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Leaving No Stone Unturned: Raw Material Variability within the Umhlatuzana Rock Shelter Middle Stone Age in KwaZulu-Natal, South Africa

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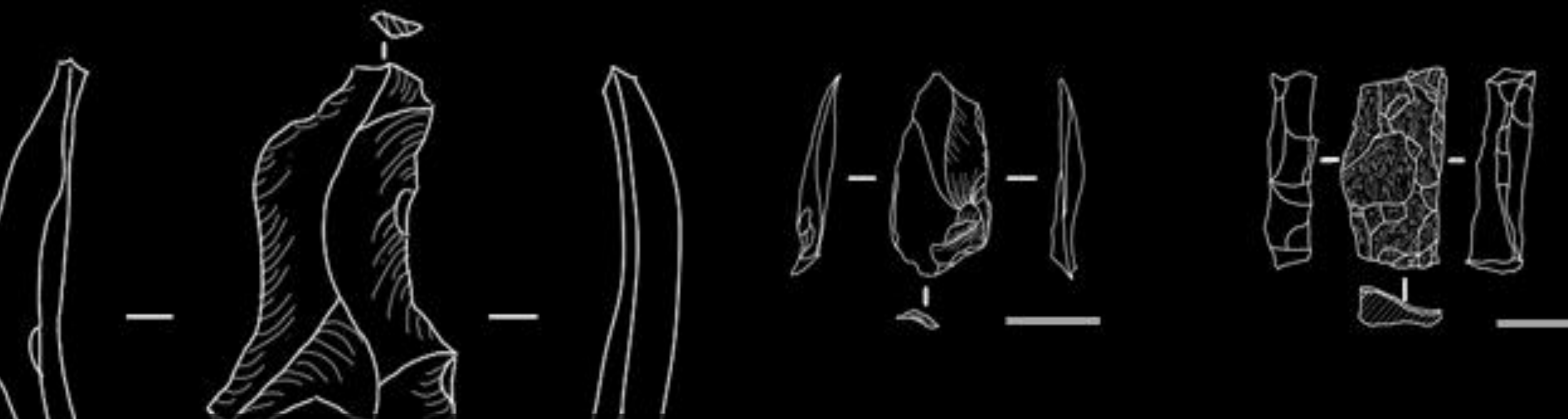

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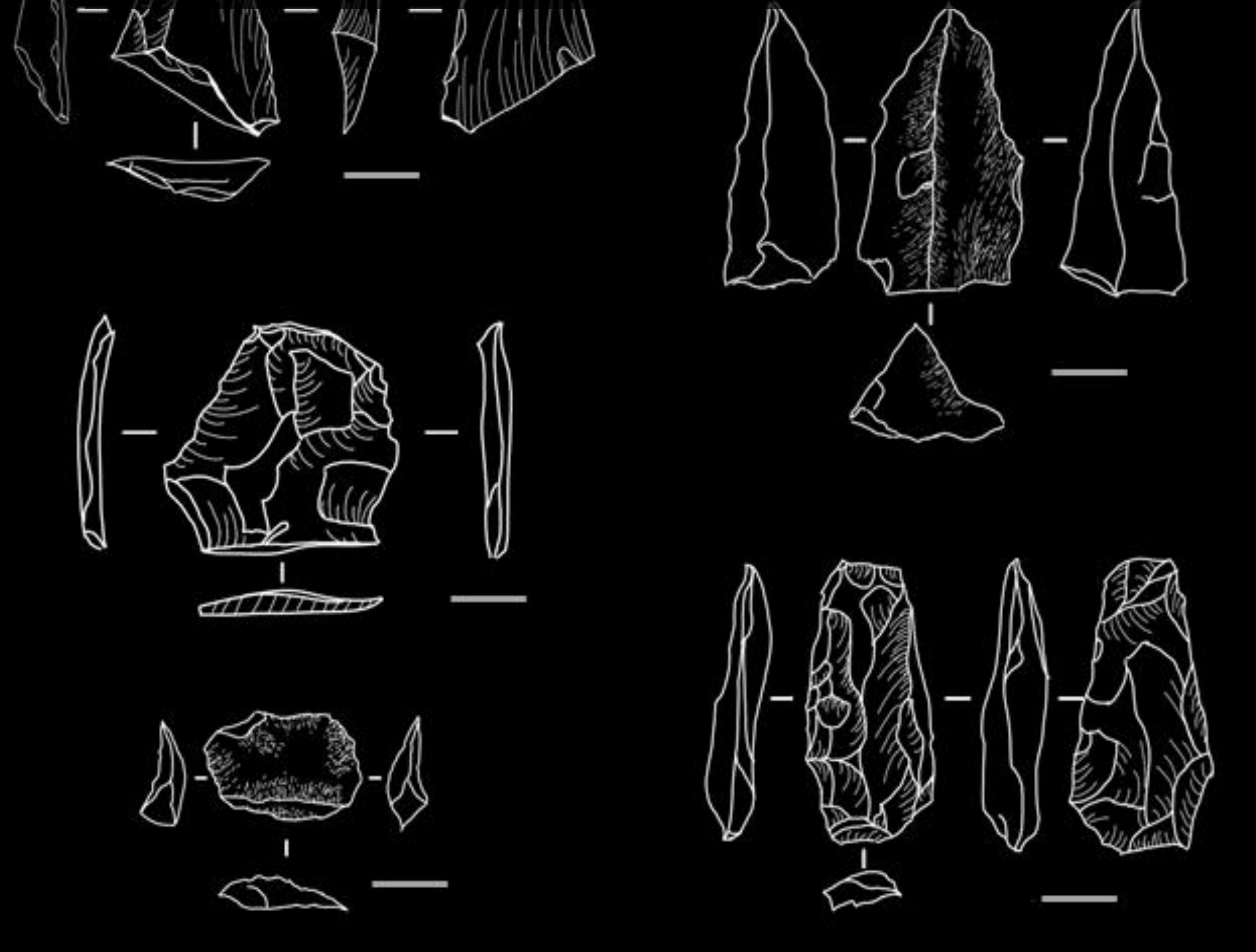

Cover image: a selection of lithic artefacts studied in this thesis. Drawings by the author.

Leaving No Stone Unturned:

Raw Material Variability within the Umhlatuzana Rock Shelter Middle Stone Age in KwaZulu-Natal, South Africa

Viola Fratta

BA3 Thesis 1083VBTHEY

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Table of Contents

1. Introduction

Umhlatuzana Rock shelter is a site located near Durban, in the KwaZulu-Natal province in South Africa (see Figure 1). Occupation at the site began in the Late Pleistocene at about 70 ka (see Table 1 for the abbreviations used in text), during the Middle Stone Age (Kaplan, 1990; Lombard et al., 2010; Sifogeorgaki et al., 2020) and continued until relatively recently. Kaplan (1990, 88) suggests that the final occupation of the site could date as late as the 1800s, during the South African Late Iron Age.

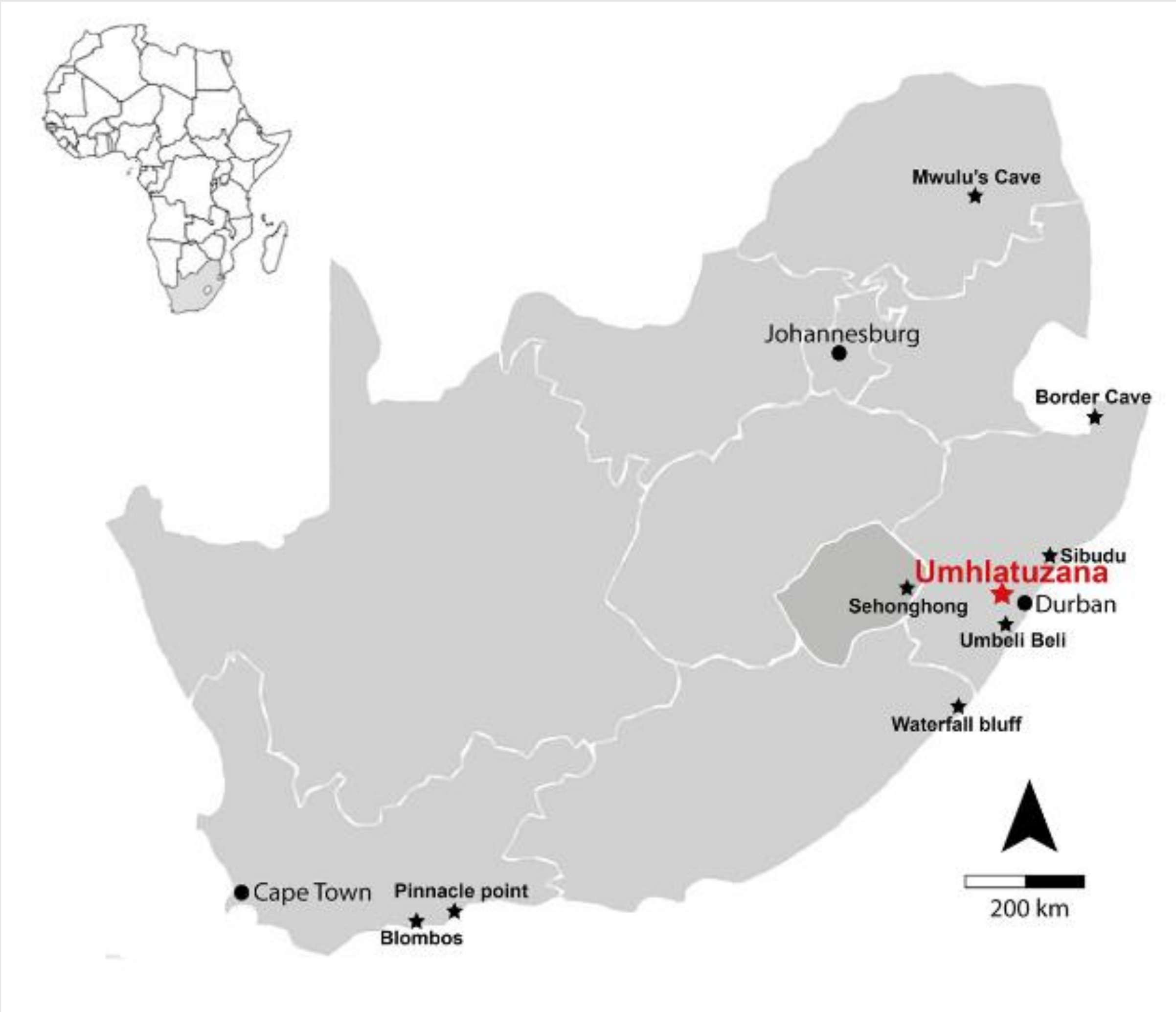

Figure 1: Location of Umhlatuzana rock shelter and other related sites (Image source: Sifogeorgaki et al., 2020, p. 553).

With a nearly uninterrupted occupational sequence spanning around 70 ka years, the rock shelter stands out from other southern African Stone Age sites, where occupation is discontinuous or restricted to shorter periods of time. This makes Umhlatuzana an important source of information on the Middle Stone Age (MSA) and Later Stone Age (LSA) periods (see Table 1 for a general chronology). Technologically, the MSA and the LSA can be loosely compared to, respectively, the European Middle and Upper Paleolithic. One of the key differences between the southern African and the European archaeological records, however, is the species that created the artefacts. While in Europe the Middle Paleolithic lithic industries are a Neanderthal creation, in southern Africa the MSA is attributed to Modern Humans from circa 130 ka onwards (Dusseldorp et al., 2013). The materials from Umhlatuzana Rock shelter can be attributed to Modern Humans and can thus provide useful information about our species' evolutionary development.

The site was excavated for the first time in the 1980s by Jonathan Kaplan and again in 2018 and 2019 by a team of archaeologists from Leiden University. Kaplan raised doubts about the stratigraphic integrity of the site, claiming that a rotational slip caused the mixing of part of the Pleistocene deposits (Kaplan, 1990; Lombard et al., 2010; Mohapi, 2013). However, geoarchaeological evidence from the recent fieldwork suggests that the stratigraphy is intact (Reidsma et al., 2021; Sifogeorgaki et al., 2020), leaving few doubts about the quality of the data coming from the site.

For this thesis, I will work with stone artefacts excavated during the 2018-2019 fieldwork. The objects date to the late Howiesons Poort (HP) and Late MSA Units. The HP is an MSA technocomplex dating between 66 and 58 ka (Lombard et al., 2012, p. 125), although some disagreements exist concerning its exact duration (cf. Jacobs et al., 2008; Tribolo et al., 2009) Dating is not the only aspect of the HP that has long been the subject of intense academic debate. While it is now accepted that the makers of the HP were anatomically *Homo sapiens*, whether or not their cognitive abilities and behavior are also to be considered "modern" is still under scrutiny (see: Wadley, 2001)

1.1. Aims and research questions

In this thesis, I focus on the raw material composition of the sample.

Currently, many believe that changes in raw material preference occurred during the MSA, specifically in relation to the HP, during which fine-grained rocks were favored. Some also claim that exotic raw materials were sought out to fulfill this preference (for a more in-depth discussion see: Ambrose, 2006; Minichillo, 2006). The HP is characterized by backed artefacts, the most iconic being the so-called segments, and evidence for hafting and symbolic behavior, which only appear much later outside of Africa (de la Peña, 2020).

In his 1990 publication, Kaplan notes a difference in the proportions of raw materials between the pre-HP, HP and post-HP periods, claiming that with the advent of the HP, hornfels substitutes quartz as the dominant raw material (Kaplan, 1990, p. 25). Preliminary observations of the 2018-2019 materials, however, have already signaled a difference between the two excavations' raw material percentages (Sifogeorgaki et al., 2021). I test these assumptions on the newly excavated artefacts.

My main research question is:

- Are there any changes in raw material proportions in the Middle Stone Age (Howiesons Poort and Late Middle Stone Age) lithic assemblage from Umhlatuzana rock shelter excavated from square L3a spits 60 and 50 during the 2018-2019 fieldwork campaigns?

This analysis allows the evaluation of the following sub-questions:

- How accurate is visual identification of raw material types? Current research relies on visual identification to differentiate between raw material categories, but it is unclear if it allows accurate distinction between rock types. My analysis employs visual methods paired with PXRF technology to evaluate the precision of visual identification.
- How are the results of my analysis different from those published by Kaplan (1990) when he first excavated at the site?
- Do my results substantiate the hypothesized increased use of fine-grained raw materials in the HP compared to the Late MSA?

To conduct the raw material determination of my sample I will first use visual characterization and then employ Portable X-Ray Fluorescence (PXRF) analysis.

The importance of studying lithic artefacts to understand human evolution cannot be understated. Stone tools are often the only components of Stone Age material culture that survives long enough for archaeologist to find. The rock types were not chosen randomly. Understanding the raw material composition of an assemblage means opening a small window into the mind of its creators. The data presented here will add to current debates in South African Archaeology, adding one piece to the puzzle of the human past.

1.2. Thesis outline

Table 1: Abbreviations used in the text and general dates for the most important periods. The dates are based on Lombard et al. (2012) and Deacon and Deacon (1999).

Term used in the text	Meaning	Dates
Ka	Thousands of years ago	-
Ma	Millions of years ago	-
ESA	Earlier Stone Age	~ 2 ma – 600/200 ka
MSA	Middle Stone Age	~ 300 ka – 20 ka
LSA	Later Stone Age	~ 20 ka – 2 ka/ colonial period
SB	Still Bay technocomplex	~ 77 ka – 70 ka
HP	Howiesons Poort technocomplex	~ 66 ka – 58 ka

The thesis is divided in six chapters. Following this general introduction and statement of the research questions (Chapter 1), in Chapter 2 I provide the background of my research. First, I focus on the South African Stone Age in general, reviewing its chronology, archaeological cultures, and relevant ongoing debates. Afterwards, I discuss Umhlatuzana specifically, introducing the site's research history and regional context. Chapter 3 examines the materials and methods. It features an explanation of the methodologies I employed and a description of my sample, including illustrations of some notable artefacts. In Chapter 4, I report the results of my analysis. The discussion takes place in Chapter 5, where I answer my main research question and sub-questions. I begin by addressing the first sub-question concerning the methodology, which provides the basis for the answers to the main question and other sub-questions. Finally, Chapter 6 contains conclusions and suggestions for future research.

2. Background

Some of the earliest signs of complex behaviors by Anatomically Modern Humans are found in the archaeological record of the MSA and LSA in southern Africa. The evidence from Umhlatuzana has been used in debates surrounding these behavioral developments (see for example: Högberg & Lombard, 2016; Lombard et al., 2010). This chapter's purpose is to understand Umhlatuzana's place in this context. To do so, I give a concise overview of the research history and chrono-cultural divisions of the Stone Age and relate Umhlatuzana to the framework presented.

2.1. The South African Archaeological Record

2.1.1. Research history and general chronology

The study of South African archaeology has its origins during the Victorian period, with the first collection of stone tools from the region in 1858 (Deacon & Deacon, 1999, p. 3). It was not until 1929, however, with the publication of "The Stone Age Cultures of South Africa" by Goodwin and van Riet Lowe, that a formal chronology was introduced (Deacon & Deacon, 1999, p. 5; Goodwin & van Riet Lowe, 1929). The book introduced the division of the southern African Stone Age into Earlier, Middle and Later Stone Age. This periodization was initially based on technological distinctions, and only later given clearer chronological boundaries thanks to the advent of radiometric dating techniques (Deacon & Deacon, 1999, p. 7).

Archaeological research is also closely tied to South Africa's colonial history. The contact between European colonists and "San" hunter-gatherers has resulted in violent conflict, but also in the production of historic ethnographic work (Deacon & Deacon, 1999, p. 131). Many groups living in South Africa at the time of the European invasion maintained a mobile lifestyle and utilized stone tools (Deacon & Deacon, 1999, p. 135).

Table 2: General characteristics of the Middle and Later Stone Age, based on Lombard et al. (2012) and Deacon and Deacon (1999). The list of notable technocomplexes is not exhaustive, but only covers those relevant to this thesis

Period	**Chronology**	**Technological Characteristics**	**Notable Industries**
MSA	300 ka – 20 ka (circa)	Prepared core technique, flake, and blade blanks. Formal tools include: backed artefacts, scrapers, unifacially and bifacially retouched points and serrated points. Evidence for hafted composite tools. Occasionally found: shell beads, engraved ostrich eggs, bone points and use of ochre.	Still Bay, Howiesons Poort, Late MSA (informal designation)
MSA/LSA Transition	40 ka – 18 ka	At some sites referred to as Final MSA or Early LSA. Characterized by regional variability and a mix of LSA and MSA elements	
LSA	40-20 ka – 2 ka/ 100 years ago (start and end dates are location dependent)	High variability between different sites. Prevalence of microliths. Wide range of formal tools such as scrapers and backed artefacts. Increased evidence of hafted tools, use of bone tools, decorated objects, cave art, ornaments, and fishing equipment. Ceramic found in the final stages.	Early LSA (informal designation), Robberg.

The overview of the Stone Age chronology published by Lombard et al. in 2012 is the most recent work of this kind available and, as such, the most aligned with the current state of research. For this reason, I chose to use their timeline to define the chronology of the three main periods (see also: Table 1 and 2)

The ESA begins at around 2 ma. At this time, southern Africa was likely occupied by the archaic hominin species *Homo erectus*, although some believe other hominins, such as *Homo habilis* and Paranthropus, were also present (Dusseldorp et al., 2013). The latest date is estimated to be around 200 ka, although Lombard et al. (2012) identify a period of transition from the ESA to the MSA from around 600 ka. In this later stage, it is hypothesized that the region was occupied by archaic *Homo sapiens* or *Homo heidelbergensis* (Dusseldorp et al., 2013).

The MSA begins at round 300 ka and ends with the LSA at around 20 ka, with a transitional period spanning between 40 ka and 20 ka. The dates for the beginning of the LSA are highly controversial, partly due to a lack of data from the MSA to the LSA transition. It can be said that the LSA starts at the latest around 20 ka, and conventionally with the Iron age at around 300 CE in the East of the country, and with the colonial period in the West (Deacon & Deacon, 1999, p. 6).

