



Raw Material Surveys and Their Behavioral Implications in Highland Lesotho

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Abstract

Archaeologists have long considered climate change a primary mechanism behind human behavioral adaptations. The Lesotho highlands' Afromontane and climatically extreme environments offer a unique opportunity to examine proposed correlations between topography, climate, and human behavior. Previous studies suggest that warmer temperatures allowed humans to expand their diet breadth and foraging range, whereas colder temperatures restricted humans to resources in riverine corridors. These studies used faunal and floral change as proxies to track changes in forager mobility but did not consider how differential access to stone resources affected human behaviors. To account for this gap, we conducted a survey for knappable rocks around the Sehonghong rock shelter in eastern Lesotho, recording the materials present and their size and shape in the modern environment. We compared the survey results to later Pleistocene (~22–11 ka cal. BP) lithic assemblages at Sehonghong to better understand whether archaeological patterns match modern knappable rock availability. Contrary to previous hypotheses, we find that past peoples at Sehonghong were not limited to exclusively riverine resources during colder conditions. We then used flake-to-core and noncortical-to-cortical flake ratios to track changes in mobility and knappable rock procurement patterns. The ratios remain constant up until the Late Glacial, ca. 14 ka cal. BP, when we see an increase in both flake-to-core and noncortical-to-cortical ratios, suggesting increased movement of stone out of Sehonghong. These conclusions show that resource procurement and mobility patterns are not solely dependent on climate change but may be driven by more complicated causal mechanisms such as increased interaction and the formation of social networks across the Lesotho highlands and beyond.

Keywords Montane environments · Lesotho · Mobility · Stone surveys · Land use · Late Glacial

Introduction

Lithic assemblages are the most abundant and well-preserved records archaeologists use to understand prehistoric human resource and landscape use. These interpretations require appropriate spatio-temporal frameworks to contextualize changes in stone artifact assemblage composition. Knappable stone resources are not ubiquitous in most landscapes, and so, prehistoric groups would have included raw material procurement within their general time budgets (Torrence, 1983). Access to knappable rock was likely a key factor influencing where humans settled and how they used landscapes. These factors impact site occupation and likely contributed to the long-term buildup of traditional landscape knowledge, decision-making, and the structure of landscape use by past peoples living within them (e.g., Clarkson & Bellas, 2014; Shott, 2018). Linking the current availability and distribution of knappable rock within landscapes to regional archaeological sequences provides a window into these prehistoric decision-making systems and mobility patterns.

The site of Sehonghong in the eastern Lesotho highlands of southern Africa provides an opportunity to address questions of stone resource availability and landscape use in Afromontane regions. Montane regions are complex adaptive environments providing a wealth of ecological resources through their high topographic diversity (Holmes and Boardman, 2018; van Zinderen Bakker, 1981). They are also challenging environments to occupy given their wide range of climatic patterns and high seasonality, which lend themselves to unpredictable resource distribution. Redistribution of food resources will often drive the movement of human and nonhuman animals differently through montane environments. As such, one argument states that seasonal variability in resource abundance will influence the mobility of past peoples throughout Afromontane regions (Stewart & Mitchell, 2018a; Stewart et al., 2016). Although highland Lesotho's rich archaeological record demonstrates humans' episodic use of this region over the past 100,000 years (e.g., Bousman, 1988; Mitchell & Vogel, 1994; Mitchell, 1996a, 2009; Stewart et al., 2012), with traces of earlier activity extending back into at least the late Middle Pleistocene (Carter, 1978), to date, there have been few attempts to survey (or source) the region's diverse knappable rocks.

Our survey work set out to examine this issue of the landscape distribution of knappable rocks around Sehonghong and its influence on past mobility patterns. Specifically, we aimed to (1) see if the most frequent available knappable rocks available today around Sehonghong match with patterns observed in the site's archaeological record and (2) track past mobility strategies through the movement of stone materials in and out of Sehonghong. It is difficult to track the mobility of past populations, but recent methods allow us to quantify the amount of stone past peoples carried into and out of sites. Several methods for tracking mobility via lithic material include cortex and volume ratios (Dibble et al., 2005; Lin et al., 2016, 2019; Phillipps & Holdaway, 2016) and the simpler flake-to-core ratio (Dibble, 1995; Holdaway et al., 2004) and noncortical-to-cortical ratios (Holdaway et al., 2004; Roth & Dibble, 1998). Dibble et al. (2005) and others

(Douglass et al., 2008) use cortex ratios on rounded, riverine, cobbles to quantify the amount of weathered exterior that remains in archaeological assemblages and how much of this cortex material is removed from the site.

Unlike the cortex ratios that Dibble et al. (2005) propose, our study area contains mostly angular cortex, which makes it difficult to interpret the amount of weathered material past toolmakers brought into the site. Therefore, we chose to use flake-to-core ratios to track the movement of stone material into and out of Sehonghong. Flake-to-core ratios provide a measurement of how intensely stone is reduced (i.e., higher reduction means more flakes and higher ratio). However, this measurement also changes significantly if cores are removed from the archaeological site to somewhere else on the landscape (Holdaway et al., 2004; see also Dibble, 1995). Likewise, noncortical-to-cortical ratios for flakes provide a means to address another metric for reduction intensity and the amount of cortex removed at Sehonghong.

Our results show that the modern availability of knappable rock does not match the observed patterns at Sehonghong. Moreover, a single rock type, fine-grained chert, dominates the Sehonghong assemblage, which shows that prehistoric toolmakers targeted specific rocks for stone tool making. Our data further support the conclusion that past peoples procured their knappable rock not only from riverine sources but also from higher-elevation plateau settings that lie well above fluvial environments. We show that, regardless of significant changes in temperatures, mobility strategies varied less during the Last Glacial Maximum (LGM), ca. 25 ka cal. BP, compared with the Late Glacial, ca. 14.5 ka cal. BP (cf. Mitchell, 1996b). These results complicate assumptions about the relationship between paleotemperature and mobility strategies, contributing to debates about climatic change's role in prehistoric mobility patterns in Lesotho (cf. Mitchell, 1995; Stewart & Mitchell, 2018a, 2018b; Stewart et al., 2016). In the following sections, we introduce Lesotho's landscape and geology and the archaeological assemblage from Sehonghong. Next, we describe previous archaeological studies and interpretations of how the topography and climate in Lesotho allocate biotic and abiotic resources influencing human behaviors. Then, we describe the four layers from Sehonghong on which this study focuses ranging in time from ~22 to 11 ka cal. BP. The "Material and Methods" and "Results" sections follow a similar structure.

Background

Regional Context

Lesotho is an independent nation entirely surrounded by South Africa and comprises an extensive, rugged montane region. Its topographic and climatic variability and rich archaeological record provide a unique opportunity to examine the relationship between montane environments, stone procurement patterns, and mobility strategies across much of the Later Pleistocene (22–11 ka cal. BP) and Holocene (Fig. 1) (Stewart et al., 2016). Eastern Lesotho possesses a relatively simple geological structure dominated by ancient Lower Jurassic period ca. 195-million-year formations interrupted in places by more recent vulcanism

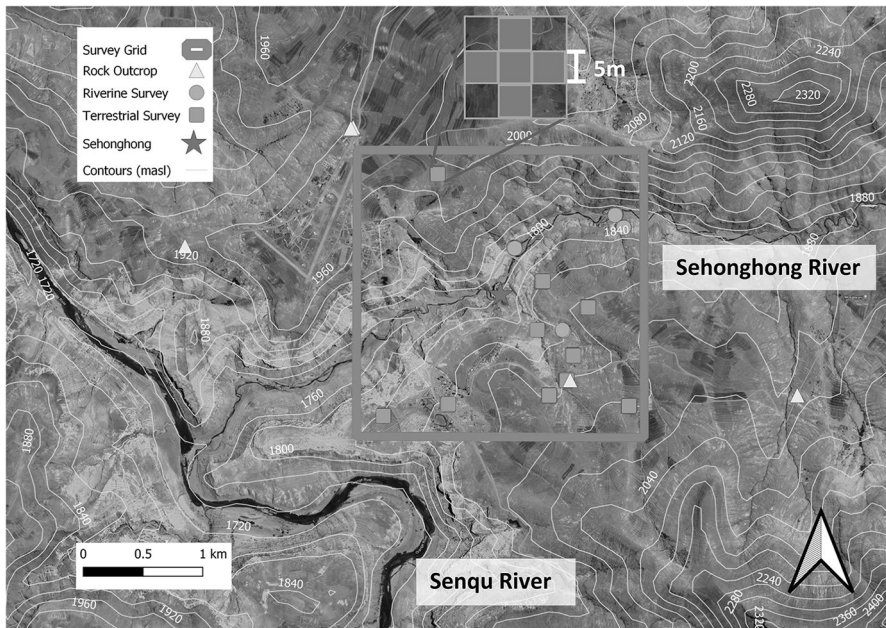


Fig. 1 Stone resource surveys around Sehonghong. This map shows the survey locations, survey extent, and previously known rock outcrops. The survey locations (squares) each represent 5 survey grids each 5 m × 5 m forming the shape of a plus sign. In total, there are 14 survey locations, each with 5 units, hence a sample of 70 surveyed areas

