation for this paradox could be that bipolar percussion produces more shatter and unidentifiable flake fragments per unit of raw material, resulting in fewer complete flakes per core.

Although the cluster five flakes are the smallest, many of their attributes are inconsistent with bipolar percussion. Pargeter’s (2017) experiment on flint found that bipolar flakes tended to have more acute EPAs. In contrast, the cluster five flakes have nearly exclusively obtuse EPAs. The most parsimonious explanation explaining the attributes and homogeneity of the cluster five flakes is that they are products of small, freehand core reduction. A study of Robberg bladelets from Rose Cottage Cave (Cochrane, 2008) found that compared to Howiesons Poort bladelets of the same length, Robberg bladelets had higher frequencies of platforms under 3mm in width, thin platforms, and missing platforms. The bladelets from the Elands Bay Cave Robberg level MOS1 also exhibit the point-type bulbs exclusive to cluster five (Porraz, Igreja, et al., 2016). The cluster five flakes are clearly not all bladelets – their mean maximum width is ~13mm – but they are the "bladiest" of all the clusters. It is likely that the cluster includes bladelets as well as the debitage created during production. Interestingly, the within-cluster sum of squares is the smallest in cluster five, indicating that the individual blanks making up the cluster are more homogenous than the blanks comprising other clusters.

In conclusion, multiple correspondence analysis identified two clusters of blanks, four and five, that may represent unique technological categories. The significantly higher frequency of cluster five blanks in context 5 may indicate a rise in freehand bladelet production. The relatively equal proportions of cluster four blanks in contexts 5 and 6-8 suggests that bipolar flake frequency may be a poor indicator of the actual prevalence of bipolar percussion. Both the three and five cluster solutions discussed here identified a cluster of blanks, cluster one, with plain platforms, EPAs ~90º, diffuse bulbs, and feather terminations. These blanks have attributes mirroring those from the Melikane MIS 5a assemblage. The lesser proportion of context 5 blanks belonging to this cluster (z-test: $p<0.001$) may indicate a decline in MSA-style flaking strategies including parallel core reduction. Overall, MCA provides a framework to interpret temporal changes in attribute frequencies that may not be meaningful when isolated from other attributes.

Cores

935 whole cores were identified from contexts 5 and 6-8. When combined, bipolar cores and core-reduced pieces comprise nearly half of each context (Table 25). Multidirectional cores are the second-most common, and other core types make up only small proportions of the assemblage. A Fisher Test identified significant differences between core types in each context, but a posthoc test of residuals indicated that only core-reduced pieces changed in a significant way over time, decreasing from 36% of all cores in contexts 6-8 to 23.5% in context 5 ($p<0.001$). Smaller changes between contexts include an increase in the frequency of multidirectional and platform cores in context 5, and a decrease in the frequency of parallel cores. Bipolar cores (but not CRPs) remain relatively stable in terms of their proportion to other types.

Table 25 Core type by context.

Type	**5**		**6-8**		**Total**	
	Frequency	%	Frequency	%	Frequency	%
Bipolar	95	*20.9*	89	*18.5*	184	*19.7*
Inclined	13	*2.9*	10	*2.1*	23	*2.5*
Initial	39	*8.6*	26	*5.4*	65	*7.0*
Multidirectional	133	*29.2*	115	*24.0*	248	*26.5*
Platform	45	*9.9*	25	*5.2*	70	*7.5*
Parallel	23	*5.1*	42	*8.8*	65	*7.0*
CRP	107	*23.5*	173	*36.0*	280	*29.9*
Total	**455**		**480**		**935**	

Figure 22 Core proportions by context.

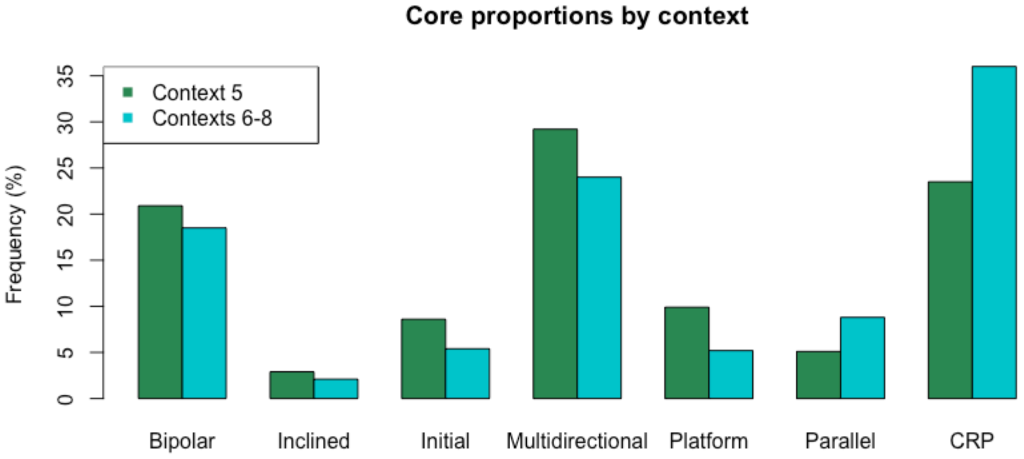


Table 26 Context 5, core type by raw material.

Type	**Material**				**Total**	
	CCS	*Hornfels*	*SQ*	*Quartz*	*N*	*%*
Bipolar	84	*2*	0	9	95	*20.9*
Inclined	11	1	0	1	13	*2.9*
Initial	37	2	0	0	39	*8.6*
Multidirectional	119	11	2	1	133	*29.2*
Platform	41	3	0	1	45	*9.9*
Parallel	19	4	0	0	23	*5.1*
CRP	98	2	0	7	107	*23.5*
Total	**409**	**25**	**2**	**19**	**455**	
%	***89.9***	***5.5***	***.4***	***4.2***		

Table 27 Contexts 6-8, core type by raw material.

Type	**Material**					**Total**	
	CCS	*Hornfels*	*SQ*	*Quartz*	*Other*	*N*	*%*
Bipolar	72	*5*	1	11		89	*18.5*
Inclined	8	2				10	*2.1*
Initial	18	5	3			26	*5.4*
Multidirectional	102	4	5	2	2	115	*24.0*
Platform	17	7	1			25	*5.2*
Parallel	37	4	1			42	*8.8*
CRP	148	8	3	14		173	*36.0*
Total	**402**	**35**	**14**	**27**	**2**	**480**	
%	***83.8***	***7.3***	***2.9***	***5.6***	***0.4***		

CCS is by far the most common raw material for cores in both contexts (Table 26, Table 27). It is disproportionately represented in comparison to its frequency in the assemblage overall, whereas hornfels and sandstone are underrepresented (G-tests, p<0.001). This mirrors the pattern seen in the Melikane MIS 5a assemblage, which was interpreted as the result of different provisioning strategies for CCS and other materials (Pazan et al., 2022). Because sandstone and hornfels are found in larger nodules further from the shelter than CCS, core reduction for these heavier materials is more likely to occur at their source to minimize transport costs. As a result, fewer cores made with these materials will be recovered at the site. The continuation of this pattern into MIS 2 affirms that the Melikane foragers were likely using the same CCS sources as their forebearers, and that their sources for other raw materials remained further away. Although contexts 6-8 overall have more hornfels and less CCS than context 5, the are no differences in the proportions of raw materials among cores (Fisher test, p=0.237). This is likely also a result of provisioning. Very few hornfels cores were reduced at the site in contexts 6-8 anyway, so a decline in hornfels use would have little impact on the core assemblage.

Core Dimensions

Core types were simplified into three groups for the purpose of comparison: bipolar cores, core-reduced pieces, and freehand cores (all non-bipolar core types). Across all types and contexts, sandstone and hornfels cores are larger than those made of CCS and quartz. The mean dimensions of final core removals do not differ significantly between contexts; however, this is likely biased by the difficulty of correctly identifying and measuring final removals on highly reduced cores such as core-reduced pieces and a subsequently small sample size (n=18). All three main core types decrease significantly in terms of at least one dimension in context 5 (Table 28, Table 29, Table 30). Because most cores in the MIS 2 Melikane assemblage feature more than one axis of percussion, core "length" represents the either the obviously preferred axis, or the axis of greatest dimension. CCS freehand cores fall from a mean of 31.26 mm in length in contexts 6-8 to 27.49 mm in context 5 (p=0.04). Bipolar CCS cores drop from 23.40 mm to 18.67 mm (p<0.001), and CRPs fall from 16.46 mm to 13.97 mm (p=0.008). All core types become lighter as well, but bipolar cores are the only type with a statistically significant drop in weight (p=0.012).

Table 28 Context 5 core dimensions.

Core dimensions, context 5		**Context 5**			
		CCS	*S/Q/H*	*Quartz*	*All*
All cores	Weight	Mean: 8.77 SD: 10.5 N: 150	Mean: 32.41 SD: 33.52 N:11	Mean: 5.32 SD: 6.93 N:7	Mean: 10.17 SD: 14.25 N: 168
	Length	Mean: 21.63 SD: 9.19 N: 150	Mean: 33.49 SD: 12.59 N: 11	Mean: 18.49 SD:7.60 N: 7	Mean: 22.28 SD: 9.81 N: 168
	Width	Mean: 17.40 SD: 6.55 N: 150	Mean: 27.92 SD: 11.06 N: 11	Mean: 14.51 SD: 6.69 N: 7	Mean: 17.97 SD: 7.39 N: 168
	Thickness	Mean: 12.17 SD: 5.08 N:150	Mean: 17.65 SD: 8.88 N:11	Mean: 9.80 SD: 4.86 N:7	Mean: 12.43 SD: 5.54 N: 168
Bipolar cores	Weight	Mean: 5.30 SD: 3.42 N: 29	8.48 N: 1	Mean: 4.505 N: 2	Mean: 5.35 SD: 3.33 N: 32
	Length	Mean: 18.67 SD: 6.73 N: 29	20.44 N: 1	Mean: 16.54 N: 2	Mean: 18.59 SD: 6.45 N: 32
	Width	Mean: 16.68 SD: 3.96 N: 29	17.98 N: 1	Mean: 17.66 N: 2	Mean: 16.78 SD: 4.01 N: 32
	Thickness	Mean: 12.11 SD: 2.93 N: 29	11.54 N:1	Mean: 9.36 N:2	Mean: 11.92 SD: 2.88 N: 32
CRP	Weight	Mean: 1.91 SD: .86 N: 46	.64 N=1	Mean: 1.57 SD: .38 N: 3	Mean: 1.86 SD: .85 N: 50
	Length	Mean: 13.97 SD: 3.34 N: 46	10.38 N:1	Mean: 14.47 SD: 2.24 N: 3	Mean: 13.93 SD: 3.27 N: 50
	Width	Mean: 11.69 SD: 2.14 N: 46	11.24 N: 1	Mean: 10.01 SD: 1.32 N: 3	Mean: 11.58 SD: 2.10 N: 50
	Thickness	Mean: 8.28 SD: 1.85 N: 46	4.84 N: 1	Mean: 6.76 SD: 1.40 N: 3	Mean: 8.12 SD: 1.89 N: 50
Freehand cores	Weight	Mean: 14.76 SD: 12.35 N: 75	Mean: 38.60 SD: 34.11 N: 9	Mean: 11.76 N: 2	Mean: 16.80 Median: 12.12 SD: 17.34 N: 86
	Length	Mean: 27.49 SD: 8.46 N: 75	Mean: 37.52 SD: 9.59 N: 9	Mean: 26.48 N: 2	Mean:28.51 Median: 28.04 SD: 9.07 N: 86
	Width	Mean: 21.19 SD: 6.54 N: 75	Mean: 30.88 SD: 9.79 N: 9	Mean: 18.10 N: 2	Mean: 22.13 Median: 21.44 SD: 7.53 N: 86
	Thickness	Mean: 14.59 SD: 5.59 N: 75	Mean: 19.75 SD: 8.27 N: 9	Mean: 14.80 N: 2	Mean: 15.13 Median: 13.56 SD: 6.07 N: 86

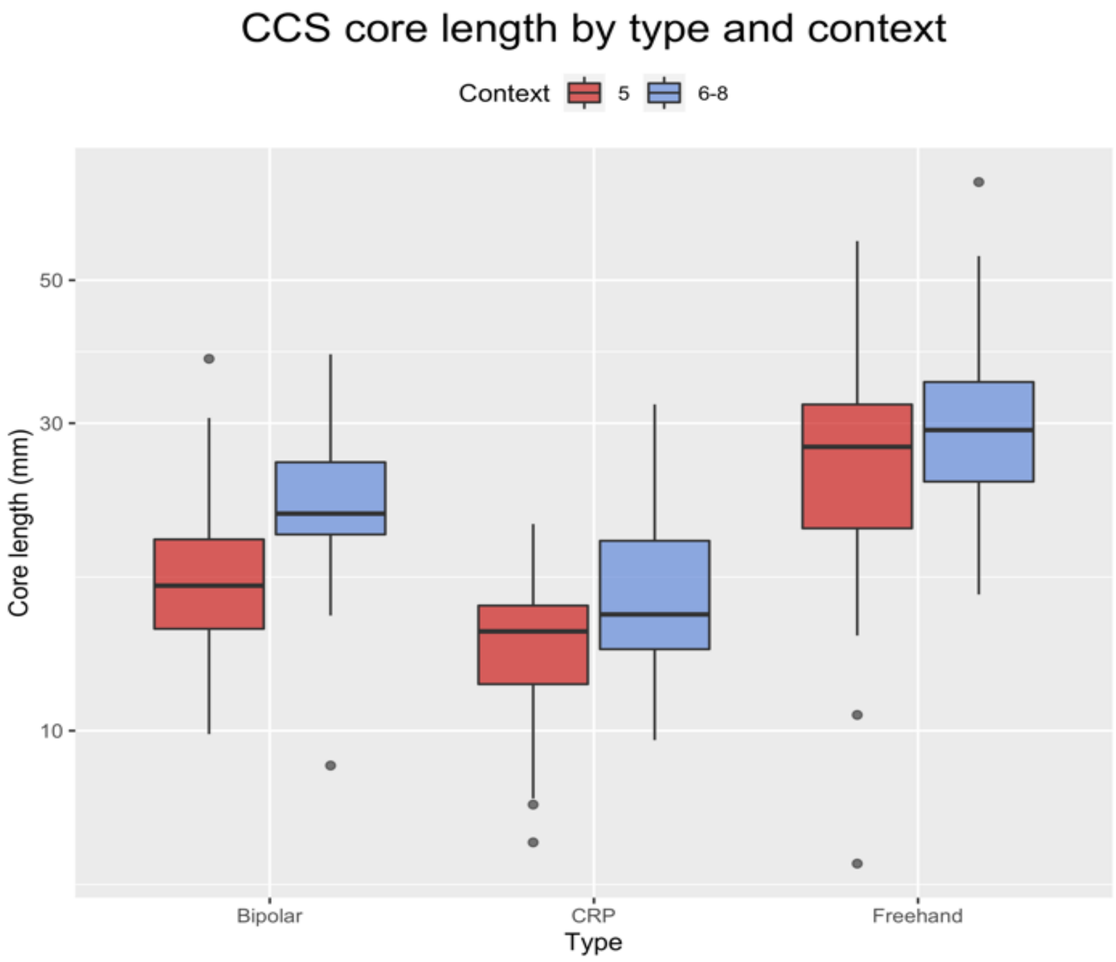
Table 29 Contexts 6-8 core dimensions.

Core dimensions and attributes, contexts 6-8		**Contexts 6-8**			
		CCS	*Sandstone/quartzite/ hornfels*	*Quartz*	*All*
All cores	Length	Mean: 23.25 SD: 9.84 N: 166	Mean: 28.89 SD: 12.20 N: 23	Mean: 21.82 SD: 10.80 N: 10	Mean: 24.07 SD: 10.56 N: 201
	Width	Mean: 16.64 SD: 6.75 N: 166	Mean: 22.59 SD: 9.78 N: 23	Mean: 15.22 SD: 8.15 N: 10	Mean: 17.38 SD: 7.54 N: 201
	Thickness	Mean: 11.10 SD: 4.48 N: 166	Mean: 15.28 SD: 6.66 N: 10	Mean: 12.07 SD: 5.87 N: 10	Mean: 11.73 SD: 5.12 N: 201
	Weight	Mean: 8.17 SD: 10.73 N: 166	Mean: 19.47 SD: 19.23 N: 23	Mean: 8.52 SD: 12.18 N: 10	Mean: 9.83 SD: 13.12 N: 201
Bipolar cores	Length	Mean: 23.40 SD: 6.78 N: 27	Mean: 25.41 SD: 8.32 N: 3	Mean: 27.57 SD: 7.71 N: 3	Mean: 23.96 SD: 6.86 N:33
	Width	Mean: 17.22 SD: 4.40 N:27	Mean: 23.68 SD: 7.39 N:3	Mean: 18.25 SD: 3.75 N: 3	Mean: 17.90 SD: 4.85 N: 33
	Thickness	Mean: 12.43 SD: 2.75 N:27	Mean: 15.27 SD: 4.34 N: 3	Mean: 14.60 SD: 0.34 N: 3	Mean: 12.88 SD: 2.88 N: 33
	Weight	Mean: 8.16 SD: 6.41 N:27	Mean: 14.52 SD: 7.69 N: 3	Mean: 12.11 SD: 7.73 N: 3	Mean: 9.10 SD: 6.72 N: 33
CRP	Length	Mean: 16.46 SD: 4.56 N: 75	Mean: 14.71 SD: 2.42 N: 6	Mean: 14.28 SD: 1.73 N: 6	Mean: 16.23 SD: 4.38 N: 89
	Width	Mean: 11.77 SD: 3.03 N: 75	Mean: 12.57 SD: 2.66 N: 6	Mean: 9.86 SD: 2.15 N: 6	Mean: 11.70 SD: 2.98 N: 89
	Thickness	Mean:7.94 SD: 1.76 N:75	Mean: 9.62 SD: 1.20 N: 6	Mean: 8.03 SD: 1.88 N: 6	Mean: 8.05 SD:1.77 N: 89
	Weight	Mean: 2.72 SD: 1.74 N: 75	Mean: 2.10 SD: .82 N: 6	Mean: 2.10 SD: .816 N: 6	Mean: 2.22 SD: 1.63 N: 89
Freehand cores	Length	Mean: 31.26 SD: 9.49 N: 65	Mean: 35.15 SD: 10.27 N: 14	Mean: 42.3 N: 1	Mean: 32.5 SD: 9.99 N: 82
	Width	Mean: 22.15 SD: 6.41 N: 65	Mean:26.18 SD: 9.58 N: 14	Mean:32.93 N: 1	Mean:23.20 SD: 7.29 N: 82
	Thickness	Mean: 14.27 SD: 4.78 N: 65	Mean: 17.47 SD: 7.19 N: 14	Mean:24.74 N: 1	Mean: 15.18 SD: 5.61 N: 82
	Weight	Mean: 14.96 SD: 13.75 N: 65	Mean: 27.97 SD: 19.84 N: 14	Mean: 38.5 N: 1	Mean: 18.17 SD: 16.48 N: 82

Table 30 P-values for Kruskal Wallis and Mann Whitney U-Tests comparing core dimensions between contexts 5 and 6-8.

		P-values				**Significance**
		CCS	*S/Q/H*	*Quartz*	*All*	
All cores	Length	.137	.308	.681	.10	
	Width	.216	.289	1	.45	
	Thickness	**.05**	.457	.470	.22	Overall, CCS-5 cores are thinner.
	Weight	.344	.214	.961	.82	
Bipolar cores	Length	**.003**	NA	NA	**<.001**	Bipolar-5 cores are shorter.
	Width	.987	NA	NA	.681	
	Thickness	.512	NA	NA	.117	
	Weight	.06	NA	NA	**.012**	Bipolar-5 cores are lighter.
CRP	Length	**.010**	NA	NA	**.008**	CRP-5 cores are shorter.
	Width	.598	NA	NA	.709	
	Thickness	.337	NA	NA	.875	
	Weight	.796	NA	NA	.551	
Freehand cores	Length	**.04**	.60	NA	**.03**	Freehand-CCS-5 cores are shorter.
	Width	.40	.50	NA	.30	
	Thickness	.90	.70	NA	.90	
	Weight	.60	.50	NA	.40	

Figure 23 CCS core length.

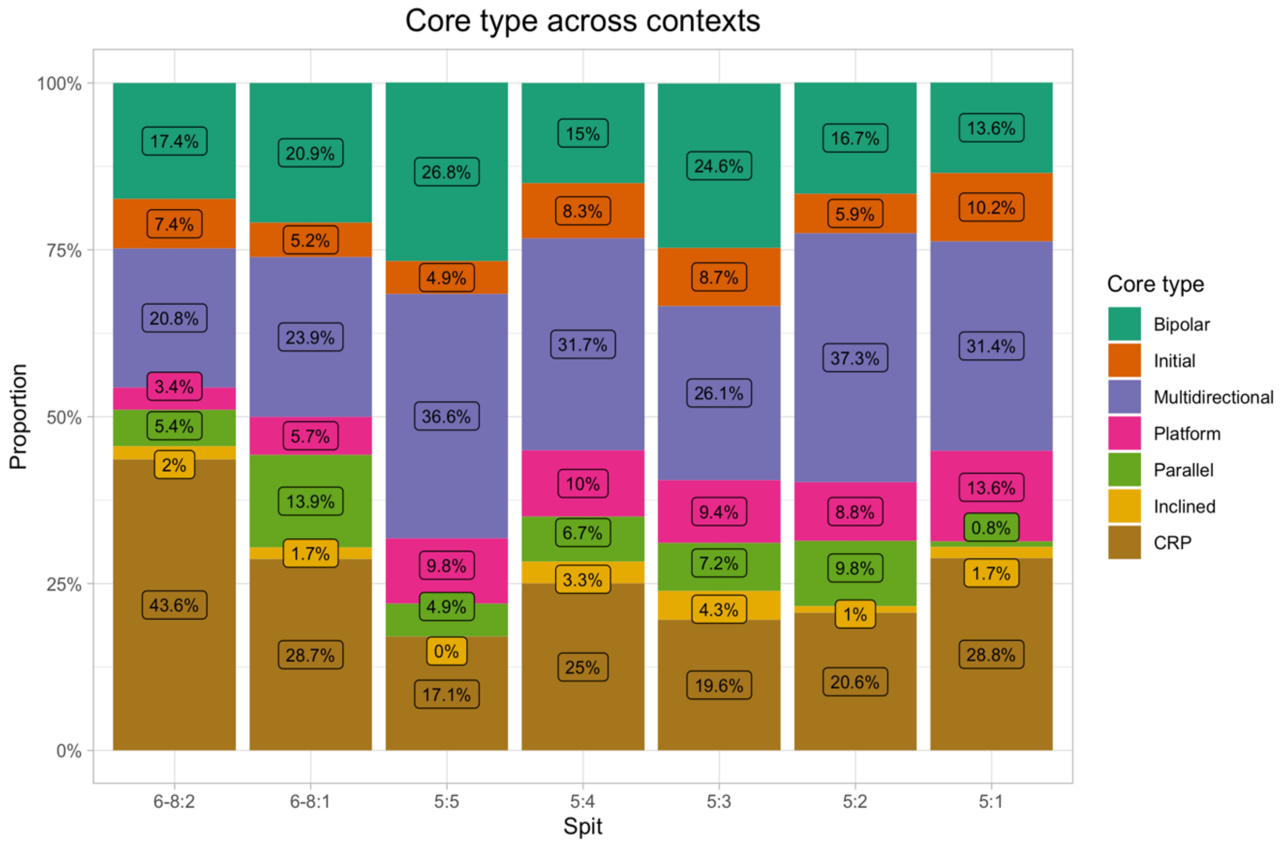


Changes by Spit

Although large-scale trends including a decline in the frequency of core-reduced pieces and a decrease in mean core size are visible from the level of context, core types were further broken down by spit to address changes within contexts. Although each context was subdivided into arbitrary 5 cm spits, it is probable that even considering postdepositional disturbances, the sequence of spits maintains some temporal integrity. When broken down by spit, contexts show smaller variations within the large-scale trends (Figure 24).

Just as core-reduced pieces become less frequent in context 5, they are less frequent in the first spit of context 6-8 (6-8:1) than the second (6-8:2), falling from 43.6% to 28.7% of all cores, and then to 17.1% in the bottom spit of context 5 (5:5). A second obvious change from 6-8:2 to 6-8:1 is a sudden spike in the number of parallel cores, from 5.4% to 13.9%, followed by an equally sudden drop in 5:5 to 4.9%. Through the rest of context 5, parallel cores wax and wane, reaching 9.8% in 5:2 and again falling in 5:1 to 0.8%. Multidirectional cores are more common in every spit of context 5 than either spit in contexts 6:8, as are platform cores. It is interesting to note that platform cores – often associated with the LSA and blade technology – reach their peak in 5:1, where parallel cores – associated with MSA technology – nearly disappear. Platform and parallel cores, however, do not have a precisely inverse relationship. Throughout most of context 5, both are present in modest numbers, and in 5:2, are nearly equal in proportion.

Figure 24 Core type by spit.



Initial cores present a conundrum when considered alongside core-reduced pieces. The two core types should represent opposite ends of the reduction intensity spectrum – initial cores with only a few removals, and core-reduced pieces often with so many as to make counting them impossible. It would be expected that they should vary inversely if this were the case. However, in 5:5, both core types are lower in proportion than anywhere else in the assemblage. One possible explanation for this anomaly is that the nodules on which initial cores were made were simply too small to reduce further, even by bipolar percussion. However, initial cores average 31.38 mm in length, which is longer than the mean lengths of all cores in either context. Instead, initial cores vary inversely with multidirectional cores – when the prevalence of multidirectional cores increases, the prevalence of initial cores decreases, and vice versa. This suggests that initial cores may not be the earliest stages of a bipolar core or CRP, and instead are the beginnings of multidirectional cores, or multidirectional cores abandoned due to low raw material quality or better available options. There is no difference in mean lengths between multidirectional and initial cores (p=0.467), but there is also no correlation between core length and scar number among multidirectional cores (Spearman's Rho=0.077, p=0.526) or initial cores (rho=0.243, p=0.316). This suggests that bigger initial and multidirectional cores are not necessarily at an earlier stage of reduction than smaller cores, and that core size cannot be seen as a proxy for reduction intensity among these particular core types.

As previously indicated, platform cores rise in frequency from a low of 3.4% in 6-8:2 to a high of 13.6% in 5:1. This is consistent with what would be expected across the MSA/LSA transition if platform cores are indeed associated with the LSA. To test for the significance of this trend, a two-sided Cochran-Armitage test was performed on the proportions of parallel cores to other cores in each spit. It produced a p-value of 0.001, confirming that the increase in platform cores over time from 6-8:2 to 5:1 is significant. Another interesting trend is a decrease in the overall proportions of bipolar cores and CRPs and an increase in the overall proportions of freehand cores across both contexts. Together, bipolar cores and core-reduced pieces comprise 61% of all whole cores in 6-8:2, but only 42.4% of all cores in 5:1. A Cochran-Armitage test also confirmed the significance of this trend (p<0.001). There does not appear to be a relationship between the proportion of bipolar cores and the proportion of core reduced pieces – neither becomes more or less common over time at the expense of the other.

The changes in core dimensions between context 5 and contexts 6-8 can also be tracked over time by spit (Table 31). There is a moderate correlation between spit and bipolar core length (Kendall's Tau-B=0.277, p=0.003), as well as a weak correlation between spit and CRP length (Tau=0.158, p=0.015). There is no correlation between multidirectional core length and spit (Tau=0.095, p=0.274), even when raw material is controlled for. Instead, multidirectional core length changes cyclically, peaking in 6-8:1 and again in 5:3, with troughs in between. None of this variation is significant, however (Kruskal-Wallis test, p=0.109).

Table 31 Core length (mm) by spit.

	6-8:3	6-8:2	6-8:1	5:5	5:4	5:3	5:2	5:1	Kendall's Tau-B
Bipolar	NA	21.85	25.86	NA	22.68	18.01	18.86	14.76	0.277, p=0.003
CRP	16.77	16.19	15.82	16.32	14.13	14.05	12.33	14.49	0.158, p=0.015
Multidirectional	NA	31.54	34.56	21.60	28.18	33.22	31.77	24.82	Insignificant

Bipolar Percussion

If bipolar percussion at Melikane is used to take advantage of small cobbles and conserve raw material, then there should be a size threshold at which the knapper abandons freehand percussion and switches techniques. Hiscock (2015) terms this the "recycling window." An additional threshold beyond that should exist, representing the point at which a bipolar core is too exhausted to continue to work and becomes a core-reduced piece. Identifying these thresholds, however, is a challenge. All metric dimensions – length, width, thickness, and weight – overlap significantly between core types. To understand the dynamics between these dimensions and the concept of a core size threshold, three multivariate techniques – multinomial logistic regression, PAM cluster analysis, and k-means cluster analysis – were used to uncover structure in the data.

Multinomial Logistic Regression

Table 32 Relative risk ratios for core regression

	Dependent variable:	
	Freehand (1)	CRP (2)
\`Core length\`	1.197*** (0.057)	0.799** (0.088)
\`Core width\`	1.169** (0.068)	0.846 (0.139)
\`Core thickness\`	0.997 (0.108)	0.553*** (0.202)
Weight	0.906 (0.066)	1.236 (0.263)
Constant	0.002*** (2.108)	291,023.500*** (3.116)
Akaike Inf. Crit.	215.559	215.559
Note:		$^{*}p^{**}p^{***}p<0.01$

Multinomial logistic regression is used to predict a nominal outcome variable based on multiple dichotomous or numeric independent variables. The nominal outcome variable must have at least three non-ordered possibilities. In situations with a dichotomous outcome variable, binomial logistic regression in a more appropriate technique, and in situations with ordered outcome variables (ie. Less likely, likely, most likely), ordered logistic regression is used instead. Multinomial logistic regression was chosen because an ordered logistic regression would assume that freehand, bipolar cores, and CRPs represent subsequent stages in a single reduction process. Because of the differences in core dimensions between contexts, I decided to use only contexts 6-8 for this analysis. Contexts 6-8 were chosen over 5 because they included more even numbers of measured freehand, bipolar, and CRP cores. A multinomial logistic regression using the multinom*()* function from the *nnet* package (Venables et al., 2002) was performed using weight, length, width, and thickness as predictor variables and core type (either bipolar, freehand, or CRP) as the outcome variable. Bipolar cores were chosen as the reference category because they are in between the sizes of freehand cores and CRPs. Relative risk ratios for the model were calculated by exponentiating the values of the produced logit coefficients (Table 32). Relative risk values are easier to interpret than logit coefficients, as they have real value in terms of the units used in the model's variables.

To check for collinearity between the predictor variables, a test of the variance inflation factor (VIF) was performed using a linear version of the same model. The VIFs for length, width, thickness, and weight were 3.53, 3.88, 4.20, and 6.52 respectively (vif(), car package; Fox & Weisberg, 2019). VIF measures how much any given variable can be predicted by the others. Higher VIFs indicate collinearity, which creates instability and inaccuracy in regression models. Hair et al. (2009) consider a VIF of 10 to be the maximum allowable value in a regression model, clearly indicating multicollinearity. In the case of the core type model, all VIF values fall well under 10, indicating that the degree of collinearity in the model is acceptable. The relative risk ratios for core length indicate that when other variables are held constant, for every unit (in this case, millimeter) of increase in core length, a core is 1.197 times more likely to be a freehand core than to be a bipolar core (because bipolar is our reference category), and 0.799 times more likely to be a CRP than a bipolar core. Both of these values are significant. For core width, for every millimeter increase, a core is 1.169 times more likely to be a freehand core than a bipolar core. The relative risk ratio for CRPs and core width is insignificant, indicating that changes in core width do not affect the chances that a core will be either a bipolar core or CRP. For core thickness, for every millimeter increase, a core is 0.553 times more likely to be a CRP than a bipolar core, but the value for freehanded vs. bipolar cores is insignificant. Neither of the relative risk ratios for weight is significant, indicating that changes in weight do not affect the likelihood that a core will be either a freehand core or CRP rather than a bipolar core.

In summary, the model indicates that core length is the best predictor of core type. Shorter cores are more likely to be core-reduced pieces, and longer cores are more likely to be freehand cores. Core thickness is the variable influencing core exhaustion. It does not distinguish bipolar and freehand cores but does divide them from CRPs. Core width is the best predictor of percussion type. Wider cores are more likely to have been reduced using freehand percussion. Weight is an insignificant actor in this model, indicating that nodule shape is more influential than core mass in dictating percussion method and core exhaustion.

PAM Cluster Analysis

Cluster analysis was used to understand how the three core shape dimensions – length, width and thickness – interact to determine core type. I wanted to see if the resulting clusters would mirror the actual recorded types and allow the identification of dimensional "thresholds." PAM cluster analysis was chosen over kmeans for this exercise because it is less sensitive to outliers. PAM forms clusters around actual data points, called "medoids," which are the most representative cases for each cluster. The Manhattan distance clustering algorithm was chosen because of its higher accuracy in PAM clustering than Euclidean distance (Mondal & Choudhury, 2013). Three clusters were chosen because the cores had already been divided into three types. The goal was to determine the "error rate" of the cluster solution. However, the three-cluster solution had an overall average silhouette width score of 0.417, and was *not* the most parsimonious solution based on the data. Using the R function clValid() (Brock et al., 2008), two and four cluster solutions would have been more parsimonious.

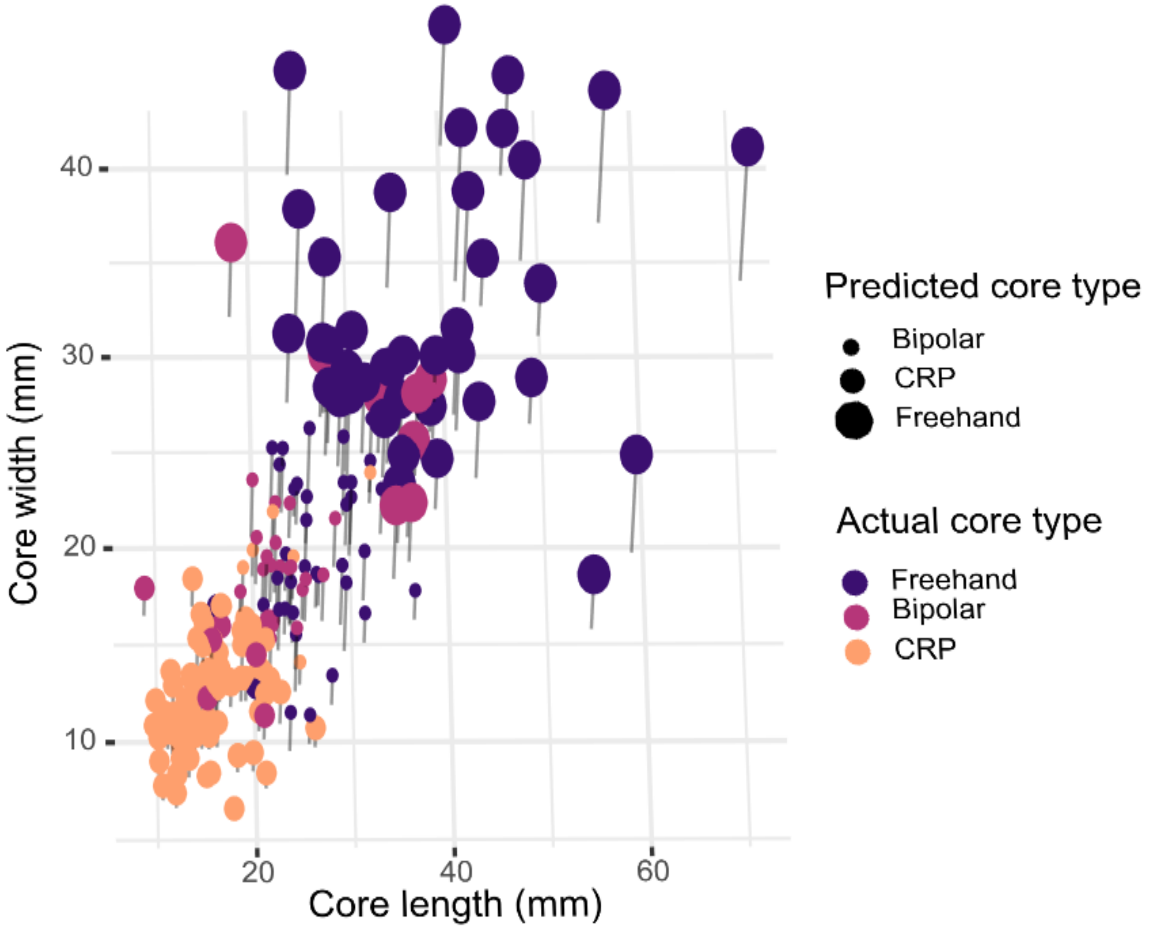
Table 33 PAM cluster mediods.

Cluster	ID	Core length	Core width	Core thickness	Weight
1 (n=61)	2792	24	17.34	11.8	7.03
2 (n=85)	2911	14.65	11.98	7.85	1.46
3 (n=47)	2725	35.07	24.09	17.06	23.17

Table 34 Actual cluster composition by core type (misclassified in red.)

	Freehand	Bipolar	CRP	% misclassified
1	37	18	6	70.5%
2	2	7	76	10.6%
3	39	8	0	17.0%
% misclassified	50%	45.5%	7.4%	

Figure 25 Core dimensions, actual type, and predicted type (z=thickness).



Three clusters of sizes 61, 85, and 47 were identified (Table 33). Based on the sizes of the dimensions of the medoids of each cluster, it was hypothesized that cluster 1 represents bipolar cores, cluster 2 represents CRPs, and cluster 3 represents freehand cores. The overall mean error of the clustering algorithm in this case is 31.08%. A contingency table (Table 34) of cluster membership and actual core type shows that cluster 2, the hypothesized CRP cluster, has a misclassification rate of only 10.6%. However, the bipolar cluster (cluster 1) has a misclassification rate of 70.5%. Nearly half of the freehand cores were assigned to the bipolar cluster, and half of bipolar cores were assigned to the other two clusters. Freehand cores were most commonly misclassified, with only 50% falling into the correct cluster. Bipolar cores were also commonly misclassified (45.5%), but CRPs were misclassified only 7.4% of the time.

What we can infer from this is that CRPs are a relatively stable morphological category, but freehand and bipolar cores are harder to parse based on dimensions alone. This is interesting because it implies that the size threshold between CRPs and other cores is "more real," and that the threshold dividing freehand and bipolar cores is flexible. Figure 25 shows considerable overlap between the ranges of freehand and bipolar cores, but a length threshold at ~40mm can be identified for bipolar cores – no cores over 40mm in length were reduced using bipolar percussion. However, many cores under 40mm in length were still reduced using freehand percussion. Thus, although bipolar cores are on average smaller than freehand cores, bipolar percussion may not only be used at Melikane as a means eke out use from reduced freehand cores. This reconciles the abundance of raw materials around Melikane with the high frequency of bipolar percussion. Instead of being a technique used to efficiently use raw materials, bipolar percussion may have been preferred for other reasons related to time or desired implement form. It appears to have been a choice, performed on some cores, but not others.