It is important to note, however, that this timeline represents only a broad chronological subdivision of the Stone Age. Within each period, multiple subdivisions are recognized (see Table 2). These are often matched to lithic industries whose exact dating can be ambiguous. In the following sections, I discuss in more detail some of the subdivisions relevant to this thesis.

2.1.2. The Middle Stone Age

The MSA took place during the Late Pleistocene. It is described as a period of intense technological development, often associated with the initial evolution of anatomically Modern Humans (Deacon & Deacon, 1999, p. 93).

At different points during the MSA, multiple formally recognized lithic industries arose across the region. These are found at sites located in very different environments, raising questions concerning their relationship with the biomes they operated in. Two of these industries, the Still Bay (SB) and the HP are attested at Umhlatuzana.

The Still Bay

The SB industry dates to around 77 – 70 ka (Lombard et al., 2012, p. 138), and was only recently reinstated as an industry after it was documented at sites such as Blombos Cave, Diepkloof Rock Shelter and Sibudu (Lombard et al., 2010, p. 1773). One of its main characteristics is the presence of bifacially worked foliate points (Lombard et al., 2012). At Umhlatuzana rare serrated points were found in the layers corresponding with the industry (Lombard et al., 2010, p. 1782). SB assemblages have also been found in association with ornaments and ochre engravings (d'Errico et al., 2005, p. 8; Henshilwood et al., 2018, p. 116).

The Howiesons Poort

The HP is a technocomplex attested at numerous sites across the entirety of southern Africa. In the chronology compiled by Lombard et al. (2012), it dates to between 66 ka and 58 ka. The exact HP chronology is a heavily researched topic. Jacobs et al. (2008) conducted a study aimed at providing a more exact timeframe for the MSA. They place the HP around 64.8 - 59.5 ka, a slightly narrower time frame than that later used by Lombard et al. (2012).

One important feature of HP lithic technology is the high prevalence of blade blanks, compared to flakes. These were used to produce backed tools such as segments, scrapers and backed blades, the prevalence of which is characteristic of the industry (de la Peña, 2020, p. 3; Wurz, 2013, p. 310). There is evidence pointing to the possibility that backed artefacts during the HP were hafted onto bone or wood shafts and used as composite weapons (Gibson et al., 2004; Wadley & Mohapi, 2008).

There is a great degree of raw material variation between different sites and each assemblage has a unique raw material composition. A pattern emerges when looking at the characteristics of the raw materials selected, which are often fine-grained rock types such as hornfels and quartz. This pattern is visible at sites such as Rose Cottage Cave (Soriano et al., 2007) and Klasies River Mouth (Deacon & Deacon, 1999, p. 105), among others.

The HP is not a static entity and variations are found within individual sites. At Rose Cottage Cave, for example, three distinct HP phases have been described (Soriano et al., 2007). Differences are even more prominent between sites. Mackay et al. (2014) conducted a region-wide analysis of technological change during the Stone Age. They describe the HP as a moment of coalescence, in which populations were closely interconnected and maintained an interregional network of relationships and exchange. Even then, the authors point out differences between environmental zones, such as the persistence of bifacial points during the HP in the summer rainfall zone sites, in contrast with their near disappearance everywhere else (Mackay et al., 2014, p. 44).

The Late MSA

The transition between the HP and the Late MSA period is a relatively controversial topic. The start of the HP has been correlated with the deterioration of climate conditions during MIS4 (Cochrane, 2008, p. 159). As a result, the spread and maintenance of the HP over a large area is often interpreted as a survival adaptation to cope with a new environmental situation (Cochrane, 2008, p. 161; Wurz, 2013, p. 311). The end of the HP, however, predates the MIS3 climatic amelioration (Cochrane, 2008, p. 162), raising questions on the role of the environment in the transition. Other theories include changes in group dynamics and demography (Mackay et al., 2014) and transforming subsistence practices (Dusseldorp, 2014). During this period, technology takes up a form closer to that of the pre-HP period, with a return to artefacts such as unifacial points and scrapers and a decline in frequency of backed tools (Mackay et al., 2014, p. 38; Wurz, 2013, p. 312). The post-HP/Late MSA period is also characterized by great variation between assemblages, which may suggest a return to more localized networks of connectivity between hunter-gatherer groups (Mackay et al., 2014, p. 45). Recently, the period immediately after the HP has been identified at some sites as the “Sibudu” technocomplex, dated to 58-45 ka and characterized by the presence of “Sibudu unifacial points” (Lombard et al., 2012, p. 67). The Sibudu technocomplex has also been identified by Lombard *et al.* (2012) in the assemblage excavated by Kaplan at Umhlatuzana.

2.1.3. The MSA/LSA transition

Little is known about the transition from the MSA to the LSA period. Umhlatuzana is one of the few sites where occupation at this time is attested. The timing of the start of the LSA is a highly debated topic, with evidence from Border Cave pointing towards an early beginning of the LSA at around 40 ka (Villa et al., 2012). The period between 40 and 18 ka is also named by Lombard et al. (2012) as the Early Later Stone Age, which overlaps chronologically with the end of the MSA.

At Umhlatuzana, the transitional assemblage contains a mix of MSA and LSA elements paired with a gradual shift towards microlithic tool forms, which points towards the MSA/LSA being a gradual transition rather than a marked shift (Kaplan, 1990, pp. 82–85). The newly defined stratigraphy at the site excludes the possibility of the sediments mixing (Reidsma et al., 2021; Sifogeorgaki et al., 2020b) and validates this interpretation, as the combination of different elements cannot be due to post-depositional processes.

2.1.4. The Later Stone Age

The earliest phases of the LSA took place during the Late Pleistocene. The LSA persisted during the Holocene and South African Indigenous "Khoisan" groups were observed using lithics by European colonists (Deacon & Deacon, 1999, p. 108). One of the main technological differences between the LSA and the MSA is the prevalence in the LSA of microlithic stone tools. Most importantly, during the LSA we see a significant increase of evidence for symbolic behavior such as rock art, ornaments or painted stones (Deacon & Deacon, 1999, p. 109).

The Robberg

The Robberg industry, dated to 18-12 ka, has been identified at numerous sites across South Africa (Lombard et al., 2012, p. 135). It is technologically characterized by the systematic production of microlithic bladelets and the lack of formal tools (Lombard et al., 2012, p. 135). The Robberg Umhlatuzana assemblage fits within this broad technological description. Systematic bladelet production at the site, however, is not unique to the Robberg and both predates and succeeds the technocomplex (Kaplan, 1990, p. 85).

2.2. The Site: Umhlatuzana Rock Shelter

2.2.1. Regional context

Umhlatuzana is a shallow northeast-facing rock shelter that overlooks the Umhlatuzana river valley. Geologically, it is located within the Natal Group quartz arenite sandstones (Reidsma et al., 2021, p. 3). The modern environmental setting of the site is the South African summer rainfall zone, in a coastal scarp forest with grassland growing in nearby plateaus (Sifogeorgaki et al., 2020, p. 554). Other sites close to Umhlatuzana that show occupation during the HP and/or the Late MSA are Sibudu and Umbeli Belli, both located in the KwaZulu-Natal province.

Sibudu is a well-known site, whose occupational sequence begins with the SB and does not extend further than the Late MSA (Soriano et al., 2015, p. 4). It is often used as a regional proxy thanks to its lengthy research history and well-defined archaeological sequence.

The MSA assemblage at Umbeli Belli is still in the process of being analyzed. OSL dating was carried out on the newly excavated layers, suggesting occupation took place between the later stages of the MSA, 40.3 ± 3.5 ka, and the LSA, 17.8 ± 1.5 ka (Gregor D. Bader et al., 2018, p. 738).

2.2.2. Discovery and initial excavations

Umhlatuzana was first discovered by R. R. Maud in 1982 and later excavated in 1985 by J. Kaplan (Kaplan, 1990, p. 1). Kaplan's excavation consisted of a 6 m^2 trench divided into six 1 m^2 squares (see Figure 2), four of which (J2, J3, K2 and K3) reached the bedrock at 2.5 m below the surface (Kaplan, 1990, p. 4).

The site was excavated in 50 – 100 mm thick horizontal layers. The stratigraphic sequence was divided into 28 layers, which can be split between Pleistocene deposits (layers 5 – 28) and Holocene deposits (layers 1 – 4) (Kaplan, 1990, p. 9). Kaplan raised doubts concerning the stratigraphic integrity of parts of the Pleistocene layers, at the boundary between the Purple Brown and Red Brown Sand deposits, which he believed may have been mixed after a post-depositional event (Kaplan, 1990, p. 7).

The site yielded over 1.25 million lithic artefacts, most of which can be categorized as waste (Kaplan, 1990, p. 77). Non-lithic artefacts such as pottery, ochre, ostrich eggshells, worked bone, zoological and botanical remains were also found, but their distribution was concentrated in the upper Holocene layers (Kaplan, 1990, p. 62-68).

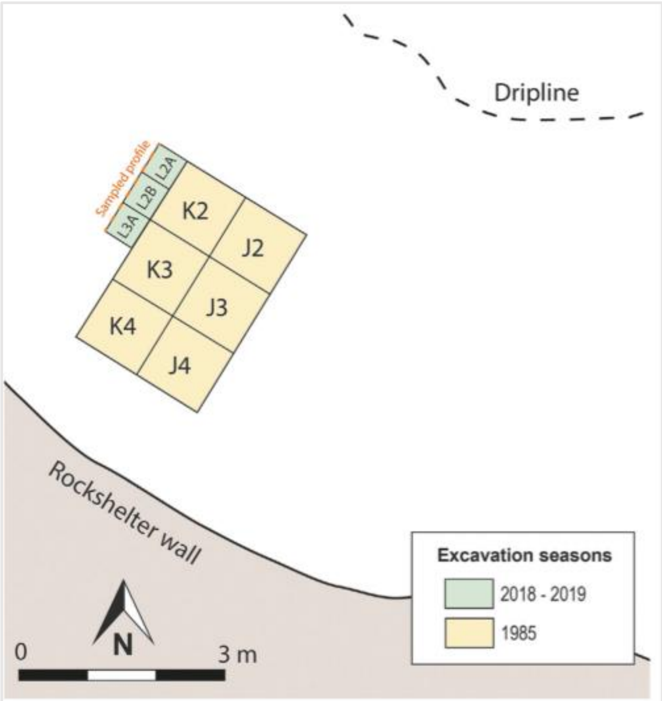

Figure 2: Excavation plan of Umhlatuzana, showing the 2018-2019 squares next to the Kaplan squares (Image source: Reidsma et al., 2021, p. 4).

2.2.3. Recent fieldwork

In 2018 and 2019 fieldwork was conducted again at Umhlatuzana, led by a team from Leiden University in collaboration with the KwaZulu-Natal Museum. The excavation consisted of three 50 x 50 cm^2 squares (L3A, L2B and L2A; see Figure 2) which were excavated with horizontal spits to a depth of 2 – 2.40 m. Large stratigraphic Units were excavated in spits of 2 cm (Sifogeorgaki et al., 2020).

The stratigraphic sequence was divided between Group P and Group H (see Figure 3). Group P, Units P1 – P17, corresponds to Kaplan’s Pleistocene deposits and has a higher find density than Group H (Sifogeorgaki et al., 2020, p. 560). Group H corresponds to the Holocene deposits and includes Units H1 – H10. It is characterized by well-defined stratigraphic boundaries, in contrast to Group P, where the stratigraphy appears nearly homogenous. Two articles, one by Sifogeorgaki et al. (2020) and one by Reidsma et al. (2021), were published using data from the recent fieldwork. Their studies focused on the stratigraphy and taphonomy of the site and reject the idea that post-depositional processes may have compromised the integrity of the stratigraphy (Reidsma et al., 2021, p. 18; Sifogeorgaki et al., 2020, p. 578).

2.2.4. Dating of the site

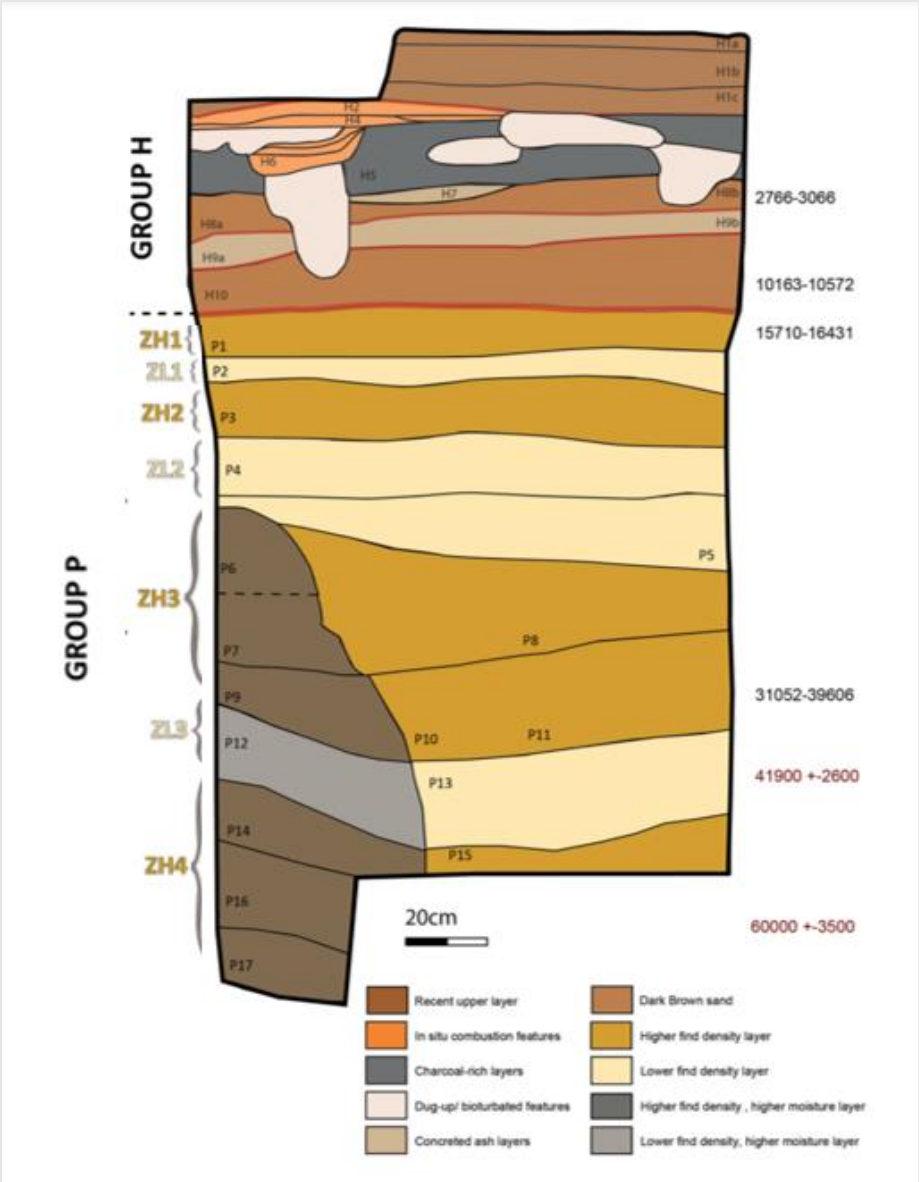

Figure 3: Drawing of the stratigraphy of the western profile of the 2018-2019 excavations with Units and find density zones indicated. Spit 60 is located in ZL3 and spit 50 in ZH3 (Image Source: Reidsma et al., 2021, p. 5).

Kaplan originally carried out radiocarbon dating on the materials excavated at Umhlatuzana. Based on the dates and the material typology, he identified layers 28 – 22 as the pre-HP and HP layers, 21 – 19 as Late MSA, layers 18 – 14 as MSA/LSA transition and layers 13 – 4 as Robberg (Kaplan, 1990, p. 17-47).

In 2010, Lombard et al. carried out OSL dating on sediment samples from the site. A sample from layer 25 was dated to 70.5 ± 4.7 ka, which corresponds to the SB industry. Layer 22 was dated to 60 ± 3.5 ka which fits within the HP age range. Lastly, layer 20 had an age of 41.9 ± 2.6 ka, which can be termed Late MSA (Lombard et al., 2010).

Group P from the most recent excavation has been divided into four zones with high find density (ZH), alternating with three zones of lower find density (ZL) (see Figure 3). The difference in find density shows that the artefacts belong to separate occupational events (Reidsma et al., 2021, p. 5).

Units P17 – P14 belong in ZH4 and correspond to layers 28 – 22 from the first excavation. These are associated with the SB and HP industries. P12 – P13 are in the ZL3 zone, which can be characterized as final HP (layer 21) and Late MSA and parallels Kaplan's layers 21 – 19. The ZH3 zone (Units P11 – P6) can also be considered Late MSA and, partly, MSA/LSA transition, based on the presence of hollow-based points (Sifogeorgaki et al., 2020, p. 571; Reidsma et al., 2021, p. 6). The Units in ZH3 match layers 18 – 14 from Kaplan's excavation. Finally, the Units in ZL2 and ZH1 correspond to Kaplan's Robberg layers, 13 – 4 (Reidsma et al., 2021, p. 6).

2.2.5. Raw Materials of the 1985 Assemblage

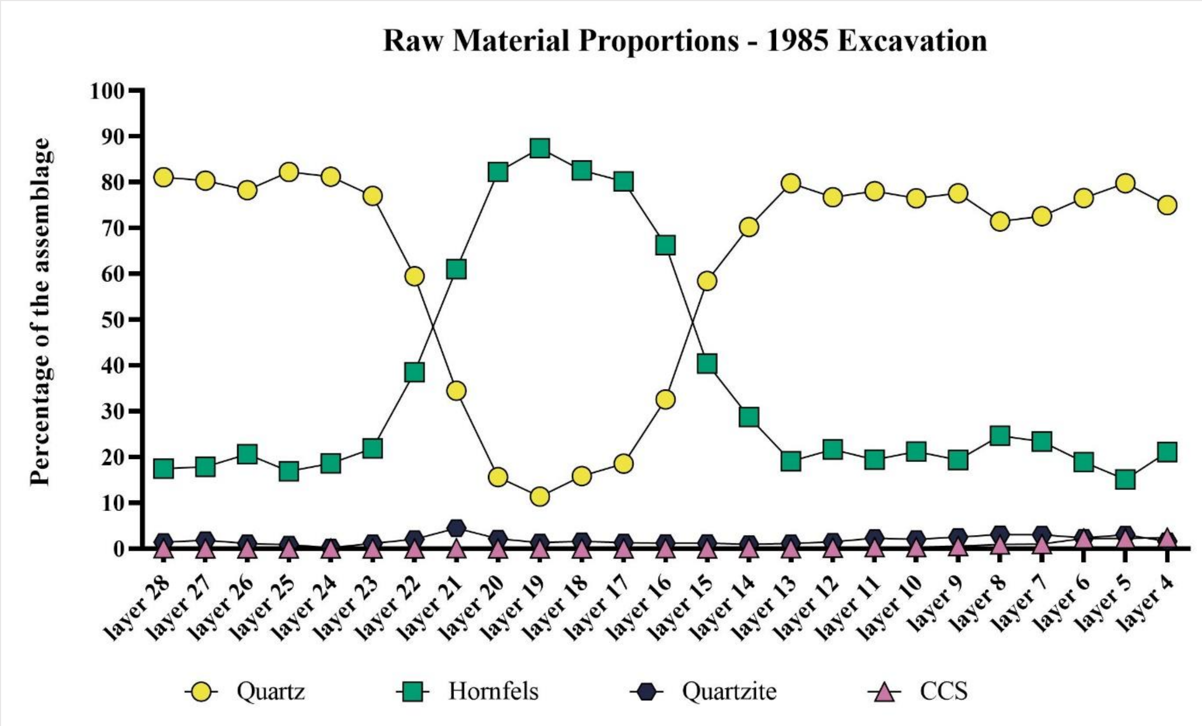

Figure 4: Chart showing the changes in raw material proportions in Kaplan's assemblage across all layers. All percentages are relative to the total of each layer. (Data source: Kaplan, 1990, table 4, table 9, table 11, table 14, table 16; Chart created by author).

