

A TECHNOLOGICAL STUDY OF CERAMICS FROM TWO  
GREATER MAPUNGUBWE LANDSCAPE SITES USING  
PORTABLE X-RAY FLUORESCENCE AND PETROGRAPHY

By

LARA LUCIJA KRALJEVIĆ

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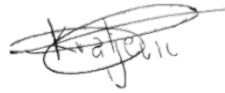
Supervisor: Dr Alexander Antonites

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## Declaration

I, Lara Lucija Kraljević, declare that this dissertation is my own original work. Where secondary material is used, this has been properly acknowledged and referenced in accordance with university requirements. This work has not been submitted before, in whole or in part, for any other degree or examination.

**Signature:**



**Date:** August 2021

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## Abstract

This research made use of portable x-ray fluorescence and petrography to analyse ceramics from two Middle Iron Age sites forming part of the Greater Mapungubwe Landscape. The two sites, Evelyn (EV01), and Klein Bolayi (EV02) situated within the Klein Bolayi Game Lodge have been identified as TK2 sites based on ceramic stylistic analysis. For this study, ceramic assemblages were analysed chemically and mineralogically to compare any present relationships in the clay and ceramic technology. Chemical and mineralogical analysis of Evelyn and Klein Bolayi showed an overarching similarity in ceramic compositions of both sites. Evelyn presented ceramics which were compositionally and technologically similar with the implementation of grog tempering and a pinching forming method. Klein Bolayi showed greater compositional and technological variation with two petrographic samples showing presence of non-local clay within the ceramics. One of the petrographic outliers of Klein Bolayi had also been identified as a chemical outlier based on pXRF analysis. The technological variations were present in the usage of both pinching and coiling forming methods.

Both sites were likely to have used the same clay source for ceramic production alongside similar technological styles.

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## CHAPTER ONE – INTRODUCTION

Mapungubwe is a thirteenth century settlement located at the confluence of the Shashe and Limpopo Rivers, and is commonly referred to as the first state society in southern Africa (e.g. Calabrese 2000). Ceramics from this region have been studied and classified into style groupings or *facies* (e.g. Huffman 2000; 2007).

In recent decades, stylistic schema has come under review as archaeologists have pressed the need to analyse ceramics beyond their stylistic features alone. One alternative is a ceramic technology approach that seeks to examine pottery production and decisions made by the potter throughout the production process (Sillar and Tite 2000). These choices can often be a behavioural reflection on the complex daily dynamics within a community (Dobres and Hoffman 1994, Killick 2004, Pfaffenberger 1988) and allows for a more nuanced approach when combined with traditional stylist approaches.

This research will focus on two closely situated Mapungubwe hinterland sites found in the Klein Bolayi Game Lodge 50km east of Mapungubwe and approximately 14km south of the Limpopo River. The sites Evelyn (EV01, GPS 22°17'39"S 29°51'09"E) and Klein Bolayi (EV02, GPS 22°17'11"S 29°51'44"E) were selected for this study of ceramic technology. Radiocarbon dating produced dates of approximately AD 1028 – AD 1300 for Evelyn and AD 1020 – AD 1225 for Klein Bolayi. The ceramic assemblages of both sites were analysed through chemical and petrographic analysis of Evelyn and Klein Bolayi through applying a ceramic technology approach. Stylistic analysis (see Rossouw 2021), shows the prevalence of K2, TK2 and Mapungubwe facies ceramics present in the assemblages of Evelyn and Klein Bolayi. Based on the ceramic assemblages, both sites were identified as TK2 sites.

### 1.1 Research Questions and Aims

This research aims to analyse ceramic pastes chemically and mineralogically to answer the following research questions and gain a better understanding of the two sites from a technological viewpoint.

1. What is the relationship between the clay of Evelyn and Klein Bolayi?

2. What technological features can be observed in the ceramics of Evelyn and Klein Bolayi?
3. What assumptions can be made on the locality of the ceramics based on the local geology?

The aim of this study was to apply various analytical techniques in order to analyse the clay and technological features of the ceramics at Evelyn and Klein Bolayi. This was done through means of macroscopic fabric analysis, portable x-ray fluorescence, and petrographic analysis. Chemical and mineralogical analysis of ceramic body sherds from Evelyn and Klein Bolayi were used as means of understanding technological processes applied at both sites. This included clay compositions, forming methods, tempering agents, and relative firing conditions. Any differences or similarities were sought out as a way to understand the relationship between Evelyn and Klein Bolayi. Local geology was also taken into consideration during processing of mineralogical analysis to speculate whether pottery was produced using local clay sources or from outside of the local region.

## **1.2 Thesis Overview**

Chapter two serves as a background chapter discussing the Shashe-Limpopo Confluence Area and its hinterland as well as presenting the research area, followed by a discussion of the methodologies selected and applied to this study.

Chapter three discusses the ceramic production process along with various approaches to ceramic analysis with an emphasis on ceramic technology and technological style which was implemented in this research.

Chapter four provides the step by step process of how the analytical methods were applied during the study as well as how the results were processed.

Chapter five presents the results of macroscopic observations, pXRF data processed into meaningful graphs, and thin section reports and observations.

Chapter six applies the results of the research into an archaeological context as to answer research questions.

Chapter seven concludes and summarises the study as well as presents ideas for future research in relation to this study.

## **CHAPTER TWO – BACKGROUND**

The Shashe-Limpopo Confluence Area (SLCA) in Limpopo, South Africa, is believed to be the setting for the first signs of social complexity within southern Africa during the Middle Iron Age (Calabrese 2005, Huffman 2007a; 2015). The focus of this research was on two sites in the Greater Mapungubwe Landscape (GML), approximately 50km east of Mapungubwe. This chapter focuses on the Middle Iron Age sequence within the SLCA as to provide for background context for this study. The research sites, Evelyn (EV01) and Klein Bolayi (EV02) will be discussed along with the applicable methodology selected for this research.

### **SHASHE LIMPOPO CONFLUENCE AREA**

#### **2.1 Iron Age Sequence of the Shashe-Limpopo Confluence Area**

The earliest ceramics found in the SLCA date back to the Early Iron Age, between AD 500 and AD 750 (Huffman 2000; 2008: 2036, Meyer 1998). These ceramics, found in the lower stratigraphic layers at the base of Mapungubwe hill were stylistically similar to Happy Rest ceramics found near Louis Trichardt (Huffman 2008, Meyer 1998). The lack of evidence of archaeological sites shows the likelihood of very short occupation periods during this time. Unfavourable climatic conditions within the area then meant these communities would have probably left in search of a better landscape to settle in (Huffman 2008). Hereafter, the SLCA remained largely unoccupied until around AD 900.

The Middle Iron Age starts with the influx of new settlers in the SLCA at around AD 900. These communities using and making Zhizo ceramics entered the area and established their settlement in the SLCA. One of the largest settlements during this period was Schroda (Hanisch 2002, Huffman 2000, Meyer 1998). It was initially believed that this new movement of people into the region was due to climatic and agricultural conditions becoming once again favourable for settlement and agricultural activities (Huffman 1996). Higher rainfall associated with the onset of the Medieval

Warm Epoch was speculated to be the driving force behind this influx of people settling into the SLCA (Huffman 1996: 57, Meyer 1998). Subsequent analysis of stable nitrogen isotopes (See Smith et al 2007), however found that the climate of AD 880 – 1010 was in fact drier than formerly speculated. The SLCA instead showed climatic conditions similar to that of present day SLCA with semi-arid conditions with an average rainfall of between 350mm- 450mm per annum. This made the area largely unfavourable for dryland agricultural practices.

Trade has been postulated as a possible factor for the migration into the valley. One hypothesis suggests that large elephant herds would have attracted new settlers, as ivory was very valuable within the Indian Ocean trade networks at the time (Calabrese 2005: 35, Huffman 2000). Forssman et al (2014), found that the elephant population was indeed high enough to allow for substantial ivory trade with the Indian Ocean trade networks. Evidence in the archaeological record has shown significant amount of ivory and ivory processing found within the SLCA, especially at Schroda (Calabrese 2005: 35, Meyer 1998, Raath 2014). Schroda is believed to have shown the earliest signs of the interior having trade connections with the Indian Ocean trade networks (Huffman 1996: 56, Wood 2000: 79). This allowed for the exportation of ivory as well as metal artefacts in exchange for glass beads, cowrie shells and soapstone beads amongst other foreign prestige goods (Huffman 2000, Meyer 1998, Raath 2014, Wood 2000). These trade connections allowed Schroda to have strong influence over the immediate landscape.

Around AD 1000, new communities entered and settled in the SLCA (Huffman 1996; 2000). These new settlers, associated with their distinctive Leopard's Kopje ceramics, settled in large communities throughout the valley. Over time though, one community known as K2 seems to have claimed control over the wider region, establishing it as a political capital with control over the foreign trade networks (Calabrese 2005: 41, Huffman 1996).

Initially it was speculated that the new Leopard's Kopje using community had forced all the Zhizo users out of the area (Huffman 1996: 56), but later Calabrese (2005), demonstrated that some communities remained behind as a political underclass. Re-examination of ceramics at Schroda found that Zhizo making communities continued to live in the area but slowly started adding stylistic elements of Leopard's Kopje

ceramics into their own (Calabrese 2000a; 2007, Antonites 2018). This new facies of ceramics was called Leokwe ceramics (Calabrese 2000a; 2007). Leokwe using communities and the Leopard's Kopje using communities then co-existed in the landscape for about 200 years before becoming fully absorbed into the Leopards Kopje community (Calabrese 2000, Vogel and Calabrese 2000). These Leokwe ceramics were present on the landscape until roughly AD 1200 (Calabrese 2005: 372). During this period, it is estimated that the SLCA underwent a significant population increase (Huffman 1996; 2000, van der Walt 2012: 20).

The settlement had moved from K2 to Mapungubwe Hill between AD 1200 and AD 1220 about one kilometre away (Meyer 1998: 263, Calabrese 2000a, Huffman 2000). Many changes occurred during this move including ideological changes and settlement pattern changes. Huffman, (1986, 2007) identified the three largest shifts from K2 to Mapungubwe's reign as the movement of the cattle kraal which was previously positioned within the centre of the settlement. The second shift was that of spatial separation of the community with the ruling elite settling on Mapungubwe's summit with the commoners residing below on the southern terrace. This shift was represented through the three spatially separate occupation areas of Mapungubwe based on class. The hilltop, the southern terrace and the area surrounding the hill all were a vertical representation of this socially stratified community (Meyer 1998: 5). The third change was the introduction of stonewalled structures as a mean of controlling area access (Huffman 2000). Huffman (2000), believed these changes to be a large contributing factor in the development of the socially stratified society at Mapungubwe. This period also showed a rise in the use of foreign trade goods as a measure of wealth beyond the former wealth marker of cattle.

The introduction of sacred leadership along with social stratification presented through designated living spaces reinforced the new class-based society of Mapungubwe. This allowed those of higher status better access to resources such as prestige foreign goods, which would in turn solidify their social rank. Stratification was further reiterated through the restriction of access to certain areas within the site (Calabrese 2005: 41). With the shift from cattle wealth to prestige goods as form of wealth, elites and those with higher social rankings possessed much larger quantities of prestige goods than commoners (Calabrese 2005: 43). This was also reflected in high status burials on Mapungubwe Hill which yielded thousands of gold beads as

opposed to the relative absence of elite funerary goods in commoner graves (Calabrese 2005: 25, Huffman 2000, Meyer 2000).

It is speculated that during Mapungubwe's peak it was home to upward of 5000 people and by AD 1300, it was abandoned (Calabrese 2005: 37, Huffman 1996; 2000:23; 2009). Many associated the decline of Mapungubwe to the climatic changes of drier, colder weather of the Little Ice Age, which would have negatively affected agricultural activities (Huffman 2000, Calabrese 2005). Mapungubwe pottery could still be found in the surrounding landscape well after the decline of the Mapungubwe capital (Calabrese 2005: 38). It was theorized that Great Zimbabwe became the successor of Mapungubwe after its decline (Huffman 2009: 15), but recent studies reanalysing radiocarbon dates and material culture found Great Zimbabwe to have been contemporaneous with the sites in the SLCA a hundred years earlier than originally thought (Chirikure et al 2013: 345). Another theory is that the rise of Great Zimbabwe made it possible for them to overthrow Mapungubwe's control over trade networks (Pikirayi 2002). With direct access to gold mines, Great Zimbabwe had vast amounts of gold for trade purposes which became especially beneficial during the switch from cattle wealth to prestige goods wealth (Woodborne et al 2009).

## **2.2 Central Capital's Relationships with Hinterland Sites**

The SLCA, with its rapid rise in social complexity was, by the time Mapungubwe was the capital, believed to control over an estimated 30 000km<sup>2</sup> of land (Huffman 2009). Mapungubwe was thought to have full hegemony over the Greater Mapungubwe Landscape (Huffman 2009; 2015). Within this 30 000km<sup>2</sup> sphere, Mapungubwe was believed to be the sole capital of the landscape and would have exclusive control over redistribution of prestige goods acquired through the Indian Ocean trade networks.

Huffman and Hanisch (1987), presented their model of a five level ranking for the hierarchical system of the landscape. Levels one and two were the family heads and ward headman who resided on smaller sites and were often referred to as commoners. Level three belongs to the petty chiefs whose sites were often three times larger than those of levels one and two. These sites would often have a court where the chief would sit and watch others below. Level four was of senior chiefs with the sites being

significantly larger than those of levels one through three. Lastly, level five ranking sites were those of paramount chiefs with the largest sites and better architectural values. Level five sites were seen to have had the most control over the landscape they resided in. Mapungubwe was classified as a level five site with paramount chiefs and elites who ruled the landscape. Level five ranking sites were associated with a vast amount of prestige goods, which solidified ones ranking at an intra and inter-site level. It was widely accepted that to acquire prestige goods was a direct reflection of elites having influence over trade to acquire trade goods (Calabrese 2005: 63).

Through many excavations and analyses of hinterland sites (see Antonites and Ashley 2016), it has been found that communities classified as lowest ranking levels have presence of prestige goods, such as glass beads, marine shells and imported celadon (Lippert 2019). By reviewing these facts one must consider the level at which peripheral sites were truly controlled. Rather, it is more likely that instead of playing a passive, submissive role within the landscape, hinterland sites were active agents contributing to the larger network throughout the landscape (Antonites 2012: 270). These smaller sites had their own independent authoritative roles within their own communities, which could not have been fully controlled by the SLCA capital. It is more likely that the capital within SLCA had the control over daily living of the sites in the direct vicinity with dwindling direct control the further away a site was (Antonites 2012: 270, Antonites and Ashley 2016). Peripheral sites were likely to have used their level of power, no matter how seemingly insignificant, to gain access to items of foreign wealth.

Archaeological evidence of metal smithing has been found all over the SLCA along with metal artefacts (Calabrese 2000b, Miller 2001). Research has shown that the SLCA geologically has little to no immediate ore deposits within the area (Calabrese 2000b: 106, Hanisch 1980, Jacobson 2005). This meant that all metal ores or ingots were acquired through local trading networks with hinterland sites, therefore the SLCA sites relied on peripheral sites for metals. The closest copper mines were situated in Musina (Calabrese 2000b), with copper smelting having been evident in the SLCA but lacking the raw copper themselves. Peripheral sites within range or having territorial control over such pieces of land with ores would have been at an advantageous position to acquire goods from the capital. Mapungubwe would have likely relied on the trade goods and raw materials from peripheral sites to reinforce

their political power (Antonites and Ashley 2016). This meant that hinterland sites could use their local ores as means of acquiring foreign goods from the centre as Mapungubwe fully relied on hinterland site raw metals.

### **2.3 Ceramic Facies Associated with the SLCA**

Ceramic facies refer to groups of stylistically similar ceramics associated with a certain period and geographical setting (Huffman 2009: 117). These ceramic facies have also been used in reference to the specific groups of people making these ceramics as well as their associated time frame and general geological location. The following facies are very useful during ceramic studies of the Greater Mapungubwe Landscape and are commonly found within the Shashe-Limpopo Confluence Area.

Zhizo ceramics first appeared around AD 900 in the SLCA and are distinguished by slanting incisions and comb stamping along lower rims, triangles stamped and a horizontal line of stamping on the upper shoulder, (Huffman 2000, 2007a: 145). Necks of recurved jars were often decorated with comb stamping and bead bangle impressions (Calabrese 2005: 307).

The Leokwe facies, originally identified by Calabrese (2000a, 2005), dates back to around AD 1000. This facies was created by Zhizo making potters who had remained within the confluence area and interacted with the Leopard's Kopje making communities. Leokwe ceramics have Zhizo similarities but with higher prevalence of incisions and decrease in comb stamping (Calabrese 2005: 325). Rim decoration had disappeared as well as had less placement on the central neck. Decorative motifs were then more prominent on lower necks and shoulders (Calabrese 2005: 325).

Co-existing with Leokwe ceramics in the SLCA, the Leopard's Kopje tradition was linked with the influx of new groups (Huffman 1996; 2000). K2 ceramics have incision stamping and decoration on the lower neck or shoulder (Huffman 2007a:281; 2007b), as well as hatched bands on the neck and bottom of beakers with triangle incisions along the neck (Huffman 2007a: 281). K2 ceramics have been dated to between around AD 1000 and AD 1200 (Huffman 2007a: 279).

Between K2 and Mapungubwe, a transitional ceramic facies has been identified called transitional K2 or TK2 (van der Walt 2012). TK2 ceramics are decorated with upward

triangles on the lower neck and upper shoulder as well as alternating triangles on the shoulder of beakers (Huffman 2007a: 283).

Mapungubwe ceramics have more complex motifs than K2 ceramics (Huffman 2000). Crosshatched triangles and other complex motifs along the shoulder were popular of this facies (Huffman 2007a: 287; 2007b), as well as dark burnished bowls (Huffman 2007a: 287).

## **SITE BACKGROUND**

### **2.4 Klein Bolayi Game Lodge**

The Klein Bolayi Game Lodge, which is situated roughly 50km east of Mapungubwe, is home to ongoing archaeological research by A. Antonites and C. Ashley. The two sites, Evelyn (EV01) and Klein Bolayi (EV02) that form part of this research were excavated in 2015 and 2016 respectively. The sites are situated approximately 1.3km from each other. The small perennial river, the Klein Bolayi River runs approximately 700m east of the sites.

The game lodge itself was named after the large, distinctive granite outcrop situated within the lodge itself. Similar granitic outcrops can be found within the reserve on a much smaller scale. Numerous baobab trees can be found scattered throughout the terrain. Both sites form part of a larger series of ongoing research on hinterland sites of the SLCA.

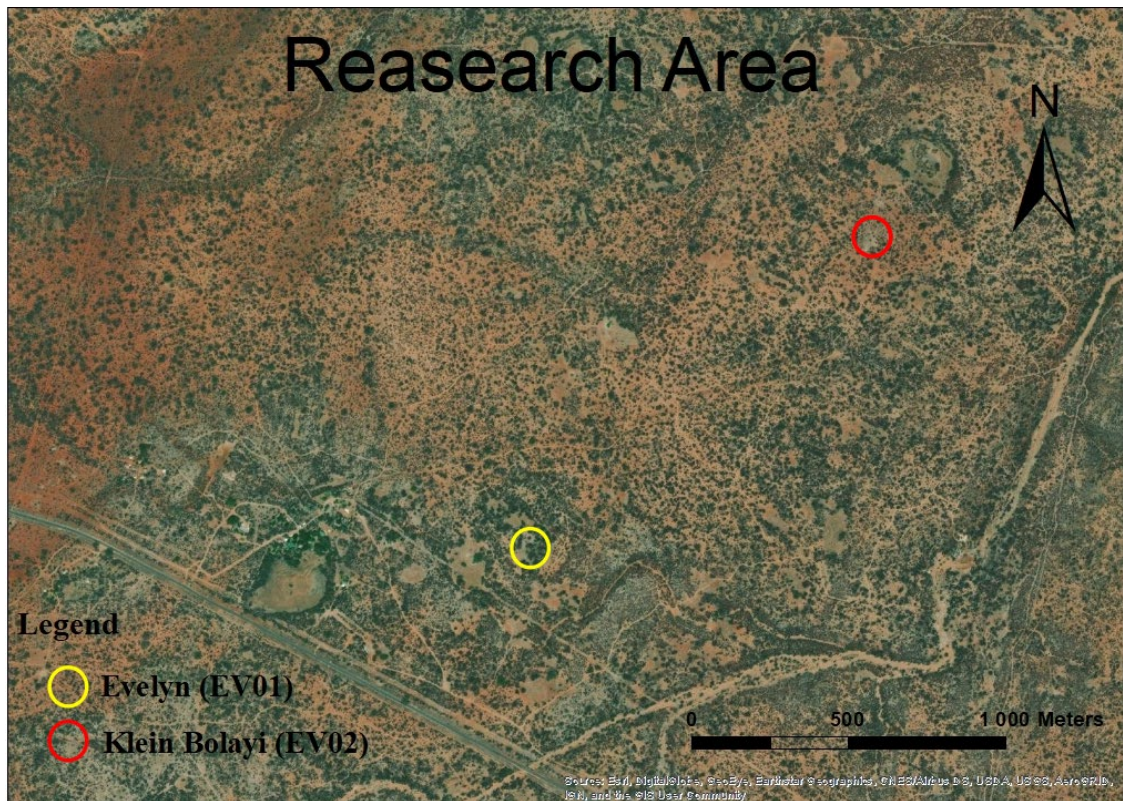


**Figure 2-1: Research area**

## 2.5 Landscape Overview

The semi-arid northern region of the Limpopo province experiences annual summer rainfall varying from 140mm to 500mm per annum with prolonged periods of hot and dry weather (Meyer 1998; 4). The rainy season spans from October to March with January and February seeing the peak rainfall (Smith 2005). The summer seasons see an average temperature of around 32°C while winter months have an average of 22°C. Vegetation of this area is abundant with low lying Mopani bushveld (*colophospermum mopane*) among the thick grassveld as well as Acacia trees. In the valleys larger species of trees can be found, most notably Baobab trees. (Meyer 1998; 4).

## 2.6 Local Geology

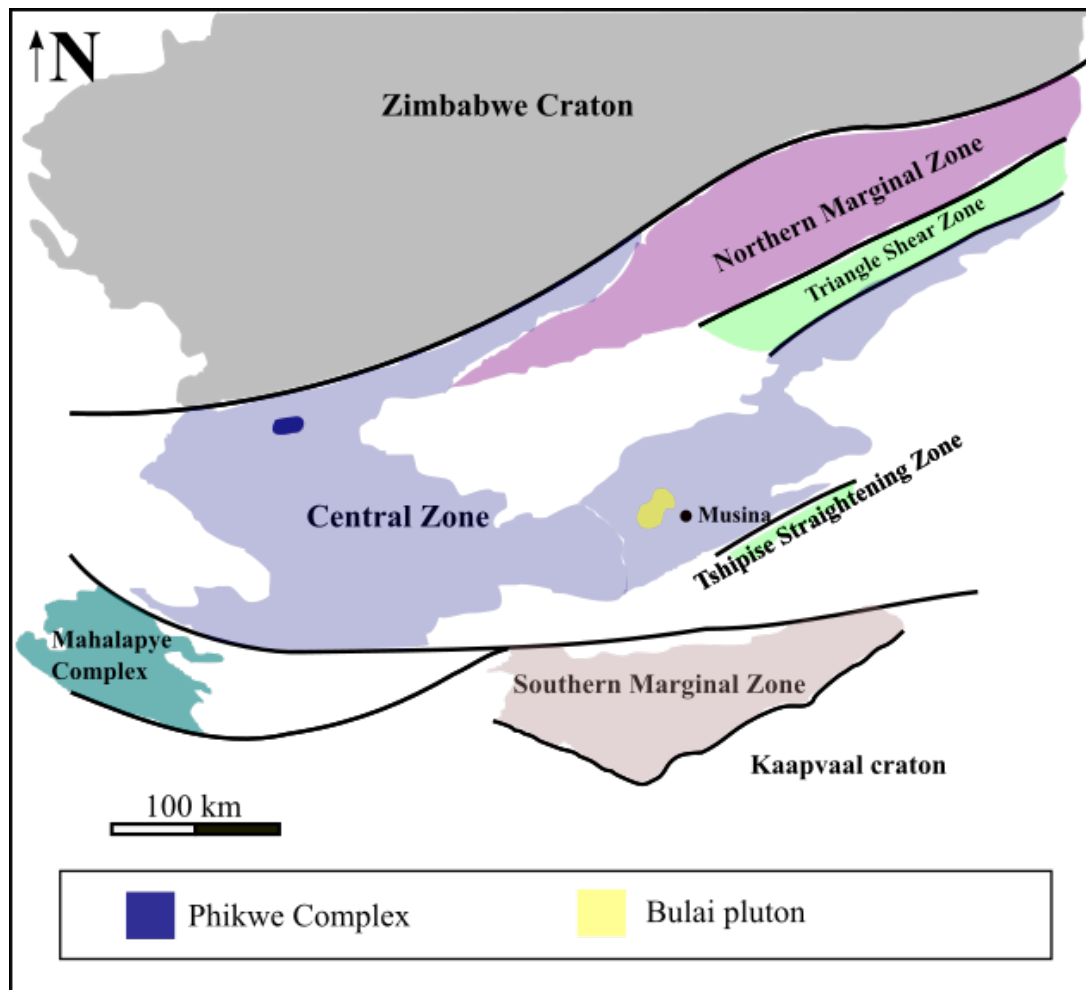


Figure 2-2: Simplified geology of the Limpopo Mobile Belt (Adapted from Brandt et al 2018)

The Limpopo Mobile Belt (LMB) is a low lying belt rich in granulite rock outcrops that is of a late Archean age (Chinoda et al 2009: 10). The high-grade metamorphism present in the belt has been speculated to be the result of tectonic continental collisions which occurred around 2.7 Ga and 2.65 Ga (Flattery 2005: 1, Millonig et al 2008: 334). The LMB, spanning roughly 600km long and 250km wide (Brandt et al 2018: 472), can be found in the northern region of the Limpopo province in South Africa as well as in eastern Botswana and southern Zimbabwe (Chinoda et al 2009: 10). The belt runs between the northern Zimbabwe craton and the southern Kaapvaal craton, both of granite-greenstone lithology (Brandt et al 2018, Chernicoff 1984: 6, Chinoda et al 2009, Millonig et al 2008: 334).

Based on lithological properties, the LMB has been subdivided into three distinct tectonic domains namely; the Northern Marginal Zone (NMZ), the Central Zone (CZ), and the Southern Marginal Zone (SMZ) (Chinoda et al 2009: 10, Chernicoff 1984). The NMZ lithologically is comprised of granulite-facies charno-enderbitic and enderitic orthogneisses as well as greenstones and granitoid rocks (Kröner et al 2018: 320, Zeh et al 2007: 1606). Whereas the high-grade SMZ consists of tonalitic, trondhjemitic and granodioritic rocks with instances of greenstones (Zeh et al 2007: 1606).

### **2.6.1 The Central Zone**

The Central Zone (CZ) is a lithologically unique terrane when compared to the SMZ and the NMZ. The CZ, which will be discussed more in depth as the research area falls therein, is comprised of amphibolite to granulite-facies granitoid gneisses as well as supracrustal sequences (Kröner et al 2018: 320). The Central Zone is separated from the two marginal zones by two major shear zones namely; the Palala Shear Zone/ Tshipise Straightening Zone which separates it from the SMZ, and the Triangle Shear Zone separating it from the NMZ (Brandt et al 2018: 472, Chinoda et al 2009: 10). These shear zones are believed to have formed around 2.0 Ga due to high-grade metamorphic events (Zeh et al 2007: 1606).

The basement suite of this zone is commonly referred to as the Sand River Gneiss, comprising of greyish hypersthene and quartz rich rocks with high amounts of diorite and granodiorite as well as plagioclase, biotite, hornblende and K-feldspar (Chernicoff 2009: 9, Chinoda et al 2009: 24, Kröner et al 1998: 202). The exact colour of the gneiss can range from dark to light grey based on its exact geographical location (Kröner et al 1998: 202). Although considered to be the basement suite, isotopic research by Zeh et al (2007) shows that the oldest crust which was formed within the CZ was fully formed roughly 300 to 400 Myr earlier than the establishment of the Sand River Suite.

Quartzo-feldspathic gneisses, such as the Singelele Gneiss are the most common gneisses within the CZ. These gneisses have varying compositions of quartz, feldspar, amphiboles, mica, garnet and pyroxene (Chinoda et al 2009: 25).

The Central Zone was further subdivided into three metamorphic complexes originally by Aldiss (1991), but then later revised by Barton et al (2006). Firstly the Mahalapye Complex occurring in the southwest region of the CZ, the Phikwe Complex found in the northwest region, and the Beit Bridge Complex found in the central-east region of the CZ.

### **2.6.2 Beit Bridge Complex**

The Beit Bridge Complex is an umbrella term given to the supracrustal rocks of the basement suite of the CZ (Chinoda et al 2009: 24). The Beit Bridge Complex, a large complex spanning approximately 300km long and 200km wide can be found in the central-eastern area of the CZ (Brandt et al 2018: 472). The supracrustals of the Beit Bridge Complex have been seen to be interfolded within the Sand River Gneiss and as such has proven difficult to definitively age and define the distinction between the two. The Beit Bridge Complex was not merely formed uniformly onto of the Sand River Gneiss (Kröner et al 1998). The Beit Bridge Complex within the Musina area consists of metaquartzite, quartzo-feldspathic gneisses, and marble with metaelite inclusions, amphibolite, calc-silicate rocks and quartzite with magnetite (Kröner et al 1998: 203). The Beit Bridge Complex is also host to various granitic and granodioritic orthogneisses, for example the Alldays, Bulai, Zanzibar, Singelele, Zoetfontein and Verbaard gneisses (Brandt et al 2018: 472, Zeh et al 2007: 1607). Garnet can be found within majority of these supracrustals (Chinoda et al 2009).

### **2.6.3 Bulai Pluton**

This granitic intrusive body found west of Musina can be found throughout the Klein Bolayi Game Lodge and beyond. The large granitic rock near the entrance of the lodge is a true example of the Bulai pluton as well as a larger version thereof, Groot Bolayi, which is situated south-east of the Klein Bolayi Game Lodge. The calc-alkaline pluton was distinguishable from around 2.6 Ga and comprises of granite, granodiorite, charno-enderbite, enderbites as well as K-feldspar (Brandt et al 2018: 474, Flattery 2005: 25-26, Laurent et al 2011: 74). Leucogranites, quartzodiorites and tonalities are also common within this pluton as well as the presence of many

xenoliths of surrounding gneisses can be found throughout (Flattery 2005, Millonig et al 2008: 18). Common hand specimens of the pluton are porphyritic granodiorite which are reddish in colour (Laurent et al 2011: 76).

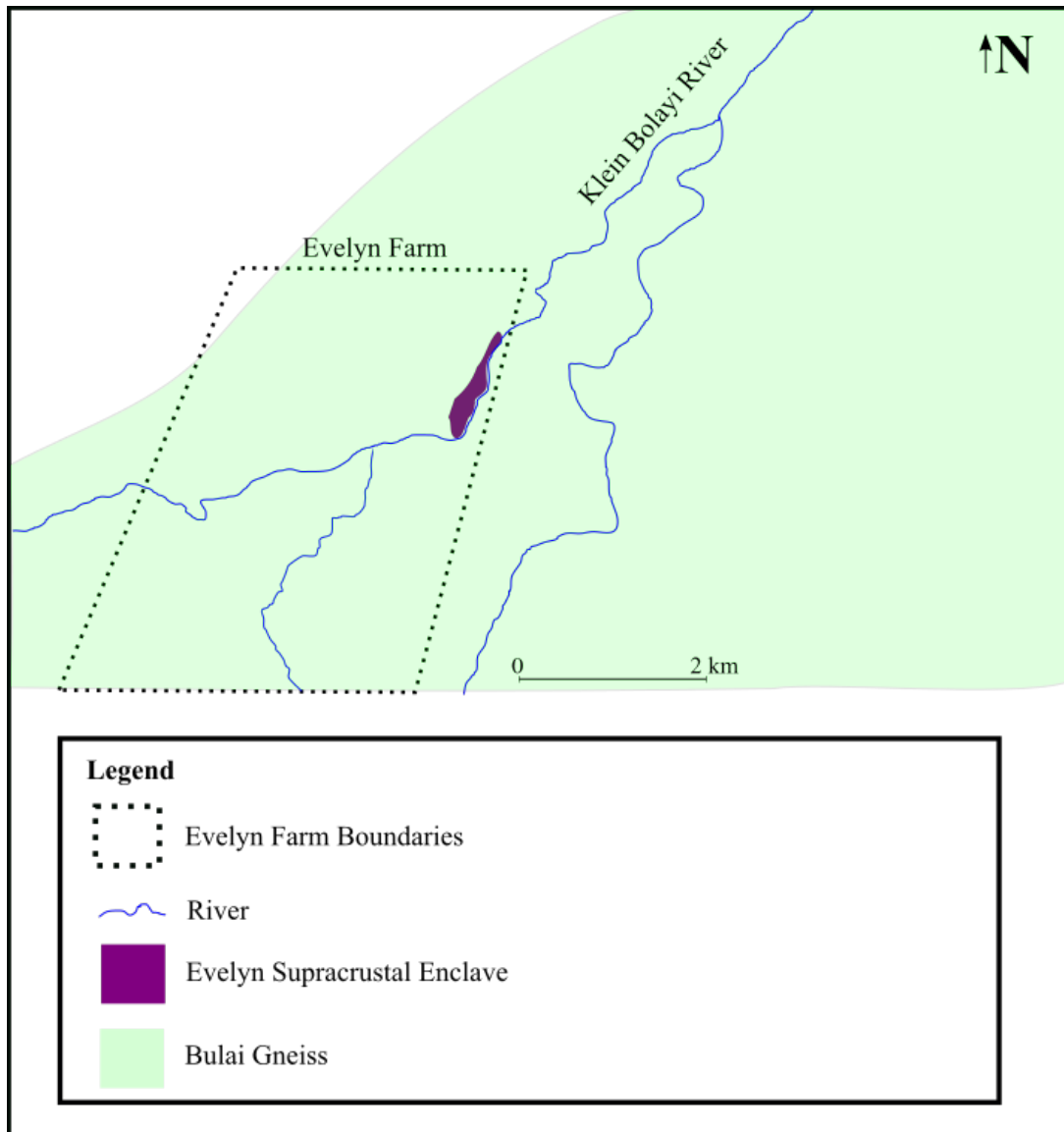


**Figure 2-3: Geology map depicting Bulai Gneiss and Evelyn Supracrustal Enclave (Adapted from Brandt et al 2018)**

#### 2.6.4 Evelyn Enclave

In recent field research (Brandt et al 2018: 474), a 700m long enclave named the Evelyn enclave was distinguished amidst the Bulai Pluton. The enclave can be found near the riverside of the Klein Bolayi River. The lithology of this enclave shows

presence of calc-silicate gneiss, magmatic metapelite, meta-anorthosite and tonalitic to granitic gneisses (Brandt et al 2018: 474).

### **2.6.5 Bulai Gneiss**

To the west of Musina, running through Klein Bolayi Game Lodge, appears the Bulai gneiss which consists of coarse grained porphyritic rocks of a brown and pinkish hue (Barton et al 1979: 260, Chinoda et al 2009: 22). In this porphyritic gneiss, one can find plagioclase, quartz, biotite, hypersthene, hornblende and garnet (Barton et al 1979, Chinoda et al 2009: 22). The Bulai gneiss is also known for having rich granitic deposits throughout (Barton et al 1979: 260). The Bulai gneiss was established around 2700 million years ago and the current level of the terrain was estimated to have been reached 1950 million years ago (Barton et al 2009: 265).