In conclusion, a size threshold between bipolar and freehand cores, at which bipolar percussion was used to further reduce freehand cores and efficiently use raw material, is not fully supported by the data. PAM cluster analysis failed to correctly classify freehand and bipolar cores based on dimensions and/or raw material. However, PAM was relatively accurate in differentiating CRPs from the other core types. Assuming CRPs would represent the cluster with the smallest mean dimensions, only 7.4% of CRPs were misclassified. Additionally, bipolar cores were slightly more likely to be misclassified as freehand cores than as CRPs. This suggests that a size threshold between CRPs and bipolar cores does exist, confirming that they are highly reduced bipolar cores as interpreted in the assemblage. Multinomial logistic regression identified a few subtler patterns in the data. Core length is the only metric variable that significantly increases or decreases the odds of a core being assigned to any type. Core width is only a significant factor in the odds of a core being freehand versus bipolar, and core thickness is only a significant dimension differentiating bipolar cores from CRPs. The odds ratios for core weight were insignificant, showing that all other variables held constant, weight is a poor predictor of core type.

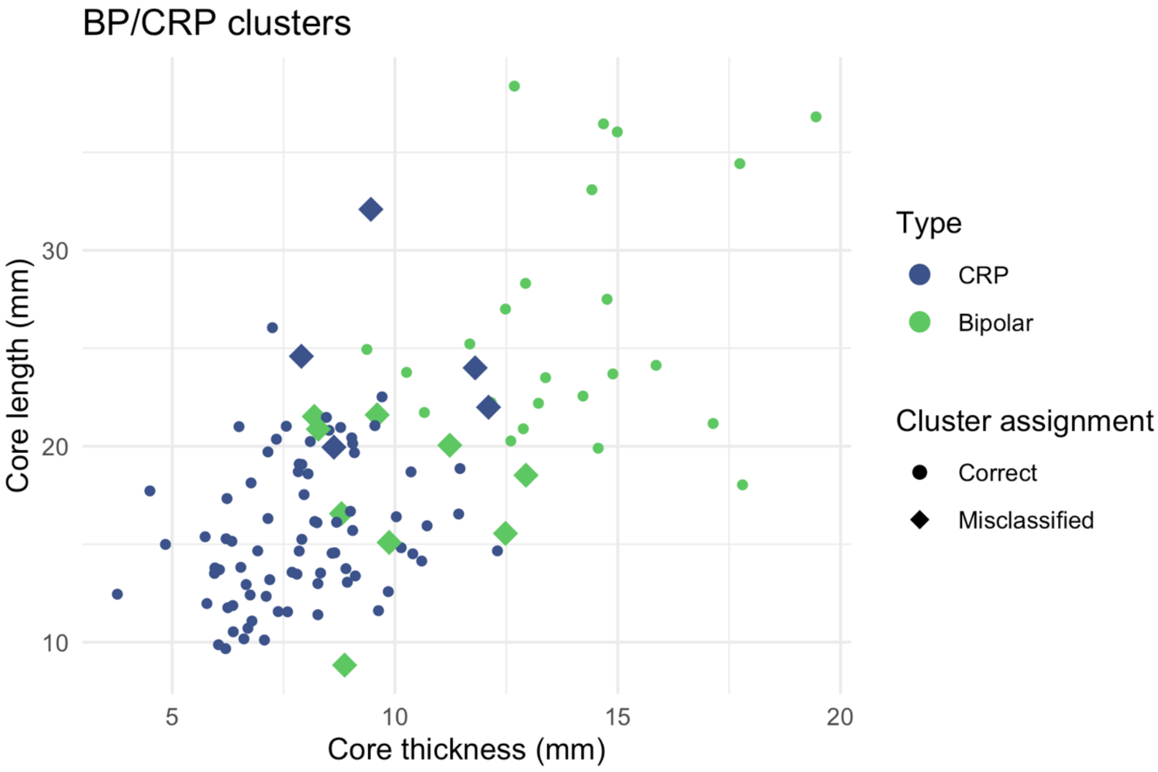
Bipolar Cores vs. CRPs

When all core types are used in cluster analyses, CRPs show extraordinary stability in clustering – they are rarely misclassified. I wanted to further investigate the concept of a size threshold between CRPs and bipolar cores by removing the "noise" produced when freehand cores were included. Because excluding freehand cores also excluded most of the size outliers present in the previous analysis, PAM and kmeans were compared to determine the most parsimonious clustering technique. The clValid() function (clValid package; Brock et al., 2008) found that kmeans with two clusters was a marginally better fit than PAM, with an average silhouette width score of 0.514. The kmeans() function (stats package; R Core Team, 2021) was used to perform the analysis. I predicted that the bipolar cores should belong to the cluster with the greater mean dimensions and that the CRPs should belong to the smaller cluster. Under this prediction, the overall error rate for the cluster solution is 12.2%. This is significantly lower than the error rates the PAM cluster analysis using all three core types (Table 35). Bipolar cores, again, were more likely to be misclassified than CRPs.

Table 35 Mean dimensions and cluster assignments for kmeans clusters.

	Core length	**Core width**	**Core thickness**	**CRPs**	**Bipolar cores**
Cluster 1 (n=86)	15.75 mm	11.43 mm	8.10 mm	77	**9**
Cluster 2 (n=29)	26.03 mm	19.33 mm	13.27 mm	**5**	24

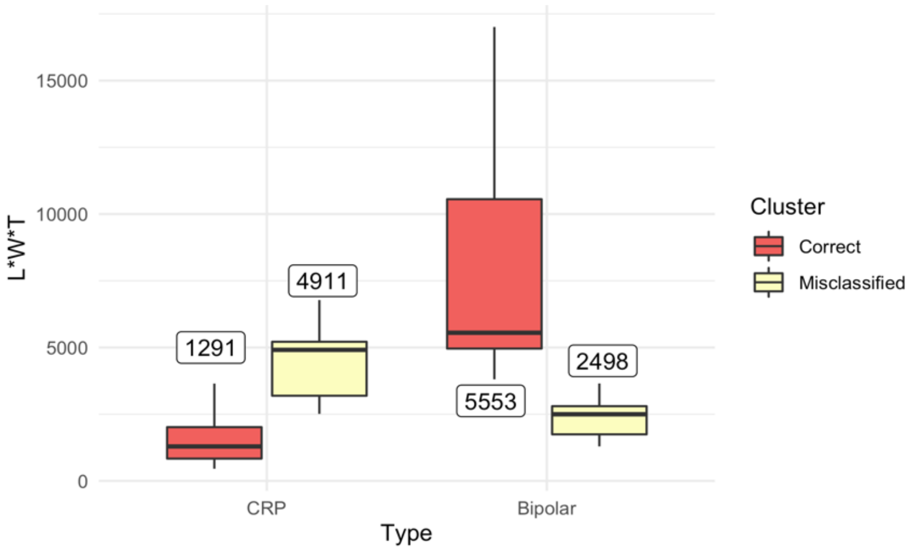
Figure 26 Bipolar core and CRP clusters and dimensions.



The cores misclassified during clustering could be the result of analyst subjectivity (the line dividing the two core types is somewhat vague), but likely represent the dimensional threshold at which point bipolar cores become CRPs. Figure 26 shows the dimensions of the bipolar cores and CRPs in contexts 6-8. Length and thickness were chosen as the variables for plotting because the multilinear logistic regression model identified significant odds ratios associated with them, but not for width. The misclassified cores fall into a range of 8-13 mm in thickness and are less than ~32 mm in length. There are no CRPs >12.5 mm in thickness, but all five misclassified bipolar cores fall under this threshold. There is a hard "stop" at ~8mm in thickness, below which all cores are CRPs. This boundary does not exist for core length. The shortest core in the assemblage at x=9, y=9 is bipolar. It appears out-of-place but is >16 mm in width.

Core length, width, and thickness were multiplied to find the estimated volume (EV, in mm^3) for each core to see where misclassified cores fell in comparison to properly classified cores. The median EV for the misclassified bipolar cores, 2498 mm^3, is well below the median EV for the properly classified bipolar cores, 5553 mm^3, and falls closer to the properly classified CRPs

Figure 27 Estimated core volume and median values (mm).



(median EV=1291 mm^3). The misclassified CRPs (median EV=4911 mm^3) are likewise more similar to the properly classified bipolar cores. Based on these overlaps, the “grey area,” or threshold in which cores are frequently misclassified or typology becomes completely subjective, is within the range of 2498-4911 mm^3. The actual dimensions of the cores representing the median EV (2717.08 mm^3) of all misclassified specimens are 21.52 x 14.94 x 8.18 mm and 20.05 x 12.44 x 11.23 mm.

If CRPs are interpreted as the end-result of extensive bipolar reduction, then thickness is the most important variable determining core exhaustion. Cores under ~8mm in thickness, regardless of their measurements in other dimensions, cannot be further reduced. If knappers were trying to save raw material, then they should attempt to reduce cores as much as possible in the other dimensions before reaching this threshold. The fact that there are CRPs well-within the range of bipolar core length and width suggests that this was not the case.

Bladelet Products

Bladelet Cores

Bladelet cores are present in both contexts 5 and 6-8. Laminar removals exist on a variety of core types, including bipolar cores, multidirectional cores, platform cores, and parallel cores. This is consistent with Pargeter and Redondo's (2016) analysis of Sehonghong bladelets, which determined that the costs of bladelet production at that site were also distributed across multiple technologies. Bladelet cores were not anticipated as a significant component of the Melikane assemblage. They were noted in the database when found, but were not classified using the same bladelet core typology as previous LSA studies in southern Africa (Carter et al., 1988; J. Deacon, 1984b; P. J. Mitchell, 1988a, 1995). It is likely that additional cores with bladelet removals exist in the Melikane assemblage but were subsumed under a different, primary type. After the lithic analysis was complete, a sample of bladelet cores was photographed for each context. These photographs provide the best evidence for the type of bladelet reduction at Melikane.

Figure 28 Single-platform "high-backed" bladelet core from Melikane's context 5. Note the wedge-shaped striking platform and crushing/scraper-like edge damage.

In total, 15 bladelet cores were recorded in context 5, and six were recorded in contexts 6-8. As previously stated, the actual prevalence of bladelet cores is likely much higher than these numbers. In context 5, seven of the 15 bladelet cores were single platform cores. Multidirectional cores were the second-most-common (n=4), followed by opposed platform cores (n=3) and one initial core. Some of these appear to be the "high-backed" bladelet cores recorded in the Robberg and in level BAS at Sehonghong (Mitchell, 1995). The bladelet cores from contexts 6-8 are more diverse in type. Bipolar (n=1), multidirectional (n=2), opposed platform (n=1), single platform (n=1), and parallel-bidirectional (n=1) cores were recorded.

Although bladelet cores are a strong indicator of LSA-type technologies, it is now acknowledged that bladelet production in southern Africa has deep roots in the MSA (Mitchell, 1994, 1995). Bladelet cores were recorded in the final MSA (level Ru) at Rose Cottage Cave (A. M. B. Clark, 1997a), as well as “transitional” levels OS, MOS, and RFS at Sehonghong (Mitchell, 1996). At both RCC and Sehonghong, the true Robberg is separated by an increased frequency of bladelet cores and bladelets, alongside changes in the formal toolkit such as the abandonment of MSA knives in favor of smaller scrapers. Due to the extremely intense core reduction present at Melikane, it is improper to make an argument for or against assignment to the LSA based solely on bladelet core frequencies. Many of these Melikane cores may once have had bladelet removals but became shorter and smaller as they were further reduced. Thus, bladelet core frequencies at Melikane may be measuring reduction intensity, not the actual degree of bladelet production. This might also be true in Sehonghong’s transitional contexts, which have similarly high frequencies of bipolar cores and core-reduced pieces (Mitchell, 1995).

Despite a low overall frequency of bladelet cores at Melikane, the presence of “high-backed” or “wedge-shaped” cores provides compelling evidence for ties to the Robberg (Figure 28). These cores, which were initially called “high-backed scrapers” by Deacon (1978), exhibit crushing along their striking platform that can resemble scraper-like use. Images of these cores show that angle between the striking platform and removal surface is often less than 90º, resulting in a distinct “wedge shape” (J. Deacon, 1978, 1984b; P. J. Mitchell, 1995; Pargeter & Redondo, 2016). Level BAS in Sehonghong was separated from the site’s transitional industries based on the sudden appearance of these cores in the assemblage (Mitchell, 1995). If the same criterion is applied to Melikane, then context 5 belongs to the same industry.

Bladelet Frequencies and Definitions

Because of conflicting views of what constitutes a “bladelet” or a “blade,” laminar products were not separated from other products during the analysis of the measured artifacts from squares S5 and S6. “Bladelets” are defined by variable criteria at different southern African sites, which makes counting and comparing frequencies difficult. J. Deacon (1984b, p. 375) defined a bladelet in southern African as “a narrow parallel-sided flake with a length greater than twice the maximum width and a width of less than 12 mm”. Mitchell (1995) includes flakes with tapered tips as bladelets. When a length cut-off is used, 25mm is normally the maximum (Pargeter and Redondo, 2016), although A.M.B. Clark (1997) used 26mm in her work at Rose Cottage Cave.

In total, absolute length and maximum width were recorded for 193 blanks >10mm in length in context 5 and 117 blanks >10cm in length in contexts 6-8. Using Mitchell's (1994, 1995) criteria - 25mm in absolute length, 12mm in maximum width, and a length/width ratio > 2 - there are 13 complete bladelets in context 5 and 9 in contexts 6-8, comprising 6.7% and 7.7% of whole blanks >10mm in the contexts respectively. These numbers sound small, but there are few laminar blanks in general in the Melikane assemblage. 76.5% of laminar blanks in context 5 and 60% in contexts 6-8 were bladelets. Melikane's contexts 5 and 6-8 have bladelet frequencies comparable with the early Robberg layer BAS at Sehonghong. Using the data in Mitchell (1995, p. 31 Table 2), 7.5% of unmodified blanks and fragments in level BAS were bladelets. In the Sehonghong transitional assemblages, bladelets are less common, comprising ~4.73%, 4.26%, and 3.47% of unmodified flakes >10mm in levels OS, MOS, and RFS respectfully (P. J. Mitchell, 1994a).

Table 36 Blade and bladelet frequencies for MLK and SEH (data from Mitchell, 1994, 1995).

Level/context	Bladelets	Blades	Bladelet %	% blanks
Context 5	13	4	76.5%	6.7%
Contexts 6-8	9	6	60%	7.7%
BAS	836	116	87.8%	7.5%
OS	15	21	41.7%	4.73%
MOS	46	38	54.8%	4.26%
RFS	7	15	31.8%	3.47%

However, the 25/12 mm cut-off is not universal in southern Africa, and a typological approach prevents the detection of change within the bladelet assemblage. Furthermore, bladelets are extremely fragile and potentially more prone to post-depositional damage than blades. Differences in post-excavation storage or in excavator skill could skew blade/bladelet proportions. Bladelet frequencies are also dependent on the artifact size cut-off used in any particular assemblage. For example, in the Elands Bay Cave Robberg, the high bladelet frequency of 55% only includes flakes >2cm (Porraz, Igreja, et al., 2016). If this cut-off were applied at Melikane, then bladelets comprise 16.1% of context 5 and 10.9% of contexts 6-8 blanks. Pargeter and Redondo (2016) problematized bladelet frequencies at Sehonghong and showed via a contextual kmeans cluster analysis approach that defining bladelets based on the 25mm cut-off prevented the detection of subtle variability and change. Following Pargeter and Redondo (2016), the kmeans cluster analysis approach was used on the Melikane assemblage under the assumption that the clustering algorithm would identify two clusters, one comprised of smaller, unretouched flakes (bladelets) and another comprised of blades. The goals of this analysis were multifold: to assess the validity of the arbitrary 25mm cut-off, uncover subtle changes in the Melikane blade and bladelet assemblages over time, and to compare the Melikane bladelets to those from Sehonghong rockshelter. To facilitate comparisons with Pargeter and Redondo's (2016) work, only CCS blanks with a percussive length/percussive width ratio >1.80 and length >10mm were selected for analysis.

Laminar Products From Contexts 5-8

A closer inspection of CCS blanks with a percussive length/midpoint width ratio of >1.8 from context 5 (n=48) revealed three outliers greater than 38.20mm in length ($Q_3 + 1.5*IQR$). These were removed prior to clustering. In order to confirm two clusters with kmeans as the most parsimonious solution for the data, the function clValid() in R (clValid package; Brock et al., 2008) was tested on solutions of 2-8 clusters using either kmeans or PAM. The algorithm identified PAM with two clusters and kmeans with two or three clusters as the most parsimonious methods. Kmeans with two clusters was chosen, both because it was identified as a parsimonious solution and because it had the greatest likelihood of finding meaning in the data. The kmeans() function was used to identify two clusters of sizes 33 and 12 (bss/tss = 70.5%, sil. width=0.631).

Laminar products from contexts 6-8 (n=28) were clustered using the same process as those from context 5. Outliers greater than $Q_3 + 1.5*IQR$ (36.89mm) were removed, and clValid() was used to confirm the two-cluster kmeans solution as the best fit. The algorithm suggested three clusters, but the criteria for two versus three clusters are extremely close. For example, the silhouette score for two clusters is 0.534, versus 0.545 for three clusters. The function NbClust() from the *NbClust* package (Charrad et al., 2014) also identified kmeans with two clusters as the second-best solution. Therefore, although kmeans with two clusters might not be the *best* solution, it is still an appropriate solution in this case, and allows comparison with context 5.

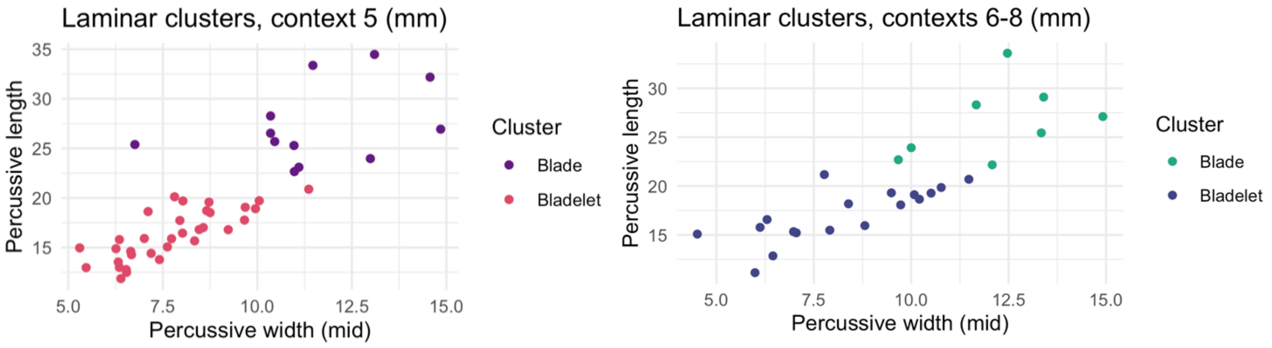
Table 37 Laminar product dimensions by cluster.

	Percussive length	**Percussive width (mid)**	**Max thickness**
Context 5 bladelets (n=33)	Mean: 16.31 Min: 11.86 Max: 20.88	Mean: 7.76 Min: 5.3 Max:11.36	Mean: 4.88 Min: 1.44 Max: 11.00

Context 5 blades (n=12)	Mean: 27.32 Min: 22.66 Max: 34.47	11.50 6.76 14.85	7.03 3.51 13.82
Contexts 6-8 bladelets (n=18)	Mean: 17.09 Min: 11.13 Max: 21.17	8.25 4.51 11.48	4.76 2.00 11.31
Contexts 6-8 blades (n=8)	Mean: 26.54 Min: 22.17 Max: 33.59	12.19 9.67 14.92	6.84 4.65 10.28

Three blanks from context 5 fitting the standard "bladelet" definition (<25mm) were assigned to the larger cluster with blades (Table 37, Figure 29). The longest blank classified as a "bladelet" measures 20.88mm in percussive length and 11.36mm in percussive width. The Kmeans algorithm also "misclassified" three bladelets from contexts 6-8. The longest bladelet measured 21.17 mm, and the shortest blade measured 22.17 mm. When the bladelet clusters from both contexts are compared, their means do not differ significantly for either percussive length (Mann-Whitney, p=0.260) or width (p=0.402). The methodological conclusions drawn from these results is that, like Pargeter and Redondo (2016) surmised, 25mm is an arbitrary cut-off that cannot necessarily be transferred between sites and datasets. When blanks were clustered based on their similarities and dissimilarities, they did not separate on the 25mm cut-off, but at a ~21-22mm cut-off. Unlike the 25mm cut-off, these cut-offs are based on actual similarities and dissimilarities in the data. Rather than simply counting the frequency of artifacts above and below this boundary and comparing blade/bladelet ratios, which allows only for a crude understanding of microlithization over time, studying the movement of this boundary has the potential to show subtler changes.

Figure 29 Dimensions of laminar clusters, contexts 5 and 6-8.



MSA Laminar Products

The extensive MSA sequence at Melikane provides the opportunity to study the process of microlithization at Melikane over a longer period. The assemblages dated to MIS 5a (~80 ka) capture the essence of an informal, yet idiosyncratic MSA toolkit. Two other contexts, 28 and 25, were also chosen for study. The MIS 5a contexts (29-33) were previously published in Pazan et al. (2022). The assemblages boasts a total of 94 complete laminar CCS blanks. One outlier >58.67mm in percussive length was removed prior to clustering. Both clValid() and NbClust() recommended kmeans with two clusters as the most parsimonious method (bss/tss=65.6%, sil. width = 0.571). The "bladelet" cluster (n=65) had a mean percussive length of 24.16 mm and a maximum length of 33.30mm (Table 38). One shorter blank measuring 32.38 mm was classified as a "blade" (n=28).

Table 38 MSA laminar product dimensions.

Phase/Context	Cluster	Percussive length	Percussive width (mid)	Max thickness
Fluorescent Howiesons Poort (~60 ka) *Context 25*	Bladelets (n=20)	Mean: 24.50 Min: 15.86 Max: 29.92	8.44 5.64 12.40	3.52 1.90 6.17
	Blades (n=9)	Mean: 36.27 Min: 31.02 Max: 40.39	14.03 9.70 22.02	5.00 2.72 7.52
Early Howiesons Poort (78~60 ka?) *Context 28*	Bladelets (n=26)	Mean: 23.35 Min: 11.90 Max: 31.39	10.28 4.32 15.00	4.13 1.32 10.92
	Blades (n=26)	Mean: 37.52 Min: 30.84 Max: 49.20	14.79 6.33 22.77	7.01 2.89 11.66
MIS 5a (~80k) *Contexts 29-33*	Bladelets (n=65)	Mean: 24.16 Min: 13.05 Max: 33.30	9.93 3.95 16.05	4.22 1.86 10.06
	Blades (n=28)	Mean: 41.77 Min: 32.38 Max: 58.34	16.96 11.73 25.76	7.81 2.01 17.26

Context 28 was previously analyzed by the author but remains unpublished. Its precise date is unknown. It may belong to an earlier phase of the MIS 5a occupation, but the character of its artifacts suggests a date during MIS 4. It is distinguished from the MIS 5a contexts by an increase in CCS frequency to 62.8% of all artifacts (up from 35.9%), the presence of unretouched points as the most common tool type other than borers, the prominence of parallel cores (57.8% of complete cores), and excavation notes describing a geometric pseudo-segment. In contrast, points, prepared cores, and segments are rare in the MIS 5a assemblage. Context 27, which bears distinct Howiesons Poort characteristics including frequent backed artifacts, separates context 28 from context 25. Context 25 is the "heart" of the Howiesons Poort at Melikane, dating to 60 ± 2.5 ka (Stewart et al., 2012). The Howiesons Poort is sometimes considered as a "false start" towards the LSA and has the potential to show evidence of microlithization long before the Robberg.

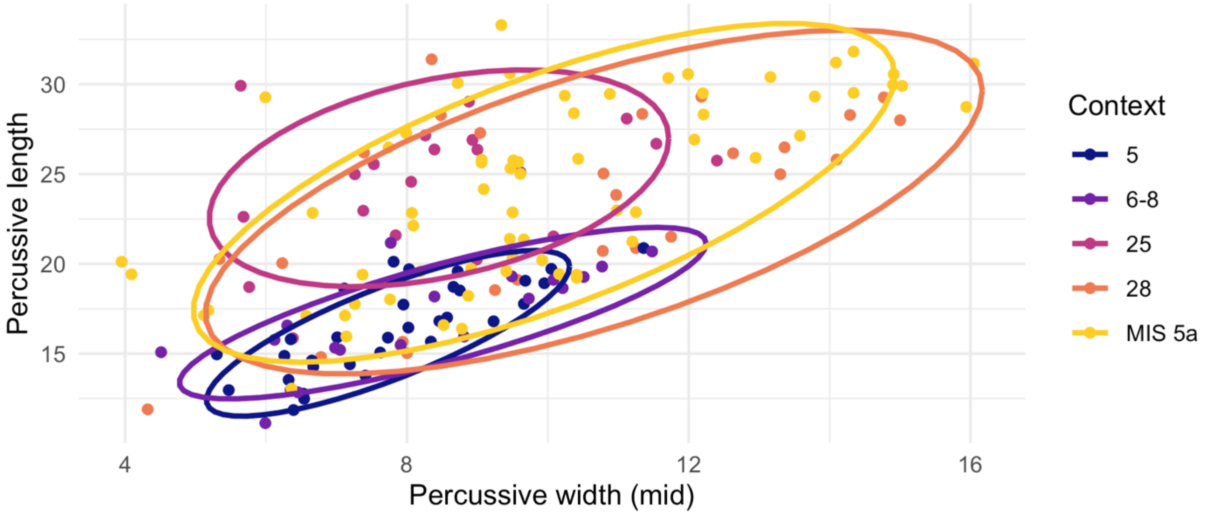
Fifty-four complete CCS blanks with a percussive length/width ratio >1.8 were recorded in context 28. Two outliers were removed based on percussive length. The NbClust() function found that a plurality of eight clustering indices recommended using kmeans with three clusters. Six indices recommended kmeans with two clusters. These results were cross-checked with clValid(), which instead recommended kmeans with two clusters. The two-cluster solution was chosen for continuity (between SS/total SS= 57.2%, sil. width=0.451). Two clusters of 26 artifacts each were identified. The maximum length of blanks in the "bladelet" cluster is 31.39mm. One shorter blank (30.84 mm), however, was placed into the "blade" cluster. Twenty-nine laminar blanks were randomly selected and measured from context 25, which had been previously sorted by the author based on typology. No outliers were present. Both NbClust() and clValid() both recommended kmeans with two clusters (BSS/TSS=67.8%, sil. width = 0.587). The longest bladelet measured 29.92mm, and the shortest blade measured 31.02mm (Table 38).

There are no significant differences in the lengths of any of the MSA "bladelets" ($p>0.05$), but their widths are significantly different ($p=0.026$, $p=0.022$). "Bladelets" from context 25 are narrower than those from context 28 and the MIS 5a contexts. This difference in width could reflect a change in hafting styles during the Howiesons Poort, or prioritization of raw material efficiency (Muller & Clarkson, 2016). The "bladelet"/blade threshold drops consistently through the MSA, from ~33 mm in MIS 5a to <30 mm in context 25.

Contexts 5-8 Versus the MSA

The distinctly LSA character of contexts 5 and 6-8 is visibly apparent in the differences between the blade/bladelet thresholds and in the mean percussive lengths for the bladelet clusters. Although there is a continuous trend in microlithization through the MSA at Melikane, two major "gaps" stand out in the data: a "width gap" between contexts 28 and 25, and a "length

Figure 30 Dimensions (mm) of "bladelet" clusters in Melikane MSA and LSA contexts, surrounded by 85% confidence ellipses (multivariate distribution).



gap" between contexts 25 and 6-8. The "width gap" is best interpreted as a side effect of a change in hafting styles during the Howiesons Poort or as a sign of increased raw material efficiency. The "length gap" shows a sudden shift in what constitutes "small" across the MSA/LSA transition. The fact that the bladelets from contexts 6-8 are statistically indistinguishable from those in context 5, but are very different from those in context 25, highlights its distinction from the MSA at Melikane. The subtle changes between 6-8 and 5, including slight decreases in mean length and mean width, suggest that microlithization continues into the LSA.

Table 39 Dimensions for Melikane bladelet clusters (mm). (Cut-off = (longest bladelet + shortest blade)/2.)

	Length cut-off	**Max length**	**Mean length**	**Max width**	**Mean width**	**BSS/TSS**
5	21.77	20.88	16.31	11.36	7.76	70.5%
6-8	21.67	21.17	17.09	11.48	8.25	64.7%
25	30.47	29.92	24.50	12.40	8.44	67.8%
28	31.12	31.39	23.35	15.00	10.28	57.2%
29-33	32.84	33.30	24.16	16.05	9.93	65.6%

Comparisons With Sehonghong Rockshelter

The Sehonghong bladelets discussed here were obtained from two excavation squares, I12 and I13, and measured by Justin Pargeter. Dr. Pargeter kindly shared his raw data from his initial Sehonghong bladelet analyses (Pargeter and Redondo, 2016) for technological length and width at the midpoint. Five Sehonghong levels are clustered and discussed here: RFS (31.2-28.1 kcal

BP), MOS (24.9-24.1 kcal BP), OS (24.5-24 kcal BP), BAS (24.3-23.1 kcal BP), and RBL-CLBRF (16.2-14.6 kcal BP) (Pargeter et al., 2017). Previously, RFS, MOS, and OS have been assigned to the MSA/LSA transition, and BAS and RBL-CLBRF to the Robberg (P. J. Mitchell, 1994a, 1995, 1996b). The date of 24.2-23.6 kcal BP from Melikane's contexts 6-8 potentially overlaps with MOS, OS, and BAS. Context 5, therefore, is likely to be no older than BAS.

Pargeter and Redondo's cluster analyses were reperformed on the raw data using the same clustering and selection criteria used for the Melikane analyses. Artifacts under 10mm in length were filtered out, and outliers from each level were removed as necessary. Kmeans with two clusters was a parsimonious solution for each level except OS, in which 3 or 5 clusters were chosen by *clValid()* and *NbClust()* (Table 40). OS also had the lowest sample size of 21 artifacts (tied with MOS). The clustering results for OS should thus be interpreted carefully.

Table 40 Cluster information for Sehonghong data.

	N	Outliers?	clValid	NbClust	Bss/tss %	Sil width
RFS	26	No	Pam 2, kmeans 3	Kmeans, 2 or 3	72.6%	0.638
MOS	21	No	Kmeans 2, pam 5.	Kmeans, 2.	71.4%	0.568
OS	21	No	Pam, 2, kmeans, 5.	Kmeans, 3.	63.3%	0.490
BAS	28	Yes, 2 (>37.11).	Pam, 2, kmeans, 4.	Kmeans, 2.	69.3%	0.608
RBL_CLBRF	45	Yes, 2.	Pam, 2 or 5.	Kmeans, 2.	65.1%	0.543

Table 41 Length and width cut-offs for MLK and SEH bladelets.

Site	Context	Date (kcal BP)	Length cut-off	Width cut-off	Mean length	Mean width	L/W ratio	AQlw	Bladelet %
MLK	**5 (n=33)**	<24?	21.77	9.06	16.31	7.76	2.12 SD: 0.25	0.712 CV: 0.139	73.3%
	6-8 (n=18)	24.2-23.6	21.67	10.58	17.09	8.25	2.14 SD:0.42	0.707 CV: 0.209	69.2%
SEH	**RBL-CLBRF (n=26)**	16.2-14.6	25.33	8.96	17.55	5.77	3.17 SD: 0.83	1.00 CV: 0.202	60.5%
	BAS (n=20)	24.3-23.1	21.83	7.79	15.36	5.79	2.87 SD: 1.08	0.903 CV: 0.270	76.9%
	OS (n=12)	24.5-24	19.62	8.10	15.09	7.23	2.13 SD: 0.38	0.709 CV: 0.197	57.1%
	MOS (n=11)	24.9-24.1	24.00	10.06	16.96	7.38	2.30 SD: 0.28	0.778 CV: 0.136	52.4%
	RFS (n=19)	31.2-28.1	24.71	11.69	17.21	8.06	2.14 SD: 0.26	0.720 CV: 0.135	73.0%

After clustering was completed, a "length cut-off" and a "width cut-off" were calculated for each level. Each cut-off is defined as the average of the largest bladelet and smallest blade in a particular dimension. Level OS had the lowest bladelet length cut-off of 19.62mm, followed by BAS at 21.83mm (Table 41). This is comparable to the length cut-offs from contexts 5 and 6-8 of 21.77 and 21.67mm respectively. The mean length of BAS bladelets (15.36mm) is less than that of the Melikane bladelets (16.31 and 17.09 mm), however, and the BAS bladelets also tend to be narrower. The Melikane bladelets are more similar in mean width to the MOS and RFS bladelets, but width is less related to cluster assignment than length, and the ranges for width among blades and bladelets overlap in every context. Interestingly, the post-LGM layer RBL-CLBRF had the highest length cut-off of any of the levels at 25.33mm. This is consistent with Pargeter and Redondo's (2016) argument that bladelet tasks, and thus morphology, changed significantly after 18 kcal BP. They speculate that decreases in the frequency of bipolar technology may also be responsible for morphological changes, which tracks with RBL-CLRBF's relatively low bipolar core frequency in comparison to the other levels at Sehonghong (Pargeter et al., 2017).

The Sehonghong and Melikane foragers had access to similar CCS cobbles, and thus the sizes of bladelets at each site are comparable. As discussed above, both Melikane contexts have length cut-offs comparable to those of levels BAS and OS, but the Melikane bladelets tend to be wider. When length/width ratios are compared between levels and contexts, context 5, contexts 6-8, OS, MOS, and RFS all average between 2.12-2.30 and have standard deviations under 0.42. BAS marks a significant departure from this morphology, with a mean length/width ratio of 2.87 and a standard deviation over one. Length/width ratio rises again in RBL, and the standard deviation remains high. A Dunn Test shows these differences are statistically significant for 5, 6-8, OS, and RFS vs. BAS ($p=0.002$, 0.001, 0.005, 0.01), as well as 5, 6-8, MOS, OS, and RFS vs. RBL ($p<0.001$, <0.001, $p=0.01$, $p<0.001$, <0.001). BAS and RBL are not statistically different from one another, nor are there pairwise differences between 5, 6-8, RFS, MOS, and OS.

This separation in length/width morphology between BAS and RBL and the earlier contexts is not anticipated by Pargeter and Redondo's (2016) work. Instead, the authors found that the asymmetry quotients for length/width did not differ between BAS and the transitional contexts but did differ between BAS and the post-LGM contexts. For consistency, asymmetry quotients (AQs) for length and width were calculated for the data discussed here, but a Dunn Test ($p<0.001$) produced a similar result as the Dunn Test for length/width ratios. RBL was significantly different from every context except BAS, and BAS was significantly different from contexts 5, 6-8, OS, and RFS. MOS, however, was not statistically different from any context except RBL. The discrepancy between the asymmetry quotients discussed here and those in Pargeter and Redondo's (2016) paper could be attributed to the use of only CCS flakes in this study, my choice to remove outliers, or the larger discrepancy in sample sizes in the 2016 study.

The standard deviations for length/width ratio and coefficients of variation (CVs) for AQ show that bladelet length/width morphology fluctuates in its degree of standardization over time. Context 5, RFS, and MOS have similarly low standard deviations and CVs. Contexts 6-8, OS, and RBL have slightly higher values, and BAS is the least standardized of all the contexts. Greater variation in the BAS sample could be due to a change in bladelet reduction strategies. Bipolar percussion does become infrequent in BAS, but this should result in *more*, not less, standardization (Pargeter et al., 2017). Another notable change in BAS is the introduction of the high-backed bladelet core into the Sehonghong lithic repertoire (Mitchell, 1995; Pargeter and Redondo, 2016). These cores are absent in contexts 6-8, OS, MOS, and RFS (P. J. Mitchell, 1995). However, their presence in Melikane's context 5, which has highly standardized bladelets, precludes this as a sole explanation.

BAS was assigned to the Robberg by Mitchell (1995) partly because of its greater emphasis on bladelets than the earlier contexts. However, Pargeter and Redondo (2016) and Mitchell (1995) also argue simultaneously that BAS did not represent a severe break with the "transitional" industries. My reanalysis of the Sehonghong bladelet data supports both statements. Bladelets do comprise a larger percentage of blanks in BAS than in the transitional industries, and the blade/bladelet threshold does decrease over time, but the most prominent drop in bladelet length occurs in transitional level OS. BAS also has the greatest percentage of artifacts in its bladelet cluster, but blade/bladelet proportions do not differ significantly from the transitional industries (RFS: p=1, OS: p=0.258, MOS: p=0.126). However, this analysis identified a distinct change in bladelet morphology that suggests that BAS should remain distinct from the earlier levels: a decrease in width, occurring between OS and BAS. This shift is the best argument for drawing a distinction between BAS and the earlier contexts. Because narrower flakes produce more cutting edge per unit mass, this may reflect a shift to a reduction strategy more geared towards optimizing raw material efficiency (Muller & Clarkson, 2016).

This analysis also confirms similarities between contexts 5, 6-8, and the Sehonghong levels. When the length cut-off of 25mm is used, contexts 5 and BAS have the most bladelets relative to blades. These two levels still have the highest bladelet frequencies when the cluster analysis approach is used and have similar frequencies of bladelets overall. Context 6-8 is not far behind in terms of its bladelet frequencies, and certainly has a heavier focus on bladelets than any of the Sehonghong transitional industries. Using the cluster analysis approach, the bladelet length cut-offs for contexts 5, 6-8, and BAS are also similar. The main difference between BAS and Melikane's contexts is in bladelet width. As previously noted, this may reflect a difference in core reduction strategies or a heavier focus on raw material economy in BAS.

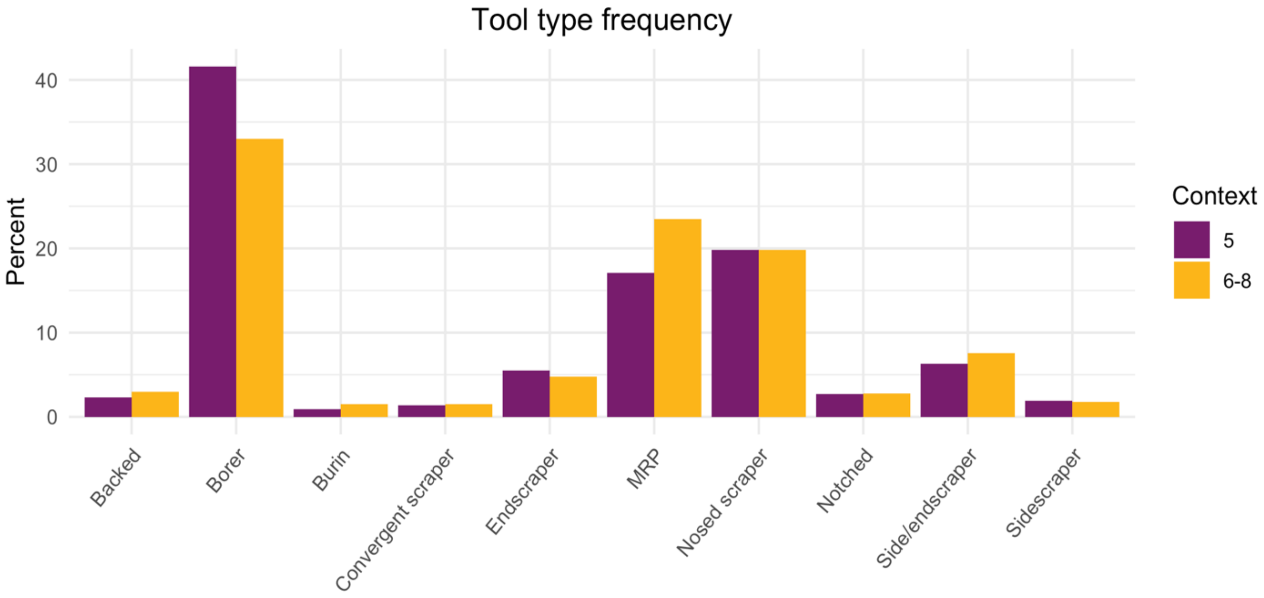
Chapter 6: Reconstructing the Melikane Toolkit

Table 42 Tool types by context.