The raw materials identified by Kaplan are quartz, hornfels, quartzite and crypto crystalline silicates (CCS). These are found at different rates, with quartz being, overall, the most represented material in the Pleistocene (Kaplan, 1990, p. 77). The proportions, however, vary significantly between layers (see Figure 4). While quartz is the dominant rock type at the bottom of the sequence, from layer 22 to layer 15 its presence diminishes. This trend is paired with an increase in the use of hornfels, ranging between 60% and 87% between layers 21 – 16. From layer 15 onwards, quartz replaces hornfels again as the dominant rock type (Kaplan, 1990, p. 17-47).

The raw material frequencies reported during the processing of the 2018 – 2019 finds do not match Kaplan’s findings, although the two assemblages may have similar chronological trends (for initial results see: Sifogeorgaki et al., 2021; see also: Chapter 5 of this thesis).

3. Materials and methods

3.1. Materials

The analyzed sample was excavated from square L3a (see Figure 2) and consists of a total of 100 artefacts, 77 from spit 50 and 23 from spit 60.

Spit 60 has an elevation of 529,249 m asl (above sea level) and belongs to Unit P12, in the low find density zone ZL3 (end of the HP/Late MSA). The Unit corresponds to Kaplan's layer 21 (Sifogeorgaki et al., 2020, p.565).

Spit 50 was excavated at an elevation of 529,532 m asl, in high find density zone ZH3 (Late MSA). Its position concurs with Units P7/P8, which roughly coincide with Kaplan's layer 18 (Sifogeorgaki et al., 2020, p.565).

The finds included in the sample consist mostly of debitage, although there are some pieces that appear to have retouch (see Figures 5 and 6). The sample includes all the lithics that were excavated from the two spits, except for two artefacts from spit 50 (find numbers 3822 and 3776), which are currently stored in the KwaZulu-Natal Museum in Pietermaritzburg, South Africa. The analyzed assemblage has been temporarily exported to the Leiden University Faculty of Archaeology for analysis and will later return to the Kwa-Zulu-Natal Museum where it is curated.

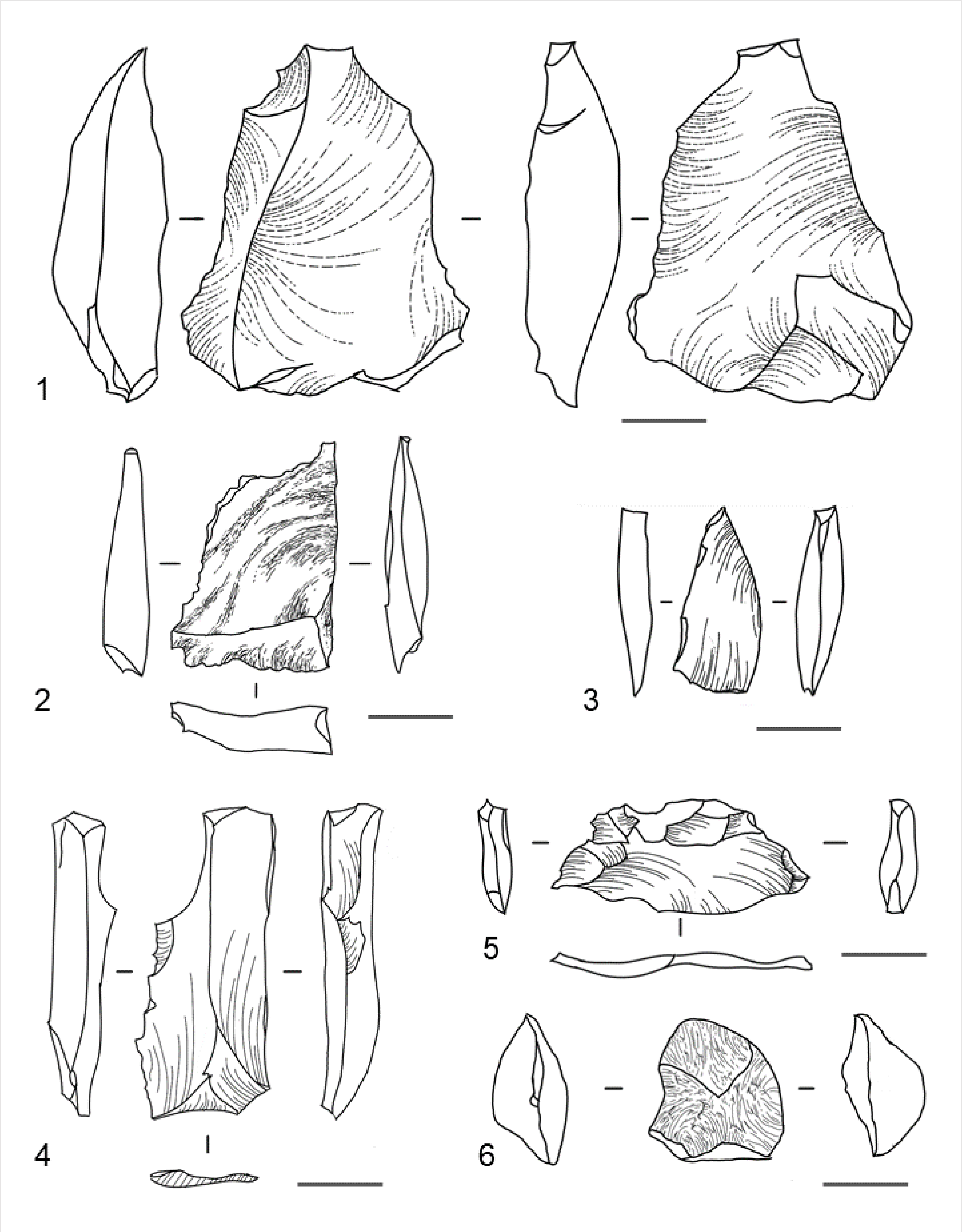

Figure 5: Illustration of notable finds from spit 60. The scale is 1 cm, and the artefacts were illustrated using the French method. The illustration reflects the visual determination of the raw materials. (1) 4449, quartzite; (2) 4452, sandstone; (3) 4462, fine hornfels; (4) 4445 fine hornfels; (5) 4444, coarse hornfels; (6) 4453, quartz. (Illustration credits: author).

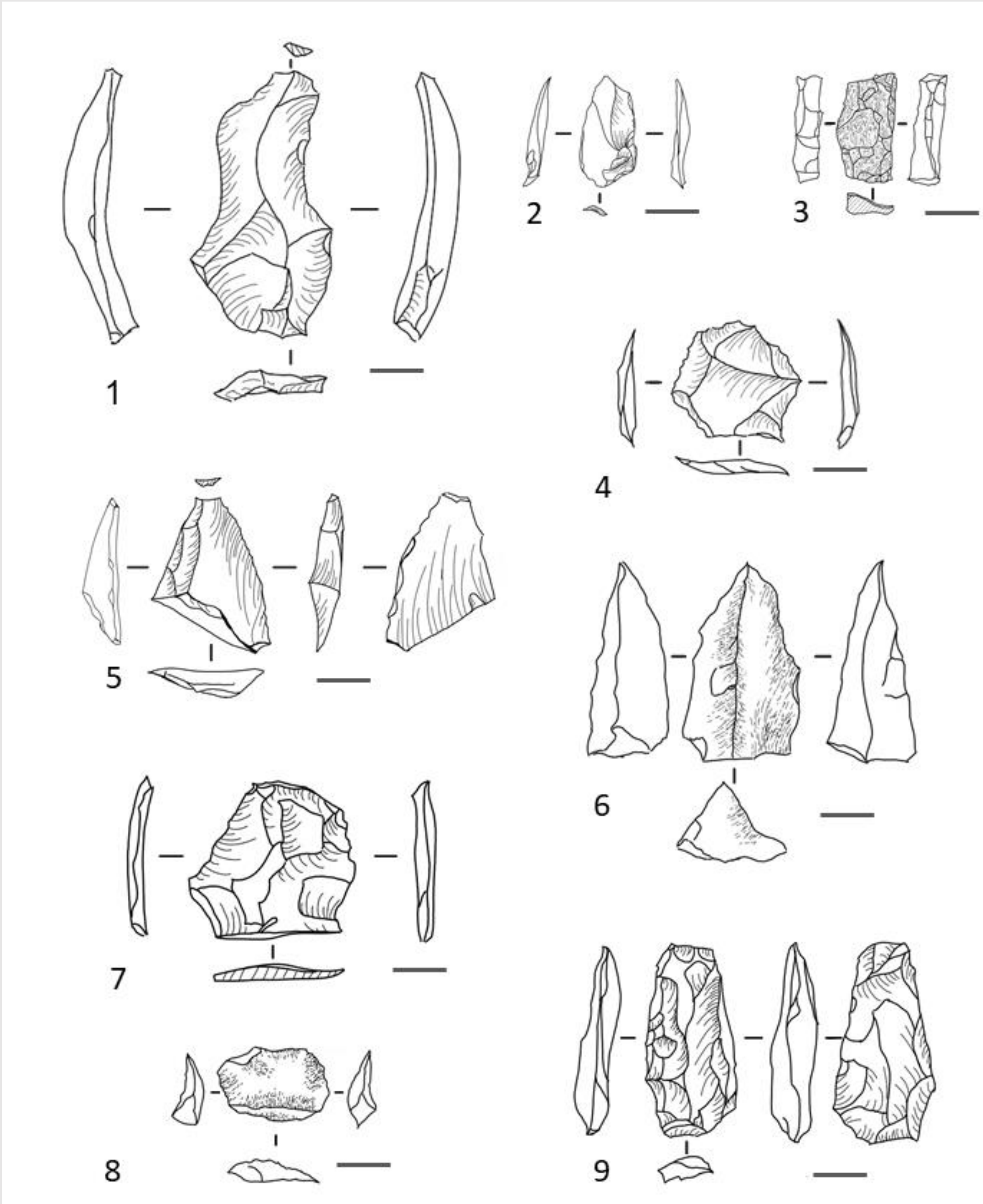

Figure 6: Illustration of notable finds from spit 50. The scale is 1 cm, and the artefacts were illustrated using the French method. The illustration reflects the visual determination of the raw materials. (1) 3765, coarse hornfels; (2) 3804, fine hornfels; (3) 3781, quartz; (4) 3809, coarse hornfels; (5) 3803 coarse hornfels; (6) 3845, sandstone; (7) 3758, fine hornfels; (8) 3820, sandstone; (9) 3793, coarse hornfels. (Illustration credits: author).

3.1.1 The raw materials

The lithic raw materials were preliminarily identified during the excavations. A portion of the total assemblage from Umhlatuzana has already undergone XRF analysis and micromorphology analysis to determine the raw material. Based on the XRF and petrographical data (micromorphology), the raw materials expected are sandstone, quartz, hornfels and, in smaller proportions, dolerite and chert (Sifogeorgaki et al., 2021). The presence of unknown raw materials is also recorded.

Sandstone and Quartzite

Sandstone is a sedimentary rock composed of well-sorted quartz grains (Pellant & Pellant, 2021, p. 225). It is medium grained and heterogenous, which makes it harder to flake. Heterogenous materials have unpredictable fracture patterns and can lack conchoidal fracture, which is characteristics of more fine-grained materials such as flint or chert. Sandstone lithic artefacts from the MSA are known in the region, for example from the site of Sibudu (Will, 2021). Sandstone is the main component of the bedrock and cave walls at Umhlatuzana (Reidsma et al., 2021).

Notably, in Kaplan's analysis sandstone is absent. Instead, he reports small amounts of quartzite (see Figure 4). Quartzite is the metamorphized equivalent of sandstone, that is the result of contact or regional metamorphosis. Quartzite has not been found in the micromorphology thin section analysis carried out on other spits from Umhlatuzana (Sifogeorgaki et al., 2021).

Quartz

Quartz is a common rock-forming mineral found in sedimentary, igneous, and metamorphic rocks. It is well-represented as a lithic raw material, especially in southern Africa. Kaplan recognizes it as the most represented raw material in the whole assemblage. It is hard and difficult to flake, but maintains sharp edges for a long time, without the need for re-working (Wadley & Mohapi, 2008, p. 2597).

Hornfels

Hornfels is fine-grained metamorphized shale high in silica content. Together with its brittleness, these characteristics make it relatively easier to knap compared to either quartz or sandstone. Its use as a lithic raw material has been widely attested across southern Africa (Wadley and Kempson 2011).

3.2. Methods

3.2.1 Sample preparation

Figure 7: Sorted finds from spit 50. The materials were identified on the field as hornfels and visually catalogued as fine hornfels (Photo credits: author).

To determine their raw material, the lithics were washed to remove leftover sediment from the surface.

I soaked each artefact in lukewarm water and gently scrubbed it using my hands and a small toothbrush. No soap or other chemicals were used.

Once clean, I placed them on a drying rack. Each rock was put in a separate basket together with its find card.

3.2.2. Visual identification

Once the artefacts were dry, I carried out the visual identification of the raw materials.

I observed the artefact with the naked eye and with a 10x-20mm handheld loupe. I laid all the pieces on a table and arranged them based on the raw material I assigned them. For each piece, I created a small tag containing the object's find number, some comments and 2 colored stripes on each side (see Figure 7). The stripes were color-coded according to a system I designed. The stripe on the left indicated the field identification, while the one on the right represented my assessment of the raw material of the artefact. All observations were recorded in Microsoft Excel (Appendices A, B and C).

I used multiple literature-based sources to distinguish between the raw materials. I derived some general information about the rocks from the books "Rocks and Minerals" (Pellant & Pellant, 2021) and "Field Guide to Rocks and Minerals of Southern Africa" (Cairncross, 2011) using the pictures included in the books as reference. Furthermore, I consulted literature on the southern African MSA (mainly: Bader et al., 2018; Mohapi, 2013; Soriano et al., 2015; Wadley

& Kempson, 2011; Will, 2021) to better understand the appearance of the materials. These publications were selected not only based on their content, but also based on the inclusion of high-quality images of materials from the same periods and region where the raw material is clearly indicated.

In addition, prior to the start of my work, I had the chance to observe objects from Umhlatuzana that had already undergone PXRF analysis, which made it so that the artefacts had well-defined raw material categories. Furthermore, I also had access to micromorphology thin sections from the site where different raw materials were visible. Taken together, the artefacts and the thin section served to supplement the literature references and train my ability to recognize the raw material categories.

3.2.3. PXRF

Figure 8: PXRF equipment. The PXRF scanner is inserted in a small chamber to isolate the radiation (Photo credits: author).

After I finished the visual determination, I carried out X-Ray Fluorescence (XRF) analysis of the sample. The XRF measurements were taken at the laboratories of the Dutch Cultural Heritage Agency in Amersfoort, using a Thermo Scientific Niton XL5 handheld XRF analyzer (see Figures 8 and 9). The specific settings used are described in Huisman et al. (2017, p. 63). The raw material specialist (Dr. Bertil J. H. van Os) provided a raw material for each measured specimen (refer to Appendix A)

XRF analysis works by exposing an object to X-Rays, leading to the object becoming ionized. This causes the elements present in the sample to emit fluorescent radiation. The radiation signal of every element on the periodic table is known, allowing the machine to create a list of all the elements that make up the item analyzed (Shackley, 2011, p. 16). The elemental signal of an object does not equal a geological stone classification. However, chemical signals reflect a raw material's mineralogical composition, which is used to differentiate between different rock types.

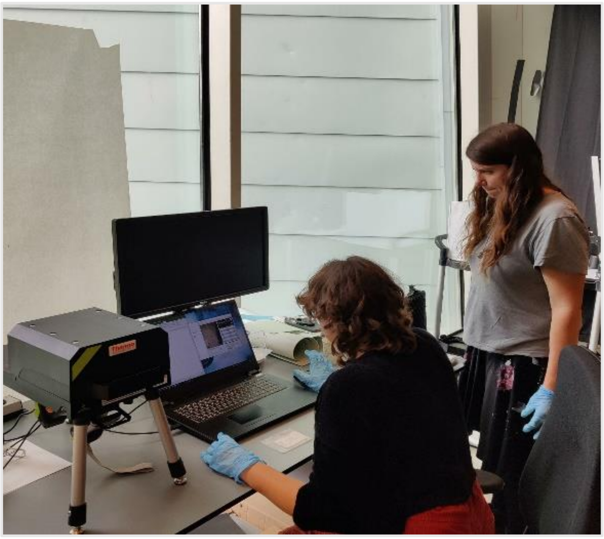

Figure 9: The PXRF analysis being carried out by the author (Photo credits: Dr. G. Dusseldorp).

The technique has a long history of application in archaeology. Portable XRF (PXRF), specifically, has the advantage of being a non-destructive and easily employable version of XRF analysis, which can be carried out outside of laboratory environments (Liritzis & Zacharias, 2011, p. 112). Due to the PXRF equipment malfunctioning, it was not possible to analyze the entirety of the assemblages. Out of 77 total objects in spit 50, 71 were analyzed. Furthermore, in spit 50, the ventral and dorsal sides of four objects were measured separately (see Appendix A). A methodological precedent to the research presented here is the study by Wadley and Kempson (2011), who argue for the importance of integrating geochemical analysis in the discussion of MSA lithic raw materials.

3.2.4. Analytical methods and data visualization

I analyzed the visual determination data separately from the PXRF data. To visualize the data gathered, I created bar charts for each spit showing the percentage in the assemblage of the raw material categories. To compare the macroscopic determination with the XRF results, I combined the data in one excel sheet (Appendix A) and identified any discrepancies in the results.

To further understand the petrographical characteristics of the lithics, I created scatter plots to compare the behavior of the different raw materials when piece plotted to selected elements. Strontium (Sr) and Rubidium (Rb), Manganese oxide (MnO) and Iron oxide (Fe_2O_3), Calcium oxide (CaO) and Fe_2O_3, and Zirconium (Zr) and Barium (Ba) were chosen as they characterize the raw material categories present (van Os pers. comm.).

I compiled a final categorization of the raw materials present by combining the visually identified categories with the XRF data. This allowed me to create a stacked bar graph where the raw material proportions are visually comparable. All graphs included in this thesis were made using GraphPad Prism. The color scheme chosen is adapted to be colorblind-accessible.

4. Results

4.1. Visual Determination

The visual analysis led me to identify a total of seven raw material categories, although not all are present in both spits. All the expected raw materials were found in the assemblage.

Hornfels

Hornfels was found in both spits. I divided it into two different categories, fine hornfels (see Figures 10 and 12) and coarse hornfels (see Figures 11 and 13). The surface of the coarse hornfels is rougher in appearance and to the touch compared to the fine variety. Moreover, the fine hornfels is homogenous in color. The coarse hornfels often has a light-colored patina on it, also found in the fine variety, but to a lesser extent.

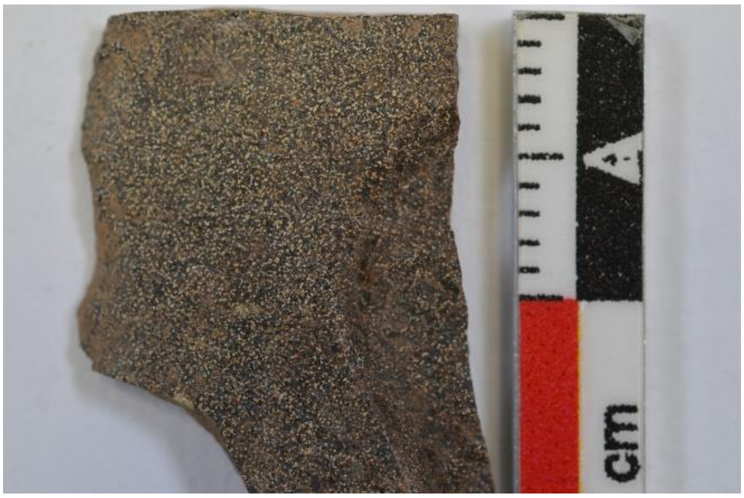

Figure 10: Fine hornfels from spit 50, object 3801 (Photo credits: author).