(Schmitz & Rooyani, 1987, 38). Lesotho Formation lava beds form a series of basal exposures that cover most of eastern Lesotho apart from the region's river valleys. Dolerite dykes and sills intrude into these more ancient volcanics, morphing into hornfels at contact zones with shale and sandstone (Chevallier & Woodford, 1999). Prehistoric groups occasionally knapped these basaltic rocks, but they favored crypto-crystalline silicas (CCS) for tool production (Loftus et al., 2019, 12; Mazel, 2022, Table 9; Mitchell et al., 2022, 168–169). Crypto-crystalline silica defines a range of sedimentary silicas that fall into three categories: granular microcrystalline quartz, fibrous silica, and megaquartz (Knauth, 1994, 234). Several of these sedimentary silicas exhibit conchoidal fractures and occur in the form of relatively small nodules, either weathered out in streams or exposed in lava flows. The CCS category comprises a range of microcrystalline fibrous silicas (see Graetsch, 1994 for the structure of microcrystalline silica), such as agates, chalcedony, and jasper, that form naturally in pipe amygdalae at the base of lava flows (Staples & Hudson, 1938; Schmitz & Rooyani, 1987, 38–39). Chert and flint are sedimentary stones and an example of a granular cryptocrystalline variety of silica (Knauth, 1994, 234; Schmitz & Rooyani, 1987, 184). Since flint is not present in South Africa (Wadley & Kempson, 2011), chert is a relatively fine-grained stone resource that past peoples recurrently favored for making stone tools. Previous studies (e.g., Mitchell, 1995, 30) have used the term “opalines” for chalcedonies, cherts, and agates (Wadley, 1997, 441).

Carter (1969/1978) initially designed archaeological explorations in eastern Lesotho to understand the effect that climate had on prehistoric foragers plant and animal resource acquisition (see also Carter et al., 1988). He aimed to link these patterns to broader questions about human–environment interactions and landscape use. Subsequent work led by Mitchell (1996a/1996b) and Stewart et al., (2012/2016) built on Carter’s research, resulting in a rich framework for understanding climate change’s role in shaping the region’s human occupation patterns.

Beyond work on climate, Mitchell (1996a) briefly examined the effect of stone material availability on occupants. He notes that the region’s fine-grained knappable rock occurs in screes and terrestrial veins that lie on upland plateaus in addition to river gravels, though the terrestrial veins are of coarse quality, deemed unsuitable for making stone tools. Later, Pargeter (2017) demonstrated that a large portion of Sehonghong’s flaked stone artifacts show tabular and coarse cortex, suggesting that toolmakers did indeed source them from terrestrial locations beyond fluvial environments. Pazan and colleagues (2022) show similarly high frequencies of nonriverine cortex on the ~80 ka lithic assemblage from the nearby site of Melikane. While toolmakers sourced some of their rocks from riverine environments, there are enough data to suggest that people extended their foraging beyond riverine valleys and into higher altitudinal, more terrestrial, sources.

Stewart et al. (2016) argue that the Lesotho highlands’ prehistoric inhabitants depended heavily upon the region’s riverine corridors to source food, shelter, and knappable rock. They hypothesize that climatological shifts caused changes in the way ancient foragers used these river systems. Specifically, they argue that cooler periods reduced edible biomass at higher elevations, forcing foraging groups either to descend to lower elevations, or to aggregate along riverine channels to exploit aquatic resources. Stewart and Mitchell (2018a) show that during cold periods, people in eastern Lesotho procured more fish, whereas warm periods reflect a greater emphasis on the hunting and trapping of terrestrial bovids (see also Plug & Mitchell, 2008). Pargeter and Dusseldorp (2022) show that at Sehonghong, aquatic resource exploitation is not always correlated with increased occupation intensity, and that aquatic resource use is not correlated with lithic technological intensification, by which we mean the investment of increased energy for similar returns (Morgan, 2015). These ongoing debates show that the relationships between climate change, hunter-gatherer mobility, the (re)organization of lithic technology, and dietary shifts at Sehonghong are not straightforward. To further supplement these data, we propose an investigation into mobility patterns using another line of evidence tracking the procurement and movement of stone resources into and out of Sehonghong.

Background to Sehonghong

Sehonghong is a large, roughly west-facing rock shelter formed in outcropping sandstone (Fig. 2). It measures ~86 m across the front entrance and ~19 m from the dripline to the rear of the shelter. The site is located 20 m above the Sehonghong River and ~1870 m.a.s.l. in the Qacha’s Nek District of eastern Lesotho and today lies within southern Africa’s summer rainfall zone (Carter et al., 1988). The shelter

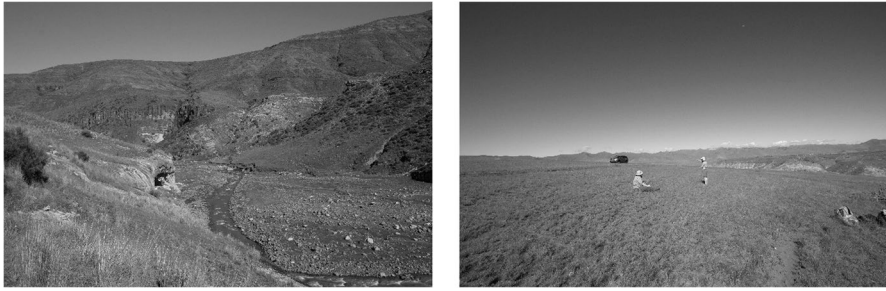


Fig. 2 Photographs of riverine and terrestrial environments. This figure shows examples of surveyed riverine (left) and terrestrial (right) environments in eastern Lesotho

is situated on the south side of the Sehonghong River, 3 km upstream from where it joins the Senqu River. It preserves a rich archaeological record extending back to 57.6 ± 2.3 ka and continuing into the late nineteenth century (Jacobs et al., 2008; Mitchell, 1996b, 2010; Pargeter et al., 2017).

For this study, we are concerned with Sehonghong's four uppermost Pleistocene layers labeled brown ashy sand (BAS), red brown loam/carbonaceous loams below rockfall (RBL-CLBRF), rockfall (RF), and beige ash above rockfall (BARF). These layers have relatively large and diverse lithic assemblages, and they track key changes in human behavior across the LGM and Late Glacial, 25 ka cal. BP to 11.9 ka cal. BP (Pargeter et al., 2017; see Table 1 below). These assemblages document key lithic technological changes related to what archaeologists in southern Africa refer to as the Robberg Industry (Mitchell, 1995; Wadley, 1996). Robberg assemblages comprise high frequencies of bladelets and bladelet and bipolar cores, and relatively low retouched tool frequencies (Low & Mackay, 2018; Mitchell, 1988). Some archaeologists have used evidence for the Robberg's supposed technological uniformity to support arguments for the existence of long-distance

Table 1 Radiocarbon dates from previous surveys at Sehonghong. This table, adapted from Table 3 in Pargeter et al. (2017), shows the layers of interest for this study, the corresponding radiocarbon dates BP, and calibrated ranges. We used the *rcarbon* (Crema & Bevan, 2021) R package to calibrate these dates based on the SHCal20 calibration curve (Hogg et al., 2020)

Layer	Lab ID	Uncalibrated date BP	Calibrated BP range
BARF	Pta-6065	$11,090 \pm 230$	13,420–12,618
RF	Pta-6282	$12,180 \pm 110$	14,100–14,006
RF	Q-3176	$12,200 \pm 250$	15,046–13,582
RF	Q-3175	$12,250 \pm 300$	15,226–13,571
RF	Pta-6062	$12,410 \pm 45$	14,845–14,666
RF	Pta-6058	$12,470 \pm 100$	15,023–14,147
RBL-CLBRF	Q-3173	$12,800 \pm 250$	15,894–14,184
RBL-CLBRF	Pta-884	$13,000 \pm 140$	15,920–15,118
RBL-CLBRF	Q-3172	$13,200 \pm 150$	16,229–15,330
BAS	OxA-32921	$20,600 \pm 100$	25,076–24,357
BAS	Pta-6060	$15,700 \pm 150$	19,331–18,685
	Q-1452	$17,820 \pm 270$	22,238–20,880

connections, increased mobility, and/or expanded territorial ranges across variable environments (Ambrose, 2002). However, Low and Pargeter (2020) show that past foragers from spatially distant and distinct regions in southern Africa show variable stone collection practices and tool production techniques. This challenges past assumptions about the uniformity and shared technological systems of the Robberg. Moreover, Low and Mackay (2018; see also Parkington, 1984) show that Robberg toolmakers often used local rocks for their bladelets, thereby arguing against systems based on wide resource exchange and interaction networks (cf. Ambrose & Lorenz, 1990).