Tool type	Context 5		Contexts 6-8	
	N	*%*	*N*	*%*
Point	3	*.1*	4	*.1*
Hammerstone	0	*0*	1	*<.1*
Backed	56	*2.3*	102	*3.0*
Borer	1012	*41.6*	1135	*33.0*
Burin	21	*.9*	51	*1.5*
Denticulate	5	*0.2*	11	*0.3*
MRP	416	*17.1*	808	*23.5*
Nat. backed	2	*<0.1*	5	*0.1*
Notched	66	*2.7*	96	*2.8*
Convergent scraper	35	*1.4*	52	*1.5*
Endscraper	134	*5.5*	166	*4.8*
Nosed scraper	480	*19.8*	682	*19.8*
Sidescraper	46	*1.9*	62	*1.8*
Side/endscraper	154	*6.3*	261	*7.6*
	2430		3436	

A total of 5,865 retouched artifacts and one hammerstone were recorded in contexts 5 and 6-8 (Table 42, Figure 31). Retouch is significantly more frequent in contexts 6-8 (p <0.001). In both contexts, borers were the most common tool type (41.6% and 33% respectively), followed by miscellaneous retouched pieces (MRPs; 17.1%, 23.5%) and nosed scrapers (19.8%, 19.8%). A Pearson's chi-squared test eliminating tool categories with <1% representation produced a p-value <0.001. A posthoc test showed significant residuals for the cells including borers and MRPs, but not for other tool types.

Figure 31 Tool type frequency by context.



Although borers are still the most common tool type in context 6-8, they become even more prominent in context 5, at the expense of MRPs. This may reflect greater standardization in tool types in the latter context. Other changes in tool type frequency are subtle. As endscrapers increase in frequency in context 5, side/endscrapers decrease in frequency. Nosed scrapers, convergent scrapers, and sidescrapers retain similar proportions. Backed tools and burins are slightly more common in contexts 6-8 than in context 5. In neither context do points (including unretouched Levallois and retouched forms) form a significant portion of the tool assemblage. One hammerstone with evidence of use in bipolar percussion was found in contexts 6-8.

Artifacts are more or less frequently retouched depending on raw material. Overall, CCS artifacts are less likely to be retouched than hornfels artifacts. For instance, in context 5, 26.5% of all CCS artifacts are retouched, as compared to 42.5% of all hornfels artifacts (Table 43). Pairwise z-tests comparing the frequencies of retouch for each raw material type confirm that these differences are significant across all raw materials in both contexts. The only exception is the proportion of retouched sandstone compared to the proportion of retouched CCS in contexts 6-8, which did not produce significant residuals in the pairwise z-test.

Table 43 Proportions of retouched artifacts for raw material categories, pairwise z-test p-values for each context, and z-test p-values for raw materials across contexts.

	5			**6-8**			**5 vs. 6-8, z-test**
	Tools	*All artifacts*	*%*	*Tools*	*All artifacts*	*%*	
CCS	1758	6572	*26.7*	2042	5891	*34.7*	**P<.001**
Hornfels	462	1086	*42.5*	832	1674	*49.7*	**P<.001**
Sandstone	201	611	*33.4*	537	1454	*36.9*	P=0.090
Other	9	88	*10.2*	25	179	*14.0*	P=0.505
Total	**2430**	**8357**	***29.1%***	**3436**	**9198**	***37.4%***	**P<.001**
	Pairwise z-test: p<0.001. All residuals sig.			***Pairwise z-test: p<0.001. All residuals sig. except sandstone/CCS.***			

The overall frequency of retouch is higher in contexts 6-8 (p<0.001). However, this could be because hornfels, which is more commonly retouched than CCS, is also more common in those contexts. Yet, when raw materials are considered individually, the frequency of retouch is still greater in context 6-8. Hornfels is retouched at a significantly lesser rate in context 5 (p<0.001), as is CCS (p<0.001). The frequencies of retouch for sandstone and other raw materials do not change significantly. Thus, the greater retouch frequency in contexts 6-8 is not merely the product of an overall shift in raw material preferences and can be seen in the most common material types individually.

A related question deals with the rate of change in raw material frequencies between contexts. Does CCS become more common among all tools *at the same rate* as it does in the assemblage as a whole? Simply put, do changes in raw material frequency in the tool assemblage track with changes overall? To answer this question, the percent change in material frequency was calculated for both CCS and hornfels for tools and non-tools. Percent change in frequency (%) for a given material (m) was calculated as:

$$\frac{\left(\frac{m\ tools\ in\ context\ 5}{all\ tools\ in\ context\ 5}\right)-\left(\frac{m\ tools\ in\ context\ 6-8}{all\ tools\ in\ context\ 6-8}\right)}{\left(\frac{m\ tools\ in\ context\ 6-8}{all\ tools\ in\ context\ 6-8}\right)}\times 100$$

Table 44 Percent change in hornfels frequency.

	Tools	Non-tool artifacts
Context 5	462/2430 (19.01%)	624/5918 (10.5%)
Context 6-8	832/3436 (24.2%)	842/5762 (14.6%)
% change	*-21.49%*	*-28.08%*

Table 45 Percent change in CCS frequency.

	Tools	Non-tool artifacts
Context 5	1758/2430 (72.3%)	4814/5918 (81.3%)
Contexts 6-8	2042/3436 (59.4%)	3849/5762 (66.8%)
% change	*+21.72%*	*+21.71%*

CCS frequency changes at a nearly identical rate among both tools and non-tools, decreasing by ~21% in context 5 (Table 45). Hornfels frequency, however, decreases at a greater rate among non-tool artifacts (-28.08%) than it does for tools (- 21.49%) (Table 44). This pattern, along with hornfels' disproportionate representation in the tool assemblage as a whole, suggests that it was preferred for toolmaking over other material types.

Reduction Intensity

Because some tool "types" may actually be stages in the production of life of a single finished type (c.f. Dibble, 1987), interpretations based solely on typologies should be cautioned without a better understanding of the extent of reduction in each assemblage (Tostevin, 2012). This is the so-called "Frison Effect" (Frison, 1978). To this end, numerous reduction indices have been developed to measure the flake mass lost through retouch. Most are inexact, like Davis and Shea's (1998) flake-tool mass predictor, or ill-suited to tool types for which they were not developed, like Clarkson's (2002) Index of Invasiveness designed for bifacial tools. Many also require numerous measurements of individual retouch scars or thicknesses on particular points of a tool's cross-section, such as Kuhn's (1990) Geometric Index of Unifacial Reduction. Kuhn's GIUR is perhaps the most tested reduction index for Paleolithic tools, with some experiments supporting its use (Hiscock & Clarkson, 2005, 2009) and others stoutly refuting it (Eren & Sampson, 2009). Methods involving 3D scanning of tool platform areas are promising (Clarkson & Hiscock, 2011; Morales et al., 2015), but likewise have also been debated (Muller & Clarkson, 2014), and are of little use in assemblages like Melikane's with frequently retouched, undiscernible, or crushed platforms.

Tostevin's (2012) approach to reduction intensity, which looks at other aspects of a lithic assemblage instead of focusing on quantifying the amount of lost mass for each individual tool, is a more practical means of understanding reduction at Melikane. A high frequency of retouched artifacts makes taking additional measurements from each tool highly impractical, and the frequent use of bipolar percussion resulting in unclear platform morphologies would lead to biased results if 3D-scanning methods were used. I also introduce here a new index, the Edge Modification Index (EMI), which aims to quantify the percentage of a tool's total edge length that has undergone modification. EMI has a slightly different purpose than other reduction indices. Instead of trying to quantify resharpening, it attempts to assess multifunctionality and repurposing. At Melikane, most tools have multiple working edges. Counting the number of retouched edges has some utility for assessing multifunctionality, but falls short when edges are not continuously retouched, or only have a few retouch scars. EMI, however, avoids this problem and gives a more precise picture of tool morphology. Tostevin (2012, p. 147) uses four criteria for comparing reduction between assemblages: the complete tool/flake ratio, non-cortical/cortical debitage ratio, Henry's Dimensional Analysis, and proximity to raw material sources. Because proximity to raw material sources is the same for contexts 5 and 6-8 at Melikane, it is not considered here. A high tool/flake ratio assumes that many flakes have been retouched, and that therefore, there is a high degree of retouch per flake. The ratio of non-cortical to cortical debitage reflects degree of "field processing" at a site. A low ratio, in which cortical debitage is frequent, suggests either that the earlier stages of core reduction were practiced at that site, or that reduction is generally unintense. Henry's Dimensional Analysis (Henry, 1989) is actually a measurement of core reduction intensity, and compares core facet and blank size. A highly reduced assemblage will show core facets within the range of the smallest blanks. Although only the first of these three criteria is directly related to the reduction intensity of the actual tools in an assemblage, the second and third criteria help to develop a more generalized picture of overall assemblage reduction.

Because hornfels and CCS have very different signatures in terms of provisioning and retouch frequency, the two materials were separated for inter-context comparisons. Then, CCS and hornfels overall were compared against each other. The tool/flake ratio, like the overall rate of retouch, is significantly greater in contexts 6-8 for both CCS and hornfels (Table 46, Table 47). The non-cortical/cortical debitage ratios for neither raw material differ significantly between contexts. Henry's dimensional analysis could only be performed for CCS because of extremely low numbers of hornfels cores. The core facets for context 5 fall mostly within the range of the smallest blanks, with one outlier ~26 mm in length (Figure 32). The facets for contexts 6-8 are distributed more broadly across a range of sizes, including both non-cortical blanks and cortical products. However, core facets are impossible to measure on core reduced pieces, which are more common in contexts 6-8. Thus, it is unlikely that the wider range of facet sizes in contexts 6-8 is indicative of less intense reduction overall. Instead, it likely reflects less intense *freehand* reduction. Taken as a whole, these data suggest that context 6-8, with greater tool/flake ratios for both raw materials, is more highly reduced in terms of retouch than context 5.

Table 46 Reduction intensity for CCS artifacts, 5 vs. 6-8 (p-values calculated using z-tests).

	Context 5	**Contexts 6-8**	**P-value**
Tool/flake ratio	1758/3374 (0.52)	2042/2332 (0.88)	***p<.001***
Non-cortical/cortical debitage ratio	577/162 (3.56)	382/82 (4.66)	p=.087
Henry's dimensional analysis	Concentrated within range of smallest non-cortical blanks.	More dispersed among larger flakes and cortical blanks.	

Table 47 Reduction intensity for hornfels artifacts, 5 vs. 6-8.

	Context 5	**Contexts 6-8**	**P-value**
Tool/flake ratio	462/485 (0.95)	832/607 (1.38)	***p<.001***
Non-cortical/cortical debitage ratio	165/16 (10.31)	170/26 (6.54)	p=.230

Figure 32 Henry's dimensional analysis for CCS in contexts 5 and 6-8.

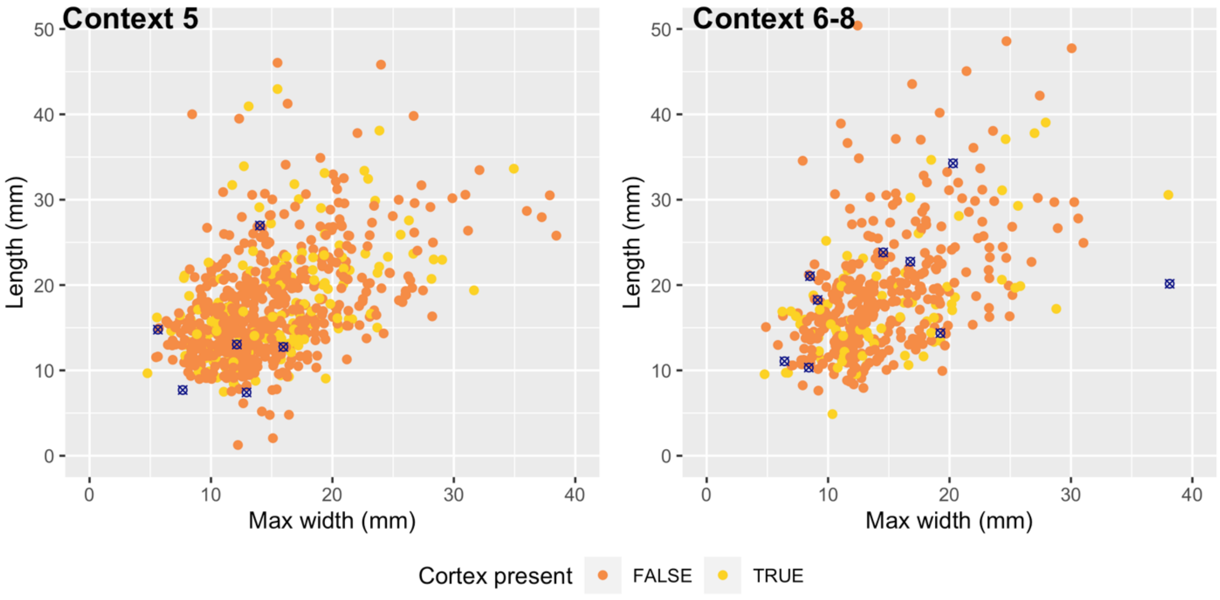


Table 48 Reduction intensity for hornfels vs CCS overall.

	Hornfels	CCS	P-value
Tool/flake ratio	1294/1092 (1.18)	3800/5706 (0.67)	**P<0.001**
Non-cortical/cortical debitage ratio	335/42 (7.98)	959/244 (3.93)	**P<0.001**

Reduction intensity also differs between raw materials. The tool/flake ratio for hornfels is significantly greater than that for CCS, as is the non-cortical/cortical debitage ratio (Table 48). Because hornfels has a significantly greater non-cortical/cortical debitage ratio than CCS, it is likely that the early stages of hornfels core processing did not occur in the shelter. CCS, however, was more likely to be transported back to the shelter and reduced there. This is consistent with the provisioning strategies proposed in Pazan et al. (2022), in which CCS was reduced at the site and coarse-grained raw materials were reduced at the source. Because the non-cortical/cortical debitage ratios do not change significantly between contexts, this provisioning system is likely stable over time and dictated by the physical forms of raw material nodules and/or distance from the source.

While Tostevin's (2012) criteria describe the degrees of tool and core reduction in lithic assemblages, the edge modification index (EMI) presented here attempts to quantify the percentage of tool edge that has been modified by retouch or use. EMI is calculated as the total modified edge length divided by the total edge length. The length of each retouched edge was recorded for each individual tool, but the total edge length had to be estimated using equations checked using the selection tool in Adobe Photoshop. Because EMI is based on an estimate of total flake perimeter, only rectilinear and convergent flakes, whose perimeters can be closely approximated using simple geometric equations, were used for analysis. Rectilinear tools were those defined by a midpoint width >80% of the maximum width and a difference of <20% between percussive and absolute lengths. Convergent tools were defined as those where midpoint width was ≤80% of the maximum width. The following equation was used to calculate the total edge length (TE) for both convergent and rectilinear tools:

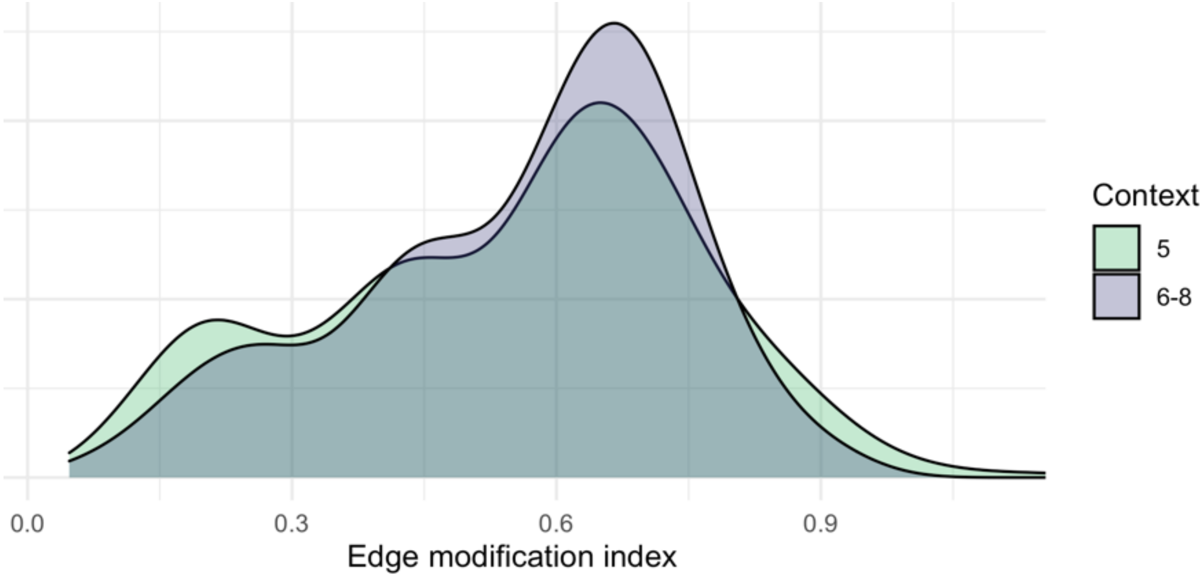
$$TE = 2(absolute\ length) + maximum\ width + width\ at\ midpoint$$

When tested against a random sample of seven photographed tools whose edge perimeters were measured using Adobe Photoshop, the equation accurately estimated total tool edge perimeter for convergent tools with a maximum error rate of 10.7% and for rectilinear tools with a maximum error rate of 3.4%. Other equations were tested for the convergent tools, but none were as accurate as the simpler TE equation presented above.

Table 49 EMI (modified length/total edge length) for convergent and rectilinear tools.

Convergent		**Rectilinear**		**Significance**
5	*6-8*	*5*	*6-8*	
Mean: 0.522 Median: 0.537 SD: 0.197 N:92	Mean:0.576 Median: 0.616 SD: 0.213 N: 128	Mean:0.549 Median: 0.595 SD:0.219 N: 396	Mean: 0.558 Median: 0.605 SD: 0.187 N: 421	*Mann-Whitney U-Test:* *Convergent, 5 vs. 6-8:* p=.10 *Rectilinear, 5 vs. 6-8:* p=.43 Fligner test: *Convergent, 5 vs. 6-8:0.6* ***Rectilinear, 5 vs. 6-8: .008***

Figure 33 EMI for rectilinear tools.



EMI was calculated for measured, whole tools belonging to either the convergent or rectilinear categories (Table 49). The two shapes were separated in statistical analyses because of their different error rates for the TE formula. Mann Whitney U-Tests did not identify any significant differences in EMI means between contexts, but a Fligner-Killeen test revealed significant differences in variance between rectilinear tools in contexts 5 and 6-8 (p=0.008). Rectilinear tools in context 5 have a lower median EMI and a greater standard deviation than those in contexts 6-8. EMIs for rectilinear tools in contexts 6-8 are less variable, with a greater concentration of tools around a higher mean. This suggests that rectilinear tools in contexts 6-8 are more likely to have a greater percentage of their total edge length modified than tools from context 5, even though the means for the two contexts do not differ significantly.

EMI is unlike other reduction indices in that it does not attempt to quantify the amount of material removed from a blank. However, it is a potentially useful proxy for reduction intensity, repurposing, and multifunctionality. In the case of an endscraper, for example, as the working edge is used, sharpened, used, and resharpened, the endscraper will naturally become shorter, decreasing the length of its perimeter. Even if the total retouched edge length does not increase, the tool's EMI will still increase because the total edge length decreases. In another scenario, EMI works as a proxy for multifunctionality and repurposing. As a tool is repurposed and given multiple functions, more of its edge length will be exploited, until eventually it consists of entirely modified edge. It is unlikely that a "fresh" tool will be retouched on all margins. The usefulness of EMI is boosted by its agreement here with the conclusions drawn from the differences in tool/flake ratio, which also indicate greater tool reduction intensity in contexts 6-8.

The overall picture of reduction obtained from three of the four discussed lines of evidence – tool/flake ratio, non-cortical/cortical debitage ratio, and EMI – suggests that retouch was both more common and intense in contexts 6-8, particularly for hornfels artifacts. Using Henry's dimensional analysis to assess core reduction, however, is complicated by the higher frequency of CRPs in contexts 6-8 and the impracticality of measuring their final core facets. The implications of these results for further comparison of the context 5 and 6-8 assemblages are as follows:

1. Size differences, or lack thereof, may be due to more intense tool reduction in contexts 6-8.
2. Size differences, or lack thereof, may be due to more intense tool reduction of hornfels artifacts and/or less intense reduction of CCS artifacts.
3. Intensity of tool reduction may be correlated with the frequency of bipolar percussion.

Tool Edge Count and Morphology

Because of the multifunctional and highly reduced nature of many of Melikane's tools, additional attributes related to edge morphology were recorded (Table 50).

The nominal attributes recorded for tool edges – the type of modification and edge morphology – show subtle differences between contexts (Table 50). A posthoc chi-squared test detected significant residuals for stepped retouch, which falls from 40.9% in contexts 6-8 to 33.9% in context 5. Significant residuals were also identified for pointed tool edge morphologies, which rise from 19.7% to 24.5% of all edges. Pointed edges are associated with borers and perforators, which accordingly become a more common tool type in context 5.

Table 50 Tool morphology attributes.(CMH=Cochran-Mantel-Haenszel Test, POM=proportional odds model, MW=Mann-Whitney U-Test, KW=Kruskal-Wallis Test.)

<table>
<tr><th>Attribute</th><th>Context 5</th><th>Contexts 6-8</th><th>Significance</th></tr>
<tr><td>Number of retouched/utilized edges – <i>is a tool from one context more likely to have more edges?</i></td><td>1: 18.4%
2: 27.5%
3: 41.3%
4: 12.8%
N: 749</td><td>1: 17.2%
2: 26.1%
3: 42.7%
4: 14.0%
N: 873</td><td>MW: p=0.278
CMH: p=0.753
POM: insignificant coefficient.</td></tr>
<tr><td>Number of tool edges and raw material – <i>is a tool of a certain material more likely to have more edges?</i></td><td>CMH: p=0.623
<table>
<tr><td>Edges</td><td>CCS</td><td>Hornfels</td><td>S/Q</td></tr>
<tr><td>1</td><td>18.8%</td><td>16.6%</td><td>20.3%</td></tr>
<tr><td>2</td><td>25.6%</td><td>29.6%</td><td>34.2%</td></tr>
<tr><td>3</td><td>42.4%</td><td>42%</td><td>32.9%</td></tr>
<tr><td>4</td><td>13.2%</td><td>11.8%</td><td>12.7%</td></tr>
</table></td><td>CMH: p=0.032
<table>
<tr><td>Edges</td><td>CCS</td><td>Hornfels</td><td>S/Q</td></tr>
<tr><td>1</td><td>16.3%</td><td>14.3%</td><td>23.7%</td></tr>
<tr><td>2</td><td>24.4%</td><td>26.4%</td><td>31.7%</td></tr>
<tr><td>3</td><td>43.3%</td><td>47.2%</td><td>34.5%</td></tr>
<tr><td>4</td><td>15.9%</td><td>12.1%</td><td>10.1%</td></tr>
</table></td><td>CMH combined: 0.019
KW: 0.062
POM: S/Q is 34.7% less likely to have a greater number of edges than CCS.
<table>
<tr><td>Edges</td><td>CCS</td><td>Hornfels</td><td>S/Q</td></tr>
<tr><td>1</td><td>17.6%</td><td>15.2%</td><td>22.5%</td></tr>
<tr><td>2</td><td>25%</td><td>27.8%</td><td>32.6%</td></tr>
<tr><td>3</td><td>42.9%</td><td>45%</td><td>33.9%</td></tr>
<tr><td>4</td><td>14.6%</td><td>12%</td><td>11%</td></tr>
</table></td></tr>
<tr><td>Tool edges and length – <i>is tool length correlated with the number of tool edges?</i> (Kendall's Tau-b)</td><td>P<.001, tau=0.198. Weak, positive, monotonous relationship between tool length and edge #s.</td><td>P=0.519. No relationship.</td><td>By raw material:
CCS: p<.001, tau=0.146.
Hornfels: p=0.043, tau=0.099.
SQ: p=0.303. Weak relationship exists for CCS and Hornfels, but not S/Q.</td></tr>
<tr><td>Type of modification (G-test)</td><td>Stepped: 33.9%
Feathered: 36.8%
Smoothed: 9.1%
Use: 20.1%
N: 1303</td><td>Stepped: 40.9%
Feathered: 35.6%
Smoothed: 7.3%
Use: 16.2%
N: 1336</td><td>P<.001
Post-hoc test of residuals: difference in stepped retouch significant at p=.002.</td></tr>
<tr><td>Edge morphology (G-test)</td><td>Concave: 12.0%
Convex: 23.9%
Pointed: 24.5%
Straight: 39.6%
N: 1308</td><td>Concave: 13.3%
Convex: 27.8%
Pointed: 19.7%
Straight: 39.2%
N: 1337</td><td>P=.009
Post-hoc test of residuals: significant for pointed edges at p=0.024.</td></tr>
<tr><td>Angle of retouch</td><td><30: 3.9%
31-60: 29.5%
>60: 868 66.6%
N: 1303</td><td><30: 84 6.0%
31-60: 482 34.7%
>60: 825 59.3%
N: 1391</td><td>Linear-by-linear association test:
p <.001 (angle=ordered, 2-way). Changes in angles ARE significant. Steeper in 5.</td></tr>
</table>

The number of retouched edges per tool was also recorded. Unlike EMI, tool edge count does not specify the percentage of the perimeter that has been modified, but simply how many edges have signs of use or retouch. A tool could have retouch on every margin but overall a lower percentage of modified edge than a tool with retouch on only one margin. If the number of tool edges is a good proxy for reduction intensity, then tools from contexts 6-8 and hornfels tools should have greater numbers of retouched edges than tools from context 5 and CCS tools. Neither a Mann Whitney U-Test (p=0.278) nor a Cochran-Mantel-Haenszel test (p=0.753), essentially a Pearson's chi-squared test under assumption that the response variable is ordered, detected differences between the contexts. However, neither of these tests address whether tools from one context were *more likely* to have a greater number of edges.

To answer this question, I built an ordered logit model, also known as a proportional odds model. Proportional odds models are a type of ordinal logistic regression model used to compare the probability of smaller response to the probability of a larger response (Jr et al., 2013). In this case, the model compares the probability of having a lesser number of tool edges to the probability of having a greater number of tool edges. The polr() function from the *MASS* package in R (Venables et al., 2002) was used to compute the model. The model was tested for fit and adherence to the proportional odds assumption using a likelihood ratio test (LRT) comparing it to a more complex multinomial logit model. The LRT produced a p-value of 0.99, indicating a good fit and no significant differences in accuracy between the models. The proportional odds model produced a coefficient of 0.0988 for context as well as three intercepts for different edge quantities (Table 52). When this coefficient is exponentiated, it produces an odds ratio of 1.104 (Table 53). However, because its confidence interval includes 1, this odds ratio is insignificant, indicating that tools from one context are no more likely overall than tools from the other to have a greater number of modified edges.

Table 51 Predicted probabilities of tool edges by context.

Edges	**1**	**2**	**3**	**4**
5	0.185	0.273	0.413	0.128
6-8	0.171	0.263	0.426	0.14

Table 52 Results for intercepts of proportional odds model of tool edges vs. context.

	Value	**OR**	**Std. Error**	**T value**	**P value**
1|2	-1.4814	0.227	0.0807	-18.3469	**<0.001**
2|3	-0.166	0.847	0.0698	-2.3781	**0.017**
3|4	1.9174	6.803	0.0884	21.6876	**<0.001**

Table 53 Results for coefficient of proportional odds model of tool edges vs. context.

	Dependent variable:
	Tool edges
Context 6-8	1.104***
	(0.926, 1.282)
Observations	1,623
Note:	*p**p***p<0.01

Table 54 Cumulative probabilities for tool edges by context.

Edges	**1**	**1 or 2**	**1, 2, or 3**
5	0.19	0.46	0.87
6-8	0.17	0.43	0.86

Table 55 Raw material and tool edge odds ratios.

	Dependent variable:
	Tool edges
Hornfels	0.975***
	(0.765, 1.186)
Sandstone/quartzite	0.653***
	(0.385, 0.920)
Observations	1,614
Note:	*p**p***p<0.01

The odds ratios of the three intercepts are significant and describe the likelihood of a tool from context 6-8 having a specific number of edges. However, they *do not* describe these probabilities in relation to tools from context 5. The odds ratio OR of 0.227 for intercept 1|2 indicates that tools from context 6-8 are 0.227 times more likely (or 77.3% less likely) to have one edge rather than 2 or more edges. They are 0.847 times more likely (15.3% less likely) to have 2 or fewer edges than 3 or more, and 6.803 times more likely to have 3 or fewer edges rather than 4. The model was also used to predict the probabilities of a tool from either context having a certain number of edges (Table 51, Table 54). As expected, tools from contexts 6-8 had a higher probability of having 4 edges (0.14) than tools from context 5 (0.128). Notably, context 5 tools were more likely than context 6-8 tools to have only 1 or 2 tool edges (0.46 vs. 0.43). The use of the proportional odds model in this situation added clarity to the results of the rank sum and contingency table tests. The Mann-Whitney test indicated that the mean number of tool edges does not differ by context, and the CMH test indicated that the number of tool edges is independent of context. The proportional odds model expanded these results by showing that the *probability* of having a total greater number of tool edges does not differ by context. This complicates the conclusions drawn from the results of the tool/flake ratios and EMIs for each context, both of which suggest that context 6-8 tools should be more reduced than those from context 5 and emphasizes the importance of using multiple reduction indices to gain a better understanding of reduction variability.

A similar approach was used to determine if tools made with any raw material were more likely to have a greater number of tool edges. CCS, hornfels, and sandstone/quartzite were compared, both within and between contexts. A CMH test produced a significant p-value for contexts 6-8 and the contexts combined, suggesting that raw material and tool edge number are not independent. A Kruskal-Wallis test produced a marginally insignificant p-value of 0.062. To further evaluate these results, I built a proportional odds model using CCS as the base value. The model produced an insignificant p-value in the likelihood ratio test (p=0.165), indicating that the proportional odds assumption is upheld and that the results are statistically valid. The model produced coefficients of -0.025 and -0.426 for hornfels and sandstone/quartzite respectively. When converted to odds ratios, the coefficients indicate that sandstone/quartzite tools are 0.653 times more likely (34.7% less likely) to have a greater number of tool edges than CCS. However, the odds ratio for hornfels includes one, indicating an insignificant result. This is interesting considering that hornfels has a higher tool/flake ratio than CCS, suggesting that hornfels tools should be further reduced. Again, this contradiction with the tool/flake ratio suggests that the number of retouched edges may be independent from other proxies of reduction intensity. In this case, the proportional odds model provides a more detailed description of the results of the CMH and Kruskal-Wallis rank sum tests. It confirms the insignificant differences in tool edge counts for CCS and hornfels and clarifies that the real difference is between CCS and sandstone/quartzite.

If the number of tool edges is a proxy for reduction intensity, then shorter, possibly more reduced, tools may have a greater number of tool edges. When all tool types are combined, a Kendall's Tau-b confirmed the opposite for context 5: a weak, monotonous positive relationship exists between tool length and the number of edges (tau=0.198, $p < 0.001$). No relationship at all exists in context 6-8. When the contexts are combined and the tools are separated by raw material, the same weak, monotonous positive relationship exists for CCS tools (tau=0.146, $p<0.001$). Although the p-value for hornfels was also significant, a tau-b of 0.099 indicates only the weakest of relationships. The p-value for sandstone/quartzite was insignificant. The correlation between length and tool edge count is weak at best, but even so, the positive, monotonous relationships observed are the opposite of what would be expected if a.) tool length shortens with reduction intensity, and b.) the number of tool edges is correlated with reduction intensity.

The overall impression taken from the tool edge attributes is that the number of tool edges is a poor indicator of reduction intensity in this highly reduced assemblage. Although context 6-8 shows signs of more intensive reduction through a higher overall frequency of retouch and a higher tool/flake ratio, the actual number of edges per tool is no different than in context 5. The same conclusion can be applied to CCS vs hornfels tools. Although the latter seem significantly more reduced according to the proxies discussed in the previous section, tool edge count appears to have little to do with it. Tool edge count also has little to do with length, with which it should (but does not) show an inverse relationship. It is possible that in a less reduced assemblage tool edge count would be a better proxy for reduction intensity, but in this case it reveals little about the differences between contexts and raw materials.

Scrapers

Table 56 Relative scraper type frequency.

	5		**6-8**	
	N	%	N	%
Convergent	35	*4.12*	52	*4.25*
End	134	*15.78*	166	*13.57*
Nosed	480	*56.54*	682	*55.76*
Side	46	*5.42*	62	*5.07*
Side/end	154	*18.14*	261	*21.34*

Five types of scraper were identified in Melikane's assemblages: convergent, end, side, side/end, and nosed (Table 56). Included in the "scraper" category are also tools that may otherwise be classified as adzes. Carter et al. (1988) differentiated adzes from scrapers based only on the presence of stepped use-wear on top of scraper-like retouch. When the five scraper types are isolated from the rest of the tool assemblage, no differences can be found in their relative proportions between the two contexts (p=0.349). Removing nosed scrapers, which may be more related to borers, has no effect on significance. Side, end, and side/endscrapers, however, are sometimes thought to be different stages in one reduction process (Dibble, 1995). In this case, the proportion of single to double margin scrapers might be more indicative of reduction intensity than choice in tool form. When the frequencies of single-margin (side and end) and multi-margin (side/endscrapers) were compared between contexts, the contexts were found to have significantly different frequencies of each type (p=0.047). In context 5, the ratio of single/multimargin scrapers was 1.17:1, whereas in contexts 6-8 it was 0.87:1. If side/endscrapers are indeed further reduced side or endscrapers, then context 5 would be less heavily reduced than contexts 6-8.

Reduction Intensity Hypothesis

To test the "reduction intensity hypothesis" of relative scraper frequencies, a number of predictions were made and tested, first with sidescrapers, and then with endscrapers. Differences in raw material frequency between scraper types and contexts were taken into consideration first, as raw material can greatly affect implement size, type, and form, but no differences in raw material preference were detected for side versus side/endscrapers, with the one exception of sandstone/quartzite being more common than expected among sidescrapers in contexts 6-8

(Table 57). Because sandstone/quartzite is relatively rare in the assemblage, sidescrapers and side/endscrapers were not separated by raw material for this study. However, mean sidescraper size does differ by context, so contexts 5 and 6-8 were separated.

Table 57 Raw materials for side and side/endscrapers.

Context 5	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
Side	20	*45.5*	19	*43.2*	5	*11.4*
Side/end	66	*47.8*	51	*37.0*	21	*15.2*
Fischer test: p=0.705.						
Context 6-8	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
Side	19	*31.1*	21	*34.4*	21	*34.4*
Side/end	107	*44.4*	89	*36.9*	45	*18.7*
Fisher test: 0=0.026. Significant residuals for S/Q.						
All contexts	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
Side	39	*37.1*	40	*38.1*	26	*24.8*
Side/end	173	*45.6*	140	*36.9*	66	*17.4*
Fisher test: p=0.160.						

Table 58 Raw material for end and side/endscrapers.

Context 5	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
End	90	*67.7*	32	*24.1*	11	*8.3*
Side/end	78	*50.6*	55	*35.7*	21	*13.6*
Fisher: p=0.015. Residuals for CCS are significant.						
Contexts 6-8	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
End	90	*54.9*	40	*24.4*	34	*20.7*
Side/end	125	*48.3*	89	*34.4*	45	*17.4*
Fisher: p=0.091.						
All contexts	**CCS**		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
End	180	*60.6*	72	*24.2*	45	*15.2*
Side/end	203	*49.2*	144	*34.9*	66	*16.0*
Fisher: p=0.005. CCS and hornfels residuals are significant.						

There are more profound differences in raw material proportions between end and side/endscrapers. A Fisher Test for context 5 produced a significant p-value (0.015) and significant residuals for CCS (Table 58). When all contexts are combined, both hornfels (less common in endscrapers) and CCS (more common in endscrapers) produce significant residuals in a posthoc chi-squared test. Because CCS and hornfels make up most of the assemblage, I separated end and side/endscrapers by raw material when evaluating the reduction intensity hypothesis (Table 61). Mean endscraper length does not differ between contexts, so contexts 5-8 were combined.

Side and Side/Endscrapers

Six expectations were set for the reduction intensity hypothesis concerning side and side/endscrapers. Out of the six, only two are met (Table 59). This indicates that it is unlikely that side/endscrapers are a later stage of sidescraper reduction. Because a sidescraper would lose length if retouched on its distal margin, it was predicted that side/endscrapers would be shorter than sidescrapers. However, in both contexts 5 and 6-8, the means and variances of lengths for each type do not differ significantly. In fact, sidescrapers are slightly shorter on average.

Similarly, it was predicted that side/endscrapers should be of either the same width or narrower than sidescrapers. Instead, side/endscrapers were found to be significantly wider than sidescrapers in context 5, and in contexts 6-8, the means did not differ. The length/width and length/thickness ratios, both of which should be smaller on a sidescraper that has been further reduced on its distal edge, are also not significantly different.

Table 59 Expectations, if side/endscrapers are a later stage of sidescraper reduction.

Expectation	**Result**	**Notes**
Side/endscrapers will be shorter than side scrapers because of distal removals.	False	No significant differences.
Side/endscrapers will be either the same width or narrower because their lateral margins are completely exhausted.	False	Side/endscrapers are significantly wider in context 5, no differences in contexts 6-8.
Scrapers will not differ in maximum thickness.	True	No difference.
Side/endscrapers will have a smaller length/width ratios because of their distal reduction.	False	No difference.
Side/endscrapers will have a smaller length/thickness ratios because of their distal reduction.	False	No difference.
Side/endscrapers will have steeper edge angles because they are more exhausted.	True.	However, this could simply be a function of distal edges being steeper than lateral edges, regardless of tool type.

The two expectations that were met, similar maximum thickness and steeper edge angles, are not convincing in isolation. Maximum thickness only indicates that the same raw materials were used. Side/endscrapers do have a higher percentage of angles >60º (p=0.029), which would indicate a greater degree of reduction, but it is also possible that distal edges tend to have steeper edge angles than lateral edges in general, making this statistic less illuminating about the degree of reduction and more indicative of either the presence or absence of distal retouch. Despite insignificant results for Fligner-Killeen and Mann Whitney U-Tests, Figure 34 shows that side/endscrapers have both larger interquartile ranges and larger ranges overall for their dimensions. The standard deviations for length and width are nearly twice as large for side/endscrapers as for sidescrapers (Table 60). This is further evidence that sidescrapers are distinctly different tools and do not develop into side/endscrapers later in their uselives.

Figure 34 Side vs. side/endscraper dimensions, all contexts.