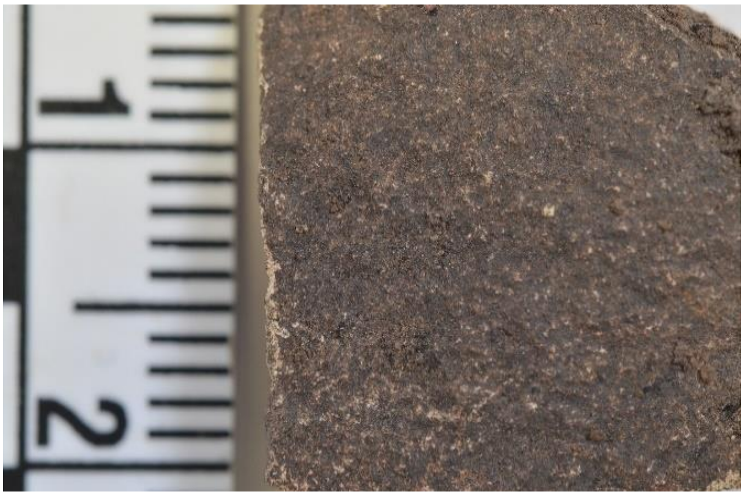

Figure 11: Coarse hornfels from spit 50, object 3760 (Photo credits: author).

Figure 12: Fine hornfels from spit 50, dorsal and lateral view; (1) 3769; (2) 3807; (3) 3815; (4) 3769; (5) 3821; (Photo credits: author).

Figure 13: Coarse hornfels artefacts from spits 50 and 60, dorsal and lateral view; (1) 3765, spit 50; (2) 3793, spit 50; (3) 4447, spit 60; 4442, spit 60; (Photo credits: author).

Sandstone

Figure 14: Sandstone from spit 50, object 3844 (Photo credits: author).

Sandstone (see Figures 14 and 16) was also present in both spits. There is some variation in the color of the sandstone across the assemblage, ranging from lighter reddish-brown shades to dark brown, but overall, the visual characteristics were consistent across spits. The quartz crystals are clearly visible with the naked eye and most pieces appear very coarse.

Quartz

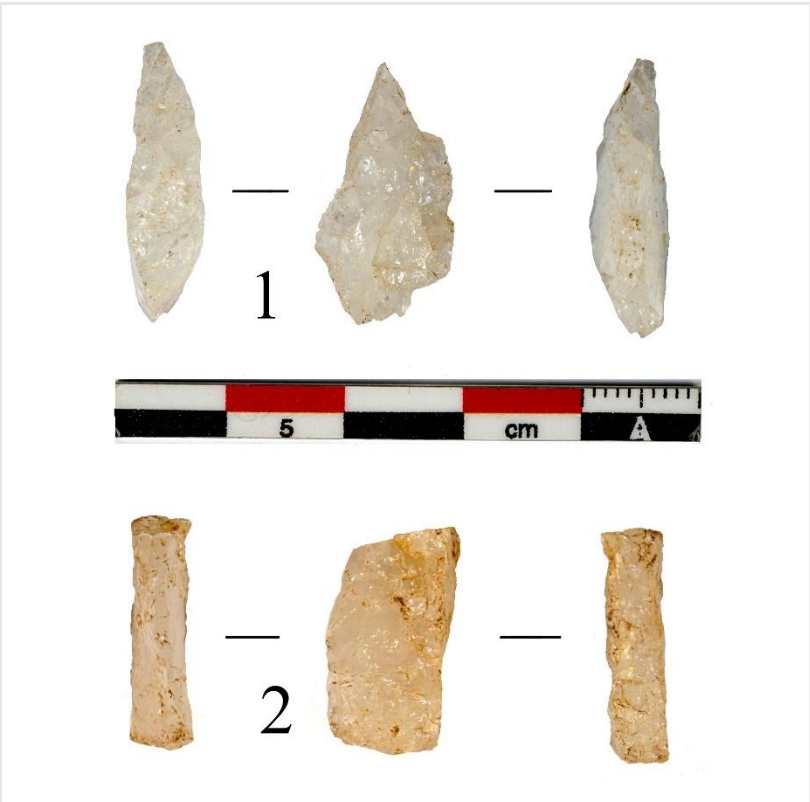

Figure 15: Quartz pieces from spit 50 and 60, dorsal and lateral view; (1) 4454, spit 60; 3781, spit 50; (Photo credits: author).

Quartz (see Figure 15) was easily identifiable in both spits. All the pieces are white, with different degrees of transparency. They all show fractures infilled with darker sediment.

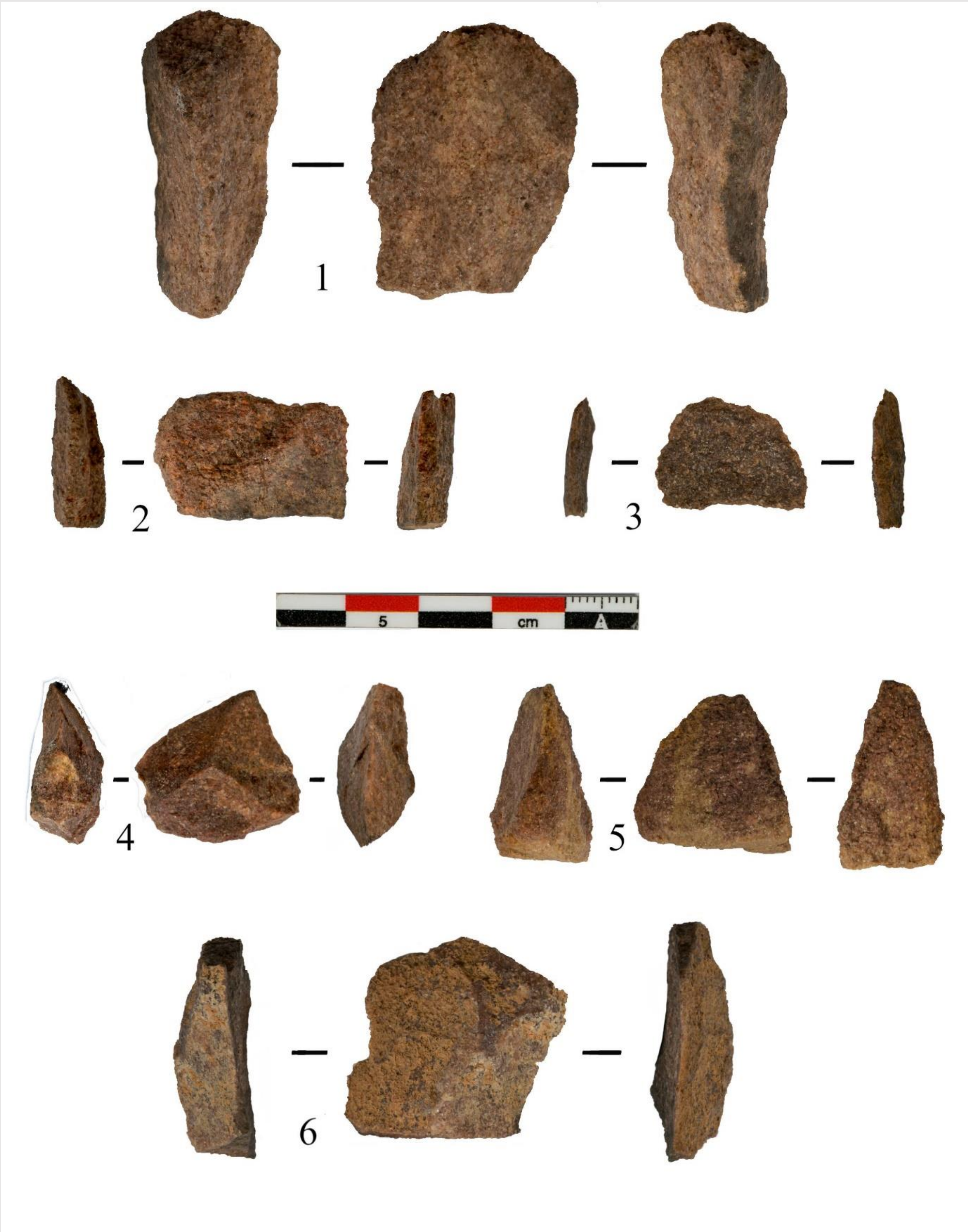

Figure 16: Sandstone artefacts from spits 50 and 60, dorsal and lateral view; (1) 3829, spit 50; (2) 3825, spit 50; (3) 3769, spit 50; (4) 3761, spit 50; (5) 4448, spit 60; (6) 4450, spit 60; (Photo credits: author).

Quartzite

Figure 17: Quartzite from spit 60, object 4449, dorsal, lateral, and ventral view (Photo credits: author).

In the whole assemblage, only one quartzite piece was found in spit 60 (see Figure 17 and Figure 5, 1). Here, the cement between the quartz grains is nearly invisible and the surface of the rock appears smoother and more homogenous compared to the sandstone. These characteristics are visible on other pieces in the assemblage, but not prominently enough to be able to categorize them as quartzite.

Unknown or uncertain material

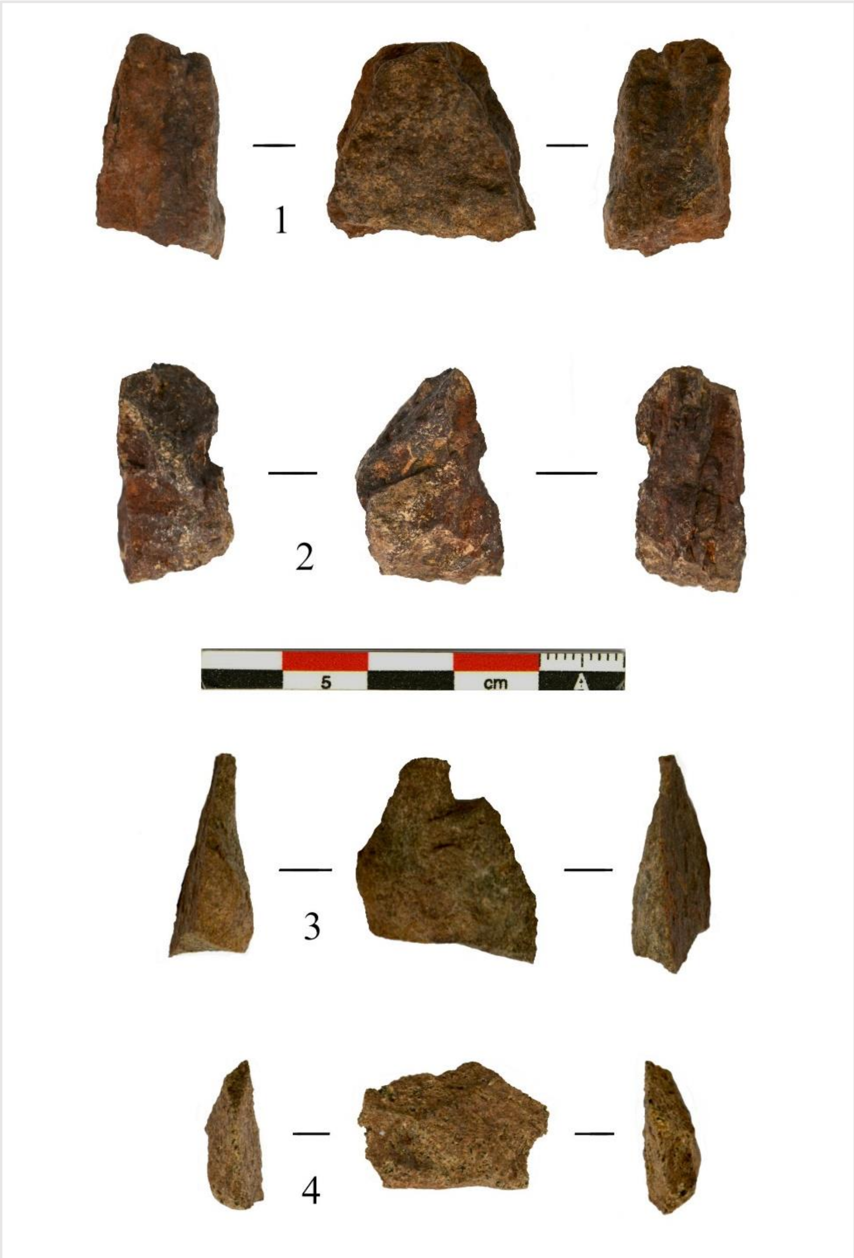

Figure 18: Artefact of unknown or uncertain raw material from spit 50, dorsal and lateral view; (1) 3824, unknown; (2) 3780, unknown; (3) 3816, potential dolerite; (4) 3811, unknown; (Photo credits: author).

One piece in spit 50 was tentatively identified as dolerite (Figure 18, 3), based on comparisons with the reference material and differences in appearance compared to the hornfels pieces. The surface of the piece is coarse and looks similar to the dolerite shown by Wadley and Kempson (2011, p. 101). The last raw material category identified was labeled "Unknown" (Figure 18, 1, 2 and 4), which encompasses all pieces that could not be definitively placed in any of the categories mentioned above.

4.1.1. Spit 50

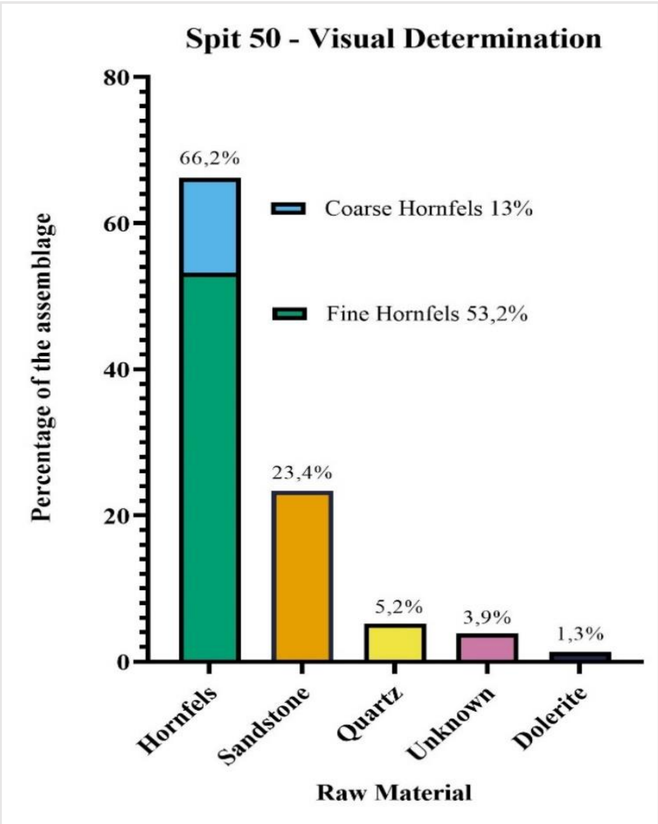

Figure 19: Column chart showing the raw material proportions in spit 50 (Chart created by author).

Six raw material categories were identified in spit 50. Figure 19 shows the exact percentages. With 41 out of 77 total pieces, the fine hornfels category makes up over half of the assemblage. The second most represented category is sandstone, with 18 artefacts. Coarse hornfels composes 13% of the total, with 10 objects.

Other categories were represented by less than 10 items. 4 stones were identified as quartz and 1 as dolerite, but this categorization is uncertain. The “unknown” category amounts to 3 items. Out of these, objects 3824 and 3780 show similar characteristics, such as horizontal banding on the sides and dark red areas. The last of the unknown materials, 3811, was categorized as such due to its poor state of preservation, which made it impossible to assess the raw material.

4.1.2. Spit 60

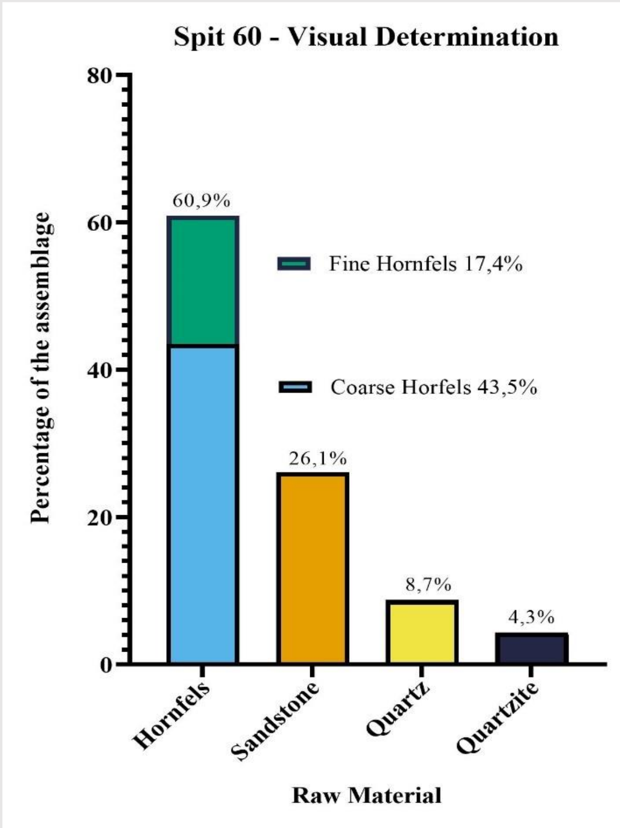

Figure 20: Column chart showing the raw materials proportions in spit 60 (Chart created by author).

I identified five raw material categories in spit 60. The exact percentages are shown in Figure 20. The most represented group is the coarse hornfels, with 10 artefacts out of 23 total. 6 objects, which correspond to about 26% of the materials, are identified as sandstone. The fine hornfels is represented by 4 objects. These 4 categories represent most of the Spit 60 assemblage. The rest is made up of quartz, with 2 items, and 1 quartzite piece.

4.2. XRF Results

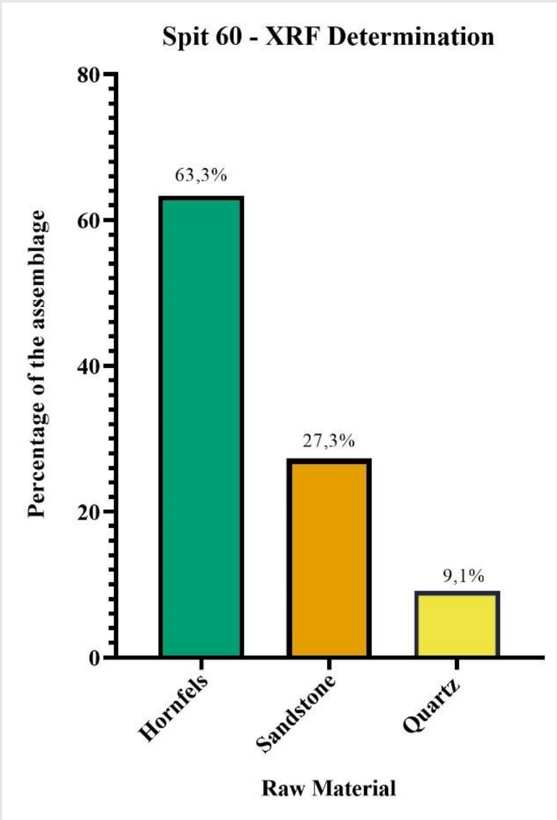

Figure 21: Bar chart showing the raw material proportions of spit 60 using the categories identified with the XRF (Chart created by author).