Mitchell (1995) and Pargeter et al. (2017) provide detailed overviews of the four layers covering the LGM into the Late Glacial period, so here we focus only on their basic attributes, from youngest to oldest.

Beige Ash Above Rockfall One conventional radiocarbon date places BARF's occupation within the Late Glacial ca. 13,900–11,900 cal. BP. Mitchell (1995) assigned the BARF lithic assemblage to the Robberg Industry based on its high frequency of bladelets and bladelet cores.

Rockfall Five radiocarbon dates (three conventional, two AMS) place RF's occupation during the Late Glacial ca. 15,400–13,400 cal. BP (Pargeter et al., 2017). Mitchell (1995) assigned RF's lithic assemblage to the Robberg Industry, and Pargeter et al. (2017) argue that this was a relatively dense lithic deposition window.

Red Brown Loam/Carbonaceous Loams Below Rockfall Five radiocarbon dates (three conventional, two AMS) place the occupation of RBL-CLBRF within the Last Glacial ca. 16,200–14,600 cal. BP (Pargeter et al., 2017). Again, Mitchell (1995) assigned the assemblage from this layer to the Robberg Industry.

Brown Ashy Sand A single AMS age from layer BAS (OxA-32921, $20,600 \pm 100$ BP) places BAS' initial deposition at around 25 ka cal. BP (Pargeter et al., 2017). Two conventional ^{14}C dates place the remaining portion of the BAS occupation further up in the sequence. The first of these (Q-1452) is from the lower part of Carter's Layer IX and dates to $17,820 \pm 270$ BP (22,250–20,820 cal. BP; 595 cal. BP) (Mitchell Carter et al., 1988). The other is from Mitchell's layer BAS (Pta-6060, $15,700 \pm 150$ BP [19,300–18, 1995]). Mitchell (1995) assigned BAS to an early expression of the Robberg Industry, and Pargeter et al. (2017) report that layer BAS contains a denser lithic deposition than earlier and later layers at Sehonghong, suggesting increased occupation intensity during its accumulation.

Mitchell (1995) identified CCS as the dominant raw material in all four layers, with dyke material (i.e., coarser-grained metamorphic rocks from volcanic dykes) comprising the next most abundant rock category. However, Pargeter (2017) subsequently showed that the stone cores recovered from layers RF and BARF exhibit a significant shift from being dominated by chert to being dominated by crystal quartz. Pargeter and Hampson (2019) document a similar trend during the same

period at the site of Ntloana Tšoana in western Lesotho and argue that this identical increase in crystal quartz over other CCS materials suggests a potential symbolic and social connection between those living in Ntloana Tšoana and Sehonghong. If correct, this implies far-reaching social relationships through the Lesotho highlands and over ~120 km in a straight line, punctuated by two mountain ranges, each of which reaches over 2800 m.a.s.l.

Stewart et al. (2020) provide additional evidence of long-distance exchange and/or mobility networks extending out from the eastern Lesotho highlands via the movement of ostrich eggshell beads. Faunal evidence suggests that ostriches are not native to Lesotho and strontium isotope analysis documents repeated movement of beads made from their eggshell into the highlands during the late Pleistocene and Holocene from areas further into the southern African interior that were, at times, at least 325 km distant. Similarly, layer BAS (22,250 cal. BP) contains a bead made from the estuarine mollusk *Nassarius kraussianus* and layer RF (15,400–13,400 cal. BP) a shell pendant made from the marine species *Nerita* sp. and a fragment of a further marine shell (*Trachycardium* sp.) that must represent transportation from, or exchange with low-lying coastal regions ~200 km to the east of Sehonghong (Plug & Mitchell, 2008). Therefore, while stone materials are not the only material culture that track mobility, their greater availability allows us to complement past evidence for past mobility and trade networks within Lesotho in a much more comprehensive way and, probably, on a much more local basis.

Sehonghong's long occupation sequence also provides us with the opportunity to explore the impact of geological and climatological impacts to past people's stone procurement and mobility strategies. We seek to use our stone resource survey to complement and test current hypotheses surrounding past mobility strategies in Lesotho. One such hypothesis is Stewart et al.'s (2016) push-and-pull model. Since Sehonghong is located along a tributary of the Senqu River, Stewart et al. (2016) argue that the inhabitants of this site should have expanded their diet breadth and foraging range during warm periods but have been restricted to the adjacent river valley during cold periods. That is, warm periods likely reflect high bioproductivity that made it easier for foragers to use larger ranges, including those at higher elevations. On the other hand, cooler periods reduce bioproductivity and reflect downslope displacement of faunal and, especially botanical, resources. Thus, this relation between climate and bioproductivity should pull and aggregate foragers along riverine corridors at lower elevations, a process further facilitated by the attractiveness of riverine fish as an alternative source of dietary protein and fat (Stewart & Mitchell, 2018a).

Occupations at Sehonghong allow us to test the proposed push-and-pull model. Each layer represents a specific climate phase for which we can compare faunal and lithic records to address the mobility of past peoples in this landscape. First, layer BAS dates to 22,250–18,595 cal. BP and stable carbon isotope analysis of the sediments from this layer suggests a cold phase in the Sehonghong sequence (Loftus et al., 2015; Stewart & Mitchell, 2018a). The next layer, RBL-CLBRF, dates to 16,200–14,600 cal. BP and represents a significantly warmer period (Loftus et al., 2015; Stewart & Mitchell, 2018a). During layer RF (15,400–13,400 cal. BP), we encounter the Antarctic Cold Reversal, which cooled the Southern Hemisphere similarly to the LGM (Stewart & Mitchell, 2018a). Lastly, layer BARF,

which dates to 13,900–11,900 cal. BP, reflects the onset of the Younger Dryas stadial (Loftus et al., 2015). Stewart and Mitchell (2018b, 9) outline regional pollen and speleothem analyses (Holmgren et al., 2003; Scott et al., 2012; Truc et al., 2013) that show this period returns to LGM temperatures and was thus colder than layer RF. The stadial and interstadial data, when linked to these four layers at Sehonghong, allow us to use Stewart et al.'s (2016) push-and-pull model.

If cold climates drove past peoples to aggregate along riverine corridors, then we expect to see signs of more restricted mobility and rock procurement. Plug and Mitchell's (2008) faunal data match this prediction. Specifically, the cold intervals BAS, RF, and BARF each show high values of fish-to-mammal ratios from faunal remains deposited at Sehonghong, suggesting increased foraging of fish. During the warmer phase represented by RBL-CLBRF the fish-to-mammal ratio drops below 1, suggesting an increase in terrestrial bovids. Pargeter and Dusseldorp (2022) show that faunal assemblage evenness remains constant during all four layers at Sehonghong and hence is not correlated with Sehonghong's fish-to-mammal ratios. That is, comparing riverine and terrestrial fauna, there is a weak correlation between increasing fish remains and cold temperatures at Sehonghong. This shows that past peoples did not intensively use riverine resources as previously suggested. Hence, there is reason to believe that while climate change clearly impacted Lesotho's highland hunter-gatherer mobility patterns, the situation is complex.

We use modern stone resource surveys around Sehonghong to track changes in resource procurement and mobility as a way of testing the push-and-pull model for highland hunter-gatherer mobility. Our starting assumption is that past peoples favored certain rocks over others because they are more abundant in the surrounding landscape (See Mitchell, 1995, 30; 2000, 150). If we find strong differences in modern rock abundances and prehistoric raw material selection, then it is reasonable to assume that hunter-gatherers practiced targeted resource procurement. Furthermore, we use the surveys we undertook near the site to generate cortex and volume ratios to track changes in mobility patterns at Sehonghong.

Materials and Methods

This paper's data comprise measurements on the archaeological lithic samples from Sehonghong and our modern raw material survey results. The methods described below outline how we sourced raw materials and how we used these datasets to begin building interpretive models for understanding prehistoric mobility. The analyses of this study were conducted in R (R Core team, 2020). The code and raw datasets can be found via GitHub (<https://github.com/Agregory198/lesotho-stone-resources.git>).

Archaeological Samples

We selected the archaeological lithic samples from two of Mitchell's (1995) 1 m² excavation squares (squares K12/K13). We sampled at least 300 flakes/layer, including bladelets and blades, (in layers with fewer than 300 lithics/layer, all were counted), and all cores were recorded. We included all flaked materials except small (<5 mm) flake fragments without platforms. Our lithic sample contains representative numbers from each of the study's four stratigraphic layers to control, to some degree, the volume of excavated material in our comparisons. For each layer, we identified the core and flake raw material types, the amount of cortex on the artifacts, and their size (maximum length, width, thickness, and mass). The raw material counts were used to compare with our survey data while we use artifact counts to compute the flake-to-core and cortical-to-noncortical ratios.