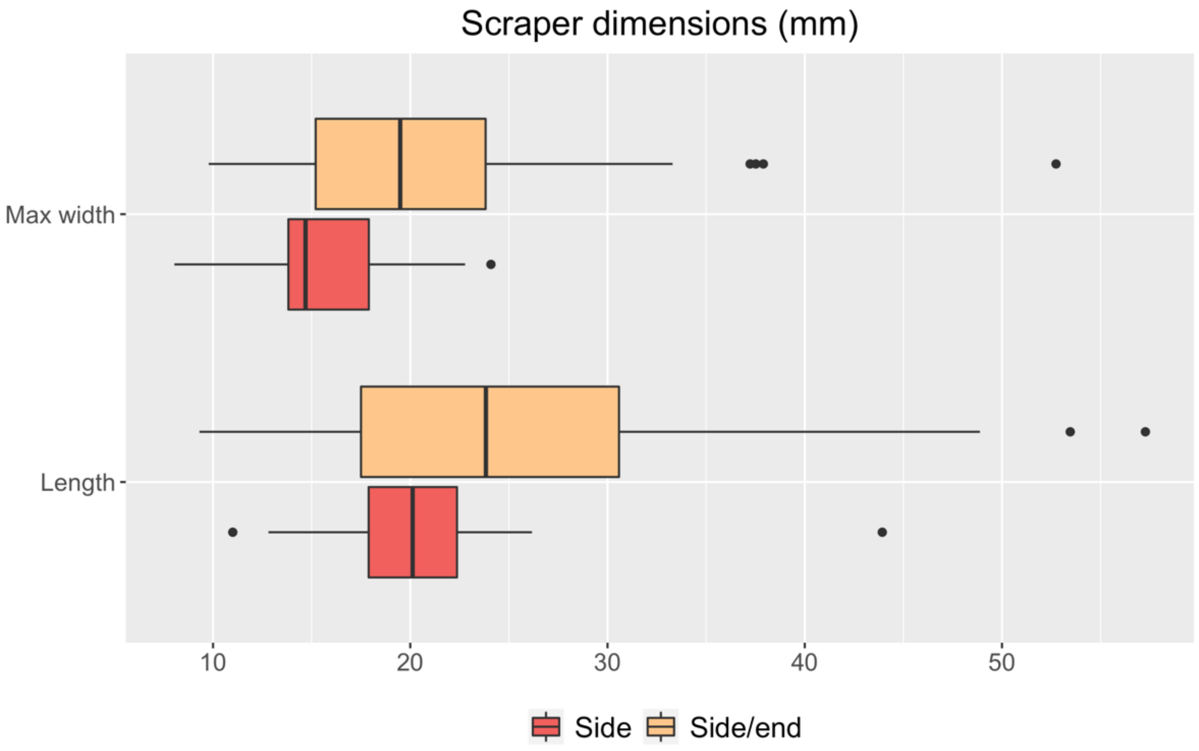


Table 60 Dimensions for side and side/endscrapers.

		Sidescrapers	**Side/endscrapers**	**Mann-Whitney**	**Fligner-Killeen**
Context 5					
	Length	Mean: 19.57 Med: 20.44 SD: 5.29 N=21	25.24 24.34 10.86 68	P=0.29	P=0.07
	Max width	Mean: 12.92 Med: 14.21 SD: 3.14	20.34 19.27 6.19	**P=0.002**	P=0.12
	Thickness	Mean:7.42 Med: 7.39 SD: 2.54	8.98 8.49 2.86	P=0.28	P=0.85
	Length/width	Mean: 1.59 Med:1.61 SD: 0.55	1.26 1.11 0.48	P=0.121	P=0.352
	Length/thick.	Mean: 2.71 Med: 2.80 SD: 0.40	2.77 2.71 0.68	P=0.967	P=0.126
Context 6-8					
	Length	Mean: 22.76 Med: 20.12 SD: 10.06 N=25	24.79 23.6 9.78 N=99	P=0.51	P=0.23
	Max width	Mean: 18.46 Med: 17.9 SD: 4.73	20.48 19.62 7.75	P=0.72	P=0.33
	Thickness	Mean: 8.81 Med: 7.3 SD: 3.53	9.41 8.03 4.38	P=0.68	P=0.32

	Length/width	Mean: 1.24 Med: 1.2 SD: 0.40	1.22 1.19 0.32	P=0.966	P=0.492
	Length/thick.	Mean: 2.66 Med: 2.56 SD: 0.75	Mean: 2.75 Med: 2.71 SD: 0.73	P=0.780	P=0.855

End and Side/Endscrapers

Five expectations were set for the reduction intensity hypothesis for end vs side/endscrapers. Because side/endscrapers may be more reduced, it was expected that they would be the same length or shorter than endscrapers. There were no differences in length for CCS scrapers, and hornfels side/endscrapers were longer than endscrapers (Table 62). Side/endscrapers were also significantly wider than endscrapers for both materials, which is the opposite of what would be expected if the lateral retouch occurred after distal retouch. The CCS scrapers did not differ in thickness, but this may be due to the constraints imposed by raw material. Hornfels side/endscrapers are also more variable in thickness than hornfels endscrapers. I also expected side/endscrapers to be "bladier" and have larger length/width ratios as a result of lateral retouch. The opposite was true for CCS side/endscrapers, which were less "bladey". There were no significant differences for hornfels scrapers. Lastly, I expected that the side/endscrapers would have length/thickness ratios less than or equal to those of endscrapers. This expectation was met for CCS, but the length/thickness ratios for hornfels side/endscrapers were significantly greater than for endscrapers. Overall, these expectations are only partially met. This suggests that like sidescrapers, endscrapers are not an early stage of side/endscraper reduction.

Table 61 Expectations, if side/endscrapers are a later stage of endscraper reduction.

Expectations	**CCS**		**Hornfels**	
	Result	**Notes**	**Result**	**Notes**
Side/endscrapers will be the same length or shorter than endscrapers because their distal edges are more exhausted.	TRUE	No differences in length.	FALSE	Side/end are longer.
Side/endscrapers will be narrower because of lateral retouch.	FALSE	Side/endscrapers are significantly wider.	FALSE	Side/end are wider.
Scrapers will not differ in maximum thickness, because they are made on the same blanks.	TRUE	No difference in thickness.	TRUE	Means do not differ, but side/end are more variable.
Side/endscrapers will have a larger length/width ratio because of lateral retouch.	FALSE	Side/endscrapers have a smaller ratio.	FALSE	No difference.
Side/endscrapers will have the same or smaller length/thickness ratios because their distal ends might be more completely exhausted.	TRUE	No difference.	FALSE	Side/end have larger ratios.

Table 62 Dimensions for end and side/endscrapers, combined contexts, by raw material.

		Endscrapers	**Side/endscrapers**	**Mann-Whitney**	**Fligner-Killeen**
CCS					
	Length	Mean: 20.04 Med: 19.21 SD: 7.080 N: 79	21.82 19.31 8.05 N: 83	0.392	0.661
	Max width	Mean: 15.72 Med: 15.68 SD: 4.83	18.07 17.24 4.69	**0.042**	0.704
	Thickness	Mean: 7.61 Med: 6.72 SD: 2.73	8.36 7.89 2.56	0.068	0.073
	Length/width ratio	Mean:1.29 Med: 1.28 SD: 0.31	1.22 1.14 0.44	**0.043**	0.164
	Length/thickness ratio	Mean: 2.79 Med: 2.60 SD: 0.85	2.62 2.48 0.71	0.509	0.212
Hornfels					
	Length	Mean: 20.91 Med: 20.7 SD: 7.22 N: 37	30.08 28.99 12.26 N: 55	**P=0.003**	**0.012**
	Max width	Mean: 17.01 Med: 16.39 SD: 4.77	23.43 21.92 8.54	**P<.001**	P=0.069
	Thickness	Mean: 8.55 Med: 8.43 SD: 3.12	10.82 9.61 5.01	P=0.088	**P=0.024**
	Length/width ratio	Mean: 1.24 Med: 1.30 SD: 0.31	1.29 1.20 0.39	P=0.979	P=0.713
	Length/thickness ratio	Mean: 2.54 Med: 2.38 SD: 0.79	2.91 2.88 0.75	**P=0.032**	=0.350

Typological Interpretations

Because side, end, and side/endscrapers do not fulfill the expectations set for the reduction intensity hypothesis, scraper types can be seen as “real,” representing distinct tools in the toolkit rather than stages on the road to the same product. Changes in their relative frequencies, therefore, likely have less to do with curation and reduction intensity than actual changes in tool type preference. Endscrapers are a hallmark of LSA technology, whereas sidescrapers and knives are distinctly MSA (A. M. B. Clark, 1999). An MSA knife is defined as a tool “having a straight cutting edge with an angle of less than 40 degrees” (A. M. B. Clark, 1997a, pp. 452–453). Wadley and Harper (1989) however, distinguish knives from scrapers by the shape of the cutting edge: scrapers have convex working edges, whereas knives have straight edges.

Table 63 Relative scraper frequency for Melikane's MSA and LSA levels.

	End		**Side**	
5	134	*74.4%*	46	*25.6%*
6-8	166	*72.8%*	62	*27.2%*
MIS 4	32	*54.2%*	27	*45.8%*
MIS 5a	33	*53.2%*	29	*46.8%*

Table 64 P-values for tests of end and sidescraper proportions.

	5	**6-8**	**MIS 4**
6-8	1		
MIS 4	**0.026**	**0.029**	
MIS 5a	**0.019**	**0.026**	1

Table 65 End, side, and side/endscraper frequencies.

	End	**Side**	**Side/end**
5	40.1%	13.8%	46.1%
6-8	33.9%	12.7%	53.4%
MIS 4	38.6%	32.5%	28.9%
MIS 5a	37.9%	33.3%	28.7%

Images of MSA knives show that they are usually laminar, with one of the lateral margins retouched (Carter et al., 1988; P. J. Mitchell, 1994a; Wadley & Harper, 1989). In the Melikane typology, most of these knives would fall into the category of sidescrapers. MSA knives have been described at other sites in the southern African interior including Rose Cottage Cave and Melikane, but no artifacts resembling those found at the latter two sites were recovered from Melikane’s deposits. It is the author’s opinion that the term “knife” implies function without sufficient evidence and should be discarded. MSA “knives” from these other sites should be categorized with side and side/endscrapers.

If endscrapers are associated with the LSA and sidescrapers and knives are associated with the MSA, then a rise in relative endscraper frequency would be anticipated over the transition. No statistically significant differences exist between the relative frequencies of side and endscrapers in contexts 5 and 6-8 (p=0.736), but when compared to the MIS 4 and MIS 5a levels at Melikane, the later contexts have significantly greater proportions of endscrapers (Table 63, Table 64). This suggests that the MSA/LSA transition may have occurred sometime before contexts 6-8, or at the very least, that the transition was already well-underway.

Side/endscrapers are also more common in contexts 5 and 6-8 than they are in MIS 4 and 5a. When end, side, and side/endscrapers are combined, the latter comprise 46.1% of context 5 scrapers and 53.4% of context 6-8 scrapers, but only ~28% of scrapers in the MSA contexts. Including side/endscrapers also makes contexts 5 and 6-8 look less similar to each other than if only endscrapers and sidescrapers are considered. In context 5, side/endscrapers become less common as endscrapers become more common. This trend is invisible when endscrapers are only compared to sidescrapers. Because it has already been established that end and side/endscrapers are unrelated types, this does not represent a decrease in reduction intensity. However, it could be reflective of the shift in raw material frequencies, as endscrapers are more common on CCS, which is more common in context 5, and side/endscrapers are more common on hornfels, which is more common in contexts 6-8. To better understand these shifts in frequency, contexts 5 and 6-8 were broken down by spit.

Figure 35 Endscraper and platform core frequency.

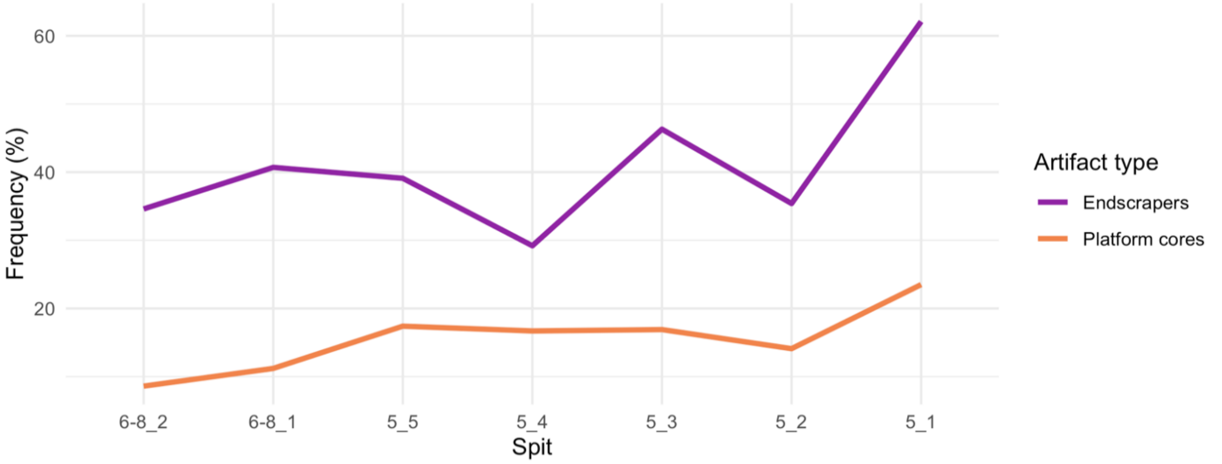


Figure 36 Scraper type by spit.

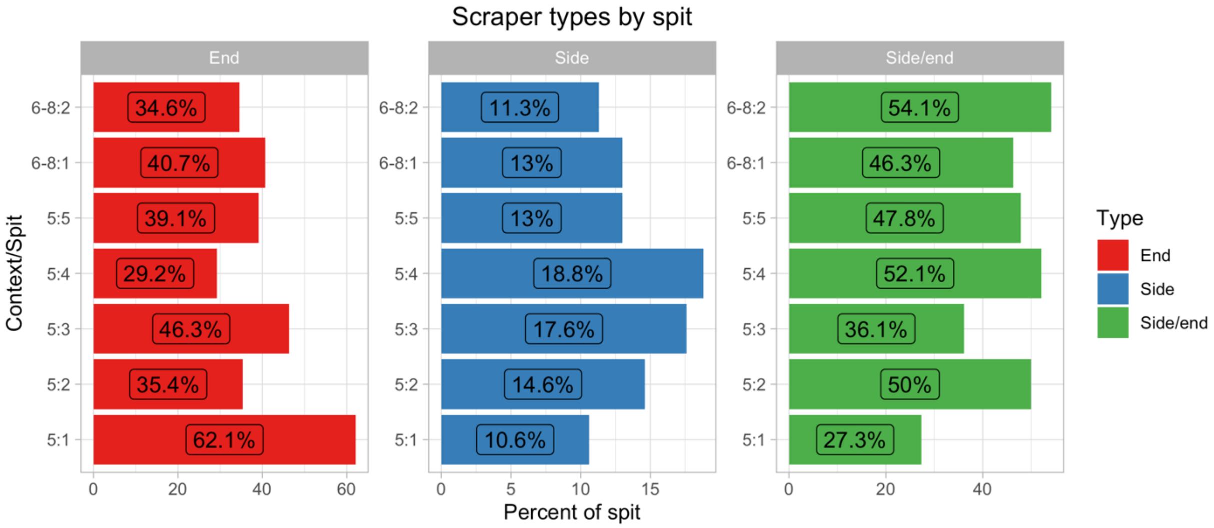


Figure 36 shows that endscrapers spike in the highest (most recent) spit of context 5, comprising 62.1% of the three types. Sidescrapers and side/endscrapers are each less prominent in this spit than they are in any other. A chi-squared test for trend in proportions shows that the proportion of endscrapers to other scrapers does trend linearly over time ($p=0.004$). Sidescrapers do not trend in comparison to other scrapers ($p=0.476$), but side/endscrapers do ($p<0.001$). Thus, when broken down by spit, the patterns observed by context are confirmed – as endscrapers rise over time, side/endscrapers drop in frequency. Explaining this trend in the context of the MSA/LSA transition is difficult, because although endscrapers are associated with the LSA, side/endscrapers are not associated with the rest of the MSA of Melikane. They are even less common in the MSA contexts than in context 5, and the data does not support them as a later stage of end or sidescraper reduction.

As previously discussed, relative platform core frequency rises through contexts 6-8 and 5. Platform cores, like endscrapers, are a stereotypically LSA "type." Although a line graph (Figure 35) of the relative frequencies of platform cores to other freehand cores and endscrapers to other scrapers suggests a possible correlation, a Spearman's correlation produced an insignificant p-value (0.2).

Endscraper Form

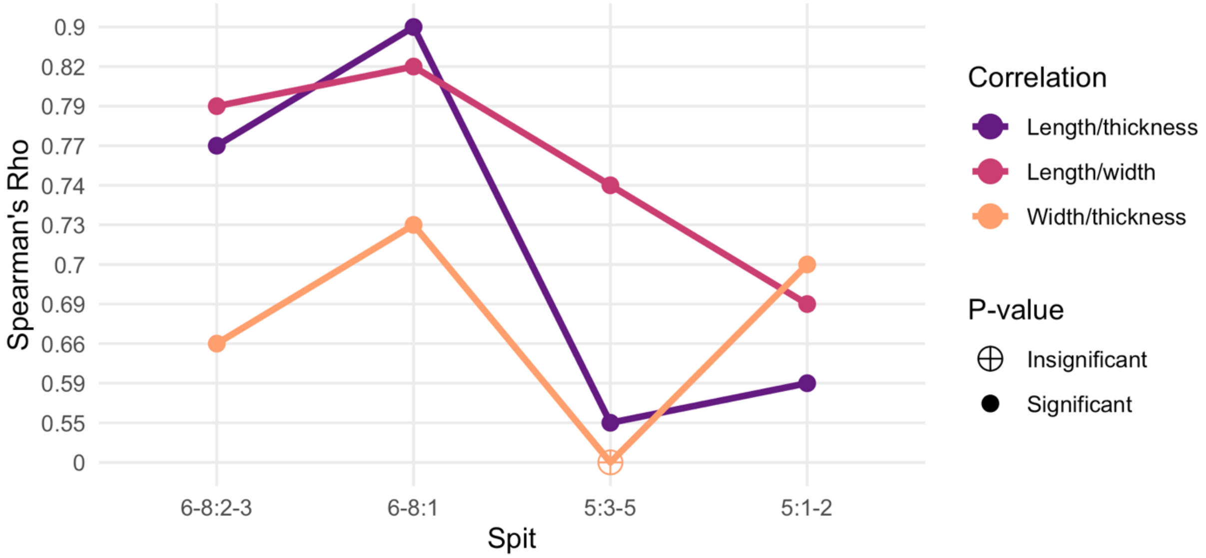
Endscrapers, particularly those made on blade blanks, are stereotypical of the southern African LSA and the European Upper Paleolithic. As previously discussed, endscrapers become relatively more common throughout context 5 at Melikane. Changes not only in the frequency, but also in the form of these endscrapers could reveal variations in reduction intensity, blank preferences, and standardization through time.

Endscrapers in both contexts are relatively similar in size and shape. The mean length for CCS endscrapers in contexts 6-8 is 17.51mm and rises to 21.48mm in context 5, although this change is statistically insignificant ($p=0.08$). A pairwise z-test for proportions indicates that the proportion of sandstone/quartzite endscrapers falls significantly in context 5, from 25% to 7.1%, but that the relative proportions of CCS (47.7% [6-8] and 66.1% [5]) and hornfels (25% [6-8]

and 26.8% [5]) do not change significantly. The overall shapes of CCS endscrapers remain relatively stable through time. Neither the mean length/maximum width, length/midpoint width, or length/thickness ratios change significantly for CCS endscrapers.

However, a series of Spearman's correlations suggests that CCS endscrapers become less standardized in terms of length and width in context 5 (Figure 37). This is the opposite of what would be expected in a stereotypically more standardized LSA. In contexts 6-8, length and midpoint width are highly correlated (Rho=0.84, p<0.001), but are less correlated in context 5 (Rho=0.69, p<0.001). Even within context 5, earlier spits have higher correlations than the later spits. Spit 3 (n=10) has a Spearman's Rho of 0.83 (p<0.001) whereas spit 1 has a Rho of 0.67 (p=0.023, n=10). Although the mean lengths of CSS endscrapers for each context do not differ significantly, those from contexts 6-8 are on average slightly shorter than those from context 5. It is possible that these shorter endscrapers from 6-8 tend to be more reduced, whereas those from 5 cover a wider range of reduction intensities. The more reduced endscrapers, if made on similar blanks of a similar width, would appear more correlated in their dimensions than those that were less reduced. If the 6-8 CCS endscrapers are more reduced than the context 5 endscrapers, then it would be expected that they would have steeper edge angles. However, endscrapers from context 5 actually had a greater proportion of distal edge angles >60º (87.8% vs 77.3%). The 6-8

Figure 37 Spearman's rho correlations over time for CCS endscraper dimensions.



endscrapers would also be expected to have a lower length/thickness ratios, but neither a Mann-Whitney Test nor a Fligner-Killeen Test detected any differences.

When Spearman's correlations are compared for other dimensions, it becomes clear that change in endscraper standardization is not linear. Length and maximum thickness are also more highly correlated in contexts 6-8 (Spearman's Rho=0.59, p=0.022) in comparison to context 5 (Rho=0.524, p=0.004), but when broken down by spit, a more complex picture emerges. Length and maximum thickness are closely correlated in 6-8:2-3 (Rho=0.77, $p<0.001$) and nearly perfectly correlated in context 6-8:1 (Rho=0.90, $p<0.001$, n=11). That correlation drops steeply to Rho=0.55 (p=0.027, n=14) in context 5:3-5 and is insignificant when spit 3 is considered alone (p=0.367, n=10). However, it rises again to Rho=0.59 (p=0.023, n=16) in context 5:1-2. Midpoint width and maximum thickness follow a similar pattern, reaching their highest correlation in 6-8:1 (Rho=0.73, p=0.026), lacking any correlation in 5:3-5 ($p>0.05$) but then become more correlated again in 5:1-2 (Rho=0.70, p=0.004).

The sudden drop in all correlations in early context 5 speaks to a sudden reorganization of endscraper technology independent of any single dimension. A closer look at the dimensions of endscrapers in 6-8:1 compared to those from 5:3-5 shows that although length does not vary significantly, the early context 5 (spits 3-5) endscrapers are significantly wider than those from contexts 6-8 (15.38mm vs. 11.54mm). This impacts the width/thickness ratios, which also differ significantly (2.18 vs. 1.62). It is possible that the Melikane toolmakers became "less picky" about the blanks they used for endscrapers in early context 5 and began using a wider variety of blank shapes. The tasks for which endscrapers were used may have diversified, resulting in a seemingly less standardized toolkit. Wider endscrapers and weaker correlations between all dimensions could also reflect increasing diversity in core reduction strategies or core reduction intensity. Changes in core frequencies between 6-8:1 and 5:5 include an increase in multidirectional cores from 23.9% to 36.6% of the assemblage, an increase in bipolar cores from 20.9% to 26.8%, a decrease in parallel cores from 13.9% to 4.9%, and an increase in platform cores from 5.7% to 9.8%. The rise of platform core technology and fall of parallel core technology may have introduced more diversity in blank size into the Melikane assemblage, increasing the randomness of finished endscraper dimensions. Alternatively, endscrapers may have been used for new tasks in early context 5. These tasks may not have necessitated the same degree of standardization seen in contexts 6-8.

However, at the end of context 5, CCS endscrapers "restandardize" in terms of length/thickness and width/thickness. Mean midpoint width and width/thickness ratio both drop, to 13.81mm and 1.87 respectively. These changes could again be accounted for by changes in core reduction strategies. By context 5:1, multidirectional cores decrease in frequency, although not to the level of 6-8:1, and platform cores reach a context-wide high. All these changes would result again in smaller, and perhaps more regular, blanks. In conclusion, a sudden drop in the correlations of length/width, length/thickness, and width/thickness in early context may reflect diversification of endscraper function or a shift in core reduction strategies. Restandardization at the end of context 5 could reflect another shift in core reduction strategies, particularly an increase in freehand platform core reduction.

Burins and Nosed Scrapers

Borers, burins, and nosed scrapers are all characterized by the presence of at least one working tip. Burins, often associated with Upper Paleolithic Europe, are defined here as pointed tools created by the "burin blow technique," which "removes a longitudinal straight spall from an edge of a blade, or a flake" (Tomáŝková, 2005, p. 85). Sackett (1989, p. 52) identified three different types of burins comprising the Standard Burin Group of the Upper Paleolithic, distinguished by the means in which their tip was formed. Dihedral burins are those characterized by two burin scars, one originating from the facet created by the other. They can be symmetric, asymmetric, or lateral. A truncated burin's burin scar originates from a steeply retouched edge, and a break burin's scar originates from the margin of a broken blank. Usewear studies have implicated burins in a variety of functions, including engraving bone and antler, drilling, and use as a projectile, whereas other studies have included certain burins in the "core" category (Kay & Solecki, 2016; Sackett, 1989; Smallwood et al., 2020; Tomáŝková, 2005). The British Aurignacian, ~33-31 BP, is characterized by two types of burin-core, the Paviland burin and the burin busqué – both of which are hypothesized to have been microblade cores (Dinnis, 2008, 2015; Nowak & Wolski, 2015). Burin busqués are characterized by a series of bladelet removals coming off a burinated tip, terminating at a retouched “stop notch.” When looking at the dorsal surface of a burin with the distal tip pointing up, burin busqués tend to have their single burination on the right and the series of bladelet removals on the left. The bladelets produced from a burin busqué are usually twisted counterclockwise in profile and curved along one margin. Paviland burins also have a flat burination on one margin, like the burin busqué, although it is usually on the left rather than the right. The removals are aimed through the thickness of the flake, originating on the dorsal and terminating at the ventral surface. The bladelets detached from Paviland burins tend to be shorter than those detached from burin busqués (Dinnis, 2008). Paviland burins, and particularly those without evidence of an initial burination, could also be categorized as “carinated scrapers” (Bar-Yosef, 2006).

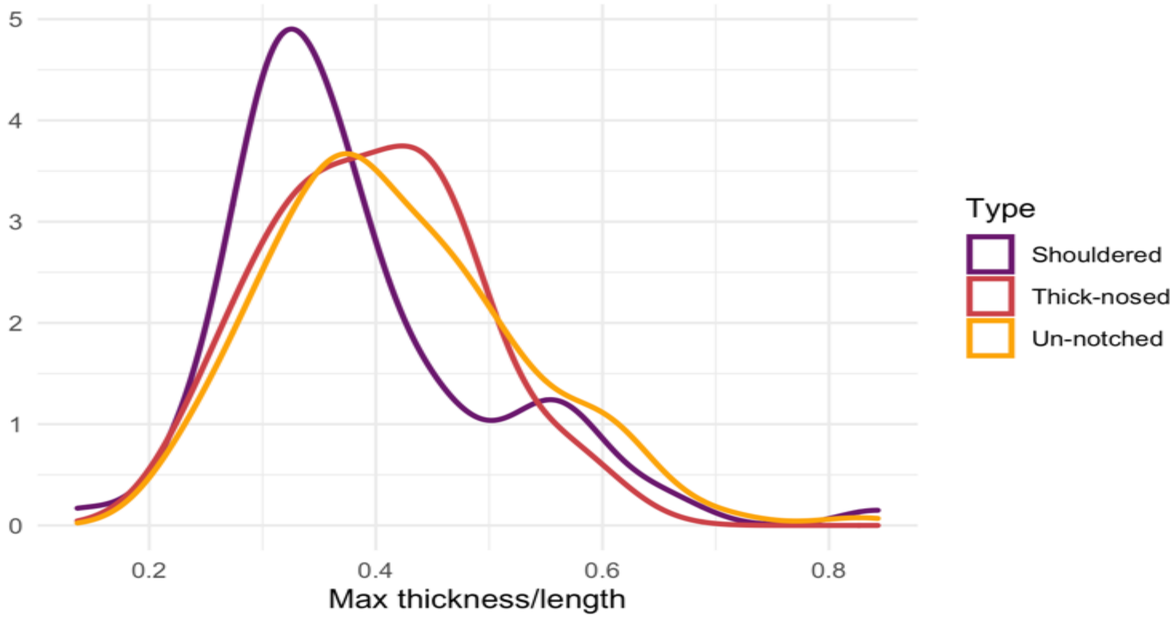
Nosed scrapers (also known as nose-ended scrapers), like burins, are sometimes regarded as cores in Upper Paleolithic literature. In the Aurignacian, these scrapers are usually thick and “carinated”, often with bladelet removals (Bar-Yosef, 2006; Movius & Brooks, 1971). They are distinguished from regular carinated scrapers by a notch on either side of the scraper projection. Movius and Brooks (1971, p. 255) break them into two types. A “thick nose-ended scraper” is a “scraper on a thick blade or flake, the scraping edge of which consists of a projection degaged by removals which are usually lamellar.” A “flat nose-ended” or “shouldered scraper” is a “scraper on a thin blade or flake, the scraping edge of which consists of a projection degaged by retouch on both sides (nose-ended) or on one side only (shouldered).” All varieties are subsumed into the “nosed scraper” type at Melikane. Aurignacian thick-nosed and carinated scrapers are best distinguished from endscrapers by their maximum thickness/maximum length (T:L) and maximum thickness/maximum width (T:W) ratios. Movius and Brooks (1971) define “chunky” flakes as having a T:W ratio of >0.60 and a T:L ratio of >0.30.

Although nosed scrapers do not change in relative frequency between contexts at Melikane and burins are rare throughout the assemblage, an increase in “chunky” and/or carinated forms could indicate additional undetected bladelet production. However, I have previously hypothesized (see Pazan et al., 2020) that borers exist on a continuum with nosed scrapers. This section seeks to answer these questions:

1. Is there a “chunky” component to Melikane’s nosed scrapers and burins?

2. Are nosed scrapers, borers, and burins actually different types?

Figure 38 Thickness/length ratio by nosed scraper type.



In order to assess the presence of a "chunky" component, Melikane's nosed scrapers were separated into three basic categories based on the presence or absence of one or more notches or concave margins. Scrapers with 2 notches or concave margins were termed "thick-nosed," those with 1 were termed "shouldered," and the remainder (including carinated scrapers) were termed "un-notched." All three types of nosed scraper had maximum thickness/maximum length ratios of >0.30, but none had maximum thickness/maximum width ratios of >0.60 (Table 66). This is likely a reflection of the different raw materials and blank sizes present at Movius and Brook's (1971) type sites versus Melikane. T:L and T:W ratios do not differ significantly overall between contexts, and the none of the means of individual types change significantly from contexts 6-8 to 5.

However, the un-notched scrapers are chunkier than either the thick-nosed (two notches) or shouldered (one notch) types (Figure 38). A Kruskal Wallis test produced a p-value of 0.02 for T:L ratios. A posthoc Dunn Test using the Bonferroni correction showed that these differences exist primarily between the shouldered and un-notched types (p=0.008). This is consistent with

Movius and Brook's (1971) observation that shouldered nosed scrapers are relatively thinner than the carinated scrapers. A Kruskall Wallis test for the T:W ratios was insignificant, but T:W and T:L are moderately correlated (Rho=0.354, p<0.001). Although the dimensions of the individual scraper types do not change between contexts, the relative proportions of each scraper type do vary. Contexts 6-8 have more shouldered and fewer un-notched scrapers than context 5, a difference in proportions significant at the p=0.01 level. This rise in relative frequency of "chunky", un-notched nosed scrapers is consistent with the changes that took place in the European Upper Paleolithic, where carinated nosed and endscrapers rose in prominence. It may indicate an increase in microlith and bladelet production undetectable in the analysis of unmodified artifacts.

Table 66 Chunkiness ratios for nosed scrapers.

		T:L		T:W		%	
		5	6-8	5	6-8	5	6-8
Thick-nosed	Mean:	0.402	0.383	0.385	0.539	4.0%	4.4%
	Med:	0.395	0.395	0.371	0.581		
	SD:	0.096	0.087	0.091	0.123		
		N=8	N=10				
Shouldered	Mean:	0.382	0.382	0.528	0.525	19.3%	31.1%
	Med:	0.328	0.364	0.470	0.532		
	SD:	0.147	0.099	0.199	0.112		
		N=39	N=71				
Un-notched	Mean:	0.493	0.406	0.534	0.556	72.8%	64.5%
	Med:	0.410	0.385	0.508	0.541		
	SD:	0.619	0.106	0.171	0.154		
		N=147	N=147				

Chunkiness in burins is more difficult to evaluate because of small sample size. Burins are not well-represented in Melikane's assemblage, with only 21 specimens measured from the contexts combined. This sample size is too small for a statistically viable comparison, but a visual inspection of a dot plot shows that burins in contexts 6-8 have a wider range of T:W ratios (Figure 39). Interestingly, the T:L ratios for both contexts are "broken" into two segments around ~0.30, exactly the threshold that Movius and Brooks (1971) identified for their chunky nosed scrapers. T:W and T:L ratios are also strongly correlated with each other (Spearman's rho=0.79, p=0.002). This supports the existence of a "chunky" set of burins in addition to a "chunky" set of nosed scrapers. However, the mean T:L ratio for burins is only 0.280, significantly lower than that for nosed scrapers. Clearly, if this chunky component is real, it is not significant enough to affect the burin assemblage as a whole.

Figure 39 Chunkiness ratios for burins.

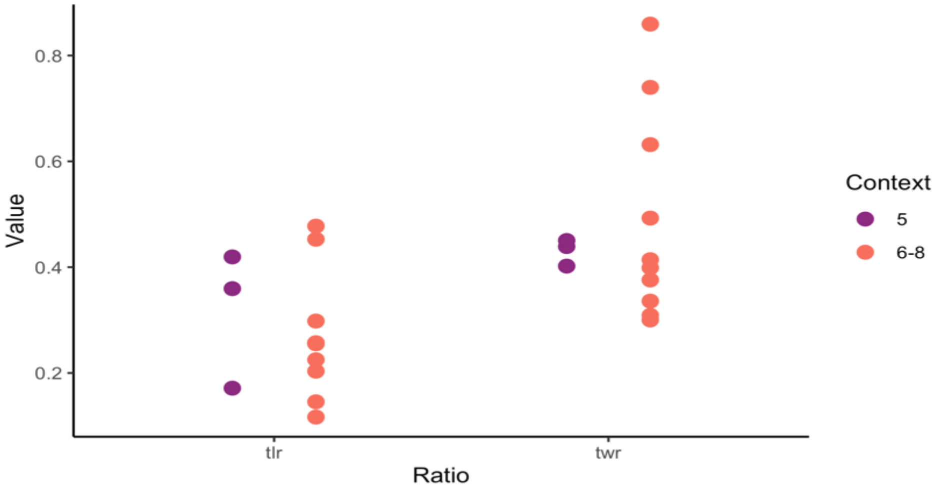
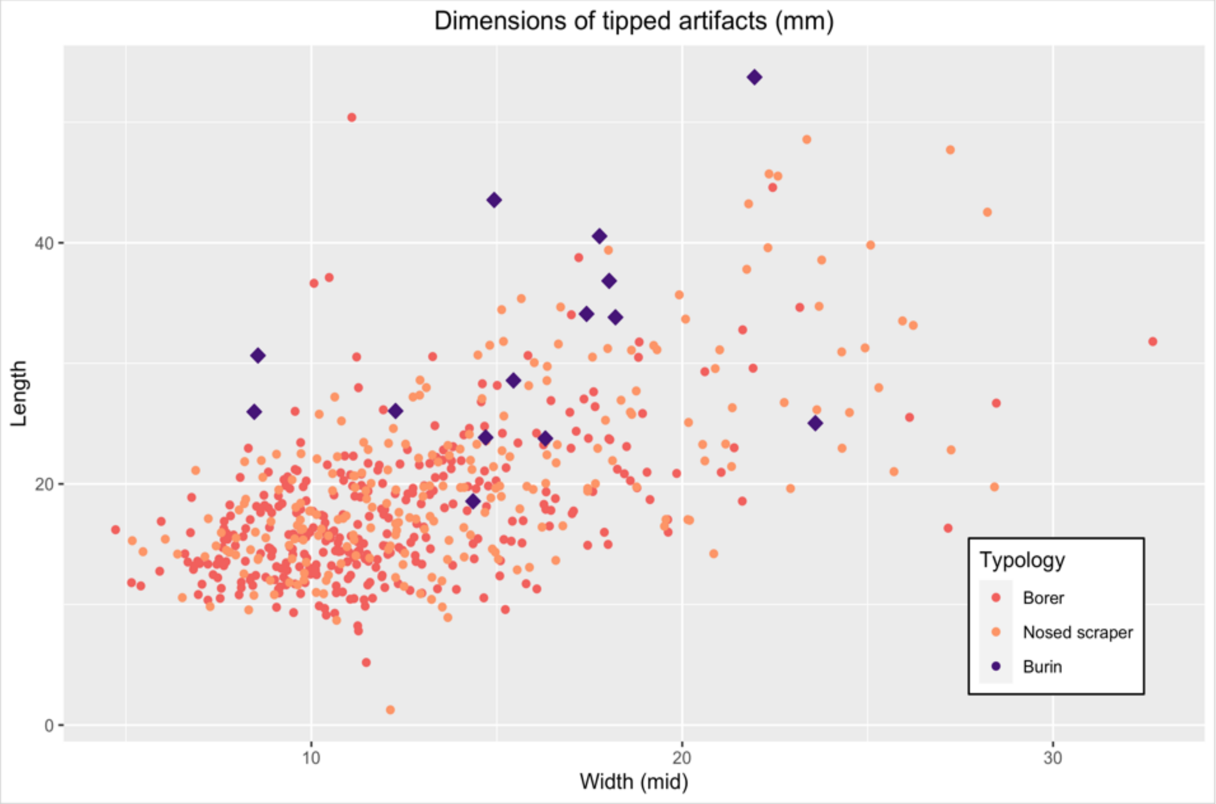
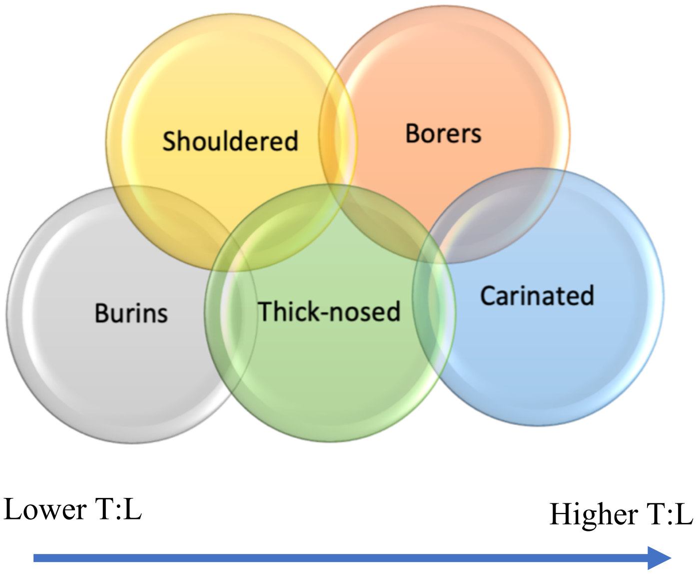


Figure 40 Dimensions of tipped artifacts (mm).