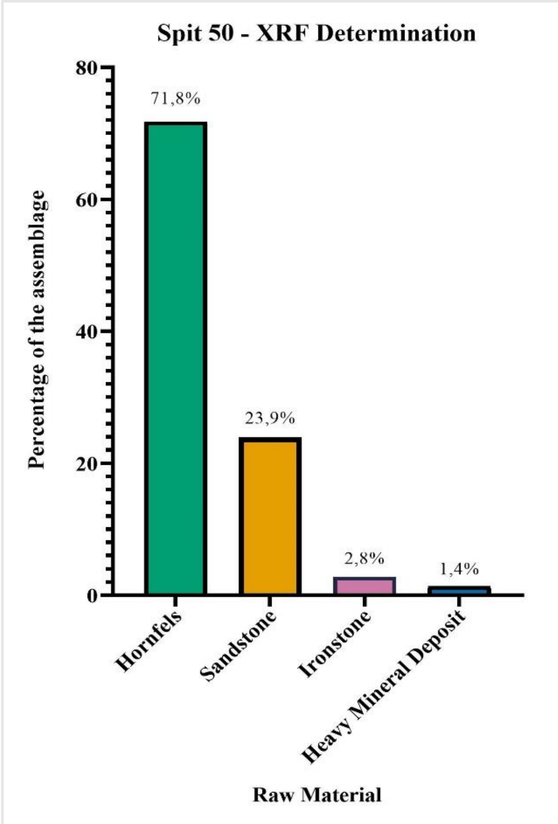

Figure 22: Bar chart showing the raw material proportions of spit 50 using the categories identified with the XRF (Chart created by author).

The XRF analysis identified 3 different raw material categories in Spit 60 and 4 in Spit 50 (see Figures 21 and 22). As mentioned in the previous chapter, six pieces from spit 50 could not be measured and are thus excluded from the data presented here. The missing artefacts are the quartz pieces, the "Dolerite" piece and artefact number 3811, categorized as "unknown". Excluded from the charts are also the double measurements conducted on some of the spit 50 hornfels. From spit 60, the measurements of artefact 4450, visually identified as sandstone, is also missing.

In both cases, the most frequent material is hornfels. In spit 60, "hornfels with low iron levels" was identified, but not given its own category (see Appendix A). The sandstone group is the second most represented in both cases and is proportionally more prevalent in spit 60. Two new categories, "ironstone", and "heavy mineral deposit", were determined by the XRF analysis. To understand the significance of these categories it is necessary to compare them to the visually identified ones and look closely at the elemental signals of the different artefacts.

4.3. Comparison of XRF and Visual Determination

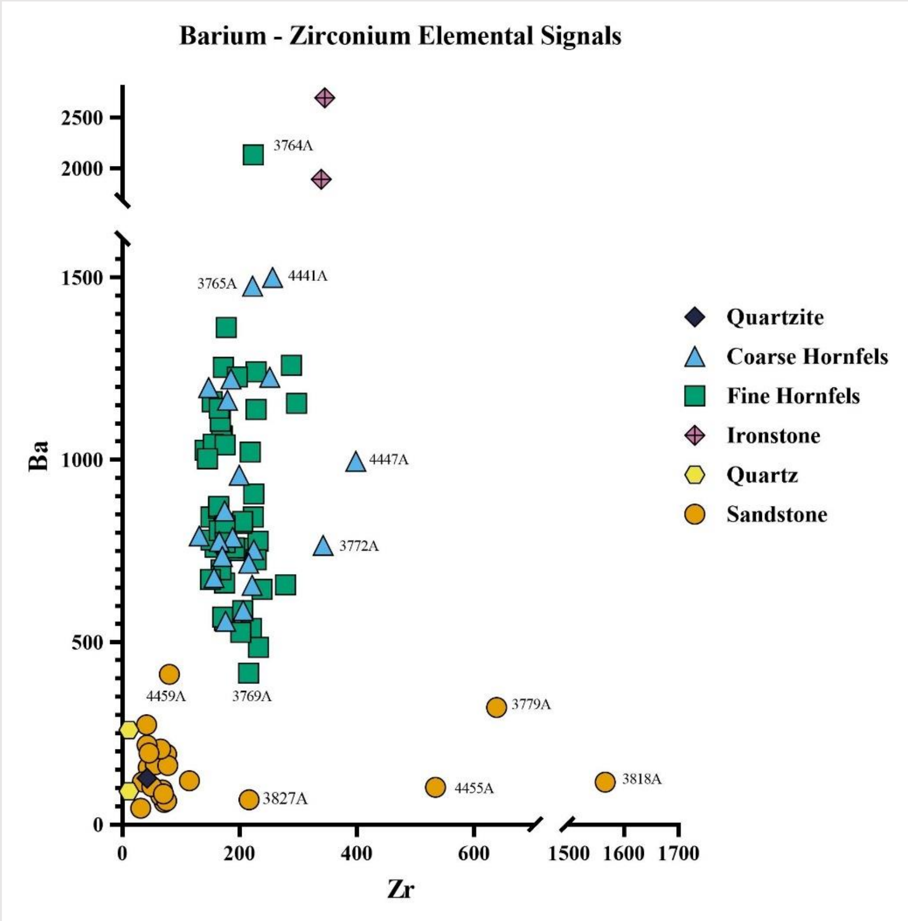

Figure 23: Scatter plot illustrating the different amounts of Barium (Ba) and Zirconium (Zr) in the artefacts from both spits. The points are categorized according to the visually determined groups, except for the ironstone (Chart created by author).

In general, the visually identified categories closely overlap with the XRF results (see Appendix A). All the hornfels from both spits was confirmed as such. The same can be said for sandstone except for artefact 3818, which was categorized as "Heavy mineral deposit" (Figure 22). Furthermore, in spit 60, the sandstone and quartzite categories were merged in the XRF and artefacts were grouped together as "sandstone". The two unknown materials that I was able to analyze were artefacts 3842 and 3780 (Figure 18). Their chemical signature is consistent with a material characterized by high iron presence called "ironstone", confirming my observation that the two pieces probably belong to the same category.

The different categories form clear and distinct clusters in the scatter plot of the Zirconium (Zr) and Barium (Ba) elemental signals (Figure 23). The scatter plot graphs, however, also show significant variation within the categories. This is explored in more detail below.

4.3.1. Sandstone, Quartz and Quartzite

Figure 24: Artefact 3818, dorsal, lateral, and ventral view (Photo credits: author).

The sandstone creates one clear cluster in the Zr – Ba scatter plot (see Figure 23). The grouped artefacts have low Zr and Ba levels compared to the hornfels. Furthermore, the quartzite clusters together with the sandstone, showing similar elemental proportions, hence its inclusion in the “sandstone” XRF group. The quartz has a more distinct signature, with Ba levels similar to the sandstone, but little to no Zr.

The sandstone group, however, also contains a few outliers. The most prominent is artefact 3818 (Figure 24), which, as stated above, belongs to the “heavy mineral deposit” category according to the PXRF results. This piece has similar Ba amounts as the rest of the sandstone but has much higher amounts of Zr.

Four other outliers are visible. Numbers 3779, 4455 3827 also have higher amounts of Zr compared to the rest, while number 4459 has higher Ba than any other sandstone artefact. This artefact also shows higher levels of Rubidium (Rb) (see Appendix B and C).

These variations are not macroscopically visible. Even artefact 3818, which according to the XRF belongs to a category other than sandstone, looks the same as other sandstone, with visible quartz crystals and the same color and texture seen in other pieces.

4.3.2. Hornfels

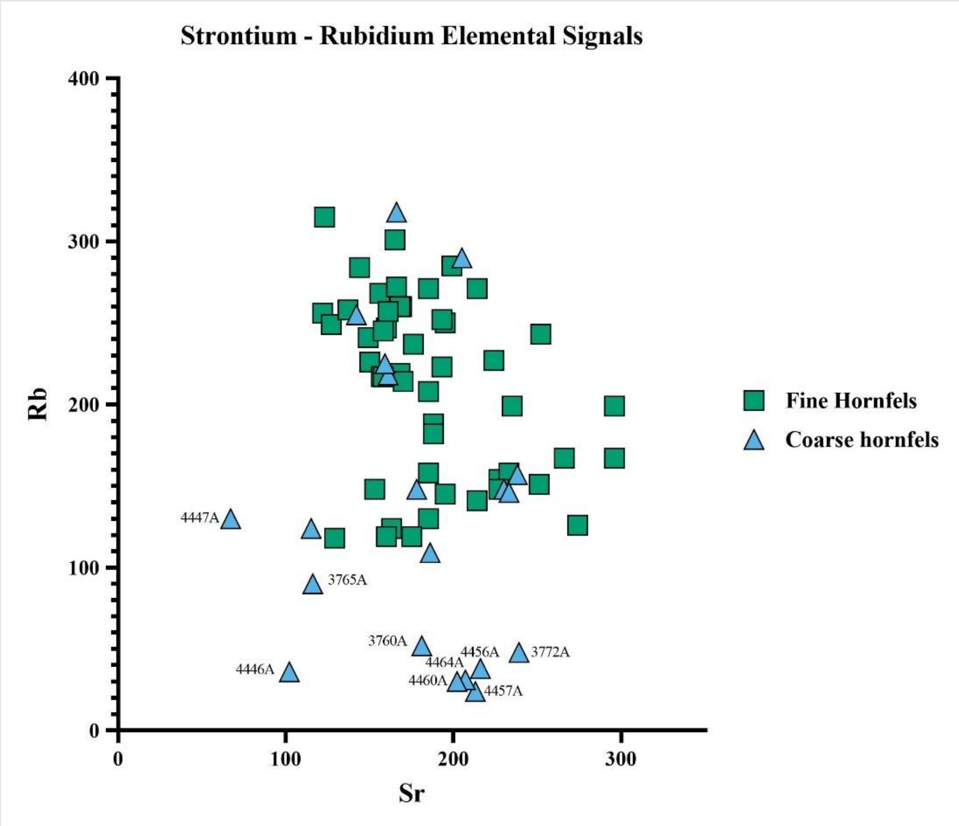

Figure 25: Scatter plot illustrating the amounts of Strontium (Sr) and Rubidium (Rb) in the hornfels from both spits (Chart created by author).

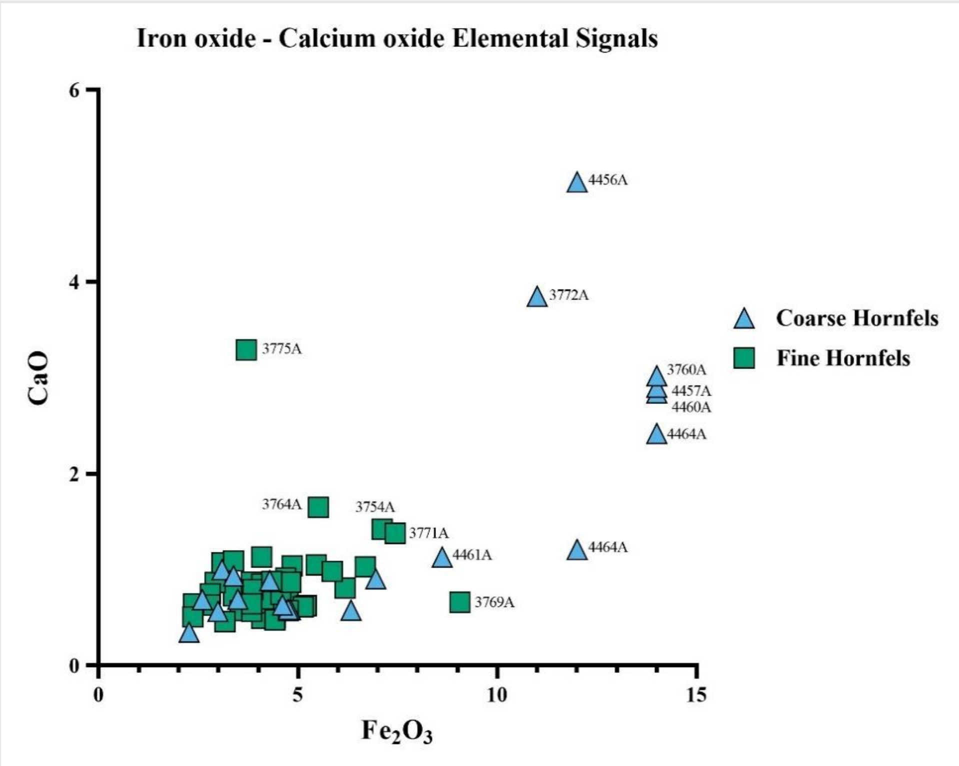

Figure 26: Scatter plot illustrating the amounts of Strontium (Sr) and Rubidium (Rb) in the hornfels from both spits (Chart created by author).

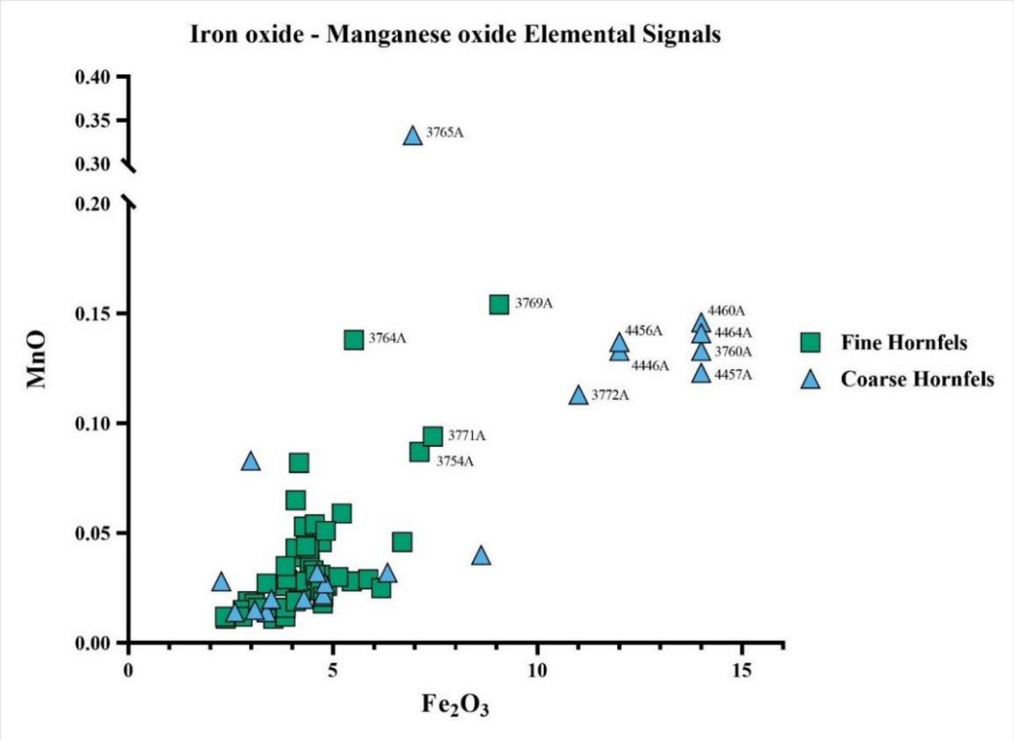

Figure 27: Scatter plot illustrating the amounts of Strontium (Sr) and Rubidium (Rb) in the hornfels from both spits (Chart created by author).

Most of the artefacts in the coarse and fine hornfels groups cluster consistently in the charts. They form one large cluster in the Zr – Ba chart, all showing similar Zr values (see Figure 23). More variation exists in the Ba levels, with piece 3764 being the most notable outlier.

Two separate clusters are visible in the Strontium (Sr) – Rubidium (Rb) chart (Figure 25). One large one includes most of the fine and coarse hornfels from both spits, and a smaller one composed of exclusively coarse hornfels from spit 50 and 60. The smaller cluster has Sr levels consistent with the rest of the hornfels, but much lower Rb. The artefacts in this group (3760, 3772, 4446, 4456, 4457, 4460 and 4464, shown in Figure 28) are either outliers or group together when looking at the Iron oxide (Fe_2O_3) – Manganese oxide (MnO) (Figure 27) and Fe_2O_3 – Calcium oxide (CaO) plots (Figure 26). Here they present high Fe_2O_3 levels and high MnO levels, while the CaO levels are variable, but generally higher than the rest.

A few artefacts also stand out in the plots as isolated outliers. One such piece, with the highest MnO levels detected in the assemblage, is 3765 (Figure 13, 1) which also belongs to the coarse hornfels group. In the other charts, this piece is always positioned at the edge of the hornfels range. Another outlier is 3764, which belongs instead to the fine hornfels category. This piece is distinctly outside the main hornfels cluster in the Zr – Ba and Fe_2O_3 – MnO scatter plots, with high Ba and MnO levels.

Figure 28: Dorsal and lateral views of the artefacts in the "high Fe_2O_3 - CaO hornfels" group; (1) 3760; (2) 3772; (3) 4446; (4) 4456; (5) 4457; (6)4464; (7) 4464 (Photo credits: author).

4.4. Spits Comparison

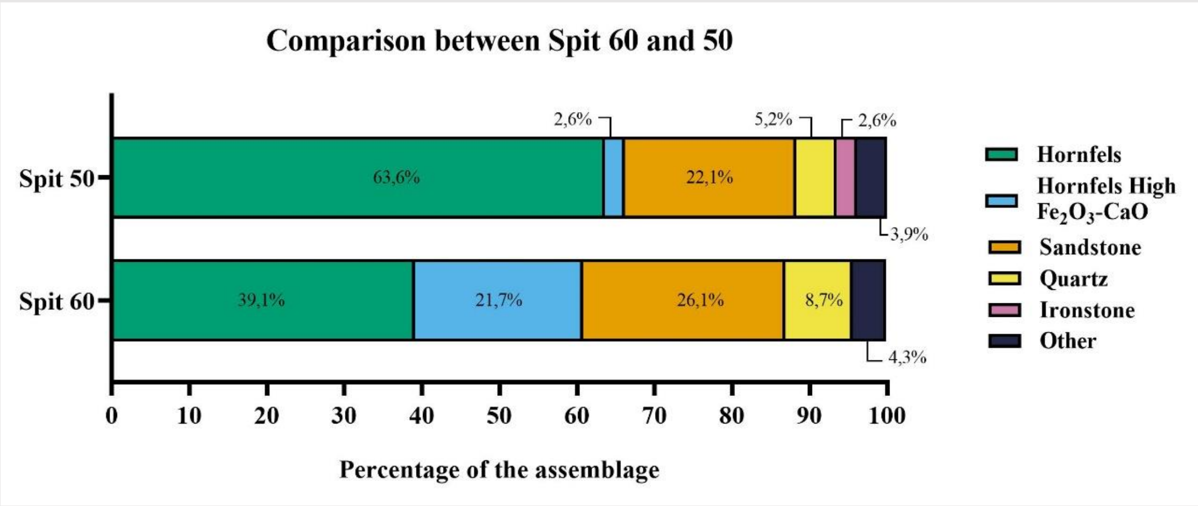

Figure 29: Bar graph showing how the two spits compare in terms of raw material distribution. The percentages are relative to the total of the artefacts per spit (Chart created by author).

The raw material categories I chose to include in my final comparison are based on the combination of visual and XRF data. In total, eight categories are present in the assemblage (see Figure 29).

The hornfels artefacts were split in two groups: "hornfels" and "high Fe_2O_3 – CaO hornfels". The latter category is introduced to account for the variation evidenced by the scatter plots. It is made up of the seven artefacts that cluster separately in the Sr – Rb, Fe_2O_3 – MnO and Fe_2O_3 – CaO plots. This division is based on the elemental readings, discarding the visual determination categories of coarse and fine hornfels, although there is a broad overlap between the high Fe_2O_3 group and the coarse hornfels in the case of spit 60. Taken together, these two categories represent more than half of the total in both spits.

The proportion of sandstone is similar, constituting over 20% of the assemblage in both spits. A preliminary examination of the technological characteristics of the sandstone objects, however, calls into question whether they can all be considered anthropogenic (V. Schmidt, pers. comm.). For this thesis, all objects are treated as archaeological artefacts, but a more in-depth analysis may modify the presented raw material proportions in the future.