Petrographic research by Brandt et al (2018), within the CZ, more specifically along the Klein Bolayi River, found high inclusions of pyrite and chalcopyrite within the hand specimens of the research. Pyrite most commonly occurs within quartz veins of rock formations.

## 2.7 Evelyn (EV01)

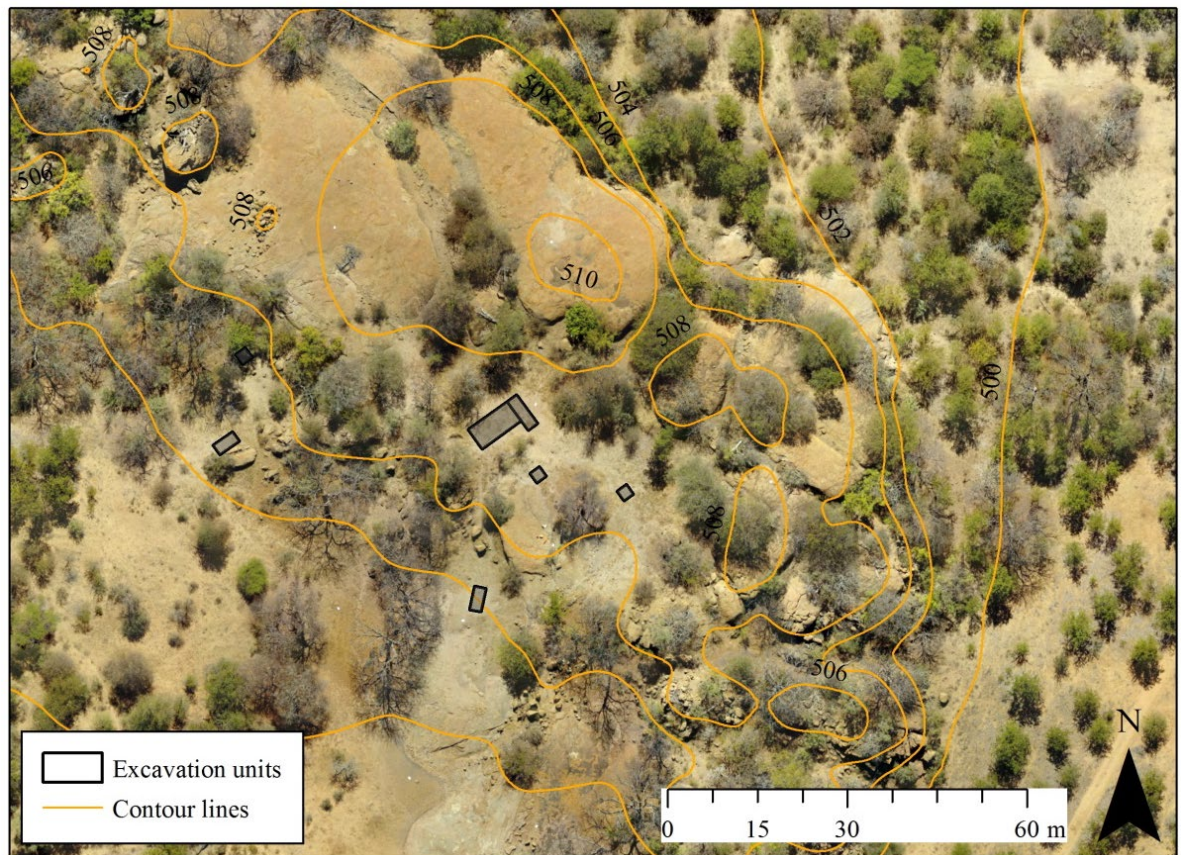


**Figure 2-4: Site overview of Evelyn (Lippert 2019)**

Evelyn, also referred to as EV01 (GPS 22°17'39"S 29°51'09"E) is situated on a rocky outcrop occupying an area of approximately 180m x 100m. Majority of the archaeological material is located on the eastern section of the rocky outcrop as well as just below it to the south. On the western end of the site there is a small 2m x 2m space located between two boulders and has a small midden, and a lower grindstone located within it. This space was most likely associated with ceremonial practices as it is small and isolated from the rest of the site. Between this space and the rest of the site to the east, the outcrop widens and forms a flat granitic platform which is speculated to have been used as a surface for the construction of huts. At the eastern edge of this platform there is a household midden and an associated grain bin base, with a kraal 10m to the east and another kraal 20m to the south just below the outcrop. To the south of the granite platform there are two grain bin bases and evidence of wash from a midden which has accumulated against the eastern side of a boulder.

### 2.7.1 Evelyn Context Descriptions

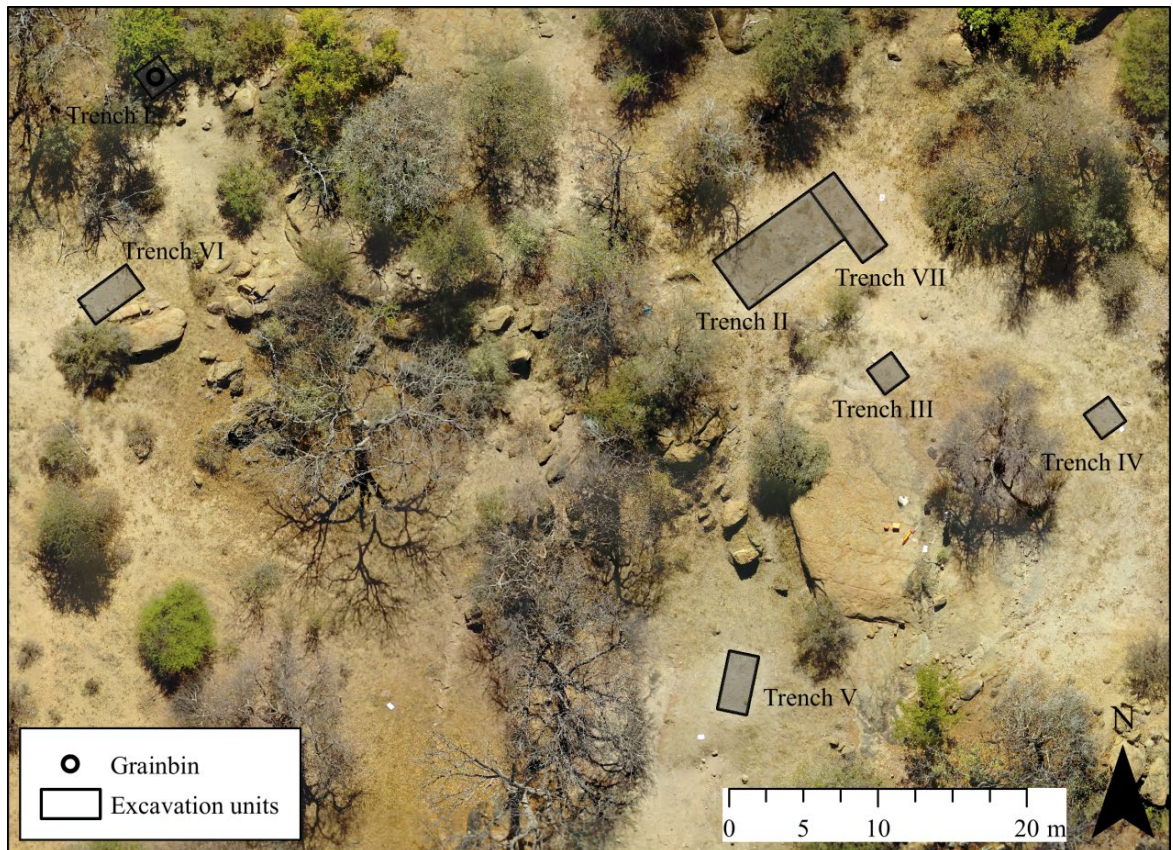


**Figure 2-5: Excavation units of Evelyn (Lippert 2019)**

Excavations at Evelyn were done in 2015 whereby seven excavation units were excavated at Evelyn, covering a total of 72m<sup>2</sup>.

#### **Trench I (N971 E946)**

This trench is 2m x 2m in size and is situated on the western slope of the site. Two grain bin bases were excavated within this trench and is comprised of the following contexts:

- C1015: Sandy surface context.
- C1016: Gravelly wash layer that has collected between the grain bin bases.
- C1017: Material excavated from between the stones was removed as a single context for flotation.

### **Trench II and VII (N1000 E967)**

Trench II, a 10m x 2m trench was later joined with Trench VII to create an 'L' shape which is situated on a south facing slope of the site.

- C1001: A layer of loose brown surface sand with root disturbances and slight erosion.
- C1002: Gravel wash layer washed down from the rock outcrop to the north.
- C1003: A bone rich deposit made up of looser soil with a high inclusion of very friable animal bones.
- C1004: Grey ashy midden deposit with a marked decrease in material culture and bone inclusions. A human burial was found within this context.
- C1005: A small shallow pit removed as a contained unit. This context appears within C1004.
- C1006: Dark reddish grey ashy lens with an increase in gravel and daga inclusions. This context only appears and ends on packed gravel flooring in both units.
- C1007: Household floors that were not excavated.

### **Trench III (N1014 E999) and IV (N1004 E998)**

Both of these 2m x 2m trenches are situated on the south east side of the site with the following contexts present:

- C1008: Loose surface layer slightly darker brown than other areas of the site with a loamy texture.
- C1009: A dark reddish grey gravel wash layer with an increase in material culture towards the bottom of the unit. Small ashy inclusions as well as yellowish dung also appear towards the bottom of context.
- C1010: Reddish yellow dung layer. Contained large chunks of intact dung and burnt dung towards the bottom.
- C1011: Brown sterile sandy layer that ends on bedrock in both units.

### **Trench V (N983 E1000)**

This trench which is 4m x 2m in size is situated near the base of the southern slope and is comprised of the following contexts:

- C1012: Loose surface greyish brown sandy deposit with ashy inclusions.
- C1013: Greyish brown ashy deposit containing slight gravel inclusions towards the bottom.
- C1014: Dung layer that contains ashy burnt inclusions and ends on sterile soil.

### **Trench VI (N961 E942)**

This 4m x 2m trench has similar stratigraphic layers to Trench I and is comprised of the following contexts:

- Both C1015 and C1016 are present in this unit.
- C1018: Brown possible midden deposit that has collected against the boulder.

## **2.7.2 Material Culture of Evelyn**

### **2.7.2a Small Finds**

A burial of an elderly woman was uncovered within the midden deposit of context C1004. Glass beads were found surrounding the skeleton itself with the surrounding soil being collected as a flotation sample as to ensure a full collection of the glass beads. Within the same stratigraphic context of the burial, a complete ceramic pot was found containing glass beads. Majority of the glass beads found at Evelyn were found in close vicinity to the skeleton (n= 426), as well as within the complete pot (n=400) near the skeleton (Lippert 2019: 91). In totality, 951 glass beads were found at the site. Analysis of these beads by Lippert (2019), shows the high probability of these glass beads belonging to a combination of the K2 Indo-Pacific and East Coast Indo-Pacific bead series. The vast amounts of beads surrounding the burial shows the deliberate practice of additions of grave goods within a burial. The site had a total of

186 disk beads, with all but 3 made from ostrich eggshell, while the other 3 were made from *Achatina* shell (Lippert 2019: 93).

Metal artefacts found were predominantly that of iron and copper which included; iron bars, metal plates, helixes, a possible pendant and two solid copper interconnected bangles. Slag was also found throughout the site with majority being found within midden areas and the kraal. This could relate to an indication of metal working activities occurring at a site level (Lippert 2019).

A single, broken cowrie shell was found at Evelyn. It appears the dorsal surface had been removed and smoothed down (Lippert 2019; 98).

### **2.7.2b Ceramic Artefacts**

A total of 17 ceramic spindle whorl fragments were found along with one whole spindle whorl. As cotton does not preserve within the archaeological record, spindle whorls are used as indicative of spinning at a site (Antonites 2019: 6). The presence of spindle whorls at the site indicates the spinning of cotton fibres at Evelyn.

Within an ashy midden deposit, an oval shaped figurine made of clay was found. The figurine appears to have been broken off of another piece but the lack of further fragments meant the shape and function remains undetermined (Lippert 2019: 98).

Huffman's (1980), standardized stylistic analysis approach was applied to the diagnostic ceramics. The combination of vessel morphology, decorative motif, and placement of motif were analysed to define ceramic typologies present at Evelyn (Rossouw 2021). Profile types identified at Evelyn include recurved jars, bag-shaped jars, bellied jars, constricted bowls, beakers, open bowls, beakers, open bowls, necked bowls, incurvate bowls, plates, and miniatures. Bellied jars were the predominant profile type present within the site whereby 51% of the vessels were bellied jars (Rossouw 2021). A total of 119 motifs were identified from Evelyn and Klein Bolayi and then grouped into eleven motif types. The combination of profile types and motif types were used to create ten ceramic types with further sub-types for the two sites which was then compared to known ceramic facies (see Rossouw 2021).

Bellied jars with incised triangles on the lower neck and upper shoulder belonging to the TK2 facies was the dominant ceramic type present at Evelyn. Five bellied jars

with arcades were also identified within Evelyn as belonging to the TK2 ceramic facies. Bellied jars with horizontal bands on the shoulder of the K2 facies were also identified. Two beakers and spouted vessels, indicative of the K2 facies were identified within the assemblage. Downward facing, cross-hatched triangles on the shoulder and interlocking triangles on the shoulder of the Mapungubwe facies were also identified at Evelyn.

One bellied jar and bag-shaped jar with herringbone decoration and fine ladder-stamping of the Eiland facies was found at Evelyn. This outlying facies could represent the occurrence of trade or inter-group marriage.

The presence of K2, TK2, and Mapungubwe ceramics at Evelyn coincide with the radiocarbon dates of AD 1028 – AD 1300 during which these ceramic facies are commonly found within the Greater Mapungubwe landscape. Based on this, Evelyn was classified as a TK2 site (Rossouw 2021).

### **2.7.3 Radiocarbon Dates of Evelyn**

Ten charcoal samples from Evelyn were sent to Direct AMS for radiocarbon dating. Results were calibrated using the Southern Hemisphere calibration curve and were plotted in OxCal v4.4. Samples D-AMS 028776 and D-AMS 028779, were from context C1014. The 2-sigma calibrated date of D-AMS 028776 was cal. AD 1045-1212 and D-AMS 028779 was cal. AD 1187-1217 (Rossouw 2021: 28). D-AMS 028778 from the bone rich lens of C1003 returned a calibrated date of cal. AD 1220-1279. Sample D-AMS 028777, from context C1004 returned a calibrated date range of cal. AD 1014-1206. D-AMS 028780 from context C1010 of the kraal returned a 2-sigma calibrated date of cal. AD 1045-1209. D-AMS 028781 and D-AMS 028782 from context C1002 were combined and returned a 2-sigma calibrated date of cal. AD 1180-1266. Samples D-AMS 028783, D-AMS 028784 and D-AMS 028785 were from context C1004, in relation to the burial found. The dates were combined and returned a 2-sigma calibrated date range of cal. AD 1150-1200.

**Table 2-1: Radiocarbon dates from Evelyn (Rossouw 2021)**

| <b>Laboratory Number</b> | <b>Uncalibrated age BP</b> | <b>1-Sigma range (cal. AD)</b> | <b>2-Sigma range (cal. AD)</b> |
|--------------------------|----------------------------|--------------------------------|--------------------------------|
| D-AMS 028776             | 943± 27                    | 1050-1187                      | 1045-1212                      |
| D-AMS 028777             | 951± 29                    | 1047-1183                      | 1041-1206                      |
| D-AMS 028778             | 821± 22                    | 1230-1271                      | 1220-1279                      |
| D-AMS 028779             | 856± 24                    | 1212-1182                      | 1045-1209                      |
| D-AMS 028780             | 946± 22                    | 1051-1182                      | 1045-1209                      |
| D-AMS 028781             | 965± 24                    | 1046-1160                      | 1035-1179                      |
| D-AMS 028782             | 776± 24                    | 1266-1293                      | 1226-1300                      |
| D-AMS 028783             | 944± 21                    | 1051-1183                      | 1045-1211                      |
| D-AMS 028784             | 988± 27                    | 1042-1146                      | 1028-1157                      |
| D-AMS 028785             | 837± 24                    | 1224-1266                      | 1210-1215                      |
| Combined Date 2          |                            | 1158-1200                      | 1150-1215                      |

OxCal v4.4.4 Bronk Ramsey (2021); r:5 Atmospheric data from Reimer et al (2020)

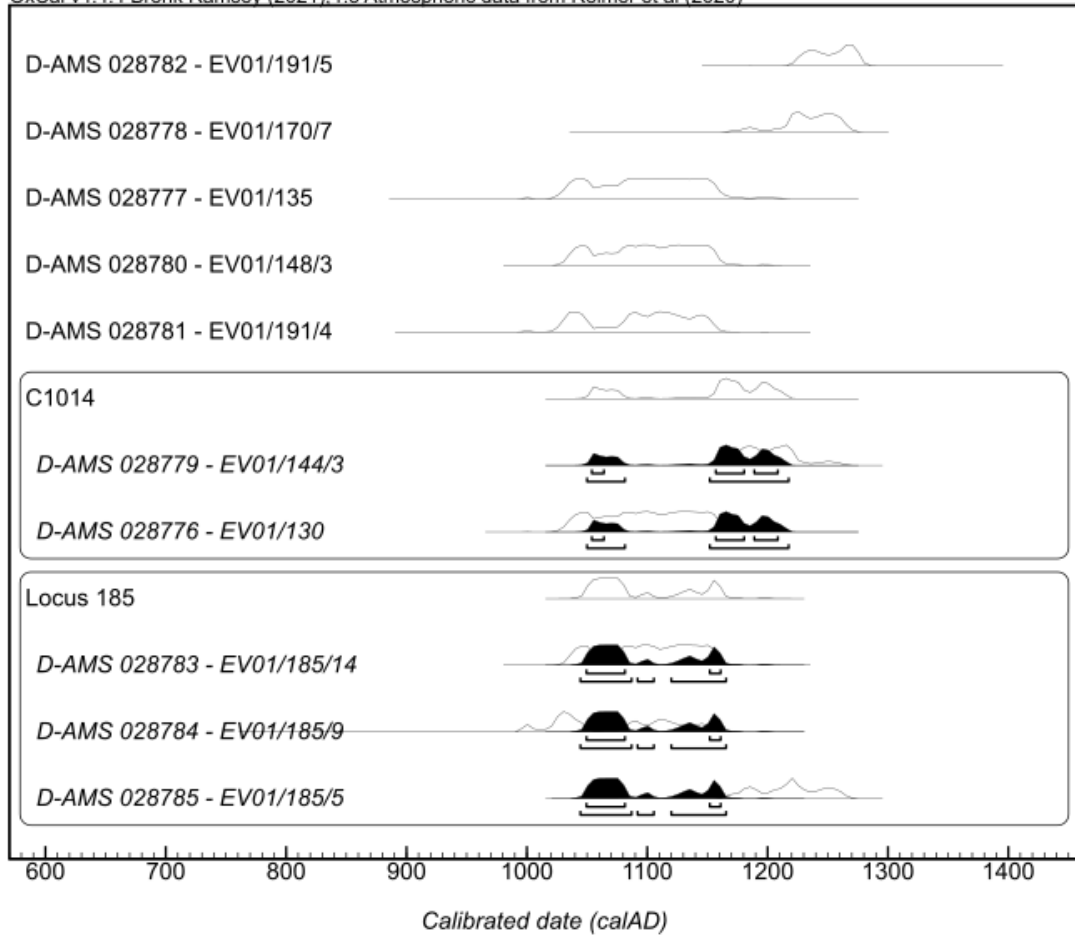


**Figure 2-6: Radiocarbon dates from Evelyn (Rossouw 2021)**

Samples S-AMS 028778, and D-AMS 028779 had calibrated dates of early 13<sup>th</sup> century compared to the other samples which were dated to the mid-11<sup>th</sup> to 12<sup>th</sup> centuries. Continuity in radiocarbon dates suggest that Evelyn was occupied from mid-11<sup>th</sup> century to the early 13<sup>th</sup> century.

## 2.8 Klein Bolayi (EV02)



**Figure 2-7: Site overview of Klein Bolayi**

Klein Bolayi, also referred to as EV02 (GPS 22°17'11"S 29°51'44"E) which is situated approximately 1.3 kilometres northeast of Evelyn, is situated on the southern base of a koppie. The site extends approximately 180m south with most of the cultural material occurring at the southern end of the site by a large kraal, with an approximate diameter of 30m. This is evident through large quantities of vitrified dung and ashy midden material with significantly more cultural material appearing within this area. Fifteen meters east of the kraal is a dark ashy deposit which is visible through insect burrows. Forty meters north of the kraal there seems to be a light ashy deposit

associated with some ceramic sherds and further 80m north there is evidence for a second smaller kraal identifiable through its ashy kraal deposit.

### 2.8.1 Klein Bolayi Context Descriptions

Archaeological excavations of Klein Bolayi took place in 2016, whereby a total of 96m<sup>2</sup> was excavated.

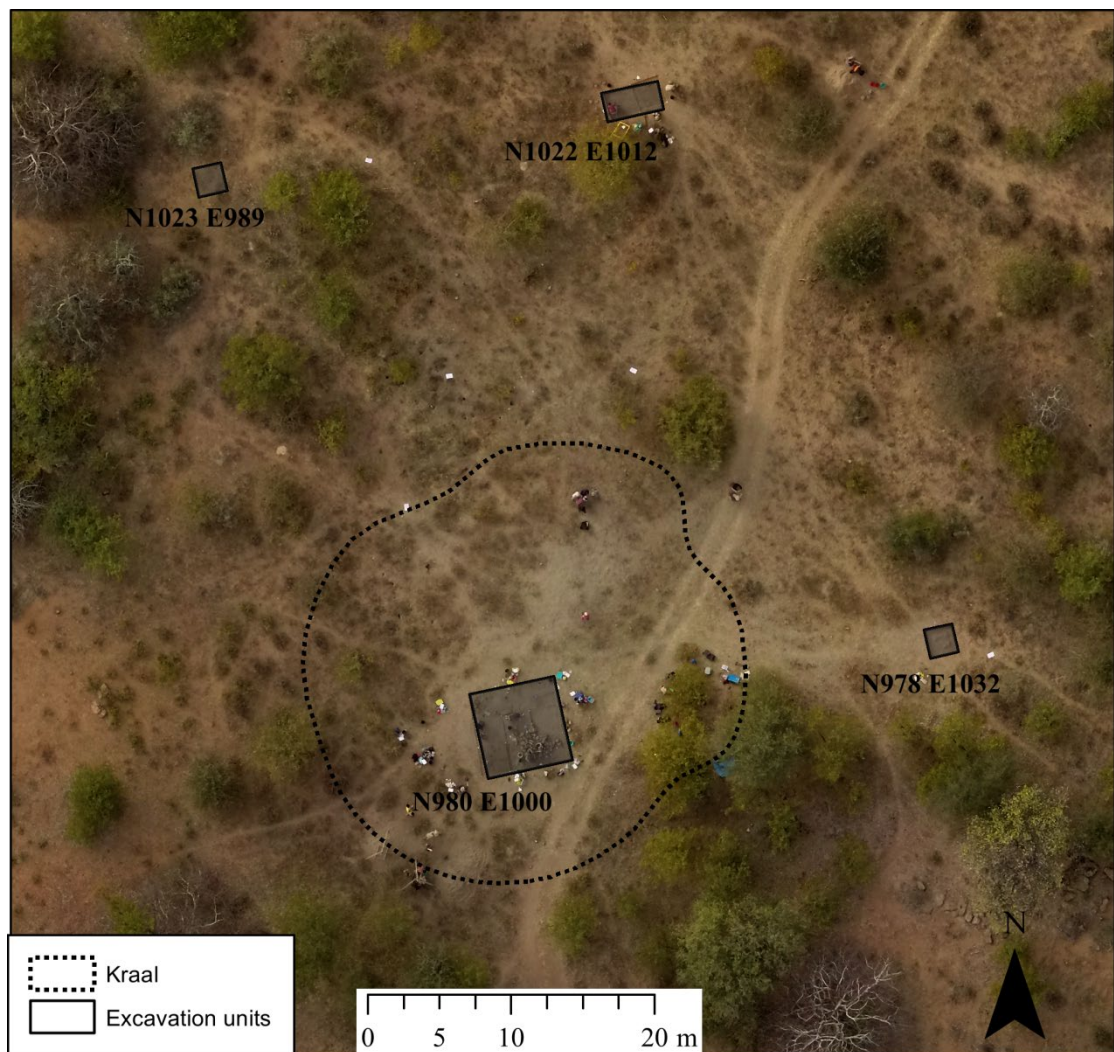


**Figure 2-8: Southern excavation units of Klein Bolayi**

#### Trench I (N980 E1000)

This trench consisted of nine 2m x 2m units situated within the southern kraal. The contexts of this trench consist of:

- C1001: Surface loose ashy midden deposit. Disturbed by animal activity.
- C1003: Undisturbed ashy deposit of variable consistency. This context ends on a layer of horizontal artefacts.
- C1006: This is an artefact rich deposit of ashy soil; containing the stone feature (C1004).
- C1004: A stone feature roughly 1m by 1m round feature of a single layer of packed stones (the midpoint of the feature is N982 E1004). Several items of material culture were trapped between the stones.
- C1009: Dark ashy soil that changes to a greyish white dung deposit towards the bottom.
- C1016: Sterile surface under the kraal context that was not excavated.

### **Trench II (N978 E1030)**

This 2m x 4m unit consisted of the following contexts:

- C1007: A gravel layer exposed after surface clean up.
- C1011: A distinct ashy deposit that containing animal bones and a few ceramic sherds. This ashy deposit had more consolidated red patches present within it. These patches were the remains of hut debris.
- C1018: The hut flooring, with a visible posthole, which is defined as a feature within C1011. The hut floor was not excavated but clearly rested on sterile soil.

### **Trench III (N1022 E1021)**

This 2m x 4m unit consisted of the following contexts:

- C1002: Top soil layer with animal disturbances. Most likely an area of wash.
- C1005: A rich artefact layer on top of a compact gravel deposit.

- C1008: Compact gravel layer with pebble and cobble inclusions. Natural wash on a downward slope.
- C1010: A small ashy deposit present in the eastern quadrant of the unit which was caused by root disturbance.

#### **Trench IV (N1023 E989)**

This 2m x 2m trench was opened due to a visible surface scatter of slag. Material culture density was low within in this trench and sterile soil was reached after approximately 10cm of exaction. Artefacts of this trench are more likely a result of wash from other parts of the site. The contexts of this trench include:

- C1015: Compact sandy layer with gravel inclusions.
- C1017: The unit ends on sterile reddish soil which extends throughout. This context was not excavated.

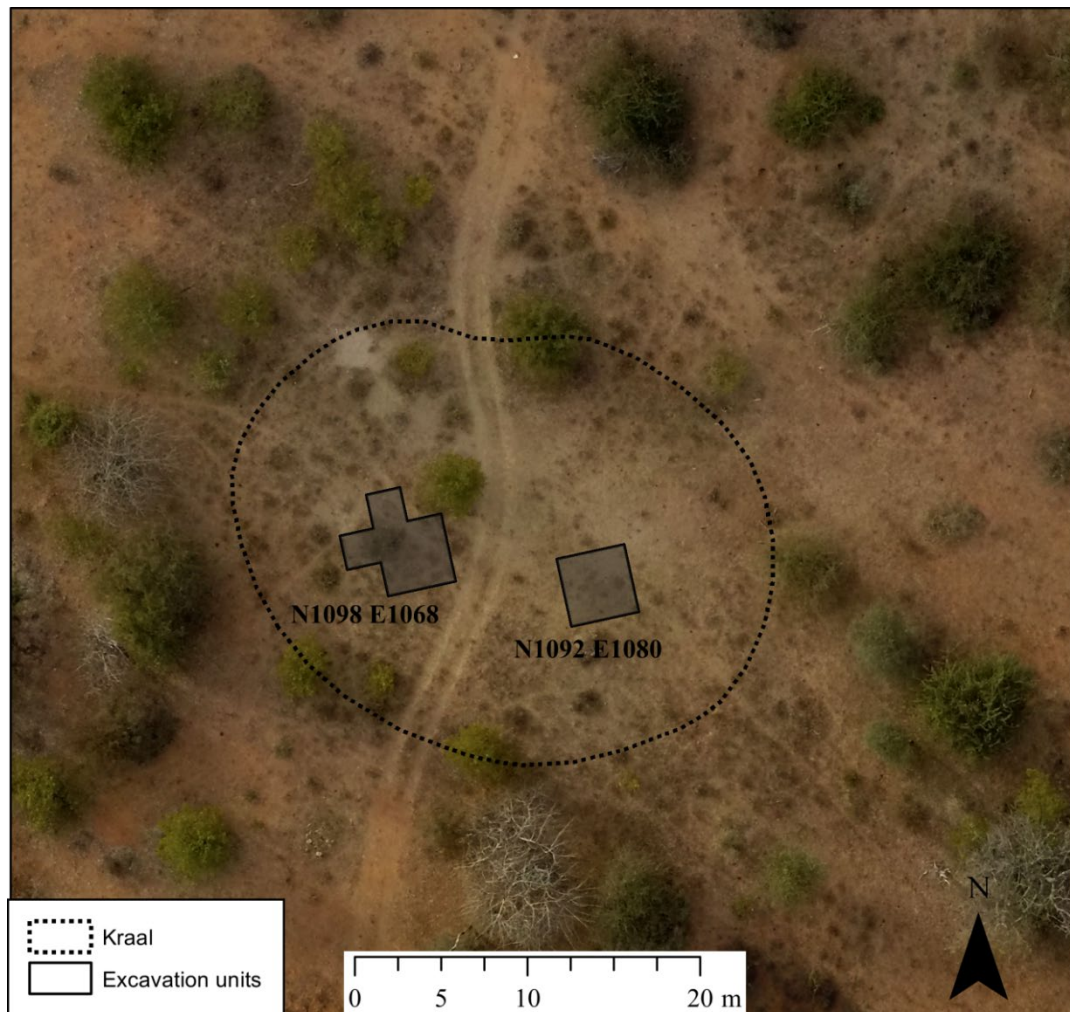


**Figure 2-9: Northern excavation units of Klein Bolayi**

### **Trench V (N1096 E1068)**

This trench comprised on nine 2m x 2m units whereby only six units were excavated. Trench V extends over a large kraal covered by an ashy layer. The contexts of this trench include:

- C1012: Loose ashy soil with a low density of ceramics present.
- C1019: Clearly defined compact kraal layer which has formed a whitish laminate surface. This surface was not excavated.

### **Trench VI (N1092 E1080)**

A 4m x 4m trench was opened southeast of Trench V to determine the extent of the kraal. Modern vehicle tracks can be seen running inbetween the two trenches. The contexts of the trench include:

- C1013: Loose ashy surface deposit.
- C1014: Dung deposit that lacks the vitrified characteristics of the previous unit.

## **2.8.2 Material Culture of Klein Bolayi**

### **2.8.2a Small Finds**

In contrast to the copious amounts of glass beads found at Evelyn, Klein Bolayi excavations only found a total of 15 glass beads throughout the site (Lippert 2019 :111), with blue-green being the most common colour (n=8). Due to the small sample size, defining their bead series with certainty was not possible although they were speculated to be part of the K2 Indo-Pacific series (Lippert 2019:112).

A total of 63 shell beads were found, with majority (n=49) being made of ostrich eggshell, while the other 14 were produced from *Achatina* shell (Lippert 2019:112). A single stone bead was also found during surface surveying.

A total of 59 metal artefacts were found made of iron and copper. This includes helixes, strands of wire, a tapered rod, an iron plate as well as a fragment of a copper bangle (Lippert 2019: 116). Slag was also found distributed around the site with a total of 80 pieces recovered with an accumulative weight of 564,3g (Lippert 20: 116).

A total of four cowrie shells were found, one of which being a complete shell. The complete shell showed prominent signs of polishing (Lippert 20:117).

### **2.8.2b Ceramic Artefacts**

Within an ashy deposit in the site, a ceramic amulet was found. The rectangular shaped amulet with two holes bored into it was likely made from an already existing

ceramic sherd as upon analysis it was noted that the amulet bears a curve resembling that seen in ceramic vessels (Lippert 20: 116).

Stylistic analysis (see Rossouw 2021), was carried out in the same manner as discussed in Evelyn. Of the ten identified ceramic types, Klein Bolayi had six types present within its ceramic assemblage. Profile types present at Klein Bolayi include recurved jars, bellied jars, constricted bowls, beakers, open bowls, and miniatures. Similarly to Evelyn, bellied jars were the dominant vessel type present comprising of 58% of the assemblage.

Bellied jars with arcades on the shoulders and bellied jars with horizontal bars on the shoulder indicative of the K2 facies were identified. Two sherds with spouts and two sherds with lugs were found and identified as K2 ceramics. Two recurved jars with a horizontal band of the K2 facies was identified at Klein Bolayi. Twelve bellied jars with horizontal bands of punctates of the K2 facies were also identified. Two undecorated beakers found at Klein Bolayi were identified as belonging to either the K2 or TK2 facies. Four Mapungubwe type open bowls with cross-hatched triangles were identified within the ceramic assemblage.

Stylistic analysis identified the prevalence of K2 ceramics present at Klein Bolayi with some TK2 and Mapungubwe facies ceramics also present. Based on ceramic typologies and the radio carbon dates (AD 1020 – AD 1225), Klein Bolayi was classified as a TK2 site (Rossouw 2021).

### **2.8.3 Radiocarbon dates of Klein Bolayi**

Seven charcoal samples from Klein Bolayi were sent to Direct AMS for radiocarbon dating. Results were calibrated using the Southern Hemisphere calibration curve and were plotted in OxCal v4.4. Sample D-AMS 028786 from context C1006 of the ashy midden deposit returned a 2-sigma calibrated date of cal. AD1021-1150. Samples D-AMS 028791 and D-AMS 028792 from context C1009 returned dates of cal. AD 893-1025 and 1046-1217 respectively. Sample D-AMS 028787 from context C1008 returned a 2-sigma date of cal. AD 1071-1224. Sample D-AMS 028790 from the northern most unit of Klein Bolayi (N987 E1030) returned a 2-sigma date of cal. AD 1042-1178. Samples from the northern kraal area D-AMS 028788 from context

C1012 and D-AMS 028789 from C1011 returned dates of cal. AD 895-1018 and 770-963 respectively.