Although “chunky” components have been identified in both the burin and nosed scraper assemblages, suggesting that some of the “tools” may have been used as cores, clearly not all burins or nosed scrapers were used for this purpose. The divisions between borers, burins, and nosed scrapers are somewhat arbitrary, and a lack of usewear evidence for the three types makes division based on function impossible. Thus, the dimensions of borers, burins, and nosed scrapers were compared, with the expectation that differences would exist between borers and burins, and between borers and the “chunky” nosed scrapers if the three types were real. When absolute length is plotted against width at the midpoint, burins fall within the upper range of both borers and nosed scrapers. Because of the small number of burins (only 14 had the measurements used for comparison), forty Mann-Whitney U-Tests were performed against randomly selected samples of fourteen nosed scrapers and borers.

Figure 41 Venn diagram of T:L ratios, where overlap indicates an insignificant p-value.



The p-values for absolute length were significant (<.05) for all forty groups, confirming that mean burin length (31.79 mm) is greater than both mean nosed scraper (20.76 mm) and borer (17.45 mm) lengths. The mean T:L ratios for borers and nosed scrapers are significantly higher than those for burins ($p<0.001$). This might have less to do with “chunkiness” and carination and more to do with the fact that burins simply tend to be longer. When nosed scrapers are broken down into the un-notched (carinated) and shouldered types, each type is still significantly different in length from both burins and borers, but the two types do not differ significantly in length from each other. When a Dunn Test is performed on thickness/length ratios using the Bonferroni correction for multiple comparisons, a series of overlapping relationships can be identified (Figure 41). Burins have the lowest T:L ratio and are statistically different from borers and un-notched (carinated) nosed scrapers. Un-notched scrapers have the highest T:L ratio and are statistically different from shouldered nosed scrapers and burins. Thick-nosed scrapers are not statistically different from any of the groups, and borers are only different from burins. If a “chunky,” core component to the Melikane borer, burin, and nosed scraper assemblage exists, it is most clearly seen in the un-notched (carinated) nosed scrapers. These scrapers are dimensionally different from longer, thinner burins and the “shouldered” nosed scrapers. They have the highest T:L ratio of all the types.

Overall, these results support the presence of a carinated, chunky component in Melikane’s nosed scraper assemblage. The division of borers from burins in Melikane’s typology is confirmed by significant differences in their dimensions. However, borers cannot be as easily separated from any of the nosed scraper types. The “pointed” tools in Melikane’s assemblage are a diverse group, consisting of distinct morphological types, some of which may have been cores first and tools second. An ongoing usewear study on Melikane’s borers will help to clarify these differences and varieties.

Borers

Borers (engravers) are the most common tool type in both contexts, increasing to 41.6% of the entire tool assemblage in context 5. They are a mainstay of the Melikane retouched assemblage from the site’s earliest occupation in MIS 5a and clearly comprise a critical part of the Melikane toolkit (Pazan et al., 2022). Borers are not common at other MSA and LSA sites in the interior and seem to be a unique adaptation to the highland environment around the site. They are shorter than nosed scrapers and burins, and tend to be chunkier than the latter, possibly due to more extreme reduction on the same blanks. Usewear studies remain ongoing but change or stability in borer form over time could provide hints related to their function. If borer form remains relatively stable, then it is likely that borers were used for a single, fixed task. If their form changes, then it is more likely that they represent a flexible “style” used for a range of activities.

Although CCS is retouched at a disproportionately low rate in relation to its prevalence in the assemblage as a whole, it is actually more common among borers than it is in the rest of the assemblage (Table 67). In context 5, 81.5% of all borers are made of CCS, compared to 78.2% of all other artifacts. A G-test comparing borers to the rest of the assemblage shows these differences are significant at the p=0.002 level. Similarly, 68.3% of all borers are made of CCS in contexts 6-8, compared to 63.5% of the rest of the assemblage (p<0.001). CCS is even more common among borers when compared to the rest of the tool assemblage, and hornfels and sandstone are strikingly less common (G-test, p<0.001 for both contexts). Despite an overall preference for hornfels in the tool assemblage, CCS is preferred for borers specifically. Just as the raw material proportions differ between contexts for all artifacts, they differ between contexts for borers as well, with CCS increasing and hornfels decreasing in context 5 (p<0.001).

Table 67 Raw material proportions for borers.

Context	**5**						**6-8**					
	Borers		*Other tools*		*All other artifacts*		*Borers*		*Other tools*		*All other artifacts*	
	N	*%*	*N*	*%*	N	*%*	N	*%*	*N*	*%*	*N*	*%*
CCS	825	*81.5%*	*933*	*65.8%*	5747	*78.2%*	775	*68.3%*	1267	*55.1%*	5116	*63.5%*
Hornfels	133	*13.1%*	*329*	*23.2%*	953	*13.0%*	215	*18.9%*	617	*26.8%*	1459	*18.1%*
Sandstone	50	*4.9%*	*151*	*10.6%*	561	*7.6%*	134	*11.8%*	403	*17.5%*	1320	*16.4%*
Other	4	*.4%*	*5*	*.4%*	84	*1.1%*	11	*1%*	14	*0.6%*	168	*2.1%*
	1012		*1418*		7345		1135		2301		8063	

CCS may have been preferred for borers because it is more easily retouched, especially when the desired implement is small. The average Melikane CCS borer is 16.74mm in absolute length, microlithic in any sense. Hornfels and sandstone/quartzite borers are longer, averaging 18.61mm and 22.27mm respectively. Kruskal Wallis tests in both contexts show that these differences are significant (5: p=0.03, 6-8: p=0.002). Unlike blanks and many other components of the Melikane assemblage, borers do not become shorter over time. Instead, the significant differences between contexts 5 and 6-8 are in borer width (Figure 42). CCS borers are significantly wider in context 5, averaging 12.01mm at the midpoint (p<0.001) and 14.04mm in maximum width (p=0.017), compared to 10.94mm and 12.72mm respectively in contexts 6-8. This affects the length/width ratio as well, lowering it in context 5. Hornfels borers are also greater in maximum width in context 5 (p=0.018). This is the opposite of the trend towards microlithization seen elsewhere in context 5 and contradicts the overall decrease in blank width in the same context. However, when outliers are removed, context 5 and 6-8 borers are indistinguishable in maximum and midpoint widths (p=0.093, 0.282).

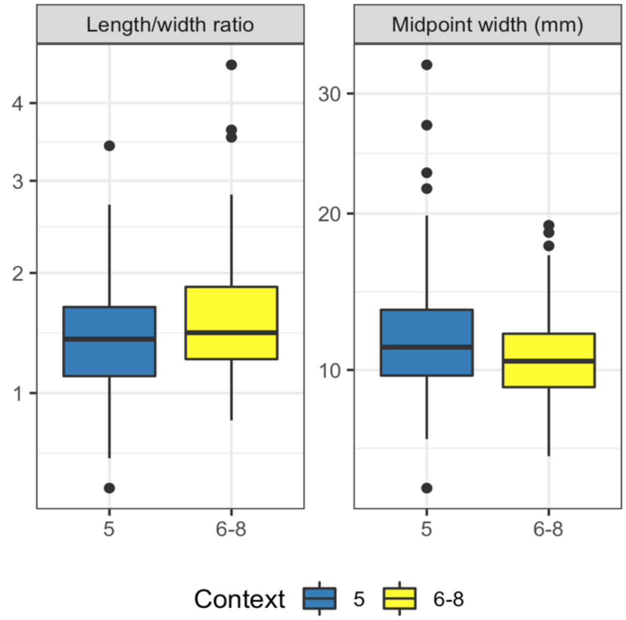
Table 68 Borer tips per tool.

	Context 5		Contexts 6-8	
# "borer-like" tips	N	%	N	%
1	129	70.9%	77	69.4%
2	49	26.9%	29	26.1%
3	4	2.2%	4	3.6%
4	0	0%	1	.9%

Table 69 Tool edges per borer.

	Context 5		Context 6-8	
# tool edges	N	%	N	%
1	24	*13.5%*	11	*9.9%*
2	54	*30.33%*	30	*27.0%*
3	77	*43.3%*	48	*43.2%*
4	23	*12.9%*	22	*19.8%*

Figure 42 CCS borer dimensions over time.



Otherwise, borer form is remarkably consistent between contexts 5 and 6-8. There are no changes in hafting, the location of the boring tip, or the number of boring tips per tool. Certain hafting damage was only recorded on a handful of borers. It was recorded more frequently on endscrapers, but even the proportion of endscrapers with hafting damage does not differ between contexts. The number of boring tips per tool is easy to calculate based on how many "borer-like" edges were recorded on each tool. The proportions for contexts 5 and 6-8 are nearly identical, with 30.6% of borers in contexts 6-8 and 29.1% in context 5 having more than one tip (Table 68). More borers in contexts 6-8 have use or retouch on all four margins in comparison to context 5 (Table 69), but a Kruskal Wallis test on the mean number of edges (p=0.101) and a z-test of proportions were both insignificant (p=0.160).

The CCS borers from contexts 5-8 were compared to those from the MIS 5a assemblage (80k) at Melikane to look at large-scale temporal changes. The MIS 5a borers were significantly longer than those from contexts 5 and 6-8, averaging 34.24mm in absolute length for all materials combined and 27.67mm for CCS only (p<0.001). The MIS 5a borers are also significantly wider, averaging 17.32mm at the midpoint and 17.41mm in maximum width (p<0.001 for both). 56.1% of MIS 5a borers are made of CCS, less than in contexts 5 and 6-8. An additional 32 borers are made of sandstone/quartzite (39.0%), and 4 are made of hornfels (4.9%). These proportions are significantly different from the raw material proportions in the rest of the MIS 5a assemblage, which is comprised of 35.2% CCS, 61.8% sandstone/quartzite, and 1% hornfels (z-test, $p<0.001$). Thus, like the context 5 and 6-8 borers, CCS was preferred to coarser-grained material for borer production in MIS 5a.

The function of the Melikane borers remains elusive. It is possible that they were used for perforating hides during clothing production. Considering their small size, it is also possible that some were used as barbs on composite weaponry. The borers from contexts 5 and 6-8 are smaller than the MSA borers. Their sharp tips may have been particularly effective at puncturing the hides of large game animals. Although most borers have only one sharp tip, most also have additional modified margins. Most of the non-boring tool edges (63.4%) have angles greater than 60º, and 11.3% of the non-boring edges are classified as "steep," implying an angle ~90º, and 60.9% of these "steep" edges had bimarginal retouch, unequivocally fitting the definition of "backed." Whether or not these borers were used as barbs in multicomponent weapons, backed microliths with sharp tips could be functionally used as such. It would also explain why they are so common in the assemblage – multiple borers/barbs would be required to fit one tool. Ongoing usewear studies with borers from various contexts at Melikane will clarify whether this is a legitimate possibility.

Some of the Melikane borers resemble the Upper Paleolithic and Mesolithic "microburins" from western Europe and the Levant (see examples in Chesnaux, 2014; Goring-Morris et al., 1999; Miolo & Peresani, 2005; Peresani & Miolo, 2012; Wilde & Bie, 2011). The "microburin technique" was used in backed microlith production, but the microburins themselves may not actually have been used as tools. A typical microburin is created by retouching a notch on a larger blank until it fractures transversely. The result is an artifact with half a retouched notch truncated by what appears to be a burination (Peresani & Miolo, 2012). Although not all the Melikane borers fit this description, the ratio of microburins to backed artifacts at Melikane is comparable to the ratios at Saflulim, a Late Natufian site in the Levant. At Saflulim, the ratio of microburins to microliths and geometrics varies by level from 30.5/1 to 7.3/1 (Goring-Morris et al., 1999). At Melikane, the ratio is 13.6/1. Microburins were first described in southern Africa in Wilton assemblages on the Cape by Heese (1934, 1935; 1946), who named them "Platbosch burins” to distinguish them from their European cousins. Malan (1950) also described them at Kai Kai, a Wilton site in the Kalahari.

Future studies will clarify whether some of Melikane borers were created through the microburin technique, used as barbs on multicomponent weaponry, or for maintenance tasks including hide processing or clothing fabrication. Considering the MIS 5a data alongside the borers from contexts 5-8, it is clear that small, CCS blanks were always preferred for borer production. However, a significant decrease in borer size during MIS 2 indicates that their function, or at least the way in which they were used, may have changed during the LSA.

Miscellaneous Retouched Pieces (MRPs)

MRPs comprise a wide variety of retouched forms, from blanks with only a few clustered removals, to multipurpose “Swiss army knives” with multiple working tips and edges. Their unifying characteristic is that they are informal and produced without dedicated intent. They may have been produced quickly to meet the needs of the moment or were opportunistically modified time and time again until their original function was lost. For example, a blank may have been initially quickly sharpened on its distal end for cutting, then hastily burinated on the proximal end to perforate hide, and then denticulated on one of its lateral margins to cut again.

MRPs represent 16.6% of Melikane’s MIS 5a tool assemblage, making them the second most-common tools behind borers (25.2%). MRPs are equally important in context 5 (17.1% of all tools) and even more important in contexts 6-8, where they comprise 23.5% of all tools. Does their decline in context 5 represent the adoption of a more “formal” toolkit in the LSA? Or are contexts 6-8 an anomaly, and high MRP frequency was an adaptation to a particular stressor? Are there any trends in the sizes and raw material proportions of MRPs? What are the most common tool edge type combinations, and do they change over time?

Table 70 Raw materials for MRPs by context.

	CCS		**Hornfels**		**S/Q**	
	N	%	N	%	N	%
Context 5	266	*63.9%*	88	*21.2%*	62	*14.9%*
Contexts 6-8	443	*55.2%*	224	*27.9%*	135	*16.8%*
Fisher: p=0.011. Significant residuals for CCS.						

MRPs are preferentially made on hornfels and sandstone. Just as CCS is more ubiquitous overall in context 5, it is more common among the context 5 MRPs than context 6-8 MRPs ($p=0.011$). In context 5, only 15.1% of all CCS tools were MRPs, compared to 19% of all hornfels tools and 30.8% of all sandstone/quartzite tools (pairwise z-test, $p<0.05$ for all raw material pairings). In contexts 6-8, 21.7% of CCS tools, 26.9% of hornfels tools, and 25.1% of sandstone/quartzite tools were MRPs. A pairwise test for proportions only produced a significant p-value ($p=0.009$) for CCS versus hornfels. These results confirm that CCS was "saved" for the formal tools like borers, whereas sandstone/quartzite and hornfels were either more dispensable or ideal in other ways for informal tool making.

Mean MRP size does not vary between raw materials or contexts. Only a Kruskal-Wallis Test of material versus midpoint width in context 6-8 produced a significant p-value, but a posthoc Dunn Test using the Bonferroni correction revealed no significant pairwise residuals. However, a significant p-value for a Fligner-Killeen Test indicates that hornfels MRPs from context 5 are more standardized in length than those from contexts 6-8 (Figure 43, Table 71). The Fligner-Killeen test assesses the variance of non-parametric data. A significant result indicates that the measurements from one data group are distributed differently around the median than measurements from the other. When applied to lithic data, it assesses relative standardization of a measurement and is reflected in the standard deviation of any value. The standard deviation for the length of hornfels MRPs is 4.48mm in context 5, but 11.08mm in contexts 6-8. The standard deviations for widths and thickness in context 5 are also approximately half of their values in contexts 6-8. This pattern of increased standardization of hornfels MRPs in context 5 does not apply to the other raw materials, and when all materials are combined, there are no differences in means or variances between contexts in any of the dimensions.

Figure 43 Density plot of length for hornfels MRPs.

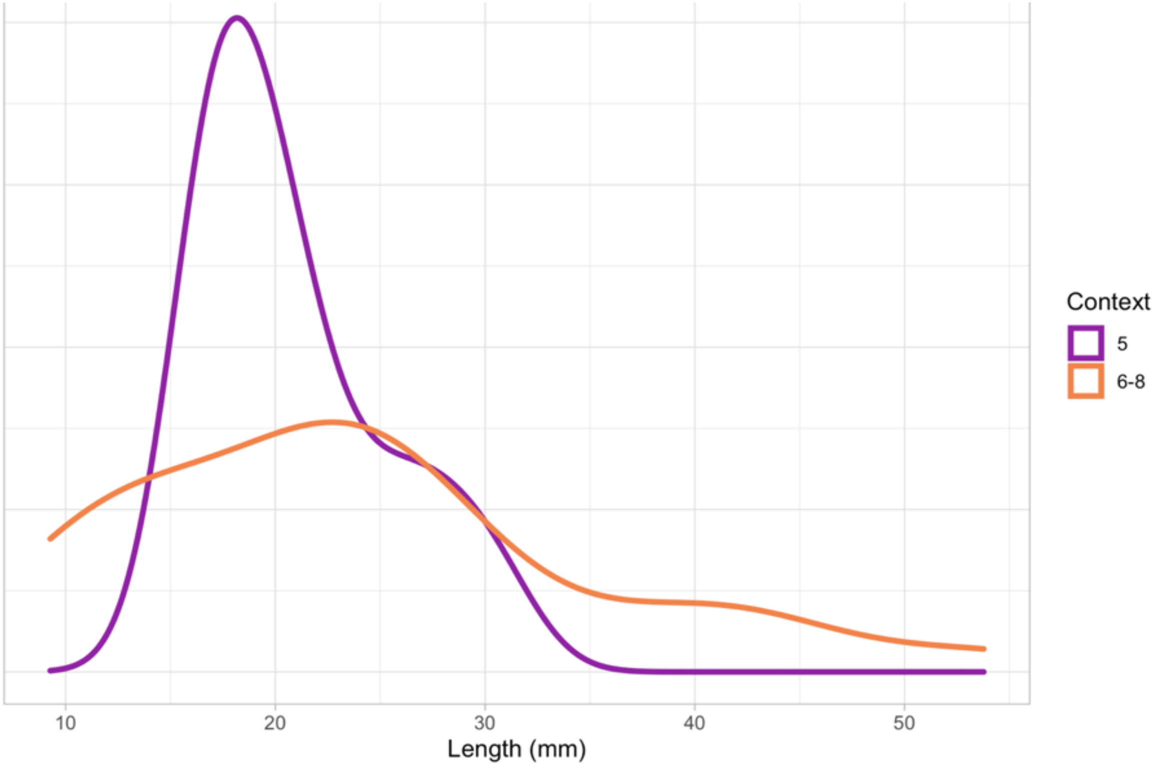


Table 71 MRP dimensions by raw material and context.

MRPs	**Context 5**				**Contexts 6-8**				**All contexts**			
	CCS	*Hornfels*	*S/Q*	*All*	*CCS*	*Hornfels*	*S/Q*	*All*	*CCS*	*Hornfels*	*S/Q*	*5 all vs. 6-8 all (KW, F)*
Length Mean Median SD N=	19.14 19.40 6.16 N=81	20.84 20.07 4.48 N=33	31.57 24.47 19.53 N=28	21.29 19.67 9.36 KW: p=0.325	21.20 18.75 7.70 N=143	23.92 23.13 11.08 N=89	25.84 23.63 9.01 N=54	22.70 21.83 9.08 N=288 KW: p=0.322	F: p=0.43 KW: p=0.37	**F: p=0.027** KW: p=0.466	F: p=0.336 KW: 0.763	p=0.366 p=0.086
Width (mid)	14.96 13.34 5.31	15.07 15.61 3.22	20.63 19.18 10.49	15.75 14.41 5.92 KW: p=0.556	14.77 12.99 5.39	18.02 16.63 6.83	19.77 16.46 8.10	16.47 14.26 6.44 **KW: p=0.04 (Dunn: no diffs)**	F: p=0.75 KW: p=0.87	**F: p=0.015** KW: p=0.313	F: p=0.280 KW: 0.920	P=0.561 P=0.303
Max width	17.17 15.18 5.63	16.52 17.08 3.35	24.19 22.51 12.13	17.92 15.78 6.64 KW: p=0.483	17.30 15.69 6.11	20.32 20.62 7.44	21.17 19.01 8.75	18.79 17.89 6.99 KW: p=0.231	F: p=0.53 KW: p=0.98	**F: p=0.027** KW: p=0.073	F: p=0.267 KW: 0.841	P=0.427 P=0.131
Max thickness	7.65 7.43 2.38	8.10 7.62 1.52	10.94 8.77 6.73	8.21 7.57 3.18 KW: p=0.235	8.15 7.79 2.67	9.01 7.94 3.75	9.44 8.55 3.93	8.58 7.82 3.21 KW: p=0.771	F: p=0.29, KW: p=0.46	**F: 0.018** KW: p=0.068	F: p=0.762 KW: 0.547	P=0.539 P=0.062
Tool edges	2.407 3 1.010	2.692 3 1.032	2.2 2 0.837	2.467 3 0.991 P=0.56	2.711 3 0.968	2.828 3 0.966	2.545 3 0.688	2.733 3 0.926 P=0.73	2.597 3 0.988 P=0.214	2.786 3 0.976 P=0.665	2.438 3 0.727 P=0.373	P=0.133, 0.231

Neither a Kruskal Wallis test nor a linear-by-linear (LBL) association test found any differences in the number of tool edges for MRPs by context (LBL, p=0.128), nor any differences in the numbers of tool edges between raw materials (LBL, p=0.397). Interestingly, the number of tool edges has a positive, weak, monotonic relationship with absolute length (Kendall's Tau-b=0.155, p=0.022). If the number of tool edges were related to reduction intensity, then an inverse relationship would be expected. When broken down by context and raw material, this relationship is strongest in context 5 (Tau-b=0.227, p=0.051) and among all CCS MRPs (Tau-b=0.194, p=0.033). P-values for contexts 6-8 and the other raw materials are insignificant. The best explanation for this relationship is that the smaller CCS MRPs were more likely to be hastily retouched on one margin, used once, and then discarded, having little potential use life left due to their small size. Larger CCS MRPs, however, may have had more use potential in the first place, and were thus selected for multifunctionality.

Scraper-like edges were the most recorded edge type among MRPs in both contexts, comprising 63% of all edges in contexts 6-8 and 74.1% in context 5. Notch-like edges were the second most common (17.4% and 12.9%), followed by borer-like, steep, and least commonly, hafting-related edges. A Fisher Test found no differences in the overall numbers of edge types between contexts, but when scraper-like edges were isolated and juxtaposed against all other edges, a z-test for proportions produced a p-value of 0.015. This suggests that scraper-like edges did rise significantly in context 5, but not enough to fundamentally change all the proportions in the assemblage. When isolated, none of the other edge types produce significant results for z-tests. Most scraper-like edges are straight, but 31.6% were convex, and 8.9% were concave. Concave, scraper-like edges are a hallmark of a Holocene LSA tool found at Sehonghong, the spokeshave (Carter et al., 1988). Cable (1984) has also called these "notched scrapers." Concave edges have been associated with wood-working tasks, but no experimental study has yet confirmed this association (Nieuwenhuis, 1998).

The most common type of MRP had just one retouched, scraper-like margin (n=32, type "1S"). The second and third most-common types had just two and three scraper-like margins (n=15, type "2S"; 12, type "3S"). These were followed by two-scraper/one-notch (n=10, type "2S/1N"), two-scraper/one-borer (n=9, type “2S/1B”), and one-scraper/one-notch (n=7, type “1S/1N”) varieties. The only MRP variety without any scraper edges to occur more than once was a one-borer/two-notch type (n=2, type “1B/2N”). The “1S”-type MRPs are small and primarily made on CCS (68.8%). The median absolute length for all 1S MRPs is only 16.67 mm. Their mean length of 19.36 mm is heavily skewed by a 56.66 mm-long sandstone/quartzite outlier but is still significantly smaller than the mean length of 22.93 mm for the other MRP types (Kruskal Wallis, p=0.016). Different edge types and combinations were also associated with particular raw materials. Only 45.9% MRPs with notch-like edges were made of CCS, compared to 60% of MRPs with scraper-like edges and 65.2% with borer-like edges.

Table 72 Linear regression results for length and tool edge type frequencies on MRPs.

	Dependent variable:
	Length
Scraper-like	0.540
	(0.841)
Borer-like	2.461
	(1.715)
Notch-like	4.678***
	(1.492)
Hafting-related	0.837
	(2.968)
Steep	3.761**
	(1.746)
Constant	18.817***
	(1.612)
Observations	130
R^2	0.135
Adjusted R^2	0.100
Residual Std. Error	8.710 (df = 124)
F Statistic	3.876*** (df = 5; 124)
Note:	*p**p***p<0.01

There is no significant correlation between MRP length and the number of scraper-like edges (Tau-b, p=0.95), but a moderate-to-strong correlation exists between the number of notch-like edges and length (Kendall’s tau-b=0.246, p<0.001). MRPs without any notch-like edges average 20.52 mm in length, whereas those with 1 notched edge average 25.75 mm, and those with two notched edges average 31.09 mm. “Steep” edges also show this positive, monotonic relationship (Tau-b=0.175, p=0.014).

To better quantify and understand the relationship between edge type and MRP length, a linear regression model was created using the lm() function in the *stats* package in R (R Core Team, 2021). The only dependent variables with significant p-values were the number of steep and notch-like edges. Scraper-like, hafting-related, and borer-like edges were insignificant in this model. The coefficient of 4.678 for notch-like edges indicates that for the addition of every notch-like edge, an MRP will increase 4.678 mm in length. Likewise, an MRP will increase 3.761 mm in length for the addition of every steep edge. An R^2 value of 0.135 indicates that the model explains only 13.5% of the data, but this is likely because of the relatively low number of MRPs with *any* steep or notch-like edges. Regardless, it confirms that larger, often coarse-grained MRPs will frequently have multiple steep or notched tool edges. These tools could be interpreted as the highly curated Swiss army knives of the Melikane toolkit, whereas the microlithic "1S" MRPs may represent expedient and disposable tools.

Backed Artifacts

"Backed" tools were those exhibiting evidence of backing, with or without usewear, whose primary form did not fit into another tool category. Fifty-six backed artifacts were recovered from context 5 (2.3% of tools) and 102 were recovered from contexts 6-8 (3% of tools). Sixteen and thirty of these were measured in contexts 5 and 6-8 respectively (Table 73). Sixty-three percent (n=19) of the backed tools in contexts 6-8 were made from CCS, compared to 73% (n=11) in contexts 6-8. The remainder of the backed artifacts were made of hornfels and sandstone/quartzite. Two of the thirty measured artifacts in contexts 6-8 were segments. Both were backed microliths, at 15.73mm and 20.9mm in maximum dimension. Another unique artifact from 6-8 is a core tool featuring one backed longitudinal margin in opposition to scraper-like, bimarginal retouch on the opposite margin and end. It is nearly as thick as it is wide, with dimensions of 31.24mm in length, 17.28mm width at the midpoint, and 13.07mm in thickness. The tool's thickness modulates the possibility that it was hafted. It was more likely used as a stand-alone tool, blunted for safer handling. Eight of the 16 backed artifacts in context 5 and 10 of the 30 in contexts 6-8 were unbroken and made on flake blanks. The dimensions of complete backed artifacts do not change over time. Mann Whitney U-Tests do not produce significant p-values for length, thickness, length/width ratio, or length/thickness ratio. The vast majority of backed artifacts in both contexts are microliths, but none are bladelets.

Table 73 Statistics for backed artifacts.

	Context 5 (n=16)	**Context 6-8 (n=30)**
% CCS	73.3%	63.3%
Mean length (complete flakes)	21.99 mm N=8	18.80 mm N=10
Mean thickness (complete flakes)	7.41 mm	6.94 mm
Mean length (inc. broken)	18.44 mm	18.25 mm
% < 25mm (inc. broken)	86.7%	80%
% bladelets (L/W>=2)	0%	0%
Length/width ratio	Mean: 1.46 CV: 21.51	Mean: 1.47 CV: 17.83
Length/thickness ratio	Mean: 3.03 CV: 19.19	Mean: 2.78 CV: 17.62

Overall, there does not appear to be a change in the organization of backed artifact technology between contexts 5 and 6-8. This is consistent with the relative unimportance of backing as a trait in either the final MSA or early LSA of southern Africa. Instead, backing is associated with the Howiesons Poort during the MSA and the Wilton in the Holocene LSA. It is relatively rare in the Robberg, where unretouched bladelets were hafted instead. The presence of two segments in contexts 6-8 does emphasize its ties with the MSA, but it is also possible that they were recycled from the landscape or mixed in from lower levels. The unimportance of backed artifacts also distinguishes these contexts from the transitional and “ELSA” assemblages of East Africa. Enkapune ya Muto, White Paintings Rock Shelter, and Mumba Rock Shelter feature backed tools heavily in their ELSA and LSA assemblages (Ambrose, 1998, 2002; Diez-Martín et al., 2009; Gliganic et al., 2012; Robbins et al., 2000; Staurset & Coulson, 2014). These tools are not a prominent component of either the context 5 or 6-8 assemblage, and do not change in form over time.

Chapter 7: Discussion

The Melikane lithic assemblages from contexts 8-5 depict *in situ*, gradual, technological change rather than punctuated transformation or replacement. Shifts in the relative proportions of technologies in context 5 signify that the LSA, rather than being an invention introduced from elsewhere, was simply the acceleration of technological trends already in progress during contexts 6-8 and the MSA. Although Melikane's contexts 6-8 are transitional in the sense that they are in between the MSA and context 5 assemblages in their degree of microlithization, they are more similar to the latter in terms of typology, dimensions, and flaking systems. Contexts 6-8 may be part of the MSA/LSA transition at Melikane, but the transition probably began much earlier. Context 5, while exhibiting tremendous continuity with contexts 6-8, is perhaps better described as "Early Robberg" and grouped with the penecontemporary assemblages at Sehonghong and Boomplaas.

The most significant differences between the contexts concern reduction intensity, bladelet production, and the loss of MSA type-fossils. Context 5 has a significantly lower tool/flake ratio than contexts 6-8, a lower bipolar core/CRP ratio, less overall evidence for bipolar reduction, and a more variable EMI (edge modification index) for rectilinear tools. As a percentage of whole blanks, bladelets are similarly common in contexts 5 and 6-8, but the presence of high-backed cores and a higher bladelet/blade ratio in context 5 signify an important technological shift. There are no MSA "holdovers" in context 5, like the MSA knives in Sehonghong and RCC's transitional assemblages (A. M. B. Clark, 1997b; P. J. Mitchell, 1994a). Points, prepared cores, and prepared platforms all fall in frequency.

Despite these differences, context 5 does not present an abrupt break in the technological sequence at Melikane. Many of its differences are the culmination of a linear trend that began in the lower spits of contexts 6-8. Trends include decreases in core and flake size, the near-disappearance of parallel cores, an increase in CCS use, and an increase in platform core frequency. Nor do provisioning strategies for each raw material do not change: CCS was always reduced at the site more frequently than hornfels. Several indicators support this, including a greater non-cortical/cortical debitage ratio for hornfels, overrepresentation of curated hornfels tools, and underrepresentation of hornfels cores. All of this suggests that if an occupation hiatus exists between the two contexts, it is brief and relatively inconsequential. Except for the high-backed bladelet cores, all technologies and types present in context 5 were present in contexts 6-8, and all trends are a continuation of trends already present in the MSA. This strong intrasite continuity supports both an in situ MSA/LSA transition in the Lesotho highlands and an early LGM date for context 5. This chapter summarizes the Melikane flaking systems and toolkits and evaluates each of the hypotheses presented in Chapter 3.

Assemblage Summary

The Melikane Flaking System

The unmodified components of Melikane's contexts 5 and 6-8 exhibit characteristics frequently associated with Pleistocene early microlithic assemblages: the use of fine-grained raw materials, bipolar percussion, microlithization, evidence of bladelet production, and only rare prepared cores (Beaumont, 1978; Beaumont & Vogel, 1972; J. Deacon, 1984b; P. J. Mitchell, 1988a). Extremely heavy bipolar reduction in contexts 6-8 lessens slightly in context 5, although a trend towards further miniaturization continues. Cluster analyses identified a species of bipolar flake based on shared attributes. These flakes have crushed platforms, acute exterior platform angles, and sheared bulbs. Interestingly, these flakes are present in nearly equal proportions in contexts 5 and 6-8, suggesting that "bipolar flake frequency" may be a poor proxy for the actual extent of bipolar reduction, or perhaps that bipolar reduction was not only occurring on-site, but also on an ad-hoc basis on the landscape. In this case, bipolar reduction may have been more extensive in context 5 than these results suggest. Cluster analyses identified two other blank types that went undetected when attributes were considered in isolation. "MSA-type" flakes with diffuse bulbs, ~90° platform angles, feather terminations, and plain platforms become significantly less common in context 5, whereas small flakes with punctiform platforms and point-type bulbs double in frequency. These changes may reflect a decline in MSA core reduction strategies and a rise in Robberg-like bladelet reduction. Bladelet frequencies are similar in contexts 5 and 6-8, but a greater percentage of laminar products from context 5 are <25mm in length. Bladelet frequencies in both contexts are like those in the Early Robberg (BAS) at Sehonghong.

MSA core and platform preparation techniques were also phased out over time. Parallel cores are half as common in context 5 as they are in contexts 6-8. Parallel cores include (but are not limited to) Levallois cores and are highly characteristic of the MSA at Melikane. In the MIS 5a core assemblage, parallel and multidirectional cores are the dominant types, present in equal numbers. In context 28 (~78-60 kya), parallel cores are most common, outnumbering multidirectional cores by a ratio of 7:1. This ratio equalizes in context 27, the fluorescent Howiesons Poort (~60 ka), in which multidirectional cores are slightly more common than parallel. In contexts 6-8, multidirectional cores outnumber parallel cores 2.74:1. This ratio then *doubles* in context 5 to 5.78:1. Parallel cores are less common in context 5 than in any other studied context of the Melikane assemblage. Like prepared cores, prepared platforms are still present in contexts 6-8 and 5, but at much lower levels than in contexts attributed to the MSA. In MIS 5a, 29.2% of all platforms are prepared, compared to contexts 5 and 6-8 where they comprise 13.7% and 16.4% of platforms respectively.

Microlithization and reduction intensity are not necessarily coupled at Melikane. Context 5 is more “microlithic,” with smaller blanks and cores. However, contexts 6-8 are more heavily reduced, with higher frequencies of shatter and a greater overall percentage of cores with evidence of bipolar reduction (54.5%). Context 5 compensates for this with greater frequencies of multidirectional, platform, and initial cores. Bladelet cores, heterogenous in contexts 6-8, become more formal in context 5. The presence of “high-backed” bladelet cores in context 5 suggests ties with the Robberg occurrence in BAS at Sehonghong as well as with other Robberg sites, including Nelson’s Bay Cave and Boomplaas (J. Deacon, 1978, 1984b; P. J. Mitchell, 1995).

The data surrounding bipolar technology at Melikane contradict theories explaining its use and the origins of miniaturization. An oft-repeated theory is that by utilizing quartz and recycling cores, foragers during the MSA/LSA transition and early microlithic LSA could avoid the costs of raw material acquisition and redirect their energy elsewhere (Eren et al., 2013; P. J. Mitchell, 1988a; also see Jeske, 1992). Eren et al. (2013) correlated higher bipolar core frequencies across the MSA/LSA transition at Mumba Rockshelter, Tanzania with rising occupation density and territoriality, arguing that bipolar reduction could balance the costs of territory protection and composite tool production and maintenance. Tryon and Faith (2016) adopted this as an explanation for bipolar reduction at Nasera Rockshelter, Tanzania over the MSA/LSA transition. At Nasera, bipolar core frequencies and artifact densities rose as tool frequencies fell, suggesting that the increased use of bipolar technology was related to longer periods of site occupation. Pargeter and Faith (2020) also explored this idea at Boomplaas Cave in the Cape Fold Mountains of South Africa during the LGM and Late Glacial, hypothesizing that decreased seasonality and subsequently more intense occupation exhausted local raw materials and encouraged more intense core reduction.

However, raw material economy does not seem to have been a priority at Melikane. If foragers were using bipolar reduction to save material, then higher frequencies of bipolar cores should correlate with smaller core sizes. However, despite the presence of more bipolar cores and CRPs in contexts 6-8, cores are smaller in context 5. We should also expect to see a distinct size threshold separating freehand and bipolar cores, representing the point at which bipolar percussion was required to further economize raw material. As expected, bipolar cores are smaller than freehand cores, with relative risk ratios indicating that longer and wider cores are more likely to have been reduced using freehand percussion. However, attempts to group cores into freehand, bipolar, and CRP clusters based on their dimensions produced high error rates for freehand and bipolar cores. Using PAM cluster analysis, 50% of freehand and 45.5% of bipolar cores were misclassified, compared to only 7.4% of CRPs. This indicates that even cobbles large enough to be reduced using freehand percussion were still reduced using bipolar percussion. This is the opposite of what would be expected if raw material economy was a concern.

At Melikane, I believe it is more likely that bipolar reduction was used because it was a quick and convenient way to obtain usable cutting edge. *Provisioning activities*, defined as “producing artifacts on an ad hoc basis as needs for them arise,” is a low-cost strategy of making expedient tools when raw materials are abundant (Kuhn, 2004, p. 432). Foragers can avoid carrying tools with the caveat that they have sufficient time and material to produce them when the need arises (Nelson, 1991). Bipolar reduction, which reduces core mass more rapidly than freehand reduction (Pargeter & Eren, 2017), would make provisioning activities possible in terms of time, and the ubiquity of CCS cobbles on the landscape around the shelter would make it possible in terms of material. By making replacement microflakes and bladelets on an as-needed basis, Melikane foragers would minimize gearing-up sessions and save space in their mobile toolkits.

Provisioning activities would also allow for greater flexibility while away from the shelter. One disadvantage of using curated technologies is that foragers must know when and where tools will be needed (Binford, 1979a; Nelson, 1991). If resource scheduling is unpredictable, a forager is faced with either the possibility of failing to capitalize on a subsistence opportunity or the inconvenience of carrying a complete toolkit at all times. Provisioning activities saves foragers from carrying unneeded implements while allowing them to take advantage of any opportunities that arise. Even carrying a small core and knapping it on-the-go could have been a viable strategy for the Melikane foragers. According to Kuhn (2004), cores are impractical in mobile toolkits because they create waste despite high use potential. However, CCS economy may not have been an issue for the Melikane foragers given that average core size was relatively small. The cores themselves could have been used as tools (c.f. Kuhn, 1994), and the ability to make a variety of forms would have been beneficial if future needs were unknown. Finally, expedient composite tool production and repair is also consistent with Bousman's (2005) and Kuhn's (1989) observations that foragers in high-risk situations will make expedient extractive tools and replace their parts more frequently in order to decrease the chances of failure.

Under this hypothesis, provisioning activities, and by proxy extensive bipolar reduction, would occur only when resources were temporally unpredictable. If resource scheduling grew more predictable but the costs of loss were high, foragers would favor curated technologies readied ahead of time (Torrence, 1983). Standardized blanks, easier but more time-consuming to make using freehand reduction, would make multicomponent tools more reliable. New blanks could be easily slotted into a haft, fitting perfectly each time without the need for additional modifications. These blanks would also be less likely to fall out than those with less-than-perfect fits. In this case, taking the time to create regular blanks would pay off in greater chances of hunting success, and the time spent preparing blanks could be scheduled in advance without cutting into subsistence activities. This may explain the slight decrease in bipolar reduction visible in context 5. More predictable resource scheduling combined with increased resource scarcity would encourage the use of reliable, curated technologies.