Raw Material Surveys

We designed the surveys to locate, describe, and map raw material sources around Sehonghong in a probabilistic fashion and to supplement unpublished data on known stone outcrop locations. We used grids of 5 m × 5 m survey squares set at a 10-km² area centered on Sehonghong (Fig. 1). Sehonghong is by far the largest rock shelter in the wider area and is a natural focal point for human activity, including stone tool production. We chose a 10-km² area for the survey as this approximates an average daily foraging radius (Kelly, 2013). We generated 1,000,000 equally sized squares over this area and classified each square into riverine or nonriverine environment. We then used the random point function in QGIS with riverine squares weighted at 0.25 and nonriverine weighted at 0.75 to account for the proportion of these environments over our survey area. We used this process to generate 100 survey squares at random in which to record nodule raw material types, counts, and basic dimensions (length, width, thickness, and mass) (Fig. 1). We captured all the data in the field using a portable scale, digital calipers, and notebooks.

We chose survey squares randomly to avoid biasing our results towards only those immediately visible or accessible rock sources. Though randomized techniques prohibit control over spatial autocorrelation, the results allow for the generation of a null distribution of raw stone materials surrounding Sehonghong and enable us to construct probabilistic understanding of raw material distributions and densities. These squares were stratified to capture both fluvial (25%) and nonfluvial (75%) locations in rough approximation to their landscape contributions. Nonfluvial environments are on upland plateaus, out of the flood plains for riverine systems near Sehonghong. In general, we will use the term "terrestrial" to refer to these upland plateaus where stone resources are less affected by fluvial transport. This configuration also allowed us to test the hypothesis that riverine locations provide access to CCS sources (see Fig. 2).

In each survey square, we focused on nodules greater than 20 mm. We did this because lithic data from Sehonghong show that the site's cortical and partly cortical

nodules are on average greater than 20 mm in maximum dimension. When a survey square contained more than 100 nodules, we recorded the shape, texture, and weight of these stones. We assume that these nodules were transported to the site for future use and represent prehistoric primary nodule selection criteria. We broke CCS down into its several sub-components: chert, chalcedony, agate, and jasper. We broke the chert class down further into coarse and fine-grained components following an unpublished chert identification and description protocol developed by Charles Arthur and Geeske Langejaans (pers. comm.) for the area surrounding Ntloana Tšoana in western Lesotho.

Flake-to-Core Ratios

An analysis of the archaeological materials at Sehonghong provides us with the information to track the movement of stone into and out of Sehonghong. To accomplish this, we computed the flake-to-core ratios for fine-grained chert. We used complete flakes for this ratio, defined as flakes that have an intact platform to account for overcounting the number of flakes represented at Sehonghong. Flake-to-core ratios inform us about the relative proportion of flakes in an assemblage (see Dibble, 1995; Holdaway et al., 2004). Since cores represent a relatively small proportion of most archaeological assemblages compared to flakes, we use this metric to inform us on the movement of cores into and out of Sehonghong. A low ratio suggests a lower number of flakes than cores and vice versa for a high ratio. We computed this ratio for layers BAS, RBL-CLBRF, RF, and BARF. Differences between these layers suggest changes in the deposition and subsequent transport of cores and flakes at Sehonghong.

Noncortical-to-Cortical Ratios

We use noncortical-to-cortical ratios to address both reduction intensity and the amount of cortex that was removed at Sehonghong (see Roth & Dibble, 1998; Holdaway et al., 2004). Again, we selected only complete flakes for this analysis. This ratio allows us to account for cortex that past peoples deposited within the site, something that flake-to-core ratios fail to account for. If past peoples were reducing stone tools that contain a lot of cortex, then we would expect the noncortical-to-cortical ratio to be low. By contrast, a high ratio would suggest that the stone contains relatively little cortical surface area.

In this study, we focused on fine-grained chert because it was well represented in both the archaeological and survey data. We then compared flake-to-core and noncortical-to-cortical ratios across the layers of interest at Sehonghong to test whether there are changes in the movement of cores and cortex into and out of the site. If we see significant changes in the flake-to-core ratios from one layer to the next, then this may suggest a change in the transportation of stone technology. Likewise, a change in the noncortical-to-cortical ratios may suggest changes in stone resource procurement, specifically suggesting a transition from reducing cortical stone at Sehonghong to

Table 2 Flake proportions from Sehonghong. Summary of the proportion and count of selected stone materials recovered from Sehonghong

Stone material	BARF		RF		RBL-CLBRF		BAS	
	<i>n</i>	Proportion	<i>n</i>	Proportion	<i>n</i>	Proportion	<i>n</i>	Proportion
Fine-grained chert	201	0.66	140	0.56	194	0.72	138	0.59
Coarse-grained chert	29	0.1	16	0.06	13	0.05	16	0.07
Dolerite	28	0.1	56	0.22	36	0.13	59	0.25
Agate	3	0.01	2	0.01	1	<0.01	3	0.01
Crystalline quartz	44	0.14	21	0.08	10	0.04	12	0.05
Quartzite	0	0	15	0.06	10	0.04	2	0.01
Sandstone	0	0	1	<0.01	6	0.02	4	0.02

Table 3 Core proportions from Sehonghong. Summary of the proportions and count of selected stone materials recovered from Sehonghong

Stone Material	BARF		RF		RBL-CLBRF		BAS	
	<i>n</i>	Proportion	<i>n</i>	Proportion	<i>n</i>	Proportion	<i>n</i>	Proportion
Fine-grained chert	4	0.33	24	0.46	74	0.86	61	0.87
Coarse-grained chert	3	0.25	6	0.12	5	0.06	4	0.06
Dolerite	0	0	0	0	2	0.02	1	0.01
Agate	0	0	1	0.02	3	0.03	3	0.04
Crystalline quartz	5	0.42	21	0.4	2	0.02	1	0.01
Quartzite	0	0	0	0	0	0	0	0
Sandstone	0	0	0	0	0	0	0	0

reducing cortical material somewhere else on the landscape before bringing the stone to Sehonghong.

Results

The following section presents our survey results and their prehistoric behavioral implications. First, we describe the raw material data from Sehonghong's four layers of interest. Second, we present results from the raw material survey. Third, we compare the survey results with Sehonghong's raw materials. Fourth, we use flake-to-core and noncortical-to-cortical ratios to explore aspects of raw material selection, mobility, and decision-making at Sehonghong.

Raw Materials at Sehonghong

Tables 2 and 3 present summary data of Sehonghong's flake and core raw material frequencies (see raw files as comma-separated values at <https://github.com/Agregory198/lesotho-stone-resources.git>). Fine-grained chert dominates in all four flake assemblages (range: 56–72%) followed by dolerite (range: 10–25%). Coarse chert, agate, and quartzite comprise minor portions in each of the layers' flake assemblages, while sandstone is the least common raw material. Sehonghong's core data show different raw material compositions compared with the site's flake data. Fine-grained chert still dominates in layers RBL-CLBRF (86%) and BAS (87%), whereas in layers RF and BARF, it is notably less common (46% and 33%, respectively). Crystalline quartz increases in frequency in layers RF and BARF. That this pattern is not reflected quite so markedly in these layers' flake data suggests the differential movement and use of different rocks at the site (Pargeter & Hampson, 2019). Layers RF and BARF are also admittedly smaller assemblages and so these data may be biased in comparison with the larger assemblages from layers RBL-CLBRF and BAS. Mitchell (1995) notes that technological strategies geared towards more plain striking platforms and bipolar reduction in layers RF and BARF mark a distinct break with those in RBL-CLBRF and BAS. There are grounds to argue, then, that these differences in raw material composition are meaningful.

Results from the Stone Material Survey

Table 4 highlights the results of the raw material survey around Sehonghong. The data show that riverine and terrestrial survey locations contain varying masses and raw material types (see Fig. 3). On average, the knappable rocks, not attached to a scree or outcrop, located in riverine settings are of greater mass than those in terrestrial environments. The exceptions to this are fine-grained chert and when no rocks were found in the respective environments (i.e., $n=0$). In the case of the latter, raw nodules of chert contain greater mass in terrestrial settings. A two-way ANOVA suggests a significant difference in mass between raw material, environment, and their interaction ($F[4, 741]=4.2, p<0.01$) (Fig. 4). Post hoc comparisons using Tukey Kramer's method show that sandstone nodules drive this difference (adj. p -value <0.001 , difference = 0.99, CI [0.44, 1.53]), with no other stone material exhibiting a significant difference in log-mass. In other words, there are no statistically significant differences in the two area's raw material masses.