**Table 2-2: Radiocarbon dates from Klein Bolayi (Rossouw 2021)**

| Laboratory Number        | Uncalibrated age BP | 1-Sigma range (cal. AD) | 2-Sigma range (cal. AD) |
|--------------------------|---------------------|-------------------------|-------------------------|
| D-AMS 028786             | 1012± 27            | 1028-1136               | 1021-1150               |
| D-AMS 028787             | 910± 22             | 1163-1210               | 1071-1224               |
| D-AMS 028790             | 963± 19             | 1047-1160               | 1042-1178               |
| D-AMS 028792             | 934± 23             | 1071-1203               | 1046-1217               |
| <b>Anomalous samples</b> |                     |                         |                         |
| D-AMS 028788             | 1127± 19            | 901-995                 | 895-1018                |
| D-AMS 028789             | 1227± 27            | 776-890                 | 770-963                 |
| D-AMS 028791             | 1115± 31            | 905-1018                | 893-1025                |

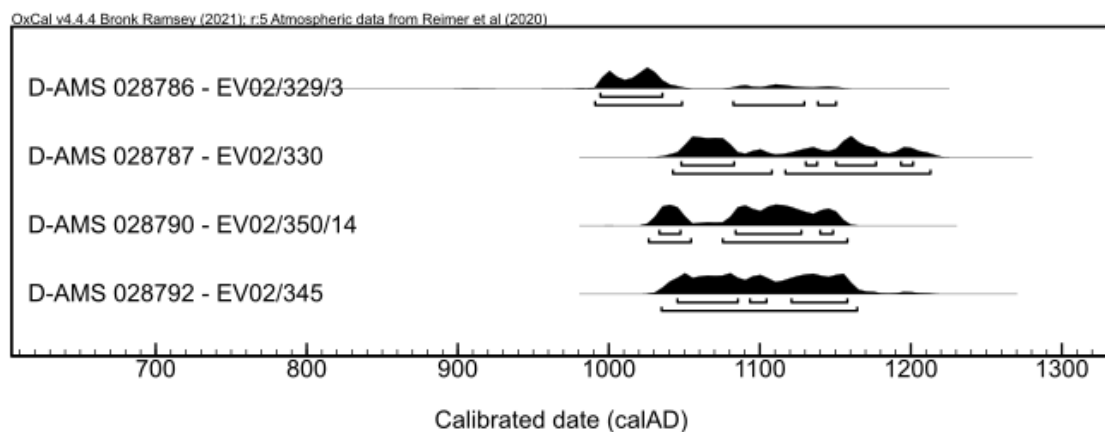


**Figure 2-10: Radiocarbon dates from Klein Bolayi (Rossouw 2021)**

Three samples of an anomalous nature (D-AMS 028788, D-AMS 028789, and D-AMS 028791) presented dates which were older than the other samples. Other

material culture such as ceramics and glass beads associated with these samples do not suggest an occupation period of earlier than AD 1200. The charcoal of these samples could have been a result of old wood such as a post.

#### 2.8.4 Radiocarbon Date Comparison of Evelyn and Klein Bolayi

Radiocarbon dates of each site was compared to determine any overlap in occupation periods present.

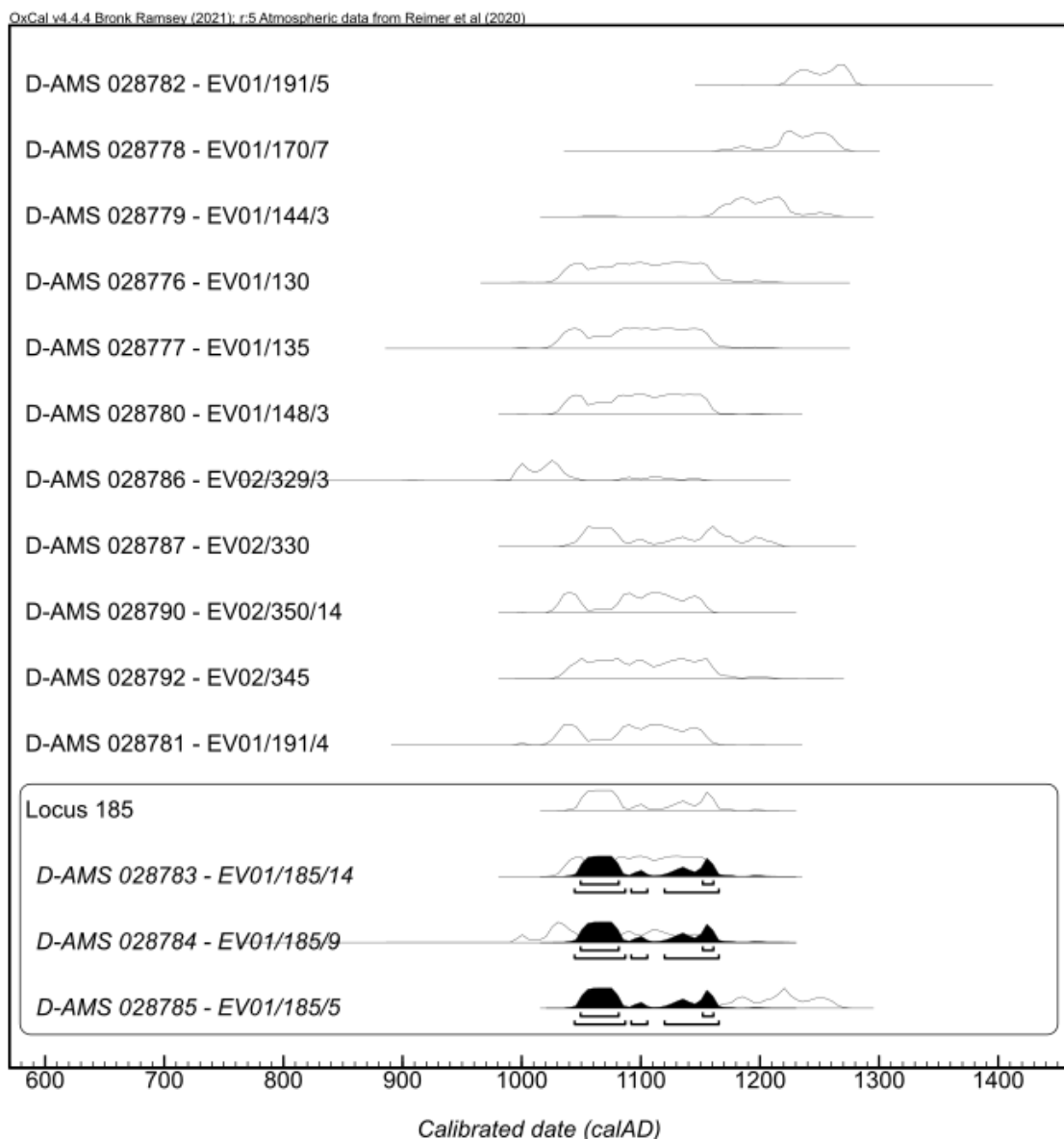


Figure 2-11: Radiocarbon dates from Evelyn and Klein Bolayi (Rossouw 2021)

Calibrated dates from Klein Bolayi are slightly earlier than dates of Evelyn. Both sites do however have a large overlap within the late 12<sup>th</sup> and early 13<sup>th</sup> century which may show that the two sites were occupied contemporaneously for a period of time.

## **METHODOLOGY**

Portable x-ray fluorescence and petrography were implemented on body sherds of the aforementioned sites as to best answer the research questions. These methodologies both make use of disciplines such as chemistry and geology in order to understand the technology of the respective ceramics. The use of pXRF is not enough for making concrete theories pertaining to ceramic technology, therefore petrography was used alongside it for a more holistic technological approach.

### **2.9 X-Ray Fluorescence (XRF)**

X-ray fluorescence (XRF) is a process whereby x-rays are bombarded into the atoms of the elements within the sample (Gullayanon 2011, Shackley 2010; 2014). This bombardment causes an excitation within the electrons circling near the nucleus of the atom. An electron from the inner shell of the atom, will then become positively charged thus causing it to dislodge and repel against the positively charged nucleus and shoot out of its orbital shell (Wurtzburg 1991). To compensate for this current atom instability, the empty space will then cause an electron from a more outer shell, referred to as the photoelectron to fall down and fill the empty space (Shackley 2010: 17, Wurtzburg 1991:93). This movement of the outer shell electron is referred to as the photoelectric effect (Gullayanon 2011: 8). The photoelectric effect is what then creates the secondary or fluorescence x-rays which is what the detector within the XRF instrument will then register and classify (Rice 2005:393). Each element has a unique energy or wavelength as the electron moves from its outer orbital shell to the lower orbital shell. This distinctive energy signature is based on the uniqueness of the spacing between orbital shells within each element. In turn, this can then determine the presence of elements as well as their particular quantities within a given sample

and in essence, provide the ‘chemical fingerprint’ of the ceramics (Freeland 2013: 46, Rice 2005: 393, Shackley 2010; 2014).

XRF detection can be classified as either energy dispersive (EDXRF) or wavelength dispersive (WDXRF). EDXRF XRF’s detectors are equipped to detect and process signature energy of elements, WDXRF detects signature wavelengths emitted from secondary x-rays (Gullayanon 2011: 15, Shackley 2010: 17). This research makes use of EDXRF. Portable x-ray fluorescence (pXRF) is a portable variant of an XRF instrument which can be used for in-situ analysis as well as within a lab but at a much cheaper cost than standard XRF instruments. This cost efficiency means that more labs can have access to this powerful analytical tool.

### **2.9.1 XRF Uses within Ceramic Studies**

XRF is a useful method for studying larger regional patterns by showing differences or similarities of ceramics within a geographical setting. By analysing the chemical composition of ceramic sherds, one can identify different ‘chemical fingerprints’ within an assemblage. These chemical fingerprints represent the raw material as well as provide details on the raw material procurement and possible sources (Freeland 2013: 17, Jacobson 2005: 53). This can be useful in understanding social boundaries within pottery production such as access to clay sources by different groups of people. It is also useful to potentially differentiate multiple types of clays occurring within a site and across the landscape.

As XRF provides a bulk chemical reading, reliance thereon for exact provenance can prove problematic as the exact mineralogy is not pinpointed. As a result, it should be used alongside other analytical techniques to answer specific questions about the clay provenance. For this research, the elemental analysis was used to distinguish broader chemical patterns within the assemblages and compare the chemical fingerprints of ceramics from both sites.

With the cheaper options of pXRF instruments and its non-destructive process in that it is not necessary to make briquettes from samples, this is a useful tool for museums and world heritage sites to perform quick and effective analysis without ruining the

integrity of artefacts (Forster et al 2011). This then opens a scope of new possible research to be done where it would otherwise not be possible.

### **2.9.2 pXRF Limitations**

It is important to note the limitations of the use of pXRF as it is often under criticism as it is seen to be less reliable than standard XRF instruments.

PXRF instruments can be calibrated numerous different ways and often this can create differences in data results. As a result, this lowers the capability for data comparison done by different models and different calibrations. The use of certified ceramic reference material can aid in this limitation as the elemental ranges of these material are known and according to the results ones specific instrument and calibration generates, the researcher can formulate to adjust all results should they deem it necessary (Jacobson 2005: 196). Within this study the standard reference materials SARM 42, 44, 45, 46, 49 and 69 were analysed.

When analysing ceramics, which are heterogeneous specimens, it is important to be aware of features such as tempers, grain size variations, weathering and coatings (be it deliberate or post depositional) as these can largely skew the data (Forster et al 2011: 393). This can create problems within a dataset and results when one is relying solely on the chemical results for archaeological interpretations.

As the process of pXRF identifies a chemical reading of the area of the sample visible within the detector window, one cannot deduce and pinpoint certain inclusions based off of chemical compositions (Rice 2005: 374). Reliance on pXRF data for mineral identification can prove problematic. To combat this, the use of petrographic thin sections can aid in the identification of mineral inclusions.

Another limitation to be mindful of when using pXRF is the constraints of elemental ranges the instrument can detect and analyse (Shackley 2010:17). Due to the high energy needed to dislodge electrons in elements of higher atomic numbers, these elements cannot always be detected and processed with high accuracy or even at all.

## 2.10 Petrographic Thin Sections

Petrographic analysis follows the same principles borrowed from the geological methodology of petrology whereby a specimen's optical properties are analysed to determine its mineralogical composition (Reedy 2008: 1). This form of analysis was developed as a way to classify rocks, sand and soils with certainty. All inclusions larger than 0.02mm can accurately be identified under polarized light (Druc and Gwyn 1998:708). A polarizing microscope is necessary for the analysis of thin sections as it alters the vibration of light waves into the specimen unlike a regular microscope which does not alter light waves. Standard light (unpolarized light) that is emitted from the microscope's light source beneath the sample, vibrates and scatters in many different directions (Pichler and Schmitt-Riegraf 1997: 2). The microscope is equipped with a polarizer situated beneath the rotatable stage to convert the scattered light into polarized light which vibrates on a single plane (Pichler and Schmitt-Riegraf 1997: 3, Raith et al 2011:18). The stretched polyvinyl film of the polarizer allows the sample to be viewed in polarized light whereby optical properties become apparent (Pichler and Schmitt-Riegraf 1997: 18, Raith et al 2011: 18). This filter absorbs light waves vibrating in undesirable directions, allowing for only the polarized light to be passed through. The analyser, situated between the eyepiece and objective, allows the analyst to view and check for polarized light (Pichler and Schmitt-Riegraf 1997: 2-27). The analyser, which can be moved in and out of the light path is used to analyse the plain polarized light and cross polarized light emitted from the polarizer (Raith et al 2011). This is achieved through the perpendicular position in relation to the polarizer, which will once again create changes to the light waves. When the polarized light enters a birefringent specimen, it splits into two light waves whereby only the waves vibrating perpendicular to the analyser will pass through the analyser to be viewed when the analyser is inserted (Pichler and Schmitt-Riegraf 1997: 2-27). The splitting of the light through the specimen will change according to the type of minerals present as well as the orientation of the sample. This phenomenon is how signature optical properties of the present anisotropic minerals are then visible under the microscope.

The removal of the analyser allows analysis of plane polarized light whereby colour, pleochroism, form/habit, cleavage, relief, and alteration are analysed (Raith et al 2011: 18, Rice 2005: 378, Wahlstrom 1995: 25-31). Colours within plane polarized

light are of lighter, earthier toned colours. The use of the analyser and change of light waves allows for analysis under cross polarized light whereby optical axis, birefringence, extinction angle, twinning, and zoning is visible (Wahlstrom 1995: 28-33). Each mineral has a unique set of optical properties across the mentioned optical and morphological properties which allows the analyst to classify each mineral present in the sample as well as their semi-quantitative frequencies.

### **2.10.1 Petrographic Uses within Ceramic Studies**

Provenance studies of ceramics is one of the most common aspects and purposes for analysing thin sections. By comparing the local geology to what is found within a thin section, assumptions can be made on the origins of ceramic vessels or the actual raw clay (Druc and Gwyn 1998: 707, Reedy 2008, Rice 2005: 415). Some researchers also create fired briquettes using the local clay source to fully compare the thin sections. This does however require extensive knowledge on the local clay source as a mean of exact provenancing.

Petrography is a valuable tool for studying ceramic technology (Druc and Gwyn 1998, Reedy 2008, Rice 2005: 376). Thin sections can give great insight into production processes implemented by potters such as clay treatments, inclusions, tempers, forming methods, relative firing temperatures, and surface treatments. When studying a site of a longer occupation period, one can use thin sections to analyse technological changes over time which may have occurred (Reedy 2008: 1).

Petrography is a helpful form of analysis to do comparative studies on different sites to study ceramic pastes of different vessels (Druc and Gwyn 1998). Studying pottery production through petrography can also aid in regional comparisons to determine differences or similarities of mineralogical compositions to determine the use of shared clay sources. This can speak to broader topics of clay procurement in terms of raw material and trade access of different groups. The use of similar clay pastes and forming methods can be an indicator of some form of interaction between groups in terms of pottery trade or knowledge exchange (Fitzpatrick et al 2003). Similarly, a study done by Wilmsen et al (2019), used thin sections of ceramics in Botswana to trace the movement of people, along with their pottery based on ceramic fabric, rather

than stylistic markers only. This research also discussed possible interactions and negotiations made when accessing clay sources when making pottery.

## **2.11 Conclusion**

Mapungubwe, situated in the Shashe-Limpopo Confluence Area, was thought to be the regional capital which saw the rise of the first socially complex society within southern Africa. Within the hinterland of Mapungubwe, two closely situated Middle Iron Age sites, Evelyn and Klein Bolayi were selected as the focus of this study. Through the implementation of portable x-ray fluorescence and petrography of the two sites ceramics, research questions could be answered pertaining to the ceramic technology of the sites.

## CHAPTER THREE – LITERATURE REVIEW

Ceramic technology in southern Africa dates to approximately 2000 years ago (Huffman 1980; 1989, Miller 1991). The various methods of ceramic analysis in southern Africa has evolved over the decades to answer a magnitude of archaeological questions and will be discussed in this chapter. This chapter focuses on pottery production as well as stylistic and technological analysis with an emphasis on technological style.

### 3.1 Stages of Pottery Production

Ceramics are comprised of inclusions, voids and the clay matrix. All three components can be analysed and documented to make observations pertaining to the stages of pottery production and any intentional steps taken in preparing the pottery.

Clay minerals can be defined as minerals of a grain size smaller than 0.002mm in diameter which when added with water become plastic and workable (Orton et al 1993: 114). Clays are derived from weathering rocks which have broken down into clay minerals. Clays can be divided into primary or secondary clays based on their physical origins. Primary clays refer to in situ clays which are found at their original parent rock and are of a purer geological composition (Goffe 2006: 233, Rice 2005: 37). This is the preferred clay type for ceramics such as porcelain (Goffe 2006: 233). Secondary or sedimentary clays are clays which have undergone a natural redistribution through wind, water, glaciers or rivers and have accumulated elsewhere (Reedy 2008: 109, Rice 2005: 37). Clay minerals from secondary clays are often more rounded as a result of smoothing during the process of natural transportation (Reedy 2008: 109). As a result, secondary clays contain a higher percentage of non-clay inclusions and larger grained inclusions. Typically, ceramics are mostly comprised of secondary clays as it is the most commonly found clay (Orton et al 1993: 114). Chemically, clays are comprised of varying quantities of silica dioxide ( $\text{SiO}_2$ ), aluminium dioxide ( $\text{Al}_2\text{O}_3$ ) and water with a small percentage of varying trace elements.

### **3.1.1 Clay Procurement**

The first stage of pottery production involves the procurement of raw clay. The clay source used by potters may be shared among communities or there may exist ownership with restricted access to outsiders (Rice 2005: 115, Rye 1981: 17). Some potters may also have access to a private clay source of their own. Ethnographically, it has been seen that potters are willing to travel far distances for a clay source which bares favourable clay, but often the clay sources are within a 5km radius to their settlement (Gosselain 1992, Gosselain and Livingstone Smith 2005, Rice 2005: 116). Further distances of procurement require means of transportation for returning the clay.

Clays are collected by means of hand collection or with the use of tools and taken back to begin clay preparation (Lawton 1967: 7, Santacreu 2014: 60). The process of clay procurement is often intertwined with taboos a certain group may believe and conform to (see Fredriksen 2011, Lindahl and Pikirayi 2010, Pikirayi and Lindahl 2013). As such, great care is taken to avoid these taboos as to allow for a successful creation of pottery. Often when vessels may crack or shatter during drying and firing, group members may believe another member did not respect the taboos during pottery production.

### **3.1.2 Clay Treatment and Preparation**

Clays may be used as is, but generally undergo treatments as to create a favourable working paste. Many potters first pre-treat the clay by soaking, drying or souring it for an extended period of time (Rice 2005: 118-119).

Dry clay is then mixed with water and treated to create a mouldable paste to create ceramic vessels. Clay bodies have naturally occurring inclusions which may be of large fragments of the weathering rock or organic material. Undesirable natural impurities such as pebbles, grass, roots and other organic materials are often removed by means of washing, sieving, winnowing, levigation, or removal by hand (Gosselain and Livingstone Smith 2005, Reedy 2008: 110, Rye 1981: 18). Such inclusions are generally those which are 5mm or larger in diameter (Santacreu 2014: 67). This process of purification does create chemical, mineralogical and textural changes to the

clay itself as it then creates a new fabric paste which differs from the original raw clay (Santacreu 2014: 68).

The potter may also decide to deliberately add inclusions to create a paste which is favourable for workability and plasticity. The deliberate addition of inclusions is referred to as temper (Rice 2005: 406, Rye 1981: 31). Temper can range from crushed rocks, organic materials such as bone, shell, hair, grass, or crushed up ceramics, referred to as grog (Arnold 1988: 22, Lawton 1967: 8, Rice 2005: 409, Santacreu 2014: 70). The addition of temper is often to allow for thermal resistance in the pottery whereby the vessel may be heated and re-heated throughout its lifetime without cracking or shattering (Arnold 1988: 23, Rye 1981: 34). Once the clay has been treated and tempered, the paste is then worked into a homogenised paste by means of pounding, trampling, kneading, or beating with tools (Gosselain and Livingstone Smith 2005).

The process of clay treatment allows for infinite different combinations of preparation whereby the style of a potter or their community's practices are implemented (Gosselain and Livingstone Smith 2005, Santacreu 2014: 70). The clay paste will also reflect the type of pottery the potter intends to create as different clays and inclusion ratios may perform differently in succeeding production stages.

The process of treatment is important as the potter can control the plasticity of their clay. Plasticity refers to the ability of clay whereby it can be moulded and retain its shape (Rice 2005: 58, Rye 1981: 146). Skilled potters use their knowledge to create the best clay paste which has the right balance of plasticity and workability (Gosselain and Livingstone Smith 2005, Rye 1981: 16).

### **3.1.3 Forming**

There are numerous forming methods for shaping pottery, often with the occurrence of multiple methods used within a single vessel. Such methods include wheel throwing, coiling, slabbing, paddling, and pinching (Orton et al 1993: 117-118, Rice 2005: 124, Rye 1981: 62). Wheel throwing includes the use of a pottery wheel whereby a spinning mechanism is used as the potter uses their hands with the use of tools to form a vessel (Rice 2005: 124-131, Rye 1981: 74). Ethnographic studies have

shown this method to be less common within southern Africa as hand forming techniques (Lawton 1967: 8-9, Lindahl and Pikirayi 2010, Pikirayi and Lindahl 2013).

The simplest hand forming method is pinching and entails a lump of clay that is pinched between the thumb and fingers from the centre and drawn out to create the desired vessel shape (Lawton 1967: 10, Rye 1981: 70). The other common hand forming technique is coiling whereby the pot is shaped by numerous long cylindrical clay pieces coiled on top of each other (Lawton 1967: 10, Rice 2005:127, Rye 1981: 67). The stacked coils are then smoothed out and blended with the use of tools or by hand. Slab building makes use of flattened lumps of clay moulded together into the desired vessel shape (Lawton 1967: 10, Orton et al 1993:118). Commonly, potters will employ a combination of techniques when forming pottery. Forming methods are often influenced by learnt practices and carried over generations and often with a higher degree of resistance to change (Arnold 1988: 235, Gosselain 2000).

Once the vessel has been formed, it undergoes secondary forming whereby the potter may use techniques such as scraping, beating, trimming, or turning to even out the impressions made in the clay during the initial forming process (Rice 2005:136, Rye 1981: 84).

### **3.1.4 Drying**

The process of drying is essential prior to firing to ensure the vessel preserves its form. Drying occurs either outside naturally or with the aid of a small heat source until the vessel is leather-hard (Lawton 1967: 11, Orton et al 1993: 126). Shrinkage and subsequent cracking are both common during this stage as water evaporates from the clays crystalline structure. This can be a reflection on the procedures undertaken by the potter during the previous production stages (Orton et al 1993: 126). If drying occurs too rapidly, water might evaporate unevenly which may lead to differential shrinkage which may misshape the vessel or allow for frequent cracking (Arnold 1988: 62, Lawton 1967: 11). Vessels which have cracked significantly may be discarded prior to firing (Rye 1981: 66). The use of tempers fills up space otherwise occupied by water and clay particles which will allow for less shrinkage. Often the

vessel undergoes a slight colouration change as the natural salts within the water are drawn to the structure wall as the water dissipates.

### **3.1.5 Surface Treatments**

Surface treatments include the addition of decorations by means of impressions, hatching, combing, rouletting, incising, and stamping amongst others (Lawton 1967: 17-18, Rice 2005: 144-147). This also includes the addition of appliqués which includes handles, lugs, spouts, spikes, pellets, and feet onto the vessels structure (Orton et al 1993: 119, Rice 2005: 144-147).

Some potters create a special overlay mixture to coat their ceramics. Such finishing include slips, glaze, pigment, colourants, paint, and wash (Lawton 1967: 19, Rice 2005: 144-151, Rye 1981: 89-90). Coatings are mostly made from a mixture of natural pigments whereas slips are often created using watered down clay (Santacreu 2014: 83).

Surface treatments can also be applied to wet clay or after the vessel has been fired, the desired outcome of the vessel will determine when surface treatments are applied.

### **3.1.6 Firing**

Firing of a clay body allows for the full removal of water and the crystallization of clay minerals as to create a permanent structure (Reedy 2008: 190). Between 100°C - 500°C, water evaporates out of the clay body and all organic material disintegrates and leaves voids in their place (Goffier 2006: 242, Schneider 2016: 164). Around 500 °C - 900°C, chemical and physical changes begin within the clay whereby clay particles form a permanent bond (Santacreu 2014: 91, Schneider 2016: 164). Firing temperatures below this will result in vessels that will eventually disintegrate as clays only start to harden and solidify above this temperature. Once all the water within the clay particles has been lost, the clay particles begin to compact together and dehydroxylation occurs whereby structural water is lost (Goffier 2006: 236, Schneider 2016: 164). This processes of dehydroxylation results in a permanent bond in the clay particles and a hardened ceramic structure. Temperatures of 700°C and higher are preferable for removal of plasticity and allowing for permanent hardness (Goffier

2006: 243, Santacreu 2014: 91). This allows for a vessel which can endure stress of re-heating and daily use. Cracking and shattering of pottery is common during post-firing if the vessel is cooled down too quickly as this drastic change in temperature causes greater thermal shock to the pottery.

Ceramics are fired either by means of a kiln or open-firing. A kiln is a specialised enclosed structure built for ceramic firing. Ceramics are placed inside the kiln along with fuel such as wood, grass, straw or dung which is then lit (Orton et al 1993: 130, Rice 2005: 158-162). The use of kiln firing allows for high temperatures over longer periods of time to be achieved as the fire is in an enclosed space (Rice 2005: 158-162). Temperatures in a kiln vary between 1000 - 1300°C allowing clay bodies to vitrify (Rye 1981: 98). This method allows for greater temperature control as the enclosed structure is not subject to natural elements such as wind and rain (Arnold 1988: 216).

More common in southern Africa, open-firing makes use of building a large fire in an open space whereby the vessels are placed within the fire to harden (Lawton 1967: 14, Lindahl and Pikirayi 2010, Rye 1981: 87). The chosen source of fuel is piled up with vessels placed on top and within the fuel and then lit. This method of firing does not reach very high temperatures due to the lack of heat retention as the fire is not contained into an enclosed space (Orton et al 1993: 127, Rye 1981: 87). Open fires reach maximum temperatures of around 1000°C and do not retain maximum temperatures for long periods of time (Rye 1981: 25, Santacreu 2014: 105). This method also generally shows signs of uneven firing as elements such as wind may blow the fire around causing uneven coverage of the vessels during the firing duration. This is evident through darker patches on the vessel where the vessel came in direct contact with the flame (Santacreu 2014: 105).

Firing also changes the composition of pottery as some minerals may be altered due to high firing temperatures (Santacreu 2014: 101). Such changes may be visible under polarising light to determine mineralogical changes.

### 3.1.7 Ceramic Usage and Discarding

Once a vessel has been fired and solidified it will then be used for its intended function whether it be cooking, storage, or serving. Chemical changes will occur during this stage as chemical atoms may leech into the ceramic structure over time. Such changes include higher percentages of phosphorus and calcite (Santacreu 2014: 66). Re-heating of a vessel throughout its lifetime may also alter the mineralogy of certain points of a vessel due to contact with fire and subsequent re-firing of minerals within the ceramic body.

Once a vessel has been discarded and buried for an extended amount of time, post-depositional changes may once again alter chemical and mineralogical compositions. Elements such as calcium, copper, magnesium, sodium, zinc and potassium are the most common elements within ceramics which get altered through post depositional processes (Santacreu 2014: 46, Schneider 2016: 166). This is due to their atomic structure whereby an exchange of cations are more likely to occur than in other elements. As soils are potassium rich, post depositional absorption within the ceramics occur easily and as such,  $P_2O_5$  levels in ceramics above 0.5% are generally attributed to post depositional absorption (Schneider 2016: 167).

As a result of the continuous chemical changes occurring during stages of ceramic production and usage, the original raw clays chemical composition may not be accurately established.

### 3.2 Stylistic Analysis

Ceramic analysis has fundamentally been partial to the need to group like objects to create typologies and chronological sequences (Arnold 1988: 1-3, Pikirayi 2007). Stylistic features have been the forefront of ceramic analysis with repetitive features used to establish ceramic types (Matson 1942: 25, Hall 1983, Miller 1991, Pikirayi 2007). Stylistic analysis makes use of the observation of the repeated combination of physical features of pottery to group them together (Huffman 1980). These groupings have been used as a marker to identify certain geographical groups of ceramic users who may share similar identities (Huffman 1980). This approach is beneficial in detecting a chronological sequence of a site based on the ceramic assemblage present.

These ceramic typologies were then used to define movement of people based on the theory of migration (Pikirayi 2007: 287). Stylistic analysis does however draw on culture-historical school of thought whereby pots are equated to people which can prove to be problematic.

By the 1980's, Huffman's (1970; 1980; 1989; 2000; 2007a), typological series of the southern African Iron Age had been fully established and vastly in use. These ceramic cultures used the basis of stylistic features and their unique combination thereof to create ceramic groups which would then be equated to different groups of people. These typologies were used as ethnic markers and to create a chronology of the Iron Age of southern Africa. This 'core-concept' approach (Huffman 1970; 1980), studied ceramics stylistically through their morphological shapes, decorative motif, and placement of motif, to then place them into unique ceramic groups. This has proved useful in identifying ceramic traditions and their potential chronology of a ceramic assemblage. This typological series and technique has created a standardized method for subsequent stylistic analysis studies within southern Africa.

### **3.2.1 Active Style**

Wobst (1977), argued that style in material culture served as an active and deliberate tool for conveying messages and information pertaining to one's identity, group status and group conformity. This information exchange theory focused more on style as representation of stylistic features of material culture. Style is used as marker of social identity whereby one decides the style they wish to present based on the comparison of style of others (Wiessner 1984; 1989). It was argued that humans shared a need to perceive and portray cultural symbols (Hodder 1989, Wiessner 1989). Symbolism of material culture is however more complex as symbolism may not be correctly interpreted or may change as the object moves (Hodder 1989). Hodder (1982), stated that style would gradually change as one is further away from the centre of the styles origin. As such, style was used as a diagnostic tool for allocating cultural groups within a certain space and time (Sackett 1982). This was however under critique stating that these messages or symbols would be context specific and limited as messages may be misinterpreted by others (Hegmon 1992).

Sackett (1990), argues that style may also be passive as it may not be deliberate but more so influenced by one's cultural settings. This was termed as isochrestic style whereby a choice was made from a set of feasible options that would reflect these learnt behaviours. This isochrestic model stated the low likelihood that two different communities would make the same combination of isochrestic choices (Sackett 1982: 67-80). Therefore isochrestic style would be socially transmitted within the same ethnic group.

### **3.3 Technological Analysis**

In more recent decades, archaeologists sought to analyse material culture beyond its design styles. Technological studies seek to understand the process of production and choices the potter made throughout (Sillar and Tite 2000). These choices are applied in every stage of production by the community as well as the individual (Sackett 1977, Hegmon 1992). Technological analysis aims to identify the driving forces behind making such decisions, as well as implementation of technological style throughout the process (Fowler 2002, Hegmon 1992). Technology is often a reflection of larger complex systems of social, political and behavioural structures, daily activities, and worldviews within a community (Dobres and Hoffman 1994: 212, Killick 2004, Pfaffenberger 1988). It is also a reflection of conscious and unconscious practices and gestures made by potters (Santacreu 2014: 53, Stark 1998). As such, technological changes may also be a reflection of changes in these complex systems as well as environmental changes (Lindahl and Pikirayi 2010).

Technological behaviour can be limited to environmental and geographical factors in what resources may be readily available as well as any possibly cultural taboos or practice preferences (Sillar and Tite 2000). Some groups within a landscape may have territorial ownership of clay resources and can choose to withhold or share such resources from other groups. Shared clay sources may show mutual agreements pertaining to elements within the landscape. This can show inter-group interactions as groups are sharing raw materials and possibly sharing knowledge.

As members of a community interact with those around them, they may draw inspiration and learn new methods to use within their own practice (Gosselain and

Livingstone Smith 2005). Technological features may cross boundaries regardless of language, ethnicity or social practices. This can also be seen through cross group marriage whereby one group may account for numerous different stylistic patterns being employed through a new wife who might bring pottery with her as well as adopt to her new groups design style (Antonites 2012: 255).

Matson (1942), stated the necessity for ceramic studies to use the baseline of current stylistic analysis and build on it to explore topics such as; the potter's status, the production process, and raw materials. A technological system of a society can comprise of numerous elements, namely; the actual work being done, gestures and movements used to complete this work, the object itself and an individual's knowledge (Lemonnier 1989: 156). The combined use of stylistic and technological analyses allows for a holistic ceramic analysis (Matson 1942). Hegmon (1998: 276), states that incorporating style, technology and function would create the baseline of a more nuanced approach to ceramic analysis.

### **3.3.1 Technological Style**

The term 'technological style' was first used by Lechtman (1977), who sought to understand the behaviours and the reasoning thereof during operational sequences. Different to design style, technological style is less focused on physical attributes but more so on choices made during production of material culture. Lemonnier (1989), presented the notion 'different ways of doing the same thing', which may be visible in stages of ceramic production, as infinite combinations of technological choices may be employed in producing a pot.

Technological style can be used as a form of group expression by making choices pertaining to ones learnt methods of production and implementing shared techniques (Hegmon 1998). Technological style can also be a form of individual self-expression whereby a potter is making choices through all stages of production and using agency to control the flow and process of production (Hegmon 1998). Style can be expressed through all stages; from clay procurement subsequently up to using and discarding the vessel. When presented with multiple choices in which to do something, one might often make a choice based on what is learnt within the community (Sackett 1990: 33).

These choices can be a reflection of social factors learnt throughout a potter's life but can also be uniquely individual to each potter as cultural traditions and techniques may be visible in the choices made during pottery production (Santacreu 2014, Sellet 1993, Pikirayi and Lindahl 2013). Through these learnt processes as well as unconscious habits a potter may form through their life by applying their own unique style, it may give researchers insight into how potters operated within their community. This approach can also account for any unintentional steps taken or accidental actions taken by potters which are often insignificant (Schott 2003).

Sillar and Tite (2000), describe five areas in which style will directly impact technology and the pottery created. These include: raw material clays and whether or not to prepare or temper clay, tools which are used to create and decorate the pot, drying and firing and the conditions surrounding these practices, techniques used throughout the process, and lastly the *chaîne opératoire*. The term was first described by Leroi-Gourhan in 1964 when he stressed the necessity to study material culture beyond their physical appearances and as merely an end product of a process (Schott 2003). Originally the *chaîne opératoire* was applied to lithic analysis but has since branched out and become popular in other material analyses such as ceramics. Each individual step taken during manufacturing is analysed as well as the choices which were made with implementation of style throughout each stage (Sellet 1993, Schott 2003, Pikirayi and Lindahl 2013, Stark 1998).

Technological style may be a reflection of social interaction as communities increasingly interact and their 'ways of doing' may have overlaps and similarities, emphasising the importance of observing technological style within ceramic assemblages (Roddick 2009: 55). This can be evident in stylistic features as well as technological features. As groups interact and share knowledge, they develop their own way of performing tasks and artefact production. This concept is referred to as micro-style whereby different communities will have slight differences in these daily tasks (Dietler and Herbich 1998, Herbich 1987: 195-199). Interactions with neighbouring communities through trade or daily interaction may give shape to micro-styles as well as cross group marriage whereby a woman may bring her existing technological or design style or adopt the new community's technology (Antonites 2012: 258, Herbich 1987: 200, Lindahl and Pikirayi 2010). However, interaction does

not equate technological change, rather it creates a broader spectrum of knowledge for the potter (Gosselain and Livingstone Smith 2005).

Changes in technology within a community can be a direct result of external changes such as environmental changes, settlement changes or internal changes such as changes in methods, techniques, climate and access to resources (Fredriksen 2011, Lindahl and Pikirayi 2010). This can be best observed through sites of long occupation or multiple occupation periods whereby possible technological changes can be recorded as technology may be resistant to change (Stark 1998).