It is also possible that hafting styles changed in context 5, favoring the use of standardized blanks and bladelets. There are ethnohistorical examples of multicomponent tools using irregular parts, including the aforementioned Australian death spear (Davidson, 1934). Because of the excessive use of mastic, death spear barbs did not need to fit perfectly into hafts. It is possible that the foragers in contexts 6-8 preferred this type of tool but switched to slotted hafts in context 5. The flakes fitted into these slots would be necessarily more uniform than those indiscriminately slathered in mastic and stuck on. Microwear and residue analyses of the Melikane microflakes and bladelets could provide a means for testing this hypothesis.

Overall, the Melikane flaking systems in both contexts 5 and 6-8 were concentrated on microflake production, but by slightly different means. In contexts 6-8, bipolar reduction was the primary method for obtaining microlithic blanks. In context 5, bipolar reduction remained the dominant technique, but freehand percussion on single-platform cores became slightly more common, possibly because reliability became paramount as the consequences of subsistence failure rose. Assuming continuity in hafting technology, irregular microliths may have been preferable when resource scheduling was unpredictable in terms of time, but the risk of failure was relatively low. Increasing consequences of failure would select for better planned and more reliable implements if predictable resource scheduling allowed for their production.

A shift from bipolar to freehand percussion also occurs at other transitional and Early Robberg sites. BAS has less evidence of bipolar percussion than the transitional levels (P. J. Mitchell, 1995). At Boomplaas, bipolar percussion reaches its apex in member LP, and then declines during the LGM in members GWA/HCA, and rises again after the LGM in member CL (Pargeter, 2017). In all three cases, the rise of high-backed bladelet cores coincides with the decline of bipolar cores (P. J. Mitchell, 1995; Pargeter, 2017; Pargeter et al., 2018). At these sites and at Melikane, bipolar percussion may have initiated miniaturization, but freehand percussion refined it.

The Melikane Toolkit

The high frequency of formal tools in the Melikane assemblage distinguishes it from many other late Pleistocene southern African assemblages (J. Deacon, 1984a). While it is possible that some scrapers and MRPs are heavily utilized flakes, borers are more difficult to misidentify and comprise 33% of tools in contexts 6-8 and 41.6% in 5. Additionally, comparatively high frequencies of retouch characterize all of Melikane's studied contexts, from the Howiesons Poort to MIS 5a (Pazan et al., 2020). Heavy retouch, rather than being a diagnostic tool, is simply a persistent site idiosyncrasy. Retouch frequencies are also heavily affected by mobility. If Melikane foragers had both low residential and logistical mobility, then they would produce assemblages with both high artifact densities and high retouch frequencies (Marean, 2016; Schoville et al., 2021).

High retouch frequencies and heavy tool reduction, particularly in contexts 6-8, may also have been a response to increased risk. Bousman (2005) observed that periods of aridity and high subsistence risk during the LSA at Blydefontein Rock Shelter were associated with "resource-maximization tactics," evidenced by the more frequent disposal of extractive tools (those used for procuring resources, ie. composite spears) but the more intensive curation of maintenance tools (those used for processing or making tools, ie. endscrapers). Most retouched tools at Melikane likely fall into the "maintenance" category, and their presence at the shelter indicates that they were not readily disposed of. Lower frequencies of unretouched bladelets and microflakes at the site could indicate that they were being expediently produced and disposed of in the field during extractive tasks.

Regardless of the high frequency of retouch at Melikane, infrequent retouch is also somewhat overstated as a characteristic of the ELSA and LSA in southern Africa. For example, the Robberg assemblages at Boomplaas are nearly 10% retouched (J. Deacon, 1984b). Porraz et al. (2016) note that some of the variation in tool frequencies can be attributed to how tools are recorded. They note that expediently retouched tools are sometimes counted as “utilized” and exist on a continuum with formally retouched and edge-damaged pieces. Varying degrees of retouch in these assemblages may also represent different mobility, site use, and provisioning patterns. It is important to note, moreover, that the sheer size of the Melikane retouched assemblages raises the likelihood of rarer tool types being found. There are thousands of retouched artifacts in contexts 5-8, compared to a total of nine in Sehonghong’s transitional levels (Mitchell, 1994). Thus, the presence of certain types (for example, points) in extremely small numbers at Melikane should not be seen as equivalent to their presence in smaller assemblages.

The Sehonghong transitional assemblages and level BAS provide the closest comparison, both spatially and temporally, to the Melikane toolkit. Mitchell’s (1994) study of levels OS, MOS, and RFS identified MSA-type knives in addition to a few scrapers, a naturally backed knife, and a truncated flake (Mitchell, 1994). In BAS, truncated flakes are the most common tool type, followed by assorted, unstandardized scrapers, MRPs, and a small number of backed artifacts (Mitchell, 1995). Truncated flakes, usually made on CCS, have no signs of use and a distal end that is “steeply and abruptly retouched to form a truncation that is straight in a little more than half of the cases and otherwise shallowly concave or convex” (Mitchell, 1995, p. 33). Mitchell’s truncated flakes are evocative of the “trapeze flakes” identified by Nieuwenheuis (1998) at the Late Pleistocene/Early Holocene sites of Tequendama and Galindo on the high plateau of the Colombian Andes. Ninety percent of these flakes at Tequendama showed evidence of hide-working, and one flake Galindo also showed evidence for wood working. These sites share ecological similarities with Sehonghong, located near a river in the highlands at ~2570 masl, and thus may provide a useful analogue.

Carter et al.’s (1988) earlier analyses did not identify these truncated flakes in his amalgamated layer “MSA 9” (which includes BAS), instead identifying endscrapers as the most common tool type along with an adze, a backed bladelet, and a retouched point. Scrapers also dominate the retouched portion of Carter et al.’s (1988) bladelet industry (the post-LGM Robberg), accompanied by a few retouched blades, bladelets, backed artifacts, adzes, a naturally backed knife, and one retouched point. Endscrapers are the most common scraper subtype, but a diversity of forms including sidescrapers and side/endscrapers are present. Carter et al. (1988) noted that most of the scrapers have steep edge angles, suggesting that they were heavily used and discarded only when their utility had been maximized. These steep-edged scrapers might be the "truncated flakes" referred to by Mitchell (1995).

Borers excepted, Melikane's toolkit resembles Sehonghong's with its focus on MRPs and scrapers. Like Carter et al.'s (1988) bladelet industry scrapers, Melikane's endscrapers are also extremely steep, with 87.8% of distal edge angles in context 5 measuring >60º. Truncated flakes were not initially identified in the assemblage, but a posthoc analysis separated 26 tools (11 from contexts 6-8 and 15 from context 5) with distal edge angles marked as "steep" (~90º) during attribute analysis. Seven of these were backed tools with other working edges. Eight borers and one nosed scraper had their distal edges blunted, presumably for safer handling. The remaining tools were five MRPs, one endscraper, and four side/endscrapers. The endscraper is the only one of these tools to have no other signs of use or retouch. It is from contexts 6-8, made of CCS, and measures 31.69mm in length and 27.33mm in maximum width. Its distal end is convex with stepped removals. Several other pieces resembling Mitchell's truncated flakes were identified during photography of the assemblage, but all have multiple modified margins rather than a single truncated margin.

Because Melikane's MSA contexts lack some stereotypically MSA tools, judging contexts 5-8 based on the presence or absence of MSA type-fossils is somewhat impractical. MSA knives, present in Sehonghong's transitional levels and at RCC, are absent from contexts 5-8. However, knives were never a significant component of Melikane's assemblage. Denticulates are the only tool type present at Elands Bay Cave (EBC) in the site's ELSA levels (Porraz, Igreja, et al., 2016; Porraz, Schmid, et al., 2016; Tribolo et al., 2016), and are present alongside knives at Rose Cottage Cave during the final MSA (A. M. B. Clark, 1997b; Wadley, 1991a, 2005). Denticulates make up ~0.2-0.3% of tools in contexts 5 and 6-8, but are also uncommon (~1% of tools) in Melikane's MIS 5a deposits, despite being the type fossil of Singer and Wymer's MSA 2a technocomplex (Singer & Wymer, 1982). Although it is tempting to view the rarity of knives and denticulates at Melikane as evidence that the assemblages are primarily LSA in character, to do so would neglect the site's history of implement use and idiosyncracies. It is possible that Melikane's ecological context never required the use of these tools.

Points, however, are present, albeit again in lower numbers relative to most other sites, in Melikane's MSA contexts. They are considered a hallmark of the MSA and also appear in the final MSA and MSA/LSA transitions at Sibudu, Umbeli Belli, and Umhlatuzana (Bader et al., 2018; J. Kaplan, 1990; J. M. Kaplan, 1989; Sifogeorgaki et al., 2020; Will et al., 2014), as well as in the LSA Sakutiek industry at Enkapune ya Muto (Ambrose, 1998). In contexts 5-8 combined, points comprise only 0.1% (n=7) of formal tools. In contrast, they comprise 7.4% of the total toolkit in MIS 5a and 23.3% of tools in context 28. The near-absence of points in contexts 5-8 at Melikane distinguishes the assemblage both from the earlier MSA assemblages at the site and from final MSA and transitional assemblages elsewhere.

The other types present in the contexts 5 and 6-8 toolkits are not particularly different from those found in the Melikane MSA assemblages. Borers are still the most common tool type in MIS 5a, followed by MRPs and various scrapers. Melikane's MSA borers are larger than the later borers, but a preference for CCS reaching back to the site's earliest occupation level suggests at least some continuity in use and form through deep time. Clearly, borers always served an indispensable role in the Melikane toolkit. The prominence of nosed scrapers is also unique to the Melikane assemblage. They are not a significant component of any penecontemporary transitional or LSA assemblages and instead seem to represent a hold-out from earlier contexts at the site.

Subtle changes in tool dimensions indicate that the tasks for which individual tool types were employed may have changed between contexts 5 and 6-8. Hornfels MRPs in context 5 are more standardized than those from contexts 6-8. Endscrapers are relatively more common than sidescrapers and side/endscrapers in context 5, but are actually less standardized than they are in contexts 6-8. Burins are less variable in size in context 5. Although the overall frequency of nosed scrapers does not change between contexts, contexts 6-8 have more "shouldered" nosed scrapers, or those whose nose is created with one notch. Context 5 has a greater proportion of chunky, un-notched nosed scrapers, which may include carinated types like those found in the

European Upper Paleolithic and indicate an additional undetected bladelet component. Other tool types do not change. Borers maintain the same mean dimensions and attributes in both contexts.

All proxies of tool reduction intensity indicate that contexts 6-8 are “more reduced” than context 5, and that hornfels is more reduced than CCS. It is possible that access to hornfels was limited, potentially due to extreme territoriality or natural topographic barriers made less passable by snow or glacial features. There would be two ways of solving the “hornfels problem.” The first is to heavily reduce all hornfels artifacts and eke out as much use from them as possible. This is the solution used by the foragers in contexts 6-8. The second is simply to use less hornfels, as is seen in context 5, and to modify the toolkit to better use other materials. Borers, which unlike other tools are preferentially made on CCS, increase in frequency in context 5. MRPs, which are made primarily of hornfels, drop in frequency. Lower hornfels availability may also have accelerated the microlithization process and the shift to multicomponent tools. The large scrapers, MRPs, and points in the Melikane MSA are usually made from hornfels and sandstone/quartzite. It is impossible to make the same large tools (>5 cm) using locally available CCS cobbles, which are often smaller than the former. A way around this would be to replace one large implement, such as a knife, with smaller implements grafted together onto one multicomponent tool. Interestingly, hornfels is also the dominant raw material in the Umhlatuzana Early Robberg tool assemblage, despite comprising only ~20% of raw materials overall (J. Kaplan, 1990). It is worth considering that microlithization at Melikane may have been a forced solution to a raw material problem rather than an improvement on existing technologies.

Evaluation of Hypotheses

In the following section, I evaluate my three hypotheses based on my assessment of the Melikane flaking and provisioning systems, toolkit, and mobility patterns.

Hypothesis A: Population Replacement/Migration

Hypothesis A posits that the MSA/LSA transition was the result of either population replacement or migration. Bousman and Brink (2018) argue that the transition is comprised of two events.

The first event, the final MSA/ELSA transition, is a population replacement event occurring over a period of 20,000 years. The second event, the ELSA/Robberg transition, is faster, beginning in the southern Cape, spreading into the Drakensberg, and then into the interior. According to the authors, there should be no visible transitions at individual sites, but instead a series of “dynamic and punctuated events” (C. B. Bousman & Brink, 2018, p. 130). They also view both the ELSA and the Robberg as entirely unrelated to each other and to the MSA. The expectations of this hypothesis were a lack of technological continuity, the sudden appearance of new technological forms, and/or strong similarities between the Melikane, the other SRZ assemblages, and the “source” assemblages.

MSA to “ELSA” (Contexts 6-8) Transition

If contexts 6-8 supposedly represent the ELSA at Melikane, then the first and second expectations of hypothesis 1 are clearly unmet. The toolkit from contexts 6-8 is typologically similar to the earlier MSA toolkits at Melikane, showing a great deal of intrasite continuity and no evidence of sudden replacement. Borers, which are a mainstay of the Melikane toolkit as far back as MIS 5a, remain the strongest component of the tool assemblage. The proportions of scraper types change slightly, with side/endscrapers increasing in importance relative to the MSA. Notches and denticulates remain rare, and knives are absent. The most conspicuous difference between the contexts 6-8 and MSA toolkits is the disappearance of points. However, many of the ELSA assemblages that Bousman and Brink (2018) identify actually *include* points, and they are relatively insignificant even in Melikane’s MSA assemblages.

Flaking systems also show a significant degree of continuity. Bipolar percussion is far more prevalent in contexts 6-8 than during the MSA but is still a component of the MIS 5a flaking system. Even bladelet technology is present in the Melikane MSA – three cores with bladelet removals are present in the MIS 5a contexts. The major differences between contexts 6-8 and the Melikane MSA can be attributed to shifts in core type and raw material frequencies, not to the introduction of new forms and technologies. Blades are a stand-out component of Melikane’s MSA contexts, representing nearly one third of all blanks in MIS 5a. In contrast, flakes in contexts 6-8 tend to be broad and irregular. Parallel cores are more common in MIS 5a, but bipolar cores are more common in contexts 6-8. These two phenomena are likely interrelated. Bipolar percussion tends to produce wide, irregular flakes, whereas parallel cores allow for greater control over final flake form. It is also easier to make blades out of hornfels and sandstone/quartzite, which are more common in MIS 5a. The local CCS cobbles preferred by the foragers in contexts 6-8 are shorter and provide less longitudinal surface area on which to produce blades.

The third expectation of the migration/replacement hypothesis, that the Melikane "ELSA" assemblage should resemble other ELSA assemblages, is more difficult to unpack. Bousman and Brink (2018) posited that the ELSA began at Border Cave, and then spread from east to west across southern Africa. Thus, if contexts 6-8 are ELSA, they should resemble the Border Cave assemblage and penecontemporary assemblages in the SRZ, including those at Sehonghong, Rose Cottage Cave, and Umhlatuzana. We would expect to see similarities primarily in flaking systems, which usually only transfer alongside genes and are transferable between different environments (Tostevin, 2012). Villa et al.'s (2012) study of the Border Cave ELSA material describes a microlithic, bipolar-dominated assemblage, but Beaumont (1978) also described "very crude radial prepared cores" and flakes with facetted butts. Backwell et al.'s (2018, p. 425) new excavations found "big flakes probably from multifacial cores," indicating that the Border Cave ELSA flaking system was clearly still borrowing from the MSA. Melikane's contexts 6-8 do share a microlithic, bipolar-focused flaking system with the Border Cave ELSA, but as previously discussed, bipolar technology has deep roots at Melikane, reaching back to MIS 5a. Furthermore, contexts 6-8 have a small platform core element unknown in the Border Cave ELSA, wherein bladelets were only produced from bipolar cores (Villa et al., 2012).

Three other sites in the Drakensberg/KwaZulu-Natal region – Sehonghong, Umhlatuzana, and RCC – are linked to Melikane by the presence of single platform bladelet cores. They are present in the final MSA (layer Ru) and transition (layers G and G2) at RCC (A. M. B. Clark, 1997b), in Sehonghong's transitional levels (P. J. Mitchell, 1994a), and in the MSA/LSA transitional layers at Umhlatuzana (J. Kaplan, 1990). These cores were not present in the Border Cave ELSA and rise in frequency at all four sites leading up to the LGM. Despite Umbeli Belli's proximity to Umhlatuzana, its final MSA (29 ± 2 ka on OSL) "platform cores" were reduced using a distinctly different flaking system. These cores feature an angle between the platform and removal surface of 55-80º, prepared convex removal surfaces, and flat or cortical backs. This flaking system is not described at the other SRZ sites. Although the SRZ sites all have small vestiges of prepared core technology, their single platform core flaking systems are more prominent and grow steadily from ~30-24 kcal BP. Like bipolar cores, single platform cores were not a new invention and did not "appear" first at a source area. However, their synchronous growth hints at an element of information flow in the SRZ ~30-24 kcal BP.

Toolkits transfer more easily than flaking systems, but only when environments are the same. Melikane's contexts 6-8 toolkit differs substantially from earlier ELSA toolkits in the SRZ. Points are common in the Umhlatuzana, RCC, and Umbeli Belli assemblages, and knives (or ACTs, in the case of Umbeli Belli) are also present in Sehonghong's layer RFS (Bader et al., 2018; A. M. B. Clark, 1997b; J. Kaplan, 1990; J. M. Kaplan, 1989; P. J. Mitchell, 1994a; Sifogeorgaki et al., 2020). These tools are uncommon or absent at Melikane. However, southern African environments ~30 kcal BP were different from the environment faced by Melikane's later foragers. The toolkits from layers MOS and OS at Sehonghong, deposited just before contexts 6-8, are more similar. Like Melikane, these layers lack significant numbers of points. However, they do contain examples of MSA-type knives, and borers are absent (P. J. Mitchell, 1994a). Overall, contexts 6-8 share a microlithic, bipolar reduction strategy and a small platform core element with the other SRZ ELSA sites, but have a different, less stereotypically MSA toolkit. There is no evidence that elements of any of the SRZ sites were transferred there from Border Cave, but a certain amount of back-and-forth connectivity between the interior, mountains, and the coasts was likely (P. J. Mitchell, 1996a; Stewart et al., 2020).

The ELSA flaking systems of the WRZ and YRZ are similar to those of the SRZ but show more continuity with later Robberg layers at each individual site. The environments experienced by the foragers in the WRZ and YRZ during the early LGM were very different than those experienced by the SRZ foragers, with different vegetation types and faunal resources, so toolkits would be expected to differ even in the event of population replacement. Putslaagte 8's ELSA assemblage (~25-22 kcal BP) is roughly evenly split between bipolar and freehand cores. On-site flaking was focused on the unidirectional freehand reduction of hornfels. Roughly half of the site's cores are bipolar, but Low and Mackay (2016) argue that most of these were reduced off-site. However, like Melikane, a strong bladelet element sometimes produced via freehand percussion is present, and no stereotypically MSA attributes, like prepared cores, points, or knives, were found. The Robberg at Putslaagte 8 (21-18 kcal BP) immediately follows the ELSA and shows significant technological continuity, differentiated only by more bipolar percussion and a heavier emphasis on blades (Low & Mackay, 2016). This is interesting considering that the Robberg in the SRZ is associated with *less* evidence for bipolar percussion. The ELSA at Elands Bay Cave is also characterized by a high frequency of bipolar percussion and a lower frequency of freehand percussion for the production of microliths (Porraz, Schmid, et al., 2016).

Boomplaas member LPC (26.4-24.3 kcal BP), although contemporary with the ELSA at Putslaagte 8, contexts 6-8 at Melikane, and the transitional layers at Sehonghong, is considered by Bousman and Brink (2018) to be the earliest manifestation of the Robberg industry (Pargeter et al., 2018; Pargeter & Faith, 2020). If the Robberg is unrelated to the ELSA, then Boomplaas' assemblages should contrast starkly with contexts 6-8. LPC and LP lack the small and flat bladelet cores that characterize the post-LGM Robberg (member CL) at Boomplaas and other WRZ and YRZ Robberg sites. Most bladelet cores are expedient, made on local quartz with a single platform (P. J. Mitchell, 1988a). A few high-backed cores were present in LPC, disappear in LP, and make a resurgence in the later Robberg (Pargeter, 2017). Bladelet frequencies are low compared to the overlying Robberg layers (P. J. Mitchell, 1988a). Bipolar core frequencies rise from 45.2% in LPC to 81% in LP (Pargeter & Faith, 2020). Overall, the flaking system used at Boomplaas in "Robberg" member LPC is not dissimilar to the system used in contexts 6-8 at Melikane. It uses mostly bipolar reduction and occasionally freehand platform core reduction to produce small flakes and intermittent bladelets. However, it does include high-backed bladelet cores, which are not present at Melikane until context 5. Boomplaas experienced a maximum temperature reduction earlier than Melikane in "transitional" layer YOL, ~30.1-25.9 kcal BP (Pargeter et al., 2018), consistent with the predicted relationship between freehand bladelet core technology and the onset of LGM conditions.

East African transitional and "ELSA" assemblages are easier to juxtapose against contexts 6-8 and show a different pattern of change. The assemblages assigned to the transition, including those at Kisese II, White Paintings Shelter (WPS), Enkapune ya Muto (EYM), Mumba, and Panga ya Saidi, date to the period 65-35 kya. The stratigraphic integrity of their sequences, particularly those of WPS and EYM, is sometimes questionable, and the microlithic industries often contain or are followed by assemblages with MSA artifacts like points or a return to prepared core technology. The "earliest LSA" Nasampolai Industry dating to 50-40 kya at EYM is not even microlithic, and was assigned to the LSA on the presence of a lone ostrich eggshell bead (Ambrose, 1998). It is followed by a resurgence in Levallois technology. Tryon et al. (2018) place the transition at Kisese II at 39.6-34.3 kcal BP, despite persistence in point production until ~33 kcal BP and its reuptake 22-18 kcal BP.

The primary similarity between contexts 6-8 and these East African assemblages is the use of bipolar technology. However, bipolar technology was not "invented" in East Africa and was already in use at Melikane during MIS 5a. Connecting the MSA/LSA transition in southern Africa to these East African sites on the basis of one shared flaking system is presumptive. Instead, if bipolar percussion is the primary thread tying the transitional and ELSA assemblages together, rather than looking for a migration event, we should be looking for shared ecological and social pressures. If Tryon and Faith (2016) are correct that increased population densities ~60 ka were responsible for what they term the "MSA/LSA transition" in East Africa, then population pressure may also have spurred the uptake of bipolar technology elsewhere. In this case, the transition did not spread from a source area and is not a single phenomenon. Rather, what looks like the "MSA/LSA transition" began independently in different areas when population density reached a critical level. A follow-up question is why microlithic technologies stuck in southern Africa but not in East Africa. None of the southern African sites show a return to Levallois or MSA technology after their transitions - all roads end at the Robberg, and Border Cave was abandoned until the Iron Age (Villa et al., 2012). In contrast, the East African sites have a more diverse set of LSA "endings."

Thus, the third expectation based on Bousman and Brink's hypothesis, that Melikane's contexts 6-8 should resemble other ELSA assemblages, is only partially met. The ubiquity of bipolar and bladelet technology in southern Africa before the MSA/LSA transition also complicates the comparison of flaking systems – it is impossible to track the spread of an innovation that isn't. If anything unique links the SRZ ELSA sites, it is the presence of freehand platform bladelet cores, which are absent in the Border Cave ELSA. The MSA/LSA transition in East Africa is completely different in character from the transition in southern Africa, consisting of cycles of microlithization and MSA core/tool use. It is a separate phenomenon from the MSA/LSA transition in southern Africa but left a similar signature as the same solution (bipolar percussion) was applied to the same problem (population pressure). All in all, the data from Melikane's contexts 6-8 do not support Bousman and Brink's hypothesis on the origins of the ELSA.

"ELSA" to Robberg Transition

If the ELSA was suddenly replaced by the Robberg, then there should be no continuity between contexts 6-8 and 5, the sudden appearance of new forms in context 5, and homogeneity in penecontemporary assemblages. Only one expectation of this hypothesis, the sudden appearance of new forms, is met at Melikane. Most differences between the contexts are subtle and are the logical consequence of changes already in progress. The contexts share a focus on borers, scrapers, and bipolar percussion. Platform cores become more common in context 5, but they are still present in the Melikane MSA and contexts 6-8. Bipolar percussion becomes less common, miniaturization continues to progress, and CCS becomes even more prominent as the dominant raw material.

Context 5 has distinct Robberg characteristics, but the diversity of the Robberg itself is often understated. Although points and MSA formal tools are allegedly rare, unifacial points make up nearly half of the retouched artifacts in the Early Robberg at Umhlatuzana, and do not disappear in the Late Robberg (J. Kaplan, 1990). Truncated flakes are unique to Sehonghong, and Porraz et al. (2016) suggest that they might represent a phase or regional variation within the technocomplex. Context 5 has an extremely high degree of retouch, and borers are not characteristic of the Robberg at any other site. Flaking systems also differ regionally. Bipolar flaking becomes less common in the SRZ during the Robberg, but more common in the southern Cape (J. Deacon, 1984b; P. J. Mitchell, 1988a). On the southern Cape, small, flat, bipolar bladelet cores with chisel-like platforms were identified as a Robberg type fossil (J. Deacon, 1984b, p. 373). These cores are almost exclusively made on quartz (P. J. Mitchell, 1988a).

Despite their abundance in the Robberg members at Boomplaas, they are extremely rare at Sehonghong, where quartz is nearly absent and CCS is abundant (P. J. Mitchell, 1995).

The Robberg also changes over time. Naturally backed knives appear suddenly in the Late Robberg at Umhlatuzana (J. Kaplan, 1990). An uptick in coarse-grained materials is observed at EBC, Nelson Bay Cave, and Sehonghong towards the end of the phase (J. Deacon, 1978; P. J. Mitchell, 1995; Porraz, Igreja, et al., 2016). The post-LGM Robberg contexts at Sehonghong have a much heavier emphasis on bladelet technology than BAS. Mitchell (1995) also notes that patterns of usewear change on either side of the LGM, suggesting that bladelets were used differently after 18,000 BP. This suggestion is supported by my own analysis of the Melikane and Sehonghong bladelets as well as Pargeter and Redondo's (2016). Instead of defining the Robberg based on the presence of bladelets, we might be better off heeding Porraz et al.'s (2016, p. 237) suggestion to define it on the "quasi-absence of macro-blanks."

Context 5 is linked to other Early Robberg sites by its flaking system, which includes bladelet production on high-backed cores. However, the cores do not appear at all Robberg sites, and thus should not be used as evidence for the sweeping replacement of the ELSA. Most aspects of Robberg flaking systems develop slowly and in the context of individual sites. At Putslaagte 8, the Robberg is only distinguished from the ELSA by slightly higher bladelet and bipolar core frequencies (Low & Mackay, 2016). At Boomplaas and Sehonghong, the Robberg develops slowly over the period ~30-23 kcal BP (P. J. Mitchell, 1994a, 1995). The "transition" to the Robberg at both sites is so gradual that layers at each have been ascribed to different industries by different archaeologists. At Sehonghong, BAS was lumped with the MSA by Carter et al. (1988), assigned to the ELSA by Volman (1980), and then to the Robberg by Mitchell (1988a). At Boomplaas, LPC and LP are usually assigned to the Robberg, but were assigned to the ELSA by Mitchell (1988a, p. 69), who cautioned that "too strong a division ought not to be made" between them and the later Robberg layers (dates from Pargeter et al., 2018). The same gradual transition is visible at Melikane between contexts 6-8 and 5, roughly ~23.5 kcal BP. Although high-backed cores are introduced to the assemblage, there are no other sudden changes or replacements in the technological repertoire of the Melikane foragers. Overall, the Melikane assemblages do not support the rapid development and spread of the Robberg technocomplex.

There is no indication that the flaking systems of any of the sites discussed here were suddenly replaced.

Hypothesis B: Resource Distribution and Mobility

Hypothesis B implicates mobility as a driving factor behind the form of Melikane's pre-LGM lithic assemblages. Two possible hypothetical assemblages could arise under this hypothesis. In the first case, foragers would respond to the LGM by becoming increasingly residentially mobile. In the second case, foragers would respond by decreasing residential mobility and engaging in resource intensification. In either case, trends seen in contexts 6-8 should escalate in context 5 as environmental productivity continued to decline.

Studies of provisioning and residential mobility are relatively limited in the Lesotho highlands, but the MIS 5a lithic data from Melikane provide a point of comparison for the assemblages from contexts 5-8. Colleagues and I have previously argued (Pazan et al., 2022) that the Melikane foragers in MIS 5a likely used a hybrid provisioning system to enable frequent residential moves within a small area. The abundance of CCS on the landscape around Melikane meant that sites could be provisioned with raw materials at a relatively low cost. Despite this, the Melikane MIS 5a toolkit is intensely utilized and modified. It would be advantageous to have a mobile toolkit at-the-ready in order to capitalize on short-term changes in resource distribution, but if foragers knew that they would return to the same sites, leaving some cores behind might be strategic (Pazan et al., 2022). The coupling of frequent residential mobility with occupational redundancy during MIS 5a may have occurred as a result of the Maloti-Drakensberg's topography. In areas of complex relief and attendant resource and environmental heterogeneity, species can adapt to climate change through short-range dispersals (Ackerly et al., 2010; Dobrowski, 2011; Dobrowski et al., 2013). At the same time, mountains are difficult and energetically costly to navigate, and substantial movements entail heightened climate change exposure (Dobrowski & Parks, 2016). An optimal solution to this paradox is to occupy a relatively small territory and move frequently within it to avoid exhausting local resources. In this case, Melikane during MIS 5a may have been occupied frequently, but for short periods of time (Pazan et al., 2022).

The retouched tools from contexts 5-8 are still highly curated, portable, and multifunctional, consistent with residentially mobile foragers using an individual provisioning strategy and advantageous in a temporally and spatially stochastic environment (Kuhn, 1992, 1994). The archaeological signatures from contexts 5-8 also best match that of an "RMS [residentially mobile strategy] residential camp," with high artifact densities and a high frequencies of retouch (Barton & Riel-Salvatore, 2014). However, a heavier focus on bladelet and microflake production likely reflects the more frequent use of composite tools, associated with less frequent residential movement and lower temperatures (Kuhn, 1994; Read, 2008; Shott, 1986), and high frequencies of bipolar reduction also suggest lower residential mobility (Hiscock, 1996; Parry & Kelly, 1987).

Schoville et al. (2021) suggest that residentially mobile foragers using an individual provisioning system can move infrequently if "people are essentially located on top of resources" (Schoville et al., 2021, p. 10). This is an interesting idea in the context of the Lesotho highlands, where altitudinal gradients may have clustered flora and fauna downslope into river valleys (Stewart & Mitchell, 2019). Higher proportions of C_3 grasses may have brought game closer to the shelter (B.A. Stewart, pers. comm.), lessening the demand for logistical hunting forays or residential movement, at least until populations outgrew the local landscape's carrying capacity. However, if game movements were temporally unpredictable, individual provisioning would allow foragers to capitalize on unanticipated subsistence opportunities (Kuhn, 1992).

Lower residential mobility may also have been encouraged by aquatic resource intensification. Hunter-gatherer societies in temperate and arctic environments focusing on aquatic resources are more sedentary, making only infrequent but far moves (Grove, 2009). Although Melikane lacks faunal remains, evidence from neighboring Sehonghong could provide a useful analogue. Stewart and Mitchell (2019, p. 129) hypothesized that Lesotho foragers would have shifted to a diet heavily reliant on fish when effective temperatures fell below the 12.75º C "terrestrial plant dependence threshold." The faunal remains from layer BAS suggest heavy aquatic resource use. Stewart and Mitchell (2019) also note that fish are also favored during the Antarctic Cold

Reversal ~15 kcal BP, suggesting that fishing may have been a recurrent adaptation to lower temperatures at the site.

Heavier reliance on aquatic resources could also explain some of the differences between contexts 5 and 6-8. Fish are most accessible in the Senqu and its tributaries during spawning runs in the Spring and early Summer (Stewart & Mitchell, 2019). Contexts 6-8, with their extremely heavy reduction intensity, could represent the last vestiges of year-round occupation at Melikane before the LGM. If temperatures fell to a certain threshold and the landscape could no longer support year-round occupation, foragers may have abandoned Melikane in the autumn, returning for shorter periods in the spring and summer to exploit abundant aquatic resources. Although the site may have been intensely occupied during these times, less frequent occupation throughout the year overall could result in the slightly lower artifact densities and retouch frequencies seen in context 5 (Marean, 2016; Schoville et al., 2021).

Carter (1976, 1978) was the first to propose a seasonal occupation pattern in the Lesotho highlands. He hypothesized that Sehonghong would only have been occupied during the summer months, even during interglacial periods. This was supported by the presence of fish and juvenile bovids in the site's faunal assemblage (Carter, 1978; Plug & Mitchell, 2008). Conversely, Carter viewed Melikane as a winter occupation site. More of the grass around the shelter is palatable year-round, and good firewood is present. If Carter (1978) was correct, then falling temperatures during the early LGM should have favored Melikane at any time of year. The use of Melikane in the spring and summer might indicate that environmental productivity and temperatures in context 5 fell to the point at which summer occupation at Sehonghong was no longer viable, but the permanent snow line was not yet low enough to restrict movement into and out of the mountains. However, there is little hard archaeological evidence supporting aquatic resource intensification or seasonal occupation at Melikane. Organic preservation is almost non-existent, precluding the discovery of bone points, fishhooks, and nets. Lithic evidence, like the presence of bored stones and net weights, is also absent. At a minimum, the presence of a faunal assemblage would be required to fully test this hypothesis.

Another explanation for lower residential mobility implicates environmental change as a catalyst for increased territoriality. In response to resource scarcity, groups may have doubled down on their territories, preventing each other from adopting highly mobile strategies. If resource scarcity was only local, then social boundary defense would have been a preferable tactic (Cashdan, 1983). Foragers would have been able to maintain large territories and rely on their neighbors for information and assistance. However, if the landscape reached a point of meagerness beyond which sharing was untenable and large populations could not be supported – a Malthusian limit – foragers may have switched to a perimeter defense strategy. Perimeter defense is favorable when resources regionally scarce but requires that foragers shrink the size of their territories to properly defend them (Cashdan, 1983). This would prevent the acquisition of nonlocal raw materials, potentially explaining the increase in CCS use evident in context 5. Alternatively, glacial features and snow may have imposed tight, natural territorial boundaries on the Melikane foragers, preventing access to resources and leading to many of the same problems.

In short, the pattern observed at the site is consistent with low residential mobility (Barton & Riel-Salvatore, 2014; Marean, 2016; Schoville et al., 2021). Adopting a residentially mobile strategy and concentrating on large game, however appealing as a solution to resource scarcity, may not have been an option if population densities were high. It seems likely that pressures faced by the Melikane foragers after switching to a less residentially mobile strategy encouraged the full adoption of microlithic technology. In a densely populated, territorially circumscribed pre-LGM environment (cf. Stewart & Mitchell, 2019), the costs of failing to capitalize on a subsistence opportunity would be serious. Foragers would not be able to turn to neighbors for assistance or travel to another area to hunt or gather.

Composite tool technologies are both reliable and maintainable, and by utilizing unretouched bladelets and microflakes, foragers would have been able to make and repair their tools more quickly (P. J. Mitchell, 1988a). Provisioning activities (cf. Kuhn, 2004) and the use of bipolar reduction would add additional speed and flexibility to tool maintenance, allowing foragers to capitalize on unanticipated opportunities and meet needs as they emerged. The expedient production of microflakes (contexts 6-8) followed by more formal bladelets (context 5), and intense curation of maintenance tools, rather than being a cultural trait passed to the Melikane foragers from elsewhere, may simply have been the most logical means of dealing with resource scarcity (C. B. Bousman, 2005).

Low overall mobility could also explain the idiosyncrasies of Melikane's Early Robberg assemblage. High artifact densities and low retouch frequencies like those found at Boomplaas or in layer BAS at Sehonghong are indicative of hunter-gatherers with low residential mobility but a higher degree of logistical mobility. The Melikane foragers, by virtue of topography and territorial circumscription, may never have had the option of engaging in the same degree of logistical organization as Robberg foragers in the Cape or in non-glaciated montane regions. Therefore, differences in toolkits should be interpreted cautiously.

Hypothesis C: Social Networks

The strengthening or weakening of interregional social networks could have impacted the dynamics of technological change over the MSA/LSA transition. Hypothesis C consists of two sub-hypotheses. The first, hypothesis C1, posits that interregional networks remained open during the MSA/LSA transition, linking the Lesotho highlanders with the rest of the subcontinent. Hypothesis C2 claims the converse – the interregional network linking the Lesotho highlands with the rest of southern Africa broke down during the MSA/LSA transition, either because the interior was abandoned or because environmental change made networks too difficult to maintain.

At first glance, the data seem to support hypothesis C2. Contexts 5 and 6-8 show the loss of some distinctly MSA traits, including point and prepared core production. Both contexts show a high degree of intrasite continuity. Although bipolar technology and bladelet technology are present in nearly all the transitional and Robberg assemblages discussed in this dissertation, these technologies are already present in the MSA assemblages of these sites. Borers are a mainstay of the Melikane toolkit and remain the most common tool type in MIS 2. Types at other sites are idiosyncratic and variable, including knives, denticulates, and unstandardized scrapers. As previously discussed, the lithic assemblages in contexts 5-8 are consistent high population density and low residential mobility.

The arrival of high-backed cores in context 5 necessitates an explanation. These cores, which also occur at Sehonghong in BAS, are the strongest evidence for population connectivity allowing the transfer of flaking systems. They do not occur at all Robberg sites, but are distinctive and unique, making independent invention unlikely. Their presence only at select sites suggests that population connectivity was not subcontinent-wide but contained to specific regions at certain times. In contrast, a migration or population replacement event would encourage their adoption at all Robberg sites simultaneously. Additional evidence for a Robberg-type flaking system comes from the increased presence of microflakes with punctiform, crushed, or thin platforms and point bulbs in context 5. These flakes share attributes with the post-LGM Robberg bladelets at EBC and RCC and point to a shared reduction sequence (Cochrane, 2008; Porraz, Igreja, et al., 2016).

High-backed cores first appear in member LPC at Boomplaas (26.4-24.3 kcal BP), followed soon after by layer BAS at Sehonghong (24.3-23.1 kcal BP), and in level YGL at Nelson Bay Cave (23.5-21 kcal BP) (J. Deacon, 1982; Loftus et al., 2016; P. J. Mitchell, 1988a; Pargeter et al., 2018). Considering their absence in contexts 6-8, 24.2-23.6 kcal BP, population movement was likely limited between the Cape Fold Belt and uKhahlamba-Drakensberg Escarpment until ~23.5 kcal BP. The transfer of flaking systems requires either population movement or extensive contact to promote “process copying” (Derex, Godelle, et al., 2013; Hiscock, 2014; Tostevin, 2012). Process copying often goes hand-in-hand with genetic exchange and requires extensive observation on the part of the learner (Mace & Jordan, 2011; Tehrani & Collard, 2009; Tostevin, 2012). Dispersal into the highlands from the Cape Fold Belt would be consistent with the conditions required for the transfer of the high-backed core flaking system. Interestingly, the ~23.5 kcal BP date lines up with an occupation hiatus at Boomplaas between members LPC and LP of 400-3800 years, estimated at ~24-22.9 kcal BP (Pargeter et al., 2018). The conditions at Boomplaas before this hiatus were relatively hospitable, and occupation density was high. The environment was moist and productive, with elevated ungulate diversity. It was cold, but certainly not moreso than in the Lesotho highlands (Faith, 2013). These conditions align with the suggestion made by Stewart et al. (2016) that ecological productivity and high occupation density along the coastal belt would actually encourage movement into the Maloti-Drakensberg Mountains.