However, Fig. 4 appears to suggest that there should be more meaningful differences between riverine and terrestrial quartzite and fine-grained chert nodules, although it does not indicate the frequency at which each stone material is represented within riverine and terrestrial environments. Table 4 provides one explanation for this discrepancy in the ANOVA results. Specifically, the table shows that the lowest sample size for fine-grained chert is $n=3$ for riverine environments and $n=21$ for terrestrial ones. Similarly, there are only six quartzite stone sources located in riverine environments contrasting to 92 in terrestrial ones. It is likely that the low

Table 4 Results from the landscape stone resource survey. This table describes the weight (grams) and standardized by raw material count (*n*). Mass, therefore, represents the weighted average of stone found in terrestrial versus riverine settings

Location	Fine-grained chert		Coarse-grained chert		Dolerite		Crystalline quartz		Agate		Quartzite		Sandstone	
	<i>n</i>	Mass	<i>n</i>	Mass	<i>n</i>	Mass	<i>n</i>	Mass	<i>n</i>	Mass	<i>n</i>	Mass	<i>n</i>	Mass
Riverine	3	11	0	0	132	228.3	3	8.3	34	20.9	6	190.6	171	296.8
Terrestrial	21	26.4	19	65.5	85	153.5	0	0	16	11.8	92	75.4	63	105.5
Total	24	37.4	19	65.5	217	381.8	3	8.3	50	32.7	98	266	234	402.3



Fig. 3 Stone materials surveyed in terrestrial and riverine environments. The image on the left shows terrestrial fine-grained chert outcrop. The image on the right shows a riverine environment with sandstone nodules

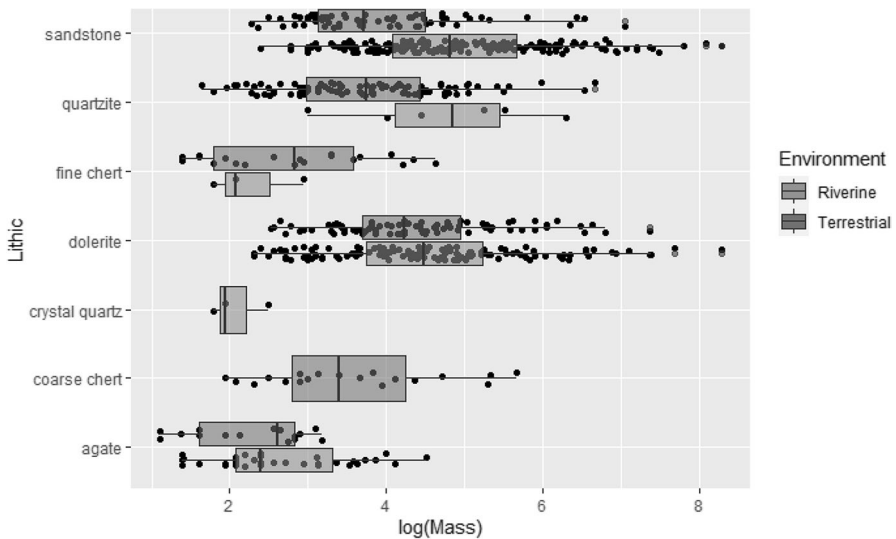


Fig. 4 Box plot for the log-mass of stone materials recorded in the landscape survey. This shows the relationship between log-mass of different stone materials as a function of landscape feature (riverine versus terrestrial). The points emphasize the difference in sample size between environments for fine-grained chert and quartzite. Only sandstone is significantly different in log-mass between riverine and terrestrial environment

sample size for fine-grained chert and quartzite material accounts for several observations too small for statistical comparisons. Regardless of statistical power, riverine environments provide a source for some raw materials (i.e., sandstone and dolerite), but not the ones used most often by Sehonghong's toolmakers (i.e., fine-grained chert). Furthermore, the survey showed that the amount of cortex coverage on these knappable rocks rarely exceeded 75%. Though the exact cortex coverage is not quantified, on average, the knappable rocks around Sehonghong did not contain 100% cortical coverage, especially in terrestrial environments. Dibble et al. (2005) and Douglass et al. (2008) implicitly assume that all knappable materials past peoples

recovered from the landscape contain 100% cortical coverage and are rounded. This is true for stone materials that have undergone fluvial transportation and weathering. However, with the available rock from terrestrial environments (Table 4), it is probable that past peoples were not limited to riverine stone resources.

Comparisons Between the Survey Data and Sehonghong Assemblages

Figures 5 and 6 show the seven most prominent raw stone materials recovered from the two survey blocks compared with Sehonghong's core and flake mass data. Fine-grained chert is over-represented in Sehonghong's cores and flakes relative to the survey data. These differences are clearer when comparing the Sehonghong assemblage to the riverine survey data in which fine-grained chert is rare. The opposite can be said of crystal quartz, a mineral particularly well represented in Sehonghong's layers RF and BARF, but rare in the surveys. Layer BAS and RBL-CLBRF's crystal quartz core frequencies match more closely with the observed survey frequencies. Coarse-grained chert again shows similar frequencies to the terrestrial survey squares, but this rock is over-represented in layers RF and BARF. Sehonghong's agate frequencies match more closely with the terrestrial survey squares, and they are heavily under-represented relative to the riverine survey squares. Again, this pattern is clearer in comparisons with layers BAS and RBL-CLBRF than it is in layers RF and BARF. Sandstone and quartzite are absent from the Sehonghong core sample, rare in the flake samples, and occur commonly in terrestrial and riverine survey squares. Dolerite is heavily under-represented in Sehonghong's cores, but its

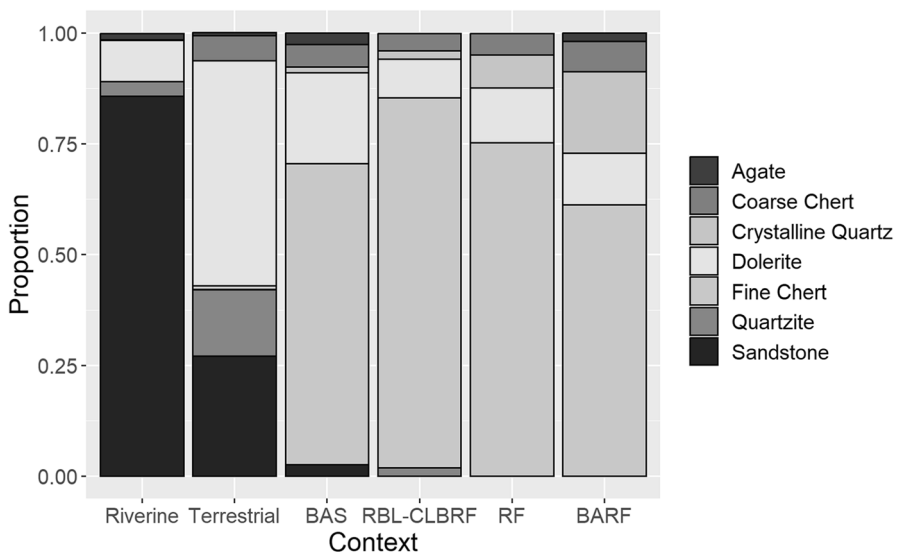


Fig. 5 Proportion of lithic material found in the environment and flakes from Sehonghong. This figure contrasts the proportion of select lithic materials recorded from the landscape survey and flakes recovered from archaeological excavations at Sehonghong within layers BAS, RBL-CLBRF, RF, and BARF (oldest to youngest)

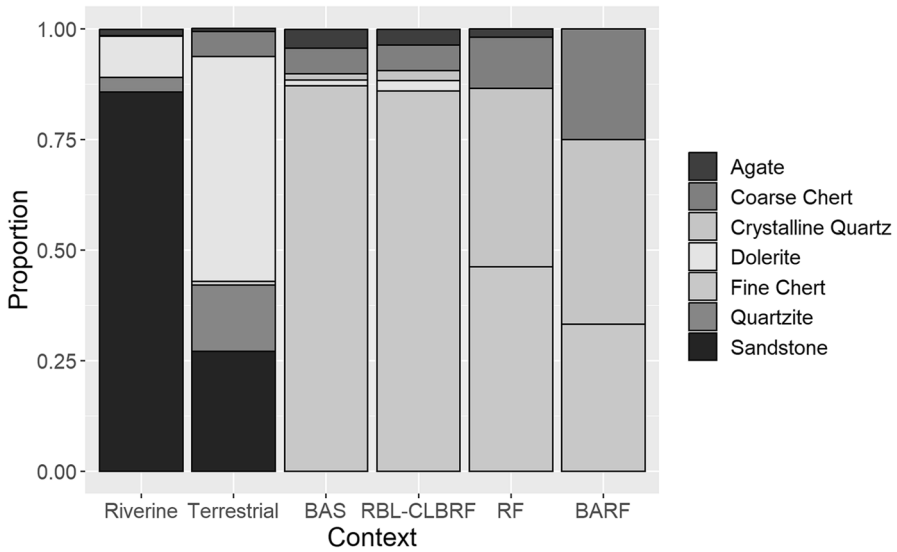


Fig. 6 Proportion of lithic material found in the environment and cores from Sehonghong. This figure contrasts the proportion of select lithic materials recorded from the landscape survey and cores recovered from archaeological excavations at Sehonghong within layers BAS, RBL-CLBRF, RF, and BARF (oldest to youngest)

frequency in the flake assemblages from layers RF and BARF compares well with the survey results. A chi-square and Fisher’s exact test shows significant differences between the survey distributions and the flake and core proportions ($X^2=1074.4$, $df=30$, $p\text{-value}<0.01$; Fisher’s test $p\text{-value}<0.01$; see *Lesotho_figures_SimpleStats.Rmd* at github page for pairwise tests). Henceforth, the significant difference between surveyed knappable rock and archaeological stone provides evidence for directed procurement.