The quartz group was classified based mainly on the visual determination, especially given the lack of measurements for the spit 50 quartz. This material represents less than 10% of both spits.

Unique to spit 50 is the “ironstone”, which was identified through the XRF analysis (Figure 18, 1 and 2). Lastly, the “other” category includes raw materials that are only represented by one or two objects. In spit 60, the only artefact included is the quartzite piece (Figure 17). In this case, the visual determination was chosen over the XRF determination. In spit 50, the “other” category includes object 3818, the “heavy mineral deposit” piece, and the two pieces I could not measure with the XRF: 3811, labelled as “unknown” and 3816, which I initially marked as “dolerite”.

Despite the raw material proportions being similar across the two assemblages, a close examination of the data reveals two differences worth discussing. First, spit 50 presents a wider variety of raw materials compared to spit 60. Spit 50 contains ironstone and few ambiguous pieces, neither found in spit 60. Second, the hornfels is less prevalent in spit 60 compared to spit 50. Spit 60 presents an almost even distribution of the raw materials, with the non-hornfels materials still making up about 39% of the assemblage. In spit 50, 66,2% of the assemblage is composed of hornfels. This is similar to spit 60, where the hornfels amounts to 60,8%, but the difference is noteworthy given the wider variety of rock types found in spit 50.

5. Discussion

5.1. Methodological Evaluation

The comparison between the results of the visual analysis and the XRF data forms the basis for the methodological evaluation.

Broadly, the XRF categories align with their visually identified counterparts. The key to the accuracy in visual identification was the use of appropriate reference materials. This includes literature and the previously specified reference collection (see section 3.2.2. of this text). In this case, visual analysis can be considered a reliable method for raw material determination. A closer look at the results, however, demonstrates that macroscopic analysis is impacted by important shortcomings.

5.1.2 The Limitations of Visual Analysis

Although no major errors were revealed by the XRF results, the reliability of visual determination only applied to broad categorizations. I could accurately differentiate hornfels from sandstone or quartz, but my in-group separations, specifically the division of the hornfels into “fine” and “coarse”, were not mirrored by the elemental readings. What the XRF measurements did show, however, is a group of hornfels pieces, “high Fe_2O_3 – CaO hornfels”, that clustered separately from the rest, indicating the existence of two chemically distinct groups within the hornfels used at the site. While it is true that all these artefacts were identified macroscopically as “coarse hornfels”, not all the objects belonging to this category had different elemental signals from the “fine hornfels” group (see Figures 23, 25, 26 and 27). This shows that visual identification alone can lead to classifications, such as the “coarse” and “fine” hornfels, which do not correspond to differences in mineralogical composition.

Furthermore, there are inconsistencies when comparing the results of my visual analysis with the raw material determination done on the field (see Appendix A). This can be attributed to my analysis being carried out on clean finds with access to a reference collection that featured raw material categories securely established using PXRF and micromorphology.

Agam and Wilson (2017) show that the effectiveness of macroscopic classification is easily impacted by the level of experience of those involved and by the reference material used. While carrying out the visual analysis, I also observed how external factors, such as lighting conditions and time available, further impact the outcome of the sorting process. The variables mentioned cannot be consistent for different research projects, or even for materials from the same site, making comparisons between assemblages vulnerable to undetected errors.

A wider issue is that lithic analysis is rooted in the study of European flint lithics. Consequently, the characteristics of flint form the basis for the classification methods used on any artefact, regardless of raw material (Knutsson, 1996). This bias makes recognizing non-flint artefacts harder for those without an extensive background in geology and/or lithic analysis, further increasing the chance of flawed data. This is problematic in the case of southern Africa, where flint is absent, and especially affects coarse grained rocks such as sandstone and less uniform materials like quartz (see also: Knutsson, 1996; Will, 2021).

Ultimately, while my data shows that macroscopic determination can be accurate, it also demonstrates that a large amount of data goes undetected when visual analysis is the only method employed in raw material categorization.

5.1.2. The Case for an Integrated Approach

The results also justify a close examination of the limitations of XRF technology. While XRF produces detailed results of the chemical composition of an object, a crucial aspect of lithic analysis are the mechanical properties of different rock types. These in turn have direct repercussions on technological characteristics (see for instance: Wadley & Mohapi, 2008).

Sandstone, quartz and quartzite, for instance, have very similar chemical signatures (see Figure 23), as quartz is often the main component of sandstone and quartzite (Cairncross, 2011, p. 438). From the mechanical and technological, point of view, however, these raw materials are distinct.

While XRF analysis is useful to classify ambiguous materials, find variation within a sample, and build a reference collection, they do not work to detect differing physical characteristics. This goes to show that visual and geochemical analysis can, and should, be used in a complementary way. An integrated approach minimizes methodological shortcomings, creating more reliable results.

5.2. The Raw Material Proportions

Now that the methodology has been discussed, the main research question can be addressed. As already stated in the "Spits comparison" section, the two spits show very similar patterns of raw material distribution. This is unlike what would be expected based on Kaplan's (1990) analysis (see 5.2.1. for detailed discussion). On their own, the data suggests a continued reliance on hornfels during different phases of occupation, supplemented in part by other rock types, mainly sandstone and, in smaller amounts, quartz and other rock types.

This conclusion does not consider the artefacts from spit 50, identified on the field as hornfels (see Appendix A), which are currently being held in the KwaZulu-Natal Museum. Their absence from the final count, however, is unlikely to make a big difference. The raw material assigned to them on the field is likely to be correct based on the images I could access (G. Dusseldorp, pers. comm.). In this case, the hornfels group would gain two more representatives, which would only further affirm this rock type as the dominant raw material of Spit 50. Furthermore, the spit 50 artefacts that could not be measured with the XRF do not significantly influence the picture either. Four of these are quartz, which does not necessitate XRF measurements to be recognized. The XRF would have helped securely assign a category to the "unknown" and "dolerite" artefacts. Although interesting, this still concerns a fraction of the total assemblage and would not revolutionize the final results.

The scatter plots of the XRF measurements (Figures 23, 25, 26 and 27) show variability in the rock types which is not always mirrored by visual characteristics. The sandstone and the hornfels both feature a few lone outliers, but the hornfels contains the distinct group: "high Fe_2O_3 – CaO hornfels". Unlike the lone outliers, which differ in appearance, the lithics of this group all display similar visual characteristics (see Figure 28). They all have spots of light-colored patina, and the surface is coarse even compared to other "coarse hornfels" (see Figure 13). Similar looking patina is found on other objects in the assemblage (see Figures 12 and 13), excluding it as the source of the chemical differences.

Different provenance could potentially explain the differences between the two groups. Geochemical data is used to source lithic raw materials, as is often done with obsidian (Liritzis & Zacharias, 2011). In South Africa, geochemical analysis has been successfully employed to source silcrete in the Cape coastal zone (Nash et al., 2013). A potential source for the hornfels excavated in Sibudu (~ 45 km from Umhlatuzana) was identified near Verulam (De La Peña & Wadley, 2017, p. 6). Bader et al. (2016, p. 611) pinpoint potential primary outcrops of hornfels near Umbeli Belli (~ 80 km from Umhlatuzana), but also suggest that the Drakensberg formations are a more likely source. There are no primary sources of hornfels in the immediate vicinity of Umhlatuzana (cfr Figure 1 in Bader et al., 2015, p. 151). The use of secondary sources, such as riverbeds, cannot be excluded, but field observations point to the absence of raw materials in the Umhlatuzana river valley (G. Dusseldorp, pers. comm.).

No geochemical data for the hornfels outcrops in the area is available and no studies sourcing archaeological hornfels in South Africa have been undertaken. Attempts on dolerite have not been successful either (Wadley & Kempson, 2011). While it is still possible that the sample's chemical variations may be due to different raw material sources, this hypothesis cannot be further tested.

5.2.1. Comparison with the assemblages from the 1980s excavation

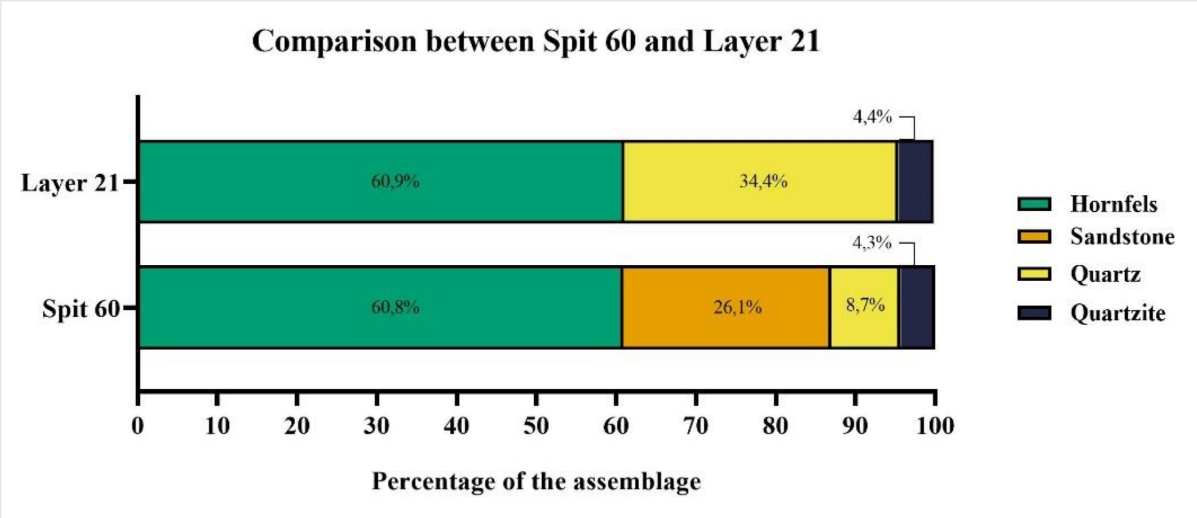

Figure 31: Spit 60 (2018 – 2019 excavation) compared to Kaplan's corresponding layer, layer 21 (Chart created by author; data source for layer 21: Kaplan, 1990, p. 32).

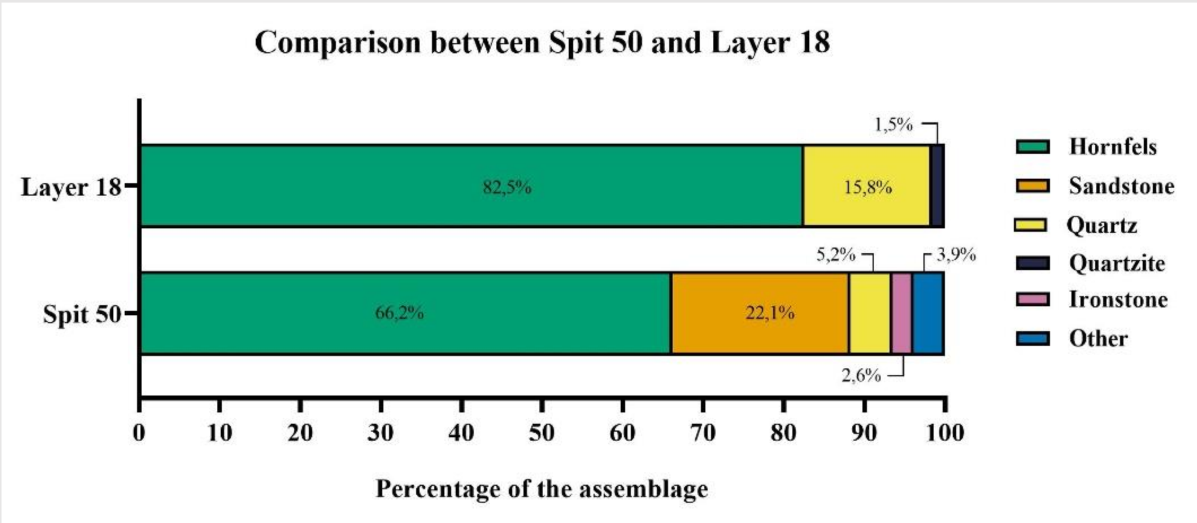

Figure 30: Spit 50 (2018 – 2019 excavation) compared to Kaplan's corresponding layer, layer 18. (Chart created by author; data source for layer 18: Kaplan, 1990, p. 39).

When comparing spits 60 and 50 with the layers from the 1980s excavation (for more detail on the correlations between the 1980s layers and the 2018 – 2019 spits see sections 2.2.4. and 3.1. of this thesis), the most noticeable similarity is the percentage of hornfels in Spit 60, which is almost the same as layer 21's (see Figures 30 and 31 for the exact percentages).

Kaplan (1990) reported that the use of hornfels increases between layers 22 and 15 (see Figure 4). This is also visible in the recent sample. Spit 50 contains proportionally about 6% more hornfels than spit 60, but that is far from the ~ 21% increase from layer 21 to layer 18.

Another discrepancy is the amounts of quartz, much smaller in the recent sample. This is especially noteworthy considering that quartz is the dominant raw material for most of the 1980s assemblage. The preliminary results from the analysis of other 2018 – 2019 spits do not align with Kaplan either, implying that the lack of quartz is not unique to my sample (Sifogeorgaki et al., 2021; I. Sifogeorgakis & G. Dusseldorp, pers. comm.).

In addition, Kaplan does not report any sandstone in his assemblage, although he does note small amounts of quartzite. It could be the case that different standards of classification were adopted during the sorting process in the 1980s. Potentially, the same raw materials could have been given different labels depending on who carried out the analysis. This makes sense in the case of sandstone, which could be labelled as quartzite, but it still does not explain the complete absence of the raw material.

No definitive explanations for these inconsistencies are possible without direct access to Kaplan's materials. For now, the only possible references are photos included in other publications. Mohapi (2013) has the most published images, and figures 4a, 4b, 5a and 5b (Mohapi, 2013, p. 34 - 36) depict finds contemporaneous to my sample. Here, the pieces identified as quartzite bear a resemblance in color to the ones I identified as sandstone, but the images do not allow for the assessment of crucial characteristics, such as grain and texture.

It should also be kept in mind that a direct comparison between Kaplan's layers and the 2018 – 2019 spits is not wholly accurate. The spits form parts of larger Units and represent 1 – 2 cm thick layers collected across a 0,25 m^2 square. Kaplan's layers, on the other hand, are ~ 10 cm thick across the entire excavation trench of ~ 6 m^2. Consequently, the 1980s layers include thousands of artefacts, while the recent spits contain less than 100 pieces each.

5.3. Archaeological interpretations

5.3.1. Raw material selection

Raw material preferences are restricted by local geology, which dictates resource availability. The preference for "exotic" raw materials during the HP has been hypothesized for sites such as Blombos Cave and Klasies River (Deacon & Deacon, 1999, p. 105; McCall, 2007; McCall & Thomas, 2012). The labels of "exotic" or "non-local" are not used consistently in the literature, as Ambrose (2006) and Minichillo (2006) point out. Semantics aside, the pattern exhibited at Border Cave and Klasies River is not seen at sites such as Rose Cottage Cave (Soriano et al., 2007), Sibudu (De La Peña & Wadley, 2017, p. 6) or Umbeli Belli (Bader et al., 2016; Bader et al., 2018;). As previously stated, it is plausible that the inhabitants of Umhlatuzana shared the same lithic sources as Sibudu and Umbeli Belli. The assemblage at Umhlatuzana is in this case dominated by non-local hornfels, although local secondary sources cannot be ruled out. Ultra-local raw materials also played a role. Likely, the source of the sandstone is the rock shelter itself, as seen in Sibudu (Will, 2021), attesting to raw material procurement strategies that made use of a variety of resources.

Mechanical characteristics pose another limitation to raw material choice, as these have practical implications for toolmaking (Wadley & Kempson, 2011; Wadley & Mohapi, 2008). Hornfels is easy to knap and produces a sharp cutting edge, but requires more resharpening and has a shorter lifespan (Wadley & Kempson, 2011). Sandstone is blunter and more difficult to knap, but its immediate availability allows expedient use. Quartz produces sharp edges which seldom need re-sharpening, but it can fracture unpredictably, making it difficult to work with (Wadley & Mohapi, 2008, p. 2597). In both spits 50 and 60 I have observed that most retouched artefacts are made of hornfels (see Figures 5, 6, 12 and 13), which implies its purposeful selection for retouched tools. This pattern is also visible at Umbeli Belli (Bader et al., 2016, p. 616) and Sibudu (Conard & Will, 2015, p. 22).

The material proportions remain fairly consistent across the two spits. This indicates that raw material preferences did not undergo radical transformations from the time of occupation of spit 60 to that of spit 50. This may be due to predictable resource availability in the region, which allowed for a wide variety of materials to be exploited in similar ways for a long time. Furthermore, a diverse repertoire of raw materials allows for increased flexibility. This does not mean that the former occupants' lifestyle and provisioning systems stayed the same across the thousands of years that separate the spits. Evidence for discontinuity can be found in the difference in find density between the two spits and in the appearance of new raw material types in spit 50.

5.3.2. Regional context

During the Late MSA period, sites in and around the KwaZulu-Natal show common patterns in terms of lithic technology (Bader et al., 2018; Lombard et al., 2012; Mackay et al., 2014). These include the presence of artefacts termed hollow-based points and the increased lack of standardization in assemblages (Bader et al., 2018; Wurz, 2013), which are also seen at Umhlatuzana (Lombard et al., 2010). In terms of raw materials selections, this period is characterized by heterogenous assemblages made up of hornfels, quartz, quartzite, sandstone, dolerite, and other rock types.

My results show results show continuity in raw material use between the end of the HP (spit 60) and the Late MSA (spit 50). There is a slight increase in hornfels use during the later period, together with the introduction of new rock types. This differs from the marked increase in the presence of hornfels proposed by Kaplan (1990) from the HP until the final MSA/LSA transition. An abrupt transition from the HP to the Late MSA was proposed by Cochrane (2008) at Sibudu, featuring an abandonment of hornfels and dolerite in favor of quartz and quartzite in the layers immediately overlying the HP. In a recent re-examination, de la Peña and Wadley (2017) counter Cochrane's claims, and argue for continuity in lithic techology between the two periods in Sibudu, similarly to Umhlatuzana. A key difference between the two sites is that at Sibudu, hornfels and dolerite decrease in importance during the after the HP period, in favour of materials such as sandstone and quartzite, while the opposite happens at Umhlatuzana. At Umbeli Belli, the Late MSA features hornfels as the dominant raw material (Bader et al., 2018; Bader et al., 2016), similarly to Umhlatuzana, but dolerite and quartz play more prominent roles in comparison. The lack of dolerite in my sample is puzzling considering how often this rock type is present in the other sites. It is entirely possible that dolerite will appear in other spits, but the ongoing analysis does not support this hypothesis (G. Dusseldorp and I. Sifogeorgaki, pers. comm.). Overall, the evidence presented supports the idea that the transition between the HP and the post-HP in the KwaZulu-Natal was not abrupt but, rather, there was continuity between the two periods.

6. Conclusions

Raw material selection during the HP and Late MSA is not very well understood. This is further complicated by potentially unreliable methods used for raw material identification. With this in mind, I have shown that quartz, sandstone and hornfels can be distinguished using visual analysis, however, this method cannot predict elemental variation within one raw material category. The integrated approach I adopted is useful to curb some of the limitations inherent to macroscopic determination, but also to show patterns of variability that would otherwise go undetected.

The main aim of this thesis was to assess the patterns of raw material variability in the MSA at Umhlatuzana. I have shown that there is a slight increase in the amounts of hornfels in the Late MSA (spit 50), paired with the introduction of new rock types in the assemblage. I have also observed that spits 60 and 50 are similar, indicating continuity in raw material preferences and/or in the lithic resource availability in the region.

I compared my results to those presented by Kaplan (1990), noting that in both samples hornfels is the dominant raw material, albeit in different proportions. The results further diverge when looking at the other raw materials. While I identified sandstone as an important component in the assemblage, in Kaplan's layers it appears to be absent, both according to his own analysis, and subsequent re-examinations (Lombard et al., 2010; Mohapi, 2013). The lack of quartz in my sample also represents a deviation from Kaplan's report.