However, there are no physical traces of the movement of people or ideas between the Cape Fold Belt and Lesotho highlands. Movement across the interior desert would be impractical, especially during the dry period of 30-22 kya. Occupation hiatuses are common at other montane sites. Grassridge Rock Shelter in the Stormberg Mountains of the Eastern Cape Province was completely abandoned between 28-12 kcal BP (Ames et al., 2020). Nearby Ravenscraig has evidence of only a very late Robberg occupation post-dating the LGM (C. B. Bousman & Brink, 2018). Dispersal up the coast into KwaZulu-Natal and then west across the Escarpment is technically possible, but Umbeli Belli and Strathalan B were both abandoned ~24 kcal BP (neither with high-backed cores), and Umhlatuzana's Early Robberg remains undated (Bader et al., 2018; J. Kaplan, 1990; Opperman, 1996; Opperman & Heydenrych, 1990; Sifogeorgaki et al., 2020). Neither Rose Cottage Cave nor Erfkroon in the western Free State has any evidence of Robberg technology until after 19 ka (B. Bousman et al., 2014; Loftus, Pargeter, et al., 2019; Palmison, 2014; Wadley, 1996). Dikbosch 1's (Northern Cape Province) Robberg layers postdate the LGM (C. B. Bousman & Brink, 2018), and the Robberg and high-backed cores at Tloutle Rockshelter in western Lesotho remain undated (P. J. Mitchell, 1990).

One possibility is that there were multiple ephemeral episodes of population isolation and reconnection, represented by the many haplogroup bifurcations found by Chan et al. (2015) during the LGM. Although these bifurcations slightly postdate Melikane's assemblages, dating using the molecular clock is imprecise (cf. Vicente & Schlebusch, 2020). Chan et al. (2015) found that haplogroup L0d1, the second-most-common haplogroup in modern southern African populations, underwent significant divergence ~21 ka. Haplogroup L0d2, today's most common haplogroup, also bifurcated multiple times during the LGM, twice ~20 ka and again ~17 ka. LGM environments were not uniform, and in some years the highlands may have been more accessible than others, leading to cycles of isolation and reconnection. Periods of fragmentation may have encouraged MSA technologies to disappear, but episodic connectivity could have allowed for the transfer of flaking systems and provided the fuel for the fluorescence of the Robberg. Increased movement into the subcontinental interior, which was humid from 22-18 kya, would have spurred further innovation and information transfer to populations in the WRZ and YRZ, explaining the later appearance of the Robberg in the western half of southern Africa. Populations with intermediate levels of connectivity create the most innovative and complex technological solutions (Creanza et al., 2017; Derex et al., 2018). In this case, fluctuating environments may have helped the development of this balance in southern Africa.

Integrating the Three Hypotheses

Having established which elements of my three hypotheses are supported by the data, the next objective is understanding how each interacts with the others to tell the story of the MSA/LSA transition (Figure 44). The charcoal and SOM samples from contexts 6-8 support a picture of a cool landscape dominated by C^3 alpine grasses. Trees would have been restricted to riparian corridors. Phytoliths from woody taxa were less common in contexts 6-8 than at any other time in the Melikane sequence, and the tree density cover index hit an all-time low (Stewart et al., 2016). The plants remaining around the site were tolerant of a range of temperature and moisture conditions but would have had difficulty surviving sudden cold snaps. Although the sediments from contexts 6-8 suggest a dry environment (Stewart et al., 2012), an increase in winter precipitation combined with cooler temperatures could have decreased evaporation potential and helped the landscape retain moisture (Mills et al., 2012).

Despite a cold environment, the Lesotho highlands may have been alluring to hunter-gatherers because of worse conditions elsewhere. Stewart et al. (2016) suggest that drier conditions in the interior of southern Africa just before the LGM prompted dispersal into the highlands. This would prompt rapid population growth along the river corridors where resources were concentrated as altitudinal vegetation gradients dropped. As resources grew scarce, instead of increasing their residential mobility, foragers became less mobile and more territorial. Greater subsistence risk may have encouraged the adoption of bladelet and microlithic technologies. Because the interior of southern Africa had been abandoned in favor of the highlands, the "Senqu network" would break down, leading to isolation, drift, and the loss of MSA technologies.

As previously discussed, the absence of a sedimentary hiatus or major differences in lithic technologies between contexts 5 and 6-8 support continuous occupation. The sediment composition of context 5 suggests an even colder environment than during contexts 6-8. Glaciation of the highlands was likely well-underway. The river corridors probably remained the most stable and productive ecotones, with predictable fish spawns every spring and summer (cf. Stewart & Mitchell, 2019). Foragers may have begun using the shelter on a less frequent or seasonal basis. The highlands may have been abandoned and repopulated several times, as evidenced in a series of haplogroup bifurcations and ephemeral archaeological deposits at Sehonghong (E. K. F. Chan et al., 2015; Pargeter et al., 2017). These dispersals would promote the transmission of flaking systems. Increased humidity in the Karoo during the peak of the LGM ~22-18 kya may have allowed southern African foragers to repopulate the previously arid interior of the subcontinent, facilitating the more rapid spread and development of the Robberg across southern Africa

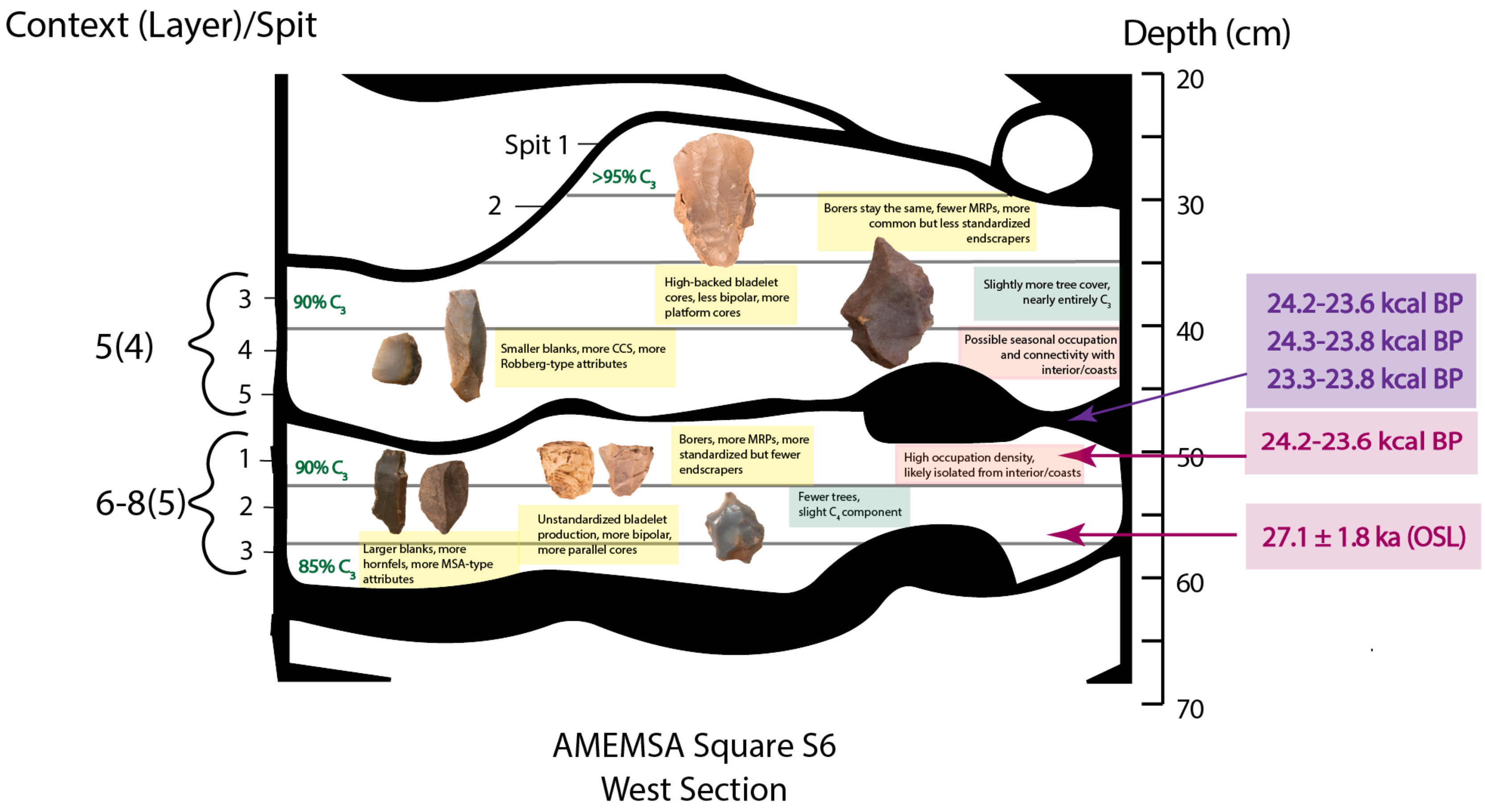


Figure 44 Technological trends at Melikane through spits and contexts, alongside dates (Carter's dates=purple, AMEMSA dates=pink) and Bousman Indices (%C_3).

Chapter 8: Conclusion

Why Does This Study Matter?

Although the beginning of the Later Stone Age is no longer associated with the development of modern human behavior, it still represents a dynamic moment in human history. In this dissertation, I have argued that the Last Glacial Maximum served as a final push towards the development of the Robberg and fully-fledged bladelet technology. All the behavioral and technological components necessary for microlithic industries were already present in southern Africa during the Middle Stone Age and did not require introduction from a source region. Instead, environmental pressures favored an emphasis on microlithic technology in some areas of the subcontinent. A series of environmentally mediated dispersals or periods of increased population connectivity allowed for the transmission of flaking systems. Multiple haplogroup bifurcations in southern Africa during the LGM show that even though archaeological visibility was low, people were changing their patterns of movement and settlement in such a way that they dramatically altered the course of technological and biological evolution (E. K. F. Chan et al., 2015).

This study adds to our collective knowledge about how humans have dealt with serious environmental change. Although microlithization occurred broadly in conjunction with the LGM, microlithic assemblages varied regionally, and not all LGM technologies were microlithic (Kuhn & Elston, 2002). The Solutrean technocomplex, famed for its bifacially flaked points, appeared in conjunction with the LGM in southwest Europe ~25 kcal BP. These macrolithic points are found in the same assemblages as backed bladelets and microliths (Straus, 2015, 2016). Straus (2015, 2016) argues that this split strategy would have provided foragers with two contrasting weapon types – a deadly but fragile large point projectile, and a more easily repaired composite projectile. Gravettian foragers just prior to the LGM used backed bladelets alongside a regionally variable collection of points and knives as their climate cooled (Polanská et al., 2021). In southeastern France ~23.5 kcal BP, they even combined a bone point with lithic barbs to create a highly effective and deadly weapon (Tomasso et al., 2018). LGM-aged "microblades" in Siberia and Japan were also used in composite bone tools (Iwase, 2016). Unlike the Robberg, however, these microblades were found in assemblages alongside a greater range and number of formal implements including burins, endscrapers, and larger blades (Doelman, 2008; Goebel, 2002; Iwase, 2016; Otsuka, 2017). These examples exemplify the variety of forms microlithic technologies took during the LGM.

Many other societies changed their mobility patterns during the LGM, but the form of change varied geographically. Australia, with its similarly diverse mountainous and desert terrain, provides an interesting parallel to southern Africa. Like foragers in the latter, Australian hunter-gatherers appear to have clustered in geographic refugia near stable sources of fresh water, often in montane regions (P. Veth, 2005; P. M. Veth, 1993; Williams et al., 2013). These refugia, or "islands in the interior," were separated by large swathes of uninhabitable desert (P. M. Veth, 1993). Elsewhere, Slack et al. (2009) associate periods of aridity during the LGM with greater residential mobility. At Puritjarra rockshelter in western central Australia, the Late Pleistocene lithic assemblage (c. 32,000-18,000 BP) exhibits evidence for high residential mobility in comparison to the Holocene levels. The presence of exotic ochre, a high flake/tool ratio, and the absence of cores all point to a highly mobile population (M. Smith, 2006). This archaeological signature could not differ more from that left by the Melikane foragers, especially in contexts 6-8.

Like some Australian foragers, Siberian hunter-gatherers also responded to the LGM by increasing their residential mobility. Middle Upper Paleolithic foragers prior to the LGM exploited the diverse resources of the "mosaic" mammoth steppe, provisioning places and using a logistically oriented settlement system. However, Later Upper Paleolithic foragers ~21 kcal BP were forced to provision individuals and focus on mobile, large game as the LGM climate desiccated the landscape (Graf, 2010). Sites are rare in Siberia during the heart of the LGM. Most offer only an ephemeral scatter of bone, adding to the argument that populations were highly mobile and untethered to the landscape (Pitulko et al., 2017). In contrast, in the coastal refugia of southwestern Europe, hunter-gatherers increased their logistical mobility. Clark et al. (2018) and Burke et al. (2018) argue that the predictable resources along the Spanish coastlines allowed foragers to remain residentially stable and undertake tactical forays when necessary (but see Canessa, 2021).

Geography would have heavily impacted the options open to hunter-gatherers, constraining the range of viable mobility responses. The Australian, Spanish, and Siberian LGM foragers were not territorially circumscribed within a rugged, potentially glaciated mountain system. Even the foragers on the South African Cape Coast and the in the Cape Fold Belt would have likely exploited larger areas, especially when lower sea levels exposed the grazer-rich Paleo-Agulhas Plain, providing a novel set of mobile resources (Copeland et al., 2016). This alone may account for Melikane's different archaeological signature. Low retouch frequencies at other early microlithic sites likely reflect the reality that these foragers were not restricted in their movements to the same degree as the Melikane foragers and could exploit the landscape in a wider variety of ways.

Hunter-gatherers have other means of adapting to environmental shifts outside of changing their mobility strategies, one of which is clothing production. The "thermal model" of clothing development suggests that complex (tailored) clothing would have been necessary for humans to occupy certain environments during this period of the Pleistocene, regardless of fire or shelter. Tailored clothing is more effective at heat retention and offers better protection against the wind because it traps air next to the body (Gilligan, 2010). Middle Stone Age peoples were certainly working hides, possibly even at Melikane during MIS 5a (Pazan et al., 2022). Usewear on a piece of polished bone from the Howiesons Poort contexts at Sibudu suggests that it was used for hide working >61 ka (L. Backwell et al., 2008). However, evidence of tailored clothing is rare globally until MIS 3, when the first eyed needles appear ~45 kcal BP in the archaeological record of Siberia (Shunkov et al., 2020) . They became increasingly common in Europe and Asia during the period leading up and including the LGM (d'Errico et al., 2018).

It is conceivable that Melikane's LGM foragers, like their European and Asian counterparts, began to make tailored clothing to exploit the highlands during less favorable climatic conditions. Melikane's borers resemble the late Paleoindian and Archaic "spurred flake gravers" dating to the Younger-Dryas Cold Event (YDCE) 12,900-11,600 cal BP, which may have been used for drilling eyes in bone needles (Irwin & Wormington, 1970; Osborn, 2014). Maika (2010, p. 74) describes these gravers as averaging ~2-3 cm in length, expedient, and "made opportunistically on whatever debitage or discarded tool was available." Paleoindian foragers may have used gravers intensively at specialized task sites resembling the "sewing" and "finishing" camps of the Netsilik and Copper Inuit (Balikci, 1970; Osborn, 2014). Drilling flakes dating to ~26-23 kcal BP at Shizitan 29, China also resemble the Melikane borers. They are associated with a bone needle fragment, awls, and numerous endscrapers. They measure 16.6-28.5 mm in length, also comparable to the lengths of the implements at Melikane (Song et al., 2015).

Melikane's LGM assemblages align with Osborn's (2014) expectations for a sewing camp and Gilligan's (2010) thermal model predictions. The assemblage is dominated by thousands of small borers, which increase in frequency during colder context 5. Despite otherwise negligible organic preservation, two bone pins were also found at Melikane, one at the base of context 4 and the other in contexts 6-8. The rest of the Melikane toolkit is characterized by scrapers and MRPs, potentially used for hide preparation. Ethnohistoric Eskimo sewing camps were usually occupied during the late summer and into the fall (Osborn, 2014). Due to its aspect, Melikane would have stayed warmer than Sehonghong as winter neared, perhaps making it a better site for late season occupation. Intensification in borer production during context 5 could indicate a response to deteriorating climate or that the site use had become highly specific, or both. Shorter occupation duration aligns with the lower artifact densities in context 5.

In this scenario, the persistence of borers over time at Melikane would suggest that the site was uniquely geographically positioned for use as a sewing camp. A reliable game migration route may have passed within short range of the shelter, presumably along the deep, protected river valley directly below, providing easy access to the hides necessary for clothing production. Melikane's abandonment until ~8 ka could then have been related to changing patterns of game movement across the Pleistocene/Holocene transition. The difference in borer size between MIS 5a and MIS 2 could be attributed to a change in borer function. Perhaps the earlier borers were used for puncturing hides for simple clothing, which may have sufficed in the milder climate. During the LGM, borers would have needed to become smaller if they functioned in needle production. Ongoing usewear studies will ascertain the function of the Melikane borers, allowing this hypothesis to be legitimately tested. Melikane's borers remind us that not all cultural responses are easy to see. Mobility and hunting patterns can be parsed out of lithic and faunal assemblages, but site use and purpose are more difficult to ascertain.

Methodological Considerations

Throughout this dissertation, several experimental statistical analyses were implemented with the aim of finding structure in data and evaluating the reality of typologies. Basic analyses of individual blank attributes in contexts 5-8 failed to detect many significant changes over time. However, blank attributes never exist in isolation, so a variety of methods were used to identify "types" of flakes based on multiple shared attributes. The main goal was to use these attributes to identify bipolar flakes in the assemblage. First, contingency tables of blank attributes produced weak to moderate effect sizes for bulb type against EPA, termination, and platform type, as well as EPA against termination. Then, multiple correspondence analysis was performed to understand not just the links between each pair of attributes, but the links between all attributes. Because multiple correspondence analysis assigns coordinates not only to attributes but also to individual cases, the coordinates of each individual blank were used as raw data for cluster analyses. The cluster analyses successfully identified groups of blanks with shared attributes. The five-cluster solution identified a group of "MSA-type" blanks, a group of "Robberg-type" blanks, and a group of potentially bipolar blanks. The changes in the proportions of these blank types illuminated patterns masked when the attributes were considered separately- the MSA-type blanks fell and Robberg-type blanks rose in context 5, while the bipolar-type blanks did not change. This method, using MCA to give numerical value to nominal data for clustering, should be considered in future studies to add complexity to the study of unmodified blanks in assemblages.

Multinomial logistic regression was used to understand the differences between freehand, bipolar cores, and CRPs. The most significant variable dividing the three core types was length. Freehand cores were likely to be longer than bipolar cores, and CRPs were likely to be shorter. Core width divided freehand and bipolar cores, but not bipolar cores and CRPs. This suggests that it is the most reliable dimension for separating cores by percussion type. Core thickness divides bipolar cores and CRPs, but not bipolar cores and freehand cores. This implies that it is the variable most relevant to core discard. Mass was an insignificant variable in this analysis, indicating that proxies of core exhaustion should focus more heavily on core shape and that the Melikane foragers may not have been using bipolar reduction to maximize their use of core mass.

Cluster analysis was implemented to understand the interactions between core dimensions. I was particularly interested in testing the existence of a "recycling window" wherein knappers were forced to switch to bipolar percussion. Cluster analysis was unable separate bipolar and freehand cores based on their dimensions, but CRPs were separated from bipolar and freehand cores with 90% accuracy. The size threshold between bipolar cores and CRPs is real and represents the point at which a core becomes too thin for further reduction. At sites like Melikane, where bipolar reduction was not used solely to exploit small cobbles, I propose that we should explore this using the bipolar core/CRP ratio as a proxy for reduction intensity rather than bipolar core percentage alone.

Where to Go From Here

Although many assemblages dating ~45-20 kya in southern Africa have been called "ELSA" or "transitional," we ought to seriously rethink our terminology and what these labels imply. Viewing the ELSA as a distinct entity displacing MSA technologies downplays its variability and relationship to the industries pre- and post-dating it. At Melikane, all the technological elements in contexts 6-8 were already established in the site's oldest lithic assemblage, ~80 ka, and are followed by an early expression of the Robberg, but with a distinctly Melikane-esque flavor. In East Africa, "ELSA" assemblages are often followed by those with stereotypically MSA technologies. At Border Cave, a long occupation hiatus lasting until the Iron Age prevents the study of its "ELSA" materials in relation to any later MIS 2 or 3 assemblages. This lack of context prevents us from understanding how they fit into the site's broader technological evolution. A comparison of these lithics to those from other ~40 ka lithic assemblages (including Melikane's) could help bring them into proper historical focus, whether they turn out to be ELSA or not. A related question is, when did the MSA/LSA transition at Melikane actually begin? Contexts 6-8 are more similar to context 5 than any of the MSA contexts studied and clearly represent a transition already in progress. This dissertation groups Melikane with sites including Border Cave, Umhlatuzana, Sehonghong, and Putslaagte 8, where archaeologists have remarked at intrasite continuity and the lack of sudden technological shifts (J. Kaplan, 1990; Low & Mackay, 2016; P. J. Mitchell, 1994a, 1995; Villa et al., 2012). The technological trajectories evident in these sequences strongly suggest we need to hammer the final nail into the coffin and abandon the idea of a "source region" for the LSA, recognizing that population movement and connectivity were complex and rarely unidirectional.

I believe the term "ELSA" is a relic of the archaeological era before the MSA's behavioral complexity was fully understood. Deacon's (1984b, p. 277) "innovative items" - ochre, digging sticks, ostrich eggshell beads, marine shell beads, and bone tools - are now frequently found at MSA sites wherever preservation is good enough to save them. In southern Africa, the beginning of the LSA was less about innovation and more about a shift in emphasis. The presence of symbolic artifacts may only indicate that people were moving more frequently on the landscape, coming into contact more often, and thus enhancing the utility of social identity markers (Kuhn et al., 2001; O'Connell & Allen, 2007; Stewart et al., 2020). Continuing to use them to define a new archaeological era (ie. d'Errico et al., 2012) ignores this fact and undermines the capabilities of MSA foragers. However, eliminating organic technologies as criteria leaves us only with lithics, which have problems of their own. Mitchell's (1988, p. 257-262) definition of early microlithic LSA technology includes three key components: 1.) the presence of microliths, 2.) the disappearance of prepared core technology and faceted platforms, and 3.) the disappearance of retouched points and blades. As previously discussed, the first component is problematic because microliths appear in the southern African MSA. The second two components are problematic because they do not leave room for the retention of old forms in cases where their replacement would be maladaptive. This is likely the case at Melikane, where borers were retained as a tool type despite small numbers of formal tools at other sites.

Moving forward, we must define the LSA contextually, studying sequences at individual sites and the unique pressures facing foragers in different environments, especially considering humans' tremendous capacity for behavioral flexibility (cf. Roberts & Stewart, 2018). Rather than attempting to identify the MSA/LSA transition, we should search for the roots of the Robberg within the MSA. We should be asking why microlithic technologies were "better" than MSA technologies and why they were not adopted earlier if the groundwork was in place. I have argued that at Melikane, the LGM provided the impetus for lasting technological change. Microliths were first produced for use in multicomponent tools that were both reliable and easy to repair. Their form changed as the risks associated with subsistence failure heightened. Up until that point, no environmental stressor had been powerful enough to force this transformation.

We should also be asking why Robberg technology endured for 12,000 years. If microliths were solely an environmental adaptation, then the end of the LGM should have prompted technological evolution. Instead, the Robberg fluoresced during a warmer period before the Antarctic Cold Reversal cooled the subcontinent again from ~14.7-13 kcal BP (Stewart & Mitchell, 2019). This speaks to the versatility of bladelet technology – it was clearly a cost-effective solution to subsistence problems in many different environments. One possible explanation for the Robberg's duration is that bladelets were a hunting adaptation, regardless of environmental conditions. At Boomplaas, post-LGM member CL is associated with warmer temperatures and more summer rainfall, but Robberg technology remained in use. Interestingly, the percentage of ungulates in the CL faunal assemblage is similar to the percentages from the LGM members, before suddenly dropping in the Holocene (Sealy, 2016). A brief examination of the data from Sehonghong show that of the Robberg layers, BAS has the lowest bladelet frequency and the highest percentage of fish in its faunal assemblage, whereas layer RBL/CLBRF has the highest bladelet frequency and lowest percentage of fish (P. J. Mitchell, 1995; Stewart & Mitchell, 2019). This pattern should be examined at other Robberg sites. If it holds, then relatively low bladelet frequencies should not exclude assemblages from assignment to the Robberg when combined with aquatic resource intensification.

Finally, we should be looking at exceptional sites and assemblages which do not look like other "early microlithic" or Robberg materials. This study of Melikane is a place to start. Despite its Robberg components, context 5 has many distinctive attributes – a high frequency of retouch, many borers, and an abundance of non-laminar microflakes. I argue from the form of borers that they must have been so task-specific that multicomponent bladelet tools were an unsuitable replacement. Ongoing usewear studies will help to clarify what these tasks were. An alternative is that the borers at Melikane functioned like bladelets on barbed spears. In this case, using a familiar form would save time otherwise spent perfecting a new technological sequence. Other Robberg sites have their own idiosyncrasies – the truncated flakes at Sehonghong, for example (P. J. Mitchell, 1995; Pargeter & Faith, 2020). Understanding these differences is likely to tell us a great deal about similarities, when and where they exist.

The organic and slow development of LSA technologies at Melikane emphasizes that change is rarely as rapid as it might appear. All innovations have roots in established technologies, but like bladelets at Melikane, may not spread and fluoresce until necessary. We should look to the archaeological record for other technological "accelerants" – unique environmental or social events that hastened transitions already in progress. If the LGM accelerated the *end* of the transition, what accelerated its *beginning*? A modern parallel could be the development of the Pfizer and Moderna mRNA vaccines. Although mRNA was first conceptualized as a vaccine vector in the 1990s, the COVID-19 pandemic accelerated the production and FDA approval of the first vaccines to actually use this technology (Hilleman, 1994). Looking at prehistory more broadly, we should continue to decouple innovation and behavioral complexity, and consider that the first known appearance of any artifact is merely evidence that an event must have occurred to make it useful, rather than showing it was invented at a certain place and time. Melikane reminds us that the human species is resourceful – we are exceptional at repurposing and recombining our knowledge to create novel solutions.

Appendices

Appendix A: Recorded Variables

Table 74 Variables recorded for all artifacts.

Variable	Notes
ID number	
Site	
Square	
Context	
Spit	
Class	Flake, core, core-on-flake, core fragment, shatter, flaked piece, heat spall
Raw material	
Weight	
Heat affected?	If so: potlidded, crazed, and/or discolored
<10mm?	If so, no further attributes recorded
Broken?	Yes/No
Comments	
Max dimension of broken artifact	Record for flaked piece, shatter, and heat spall. Record no other attributes for these classes.

Table 75 Variables recorded for cores.

Variable	Notes
Typology	After Conard et al. 2004
Core technology	Blade, bladelet, bladelet (flat), bladelet (prismatic), informal, Kombewa, Levallois (preferential), Levallois (recurrent), radial
Number of scars	Whole cores only
Core cortex	0, 1, 2, 3 (whole cores only)
Cortex type	Smooth, rough, river rolled, none (whole cores only)
Form of last removal	Blade, convergent, square, rectangular, trapezoidal, circular/oval, rectangular elongated, irregular (whole cores only)
Length of last removal	Whole cores only
Width of last removal	Whole cores only
Length	Whole cores only
Width	Whole cores only
Thickness	Whole cores only
Max dimension of broken artifact	Broken cores only

Table 76 Variables recorded for flakes.

Variable	Notes
Typology	Specify tool type, utilized, or unmodified
Transverse splits	Left, right, or central
Lateral splits	Proximal, medial, distal
Cortex present?	
Cortex amount	0, 1, 2, 3
Cortex type	Smooth tabular, rough, river rolled, smooth other, none
Number of dorsal scars	
Termination	Feather, hinge, step, plunging, worked, natural end, N/A
Platform type	Plain, faceted, dihedral, cortical, punctiform, crushed/abraded, other complex, undiscernible, N/A
Overhang removal?	Yes/No
Platform lip?	Yes/No
Retouched?	Yes/No
Utilized?	Yes/No
Bulb type	Prominent, moderate, diffuse, point
Clear orientation?	Yes/No (if, no only measure max dimension)
Unclear platform?	If so, do not take platform measurements.
Length	Whole flakes only
Width at midpoint	Whole flakes only
Max width	Whole flakes only
Percussive length	Whole flakes only
Percussive width	Whole flakes only
Bulb thickness	Whole and proximal flakes only
Max thickness	Whole flakes only
Platform <3mm?	If so, do not take platform measurements.
Platform width	Whole and proximal flakes only
Platform thickness	Whole and proximal flakes only
Platform angle	To nearest 10 degrees, whole and proximal flakes only
Max dimension of broken artifact	Broken flakes only
Profile	Straight, curved, twisted (whole flakes only)
Cross-section	Triangular, trapezoidal, rectangular, oval, irregular (whole flakes only)
Flake technology	Bipolar product, blade, bladelet, burin spall, core cleaning, platform rejuvenation, crested blade (if applicable)

Table 77 Variables recorded for retouched/utilized artifacts.

Variable	Notes
Number of modified edges	
Placement of modified edges	
Morphology (for each edge)	Concave, convex, straight, pointed
Angle (for each edge)	To nearest 10 degrees
Location (for each edge)	Unifacial, bifacial
Type (for each edge)	Stepped, smoothed, feathered, use
Distribution (for each edge)	Continuous, clustered
Length of retouch/use (for each edge)	
Comments (for used artifacts)	Borer-like, notch-like, scraper-like, steep, hafting-related

Appendix B: Artifact Typology and Count Totals

Table 78 Context 5 totals.

Class			CCS	Chalcedony	Jasper	Agate	Hornfels	Quartz	Sandstone	Other	TOTALS	%
Flakes	Unmodified											
		Whole	560	32	53	27	63	4	67	5	811	34.60
		Proximal	384	27	22	11	72	2	71	4	593	25.30
		Other fragments	660	51	29	12	96	4	86	2	940	40.10
		Total	1604	110	104	50	231	10	224	11	2344	28.05
	Utilized											
		Whole	555	38	31	23	104	1	48	3	803	47.49
		Proximal	241	8	17	13	75		33	4	391	23.12
		Other fragments	364	13	19	6	53	2	37	3	497	29.39
		Total	1160	59	67	42	232	3	118	10	1691	20.23
	Bipolar		32	7	3	1	2		2		47	1.11*
	Core-cleaning		120	6	5	4	20	1	8		164	3.86*
	All flakes		2916	182	179	97	485	14	352	21	4246	50.81***
Cores												
	Bipolar		54	6	22	2	2	9			95	9.66

Broken	140	11	31	4	17	3	5		211	*21.46*
Initial	22	3	12		2				39	*3.97*
Multidirectional	76	14	23	6	11	1	2		133	*13.53*
Opposed platform	10	4	3		2	1			20	*2.03*
Single platform	10	3	9	2	1				25	*2.54*
Parallel-centripetal	3	1	1						5	*0.51*
Parallel-bidirectional	7			1	2				10	*1.02*
Parallel-unidirectional	3		2	1	2				8	*0.81*
Inclined	7	1	2	1	1	1			13	*1.32*
CRP	62	16	20		2	7			107	*10.89*
Core-on-flake	131	16	23	9	26	2	8		215	*21.87*
Core tool	58	8	13	5	17		1		102	*10.38*
Total	583	83	161	31	85	24	16	0	983	*11.76****
Tools										
Hammerstone									0	
Backed	36	5	2		11		2		56	*2.30*
Borer	718	31	58	18	133	3	50	1	1012	*41.65*
Burin/graver	11	1		2	6		1		21	*0.86*
Denticulate	1		1		2		1		5	*0.21*
MRP	229	5	24	8	88		62		416	*17.12*
Naturally backed	2								2	*0.08*
Notched	33	1	3	3	21		5		66	*2.72*
Point (Bifacial)									0	*0.00*
Point (Unifacial)									0	*0.00*
Point (Unretouched)	2								2	*0.08*
Point (Utilized)	1								1	*0.04*

Scraper (Convergent)	12		3	2	12		6		35	*1.44*
Scraper (End)	72	3	14	1	32		11	1	134	*5.51*
Scraper (Nosed)	286	14	47	10	83	1	37	2	480	*19.75*
Scraper (Side)	20	1			19		5	1	46	*1.89*
Scraper (Side/End)	66	4	8		55		21		154	*6.34*
Total	1489	65	160	44	462	4	201	5	2430	*29.08****
Flaked pieces	63	1	8	3	11		10		96	*1.15****
Shatter	419	47	29	9	43	19	31	1	598	*7.16****
Heat spall	3						1		4	*0.05****
									0	
TOTAL ARIFACTS (w/o chips)	5473	378	537	184	1086	61	611	27	8357	
% Raw material	*65.5*	*4.5*	*6.4*	*2.2*	*13.0*	*0.7*	*7.3*	*0.3*		

***percent of all unmodified and utilized flakes**
****percent of all whole unmodified and utilized flakes**
*****percent of assemblage**

Table 79 Contexts 6-8 totals.

Class			CCS	Chalcedony	Jasper	Agate	Hornfels	Quartz	Sandstone	Other	TOTALS	%
Flakes	Unmodified											
		Whole	275	36	14	6	52	4	66	5	458	*23.50*
		Proximal	257	35	12	12	98	7	112	1	534	*27.40*
		Other fragments	516	68	20	14	134	3	194	8	957	*49.10*
		Total	1048	139	46	32	284	14	372	14	1949	
	Utilized											
		Whole	323	10	38	16	108	3	106		604	*39.74*
		Proximal	172	8	13	5	99	2	97		396	*26.05*
		Other fragments	288	16	10	9	88	2	104	3	520	*34.21*
		Total	783	34	61	30	295	7	307	3	1520	
	Bipolar		47	8		2	5	6	2		70	*1.90**
	Core-cleaning		86	5	7	4	23	1	16		142	*3.86**
	All flakes		1964	186	114	68	607	28	697	17	3681	*40.02****
Cores											0	
											0	
	Bipolar		51	4	13	4	5	11	1		89	*9.62*
	Broken		113	3	18	7	31	5	18	2	197	*21.30*
	Initial		12	2	3	1	5		3		26	*2.81*
	Multidirectional		82	5	10	5	4	2	5	2	115	*12.43*
	Opposed platform		5	2	2	1	5		1		16	*1.73*
	Single platform		5	1	1		2				9	*0.97*
	Parallel-centripetal		8	3	1						12	*1.30*

	Parallel-bidirectional	14				1		1		16	*1.73*
	Parallel-unidirectional	5	1	5		3				14	*1.51*
	Inclined	7		1		2				10	*1.08*
	CRP	105	11	17	15	8	14	3		173	*18.70*
	Core-on-flake	74	8	6	4	21	1	13		127	*13.73*
	Core tool	91	2	10	1	9		8		121	*13.08*
	Total	572	42	87	38	96	33	53	4	925	*10.06******
Tools											
	Hammerstone							1		1	*0.03*
	Backed	54	4	2	3	22	1	16		102	*2.97*
	Borer	685	23	39	28	215	8	134	3	1135	*33.03*
	Burin/graver	23	2	7		8		11		51	*1.48*
	Denticulate	1				8		2		11	*0.32*
	MRP	394	7	29	13	224	4	135	2	808	*23.52*
	Naturally backed	2	1			2				5	*0.15*
	Notched	48	1	3		22		22		96	*2.79*
	Point (Bifacial)									0	*0.00*
	Point (Unifacial)	2								2	*0.06*
	Point (Unretouched)	1								1	*0.03*
	Point (Utilized)	1								1	*0.03*
	Scraper (Convergent)	17	1	1		24		9		52	*1.51*
	Scraper (End)	76	4	8	2	40	1	34	1	166	*4.83*

Scraper (Nosed)	361	11	35	8	157	2	107	1	682	*19.85*
Scraper (Side)	19		1		21		21		62	*1.80*
Scraper (Side/End)	107	4	10	4	89	1	45	1	261	*7.60*
Total	1791	58	135	58	832	17	537	8	3436	37.36***
Flaked pieces	52	4	2	1	25	1	35		120	1.30***
Shatter	597	50	37	11	112	55	129	15	1006	10.94***
Heatspall	23		1		2		3	1	30	0.33***
TOTAL ARIFACTS (w/o chips)	4999	340	376	176	1674	134	1454	45	9198	
% Raw material	*54.35*	*3.70*	*4.09*	*1.91*	*18.20*	*1.46*	*15.81*	*0.49*		

***percent of all unmodified and utilized flakes**
****percent of all whole unmodified and utilized flakes**
*****percent of assemblage**

Appendix C: Photographs

Figure 45 Context 5 debitage..

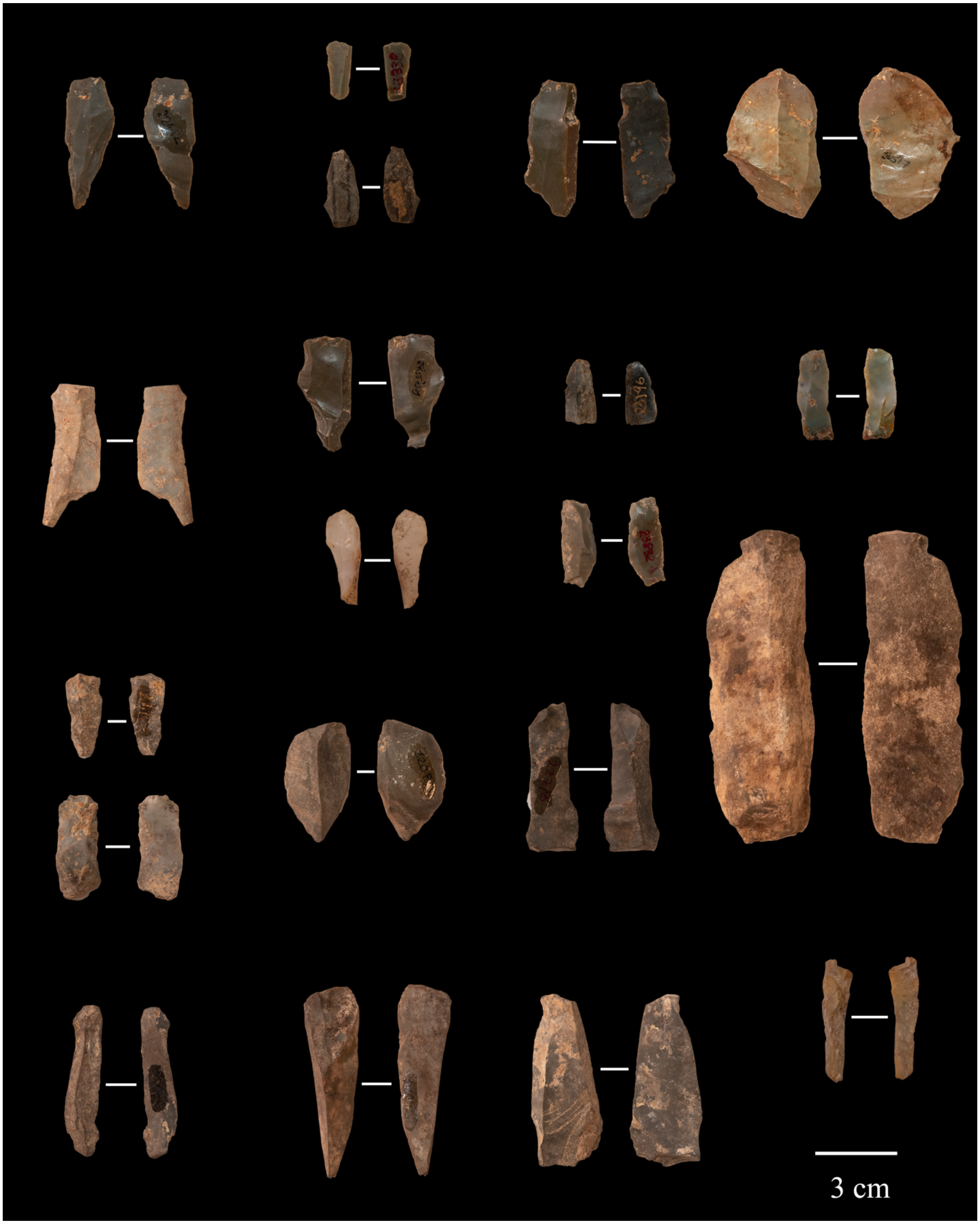


Figure 46 Contexts 6-8 debitage.