Furthermore, Table 5 shows the relative proportions of different cortex shapes. Stone materials that derive from fluvial environments are likely to have rounded, smooth, cortex, whereas the survey of terrestrial, nonfluvial environments shows that the cortex is angular. The overwhelming proportion of cortex found on

Table 5 Cortex roundness for flakes, cores, and raw stone around Sehonghong. This table illustrates the raw count (n) and percentage of cores and flakes and how closely the cortex area reflects a round surface. For some flakes, there was too little cortex to determine the shape, labeled here as indeterminate. The bottom of this table describes the shape of the raw nodules surveyed around Sehonghong. A rounder surface area reflects fluvial environments

Cortex shape	n	Angular	n	Subangular	n	Rounded	n	Indeterminate
Cores	310	89.1%	5	1.4%	3	0.9%	30	8.6%
Flakes	1965	89.2%	63	2.9%	73	3.3%	101	4.6%
Raw nodule shape	n	Angular	n	Subangular	n	Rounded		
Survey nodule	489	42.5%	538	46.5%	123	10.7%		

artifacts from Sehonghong is angular (cores: 89.1%, flakes: 89.2%) with only 0.9% and 3.3% rounded cortex on cores and flakes, respectively. In contrast, the surveyed stone nodules contain on average 42.5% angular cortical coverage. This suggests that, like the directed procurement of fine-grained chert, stone tool makers were likely procuring stone materials from nonfluvial environments.

Flake-to-Core Ratios

Here we use the number of flakes and cores recovered from Sehonghong to identify whether there is a significant shift in stone material transport into and out of the site (Table 5). Figure 7 shows the results of the flake-to-core ratios, where a ratio of 1 means there are the same number of flakes as there are cores. This figure shows that layers BAS, RBL-CLBRF, and RF have similarly low ratios, suggesting that the number of flakes is only slightly higher than the number of cores.

Furthermore, this represents a large deposition of stone cores at the site. In contrast, layer BARF has a significant increase in this ratio, suggesting very few cores when compared to the number of flakes at Sehonghong. This shows a shift from high core deposition to low core deposition, which may signal a shift in the transport of stone materials into and out of Sehonghong.

Noncortical-to-Cortical Ratios

Figure 8 shows the results of the noncortical-to-cortical ratios. Here, we measure the amount of cortex that is represented at the site, which can also be used as a measure of reduction

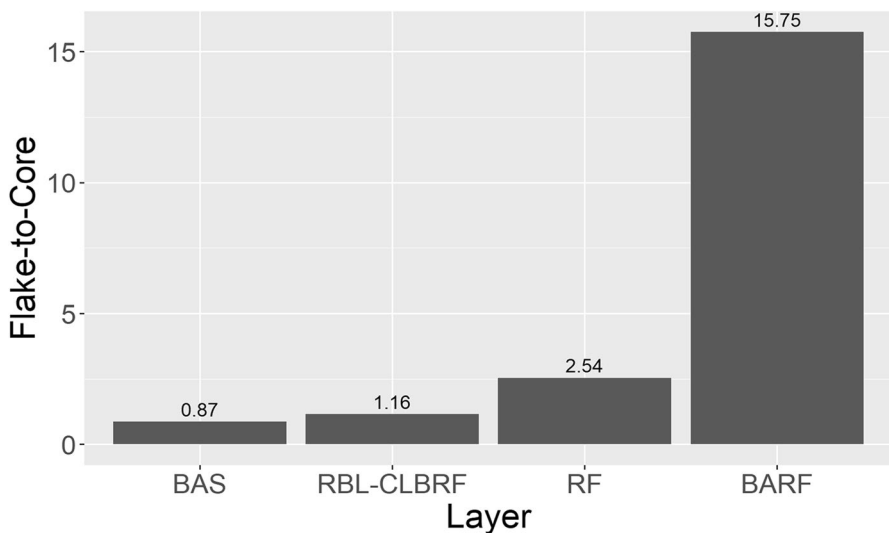


Fig. 7 Flake-to-core results. These graph shows the values and relationship between the number of complete flakes and cores in the four stratigraphic layers at Sehonghong

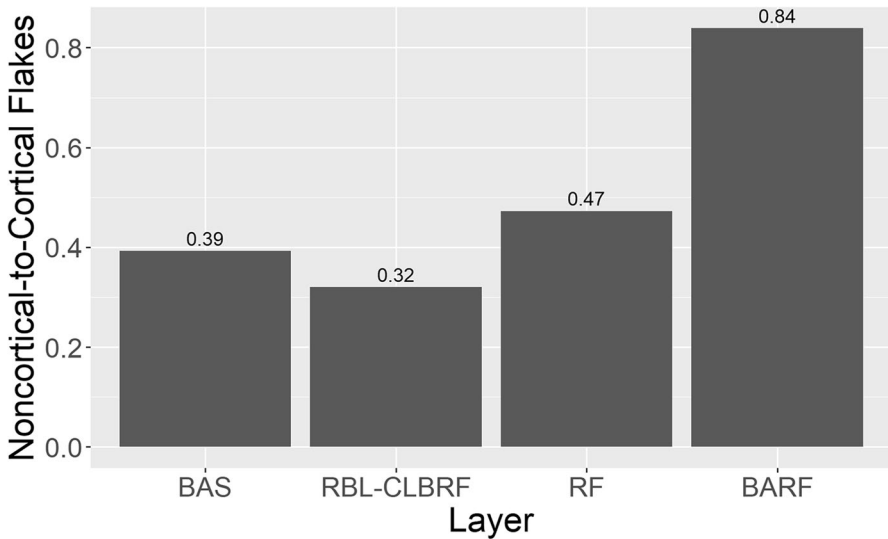


Fig. 8 Noncortical-to-cortical results. This graph shows the values and relationship between the number of complete flakes without and with cortex in the four stratigraphic layers at Sehonghong

intensity (Holdaway et al., 2004; Roth & Dibble, 1998). These results show that layers BAS, RBL-CLBRF, and RF are most similar with ratios between 0.3 and 0.5, suggesting a high number of cortical flakes represented at Sehonghong when compared to noncortical flakes. One reason for a high amount of cortex is the primary reduction of stone nodules from the landscape, representing the initial stages of stone tool reduction (Henry, 1989; Marwick, 2008). In contrast, layer BARF has a ratio near 1, which suggests close to an equal amount of noncortical and cortical flakes. Like the flake-to-core ratios, there is a shift in the amount of cortex removed at Sehonghong beginning in layer RF.

We can combine flake-to-core and noncortical-to-cortical ratios to better understand past procurement and mobility strategies. These analyses add to our understanding of where stone tool makers at Sehonghong procured their raw materials and how they transported this into and out of the site and, more broadly speaking, mobility patterns across the study area. In the next section, we explore how this new line of evidence sheds light on the complex relationship between climate and resource procurement of past peoples in eastern Lesotho.

Discussion

This study contributes to a growing body of work examining the drivers of behavioral variability and mobility dynamics among Lesotho's ancient hunter-gatherers (see Bousman, 1988; Carter, 1976, 1978; Fitchett et al., 2016; Mitchell, 1995, 1996b; Mitchell et al., 1998; Pazan et al., 2022; Stewart et al., 2012, 2016; Stewart & Mitchell, 2018a). Specifically, our results speak to past peoples' mobility in highland Lesotho during the LGM and the Late Glacial. Our raw material survey

results show that sandstone, dolerite, and fine-grained chert are the dominant rocks in the landscape today. However, none of these rocks is very common at Sehonghong where toolmakers favored fine-grained chert. The site's prehistoric inhabitants preferentially selected this rock at rates that exceed its general abundance in the landscape today. Additionally, our survey shows that chert is rare in riverine settings but common on the upland plateaus, making up nonfluvial, terrestrial, locations. These findings overturn the long-held hypothesis that the region's prehistoric inhabitants sourced their knappable rock from rivers (Carter, 1978; Mitchell, 1996a, 634; Stewart et al., 2016).