The hypothesis that fine-grained raw materials were preferred during the HP is not substantiated by my results. Overall, the evidence presented, when compared to its regional context. supports the idea that the transition between the HP and the Late MSA in the KwaZulu-Natal was not abrupt but rather, maintained continuity between the two periods. Outside of the KwaZulu-Natal, the evidence from Rose Cottage Cave also aligns with this trend (Soriano et al., 2007). Raw material choice appears to have been subject to local variation, with Umbeli Belli, Sibudu and Umhlatuzana each having different patterns in terms of chronological variability and raw material composition of the assemblages.

6.1. Suggestions for future research

Future research may benefit from combining my data with an in-depth technological analysis of the sample presented, so as to better understand its cultural designation within the MSA.

Furthermore, the results presented highlight the need for a close re-examination of the 1980s assemblage, with direct access to the artefacts, perhaps applying the same combination of geochemical and macroscopic data used here. This would potentially explain the discrepancies between Kaplan's results (1990) and mine.

In addition, the PXRF measurements collected here could be re-used in a variety of future studies. For instance, they could play a role in attempting to establish the provenance of archaeological hornfels in the KwaZulu-Natal, or in comparative studies with other sites.

This thesis' evaluation of the efficacy of visual analysis for raw material identification has wider implications for lithic analysis. I maintain that the methodological approach used here should be considered for future research on lithic raw materials, as it can be easily applied on other MSA sites, but also on archaeological research outside of South Africa.

Abstract

Umhlatuzana rock shelter is a site first excavated in the 1980s located in the ZwaZulu-Natal province, South Africa. About 70.000 years of human activity are represented at the site without occupational hiatuses, which is rarely found in the region. A recent (2018-2019) fieldwork campaign by a team from Leiden University has unearthed thousands of lithic artefacts dating between the Middle Stone Age and Later Stone Age.

This thesis aims to determine the raw material composition of a sample of 100 recently excavated lithics, coming from two different spits dating to the end of the Howiesons Poort and to the Late Middle Stone Age periods. The results from the two spits are compared to identify any chronological patterns of variation. The results are then related to the raw material proportions reported from the first excavation. A combination of visual and geochemical (PXRF) analyses is used to identify different rock types and to test the accuracy of visual determination for raw material classification. The main rock types identified in the sample are hornfels, sandstone and quartz, accompanied in smaller amounts by other materials such as quartzite and ironstone.

The data obtained suggests continuity in raw material choice from the Howiesons Poort to the Late MSA period and purposefulness in the selection of different rock types for different uses. The evidence aligns in this aspect with other nearby sites, such as Sibudu and Umbeli Belli. The exact raw material proportions of the spits, however, are unlike what is seen elsewhere, and do not conform with the results presented by J. Kaplan, the original excavator of the site.

Raw material choice is fundamental to the toolmaking process and integral to our understanding of past hunter-gatherer lifeways. The study presented here adds to a growing body of evidence on the southern African Middle Stone Age, furthering the current knowledge on the behaviors of early Modern Humans.

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Appendices

Appendix A: All studied artefacts from spit 50 and 60

XRF nr	Find nr	Square	Unit	Spit	Raw material (Field Determination)	Raw material (visual determination)	Comments	XRF determination	Comments Post-XRF	Final Classification
250	3751	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
242	3752	L3a	P12	50	Hornfels	Sandstone		Sandstone		Sandstone
251	3753	L3a	P12	50	Hornfels	Hornfels	Coarseish in some bits	Hornfels, AlPO4stained		Hornfels
252	3754	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
255	3755	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
256	3756	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	Measurement of ventral side	Hornfels
257	3756	L3a	P12	50	Hornfels	Hornfels	Coarser on ventral side	Hornfels, AlPO4stained	Dorsal side	Hornfels
254	3757	L3a	P12	50	Hornfels	Hornfles	Patina	Hornfels, AlPO4stained	no 253 because mistake	Quartz
259	3758	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
238	3759	L3a	P12	50	Hornfels	Sandstone		Sandstone		Sandstone
295	3760	L3a	P12	50	Hornfels	Hornfels (coarse)	Very coarse	Hornfels, AlPO4stained		Hornfels High Fe2O3 - CaO
232	3761	L3a	P12	50	Hornfels	Sandstone		Sandstone		Sandstone
267	3762	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
258	3763	L3a	P12	50	Hornfels	Hornfels	Coarse on top, retouch	Hornfels, AlPO4stained		Hornfels
260	3764	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
293	3765	L3a	P12	50	Hornfels	Hornfels (coarse)	Retouch?	Hornfels, AlPO4stained		Hornfels
268	3766	L3a	P12	50	Hornfels	Hornfels	Coarser on ventral side	Hornfels, AlPO4stained		Hornfels
261	3767	L3a	P12	50	Hornfels	Hornfels	I'm not sure	Hornfels, AlPO4stained		Hornfels
262	3768	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
263	3769	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
264	3770	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
265	3771	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
297	3772	L3a	P12	50	Hornfels	Hornfels (coarse)	Very similar to 3760 under loupe	Hornfels, AlPO4stained		Hornfels high Fe2O3 - CaO
266	3773	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
270	3774	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
269	3775	L3a	P12	50	Hornfels	Hornfles		Hornfels, AlPO4stained		Quartz
	3776	L3a	P12	50	Hornfels					Hornfels
273	3777	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
247	3778	L3a	P12	50	Sandstone	Sandstone		Sandstone		Sandstone
236	3779	L3a	P12	50	Quartzite	Sandstone	quartziteish	Sandstone		Unkown
309	3780	L3a	P12	50	Quartzite	Unknown		Hornfels, AlPO4stained		ironstone
	3781	L3a	P12	50	Quartz	Quartz				Quartz
	3782	L3a	P12	50	Quartz	Quartz				Quartz
299	3793	L3a	P12	50	Hornfels	Hornfels (coarse)	Coarse on top	Hornfels, AlPO4stained		Hornfels
276	3794	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
271	3795	L3a	P12	50	Hornfels	Hornfels	shaping flake	Hornfels, AlPO4stained		Hornfels
233	3796	L3a	P12	50	Hornfels	Sandstone	quartziteish	Sandstone		Sandstone
272	3797	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
274	3798	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
275	3799	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
300	3800	L3a	P12	50	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
302	3800		P12					Hornfels, AlPO4stained		
277	3801	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
280	3802	L3a	P12	50	Hornfels	hornfels		Hornfels, AlPO4stained		Hornfels
292	3803	L3a	P12	50	Hornfels	Hornfels	Backed piece?	Hornfels, AlPO4stained		Hornfels
287	3804	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels

311	3805	L3a	P12	50	Hornfels	Hornfels			Dorsal measurement	Hornfels
311	3805	L3a	P12	50	Hornfels	Hornfels			ventral measurements	Hornfels
303	3806	L3a	P12	50	Hornfels	Hornfels (coarse)	Patina	Hornfels, AlPO4stained		Hornfels
286	3807	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
305	3808	L3a	P12	50	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
304	3809	L3a	P12	50	Hornfels	Hornfels	Coarse	Hornfels, AlPO4stained		Hornfels
288	3810	L3a	P12	50	Hornfels	Hornfels	Coarseish + Patina	Hornfels, AlPO4stained		Hornfels
	3811	L3a	P12	50	Hornfels	Unknown	maybe sandstone, very weathered .			
283	3812	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	Heat treated, ventral measurement	Hornfels
284	3812	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	heat treated dorsal measurement	Hornfels
282	3813	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
285	3814	L3a	P12	50	Hornfels	Hornfels	Patina	Hornfels, AlPO4stained		Hornfels
281	3815	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
	3816	L3a	P12	50	Hornfels	Diorite	unsure			Unkown
306	3817	L3a	P12	50	Hornfels	Hornfels (coarse)		ironstone		Hornfels
249	3818	L3a	P12	50	Hornfels	Sandstone	Less quartz visible	Heavy mineral deposit		Heavy mineral deposit
294	3819	L3a	P12	50	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
243	3820	L3a	P12	50	Hornfels	Sandstone		Sandstone		Sandstone
278	3821	L3a	P12	50	Hornfels	Hornfels	ventral side coarser	Hornfels, AlPO4stained	ventral side measurement, probably heat treated	Hornfels
279	3821	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	Dorsal measurement	Hornfels
	3822	L3a	P12	50	Hornfels					
244	3823	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
307	3824	L3a	P12	50	Sandstone	Unknown	maybe sandstone	ironstone		
234	3825	L3a	P12	50	Quartzite	Sandstone	quartziteish	Sandstone		ironstone
245	3826	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
246	3827	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
248	3828	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
235	3829	L3a	P12	50	Sandstone	Sandstone		Sandstone		Sandstone
	3830	L3a	P12	50	Quartz	Quartz				Quartz
	3831	L3a	P12	50	Quartz	Quartz				Quartz
289	3838	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
296	3839	L3a	P12	50	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
290	3840	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	Red spots, not measured here	Hornfels
291	3840	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained	Red spots measurement	Hornfels
298	3841	L3a	P12	50	Hornfels	Hornfels		Hornfels, AlPO4stained		Hornfels
240	3842	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
239	3843	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
241	3844	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone
231	3845	L3a	P12	50	Quartzite	Sandstone		Sandstone		Sandstone

214	4441	L3a	P7/P8	60	Hornfels	Hornfels (coarse)		Hornfels; low iron, AlPO4stained		Hornfels
223	4442	L3a	P7/P8	60	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
228	4443	L3a	P7/P8	60	Hornfels	Hornfels		Hornfels; low iron, AlPO4stained		Hornfels
215	4444	L3a	P7/P8	60	Hornfels	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
225	4445	L3a	P7/P8	60	Hornfels	Hornfels		Hornfels; low iron, AlPO4stained		Hornfels
216	4446	L3a	P7/P8	60	Hornfels	Hornfels (coarse)	White patina on surface	Hornfels, AlPO4stained		Hornfels High Fe2O3 - CaO
219	4447	L3a	P7/P8	60	Quartzite	Hornfels (coarse)	Bit coarser than other hornfels types but not quartzite	Hornfels; low iron, AlPO4stained		Hornfels
213	4448	L3a	P7/P8	60	Quartzite	Sandstone	Different color and texture	Sandstone		Sandstone
208	4449	L3a	P7/P8	60	Quartzite	Quartzite		quartzitic		Sandstone
207	4450	L3a	P7/P8	60	Quartzite	Sandstone	quartziteish			Sandstone
210	4451	L3a	P7/P8	60	Quartzite	Sandstone		Sandstone		Sandstone
209	4452	L3a	P7/P8	60	Quartzite	Sandstone	quartziteish	Sandstone		Sandstone
229	4453	L3a	P7/P8	60	Quartz	Quartz		quartz		Sandstone
230	4454	L3a	P7/P8	60	Quartz	Quartz		quartz		Sandstone
211	4455	L3a	P7/P8	60	Quartzite	Sandstone	quartziteish	Sandstone		Sandstone
217	4456	L3a	P7/P8	60	Quartzite	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels High Fe2O3 - CaO
218	4457	L3a	P7/P8	60	Quartzite	Hornfels (Coarse)		Hornfels, AlPO4stained		Hornfels
212	4459	L3a	P7/P8	60	Quartzite	Sandstone	quartziteish	quartzitic		Sandstone
221	4460	L3a	P7/P8	60	Quartzite	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
222	4461	L3a	P7/P8	60	Quartzite	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels
226	4462	L3a	P7/P8	60	Hornfels	Hornfels		Hornfels; low iron, AlPO4stained		Hornfels
227	4463	L3a	P7/P8	60	Hornfels	Hornfels		Hornfels; low iron, AlPO4stained		Hornfels
224	4464	L3a	P7/P8	60	Quartzite	Hornfels (coarse)		Hornfels, AlPO4stained		Hornfels