### **3.4 Learning and Communities of Practice**

Communities of practice as outlined by Lave and Wenger (1991), comprises of a group of people with common interest in a skill, task, or daily activity who come together to learn how to best perform tasks. This is comprised of experienced individuals as well as those with no knowledge whereby information and knowledge is shared generally amongst members (Lave and Wenger 1991: 27-54, Lindahl and Pikirayi 2010). This draws on the social practice theory of learning whereby learning is not an isolated activity but rather one which is a single facet reflecting all activity within a community (Lave and Wenger 1991: 113).

The production of pottery is a learnt skill whereby skills and knowledge are transferred amongst individuals through verbal, non-verbal, and visual communication (Killick 2004, Stark et al 2000). Ethnographically it has been observed that pottery learning takes form in watching and repeating rather than solely following verbal instructions whereby one would manipulate clay and learn through imitation (Krause 1985: 95). The repetition of what is observed and taught thus reinforces technological style and micro-styles of a certain group. This social activity, and communal way of doing would be passed down through generations thus reinforcing pre-existing social behaviours (Huffman 2007a). Potters may often stick to this taught method with slight adaptation to suit them as needed (Gosselain and Livingstone Smith 2005, Lawton 1967: 8). Learning can have a direct influence over technological and design style as changes in learnt behaviour will change technological aspects of ceramics (Roddick 2009: 54). Learning is especially

transmitted into forming methods as well as decorative style (Antonites 2012: 114, Gosselain 2000).

Learning is not restricted to an intra site scale as communities interacted and potters could take inspiration from other communities (Gosselain 2000: 209). As pottery production is learnt visually and verbally it can therefore be learnt across groups, even when language barriers are present (Gosselain 2000, Gosselain and Livingstone Smith 2005).

### **3.5 Approach Used in this Study**

The use of technological style was applied to this research whereby chemical and mineralogical analysis was used to observe technological similarities or differences observable across Evelyn (EV01) and Klein Bolayi (EV02) through their ceramic assemblages. The application thereof would then allow for the understanding of technological aspects which may relate to social interactions and social boundaries. Aspects of pottery production of the two sites and their respective styles were analysed and compared. Technological aspects such as similarities or differences in clays, forming methods and firing conditions were observed and documented for this study.

### **3.6 Conclusion**

With early ceramic studies focusing mostly on stylistic features, recent decades have seen a shift to the inclusion of technological analysis alongside stylistic analysis as to observe the whole process of ceramic production. This shift allows for a more holistic analysis on ceramics whereby broader topics of social boundaries and interactions can be observed. The use of technological style was applied to this study of ceramic assemblages to answer research questions pertaining to technological style of two Middle Iron Age sites within the Mapungubwe hinterland.

## CHAPTER FOUR - ANALYTICAL METHODS

Specific analytical procedures were carefully followed through each stage of analysis of this study. Analytical techniques were replicated on all samples to allow for accurate analysis. This chapter discusses the sequential processes of analysis and what processes were applied during each stage of analysis.

### 4.1 Sampling Strategy

This research made use of a random stratified sampling strategy (Orton 2000: 30). This sampling strategy is useful in research where sub-sampling will take place in sequence. Each sub-sampling level is referred to as strata, with each strata also undergoing sampling. This method was implemented as the study asks very specific questions pertaining to the chemical and mineralogical compositions of the ceramics. The following sections discuss the different strata of each sampling process.

#### 4.1.1 Site sampling

To ensure samples are representative of the full stratigraphic scope of the two sites, loci from each context of the sites were randomly selected for macroscopic analysis. This ensured coverage of all the trenches. This approach ensured the removal of bias within the spatial setting of each site to ensure the site as a whole was sampled. Body sherds of each site were macroscopically analysed and sorted into their identified fabric groups.

#### 4.1.2 PXRF sampling

Once the macroscopic analysis was completed and fabric groups were established, five samples per fabric group present in each stratigraphic context were selected for pXRF. It did occur that some contexts could not yield five sherds large enough for further analysis. As the analysis requires full coverage of the eye of the pXRF, sherds smaller than 3cm would not suffice. In these instances, as many as possible were selected. These samples were selected based on which best macroscopically matched

the fabric groups description. A total of 200 samples were selected, 100 from each site.

#### **4.1.3 Thin section sampling**

Once the XRF analysis was completed for each site, the statistical program JMP®, Version 15.0.0. (SAS Institute Inc.), was used to interpret the raw data. Using the multivariate analysis with 95% ellipses, the samples were interpreted in relation to one another within each fabric group. With applying the Jackknife distances of the outlier analysis within JMP, samples lying one standard deviation either side of the mean were removed and regarded as outliers of the bulk chemical sample of that particular fabric group. Jackknife distances is an efficient statistical tool as it identifies samples with lower variability without bias. A sample from each macroscopic fabric group was then randomly selected for petrographic analysis.

#### **4.2 Macroscopic Fabric Analysis**

Macroscopic fabric groups were based on aspects including grain size, inclusion density, porosity, as well as any other unique inclusions. This was done with the use of a hand lens (Bausch & Lomb Coddington Magnifier, 10x magnification) by analysing the sherds and their profiles to get an understanding of the fabrics. Majority of the fabric groups were based on special inclusions as the sherds had numerous variable inclusions within their matrices. Each site had been assigned unique fabric group names and when possible it was noted when macroscopic similarities were seen across sites. The local geology discussed in chapter two became helpful in this process as minerals in the ceramics which coincided with the geological records were noticed within the ceramics.

#### **4.3 PXRF Sample Preparation.**

The sherds of both sites were cut using the Struers Discoplan-TS and polished using the Struers LaboPol-25 to create a flat surface to place over the eye of the pXRF detector window. The samples were then left to dry as to not alter any chemicals

through the addition of extra water. To combat the heterogeneity of a sherd that is not created into a briquette, the samples were analysed three times and the mean of the three readings was calculated and used for further statistical analysis. The samples were moved for each reading to balance any offset of readings caused by a large mineral inclusion over the detector.

#### **4.4.1 PXRF Instrument Specifications**

This research used a handheld Bruker Tracer 5i. The Bruker Tracer 5i makes use of energy dispersive x-ray fluorescence to detect elements present. Its analysis range is from magnesium to uranium while its detection range lies between sodium and uranium.

The calibration for this study was set to ‘oxide 3-phase’ as to provide a full scope of elements as well as an array of oxides in percentages. The 3 phases consisted of thirty second analysis periods each whereby different elements are analysed in each phase. Each phase automatically applies a filter in order to absorb already detected elements and only allow for readings of not yet detected elements in subsequent phases. The progression of each phase also uses higher energy kilovolts in order to excite and dislodge electrons of elements with a higher atomic number.

#### **4.4 Statistical Analysis of pXRF Data**

JMP®, Version 15.0.0. (SAS Institute Inc.), was used to visually interpret the pXRF data. Intra-site analysis was separated into major elements (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe, MgO, K<sub>2</sub>O, Ca) and minor and trace elements (P, S, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Ta, Hg, Pb, Th, Pd, Au). Chlorine was omitted from statistical analysis due to its predisposition to alteration through washing and polishing of the ceramics.

Principle component analysis was first done whereby the scree plot was analysed to determine which components were most integral to understanding the dataset.

Thereafter, the PCA bi-plots and loading plots of the selected components were

presented and the driving forces behind each component were discussed. This procedure was repeated to major as well as minor and trace elements of both sites.

As  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  represent the largest portion of clays chemistry, a bi-plot was made for each site to illustrate the relationship between the two oxides. Other major elements,  $\text{MgO}$ ,  $\text{Ca}$ , and  $\text{Fe}$  were illustrated by means of 3D scatterplots to examine sample clustering on intra-site scales. Any outliers observed at each site were then further analysed to determine which elements contributed to a samples outlying nature.

3D scatterplots using principle components 1, 2, and 3 were used to examine the relationship of the data at an inter-site level. This was separated into major, minor and trace elements. Major elements  $\text{Al}_2\text{O}_3$ ,  $\text{K}_2\text{O}$ , and  $\text{Fe}$  were then selected and illustrated through a 3D scatterplot to examine individual elemental relationships between Evelyn and Klein Bolayi. Trace elements  $\text{S}$ ,  $\text{Ti}$ , and  $\text{Mn}$  were then selected and illustrated through a 3D scatterplot to examine the individual elemental relationships based on three trace elements.

The entirety of the statistical analysis of pXRF chemical data was used to create assumptions pertaining to the bulk composition of Evelyn and Klein Bolayi. This gave insight into the relationship between the two sites based on their chemical compositions which was then further investigated through petrographic analysis.

#### **4.5 Thin Section Sample Preparation**

Since sherds were already cut and polished from the pXRF analysis, the samples selected for petrographic analysis were mounted to a glass slide using epoxy resin and hardener and left to harden overnight. Once the resin hardened, the glass slide was attached to the Struers Discoplan-TS using an air vacuum and the bulk of the sample was sliced off. The sample was then further polished down using the same machine in 0,1mm increments until the sample was roughly 1-2mm thick. Finally, the sample was polished by hand using the Struers LaboPol-25 until the sample was 30 $\mu\text{m}$  thick. At this thickness minerals become transparent and will project their characteristic optical and morphological properties (Druc and Gwyn 1998: 709). Quartz, one of the most

abundant minerals, appears clear under plane polarized light when a sample is 30µm which is a good indicator that the sample is ready for analysis.

#### **4.6 Thin Section Analysis Procedure**

Thin sections were analysed using a Nikon Eclipse 50i POL polarizing microscope to create a detailed geological report of each sample (see Appendix B), this is comprised of the matrix, inclusions and voids. Each mineral present as aplastic inclusions were recorded alongside its semi-quantitative frequency. Three specific recordings for each mineral were recorded using NIS-Elements microscope imaging software whereby length, width, shape and sphericity were recorded of the largest, smallest and middle range inclusions (in mm) and presented in the full reports. The Udden- Wentworth grain size scale was used for the determination of mineral sizes. Where present, any argillaceous inclusions such as grog and clay pellets were measured and photographed with their compositions discussed.

Types of voids as well as their shape descriptions, sizes, semi-quantitative frequency and orientation were recorded. Of each type of void present, three specific recordings were taken of the largest, smallest and middle range voids to document the size range.

The clay matrix's semi-quantitative frequency was calculated by subtracting all the percentages of inclusions and voids from 100%. Colour and textural changes throughout the sherd were also described as well as any noticeable fine features within the matrix. This was done with the use of 10x and 20x magnification objectives to have a highly magnified view of the clay matrix and its plastic inclusions. The clay matrix can give insight into relative firing temperatures through the optical activity viewed through crossed polarized light. The presence of optical activity and the changes thereof within a sample were documented.

The mineral orientation of each sample was closely analysed as to give insight into forming methods employed within the pottery production sequence. Different forming methods leave traces of different mineral orientations in relation to the samples ceramic walls.

After the thin section reports were created, fabric groups were created to group together samples of the same mineralogical compositions as well as note differences between the groups. All mineralogical and technological observations were taken into consideration when formulating fabrics. Based on the data presented pertaining to the thin sections, fabric groups and sub-groups were then created to observe relationships between the samples of both sites. A thin section fabric group refers to a group of samples which are compositionally similar in their plastic and aplastic inclusions. Similar technological aspects such as forming methods and relative firing conditions were considered alongside mineralogical features within fabrics. A sub-fabric group refers to samples which differ only slightly from the fabric group either in relative frequency of plastics or aplastics but still share a common overarching mineralogical composition. A loner fabric refers to a sample which fits into none of the present fabrics or sub-fabrics and presents different mineralogy and technology. Fabrics were named according to distinctive and prominent mineralogical features present with a brief discussion pertaining to their compositions and technological features.

#### **4.7 Conclusion**

The ceramics of Evelyn and Klein Bolayi were processed and analysed according to the methods discussed above. As this study made use of scientific methods, strict procedures were replicated to ensure correct analysis and allow for comparable results. Variables were kept constant throughout the scope of the analytical process. Results of the methods discussed have been presented and discussed in the following chapter.

## CHAPTER FIVE – RESULTS

This chapter presents the results of the macroscopic analysis of fabric groups. This data formed a baseline for selection of samples for pXRF analysis. This chapter also discusses the petrographic analysis presented into petrographic reports with technological observations pertaining to temper, forming methods, and relative firing conditions being discussed.

### 5.1 Macroscopic Fabric Groups of Evelyn and Klein Bolayi

A total of thirteen macroscopic fabric groups were identified across the two sites and summarised in Table 5-1. Pyrite inclusions were found to be the most common across both sites. This could be an indicator of local clay procurement and production as pyrite is found throughout the area's local geology. Klein Bolayi had a wider range of fabrics within the ceramic assemblage with a total of eight fabric groups of which three groups (fabrics F, K, and L) showed no similarity to the fabric groups of Evelyn. Klein Bolayi also had two unique fabric groups (fabrics J and M), consisting of only one sample each.

Fabric groups C and E were the most dominant groups present in the Evelyn ceramic assemblages with pyrite inclusions present in majority of the ceramic sherds. Fabric group H was the dominant group present at Klein Bolayi, comprising of pyrite inclusions.

These similarities and differences on an intra- and inter-site level will be further discussed alongside the pXRF data as well as the results of the thin section analysis.

**Table 5-1: Macroscopic fabric groups and their descriptions**

| Site         | Fabric Group | Description                                                                                    | Frequency within assemblage       | Similar to (across sites) |
|--------------|--------------|------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------|
| Evelyn       | A            | Dull black, opaque inclusions                                                                  | Common                            | None                      |
|              | B            | Grog-like inclusions                                                                           | Common                            | Fabric G                  |
|              | C            | Inclusions like that of fabric A, along with pyrite inclusions                                 | Very common                       | None                      |
|              | D            | Specularite inclusions                                                                         | Unique- only single sherd present | Fabric I                  |
|              | E            | Pyrite inclusions                                                                              | Very common                       | Fabric H                  |
| Klein Bolayi | F            | Fine grained matrix with low inclusion density and low porosity. No special inclusions noticed | Uncommon                          | None                      |
|              | G            | Grog-like inclusions                                                                           | Rare                              | Fabric B                  |
|              | H            | Pyrite inclusions                                                                              | Very common                       | Fabric E                  |
|              | I            | Specularite inclusions                                                                         | Rare                              | Fabric D                  |
|              | J            | White, coarse grained inclusions                                                               | Unique-only single sherd present  | None                      |
|              | K            | Reddish, transparent inclusions                                                                | Uncommon                          | None                      |
|              | L            | Inclusions like that of fabric K, along with pyrite                                            | Uncommon                          | None                      |
|              | M            | Opaque grey, coarse grained inclusions                                                         | Unique-only single sherd present  | None                      |

## 5.2 PXRF Statistical Analysis

JMP®, Version 15.0.0. (SAS Institute Inc.), was used to process and analyse all pXRF data of this study. As outlined in the previous chapter, various statistical analyses were utilised as to best interpret the chemical data to contribute towards answering the research questions. This includes principle component analysis using various components, bi-plots of certain elements and 3D scatterplots. All statistical analysis was repeated to both sites as to compare and contrast them equally.

The data analysis is split into major elements (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe, MgO, K<sub>2</sub>O, Ca) and minor and trace elements (P, S, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Ta, Hg, Pb, Th, Pd, Au). This was done to separate elements of substantially higher percentages as to best interpret the chemical data.

### 5.2.1 Evelyn pXRF Analysis

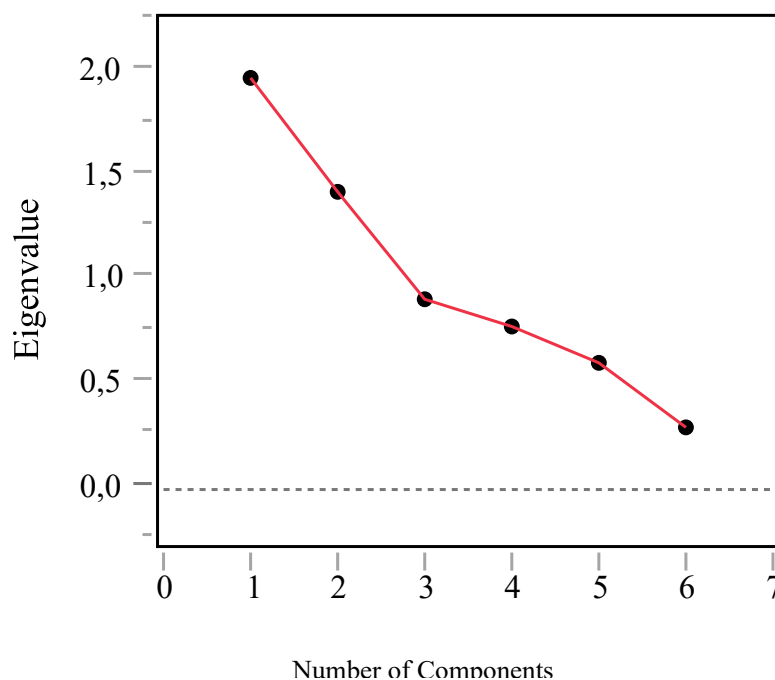


**Figure 5-1: Evelyn scree plot of major elements**

Principle component analysis of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe, MgO, K<sub>2</sub>O, and Ca presents a scree plot whereby components 1 to 3 have the highest eigenvalues. From component 3, the

eigenvalues begin to scree slightly but do not taper off completely within the scree plot, showing less importance amongst the components. The pca bi-plots and loading plots of all six components were further analysed to observe chemical relationships as well as the driving forces behind the principle components.

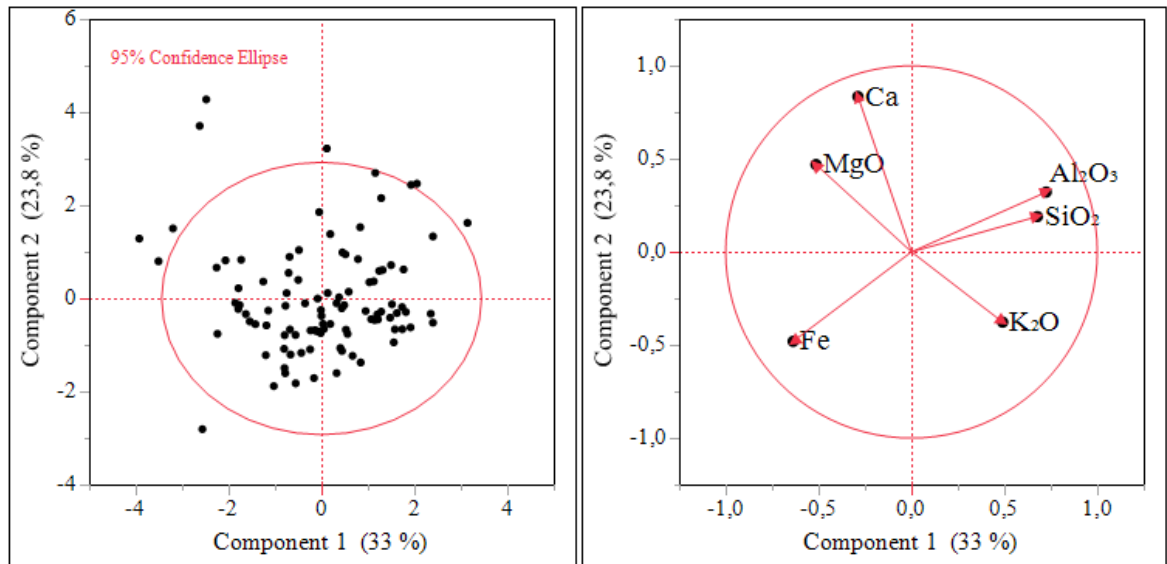


**Figure 5-2: Evelyn pca bi-plot and loading plot of major elements. Components 1 and 2**

Principle component analysis of component 1 and 2 using  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca places the majority ( $n=91$ ) of samples in the 95% confidence ellipses with 9 outliers. Based on the loading plot, principle component 1 is driven by silica dioxide ( $\text{SiO}_2$ ) as well as aluminium dioxide ( $\text{Al}_2\text{O}_3$ ). Principle component 1 accounts for 33% of variance amongst the dataset, whereby the oxides which are the driving forces behind them generally constitute for the largest percentage chemically of clays. Principle component 2 is driven mostly by calcium (Ca) and accounts for 23.8% of the variance amongst the dataset.

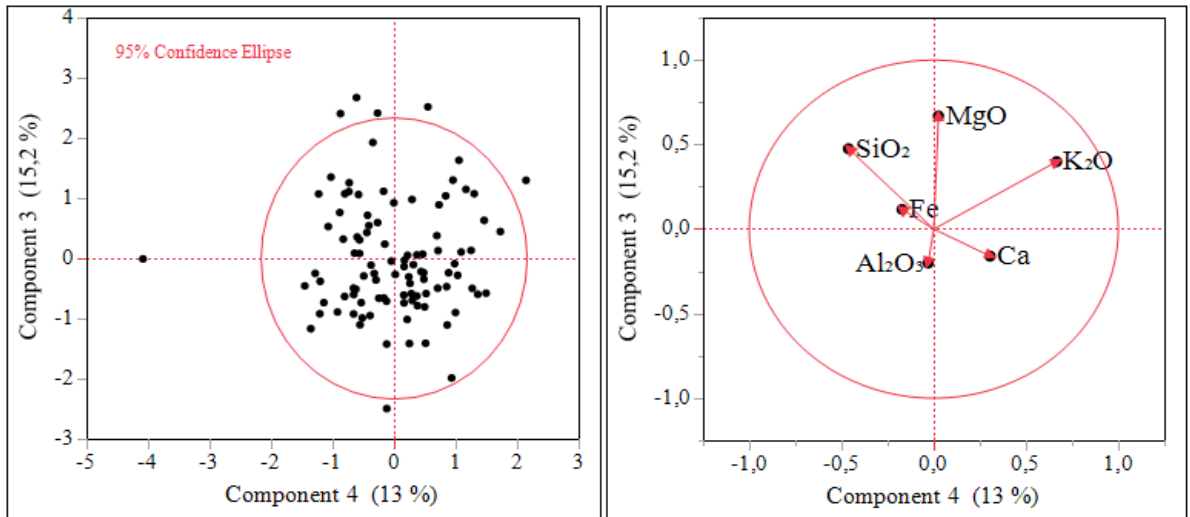


**Figure 5-3: Evelyn pca bi-plot and loading plot of major elements. Components 3 and 4**

Principle component analysis of component 3 and 4 using  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca places the majority ( $n=93$ ) of samples in the 95% confidence ellipses with 7 outliers. Based on the loading plot, component 4, which represents 13% of variance amongst the dataset is driven mainly by potassium oxide ( $\text{K}_2\text{O}$ ). Component 4 represents the most prominent outlier, sample 129, which lies on 0,-4 on the x,y axis. Component 3, which represents 15.2% of variance amongst the dataset is driven mainly by magnesium oxide (MgO) and silica dioxide ( $\text{SiO}_2$ ) and also drives the majority of the outliers from the 95% confidence ellipses. Potassium oxide, magnesium oxide and silica dioxide are all naturally occurring chemical compounds within clay bodies.

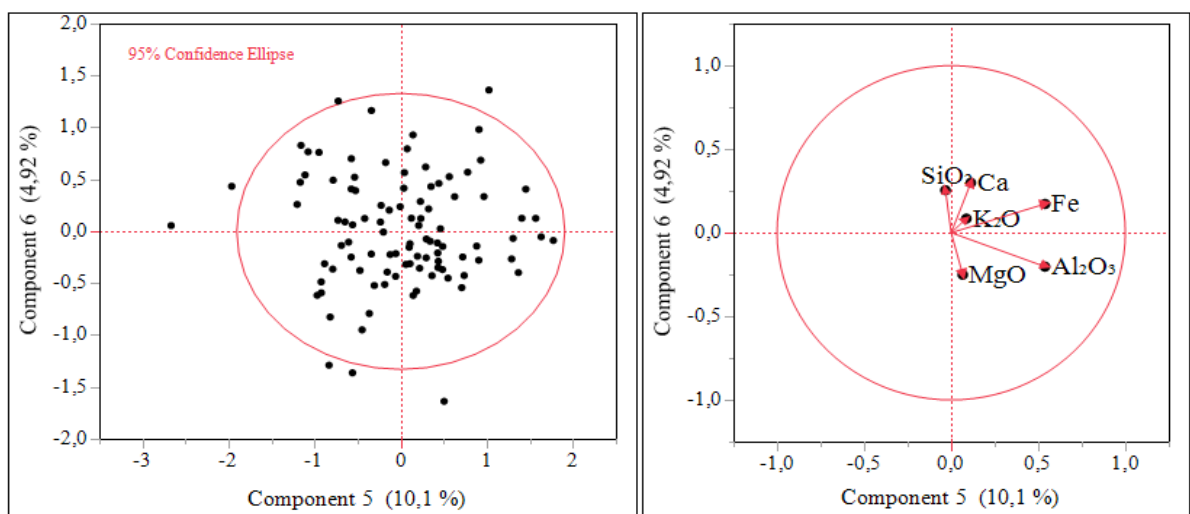


**Figure 5-4: Evelyn pca bi-plot and loading of major elements. Components 5 and 6**

Principle component analysis of component 5 and 6 using  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca places the majority ( $n=93$ ) of samples in the 95% confidence ellipses with 7 outliers. Component 5, which represents 10.1% of variance within the dataset, is driven by iron (Fe) and aluminium oxide ( $\text{Al}_2\text{O}_3$ ) based on the loading plot. Component 5 shows a fairly similar spread of data on the x axis with a few samples falling outside the 95% confidence ellipses. Component 6, which is driven by calcium (Ca), and silica dioxide ( $\text{SiO}_2$ ), represents 4.92% of variance within the dataset. As previously mentioned, silica dioxide presents the largest percentage of the chemical data in clay.

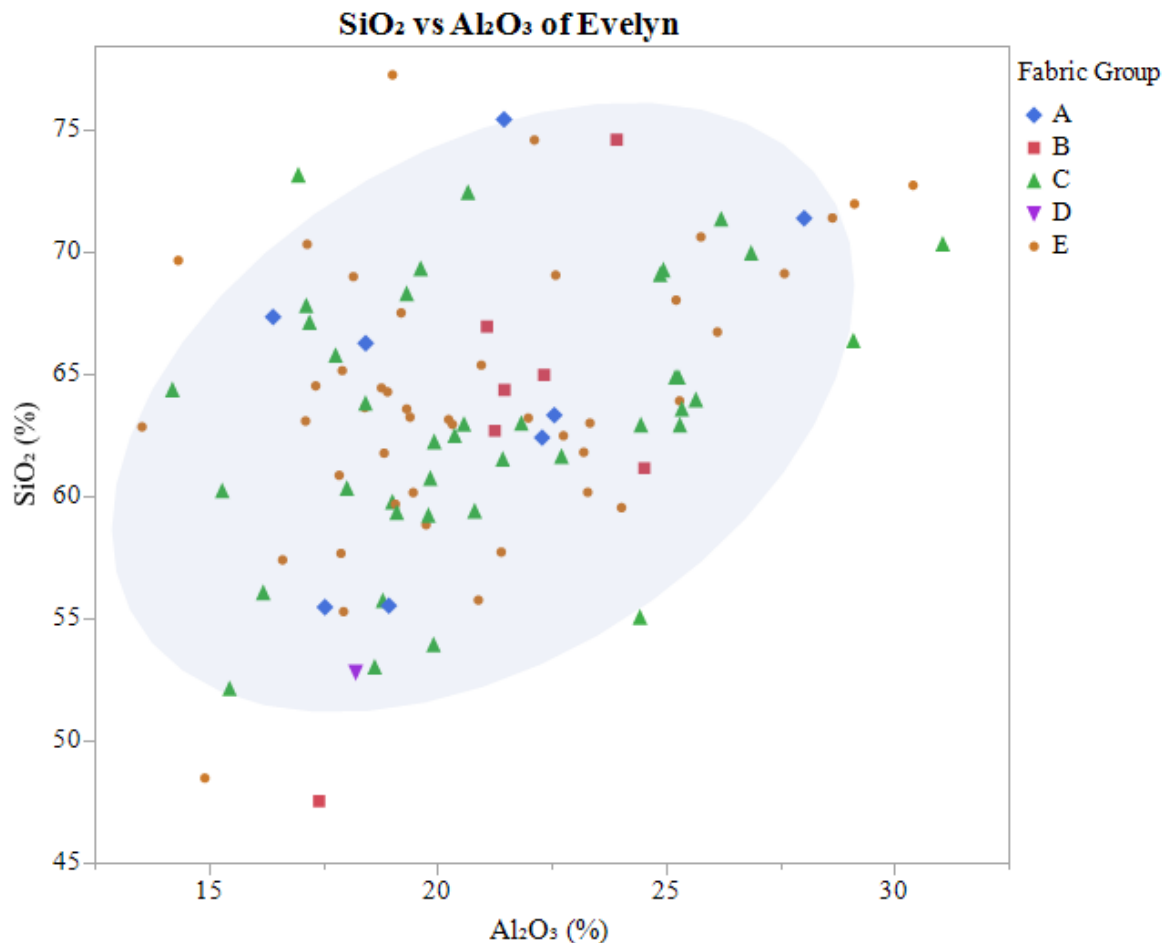


**Figure 5-5: Bi-plot of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  of Evelyn with 90% confidence ellipses**

The  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  constitutes the largest proportion of clays' chemical composition, thus it was analysed by means of a bi-plot. Majority of the dataset ( $n=89$ ) lies within the 90% confidence ellipses with 11 samples as outliers. Upon analysis of macroscopic fabric groups, samples of different groups overlap and do not tend to

form unique clusters based on their macroscopic properties. This shows the homogeneity of the whole site's silica dioxide ( $\text{SiO}_2$ ) and aluminium oxide ( $\text{Al}_2\text{O}_3$ ) levels. Silica dioxide levels range from 47.53% to 77.24% with a mean of 63.63%. This reflects abundant silicate minerals such as quartz and feldspars, which are the most common minerals on earth. As such, a large variation amongst the dataset is to be expected. The silica dioxide represents the most abundant oxide as well as the highest variation amongst the full chemical dataset. Aluminium oxide levels range from 13.54% to 31.06% with a mean of 21%. Aluminium oxide is found in minerals such as quartz, feldspars, micas, and olivine. Aluminium oxide represents the second most abundant oxide present within the chemical data.

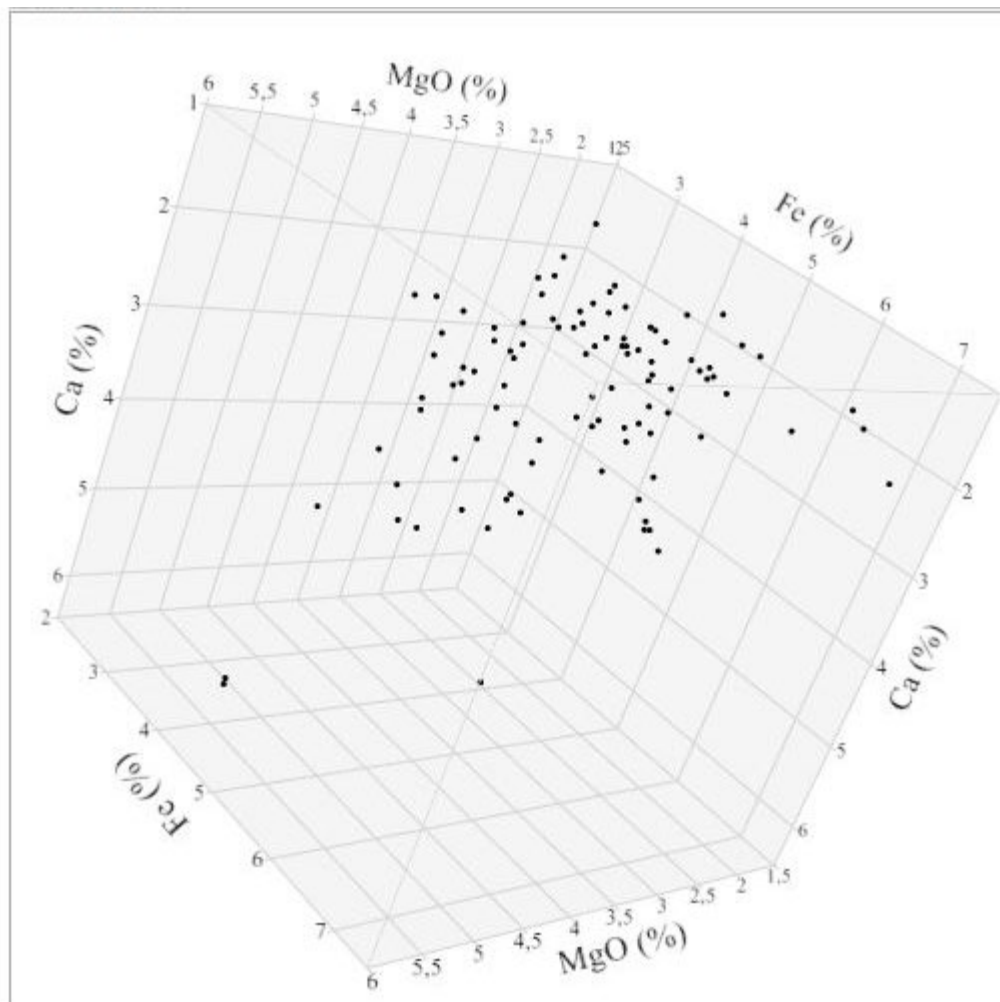


Figure 5-6: Evelyn 3D scatterplot of MgO, Ca, and Fe

The 3D scatterplot of MgO, Ca, and Fe shows a tendency for the samples to cluster in lower levels of both MgO and Fe. Calcium (Ca) ranges from 1.41% to 6.22% with a mean of 2.72% with samples clustering around 2% on the scatterplot. Magnesium oxide (MgO) ranges from 1.58% to 5.78% with a mean of 3.04% with higher variation than calcium. Iron (Fe) presents the most variation with a range of 2.88% to 7.39% and a mean of 4.27%. Higher iron levels could possibly relate to iron rich minerals such as pyrite, hematite, and magnetite. As seen in the scatterplot, data clusters towards lower percentages of calcium and magnesium oxide and spreads out along iron levels. Considering the variation in iron, the samples still present an overarching homogeneity based on the three elements combined.

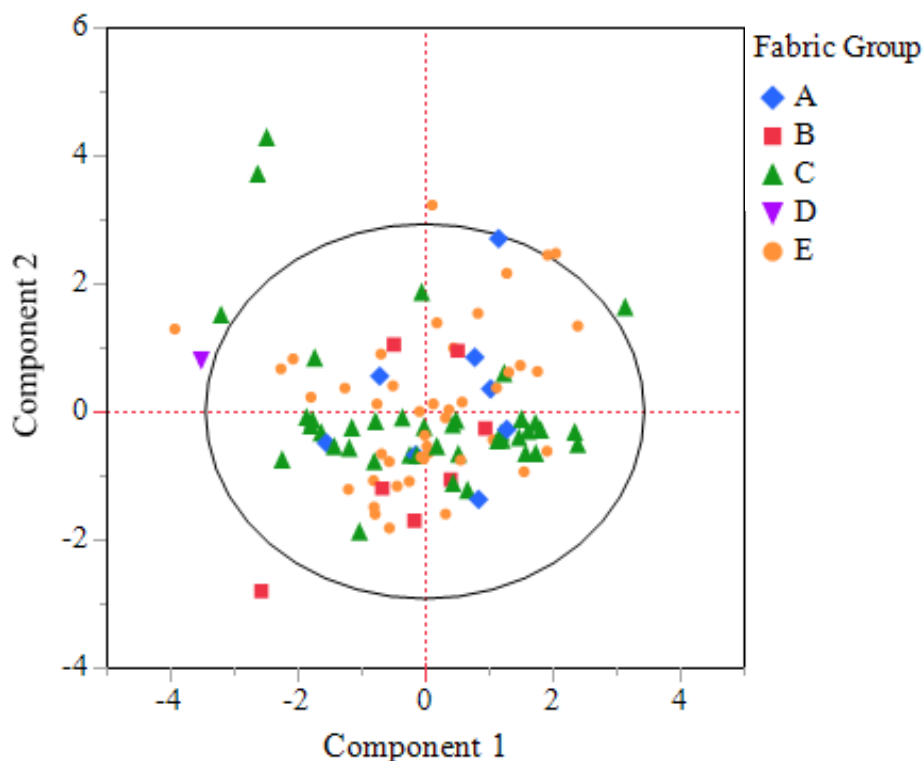


**Figure 5-7: Evelyn pca bi-plot by macroscopic fabric groups**

Figure 5-7, like figure 5-2, makes use of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe, MgO, K<sub>2</sub>O, and Ca with 95% confidence ellipses, but with the addition of macroscopic fabric groups. This was done to explore the relationship between macroscopic fabric groups and chemical data. Based on principle components 1 and 2, which are driven by SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and

Ca (see figure 5-2), the fabric groups do not form unique chemical clusters. As such, macroscopic fabric groups lack any distinctive correlations to chemical data. Rather, they largely overlap and share an overarching chemical relationship for the whole assemblage.