Lithic data from Sehonghong allow us to calculate flake-to-core and noncortical-to-cortical ratios, which inform on movement of stone into and out of the site as well as procurement and reduction strategies. Flake-to-core ratios change little between layers BAS, RBL-CLBRF, and RF despite rapidly changing environmental conditions (Loftus et al., 2015; Roberts et al., 2013). Low flake-to-core ratios suggest a high rate of core deposition compared to flake deposition. Noncortical-to-cortical flake ratios show similar patterns for layers BAS, RBL-CLBRF, and RF but increases in layer BARF, suggesting under-representation of cortical flakes at Sehonghong. Together, the ratios for layers BAS, RBL-CLBRF, and RF suggest intense use of local resources and hence reduced mobility, a characteristic Loftus et al. (2019) assign to past peoples at Sehonghong and the South African site of Rose Cottage Cave during the LGM.

Layer RF still shows a high number of cores but a slight increase in the non-cortical-to-cortical ratio. By layer BARF, we see a more dramatic shift towards a low number of cores and flakes that contain low amounts of cortex. It is likely that the transition from layer RF to BARF signals a shift in mobility and procurement strategies. Specifically, cores were likely being moved away from Sehonghong at a high rate with the cortex removed elsewhere on the landscape before people brought the stone into the site. These results show that, for layer BARF, there is likely an increase in mobility and less emphasis on procuring local stone resources around Sehonghong than in the previous three layers. We therefore see major changes in mobility taking place during the Late Glacial but not the LGM.

Previous evidence for long distance transport of cultural materials in Lesotho further supports our interpretation of significant changes in mobility during layer BARF. Our study builds upon a small-scale survey a few kilometers around Sehonghong and so does not reflect large-scale movements of lithic material into the site but, instead, small landscape-scale shifts in mobility. However, Stewart et al. (2020) show using strontium isotope analysis that an ostrich eggshell bead from layer BARF likely derives from several hundred kilometers away from the site. This suggests significantly extended movement and/or networking, something that would potentially also be detectable in the transportation of lithic materials around Sehonghong.

Though our stone resource survey is limited to a few kilometers around Sehonghong, the slope gradient between riverine habitats and the upland plateaus above them would have required increased work to forage in these terrestrial environments. Movement from Sehonghong to the upland plateaus is not an easy task. Without paved roadways, it takes up to 2 h to walk from Sehonghong to some of the

surveyed terrestrial outcrops (Mitchell, 1996a; pers. obs.). Although infrequent and short-lived, high flood levels in the Sehonghong River in summer would also have impeded, or even temporarily prevented, movement between its north and south banks, potentially affecting the choice of areas from which lithic raw materials could have been obtained. Outside our current survey area, access to raw materials on the far (i.e., western) side of the Senqu River would certainly have been impossible at such times (cf. Mitchell & Challis, 2008, 34). For foragers to favor knappable stone derived from settings that we here term terrestrial, rather than from riverbeds alone, is thus to dedicate a large amount of time and energy into collecting raw materials. Given that Pargeter and Dusseldorp (2022) find that foragers at Sehonghong consumed bovids consistently across the Late Glacial, forays onto these plateaus for stone resources likely reflect embedded procurement strategies.

Building on these results, we can also examine Stewart et al.'s (2016) push-and-pull mobility model for eastern Lesotho by comparing changes in resource procurement and mobility with changes in temperature. Under this model, cold periods (layers BAS, RF, BARF) should restrict populations to lower elevations and riverine corridors. Warmer periods (layer RBL-CLBRF) would show expanded foraging ranges into terrestrial and higher elevation environments. These changes in temperature should lead to preferential selection of riverine fauna, stone material, and mobility strategies. Our survey shows that, regardless of temperature, past peoples carried knappable rocks into Sehonghong from locations near riverine sources but that most derive from the terrestrial outcrops that lie in higher-elevation settings, including the plateaus well above the area's rivers. Additionally, the flake-to-core and noncortical-to-cortical ratios show that mobility around Sehonghong remained stable during transition from cold and warm phases. This reinforces the argument that stone resource distribution likely drove terrestrial forays during both cold and warm periods and that past peoples were not narrowly confined to strictly riverine corridors. Furthermore, we only see a complete shift in procurement and mobility during layer BARF, something that Pargeter and Dusseldorp (2022) argue using a combination of faunal and lithic analyses. These results suggest that stone and faunal resources were not seasonally limited to riverine or terrestrial environments, thereby relieving pressures on toolmaker decisions on where to forage during different climatic intervals.

These comments imply that past mobility strategies were only partially driven by past temperature ranges in the manner predicted by the push-and-pull model (Stewart et al., 2016). One reason for the contradiction between the push-and-pull model and our own is based upon the analogous relationship that Binford (2001) has drawn between present/recent foragers and their threshold for adapting to changing climate. Under this model, a reduction in the use of terrestrial fauna implies greater dependence on riverine fauna. However, any correlation between fauna and climate is likely to be masking causal factors that influence the reasons for specific mobility strategies. By contrast, knappable raw materials do not move or fluctuate in abundance through the year. They are thus predictable in their location and availability once knowledge of the local landscape has been built up. The question that remains, and that differs from the expectations of the push-and-pull model, is why there was a shift towards increased mobility during the Late Glacial.

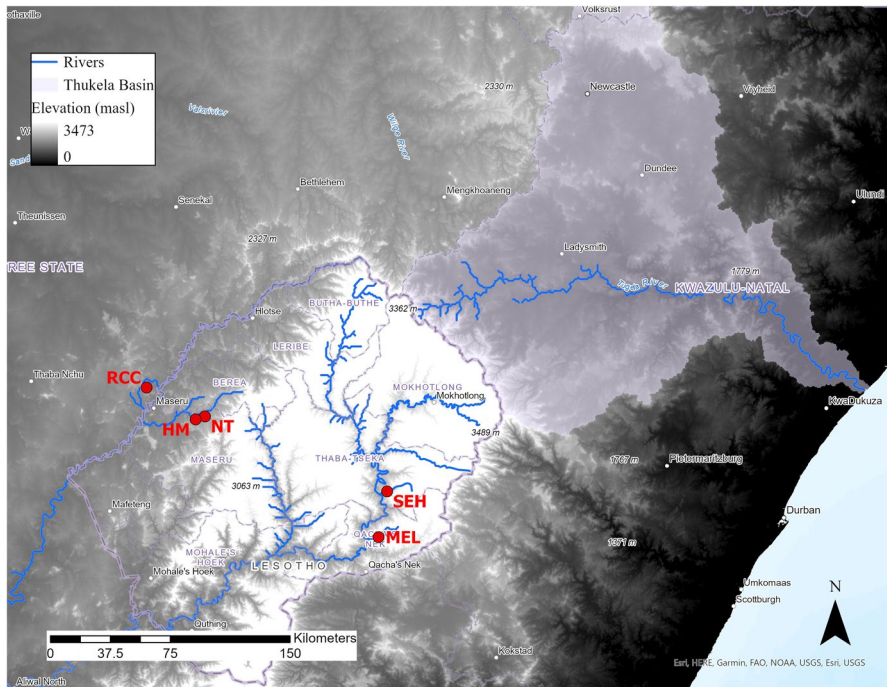


Fig. 9 Map of Lesotho and adjacent regions and sites discussed in the text. This map illustrates the geographic relationship between the sites of Rose Cottage Cave (RCC), Ntloana Tšoana (NT), Ha Makotoko (HM), Melikane (MEL), and Sehonghong (SEH). Lesotho is labeled and outlined in purple while the Thukela Basin is shaded in purple

Revision of Mobility and Social Connections in Lesotho

Montane environments are susceptible to a wide range of variation due, in part, to shifts in geological and climatological factors. The Lesotho highlands represent an Afromontane environment and present us with an opportunity to explore the relationship between changing climate in sub-Saharan Africa and the mobility of the past peoples who moved through them. Stewart et al., (2012, 2016) and Stewart and Mitchell (2018a) provide one potential model that explains the impact climate fluctuations had on past populations in the Lesotho highlands. Here, we provide evidence that changes in mobility and procurement strategies do not directly reflect shifts in climate. Instead, we argue that past peoples in eastern Lesotho maintained similar mobility and stone procurement patterns from 22,000 to 13,900 cal. BP and only exhibited a major shift in behavior after this interval, broadly coincident with the Younger Dryas stadial, an event that caused global climate to drop to near LGM temperatures ca. 13,000–11,500 cal. BP.