Appendix B: PXRF Measurements for spit 50

XRF	ID	Spit	Z	Raw Material/ Post- Excavation	Raw Material/ XRF	SiO2	CaO	P2O5	K2O	MgO	Al2O3	TiO2	Fe2O3	MnO	Bal	S	Cl	Zn	Cu	Co	Sn	Pb	Cr	Zr	Sr	Rb	As	Ba	V	Nb	Y	Th	U
250	3751A	50	529,5314	Hornfels	Hornfels, AlPO4stained	60	0,811	9,39	4,29	0,614	21	0,767	4,05	0,027	0,402	0,103	59	87	23	62	15	35	140	172	160	247	11	1253	131	4,92	20	13	3,14
242	3752A	50	529,5293	Sandstone	quartzitic	90	0,282	1,97	0,397	0,218	11	0,115	0,630	0,010	-3,919	0,008	30	15	17	18	7,90	4,04	27	34	5,68	8,09	3,43	117	14	0,756	0,638	1,07	1,34
251	3753A	50	529,5288	Hornfels	Hornfels, AlPO4stained	72	0,667	5,78	4,81	1,09	23	0,746	4,22	0,039	-10,517	0,035	48	95	21	63	19	38	123	170	144	284	10	1065	137	5,08	15	14	3,17
252	3754A	50	529,5256	Hornfels	Hornfels, AlPO4stained	63	1,42	10	4,40	1,10	21	0,876	7,11	0,087	-8,075	0,102	289	141	20	78	19	60	168	197	214	271	7,31	751	153	7,90	39	16	3,26
255	3755A	50	529,5272	Hornfels	Hornfels, AlPO4stained	69	0,722	7,18	4,68	0,927	23	0,793	4,69	0,031	-9,997	0,089	57	99	20	66	19	42	132	169	169	260	20	1066	131	5,79	19	14	3,13
256	3756A	50	529,5268	Hornfels	Hornfels, AlPO4stained	93	0,726	3,16	2,24	0,512	19	0,802	3,38	0,014	-21,883	0,071	52	86	42	78	10	35	126	215	227	154	30	758	127	11	38	20	2,71
257	3756B	50	529,5268	Hornfels	Hornfels, AlPO4stained	80	0,864	5,37	2,93	0,975	24	0,998	2,92	0,019	-16,847	0,030	44	84	33	80	17	35	137	223	233	158	29	843	158	10	38	19	2,77
254	3757A	50	529,5292	Hornfles	Hornfels, AlPO4stained	78	0,809	5,64	4,55	1,52	19	0,881	6,18	0,025	-14,922	0,071	61	144	20	78	19	42	150	158	123	315	6,18	760	164	7,35	19	11	3,36
259	3758A	50	529,5315	Hornfels	Hornfels, AlPO4stained	90	0,575	2,54	4,07	0,577	22	0,627	4,56	0,029	-24,264	0,013	48	115	19	66	13	42	111	141	149	241	5,64	1026	124	3,20	19	12	2,95
238	3759A	50	529,5343	Sandstone	quartzitic	95	0,214	0,575	0,160	0,378	3,15	0,055	0,378	0,010	0,090	0,004	33	15	18	15	8,72	4,16	0,618	65	5,69	4,43	3,46	79	17	0,817	0,666	1,08	1,45
295	3760A	50	529,5292	Hornfels (coarse)	Hornfels, AlPO4stained	34	2,42	20	1,11	1,12	20	1,50	14	0,133	6,33	0,264	70	106	71	117	32	22	138	188	181	52	5,76	787	200	1,45	33	2,28	2,98
232	3761A	50	529,5348	Sandstone	quartzitic	105	0,228	0,974	0,739	0,502	7,48	0,075	0,867	0,010	-15,749	0,018	35	15	18	24	7,22	4,21	40	60	5,71	24	4,67	181	27	0,814	0,761	1,13	1,48
267	3762A	50	529,5328	Hornfels	Hornfels, AlPO4stained	73	1,07	6,93	2,80	0,618	17	0,863	3,09	0,018	-4,829	0,085	414	81	20	54	16	31	158	228	296	167	9,99	1138	154	10	49	23	3,20
258	3763A	50	529,5306	Hornfels	Hornfels, AlPO4stained	91	0,744	3,11	3,37	1,09	16	0,645	4,57	0,031	-19,434	0,057	52	124	20	64	15	44	119	177	193	223	5,28	1363	105	3,09	15	12	3,08
260	3764A	50	529,531	Hornfels	Hornfels, AlPO4stained	90	1,65	2,47	3,61	2,24	24	1,03	5,51	0,138	-27,975	0,007	51	83	19	67	13	19	98	223	129	118	5,63	2132	109	1,17	40	1,71	2,45
293	3765A	50	529,5301	Hornfels (coarse)	Hornfels, AlPO4stained	92	0,906	2,59	2,62	0,653	12	0,780	6,95	0,333	-18,239	0,012	57	100	20	80	21	13	84	222	116	90	4,82	1476	122	1,31	35	2,65	2,49
268	3766A	50	529,5316	Hornfels	Hornfels, AlPO4stained	47	1,03	15	4,08	0,959	23	0,821	6,69	0,046	1,99	0,145	60	142	19	73	16	48	171	173	168	260	7,06	823	146	7,24	21	13	3,11
261	3767A	50	529,5219	Hornfels	Hornfels, AlPO4stained	72	0,912	8,55	2,84	0,599	17	0,574	4,69	0,024	-7,246	0,086	54	121	19	63	17	45	112	153	166	272	8,85	1159	126	3,09	12	13	3,13
262	3768A	50	529,5188	Hornfels	Hornfels, AlPO4stained	69	0,841	7,87	4,39	1,26	20	0,652	4,55	0,027	-7,122	0,039	49	107	19	63	20	48	120	155	165	301	6,03	1043	135	4,36	16	8,81	3,22
263	3769A	50	529,5182	Hornfels	Hornfels, AlPO4stained	68	0,658	6,12	3,10	0,655	31	1,06	9,06	0,154	-18,622	0,080	46	111	64	86	9,59	48	159	215	153	148	13	415	159	11	40	23	2,94
264	3770A	50	529,5208	Hornfels	Hornfels, AlPO4stained	73	0,791	9,72	2,41	1,11	20	0,896	3,87	0,029	-10,454	0,071	52	103	19	55	13	34	173	205	175	119	18	586	145	5,72	29	17	2,59
265	3771A	50	529,5217	Hornfels	Hornfels, AlPO4stained	53	1,38	14	2,44	0,780	18	1,12	7,44	0,094	2,69	0,117	58	175	28	81	16	48	218	297	274	126	8,23	1155	168	12	56	24	3,13
297	3772A	50	529,5207	Hornfels (coarse)	Hornfels, AlPO4stained	62	3,85	13	1,63	1,86	16	1,40	11	0,113	-8,644	0,125	363	104	64	103	22	25	208	342	239	48	5,78	765	157	1,58	29	3,33	2,84
266	3773A	50	529,5269	Hornfels	Hornfels, AlPO4stained	64	0,677	8,56	4,82	1,42	24	0,801	4,72	0,046	-7,529	0,088	1164	95	23	63	15	39	156	151	150	226	11	843	153	3,71	14	12	2,87
270	3774A	50	529,5164	Hornfels	Hornfels, AlPO4stained	86	0,503	2,62	5,14	1,15	26	0,800	4,43	0,036	-25,129	0,014	45	97	19	81	13	39	133	175	157	217	5,56	1041	136	4,94	18	14	2,97
269	3775A	50	529,5166	Hornfles	Hornfels, AlPO4stained	63	3,29	12	3,08	1,22	18	0,573	3,70	0,026	-3,582	0,097	483	89	19	55	12	43	110	231	296	199	7,67	777	96	7,20	30	12	2,98
273	3777A	50	529,5197	Hornfels	Hornfels, AlPO4stained	73	0,868	8,32	2,18	0,729	15	0,593	4,82	0,051	-5,606	0,098	113	106	46	69	17	41	122	165	176	237	55	1141	115	4,95	27	11	3,24
247	3778A	50	529,5329	Sandstone	quartzitic	95	0,226	0,704	0,321	0,440	5,48	0,075	0,454	0,010	-1,931	0,011	38	15	18	16	10	4,19	21	65	5,70	5,30	3,49	207	19	0,817	0,678	1,27	1,46
236	3779A	50	529,5209	Sandstone	quartzitic	102	0,197	0,470	1,42	0,678	9,70	0,992	1,09	0,011	-15,726	0,017	39	17	18	28	14	4,39	112	638	22	32	3,73	321	39	0,959	6,05	5,35	1,78
308	3780A	50	529,528	Unknown	ironstone	45	0,826	3,32	0,744	2,37	9,64	1,47	66	0,066	-27,262	0,113	67	176	114	315	38	511	1928	345	180	83	24	2695	551	3,19	3,16	193	8,96
299	3793A	50	529,5283	Hornfels (coarse)	Hornfels, AlPO4stained	83	0,686	4,39	2,30	0,480	20	0,964	2,60	0,014	-14,467	0,028	45	124	41	51	23	36	134	251	178	148	25	1226	132	9,17	44	19	2,78
276	3794A	50	529,5204	Hornfels	Hornfels, AlPO4stained	84	0,458	4,31	3,63	1,21	22	1,10	3,17	0,016	-18,630	0,040	43	139	19	50	10	41	154	278	188	182	5,01	657	141	13	36	20	2,75
271	3795A	50	529,5187	Hornfels	Hornfels, AlPO4stained	90	0,737	3,82	2,68	0,825	21	0,985	4,75	0,018	-24,365	0,080	48	89	53	61	8,42	35	138	220	251	151	6,88	538	150	11	37	21	2,76
233	3796A	50	529,5214	Sandstone	quartzitic	106	0,200	0,492	0,637	0,230	5,71	0,334	0,660	0,010	-14,362	0,004	34	15	17	20	7,13	4,08	29	71	6,14	13	3,81	61	20	0,804	0,691	1,03	1,42
272	3797A	50	529,5176	Hornfels	Hornfels, AlPO4stained	93	0,571	1,91	2,30	0,607	19	0,832	3,54	0,011	-21,467	0,008	44	74	19	55	12	31	122	204	214	141	54	826	139	8,46	36	19	2,76
274	3798A	50	529,5135	Hornfels	Hornfels, AlPO4stained	72	0,494	5,31	4,67	0,906	21	0,778	4,09	0,043	-9,100	0,084	57	83	23	62	18	43	123	164	122	256	5,48	867	160	5,31	18	11	3,07
275	3799A	50	529,5168	Hornfels	Hornfels, AlPO4stained	56	1,04	13	4,33	1,05	21	0,750	4,85	0,026	-0,447	0,095	56	124	19	65	12	32	130	178	199	285	9,73	767	156	5,74	13	16	3,27
302	3800A	50	529,5126		Hornfels, AlPO4stained	96	0,692	1,70	2,44	0,895	20	0,863	3,49	0,020	-24,302	0,011	44	82	21	75	12	35	146	215	233	146	59	716	152	9,15	35	18	2,76
277	3801A	50	529,5066	Hornfels	Hornfels, AlPO4stained	93	0,868	3,62	3,35	1,23	18	0,549	3,83	0,012	-22,536	0,035	49	108	19	57	12	32	114	174	224	227	5,34	662	99	5,13	24	7,66	2,94
280	3802A	50	529,5039	hornfels	Hornfels, AlPO4stained	85	0,507	2,30	3,07	0,600	27	0,966	2,36	0,012	-20,341	0,015	46	86	19	46	13	31	159	238	185	158	8,49	645	149	9,24	37	18	2,59
292	3803A	50	529,5104	Hornfels	Hornfels, AlPO4stained	86	0,624	3,66	4,17	1,75	19	0,808	5,21	0,059	-20,038	0,028	50	95	21	69	23	43	129	167	185	208	5,93	1106	141	5,05	24	15	3,02
287	3804A	50	529,5078	Hornfels	Hornfels, AlPO4stained	66	1,13	10	3,51	0,910	18	0,615	4,09	0,019	-4,549	0,103	56	83	22	59	11	42	121	175	235	199	21	773	116	4,18	21	15	2,92
311	3805A	50	529,5113	Hornfels	Hornfels, AlPO4stained	72	0,876	6,61	4,73	1,33	21	0,900	4,34	0,044	-10,596	0,045	47	99	22	62	16	53	146	196	193	252	7,68	1227	151	8,45	25	14	3,14
303	3806A	50	529,5088	Hornfels (coarse)	Hornfels, AlPO4stained	99	0,581	1,50	4,84	2,03	22	0,794	4,81	0,027	-33,257	0,006	50	109	19	59	13	42	142	176	166	318	5,76	557	140	8,39	22	11	3,22
286	3807A	50	529,5076	Hornfels	Hornfels, AlPO4stained	98	0,688	2,45	3,56	1,19	12	0,823	4,17	0,082	-22,223	0,021	59	90	26	66	17	51	129	205	195	250	9,82	831	139	9,04	27	17	3,39
305	3808A	50	529,5138	Hornfels (coarse)	Hornfels, AlPO4stained	87	0,886	4,29	4,42	0,898	17	0,620	4,29	0,020	-18,687	0,048	52	103	19	63	16	37	132	147	142	255	21	1198	135	3,82	19	11	3,08
304	3809A	50	529,5136	Hornfels	Hornfels, AlPO4stained	93	0,644	1,63	2,66	0,389	22	0,974	3,84	0,035	-25,114	0,007	45	84	33	54	12	31	130	202	195	145	4,76	527	127	8,13	36	17	2,77
288	3810A	50	529,5153	Hornfels	Hornfels, AlPO4stained	89	0,565	1,62	3,85	2,18	22	0,536	3,84	0,016	-21,827	0,012	46	76	19	58	13	33	109	151	170	214	5,44	780	109	1,42	19	10	2,92
283	3812A	50	529,5101	Hornfels	Hornfels, AlPO4stained	84	1,05	4,69	4,03	1,06	19	0,718	5,46	0,028	-18,746	0,868	3340	110	19	68	13	46	141	168	158	245	8,86	698	157	6,51	23	15	3,00
284	3812B	50	529,5101	Hornfels	Hornfels, AlPO4stained	65	0,983	9,88	4,82	0,857	18	0,856	5,86	0,029	-5,300	0,070	61	110	20	78	12	53	168	191	185	271	7,24	759	176	8,63	24	15	3,53
282	3813A	50	529,5125	Hornfels	Hornfels, AlPO4stained	73	1,09	8,42	2,56	1,24	22	0,981	3,38	0,027	-11,201	0,154	53	70	32	65	19	35	137	218	227	148	36	1021	153	9,05	39	20	2,86
285	3814A	50	529,5091	Hornfels	Hornfels, AlPO4stained	85	0,571	2,52	5,25	1,75	25	0,904	4,76	0,021	-23,134	0,011	50	146	19	63	12	53	156	171	161	257	7,20	569	149	7,59	20	13	2,96
281	3815A	50	529,5111	Hornfels	Hornfels, AlPO4stained	90	0,680	2,93	3,62	0,582	18	0,613	4,22	0,020	-19,402	0,028	48	97	19	87	13	38	118	164	168	219	11	872	133	3,05	19	9,69	2,99
306	3817A	50	529,5075	Hornfels (coarse)	Hornfels, AlPO4stained	89	0,998	1,48	2,79	2,15	24	0,984	3,09	0,015	-21,761	0,050	50	82	19	52	8,57	35	132	221	230	148	57	656	143	11	35	20	2,73
249	3818A	50	529,5156	Sandstone	Heavy mineral deposit	92	0,255	1,30	0,799	0,678	11	2,99	2,33	0,010	-10,376	0,023	42	41	30	43	9,51	4,77	806	1566	6,02	16	8,28	116	64	3,06	17	24	2,00
294	3819A	50	529,5	Hornfels (coarse)	Hornfels, AlPO4stained	85	0,935	5,21	2,13	0,543	19	0,792	3,38	0,014	-15,665	0,045	52	72	26	53	13	37	130	224	238	157	24	753	153	11	40	20	2,86
243	3820A	50	529,5063	Sandstone	quartzitic	90	0,305	1,43	0,773	0,460	8,40	0,101	0,728	0,011	-1,571	0,013	39	16	18	22	9,44	4,27	22	50	8,81	27	4,46	104	18	0,825	0,809	1,33	1,53
278	3821A	50	529,5212	Hornfels	Hornfels, AlPO4stained	83	0,740	3,67	2,32	0,463	26	1,04	4,52	0,033	-21,499	0,063	48	106	18	56	10	34	146	228	163	124	18	726	142	7,27	42	19	2,58
279	3821B	50	529,5212	Hornfels	Hornfels, AlPO4stained	85	0,747	3,38	2,44	0,758	14	1,02	2,80	0,015	-9,213	0,056	71	88	21	93	28	31	157	224	160	119	14	906	151	6,08	42	16	3,03
244	3823A	50	529,5164	Sandstone	quartzitic	81	0,395	1,48	0,832	0,313	9,83	0,205	1,03	0,025	5,44	0,030	41	17	18	26	12	4,19	20	77	7,53	17	3,18	162	22	0,850	0,752	1,38	1,56
307	3824A	50	529,5167	Unknown	ironstone	51	4,12	4,44	1,16	1,49	9,96	0,589	38	0,091	-9,327	0,039	108	109	44	205	35	135	62	339	189	95	11	1890	184	3,33	88	36	4,77
234	3825A	50	529,5152	Sandstone	quartzitic	109	0,193	0,410	0,296	0,245	5,13	0,073	0,419	0,010	-15,246	0,027	38	15	17	15	8,22	4,04	2,70	31	5,68	7,57	3,56	45	17	0,760	0,638	1,01	1,32
245	3826A	50	529,5104	Sandstone	quartzitic	104	0,275	0,806	0,481	0,243	9,28	0,155	0,515	0,010	-15,110	0,010	37	15	17	16	7,52	4,04	66	75	6,47	10	3,45	65	21	0,752	0,649	0,984	1,37
246	3827A	50	529,5109	Sandstone	quartzitic	102	0,255	0,742	0,427	0,416	8,45	0,241	0,612	0,010	-12,503	0,004	32	15	17	18	7,51	4,07	19	216	5,68	7,69	3,73	68	18	0,794	0,695	2,47	1,40
248	3828A	50	529,5199	Sandstone	quartzitic	97	0,219	0,421	0,267	0,304	4,75	0,092	0,448	0,010	-2,900	0,050	381	15	18	16	8,83	4,15	49	42	5,68	5,57	3,46	218	18	0,799	0,664	1,06	1,42
235	3829A	50	529,5204	Sandstone	quartzitic	88	0,353	1,60	0,414	0,755	9,93	0,124	0,837	0,010	-1,525	0,017	179	15	17	22	11	4,09	14	75	5,69	6,33	4,08	193	19	0,797	0,682	1,05	1,42
289	3838A	50	529,5115	Hornfels	Hornfels, AlPO4stained	90	0,612	2,90	4,89	1,86	25	0,816	5,13	0,030	-28,737	0,021	51	107	19	76	11	40	129	174	156	268	6,16	560	152	7,89	22	13	3,00
296	3839A	50	529,5017	Hornfels (coarse)	Hornfels, AlPO4stained	95	0,585	1,78	5,11	1,55	20	0,865	4,76	0,022	-28,463	0,010	51	109	19	92	11	49	138	206	205	290	27	587	150	11	24	12	3,28
290	3840A	50	529,5035	Hornfels	Hornfels, AlPO4stained	80	0,655	5,79	3,96	1,28	19	0,706	4,29	0,053	-14,646	0,030	52	104	19	63	12	47	123	165	127	249	6,12	806	135	4,30	15	12	2,99
291	3840B	50	529,5035	Hornfels	Hornfels, AlPO4stained	71	0,586	7,12	4,55	0,575	23	0,797	4,55	0,054	-11,481	0,047	50	109	22	63	18	47	129	175	137	258	9,46	819	138	6,37	18	13	3,02
298	3841A	50	529,5035	Hornfels	Hornfels, AlPO4stained	98	0,847	3,81	2,49	0,785	18	0,919	4,09	0,065	-27,723	0,044	54	92	30	93	9,82	42	146	232	266	167	37	486	155	13	44	23	3,01
240	3842A	50	529,5098	Sandstone	quartzitic	76	0,310	1,43	0,964	0,626	17	0,281	1,37	0,031	2,28	0,039	366	16	18	29	8,59	4,21	53	114	6,64	27	4,04	120	34	0,821	0,770	1,29	1,53
239	3843A	50	529,5024	Sandstone	quartzitic	92	0,208	0,523	1,65	0,821	12	0,126	0,923	0,010	-8,185	0,005	38	15	18	24	14	4,22	35	56	6,72	39	3,53	164	35	0,819	0,824	1,11	1,59
241	3844A	50	529,5106	Sandstone	quartzitic	93	0,214	0,978	0,601	0,473	8,09	0,187	0,622	0,010	-3,942	0,070	290	15	18	19	8,97	4,14	49	68	5,69	12	3,44	95	17	0,788	0,684	1,96	1,38
231	3845A	50	529,5193	Sandstone	quartzitic	103	0,211	0,952	0,430	0,536	6,00	0,060	0,391	0,010	-10,593	0,007	28	15	17	14	10	4,07	60	44	5,67	9,10	3,34	157	16	0,755	0,649	1,01	1,37

Appendix C: PXRF Measurements for spit 60

XRF	ID	Spit	Z	Raw Material/ Post- Excavation	Raw Material/ XRF	SiO2	CaO	P2O5	K2O	MgO	Al2O3	TiO2	Fe2O3	MnO	Bal	S	Cl	Zn	Cu	Co	Sn	Pb	Cr	Zr	Sr	Rb	As	Ba	V	Nb	Y	Th	U
214	4441A	60	529,2288	Hornfels (coarse)	Hornfels; low iron, AlPO4stained	67	0,350	5,06	2,08	0,563	20	1,01	2,27	0,028	1,72	0,081	48	66	25	51	22	24	143	256	115	124	19	1500	170	9,17	28	24	2,78
223	4442A	60	529,239	Hornfels (coarse)	Hornfels, AlPO4stained	41	0,576	16	3,61	1,04	21	0,937	6,33	0,032	10	0,185	55	118	20	75	27	46	149	185	159	225	7,08	1222	143	8,03	23	18	3,13
228	4443A	60	529,2365	Hornfels	Hornfels; low iron, AlPO4stained	33	0,694	18	3,32	0,730	20	0,843	4,14	0,028	20	0,204	58	63	22	60	14	48	134	228	252	243	6,69	1241	134	12	25	17	3,16
215	4444A	60	529,2298	Hornfels (coarse)	Hornfels, AlPO4stained	50	0,632	12	3,58	1,41	20	0,835	4,61	0,032	8,40	0,274	2578	92	22	67	18	51	115	199	161	218	6,85	958	126	7,00	20	14	3,20
225	4445A	60	529,2335	Hornfels	Hornfels; low iron, AlPO4stained	79	0,630	4,09	3,74	0,528	22	0,623	2,79	0,012	-13,228	0,051	54	66	19	48	11	34	113	150	188	188	5,69	672	110	1,81	17	9,43	2,68
216	4446A	60	529,2325	Hornfels (coarse)	Hornfels, AlPO4stained	27	1,21	18	0,974	0,593	20	1,15	12	0,133	19	0,318	853	76	88	120	37	15	314	131	102	36	5,99	791	110	1,35	13	2,88	2,64
219	4447A	60	529,2214	Hornfels (coarse)	Hornfels; low iron, AlPO4stained	80	0,564	4,36	2,96	1,12	15	0,719	2,99	0,083	-6,017	0,172	3054	56	20	54	15	26	95	398	67	130	6,96	996	69	1,94	29	9,64	2,58
213	4448A	60	529,2217	Sandstone	quartzitic	84	0,205	0,600	1,03	0,654	12	0,080	0,510	0,010	1,57	0,059	40	15	18	17	11	4,23	23	41	7,78	21	3,54	273	28	0,801	0,736	1,09	1,54
208	4449A	60	529,2331	Quartzite	quartzitic	107	0,183	0,364	0,463	0,320	4,68	0,065	0,464	0,010	-13,607	0,011	38	15	17	16	9,07	4,07	21	42	5,67	10	3,31	127	16	0,763	0,652	1,51	1,39
210	4451A	60	529,2416	Sandstone	quartzitic	108	0,212	0,561	0,391	0,309	4,99	0,063	0,491	0,010	-14,352	0,020	32	15	17	17	12	4,06	59	45	5,79	9,54	3,33	196	16	0,768	0,661	1,02	1,38
209	4452A	60	529,2304	Sandstone	quartzitic	113	~~0,192~~	0,396	0,370	0,188	4,42	0,118	0,457	0,010	-19,322	0,020	33	15	17	16	7,34	4,02	40	70	5,76	9,89	3,67	84	17	0,754	0,648	1,07	1,33
229	4453A	60	529,2302	Quartz	quartzitic	101	0,216	0,511	0,027	0,344	1,75	0,039	0,269	0,011	-3,776	0,005	42	16	19	13	11	4,33	166	11	5,70	1,78	3,71	259	14	0,894	0,684	1,19	1,57
230	4454A	60	529,236		quartzitic	122	0,166	0,265	0,008	1,23	1,75	0,030	0,228	0,010	-24,668	0,003	27	15	17	8,64	8,72	3,93	-1,539	11	5,62	1,45	3,24	91	45	0,694	0,546	0,900	1,22
211	4455A	60	529,22	Sandstone	quartzitic	107	0,217	0,446	1,50	0,997	7,70	0,842	1,07	0,011	-19,056	0,088	199	15	18	27	9,74	4,33	224	534	13	32	4,50	102	29	0,931	4,11	6,19	1,70
217	4456A	60	529,2255	Hornfels (coarse)	Hornfels, AlPO4stained	32	5,04	20	1,36	1,12	18	1,57	12	0,137	8,97	0,247	132	80	47	109	17	18	107	156	216	38	5,45	677	210	1,42	31	3,17	2,83
218	4457A	60	529,2322	Hornfels (Coarse)	Hornfels, AlPO4stained	28	2,84	23	1,12	1,24	19	1,29	14	0,123	11	0,268	1479	83	54	111	28	22	116	165	213	24	5,58	776	189	1,39	31	5,61	2,74
212	4459A	60	529,2169	Sandstone	quartzitic	89	0,210	0,669	2,34	0,373	12	0,108	1,04	0,011	-5,221	0,009	39	17	19	29	16	4,52	25	80	13	58	4,68	412	19	0,895	0,989	2,10	1,82
221	4460A	60	529,2433	Hornfels (coarse)	Hornfels, AlPO4stained	30	2,90	21	1,12	1,84	21	1,46	14	0,146	8,60	0,375	1723	98	52	117	35	21	126	170	207	31	5,56	735	210	1,45	31	2,35	2,84
222	4461A	60	529,2288	Hornfels (coarse)	Hornfels, AlPO4stained	63	1,13	7,07	4,46	1,46	25	1,36	8,62	0,040	-10,463	0,080	54	73	20	87	21	10	172	179	186	109	4,57	1163	175	1,24	21	1,69	2,68
226	4462A	60	529,2186	Hornfels	Hornfels; low iron, AlPO4stained	69	0,476	5,58	4,71	1,26	25	0,721	4,42	0,043	-9,915	0,072	48	87	19	62	16	40	112	145	158	217	5,72	1003	138	2,74	16	13	3,01
227	4463A	60	529,2222	Hornfels	Hornfels; low iron, AlPO4stained	65	0,642	6,98	2,20	0,354	25	1,03	2,38	0,011	-2,762	0,063	52	68	30	45	26	40	149	288	185	130	20	1259	156	12	29	25	2,66
224	4464A	60	529,2064	Hornfels (coarse)	Hornfels, AlPO4stained	32	3,02	19	1,01	1,50	17	1,41	14	0,141	12	0,345	4177	88	54	115	18	23	118	174	202	30	5,69	860	212	1,44	32	4,60	2,78