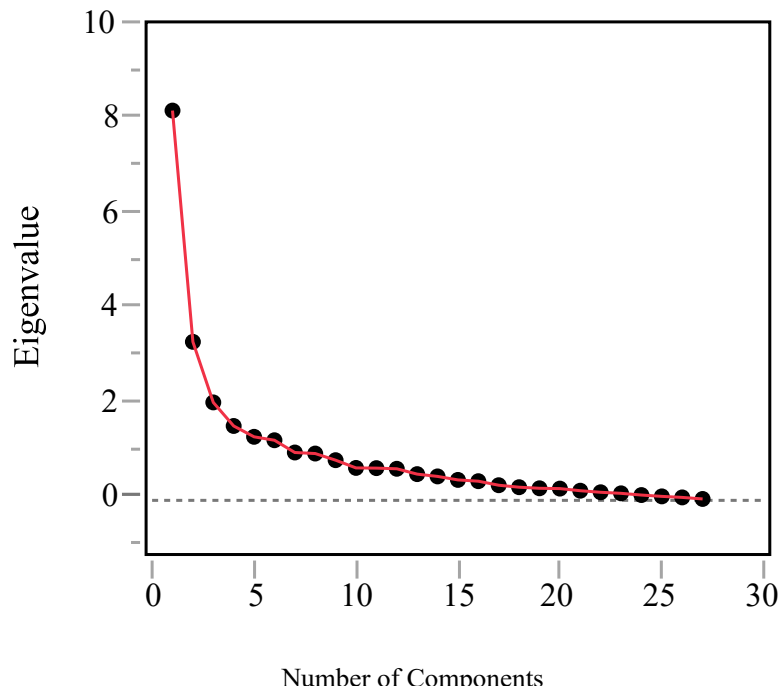


**Figure 5-8: Evelyn scree plot of minor and trace elements**

The scree plot of minor and trace elements shows that of the 27 components, components 1 to 4 have the highest eigenvalues. From component 5, the eigenvalues taper off and have similar values and are no longer central to understanding the minor and trace elements. As a result, the first four components were selected for pca bi-plots and loading plots to condense the minor and trace elements of Evelyn and to observe the driving forces behind them.

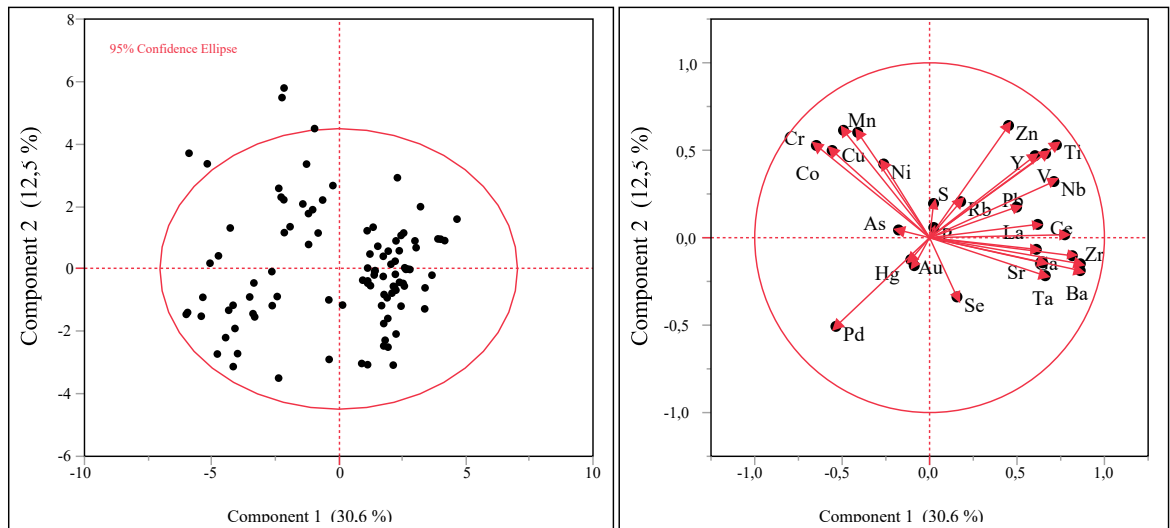


**Figure 5-9: Evelyn pca bi-plot and Loading Plot of Minor and Trace elements. Components 1 and 2**

Principle component analysis of component 1 and 2 of minor and trace elements places the majority ( $n=95$ ) of samples in the 95% confidence ellipses with 5 outliers. Principle component 1, which represents 30.6% of variance within the dataset is driven mainly by titanium (Ti), barium (Ba), and gallium (Ga). Component 2, which represents 12.5% of variance within the dataset is driven by manganese (Mn), chromium (Cr), and lead (Pb).

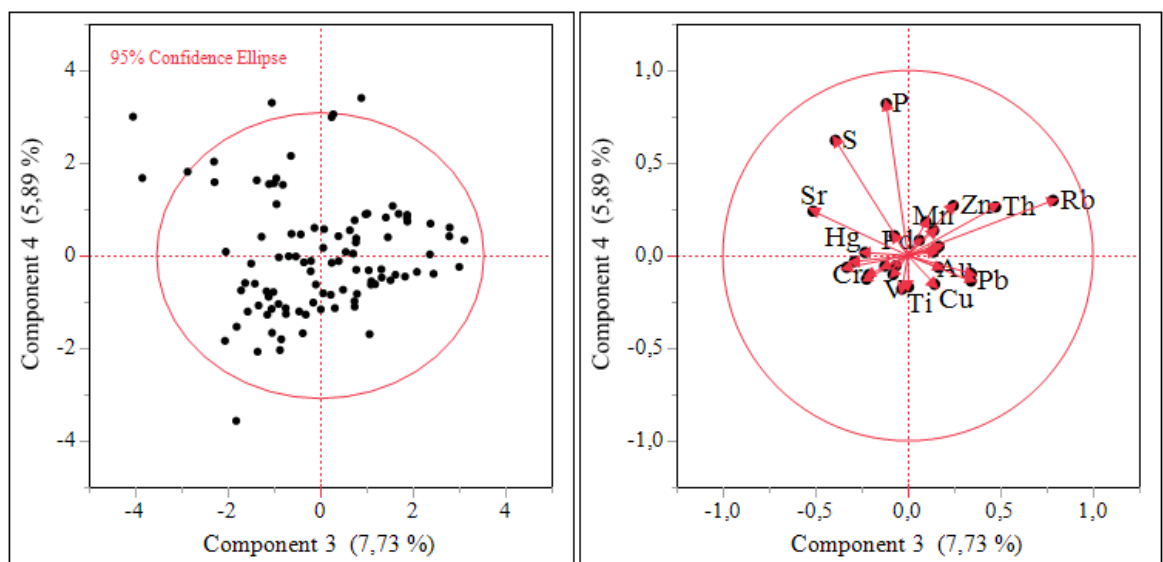


**Figure 5-10: Evelyn pca bi-plot and loading plot of minor and trace elements. Component 3 and 4**

Principle component analysis of component 3 and 4 of minor and trace elements places the majority (n=95) of samples in the 95% confidence ellipses with 5 outliers. Principle component 3, which represents 7.73% of variance within the dataset, is driven mostly by rubidium (Rb), and slightly by thorium (Th). Principle component 4, which represents 5.89% of variance amongst the dataset, is driven mostly by phosphorus (P) and slightly by sulphur (S). Phosphorus is greatly influenced by post-depositional absorption in soil, thus higher levels would represent the absorption of soil phosphates in ceramics.

### 5.2.2 Summary of Evelyn Chemical Data

Through the statistical analysis of the chemical data of Evelyn it can be argued that the clay composition of the site as a whole is largely similar. The overall composition of the clays of the site are possibly the same with slight variations within certain elements and oxides. This is best visible through the higher variation seen in silica dioxide ( $\text{SiO}_2$ ) as well as referencing the raw data (see Appendix A). The silica dioxide levels relate to the quartz and feldspars content of the ceramics, whereby a large variation is to be expected, especially in instances of the use of a heterogeneous sample as used in this study. A likely explanation in exceedingly higher levels of silica dioxide could directly be related to a large quartz or feldspar grain visible directly over the eye of the pXRF detector during the reading.

The analysis of the chemical data of Evelyn showed no distinctively separate chemical fabric groups, and as pXRF should rather be used as a preliminary analysis in ceramic technology, the correlation between chemical data of Evelyn and its petrographic samples will be further discussed. As such, the site chemically constitutes for one general chemical group as a whole with no particular outliers.

Pertaining to the analysis of the chemistry of the macroscopic fabric groups, there is no direct correlation or distinctive clustering of the fabric groups together based on chemical compositions. This relates to the overlap and similarity in the chemical data. It is more likely that during macroscopic analysis, one cannot see the full scope of inclusions whereby the absence of a mineral visible in the profiles does not necessarily mean an absence in the whole sherd. pXRF also allows for a reading of

the bulk of the ceramic paste, where macroscopic and petrographic analysis can identify mineral inclusion. While macroscopic variations may be present, chemically Evelyn presents a largely homogenous sample.

### 5.2.3 Klein Bolayi pXRF Analysis

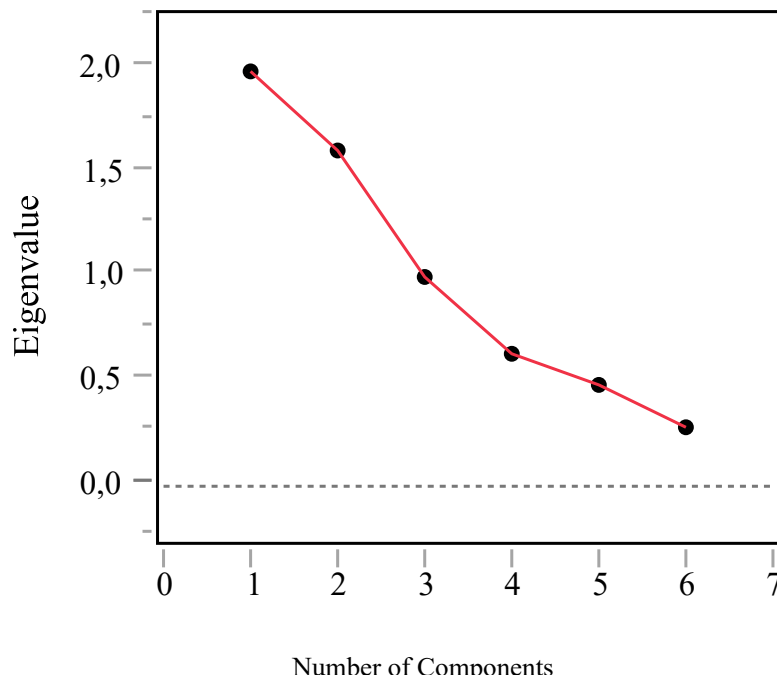


**Figure 5-11: Klein Bolayi scree plot of major elements**

Principle component analysis of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca presents a scree plot whereby components 1 to 4 have the highest eigenvalues. Components 5 and 6 begin to scree but do not taper off completely. As a result, the PCA bi-plots and loading plots of all six components were further analysed to observe chemical relationships as well as the driving forces behind the principle components.

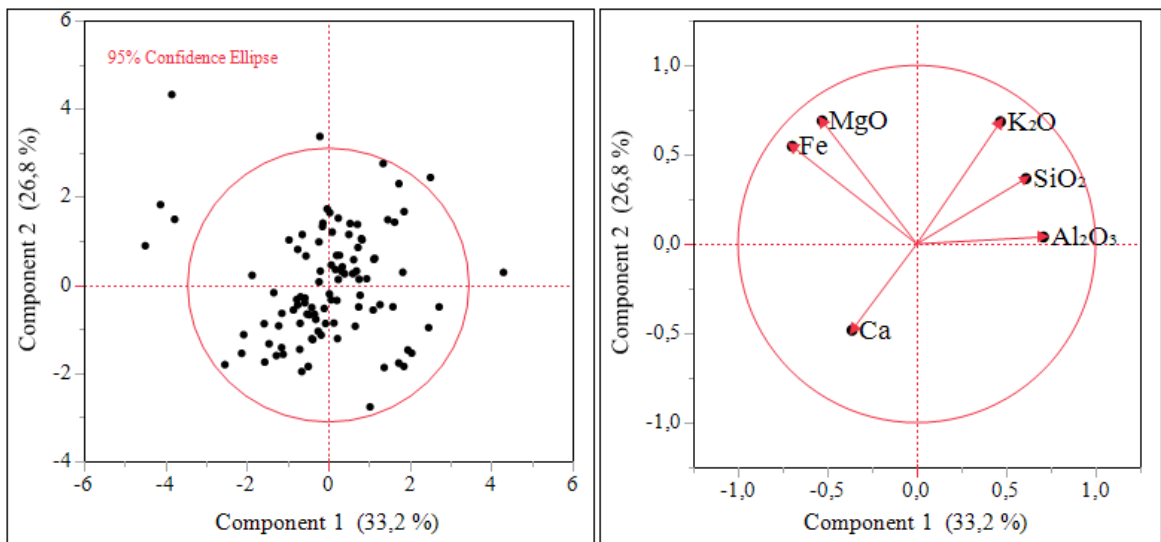


**Figure 5-12: Klein Bolayi pca bi-plot and loading plot of major elements. Component 1 and 2**

Principle component analysis of component 1 and 2 of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe, MgO, K<sub>2</sub>O, and Ca places the majority (n=93) of samples in the 95% confidence ellipses with 7 outliers. Based on the loading plot, principle component 1 is driven mostly by aluminium dioxide (Al<sub>2</sub>O<sub>3</sub>) and silica dioxide (SiO<sub>2</sub>) and represents 33.2% variance amongst the dataset. Principle component 2, which represents 26.8% variance amongst the dataset is driven mostly by magnesium oxide (MgO), iron (Fe), and potassium oxide (K<sub>2</sub>O).

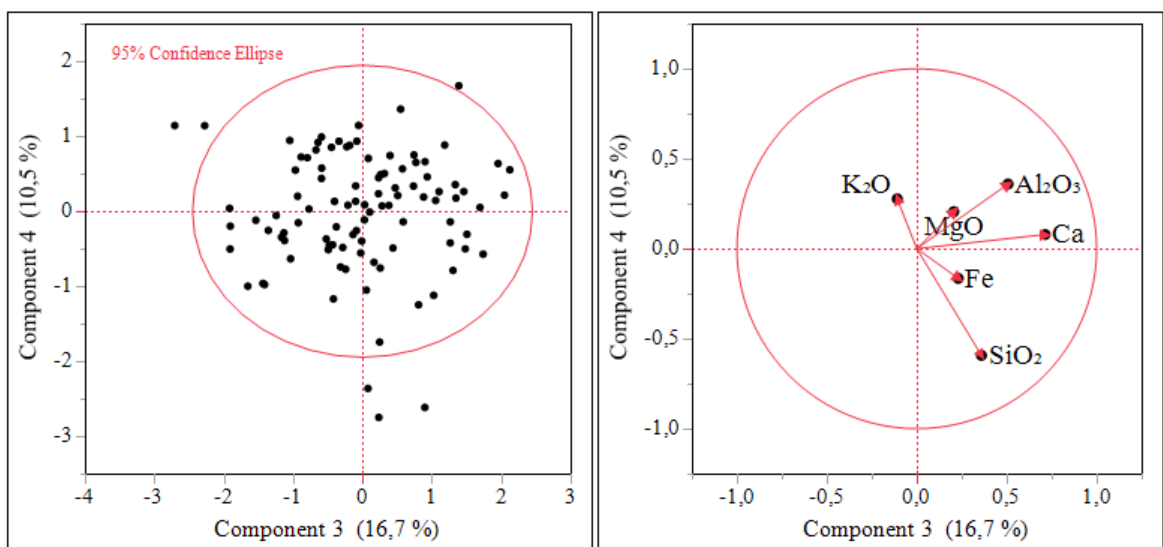


**Figure 5-13: Klein Bolayi pca bi-plot and loading plot of major elements. Component 3 and 4**

Principle component analysis of component 3 and 4 of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca places the majority ( $n=94$ ) of samples in the 95% confidence ellipses with 6 outliers. Component 3, which represents 16.7% of the variance amongst the dataset is largely driven by calcium (Ca) as well as silica dioxide ( $\text{SiO}_2$ ), and aluminium oxide ( $\text{Al}_2\text{O}_3$ ). Component 4, which represents 10.5% of the variance amongst the dataset, is driven mainly by potassium oxide ( $\text{K}_2\text{O}$ ).

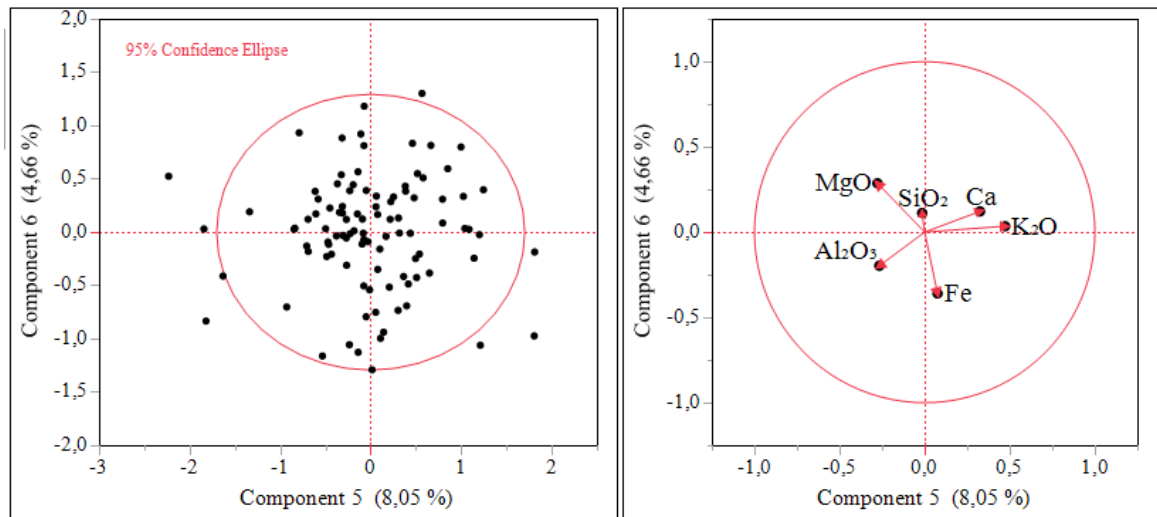


**Figure 5-14: Klein Bolayi pca bi-plot and loading plot of major elements. Component 5 and 6**

Principle component analysis of component 5 and 6 of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca places the majority ( $n=92$ ) of samples in the 95% confidence ellipses with 8 outliers. Principle component 5, which represents 8.05% of variance in the dataset, is driven by potassium oxide ( $\text{K}_2\text{O}$ ). Principle component 6, which represents 4.66% of variance in the dataset, is driven by both magnesium oxide (MgO), and aluminium oxide ( $\text{Al}_2\text{O}_3$ ).

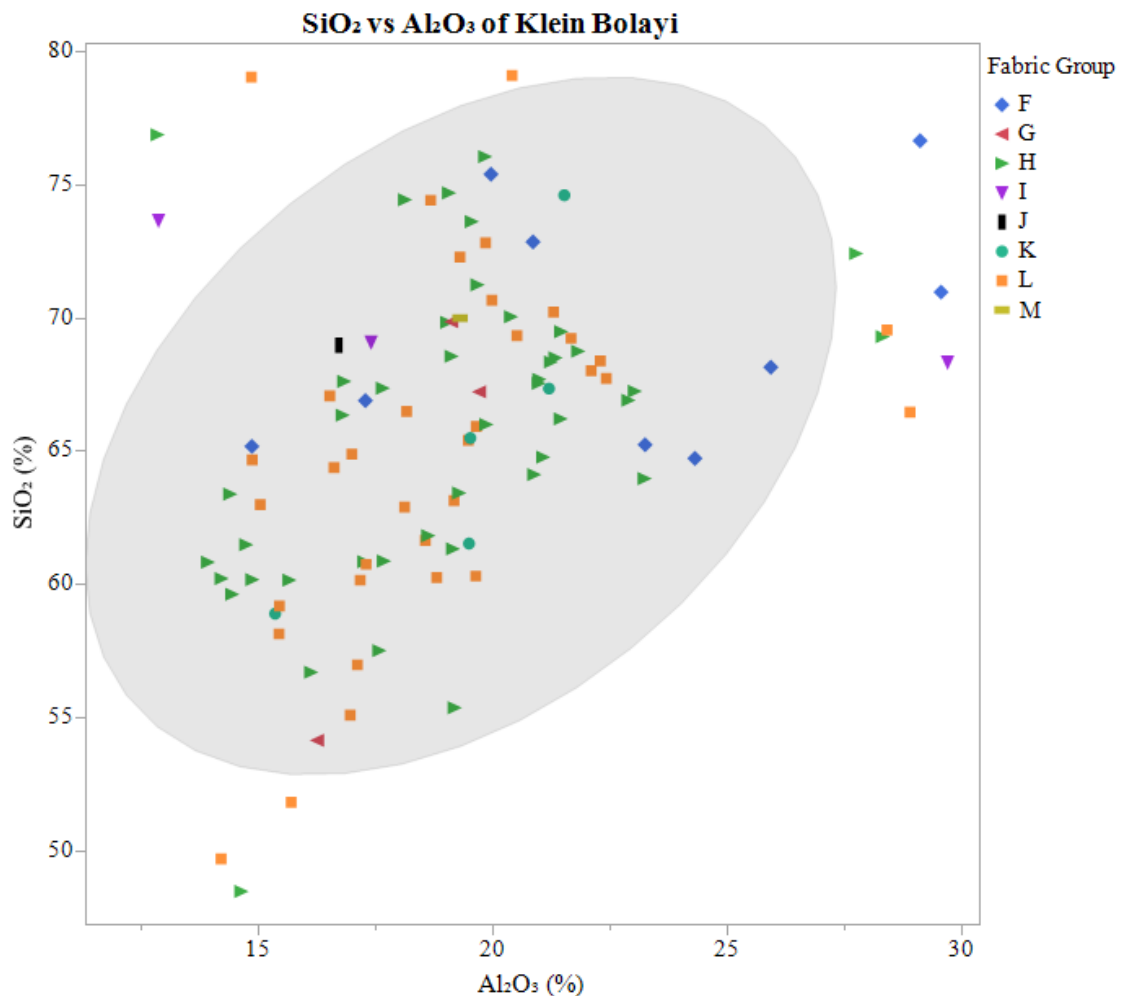


**Figure 5-15: Klein Bolayi bi-plot of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> with 90% confidence ellipses**

The silica dioxide (SiO<sub>2</sub>) and aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) constitutes the largest proportion of a clays' chemical composition, thus it was analysed by means of a bi-plot. Majority of the dataset (n=86) lies within the 90% confidence ellipses with 14 outliers. Six outliers belong to macroscopic fabric group L but do not tend to cluster together or form a pattern. Analysis of macroscopic fabric groups show that samples of different groups overlap and do not tend to form unique clusters based on their macroscopic properties. Silica dioxide levels range from 48.46% to 79.08% with a mean of 65.93%. This reflects abundant silicate minerals such as quartz and feldspars. The silica dioxide represents the most abundant oxide as well as the highest variation amongst the full chemical dataset and within clays. Aluminium oxide levels range from 12.86% to 29.70% with a mean of 19.33%. This reflects minerals such as quartz, feldspars, micas, and olivine. Aluminium oxide represents the second most abundant

oxide present within the chemical data. Based on these two abundant oxides, Klein Bolayi presents a generally similar pattern across the site.

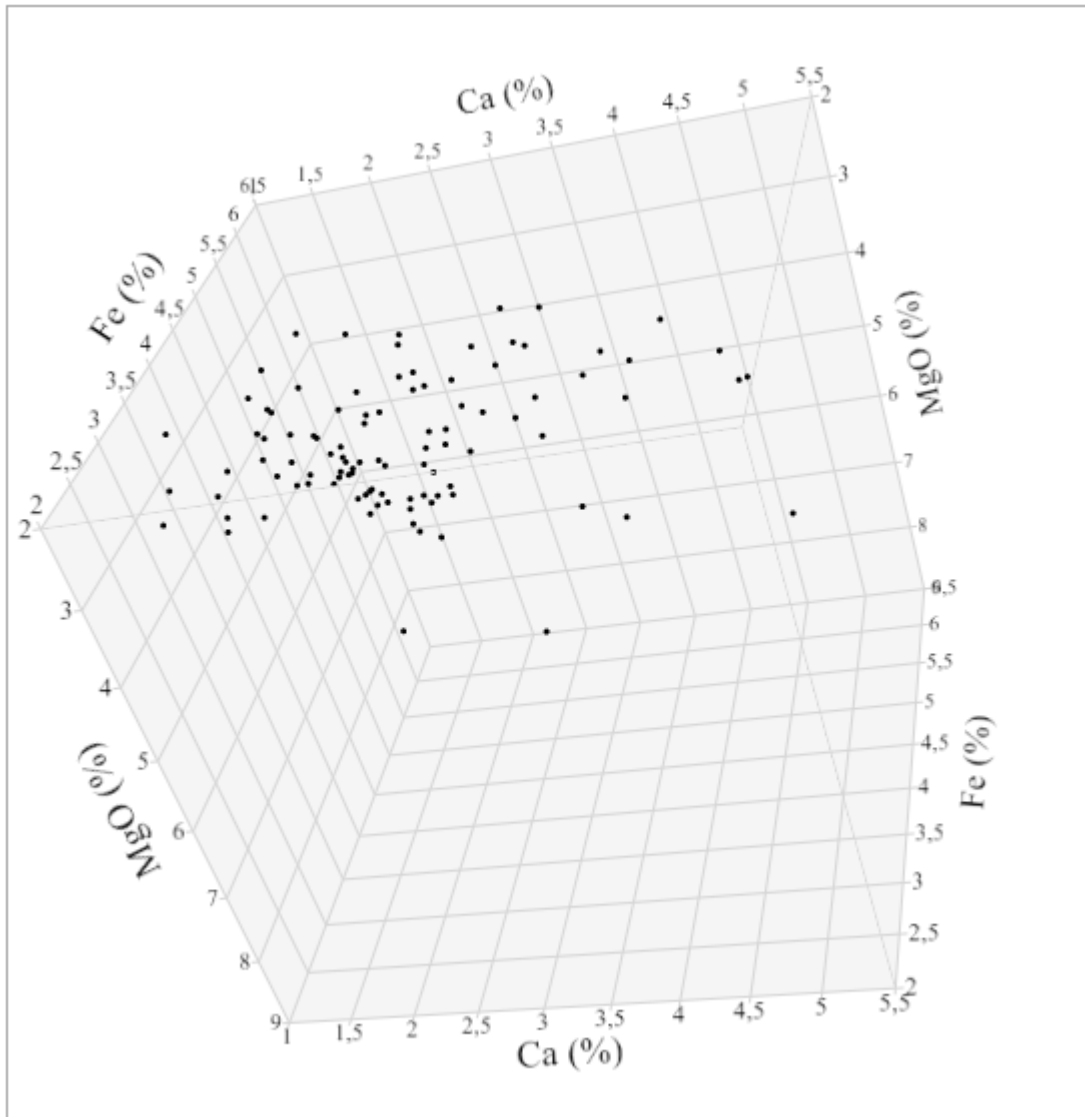


**Figure 5-16: Klein Bolayi 3D scatterplot of MgO, Ca, and Fe**

The 3D scatterplot of MgO, Ca, and Fe shows a tendency for the samples to cluster in lower levels of magnesium oxide (MgO) and varying across both iron (Fe) and calcium (Ca). Calcium ranges from 1.43% to 5.11% with a mean of 2.72%. Magnesium oxide ranges from 2.05% to 8.62% with a mean of 3.24% with higher variation than calcium and iron. Iron ranges from 2.18% to 6.18% and a mean of 3.75%. Higher iron levels could possibly relate to iron rich minerals such as pyrite, hematite, and magnetite. As seen in the scatterplot, the data clusters towards lower

percentages of magnesium oxide and spreads out along iron and calcium percentages. Based on the three elements presented, Klein Bolayi has a fairly homogenous composition.

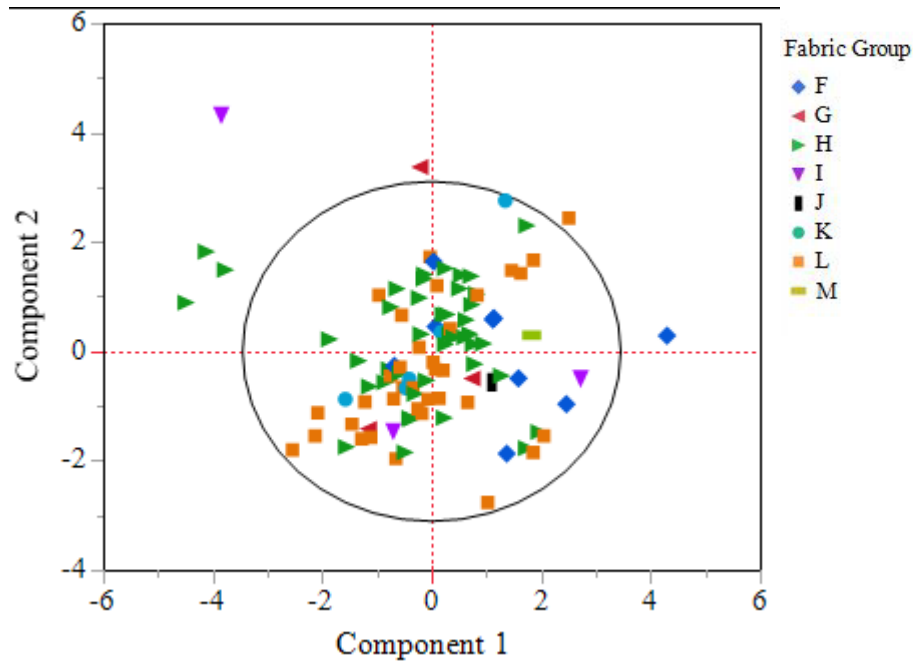


**Figure 5-17: Klein Bolayi pca bi-plot of macroscopic fabric groups**

Figure 5-17, like figure 5-12, makes use of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , Fe, MgO,  $\text{K}_2\text{O}$ , and Ca with 95% confidence ellipses with the addition of macroscopic fabric groups. This was done to explore the relationship between macroscopic fabric groups and chemical data. Based on principle components 1 and 2, which are driven by  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , MgO, Fe and  $\text{K}_2\text{O}$  (see figure 5-12), the fabric groups do not form unique chemical clusters. As such, macroscopic fabric groups of Klein Bolayi lack any distinctive correlations to chemical data. Rather, they largely overlap and share an overarching chemical relationship as a whole site.

Three outliers of group H (samples 3, 4, and 5) are clustered together as outliers in the first quadrant of the graph along with sample 34 of fabric I. These four outliers form a consistent outlying cluster throughout the statistical analysis.

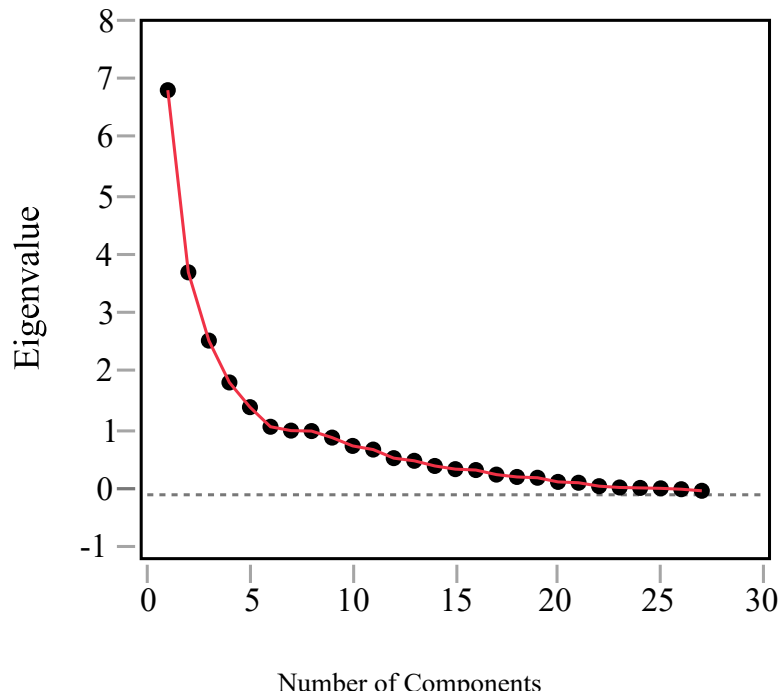


**Figure 5-18: Klein Bolayi scree plot of minor and trace elements**

The scree plot of minor and trace elements shows that of the 27 components, components 1 to 4 have the highest eigenvalues. From the fifth and especially the sixth component, the eigenvalues taper off and have similar values. As a result, the first four components were selected for pca bi-plots and loading plots to investigate the driving forces of the first four components.

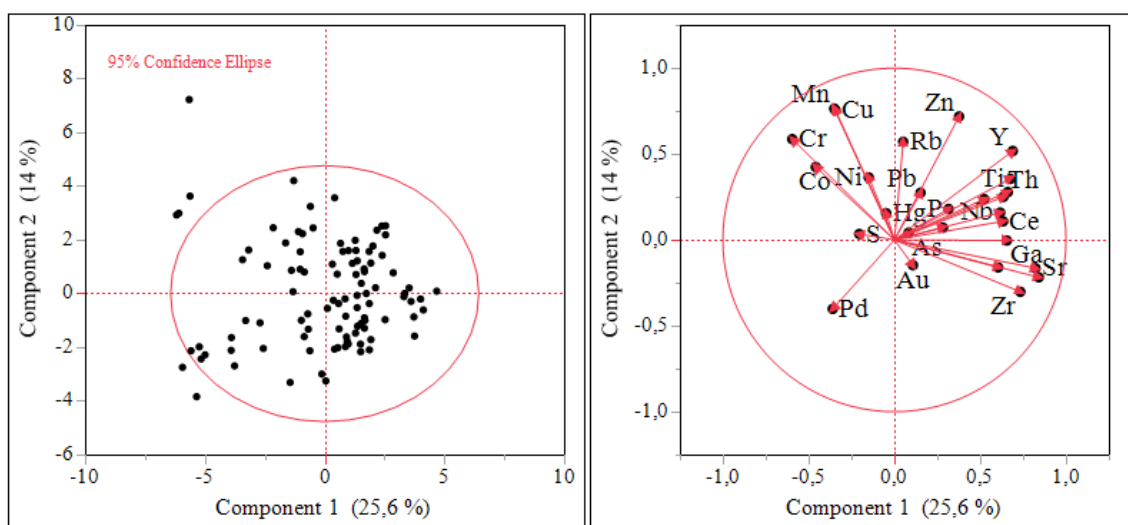


**Figure 5-19: Klein Bolayi pca bi-plot and loading plot of minor and trace elements. Component 1 and 2**

Principle component analysis of component 1 and 2 of the trace elements places the majority (n=94) of samples in the 95% confidence ellipses with 6 outliers. Component 1, which represents 25.6% of the variance amongst the dataset, is driven mostly by strontium (Sr), gallium (Ga), and yttrium (Y) based on the loading plot. Component 2, which represents 14% of the variance amongst the dataset, is driven by zinc (Zn), copper (Cu), manganese (Mn), and chromium (Cr) based on the loading plot. Most of the samples lie homogeneously to the right of the zero point of the x axis, whereas to the left the data lays more scattered. This shows an overarching homogeneity of trace elements within the assemblage, driven largely by strontium, gallium, yttrium, zinc, copper, manganese, and chromium.