In fact, the end of the Younger Dryas in Lesotho was met with a regional shift in site occupation and use (Loftus et al., 2019; Mitchell et al., 1998; Pargeter & Hampson, 2019; Roberts et al., 2013). Mitchell et al. (1998) use radiocarbon density plots to show that the transition into the Holocene is marked by contemporaneous occupations at Sehonghong and in western Lesotho and the wider Caledon Valley (see also Loftus et al., 2019; Mitchell, 1993; Mitchell & Arthur, 2014). Specifically, the sites of Ntloana Tšoana, Ha Makotoko, and Rose Cottage Cave (see Fig. 9 for geographic reference) show increased

occupation intensity that aligns with occupation and changes in procurement we see at Sehonghong (Stewart & Mitchell, 2018b). Moreover, while most other sites in the wider region were abandoned during the Younger Dryas, Ntloana Tšoana, and Ha Makotoko show evidence for re-occupation just before its end (Stewart & Mitchell, 2018b), followed almost immediately by the first evidence of Later Stone Age archaeological presence in the Thukela Basin of KwaZulu-Natal to the northeast of Sehonghong and on the other side of the uKhahlamba-Drakensberg Escarpment (Mazel, 1989). Collectively, this suggests a major reorganization of mobility by past peoples in and around the Lesotho highlands between the Late Glacial and the Younger Dryas.

To explain the concurrent occupation of the site mentioned above (see Fig. 9), our study suggests that past peoples in Lesotho may have transitioned from being forager groups with low mobility during the LGM to becoming higher mobile foragers in the early Holocene. Flake-to-core and noncortical-to-cortical ratios from layers BARF, RBL-CLBRF, and RF suggest that past peoples were transporting in, reducing, and then depositing local cortical stone, thus supporting lower mobility in the landscape. By contrast, layer BARF shows higher flake-to-core and noncortical-to-cortical ratios, which implies the removal of cortex elsewhere on the landscape before moving into Sehonghong with a continued movement of cores out of Sehonghong. Hence, these patterns reflect an increase in mobility. Loftus et al. (2019) similarly show that past people from Sehonghong and Rose Cottage Cave exhibit low mobility during the LGM. Then, just prior to the end of the Younger Dryas ~11.5 ka, there is a concurrent increase in occupations across Lesotho and adjacent sites such as Rose Cottage Cave (Stewart & Mitchell, 2018b). Thus, changes from low to high mobility patterns may reflect increased movement across this montane environment and subsequent occupations.

Furthermore, the increased mobility that we detect at Sehonghong during the Younger Dryas stadial has implications for extended cultural networks through Lesotho that may relate to the increased occupations towards the end of this stadial. Likewise, Pargeter and Hampson (2019) show that the site of Ntloana Tšoana exhibits an increase in crystal quartz procurement, despite other widely available CCS materials. Sehonghong shows a parallel trend with the increased dominance of crystal quartz cores deposited beginning in layer RF and extending into BARF. Pargeter and Hampson (2019) argue that the procurement of crystalline quartz may constitute a cultural choice, whose social influence we may be detecting in the Sehonghong assemblage. Thus, by tracking mobility and procurement decisions, we may be detecting long-distance (> 120 km) communication between peoples at Ntloana Tšoana and Sehonghong.

Future Work

The survey we present here used a randomized design to capture an unbiased distribution of stone resources that can inform the procurement and mobility strategies of past peoples. Random selection of survey areas means that the location of data collected is not influenced through subjective criteria and hence lacks control over spatial autocorrelation. Autocorrelation is a concern because this means that the data we examine are not completely independent. Moving forward, one survey design that accounts for control and bias is proportional probability. Proportional

probability uses a priori information to select several regions on the landscape to survey. Then, within these regions, a randomized survey, like this one, is conducted. This informed survey is likely to lead to improved coverage while also controlling for autocorrelation, thereby allowing us to expand our understanding of past landscape use. Following this, we can compute increasingly accurate cortex and volume ratios based upon greater landscape coverage. With finer spatial accuracy, stone resource surveys can capture important information required to accurately interpret and add to current models of forager mobility patterns.

These stone resource surveys also open the door to identifying the provenance of stone recovered from archaeological contexts. The provenance of stone requires two parts. The first is archaeological stone, and the second is known stone quarries. Previous excavations provide the archaeological material and surveys that we describe above outline a procedure to capture stone quarries. Geochemical and isotopic values between archaeological and natural stone can then be compared at a landscape level (e.g., Mathur et al., 2020). The relationship here can then explain the distance at which past foragers traveled to acquire their stone resources. Future work in this regard will complement our current study, which supports a change in foraging pattern with potential for increased mobility during the Late Glacial around Sehonghong.

With a database of available stone quarries, we can begin to build models to estimate the time and energy past foragers would invest in stone acquisition. Up to this point, mobility patterns in Lesotho have still been addressed using faunal remains (Stewart & Mitchell, 2018a), lithic materials (this study), and inferences drawn from changes in temperature (Stewart et al., 2016). These proxies are valid, but they are removed from active agents in this Afromontane environment. This study has begun to build a dataset of available knappable stone that foragers in Lesotho would have had access to, which can be used to model explicit movement of foragers in this landscape. With the advent of movement ecology (Nathan, 2008; Nathan et al., 2008), we can use these datasets to compute cost path analyses (Alberti, 2021) and agent-based models (Romanowska et al., 2021) to identify the energy and time investments that foragers in Lesotho put into stone resource procurement.

The Lesotho highlands remain an ideal environment in which to expand upon and improve our understanding of land use through stone resource surveys. However, in the current study, we focused on just a sample of archaeological material at Sehonghong. To fully understand the impact of climate change on foraging patterns for past peoples at Sehonghong, it would be beneficial to expand beyond this. Layer BARF provides insights into the most extreme cold phase at Sehonghong since the LGM and would benefit from re-excavation and subsequent expansion at the site level. To similarly examine the relationship between temperature and foraging patterns, future work would also benefit from similar stone surveys at additional sites. One such site, Melikane, similarly extends back to the LGM and beyond (Stewart et al., 2012). Melikane offers another chance to test whether past foraging patterns match the expectations we set forth here. Melikane lies near Sehonghong, and, as such, we would suspect that the foraging behaviors seen there may reflect the shift we see at Sehonghong. Thus, extending the current study design on additional sites

in Lesotho will build upon our understanding of human behavioral adaptation to changing climate.

Conclusion

Mobility was crucial to hunter-gatherer survival, especially during periods of rapid climate change. Here, we present several methods for tracking past mobility strategies through the procurement of stone resources. In doing so, we provide new evidence to test hypotheses for how past peoples moved through the Lesotho highlands of southern Africa. More specifically, we show that stone tool makers at the Sehonghong rock shelter practiced targeted raw resource procurement from terrestrial and riverine sources. Furthermore, we were able to contrast lithic raw material procurement strategies with previous studies on faunal procurement. Where those studies argued that faunal consumption was restricted to riverine resources during cold periods toward the end of the Late Glacial, when we quantify mobility and procurement via knappable rock acquisition, we find that changes in temperature did not lead to changes in mobility or procurement patterns. In fact, we see similar mobility and procurement during the late Pleistocene layers around the site of Sehonghong. This interval shows several shifts between colder and warmer climates. It is not until the onset of the Younger Dryas that we see a major shift in mobility and procurement patterns of past peoples at Sehonghong. The Younger Dryas is not only marked by shifts in human behaviors at Sehonghong but is also reflected in sites adjacent to and across the Lesotho highlands. Together, these results suggest that prehistoric mobility and resource procurement patterns were not dictated solely by temperature and its effects on resource productivity but rather probably represent some combination of both environmental and social adaptations. A more complex relationship between past peoples and the montane environment of eastern Lesotho is therefore more likely than previously thought.

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Author Contribution A. Gregory, P. Mitchell, and J. Pargeter wrote the main manuscript text. J. Pargeter conducted the field research and collection. A. Gregory prepared all figures and tables. A. Gregory conducted all analyses. All authors reviewed the manuscript.

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Data Availability The data used for this study are available via Rmarkdown files and comma-separated value (CSV) files through the github repository found at <https://github.com/Agregory198/lesotho-stone-resources.git>.

In this repository, *Lesotho_figures_SimpleStats.Rmd* contains code for the figure production (Figs. 4–8), statistics (chi-square and Fisher's test), and flake-to-core and noncortical-to-cortical ratios.

In *Sehonghong_cores.csv* and *Sehonghong_flakes.csv*, we have stored the flake and core data from the sampled archaeological assemblage from Sehonghong. Lastly, *Seh 2016 survey recording*

system_complete_03.17.17.csv contains the recorded data and attributes from the landscape surrounding Sehonghong.

Declarations

Ethical Approval Not applicable.

Competing Interests The authors declare no competing interests.

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