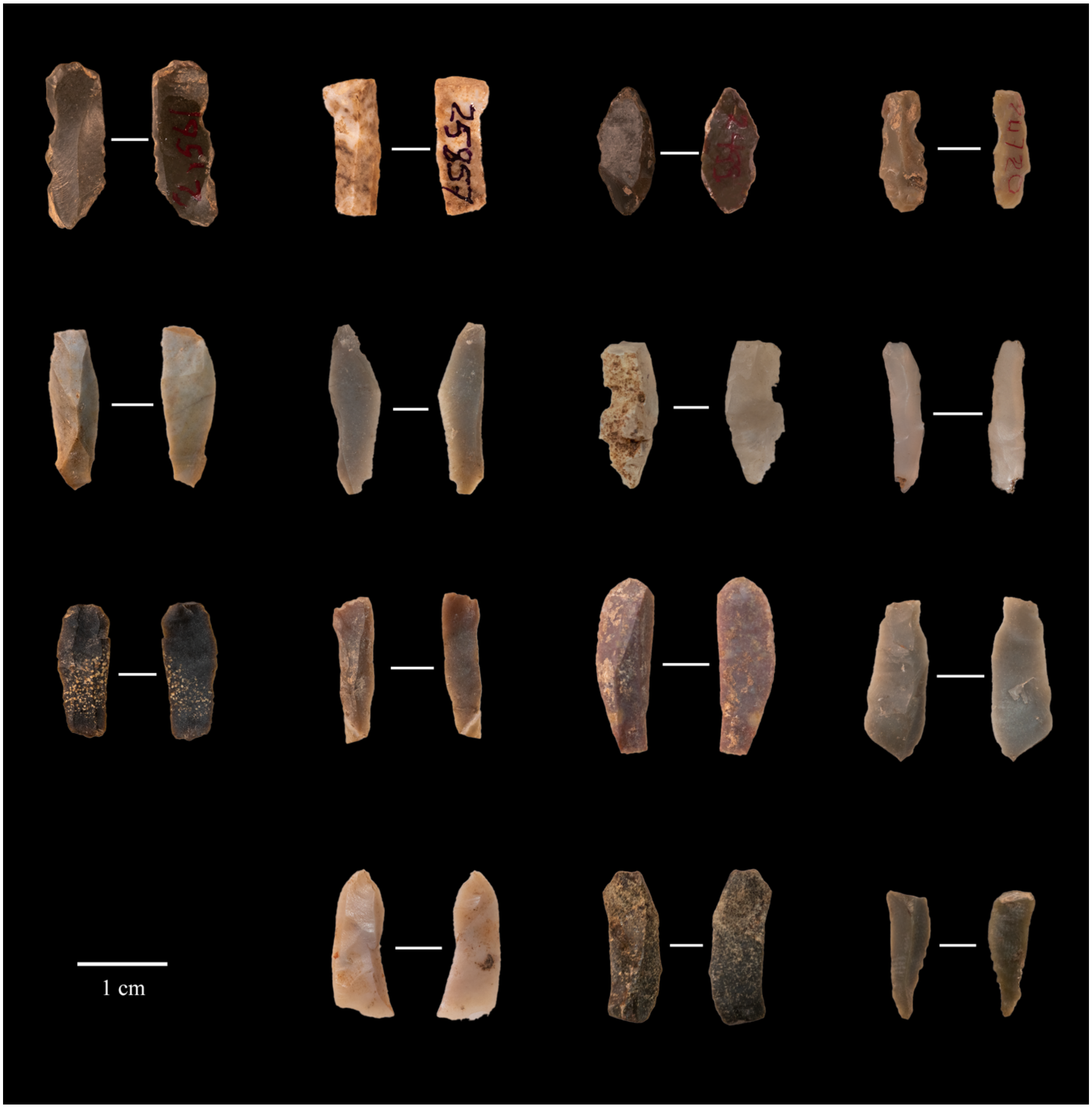


Figure 47 Context 5 bladelets.

Figure 48 Contexts 6-8 bladelets.

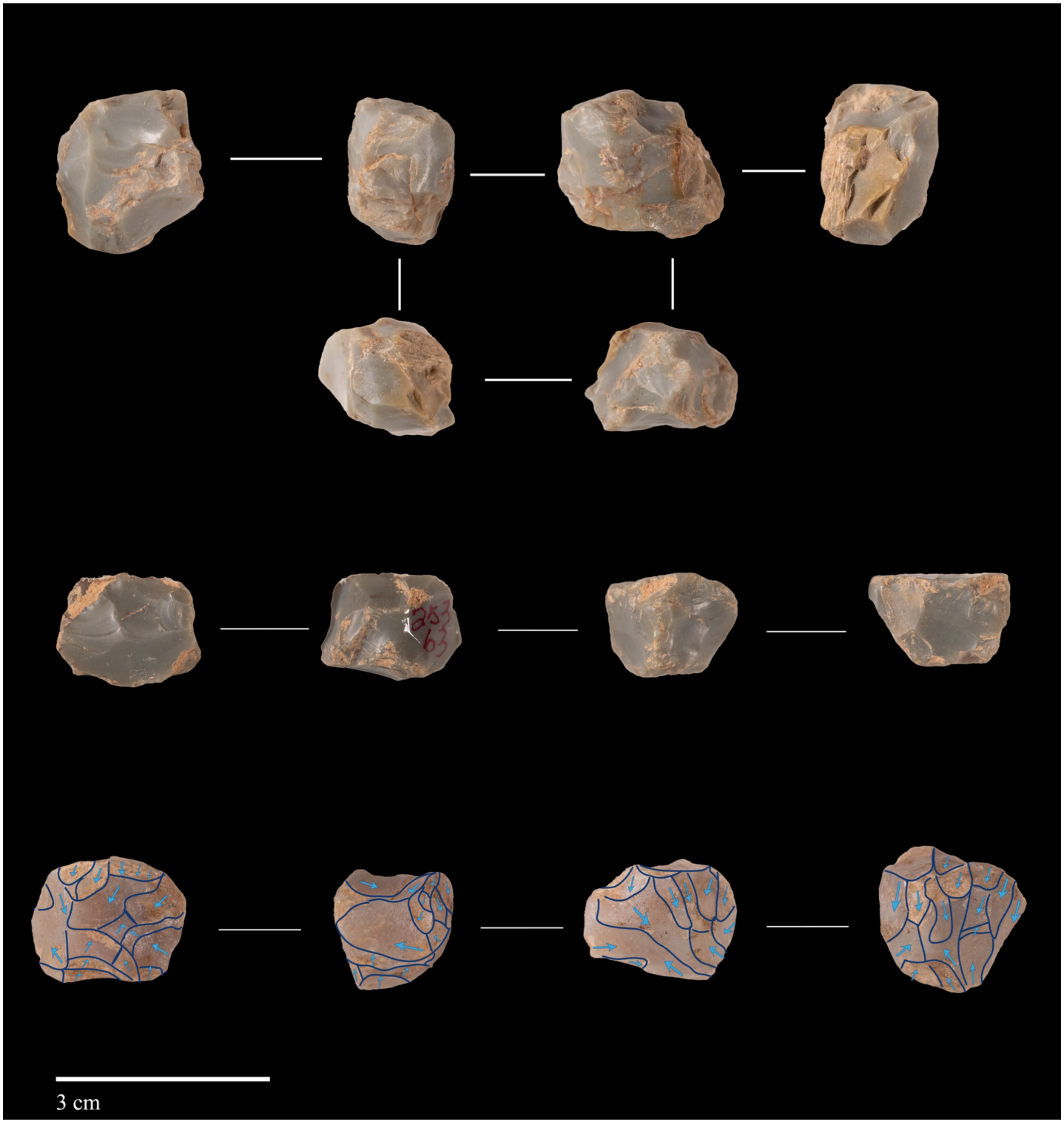


Figure 49 Context 5 bipolar cores.

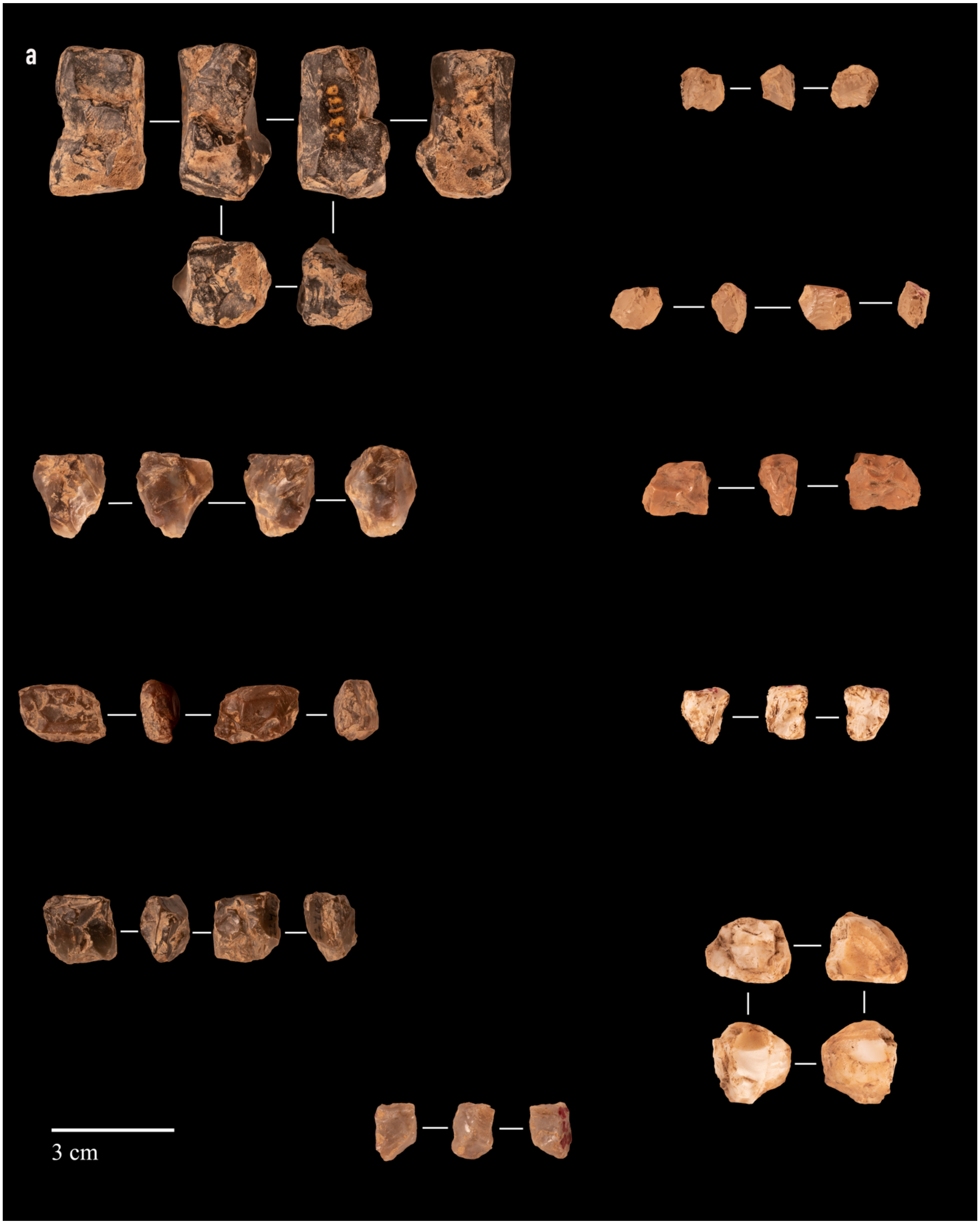


Figure 50 Contexts 6-8, bipolar cores and CRPs.

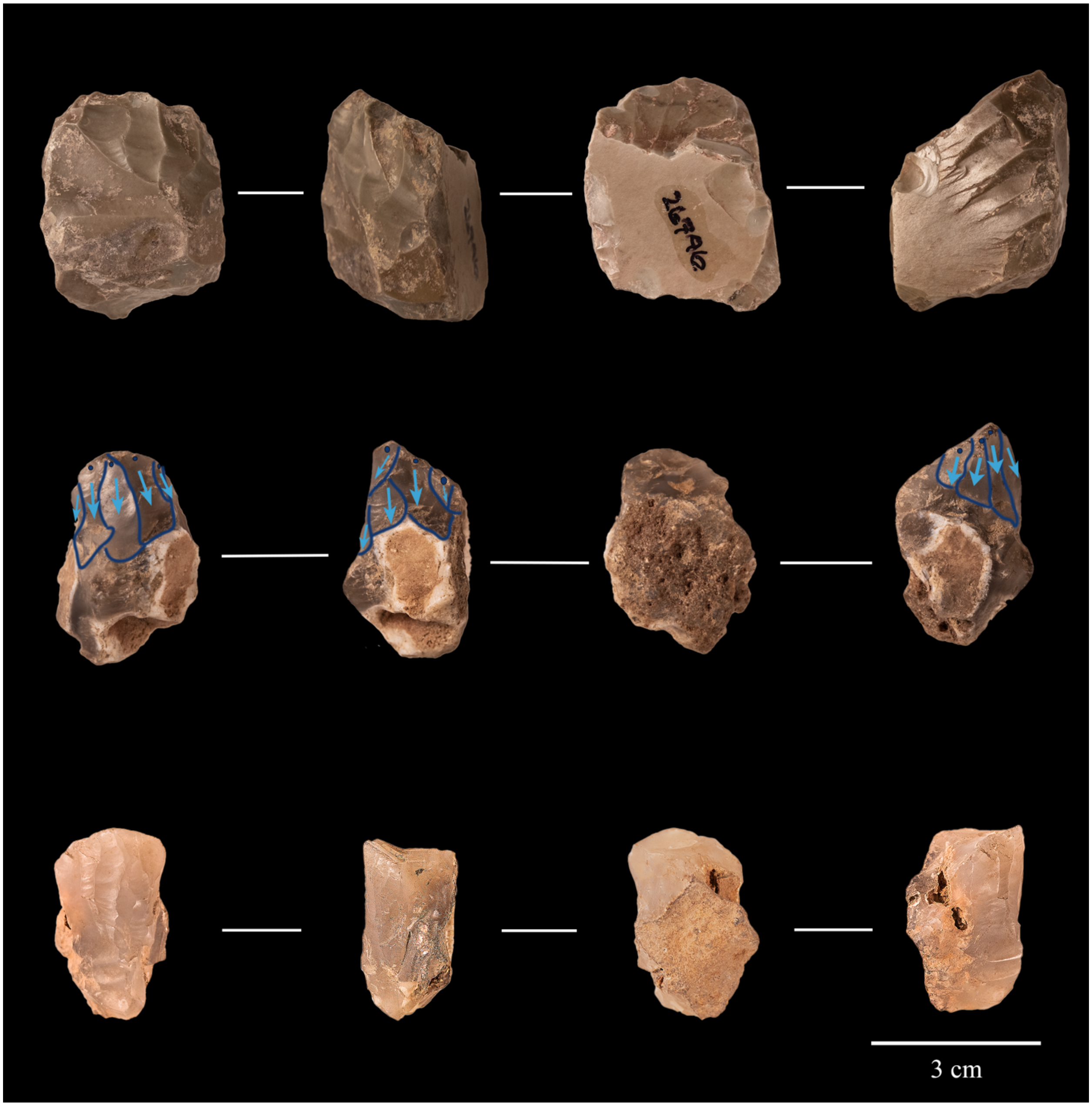


Figure 51 Context 5, high-backed bladelet cores.

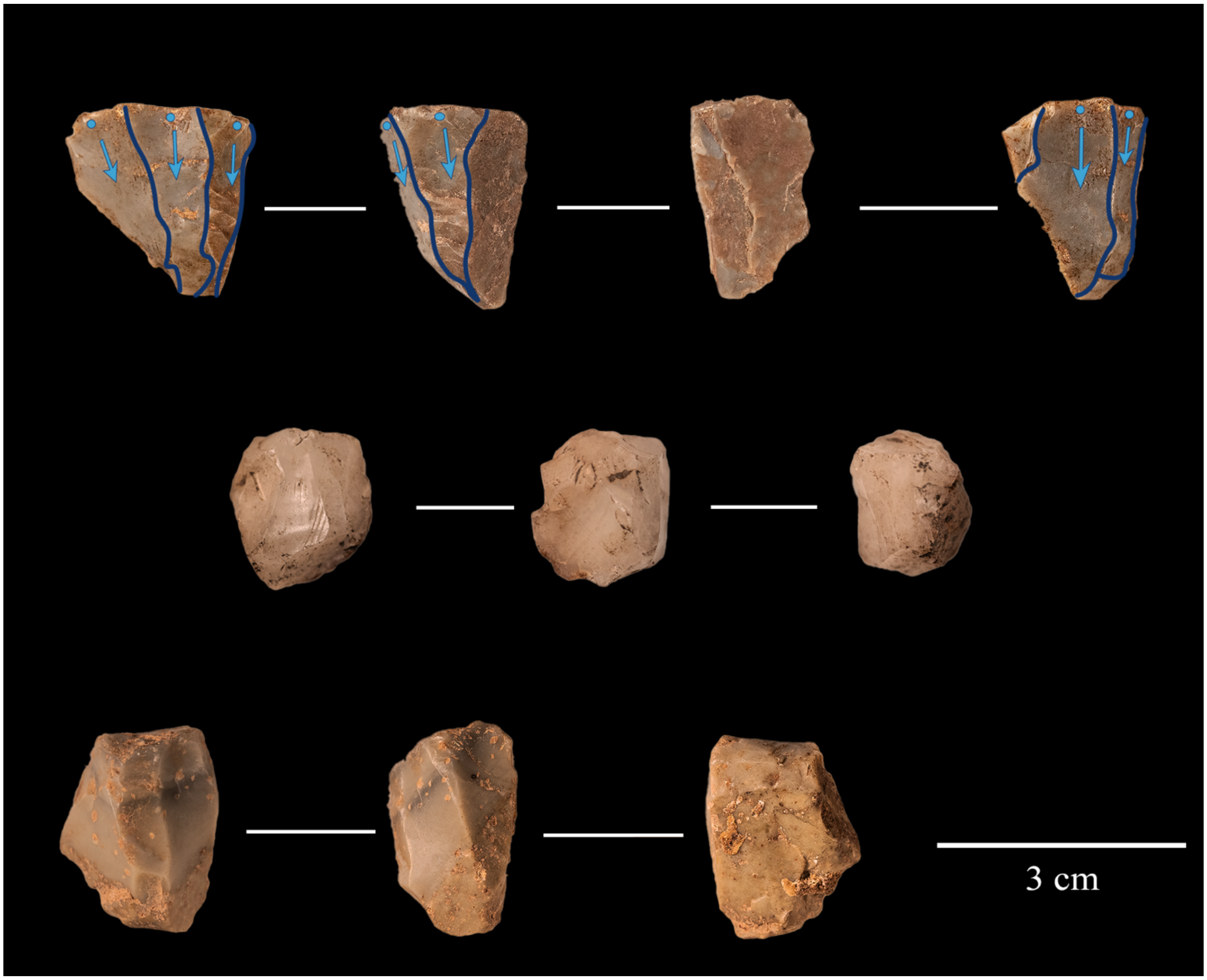


Figure 52 Context 5, other bladelet cores.

Figure 53 Contexts 6-8, bladelet cores.

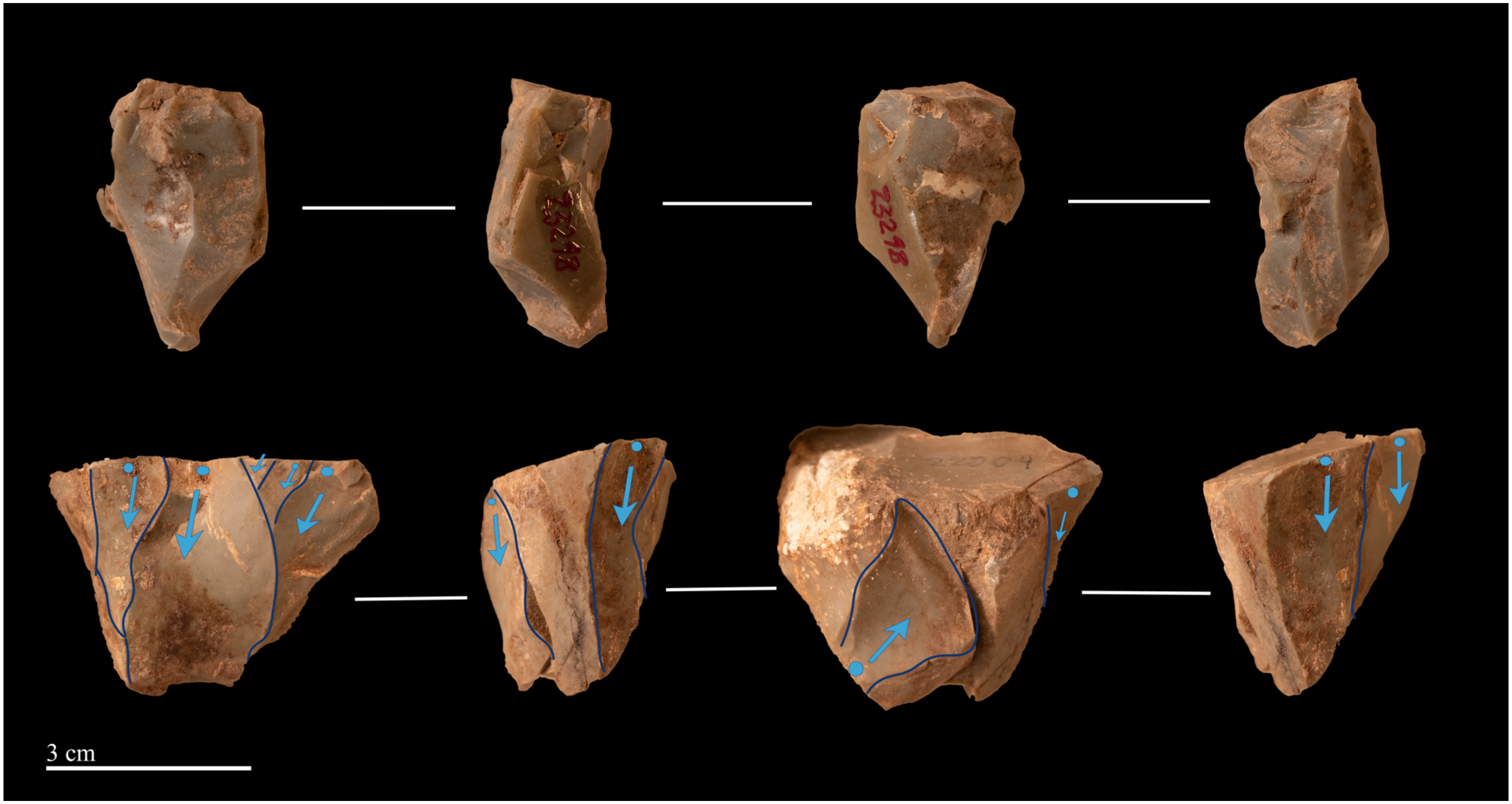


Figure 54 Contexts 6-8, platform cores.

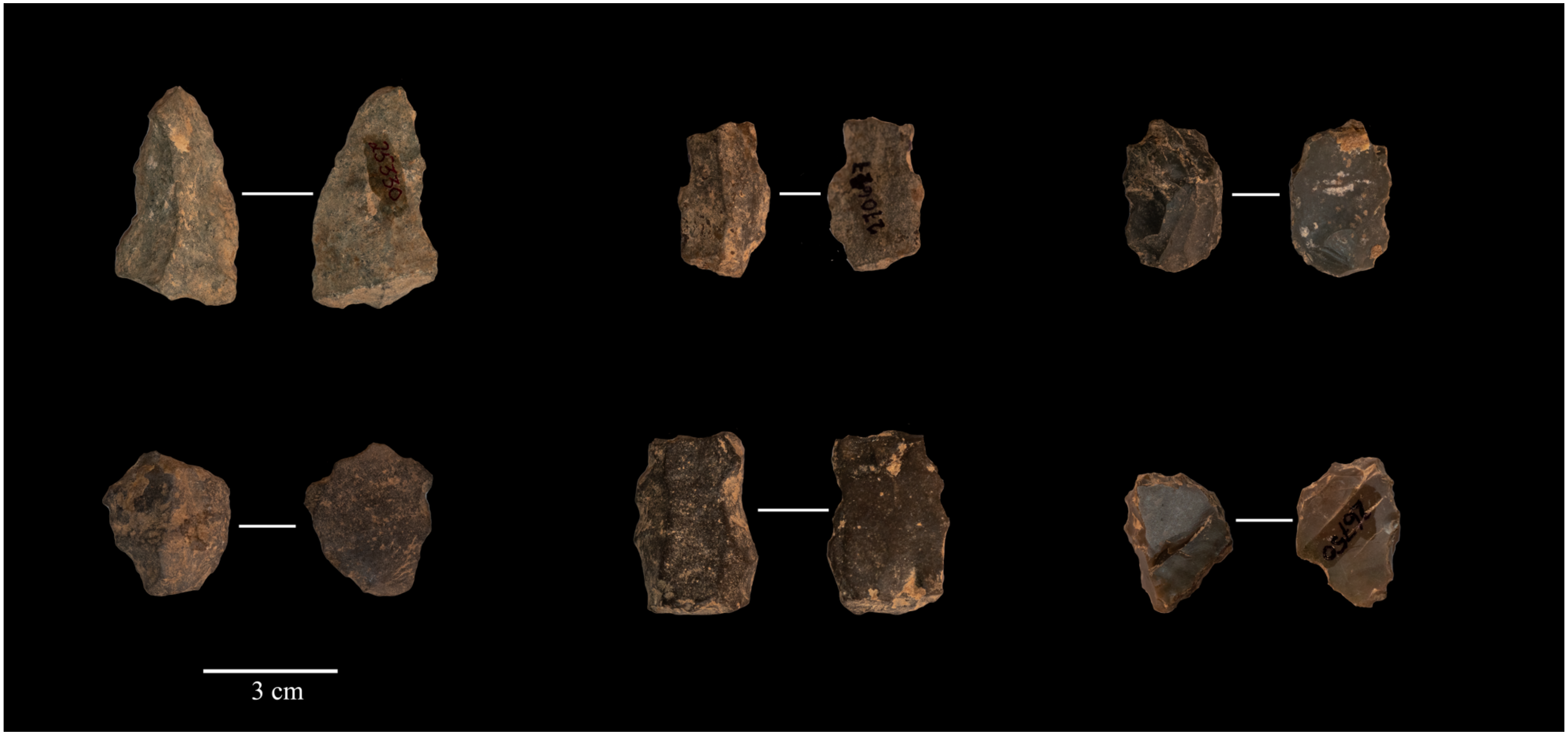


Figure 55 Context 5, assorted scrapers.

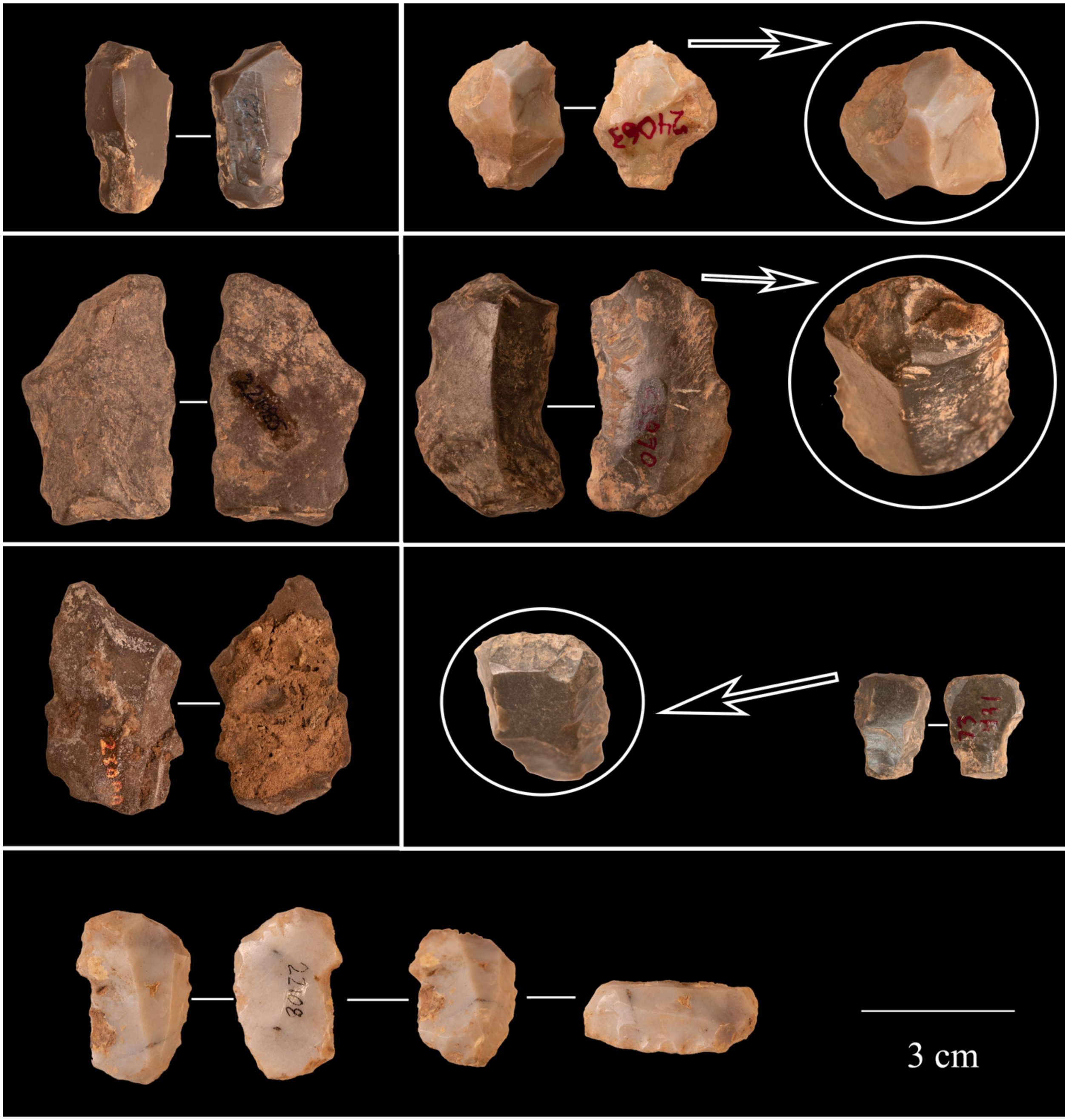


Figure 56 Contexts 6-8, assorted scrapers.

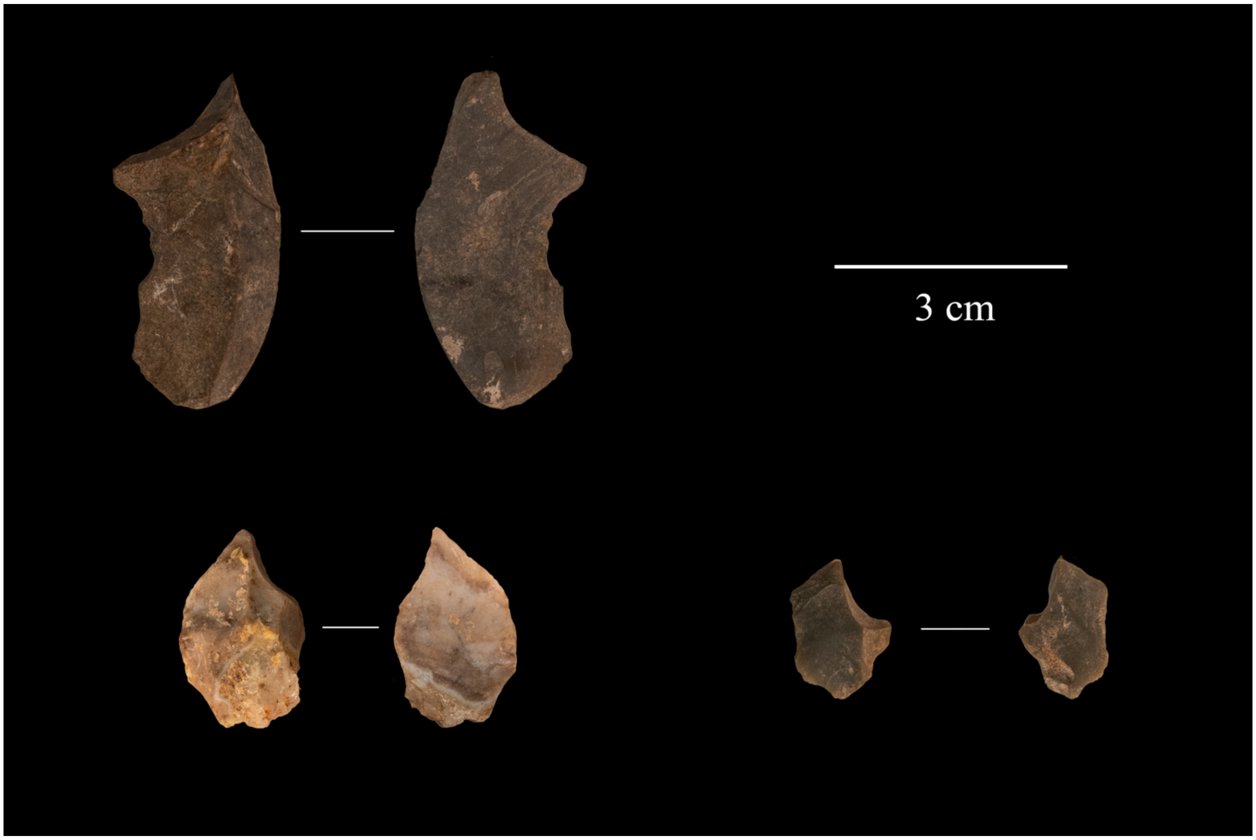


Figure 57 Context 5, burins.

Figure 58 Context 5, borers and burins.

Figure 59 Contexts 6-8, borers.

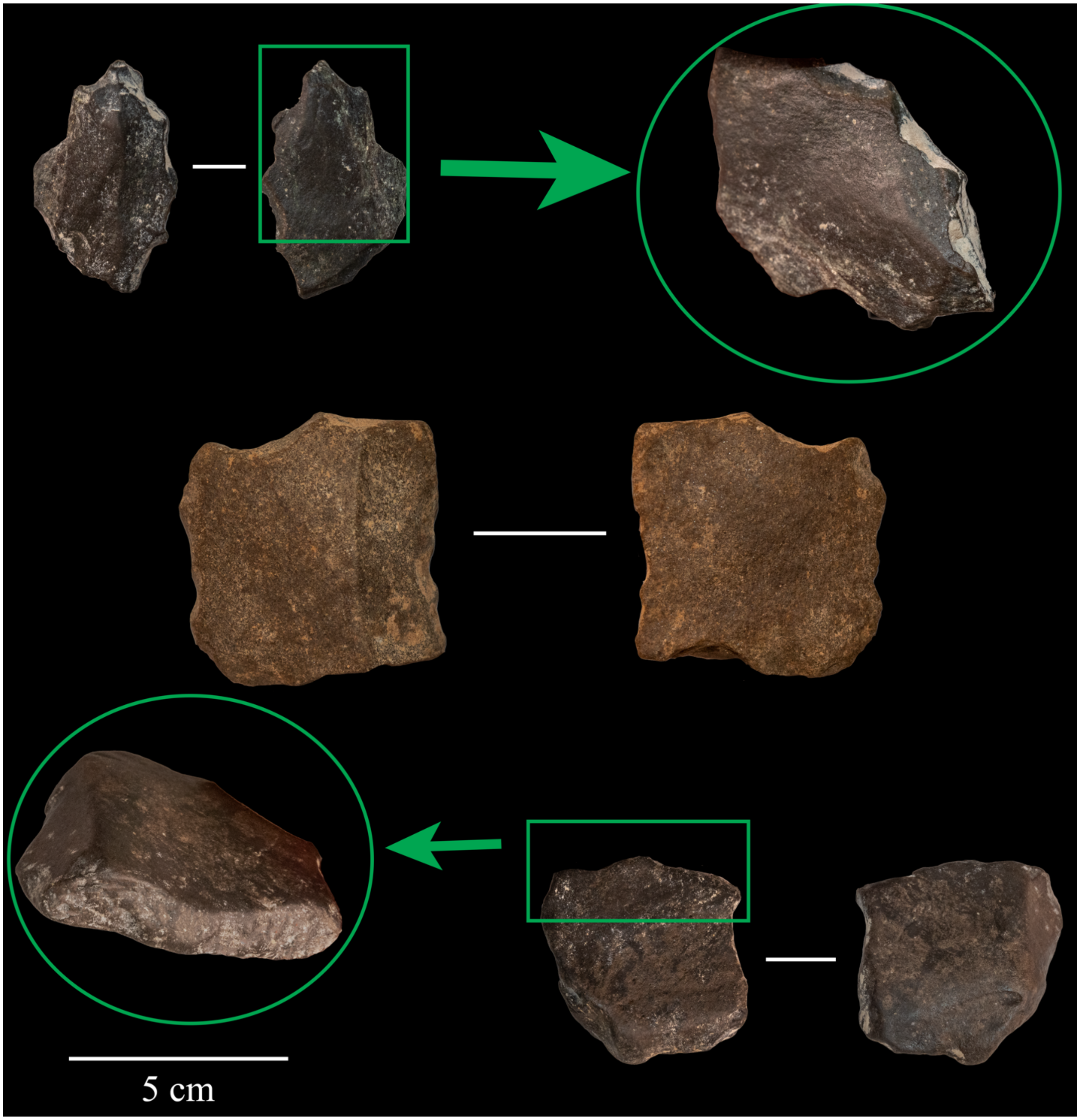


Figure 60 Context 5, MRPs. Middle and bottom row: possible truncated pieces.

Figure 61 Contexts 6-8, MRPs.

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