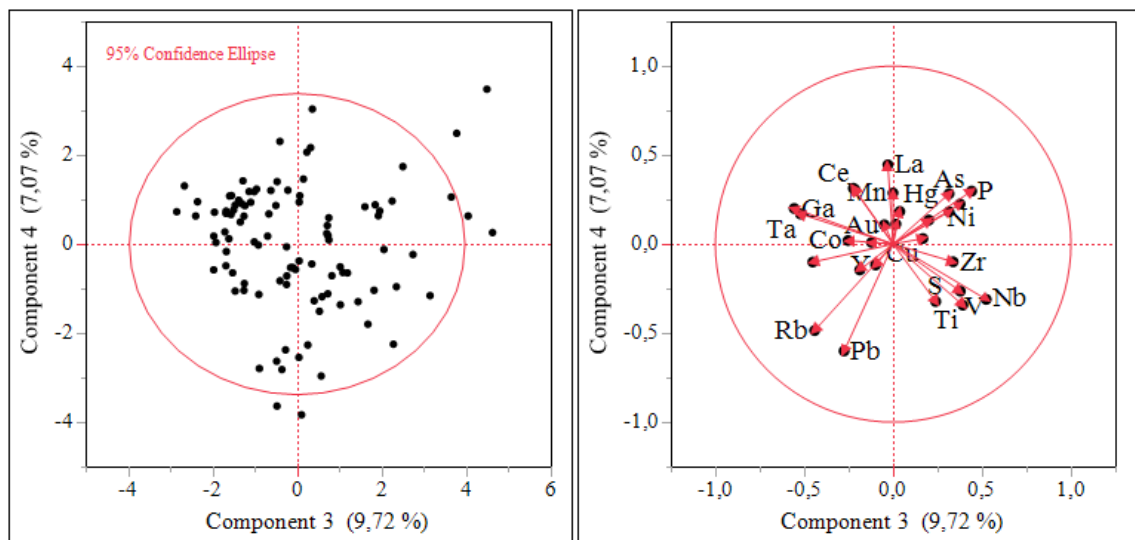


**Figure 5-20: Klein Bolayi pca bi-plot and loading plot of minor and trace elements. Component 3 and 4**

Principle component analysis of component 3 and 4 of the trace elements places the majority (n=94) of samples in the 95% confidence ellipses with 6 outliers. Component 3, which represents 9.72% of the variance is driven largely by niobium (Nb) and phosphorus (P) based on the loading plot. As previously mentioned, phosphorus is highly susceptible to post depositional absorption from soil and does not represent the phosphorus levels in the original raw clay used for pottery. Component 4, which represents 7.07% of the variance within the dataset, is driven by gallium (Ga), rubidium (Rb), lead (Pb), and tantalum (Ta).

### 5.2.4 Outlier Analysis of Klein Bolayi

Due to the consistent outlying nature of samples 3, 4, 5, and 34, further elemental comparisons were done as to indicate which elements constitute for the differences. This was done by means of bi-plots to illustrate elements which separate these samples from the bulk of the site.

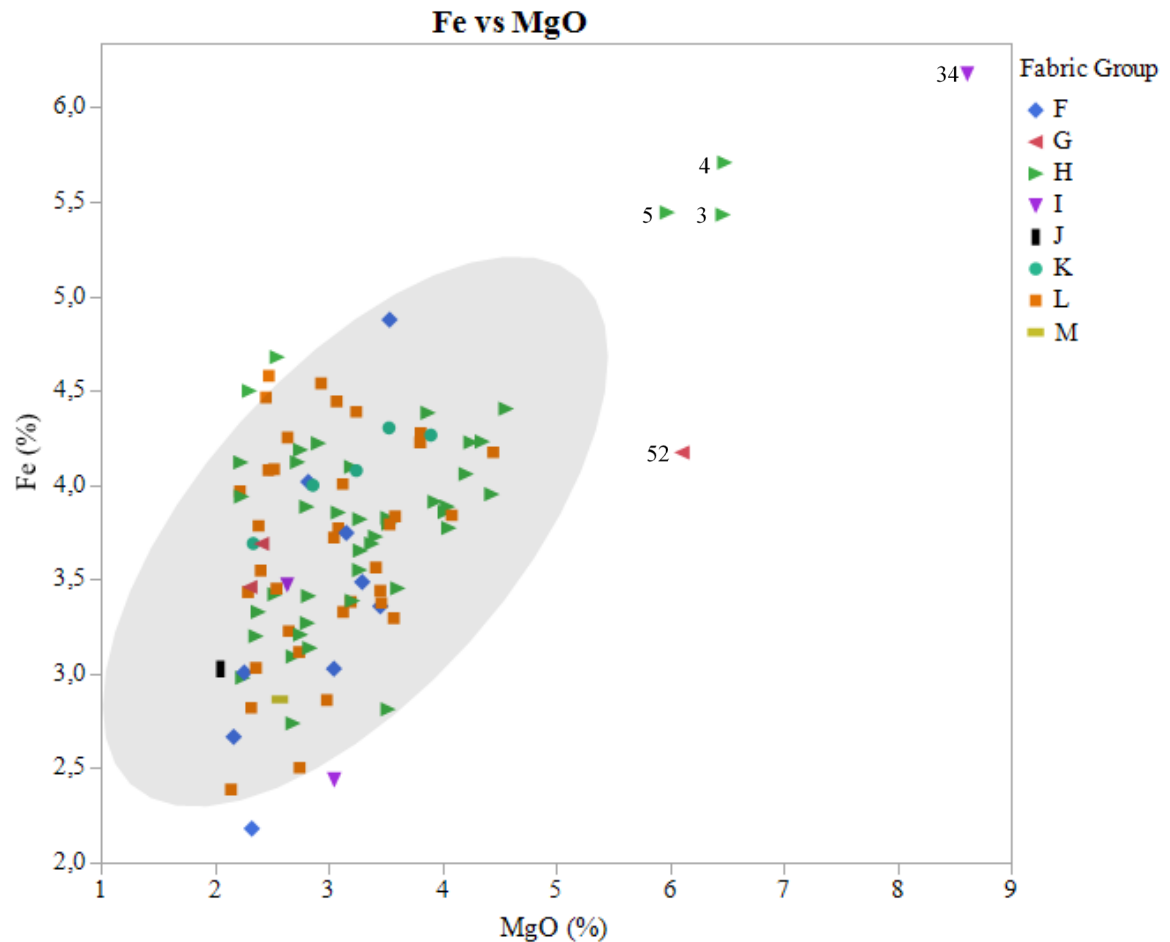


**Figure 5-21: Klein Bolayi bi-plot of Fe vs MgO with 90% confidence ellipses**

The bi-plot illustrates the higher percentages of both iron (Fe) and magnesium oxide (MgO) within samples 3, 4, 5, and 34. The three samples of fabric H cluster together while sample 34 is plotted on the higher end of both elements. Sample 52 is also depicted as an outlier due to higher levels of only magnesium oxide. This sample is further discussed mineralogically as it underwent petrographic analysis. All other samples fall within, or near the 90% confidence ellipses.

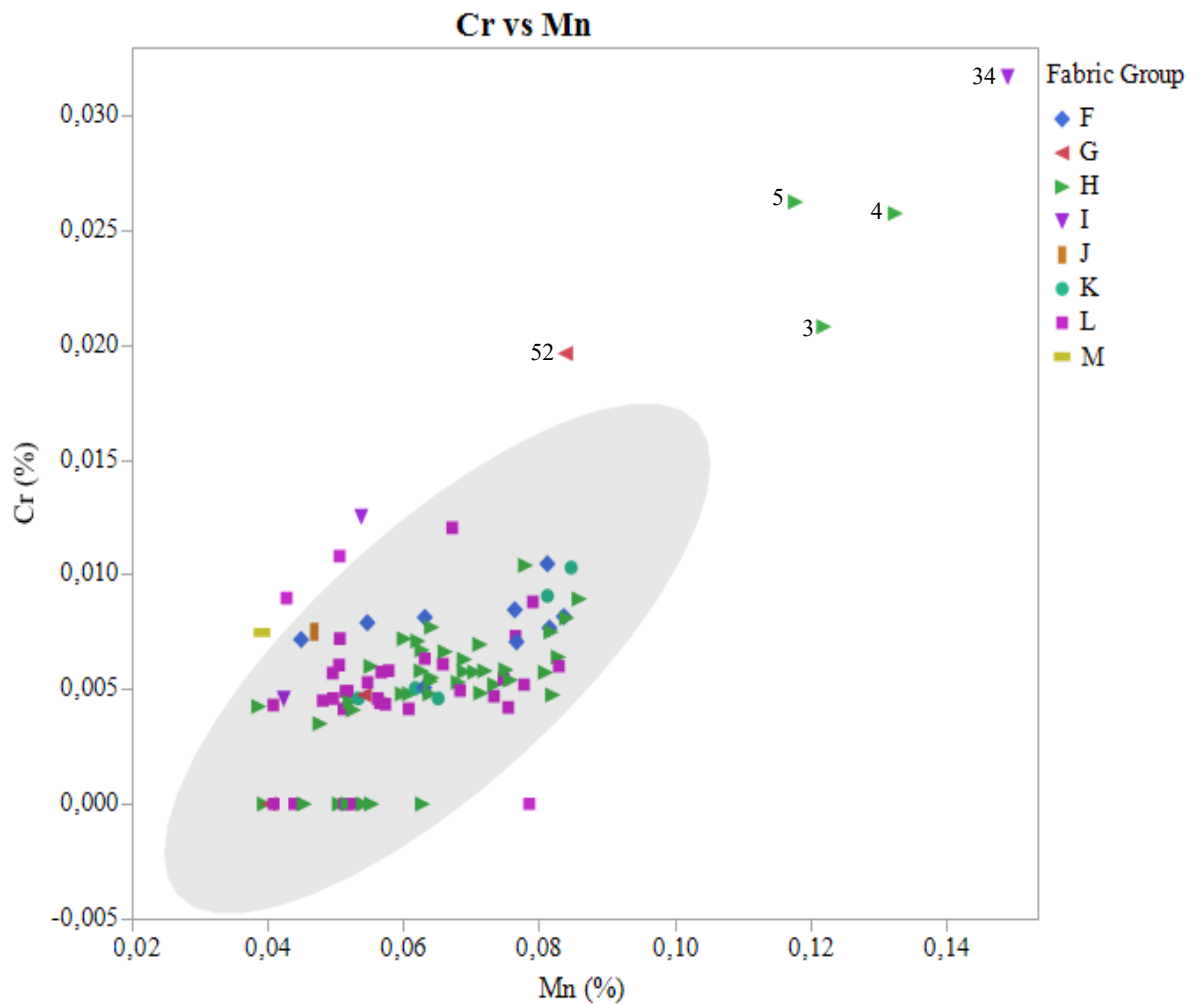


**Figure 5-22: Klein Bolayi bi-plot of Cr vs Mn with 90% confidence ellipses**

The bi-plot illustrates the higher percentages of both chromium (Cr) and manganese (Mn) in samples 3, 4, 5, and 34. The three samples of fabric H cluster closer together while sample 34 is plotted on the higher end of both elemental percentages. Sample 52 is also depicted as an outlier only due to its higher levels of chromium.

### 5.2.5 Summary of Klein Bolayi Chemical Data

Based on statistical analysis of the chemical compositions of Klein Bolayi, the majority of the samples seem to be comprised of fairly similar compositions. The exceptions hereof are samples 3, 4, 5 and 34, which consistently clustered as outliers away from the other samples. These four samples do so as a result of higher

percentages of iron (Fe), magnesium oxide (MgO), chromium (Cr), and manganese (Mn). These samples are outliers in cases of both major and trace elements and as such cluster separate from the bulk of Klein Bolayi's dataset. Whether or not these samples are truly unique as clays, can only be determined through petrographic analysis. Based on the data of the outliers thus far, it was decided that one of samples 3, 4, or 5 would be randomly selected for petrographic analysis as to further investigate the outliers in mineralogy. Samples 34 and 52, which were outliers in magnesium oxide and chromium, were already amongst the preselected samples for petrographic analysis and would be compared to their chemical data.

The highest level of variation can be seen in silica dioxide ( $\text{SiO}_2$ ) and aluminium dioxide ( $\text{Al}_2\text{O}_3$ ), as with Evelyn, this is to be expected as they constitute for the largest chemical compositions of clays. The high variation of the silica dioxide is also likely due to the heterogeneous nature of the samples, whereby a quartz or feldspar grain could have been domineering in certain readings.

In relation to macroscopic fabric groups, there is no clear correlation between the macroscopic fabric groups and the samples' chemical compositions. The fabric groups do not tend to cluster together or form any sort of pattern statistically. The only exception is the cluster of outliers, samples 3, 4, and 5 of fabric group H, but as this is the largest fabric group of the site, three samples are not enough to argue for conclusive evidence that fabric H as a whole is inherently different. Overall, the fabric groups largely overlap and are generally of a similar chemical composition.

The grouping of the chemical data of Klein Bolayi could arguably be grouped into two, one main chemical group whereby the bulk of the samples cluster together, and a separate group comprised of samples 3, 4, 5, and 34.

#### **5.2.6 Evelyn and Klein Bolayi Comparative pXRF Analysis**

Comparative statistical analysis was done to compare elements of Evelyn and Klein Bolayi as to compare the compositions of the clays.

**Table 5-2: PCA driving forces of oxides and major elements**

| Site         | Principle Components | Percentage of variation | Driving forces                                        |
|--------------|----------------------|-------------------------|-------------------------------------------------------|
| Evelyn       | Component 1          | 33%                     | SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub>     |
|              | Component 2          | 23.8%                   | Ca                                                    |
|              | Component 3          | 15.2%                   | MgO, SiO <sub>2</sub>                                 |
|              | Component 4          | 13%                     | K <sub>2</sub> O                                      |
|              | Component 5          | 10.1%                   | Fe, Al <sub>2</sub> O <sub>3</sub>                    |
|              | Component 6          | 4.92%                   | Ca, SiO <sub>2</sub>                                  |
| Klein Bolayi | Component 1          | 33.2%                   | SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub>     |
|              | Component 2          | 26.8%                   | MgO, Fe, K <sub>2</sub> O                             |
|              | Component 3          | 16.7%                   | Ca, SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub> |
|              | Component 4          | 10.5%                   | K <sub>2</sub> O                                      |
|              | Component 5          | 8.05%                   | K <sub>2</sub> O                                      |
|              | Component 6          | 4.66%                   | MgO, Al <sub>2</sub> O <sub>3</sub>                   |

Based on principle component analysis of oxides and major elements (see figures 5-2, 5-3, 5-4, 5-12, 5-13, and 5-14), silica dioxide and aluminium oxide are the most prominent driving forces behind the principle component analysis and account for component 1 at both sites. Calcium is a greater driving force in Evelyn's dataset as the driver of component 2, comprising of 23.8% of the variance amongst the dataset.

Potassium oxide is a greater driving force in Klein Bolayi's database as it acts as a driving force behind components 2, 4, and 5 while it is only a driving force behind component 4 of Evelyn's dataset.

**Table 5-3: PCA driving forces of minor and trace elements**

| Site         | Principle Component | Percentage of variation | Driving forces |
|--------------|---------------------|-------------------------|----------------|
| Evelyn       | Component 1         | 30.6%                   | Ti, Ba, Ga     |
|              | Component 2         | 12.6%                   | Mn, Cr, Pb     |
|              | Component 3         | 7.73%                   | Rb, Th         |
|              | Component 4         | 5.89%                   | P, S           |
| Klein Bolayi | Component 1         | 25.6%                   | Sr, Ga, Y      |
|              | Component 2         | 14%                     | Zn, Cu, Mn, Cr |
|              | Component 3         | 9.72%                   | Nb, P          |
|              | Component 4         | 7.07%                   | Ga, Rb, Pb, Ta |

Based on minor and trace elements (see figures 5-9, 5-10, 5-19, and 5-20), the driving forces behind the principle components vary between Evelyn and Klein Bolayi.

Gallium is a consistent driver behind principle component 1 of each site. Manganese and chromium are both driving forces behind component 2 of each site. Lead, rubidium, and phosphorus appear as driving forces within both sites but at differing principle components. Titanium, barium, thorium, and sulphur are driving forces to the principle components of only Evelyn. Strontium, yttrium, zinc, copper, tantalum are driving forces to the principle components of only Klein Bolayi.

Based on the before mentioned data, the two sites both seem to have a generally similar intra-site chemical composition. Further statistical analysis was then done to examine the relationship of the chemical compositions of the two sites to then determine the potential nature of the clay on an inter site comparative level.

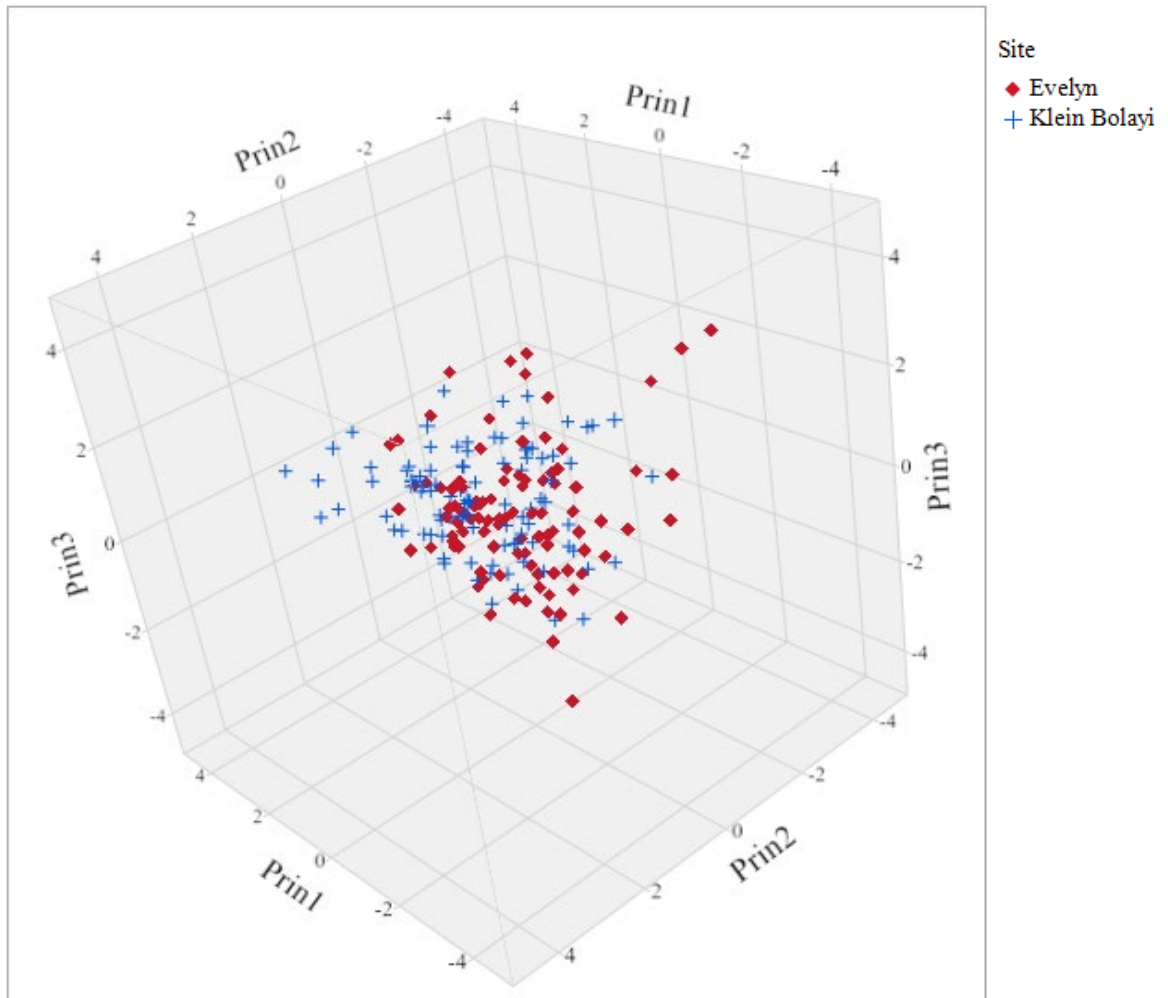


**Figure 5-23: Evelyn and Klein Bolayi 3D scatterplot of major elements**

The 3D scatterplot using principle components 1, 2 and 3 of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Fe}$  and  $\text{Ca}$  shows a large central cluster. Some outliers do tend to occur, with Evelyn samples straying to the lower eigenvalues of principle component 1 and 4, while Some Klein Bolayi samples stray towards higher eigenvalues of the same components. This slight tendency to lie away from the cluster is however, not great enough to argue for a sizeable difference in chemical compositions.

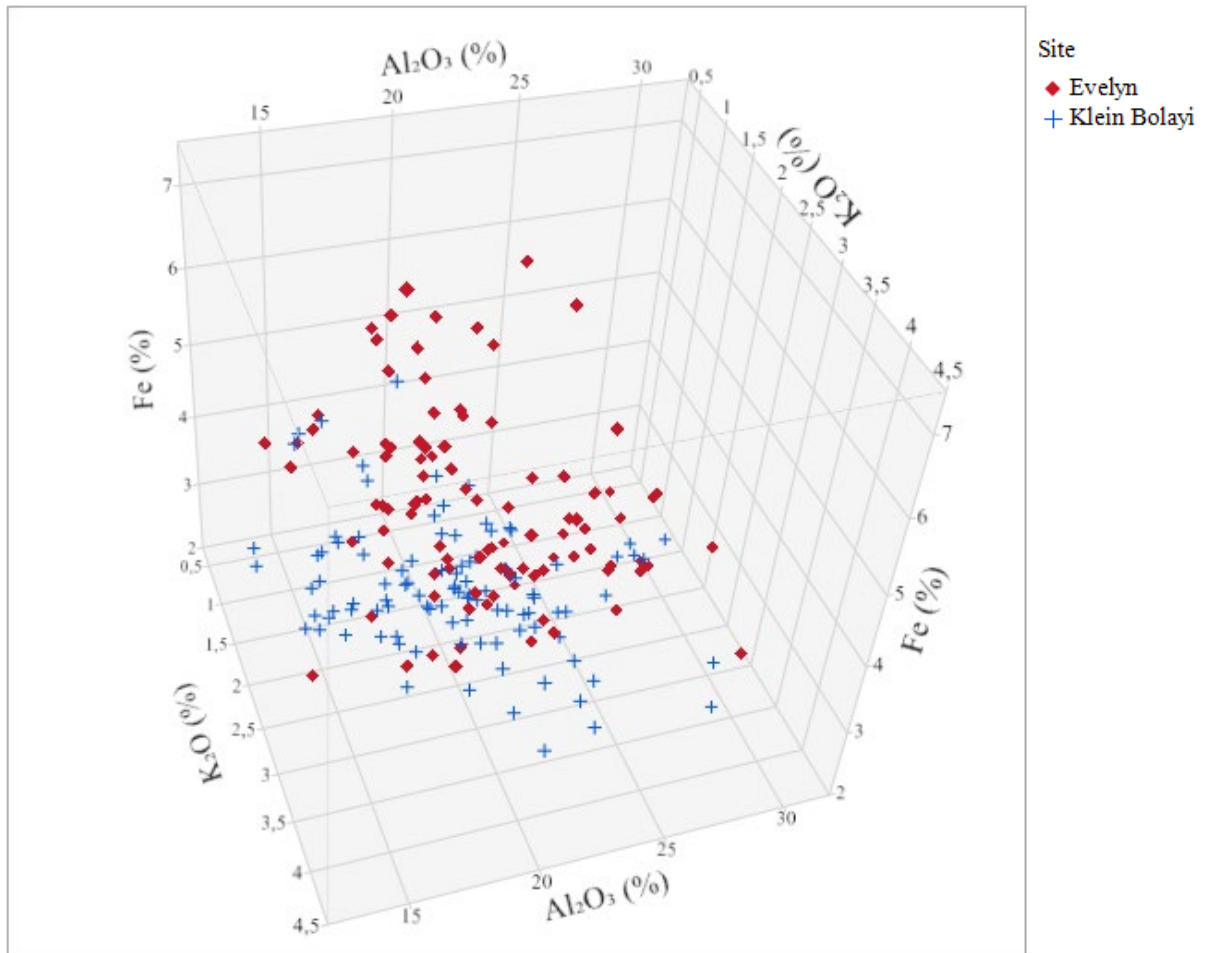


**Figure 5-24: Evelyn and Klein Bolayi 3D scatterplot of  $K_2O$ ,  $Al_2O_3$ , and  $Fe$**

The 3D scatterplot of potassium oxide ( $K_2O$ ), aluminium oxide ( $Al_2O_3$ ), and iron ( $Fe$ ) shows that Evelyn has a higher variation in iron levels whereas Klein Bolayi's iron levels cluster around the lower percentages. The mean percentage of iron is 4.27% in Evelyn and 3.74% in Klein Bolayi. Higher iron levels present in Evelyn could be related to pyrite levels as nearly all macroscopic samples were observed as having pyrite present. Potassium oxide levels of both sites are varied but similar with Evelyn having a mean of 3.04% and Klein Bolayi having a mean of 3.24%. Aluminium oxide levels are varied but similar across both sites with a mean of 21% in Evelyn and 19.33% in Klein Bolayi. Of the three major elements presented, aluminium oxide and potassium oxide vary in a similar manor while iron shows a higher percentage present in Evelyn than Klein Bolayi.

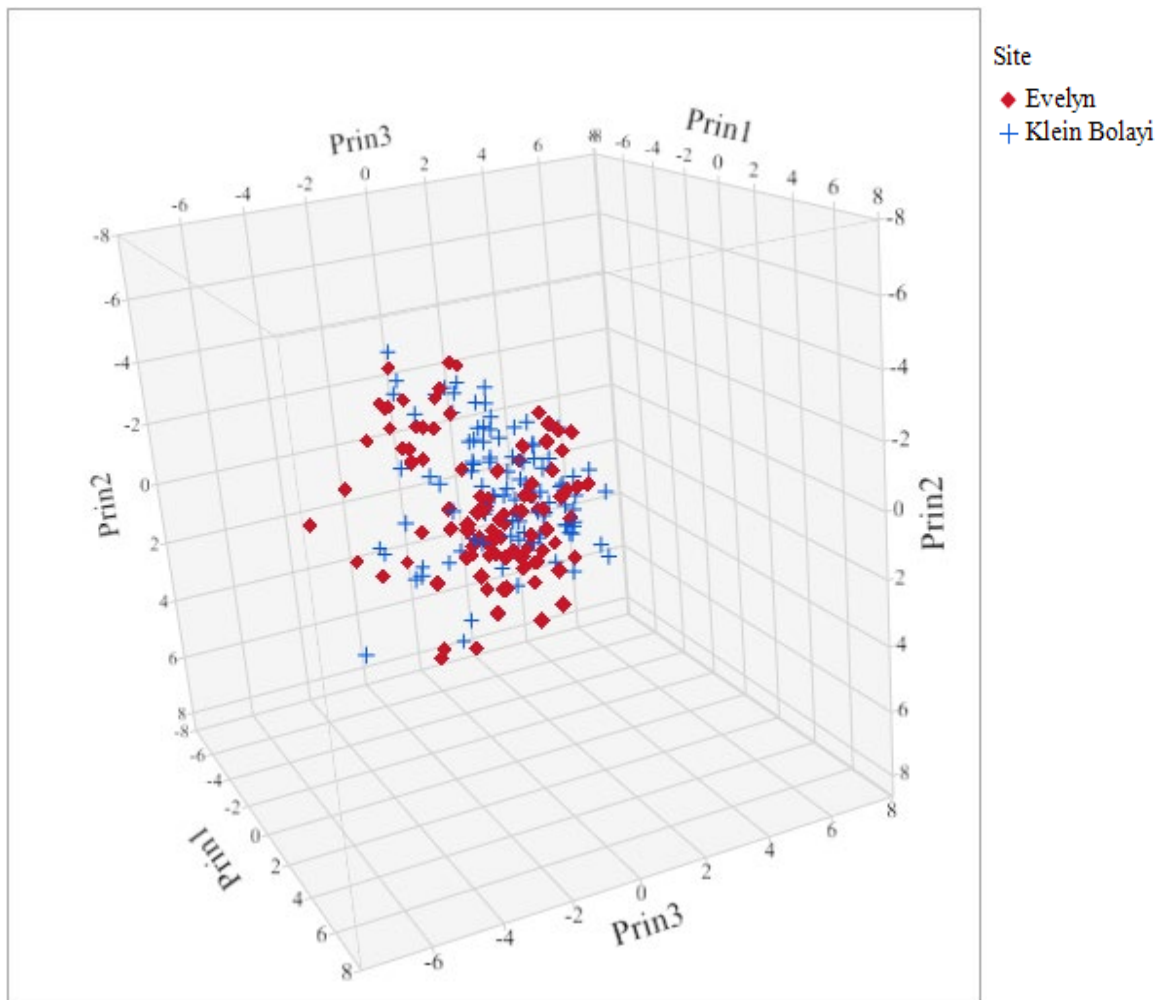


**Figure 5-25: Evelyn and Klein Bolayi 3D scatterplot of minor and trace elements**

The 3D scatterplot of both sites' trace elements once again present the data as a single cluster with only a few outlying samples. The three principle components present one homogenous cluster whereby the trace elements from Evelyn and Klein Bolayi are arguably similar.

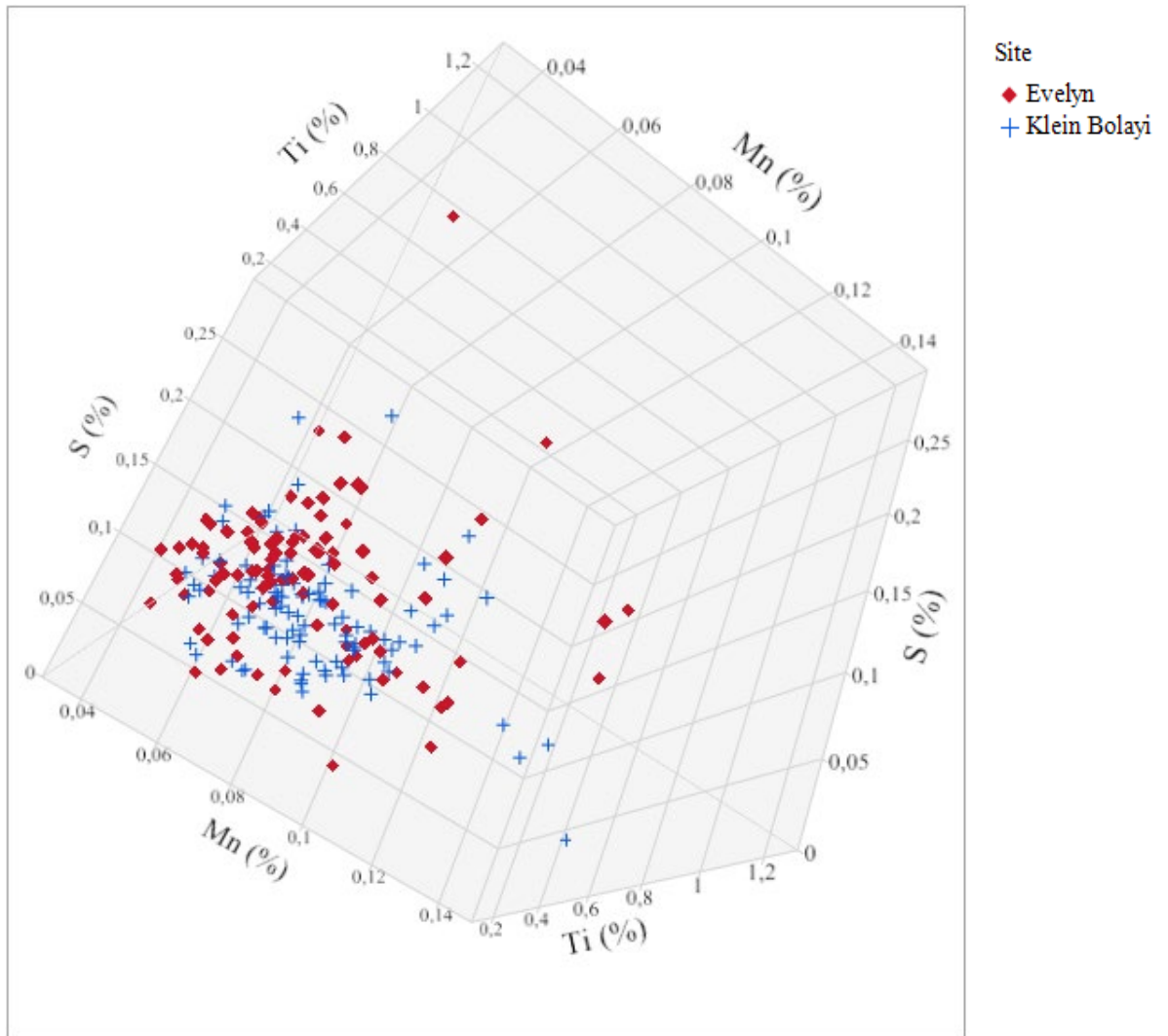


**Figure 5-26: Evelyn and Klein Bolayi 3D scatterplot of Ti, Mn, and S**

The 3D scatterplot of Evelyn and Klein Bolayi shows a clustering of samples in lower percentages of titanium (Ti), manganese (Mn), and sulphur (S). The mean percentage of titanium is 0.69% in Evelyn and 0.62% in Klein Bolayi, for manganese it is 0.06% in Evelyn and 0.07% in Klein Bolayi and for sulphur it is 0.06% at both sites. These three elements presented show a similar relationship amongst the trace elements across both sites with a tendency to overlap and form one cluster.

### 5.2.7 Summary of Evelyn and Klein Bolayi Chemical Data

Based on the statistical analysis of chemical data of both intra- and inter-site comparison, both sites are arguably of overarching similar chemical compositions.

With the exception of a few outliers, the data has a tendency to cluster together and lacks any specific pattern of samples which are consistent outliers at both intra- and inter-site comparisons. As previously discussed, samples 3, 4, 5 and 34 were consistent outliers within Klein Bolayi, but once compared to Evelyn they did not tend to lay as outliers from the main cluster for both sites. Both major as well as minor and trace elements present as fairly homogenous across both sites with no separate clustering based on the site.

As such, it is stressed that pXRF not be conducted in isolation but rather in conjunction with another microscopic analysis to verify any claims made on chemical and macroscopic data. The use of petrographic analysis is thus important as specific minerals can be identified and more accurate fabric groups can then be determined to draw more conclusive speculations.

Macroscopic fabric groups of both sites showed no correlation to differing chemical compositions. This may be due to the heterogeneity of a ceramic sherd which may present different inclusions in different breaks of its profiles and not account for inclusions not visible in that particular break. These macroscopic differences are likely due to technological differences within the assemblages rather than chemical differences.

### **5.3 Petrographic Analysis Results**

The following reports have been condensed from the full petrographic reports (see Appendix B). The mineralogical and technological observations were then used to create a set of petrographic fabrics across both sites.

#### **Sample 4**

Site: Klein Bolayi

Fabric Group: H

This sample was randomly selected from samples 3, 4, 5 based on its outlying chemical nature. The sample is poorly sorted and has moderate variation in grain sizes. The mineralogy is comprised of: quartz (10%), biotite (7%), K-feldspar (6%), plagioclase (3%), hornblende (3%), olivine (4%), clinopyroxene (2%), opaque minerals (1%), clay pellets (1%), and schist (<1%). The sample displays meso and

micro planar voids as well as meso and micro vugh voids. The clay matrix is orange-brown in colour with high optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being slightly less optically active due to uneven firing. The plastic inclusions of the clay matrix are equal biotite laths and quartz grains. The mineral orientation of the sample shows signs of a combination of coiling and pinching forming methods.

### **Sample 11**

Site: Klein Bolayi

Fabric Group: F

The sample is poorly sorted with high variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (10%), K-feldspar (10%), plagioclase (5%), hornblende (2%), opaque minerals (2%), clay pellets (1%), biotite (1%), and muscovite (1%). The sample displays macro and meso planar voids as well as macro and meso vugh voids. The clay matrix is dark reddish-brown with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half, and extending into the whole left side of the sample showing higher optical activity due to uneven firing. The plastic inclusions of the clay matrix shows fine silt quartz and lesser amounts of biotite and muscovite laths throughout. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 34**

Site: Klein Bolayi

Fabric Group: I

The sample is poorly sorted with moderate variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (10%), biotite (9%), plagioclase (5%), K-feldspar (5%), muscovite (3%), opaque minerals (3%), grog (<1%), and a granite inclusion (<1%). The sample displays meso planar voids as well as meso and macro vugh voids. The clay matrix is reddish-orange-brown with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix shows an abundance of biotite and muscovite laths as well as quartz grains. The mineral orientation of the sample shows signs of implementation of a coiling forming method.

### **Sample 36**

Site: Klein Bolayi

Fabric Group: K

The sample is poorly sorted with high variation in inclusion sizes. The mineralogy is comprised of: K-feldspar (13%), quartz (10%), opaque minerals (3%), clay pellets (3%), plagioclase (3%), biotite (2%), hornblende (1%), clinopyroxene (<1%), and a single granodiorite inclusion (<1%). The sample displays meso vugh voids and micro planar voids with no distinct orientation. The clay matrix is reddish-brown in colour with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being slightly less optically active due to uneven firing. The plastic inclusions of the clay matrix are predominantly biotite and muscovite laths with smaller amounts of quartz. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 51**

Site: Klein Bolayi

Fabric Group: J

The sample is poorly sorted with moderate variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (13%), grog (10%), K-feldspar (7%), opaque minerals (3%), plagioclase (3%), clinopyroxene (1%), and muscovite (<1%). The sample displays meso planar voids as well as meso and macro vugh voids. The clay matrix is red-brown in colour with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the top half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix shows plastic quartz and K-feldspar laths with lesser amounts of both biotite and muscovite laths. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 52**

Site: Klein Bolayi

Fabric Group: G

The sample is poorly sorted with moderate variation in grain sizes. The mineralogy comprises of: quartz (12%), olivine basalt (10%), K-feldspar (6%), plagioclase (3%), biotite (3%), opaque minerals (1%), muscovite (1%), and hornblende (<1%). The sample displays macro and meso planar voids as well as meso vugh voids. The clay matrix is orange-brown in colour with high optical activity due to low firing temperatures. The plastic inclusions of the clay matrix are predominantly quartz with small amounts of biotite laths. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

#### **Sample 54**

Site: Klein Bolayi

Fabric Group: M

The sample is poorly sorted with high variation in grain sizes. The mineralogy is comprised of: quartz (10%), grog (9%), K-feldspar (7%), plagioclase (5%), muscovite (3%), microline (2%), opaque minerals (1%), clinopyroxene (1%), hornblende (<1%), and biotite (<1%). The sample has a considerable amount of grog inclusions, a total of 47 inclusions. All the grog inclusions seem to be of a similar composition throughout the sample. The sample displays macro and meso planar voids as well as macro and meso vugh voids with no distinctive orientation. The clay matrix is dark reddish-brown in colour with high optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half of the sample being more optically active due to uneven firing. The plastic inclusions of the clay matrix are biotite and muscovite laths as well as plastic quartz grains. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

#### **Sample 72**

Site: Klein Bolayi

Fabric Group: H

The sample is poorly sorted with high variation in grain sizes. The mineralogy is comprised of: quartz (13%), K-feldspar (10%), biotite (5%), plagioclase (3%), opaque minerals (3%), hornblende (2%), granite (<1%), and granodiorite (<1%). The sample displays meso and micro vugh voids and meso planar voids. The clay matrix is dark reddish-brown in colour with high optical activity. Variation in optical activity is present with the centre being less optically active due to uneven firing. The plastic inclusions of the clay matrix are equally quartz and biotite laths. The mineral

orientation of the sample shows signs of implementation of a pinching forming method.

#### **Sample 74**

Site: Klein Bolayi

Fabric Group: L

The sample is poorly sorted with high variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (12%), plagioclase (10%), K-feldspar (7%), opaque minerals (3%), hornblende (2%), granite (1%), biotite (1%), clay pellets (<1%), grog (<1%), and granodiorite (<1%). The sample displays meso planar voids as well as meso and macro vugh voids. The clay matrix is reddish-brown with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being less optically active due to uneven firing. The plastic inclusions of the clay matrix are biotite and muscovite laths as well as quartz grains. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

#### **Sample 109**

Site: Evelyn

Fabric Group: A

The sample is poorly sorted and eroded with high variation in grain sizes. The large voids and eroded clay is also visible in the hand specimen. The mineralogy is comprised of: quartz (12%), K-feldspar (9%), plagioclase (5%), biotite (3%), hornblende (3%), opaque minerals (2%), granite (1%), granodiorite (1%), and clay pellets (1%). The sample displays macro and meso planar voids as well as mega, macro, and meso vugh voids. The clay matrix is dark reddish-brown with moderate optical activity due to low firing temperatures. Variation in optical activity is visible with higher optical activity in the bottom half of the sample as a result of uneven firing. The plastic inclusions of the clay matrix are predominantly biotite and muscovite lathes with smaller amounts of quartz and clay pellets (<0.02mm) mixed in. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

#### **Sample 137**

Site: Evelyn

Fabric group: C

The sample is poorly sorted with high variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (10%), K-feldspar (7%), plagioclase (6%), hornblende (4%), clay pellets (2%), opaque minerals (2%), biotite (1%), grog (<1%), and granite (<1%). The sample displays meso and macro planar voids as well as meso vugh voids. The clay matrix is dark brownish-red with present optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix shows an abundance of hornblende as well as mica laths and quartz grains. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 139**

Site: Evelyn

Fabric Group: D

The sample is poorly sorted with moderate variation in grain sizes and is highly eroded. The mineralogy is comprised of: K-feldspar (13%), quartz (8%), biotite (3%), hornblende (3%), plagioclase (1%), opaque minerals (1%), and clay pellets (<1%). The sample displays micro planar voids and meso vugh voids. The clay matrix is dark reddish-orange-brown with present optical activity. Variation in optical activity is present with the top half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix include K-feldspar laths, quartz and lower amounts of biotite laths. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 144**

Site: Evelyn

Fabric Group: E

The sample is poorly sorted and very eroded. The eroded nature is also visible in the hand specimen itself. There is high variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (10%), K-feldspar (10%), plagioclase (3%), opaque minerals (3%), hornblende (2%), grog (1%), clinopyroxene (<1%), and granite inclusion (<1%). The sample displays mega and meso planar voids as well as macro and meso vugh voids. The clay matrix is

reddish-orange-brown in colour with moderate optical activity likely due to low firing temperatures. Variation in optical activity with a less optically active clay matrix centre shows signs of uneven firing. The plastic inclusions of the clay matrix are predominantly biotite and muscovite laths with smaller amounts of quartz grains and clay pellets. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

### **Sample 157**

Site: Evelyn

Fabric group: B

The sample is poorly sorted with high variation in grain sizes throughout the sample. The mineralogy is comprised of: quartz (10%), K-feldspar (10%), opaque minerals (5%), plagioclase (3%), clay pellets (2%), biotite (2%), grog (1%), and hornblende (1%). The sample displays meso and macro planar voids as well as meso vugh voids. The clay matrix is dark reddish-brown in colour with present optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix are quartz as well as lesser amounts of broken mica laths and clay pellets. The mineral orientation of the sample shows signs of implementation of a pinching forming method.

**Table 5-4: Table of mineral composition in percentage**

| Mineral (%)     | Sample |    |    |    |    |    |    |    |    |     |     |     |     |     |
|-----------------|--------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
|                 | 4      | 11 | 34 | 36 | 51 | 52 | 54 | 72 | 74 | 109 | 137 | 139 | 144 | 157 |
| Quartz          | 10     | 10 | 10 | 10 | 13 | 12 | 10 | 13 | 12 | 12  | 10  | 8   | 10  | 10  |
| K-feldspar      | 6      | 10 | 5  | 13 | 7  | 6  | 7  | 10 | 7  | 9   | 7   | 13  | 10  | 10  |
| Plagioclase     | 3      | 5  | 5  | 3  | 3  | 3  | 5  | 3  | 10 | 5   | 6   | 1   | 3   | 3   |
| Microcline      |        |    |    |    |    |    | 2  |    |    |     |     |     |     |     |
| Hornblende      | 3      | 2  |    | 1  |    | <1 | <1 | 2  | 2  | 3   | 4   | 3   | 2   | 1   |
| Biotite         | 7      | 1  | 9  | 2  |    | 3  | <1 | 5  | 1  | 3   | 1   | 3   |     | 2   |
| Muscovite       |        | 1  | 3  |    | <1 | 1  | 3  |    |    |     |     |     |     |     |
| Clinopyroxene   | 2      |    |    | <1 | 1  |    | 1  |    |    |     |     |     |     |     |
| Granite         |        |    | <1 |    |    |    |    | <1 | 1  | 1   | <1  |     | <1  |     |
| Granodiorite    |        |    |    | <1 |    |    |    | <1 | <1 | 1   |     |     |     |     |
| Clay pellets    | 1      | 1  |    | 3  |    |    |    |    | <1 | 1   | 2   | 1   | 1   | 2   |
| Grog            |        |    | <1 |    | 10 |    | 9  |    | <1 |     | <1  |     |     | 1   |
| Opaque minerals | 1      | 2  | 3  | 3  | 3  | 1  | 1  | 3  | 3  | 2   | 2   | 1   | 3   | 5   |
| Olivine         | 4      |    |    |    |    |    |    |    |    |     |     |     |     |     |
| Olivine basalt  |        |    |    |    |    | 10 |    |    |    |     |     |     |     |     |
| Schist          | <1     |    |    |    |    |    |    |    |    |     |     |     |     |     |

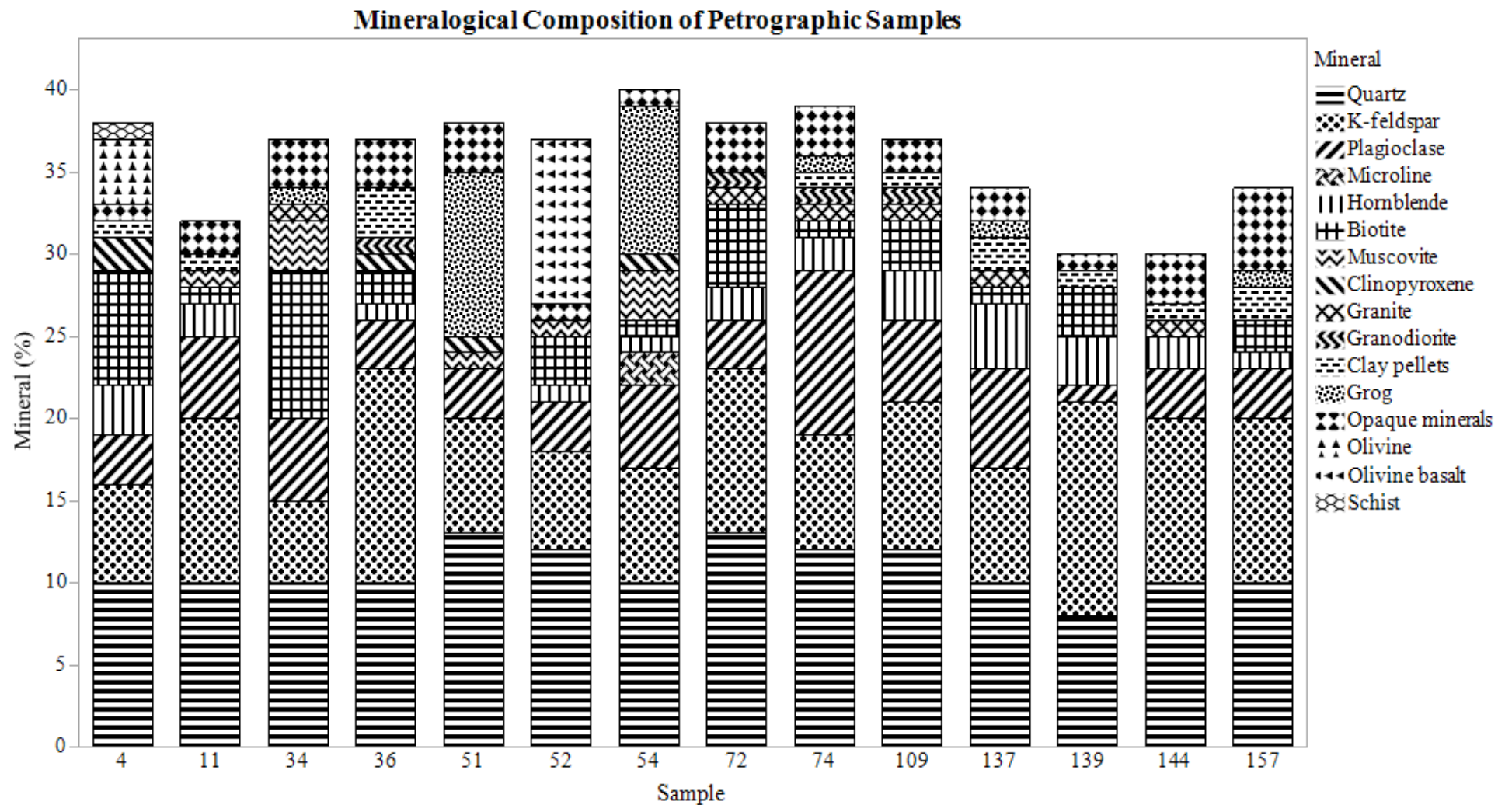


Figure 5-27: Mineralogical composition of petrographic samples

Quartz, K-feldspar and plagioclase were the predominant minerals across the samples (table 5.2). Biotite was present in all but two samples, with varying semi-quantitative frequencies and is generally present within all of the samples' clay matrices.

Hornblende was commonly found within most samples in smaller grain sizes. Other lower percentage minerals include muscovite, clinopyroxene, microcline and plutonic bodies of granite and granodiorite. Argillaceous inclusions fluctuate with some samples having an abundance of grog or clay pellets while other samples have much lower percentages. Olivine and schist are unique to only sample 4. Olivine basalt, in a high quantity is unique to sample 52.

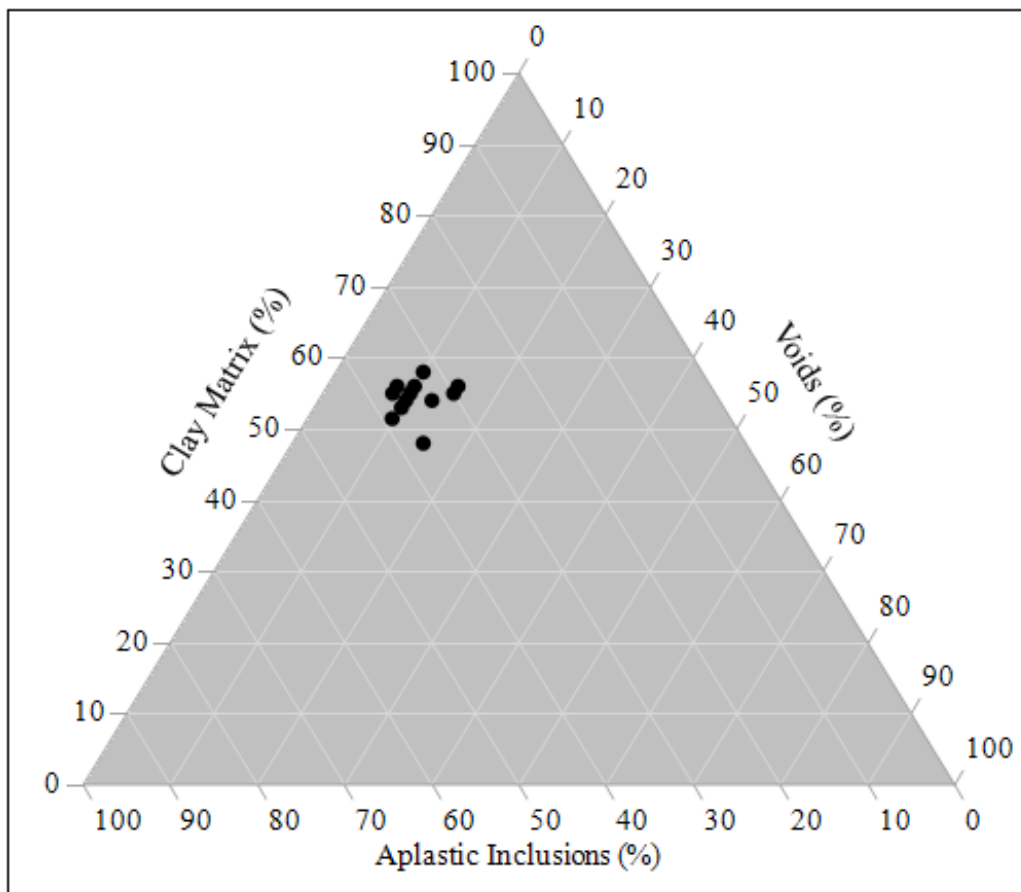


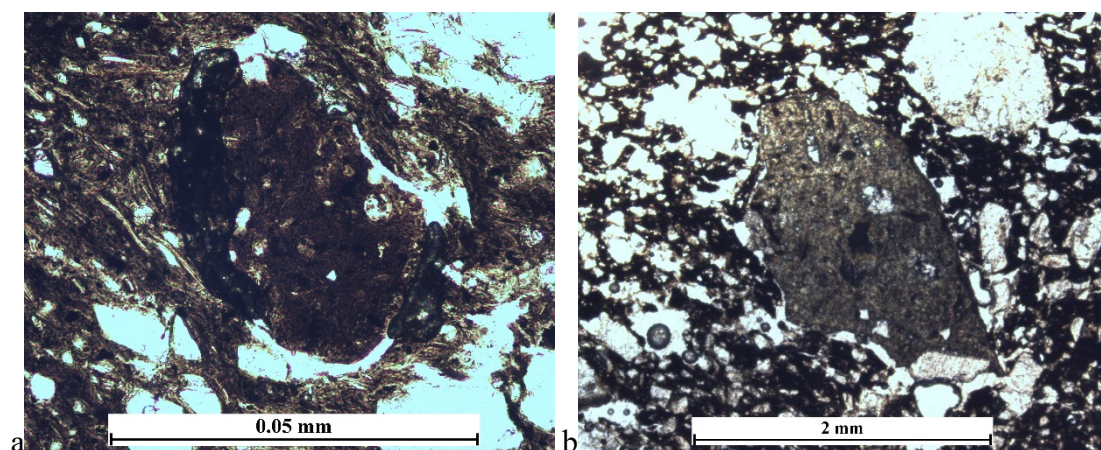
**Figure 5-28: Ternary plot of clay matrix, aplastic inclusions, and voids**

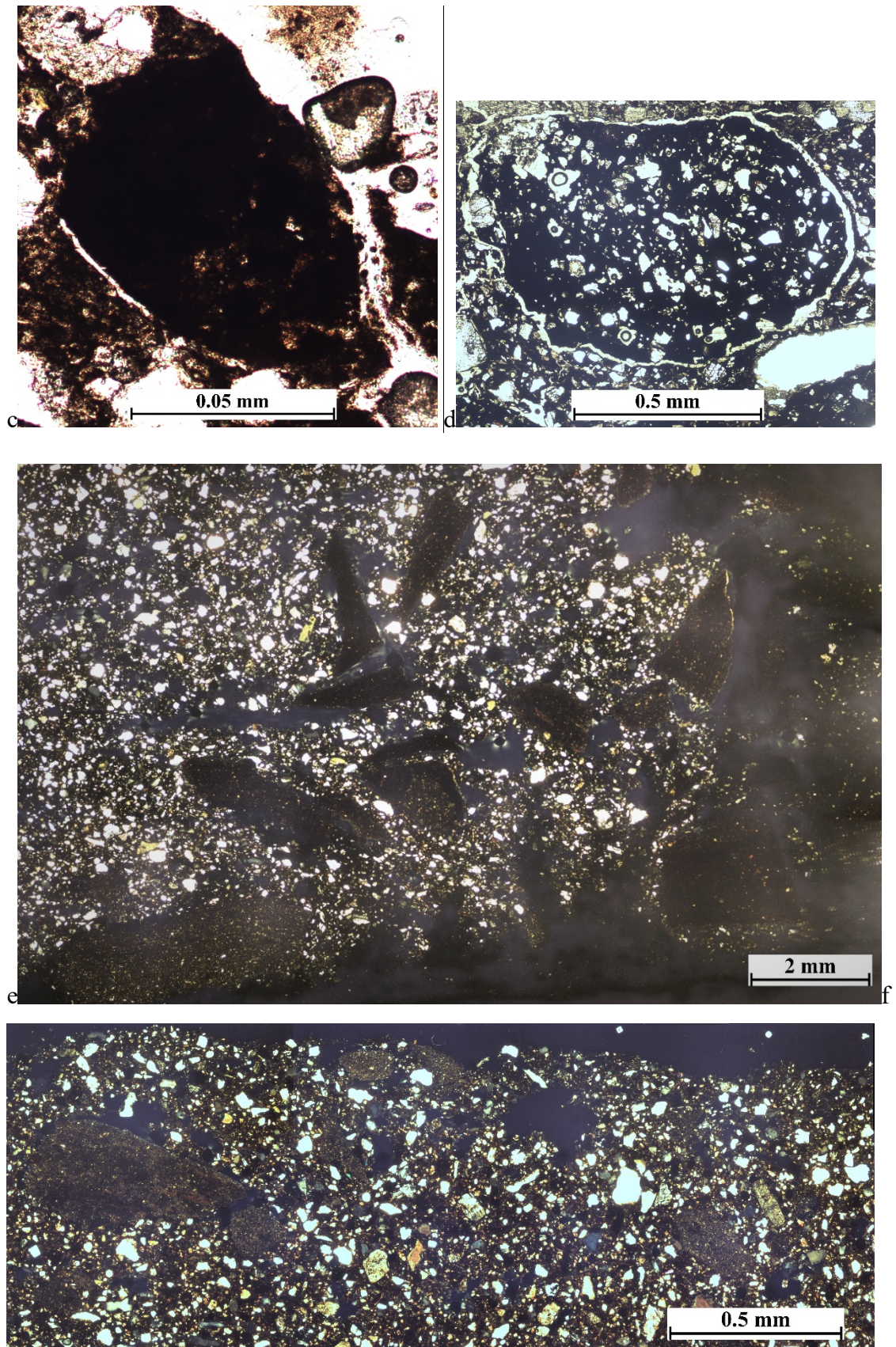
The ternary plot of the percentages of clay matrix, voids, and total aplastic inclusions shows a similar distribution amongst the fourteen samples, regardless of their mineralogical composition. The clay matrix percentages lie between 48% and 58% with most clay matrices comprising of quartz and biotite laths with some samples presenting

a lumpier groundmass texture than others, resulting in a higher clay matrix percentage. The voids range from 8% to 15%, with samples in the higher end of the range generally being attributed to high levels of erosion. All samples present planar and vugh voids ranging from micro to macro sizes with a predominant presence of meso sized voids. Total percentage of aplastic inclusions range from 29% to 37% with lower aplastic inclusions coinciding with higher void and clay matrix percentages. Sample 109 is the most atypical with the lowest percentage clay matrix (48%) and at the highest range of voids (15%) due to high erosion. The ternary plot shows a generalised similarity in the possible recipe of clay fabrics made at both sites.

### 5.3.1 Grog

Of the fourteen petrographic samples, six samples had grog present in varying percentages. Samples 34, 74, 137, and 157 had a semi-quantitative frequency of either 1% or <1% whereas samples 51 and 54 had 10% and 9% respectively. The presence of grog shows the deliberate crushing of old pottery and adding it as temper to clay as grog does not geologically occur naturally. Images of the grog were taken in crossed polarized light, but in cases of low visibility, images were taking in plane polarized light. Under low visibility, grog is best identified by its circle of shrinkage.





Figures 5-29: (a): grog of sample 34 in XPL, (b): grog of sample 74 in PPL, (c): grog of sample 137 in PPL, (d): grog of sample 157 in PPL, (e): grog cluster of sample 51 in XPL, (f): grog cluster of sample 54 in XPL

The grog which was observed in the samples all bare compositional similarities with quartz and mica visible under high magnification under crossed polarized light. Sample 51, with a semi-quantitative frequency of 10% of grog, had a total of 40 grog inclusions present. Grog sizes of this sample range from 0.59mm x 0.29mm to 4.19mm x 1.29mm in size. All inclusions were observed to be mineralogically similar and likely originated from the same relic vessel. Sample 54, with a semi-quantitative frequency of 9% of grog, had a total of 47 grog inclusions present. Grog sizes of this sample range from 0.27mm x 0.15mm to 2.73mm x 1.14mm in size. All inclusions observed in sample 54 were of a similar mineralogical composition. The grog present in sample 54 were generally smaller than those of sample 51. The grog inclusions of sample 51 and 52, on comparison under both plane polarized and cross polarized light are observably of similar colours and compositions. This is possibly a result of the continuous use of similar pottery pastes for pottery production over time or the use of the same assemblage in new pottery.

### **5.3.2 Forming Methods**

Forming methods employed were analysed using various magnification objectives under polarized light by determining mineral orientation and relating the orientation to its corresponding forming method. Forming methods can show differences or similarities in the technological feature which is often intertwined with communities of practice and reinforced learning methods.

**Table 5-5: Forming methods of petrographic samples**

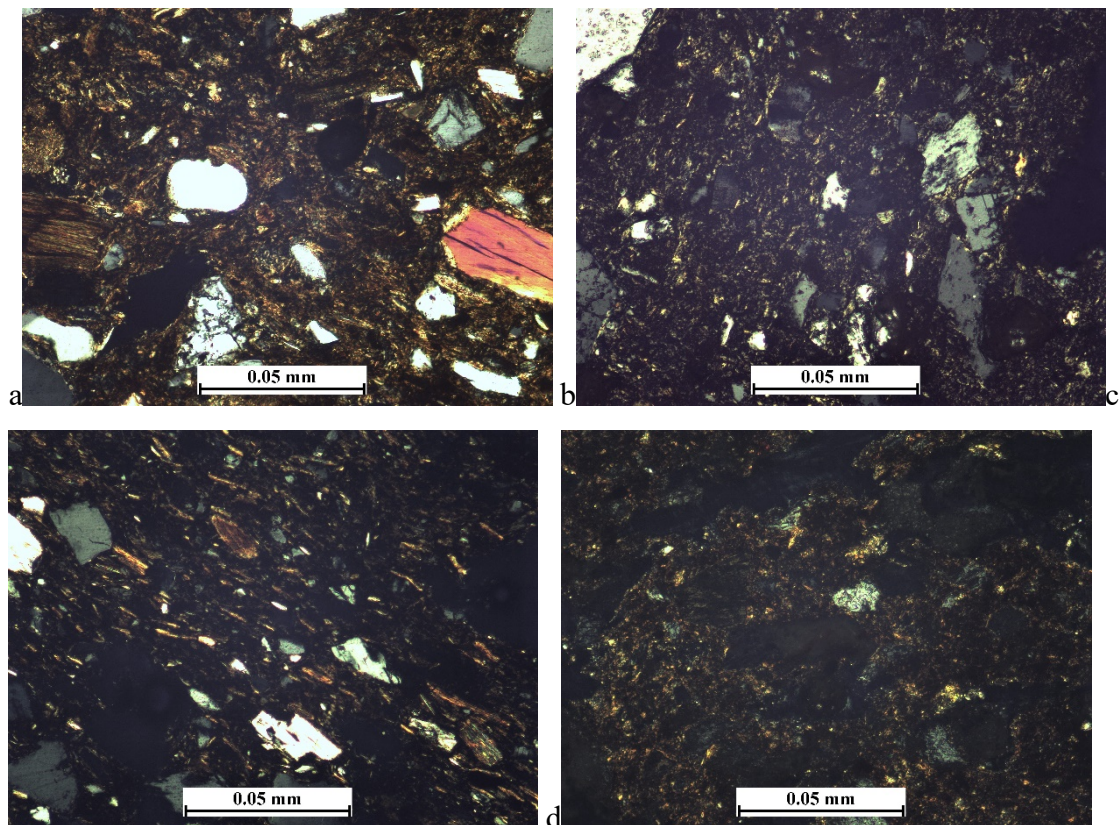
| Sample | Mineral Orientation                                           | Forming Method                         |
|--------|---------------------------------------------------------------|----------------------------------------|
| 4      | Randomly orientated with sections of alternating half circles | Combination of pinching and coil built |
| 11     | Randomly orientated                                           | Pinching                               |
| 34     | Flowing in alternating half circles                           | Coil-built                             |
| 36     | Randomly orientated                                           | Pinching                               |
| 51     | Randomly orientated                                           | Pinching                               |
| 52     | Randomly orientated                                           | Pinching                               |
| 54     | Randomly orientated                                           | Pinching                               |
| 72     | Randomly orientated                                           | Pinching                               |
| 74     | Randomly orientated                                           | Pinching                               |
| 109    | Randomly orientated                                           | Pinching                               |
| 137    | Randomly orientated                                           | Pinching                               |
| 139    | Randomly orientated                                           | Pinching                               |
| 144    | Randomly orientated                                           | Pinching                               |
| 157    | Randomly orientated                                           | Pinching                               |

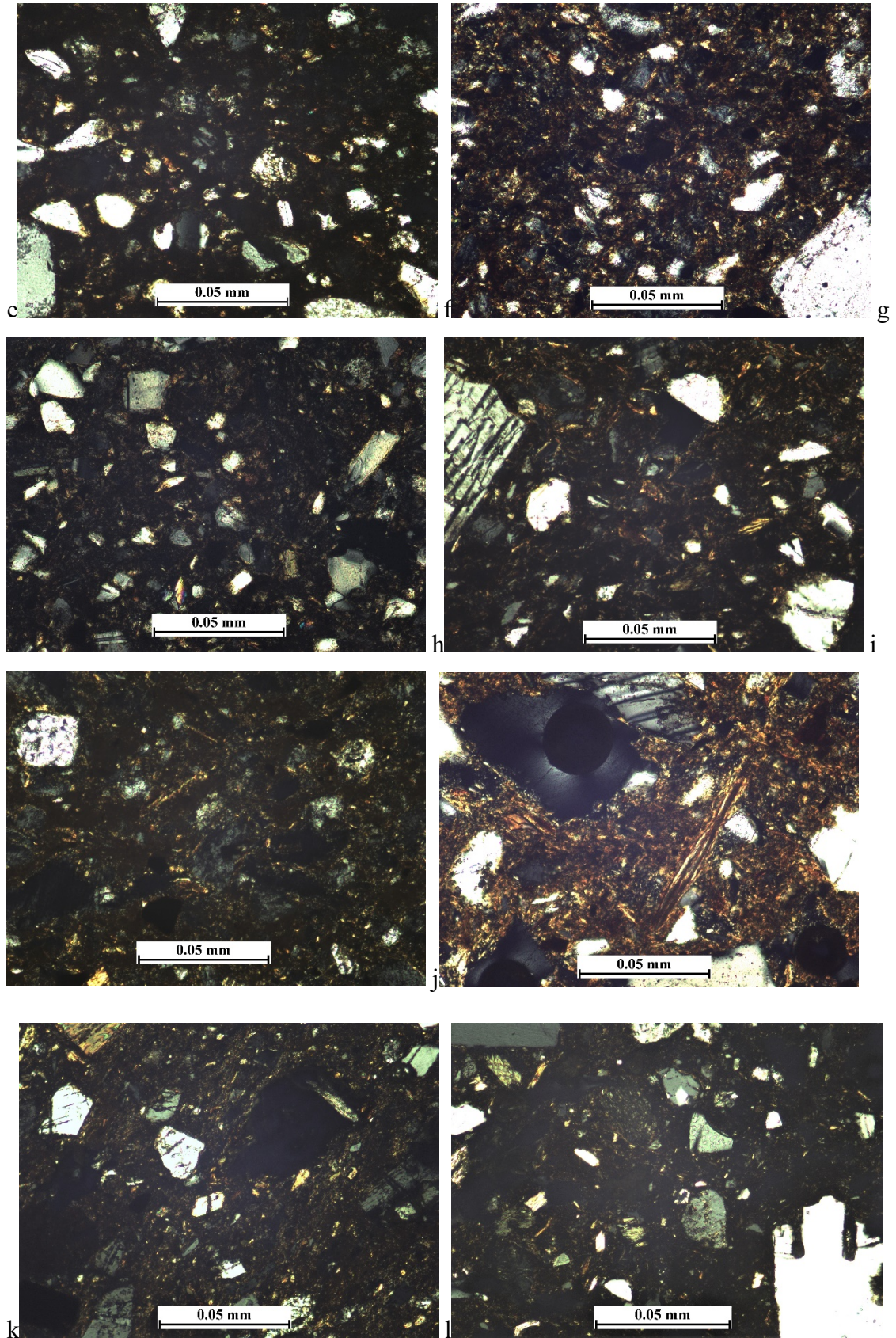
According to mineral orientation, pinching is the dominant forming method across both sites with a total of thirteen samples presenting signs thereof. As discussed in chapter three, the pinching forming method consists of using a lump of clay which is drawn out by hand to form a vessel. Coiling is less common with only two samples, 4 and 34 presenting visible signs of coiling. Sample 34 has a prominent coiling mineral orientation whereas sample 4 has signs of both coiling and pinching. Sample 4 presents

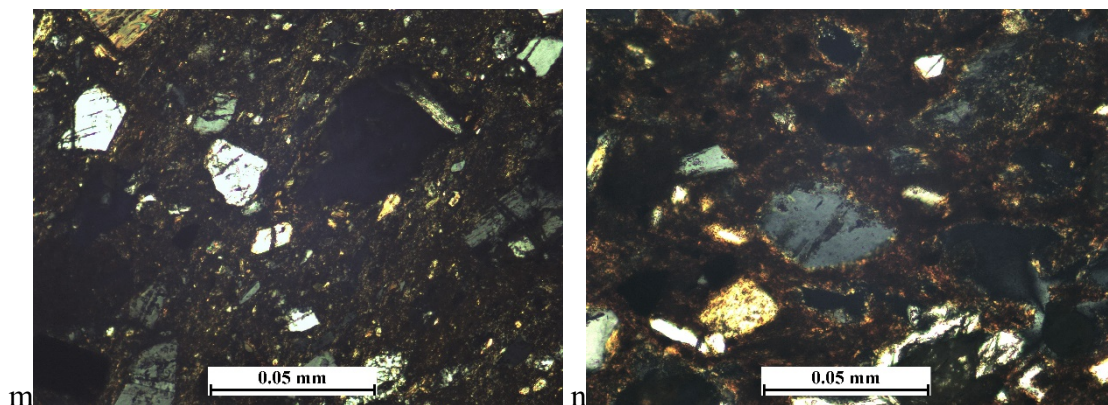
a combination of forming methods which is a common practice in pottery production. Pinching and coiling are the preferred forming methods within Evelyn and Klein Bolayi with Evelyn only presenting signs of pinching whereas Klein Bolayi has both methods present. Pinching or coiling may also reflect where the sherd originates from on the pot as often different sections of pots may be formed using a different forming method.

### 5.3.3 Clay Matrices

The clay matrix of each sample was observed to determine plastic inclusions and similarities or differences between samples. All images were taken using the 10x magnification objective and under crossed polarized light.







**Figures 5-30: (a): clay matrix of sample 4, (b): clay matrix of sample 11, (c): clay matrix of sample 34, (d): clay matrix of sample 36, (e): clay matrix of sample 51, (f): clay matrix of sample 52, (g): clay matrix of sample 54, (h): clay matrix of sample 72, (i): clay matrix of sample 74, (j): clay matrix of sample 109, (k): clay matrix of sample 137, (l): clay matrix of sample 139, (m): clay matrix of sample 144, (n): clay matrix of sample 157.**

The clay matrices of majority ( $n=11$ ) of the petrographic samples have been observed as having similar clay matrices. Samples 4, 11, 34, 36, 52, 72, 74, 109, 137, 139, 144, and 157 all have clay matrices comprised of quartz and mica laths as plastic inclusions. Samples 4 and 34 have notably higher levels of mica laths present within their clay matrices and as such their colours are slightly more orange than other clay matrices. Samples 51 and 54 were observed as the most different with quartz and K-feldspar present as plastic inclusions, while mica laths were barely present within both samples.

#### **5.3.4 Relative Firing Conditions**

The groundmass of the thin sections were analysed using the 10x and 20x objectives to determine presence or absence of groundmass optical activity as well as variation thereof. A groundmass that is optically active points to low firing temperatures as the ceramics were not fired above 700°C for a long period of time as to vitrify the clay matrix. Aplastic inclusions were also analysed such as quartz and feldspars for signs of alterations due to high firing temperatures or the lack thereof. Quartz and feldspars are prone to alteration at high temperatures which can be analysed petrographically. As they are the most abundant minerals, they were closely examined for signs of temperature alterations.

**Table 5-6: Table of relative firing conditions observations**

| <b>Sample</b> | <b>Optical Activity</b> | <b>Variation in Optical State</b> | <b>Mineral Alterations</b> |
|---------------|-------------------------|-----------------------------------|----------------------------|
| 4             | High                    | Uneven                            | Absent                     |
| 11            | High                    | Uneven                            | Absent                     |
| 34            | High                    | Uneven                            | Absent                     |
| 36            | High                    | Uneven                            | Absent                     |
| 51            | Moderate                | Uneven                            | Absent                     |
| 52            | High                    | Uneven                            | Absent                     |
| 54            | High                    | Uneven                            | Absent                     |
| 72            | High                    | Uneven                            | Absent                     |
| 74            | High                    | Uneven                            | Absent                     |
| 109           | High                    | Uneven                            | Absent                     |
| 137           | Moderate                | Uneven                            | Absent                     |
| 139           | Moderate                | Uneven                            | Absent                     |
| 144           | Moderate                | Uneven                            | Absent                     |
| 157           | High                    | Uneven                            | Absent                     |

Based on the presence of optically active clay matrices across all samples, it can be assumed that ceramics were all fired at low firing temperatures not exceeding 700°C. This was also evident in the lack of mineral alterations due to high firing temperatures especially in quartz and feldspars. The high optical activity of the groundmass paired with the variation thereof points to the possibility of the use of an open firing method. This technological feature is consistent amongst all fourteen petrographic samples of Evelyn and Klein Bolayi.

### **5.3.5 Thin Section Fabric Groups**

Based on the data presented pertaining to the thin sections, fabric groups and sub-groups were then created to observe relationships between the samples of both sites. Fabrics were formulated based on a combination of mineralogical compositions as well as technological features.

### **Quartz-feldspars-mica**

This main fabric is defined by its high frequency of aplastic quartz and feldspars in larger grain sizes. Plastics of this fabric show predominance of quartz and mica laths within the clay matrices. Clay matrix colours vary in reddish browns tones, with slight variations of darkness and hues but all have an overall similar groundmass with the presence of optical activity in varying levels. All samples have undergone low firing temperatures with even firing visible throughout.

### **Quartz-feldspars-mica with grog**

This is a sub-fabric of the quartz-feldspars-mica fabric. Similar to the main fabric, this sub-fabric has a high frequency of aplastic quartz and feldspars present. The only difference present in this sub-fabric is the presence of grog in the samples. Plastic inclusions show predominance of quartz and biotite laths. Clay matrix colours vary in reddish browns, with present optical activity. All samples have undergone low firing temperatures with uneven firing visible throughout all samples.

### **Quartz-mica-feldspars**

This fabric is a sub-fabric of the quartz-feldspar-mica group. It is also a loner fabric as only sample 34 falls into this sub-fabric. With a higher cumulative frequency of aplastic micas (12% total biotite and muscovite), this sub-fabric differs from the main fabric only in its predominance of micas. The groundmass is reddish-orange brown due to higher presence of biotite laths in the groundmass than in the quartz-feldspar plus mica fabric. The sub-fabric also shows high optical activity with varying levels throughout the sample.

### **Grog-quartz-feldspars**

This fabric shows high percentage of grog (9-10%), quartz and feldspars. All grog inclusions are of a similar composition. The clay matrix is red-brown to dark reddish-brown with quartz, feldspar laths and mica laths as plastic inclusions. This fabric shares similarities with the quartz-feldspars-mica fabric but differs greatly in temper additives

of grog inclusions and lower levels of plastic mica laths. Thus, it is presented as a separate fabric.

### **Olivine basalt-quartz-feldspars**

Distinguished by its predominance of olivine-basalt with poikilitic texture, this fabric serves as a loner fabric with only sample 52 falling into this group. The fabric is unique to others by presence of olivine basalt as well as much finer grained quartz and feldspars in comparison to other fabrics. This loner shows high optical activity with an orange-brown clay matrix, differing to colours of other clay matrices.

### **Olivine-quartz-biotite**

This loner fabric shows presence of fractured olivine as well as two schist inclusions. The uniqueness of both minerals separate this sample from the rest of the fabrics. The fabric has a high semi-quantitative frequency of biotite (7%) with tabular medium sand inclusions, larger in comparison to biotite of other fabrics. The clay matrix is orange-brown in colour due to high biotite laths and has high optical activity and likely underwent low firing temperatures.

**Table 5-7: Table of petrographic fabric descriptions**

| <b>Fabric</b>                   | <b>Description</b>                                                                                                                                                         | <b>Site Present</b> | <b>Sample</b> |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|---------------|
| Quartz-feldspars-mica           | High percentage of quartz and feldspars. Plastic inclusions consist of quartz and mica laths.                                                                              | Evelyn              | 109           |
|                                 |                                                                                                                                                                            |                     | 139           |
|                                 |                                                                                                                                                                            |                     | 144           |
|                                 |                                                                                                                                                                            | Klein Bolayi        | 11            |
|                                 |                                                                                                                                                                            |                     | 36            |
|                                 |                                                                                                                                                                            |                     | 72            |
| Quartz-feldspars-mica with grog | Sub-fabric of quartz-feldspars-mica fabric. High percentage of quartz and feldspars. Grog is present as temper. Plastic inclusions consist of quartz and mica laths.       | Evelyn              | 137           |
|                                 |                                                                                                                                                                            |                     | 157           |
|                                 |                                                                                                                                                                            | Klein Bolayi        | 74            |
| Quartz-mica-feldspars           | Sub-fabric of quartz-feldspars-mica fabric. High percentage of quartz, mica, and feldspars. Grog is present as temper Plastic inclusions consist of quartz and mica laths. | Klein Bolayi        | 34            |
| Olivine basalt-quartz-feldspars | High percentage of olivine basalt and quartz. Plastic inclusions consist of quartz and mica laths.                                                                         | Klein Bolayi        | 52            |
| Olivine-quartz-biotite          | High percentage of quartz and biotite as well as unique presence of olivine and schist. Plastic inclusions consist of quartz and mica laths.                               | Klein Bolayi        | 4             |
| Grog-quartz-feldspars           | High percentage of grog, quartz and feldspars. Plastic inclusions consist of quartz, feldspar and mica laths.                                                              | Klein Bolayi        | 51            |
|                                 |                                                                                                                                                                            |                     | 54            |

Quartz-feldspars-mica was the most common fabric with a total of six samples, three from each site. The sub-fabric Quartz-feldspars-mica with grog only differs to the main fabric in that it has grog present in the samples. The other sub-fabric of this group, quartz-mica-feldspars consists of only one sample from Klein Bolayi. This sub-group is possibly due to a technological difference in clay treatments to the Quartz-feldspars-mica fabric. The fabric grog-quartz-feldspars were both samples of unique macroscopic fabric groups J and M but mineralogical are of similar compositions with high quantities of grog. Fabrics olivine-quartz-biotite and olivine basalt-quartz-feldspars were both loner fabrics comprising of only one sample each. Klein Bolayi presents a wider variety of fabrics with each fabric present at the site, while Evelyn only shows presence of fabric quartz-feldspars-mica and its sub-fabric, quartz-feldspars-mica with grog. This could be a result of more technological variation present at Klein Bolayi than at Evelyn.

**Table 5-8: Technological features of petrographic fabrics**

| <b>Fabric</b>                   | <b>Known Temper</b> | <b>Forming Method</b>               | <b>Relative Firing Conditions</b> |
|---------------------------------|---------------------|-------------------------------------|-----------------------------------|
| Quartz-feldspars-mica           | Grog                | Pinching                            | Low, uneven firing temperature    |
| Quartz-feldspars-mica with grog |                     | Pinching                            | Low, uneven firing temperature    |
| Quartz-mica feldspars           | Grog                | Coil built                          | Low, uneven firing temperature    |
| Olivine basalt-quartz-feldspars |                     | Pinching                            | Low, uneven firing temperature    |
| Olivine-quartz-biotite          |                     | Combination of pinching and coiling | Low, uneven firing temperature    |
| Grog-quartz-feldspars           | Grog                | Pinching                            | Low, uneven firing temperature    |

Technological features of the petrographic fabrics show differences only in tempering and forming methods. Three of the six fabrics have grog present as temper within the samples while the other three do not have conclusive signs of tempering. Five fabrics show pinching as the implemented forming method while sub-fabric quartz-mica feldspars was formed using the coiling method. The loner fabric olivine-quartz-biotite also shows presence of coiling alongside pinching. Relative firing conditions amongst all fabrics are the same with low, uneven firing temperatures recorded in their clay matrices.

## 5.4 Summary

The use of macroscopic, chemical, and mineralogical analysis shows an overarching similarity in clays and technological features present at Evelyn and Klein Bolayi with some variation at Klein Bolayi. Macroscopic analysis found Klein Bolayi to have higher variation amongst its assemblage than Evelyn. Pyrite specks were observed as the most common identifiable inclusion across the thirteen macroscopic fabric groups.

From each site, one hundred samples were selected from each site for pXRF analysis. Statistical analysis of the chemical data showed that the samples from Evelyn were all fairly homogenous in nature based on major as well as minor and trace elements. Klein Bolayi, which also presented a fairly homogenous dataset, did have four samples which consistently clustered away from the bulk of the data as a result of higher levels of iron, magnesium oxide, chromium, and manganese. Due to its outlying nature, sample 4 was randomly selected for petrographic analysis to further investigate its outlying nature. Comparison of chemical data of Evelyn and Klein Bolayi showed a large overlap which shows a similar chemical fingerprint present within the landscape.

One representative sample was selected from each fabric group to undergo petrographic analysis. Petrographic analysis identified six fabrics across the two sites, with fabric Quartz-feldspars-mica as the main fabric present across both sites. Of this fabric there

were two sub-fabrics, Quartz-feldspars-mica with grog, and quartz-mica feldspars which differed only slightly from the main fabric. Klein Bolayi had the most fabric variation with fabric grog-quartz feldspars and loner fabrics olivine basalt-quartz-feldspars, and olivine-quartz-biotite present only there. The loner fabric olivine-quartz-biotite was comprised of only sample 4, also identified as a chemical outlier. This showed a similarity in clay fabrics present in both sites as well as the presence of technological variation present at Klein Bolayi which was not seen at Evelyn.

## CHAPTER SIX – DISCUSSION

Based on macroscopic, chemical and petrographic results, interpretations were made to place the results into an archaeological context. This chapter discusses each site's respective clays to compare for similarities or differences as to answer research questions pertaining to the clay fabrics. Details about stages of pottery production undergone at each sites will be discussed as far as possible based on observations made during analysis. The ceramic analysis results will be used to answer the research questions and make assumptions based on the ceramics of Evelyn and Klein Bolayi.

### 6.1 Clay of Evelyn

The ceramic assemblage of Evelyn presents ceramics of non-calcareous clays seen by quartz percentages above 5% (see appendix A and B). Chemical data shows a fairly homogeneous composition of the 100 samples analysed using pXRF with no distinctive outliers. Based on the chemical data of the site, the ceramics were likely made using the same clay. This can relate to a single clay source which was used for all the ceramics made and used at Evelyn.

Based on petrographic fabrics, three samples belonged to the quartz-feldspar-mica fabric, with two samples belonging to the sub-fabric quartz-feldspars-mica with grog. This sub-fabric is compositionally and technologically identical to the main fabric, with the addition of grog present. This addition of grog shows deliberate tempering during clay processing.

The predominant minerals in all samples were quartz and feldspars which is also visible through high silica dioxide ( $\text{SiO}_2$ ) and aluminium oxide ( $\text{Al}_2\text{O}_3$ ) percentages in the chemical data. As quartz and feldspars are of the most common minerals on earth as well as being common temper materials, it is uncertain whether their high presence was a result of natural inclusions or deliberate tempering. Biotite was also a commonly found mineral of Evelyn, especially as plastic inclusions within the clay matrices.

Based on chemical and mineralogical analysis, Evelyn likely used one clay source along with a similar overarching technology of ceramic production as samples share a technological and compositional similarity throughout.

## 6.2 Clay of Klein Bolayi

Similarly to the clay of Evelyn, the ceramic assemblage of Klein Bolayi is comprised of non-calcareous clays due to quartz percentages above 5% (see Appendix A and B). Macroscopically, Klein Bolayi has eight fabric groups present compared to the five present in Evelyn. This high variation also translated in chemical and thin section observations with chemical data consistently presenting samples 3, 4, 5, 34 and often 52 as outliers based on higher levels of iron (Fe), magnesium oxide (MgO), chromium (Cr), and manganese (Mn). The rest of the chemical data was fairly homogenous showing two chemical groups comprised of the bulk of the site as one group and the outliers as the second.

Based on petrographic analysis, Klein Bolayi showed presence of all six fabrics identified. Fabric overlap with Evelyn was present in fabric quartz-feldspars-mica and quartz-feldspars-mica with grog. Fabric grog-quartz feldspars, sub-fabric quartz-mica feldspars, and loner fabrics olivine basalt-quartz-feldspars, and olivine-quartz-biotite were all unique to Klein Bolayi and were not identified at Evelyn.

The predominant minerals, similarly to that of Evelyn, were quartz and feldspars which is also visible through high silica dioxide ( $\text{SiO}_2$ ) and aluminium oxide ( $\text{Al}_2\text{O}_3$ ) percentages in the chemical data. Whether quartz was a deliberate temper or of natural occurrence could not be determined. Biotite was also a commonly occurring mineral within Klein Bolayi in varying quantities and also as plastic inclusions within the clay matrices of all samples.

Based on chemical and petrographic analysis, Klein Bolayi did share a common clay source with Evelyn but also showed variation not present at Evelyn. Unique fabrics present at Klein Bolayi could indicate a separate clay source which was not accessible by Evelyn. The reasons for this could be myriad, such as trade, exogamous marriage patterns, or direct access of a different clay source by some potters in the community.

### 6.2.1 Klein Bolayi pXRF Outliers

Samples 3, 4, 5, 34, and in some instances 52, were present as outliers amongst the Klein Bolayi bulk chemical data. Samples 34 and 52 had already been selected for petrographic analysis. Sample 4 was randomly selected from samples 3, 4, and 5 for petrographic analysis. Mineralogical analysis of sample 4 presented a unique loner fabric, olivine-quartz-biotite with olivine and schist inclusions which were not present in any of the other thirteen petrographic samples. Sample 34, which was chemically similar to sample 4, was mineralogical classified as part of the sub-fabric quartz-mica feldspars due to its higher quantity of biotite. Sample 34 was the only sample which showed mineral orientation of coiling being used as a forming method. Sample 52, macroscopically analysed as having grog-like inclusions, mineralogical had no grog present but rather olivine basalt as its second most abundant mineral. Sample 52 was the only sample present in the olivine basalt-quartz-feldspars fabric. The outliers of Klein Bolayi which were analysed petrographically, were also mineralogically unique across all fabrics. Chemically, these outliers were driven by higher levels of iron, magnesium oxide, chromium and manganese. Samples 4 and 52 have consistently been viewed as outliers in both chemical mineralogical results. This could likely be the result of non-local production.

### 6.3 Grog Tempering

The presence of grog within a ceramic is always the result of deliberate tempering. Six of the petrographic samples show grog present as a tempering agent. The four samples of sub-fabric quartz-feldspars-mica with grog all have low quantities of one to two inclusions present. Sample 34 of the sub-fabric quartz-mica-feldspars also has one inclusion of grog present. Grog is present in lower quantities within these four samples but have all been observed as compositionally similar and show deliberate addition of grog occurring within Evelyn and Klein Bolayi.

Samples 51 and 54 of fabric grog-quartz-feldspars have 40 and 47 grog inclusions respectively. Grog across both samples have been observed as being compositionally similar. These two samples show the strong presence of deliberate grog tempering.

Grog is seen as a tempering agent which was utilised in both Evelyn and Klein Bolayi, with higher observed quantities present in samples of Klein Bolayi. Conclusively, both have employed this behavioural practice of deliberate grog tempering.

#### **6.4 Clay Pellets as Natural Inclusions or Temper**

Clay pellets appear to be a common inclusion present amongst the majority of the petrographic samples with a total of nine having clay pellets present. Clay pellets are often of natural causation as they may be the result of dried clumps of old clay which have been unintentionally added to the clay mixture (Santacreu 2014: 61). They may also be a temper of older clay or a different clay which has been mixed in but not fully homogenised. The clay pellets observed from Evelyn and Klein Bolayi are all of similar composition based on petrographic analysis. Their presence as natural inclusions or temper cannot be determined with certainty but their compositional similarities transfer into technological similarities whether it be the same clay mix or old clay mixed into a new paste.

#### **6.5 Forming Methods Present**

Analysis of mineral orientation showed the predominant presence of pinching being employed across both Evelyn and Klein Bolayi. All five petrographic samples from Evelyn showed the pinching forming method which shows an intra-site consistency in forming methods used.

The use of pinching was identified in seven samples in Klein Bolayi. One sample showed a mineral orientation indicative of coiling. Another sample showed mineral orientation of both pinching and coiling having been used. This shows higher technological variance within Klein Bolayi where two forming methods have been identified along with the implementation of a combination of both forming methods in one sample.

Forming methods are often the technological feature which are the most resistant to change and is reinforced through learning and communities of practice throughout many generations. Evelyn and Klein Bolayi show the implementation of repeated,

learned technological processes through their forming methods. Both sites share a similarity in the implementation of the pinching method as the favoured forming method.

## **6.6 Relative Firing Conditions**

Based on the presence of optical activity and variation thereof viewed under crossed polarized light, it is likely that the ceramics of Evelyn and Klein Bolayi underwent similar firing conditions. Based on the presence of optical activity of the clay matrices of all 14 samples, the samples were likely all fired at a lower temperature of around 700 degrees Celsius. All samples display variation in optical activity. This is generally the result of uneven firing, which is suggestive of open firing. As this firing method has numerous uncontrollable variables such as wind and contact with the fire, even firing throughout a vessel is generally not possible. As previously mentioned, open firing has ethnographically been documented as the favoured firing method within southern Africa over the use of a kiln. Petrographic analysis only allows for an assumption of relative firing conditions, x-ray diffraction is the preferred method for accurately determining exact firing conditions.

## **6.7 Sample Comparison to Local Geology**

The best method for geological comparison is the use of fired briquettes from known clay sources. This study however made use of mineralogy compared to geological reports to make a broad overall assumption pertaining to the ceramics locality. The mineralogy of the petrographic samples were compared to the local geology of the area as outlined in chapter two. Where applicable, macroscopic analysis was also compared to the geological reports.

The full mineralogical range of Evelyn and Klein Bolayi based on macroscopic and petrographic analysis included: quartz, K-feldspar, plagioclase, microcline, hornblende, biotite, muscovite, clinopyroxene, granite, granodiorite, opaque minerals, olivine, olivine basalt, and schist. Of the geological formations established in the area, the Bulai pluton and Bulai gneiss have the most overlap with the mineralogical compositions

present at Evelyn and Klein Bolayi. Upon comparison of the Bulai pluton formation, granite, granodiorite, charno-enderbite, enderbites as well as K-feldspar are the most common minerals present within the pluton. Of these minerals, K-feldspar is present within all fourteen samples across both Evelyn and Klein Bolayi in high frequencies. K-feldspar is present as the most abundant feldspar present within the petrographic samples. Semi-quantitative frequencies of K-feldspar range from 5% to 13%. K-feldspar size inclusion range is comprised of very fine sand, fine sand, medium sand, coarse sand, and very coarse sand with fine sand as the most common grain size across all samples. K-feldspar laths are present in the clay matrices of the samples in the grog-quartz feldspar fabric. Granite is present within six samples, with three from Evelyn and three from Klein Bolayi. The granite inclusions are visible in larger grain sizes of coarse sand to very coarse sand inclusions across all six samples. Granodiorite is present in four samples, with one from Evelyn and three from Klein Bolayi. The granodiorite inclusions are visible in larger grain sizes of coarse sand to very coarse sand inclusions across all four samples.

The Bulai gneiss is most commonly comprised of quartz, plagioclase, biotite, hypersthene, hornblende and garnet. Of these minerals, quartz, plagioclase, biotite, and hornblende were petrographically observed in ceramics from both sites. Quartz is present as the predominant mineral present within the samples with semi-quantitative frequencies ranging from 8-13%. Quartz minerals have the highest grain size variation of the mineralogy, as well as being present within the clay matrices across all fourteen samples. The quartz inclusion size range is comprised of coarse silt, very fine sand, fine sand, medium sand, coarse sand, and granules with a predominance of very fine sand and fine sand. As quartz is one of the most abundant minerals on earth, it is not considered as a defining mineral within the geological comparisons. Plagioclase, which is the second most common feldspar present within the samples, is present within all petrographic samples. Semi-quantitative frequencies range from 1-10% within the samples. Plagioclase inclusion size range is comprised of coarse silt, very fine sand, fine sand, and medium sand across all samples, with fine sand being the predominant grain size present. Biotite as aplastic inclusions are present in a total of twelve samples, four from Evelyn, and eight from Klein Bolayi, and present as aplastic inclusions in all of the samples' clay matrices. Aplastic semi-quantitative frequencies range from <1% to 9%. Biotite inclusion size range is comprised of fine silt, medium silt, coarse silt,

very fine sand, and fine sand with very fine sand and fine sand as the most common inclusions. Hornblende is present in a total of twelve samples, five samples from Evelyn, and seven samples from Klein Bolayi. Semi-quantitative frequencies range from <1% to 4%. Hornblende inclusion size range is comprised of very fine silt, medium silt, very fine sand, and fine sand with very fine sand and fine sand as the most common inclusion sizes present.

Mineralogy of the petrographic samples also share similarities to the basement suite of the Central Zone, the Sand River Gneiss. The minerals present within the Sand River Gneiss and the Evelyn and Klein Bolayi petrographic samples include granodiorite, plagioclase, hornblende, and K-feldspar.

Geological research (Brandt et al 2018), found pyrite and chalcopyrite to be abundantly present within the local geology. Macroscopically, Evelyn and Klein Bolayi's ceramic assemblage had noticeable quantities of pyrite identified within the ceramic sherds. Due to the ferrous nature of pyrite ( $\text{FeS}_2$ ) and chalcopyrite ( $\text{CuFeS}_2$ ), they present isotropic properties under polarizing light and cannot be distinguished from other ferromagnesian minerals such as hematite and magnetite. All ferromagnesian minerals were recorded together as opaque minerals and were present within all fourteen petrographic samples. Due to the low rate of indisputable petrographic identification, the macroscopic analysis of pyrite was favoured over petrographic in identifying the presence of pyrite within the ceramic assemblages.

## **6.8 Macroscopic Relationship to Chemical and Petrographic Fabrics**

Based on statistical analysis of the chemical data of Evelyn and Klein Bolayi, macroscopic fabric groups do not have a direct chemical correlation. There were no visible patterns when analysing the samples of the same macroscopic fabric groups based on their chemical compositions. This is likely a result of the bulk compositional data determined through pXRF whereas macroscopic analysis may identify specific geological inclusions within the ceramics. pXRF cannot identify specific minerals but rather gives an oversight into the general compositional properties of ceramics.

**Table 6-1: Petrographic fabrics compared to macroscopic fabric groups**

| <b>Petrographic Fabric</b>      | <b>Macroscopic Fabric Group</b> | <b>Sample</b> |
|---------------------------------|---------------------------------|---------------|
| Grog-quartz-feldspars           | J                               | 51            |
|                                 | M                               | 54            |
| Olivine basalt-quartz-feldspars | G                               | 52            |
| Olivine-quartz-biotite          | H                               | 4             |
| Quartz-feldspars-mica           | F                               | 11            |
|                                 | K                               | 36            |
|                                 | H                               | 72            |
|                                 | A                               | 109           |
|                                 | D                               | 139           |
|                                 | E                               | 144           |
| Quartz-feldspars-mica with grog | L                               | 74            |
|                                 | C                               | 137           |
|                                 | B                               | 157           |
| Quartz-mica-feldspars           | I                               | 34            |

Macroscopic fabric groups J and M were identified as unique upon macroscopic analysis, but petrographic analysis showed a strong similarity between the two and were both identified as belonging to the same fabric grog-quartz-feldspars.

The most commonly found macroscopic fabric groups of Evelyn were C and E, and H of Klein Bolayi, as previously discussed. Representative samples of E and H are part of the fabric quartz-feldspars-mica. The representative sample of C belongs to the sub-fabric quartz-feldspars with grog. The correlation between the most prominent macroscopic fabric groups with the prominent petrographic fabric and sub-fabric could show the likeliness that majority of both sites' ceramic assemblages could be classified under the quartz-feldspars-mica fabric.

Sample 34 of the rare fabric group I, based on macroscopically identified specularite, was identified as belonging to the sub-fabric quartz-mica-feldspars. Due to the ferrous nature of hematite in specularite, exact mineral identification was not possible. Of the 3% opaque minerals identified under thin section, hematite could have been the principal ferromagnesian mineral present as no pyrite was macroscopically observed within this group.

Petrographic fabrics create a more accurate fabric description as each anisotropic mineral can be observed and identified. This allows for a more cohesive set of fabrics based on a combination of similar microscopic properties. Macroscopic analysis does however aid in the initial understanding of a ceramic assemblages general fabric paste to further investigate through petrographic analysis.

## **6.9 Comparing Results of Analytical Methods**

Based on macroscopic fabrics, there was a visible overlap in fabric groups amongst both sites with clearly visible pyrite specks in majority of the assemblages. Chemical data showed a fairly homogenous composition across both sites with no general trend of clustering apart with the occurrence of a few outliers. Across both sites, silica dioxide, aluminium dioxide and iron were the most predominant elements present within the ceramic assemblages of both Evelyn and Klein Bolayi. The high silica dioxide relates to abundance of quartz and feldspars which are visible in petrographic analysis with samples having an average of 11% quartz, 9% K-feldspar, and 4% plagioclase. High silica dioxide is also present within the clay matrices of samples as all samples have plastic quartz inclusions.

Aluminium dioxide is naturally occurring in clay as well as silicates such as quartz, micas, feldspars, and olivine, all of which have varying levels within the fabrics of both assemblages. With an average pXRF percentage of 20.2% across both sites, it coincides with the presence of aplastic quartz, feldspars, micas, and olivine as well as plastic quartz and micas present in all samples clay matrices.

Iron as the third most prominent element present in the ceramics is likely a representation of ferromagnesian minerals such as pyrite, hematite, and magnetite, all of which are grouped together as opaque minerals. Due to the isotropic nature of ferrous

minerals under polarizing light, the identification of exact minerals is not always possible. As the ceramic assemblages displayed prevalence of pyrite inclusions examined macroscopically, the higher iron percentages may have been due to abundance of pyrite.

## 6.10 Spatial and Stratigraphic Relationship to Petrographic Fabrics

Petrographic samples and their fabrics were compared to stratigraphic contexts of each site to orientate them spatially within each site. This was also done to examine any possible spatial distribution patterning present within each site.

**Table 6-2: Evelyn stratigraphic distribution**

| Sample | Petrographic Fabric             | Context | Trench            |
|--------|---------------------------------|---------|-------------------|
| 109    | Quartz-feldspars- mica          | C1002   | Trench II and VII |
| 137    | Quartz-feldspars-mica with grog | C1012   | Trench V          |
| 139    | Quartz-feldspars-mica           | C1012   | Trench V          |
| 144    | Quartz-feldspars- mica          | C1012   | Trench V          |
| 157    | Quartz-feldspars-mica with grog | C1018   | Trench VI         |

The fabric and sub-fabric of Evelyn is seen in three stratigraphic contexts of four trenches. Sample 109 of fabric quartz-feldspars-mica was found within the large ‘L’ shaped excavation unit of Trench II and VII. The sample was situated below the surface context. To the south of this trench, samples 137, 139, and 144 were found in context C1012 of Trench V. Both the main fabric quartz-feldspars with mica, as well as the sub fabric quartz-feldspars-mica with grog were present within the same context. Further away from the larger ‘L’ shaped trench, sample 157 was found within context C1018 of Trench VI. Sample 157 belongs to the sub-fabric of quartz-feldspars-mica with grog.

Context C1018 is the lowest stratigraphic layer of Trench VI and is likely older than contexts closer to the surface.

The five samples were spatially spread across Evelyn with samples covering four of the seven excavated trenches. This can show the likeliness that the ceramic paste across the whole site would assumably be similar to the fabrics which have been identified within this study through petrographic analysis. The stratigraphic spread of samples found in contexts which are presumably younger as well as within context C1018 which was above sterile soil, may represent a reinforcement in the use of similar clays. It is possible that the potters of Evelyn used the same clay source for the duration of the site occupation with no significant ceramic paste changes. Further petrographic analysis of the remaining three trenches could examine the extent of the paste similarity within every trench of the site.

**Table 6-3: Klein Bolayi stratigraphic distribution**

| Sample | Petrographic Fabric             | Context | Trench     |
|--------|---------------------------------|---------|------------|
| 4      | Olivine-quartz-biotite          | C1001   | Trench I   |
| 11     | Quartz-feldspars-mica           | C1003   | Trench I   |
| 34     | Quartz-mica-feldspars           | C1006   | Trench I   |
| 36     | Quartz-feldspars-mica           | C1006   | Trench I   |
| 51     | Grog-quartz-feldspars           | C1006   | Trench I   |
| 52     | Olivine basalt-quartz-feldspars | C1012   | Trench V   |
| 54     | Grog-quartz-feldspars           | C1012   | Trench V   |
| 72     | Quartz-feldspars-mica           | C1008   | Trench III |
| 74     | Quartz-feldspars-mica with grog | C1008   | Trench III |

All six petrographic fabrics are present within Klein Bolayi, distributed along three of the six excavation trenches. Fabric quartz-feldspars-mica was found in contexts C1003 and C1006 of Trench I, and in context C1008 of Trench III. Sample 34 of the sub-fabric

quartz-mica-feldspars was found in context C1006 of Trench I. The other sub-fabric quartz-feldspars-mica with grog was found in context C1008 of Trench III. The fabric grog-quartz-feldspars was found in context C1006 of Trench I and in context C1012 of Trench V. Loner fabric olivine-quartz-biotite was found in context C1001 of Trench I. Loner fabric olivine basalt-quartz-feldspars was found in context C1012 of Trench V.

Different fabrics were spread across the site with no distinctive distribution pattern based on different mineralogical compositions. Trench I had the most fabric variation with four fabrics present across three contexts. Similar fabrics did not cluster together and were spread across more than one trench.

## **6.11 Answering of Research Questions**

Based on macroscopic, chemical and petrographic observations, the research questions were answered as follows.

### **1. What is the relationship between the clay of Evelyn and Klein Bolayi?**

The clay from both Evelyn and Klein Bolayi are all non-calcareous clays due to quartz levels above 5%. Macroscopic analysis presented five fabric groups in Evelyn and eight in Klein Bolayi. The macroscopic results had more variation observed in Klein Bolayi than Evelyn. Chemical analysis showed a homogenous dataset present in Evelyn with no significant outliers. Klein Bolayi also presented a chemically homogenous dataset with the exception of four samples (3, 4, 5, 34), which were consistently present as outliers as a result of higher levels of iron, magnesium oxide, chromium, and manganese. Sample 4 was then randomly selected for petrographic analysis to further investigate its outlying nature. Chemically, Klein Bolayi had more variation present than the dataset of Evelyn. Upon inter-site comparison, the chemical data presented a homogenous cluster with both sites sharing an overarching similar chemical fingerprint.

Of the fourteen petrographic samples, quartz and feldspars (K-feldspar and plagioclase) are noted as the most dominant minerals present in both sites. Based on the combination of mineralogical compositions and technological features, two fabrics, two sub-fabrics and two loner fabrics were formulated. Klein Bolayi showed higher fabric variation with all six petrographic fabrics present, while Evelyn only had one fabric and one sub-fabric present. This shows the use of a similar clay source between both sites with the

presence of the main fabric, quartz-feldspars-mica at both sites. All petrographic outliers were only found at Klein Bolayi, which could reflect different technological implications at an intra-site scale, or show the presence of foreign or imported ceramics at the site.

Overall, both sites bare overlapping similarities macroscopically, chemically and mineralogically, which is likely the result of a similar or same clay source. The paste variation present at Klein Bolayi could show technological variation within the landscape or ceramics coming from outside of the immediate region.

## **2. What technological features can be observed in the ceramics of Evelyn and Klein Bolayi?**

Technological features, as outlined in table 5.6, were observed as temper, forming methods, and relative firing conditions. Of the fourteen petrographic samples, six were seen to have employed the use of grog tempering whereby crushed ceramics were deliberately added to the clay as temper. Evelyn had grog present in two of the five samples in low quantities with a semi-quantitative frequency of <1%. Between both samples, the grog inclusions were observed as compositionally similar. Klein Bolayi had grog present in four of the eight samples in varying quantities. Two samples had low semi-quantitative frequencies of <1% with similar compositions. The other two samples had high semi-quantitative frequencies of 9% and 10%, both of which had compositionally similar grog inclusions.

Forming methods implemented at Evelyn show only the use of pinching based on mineral orientation.. Klein Bolayi showed presence of two forming methods, pinching and coiling. Six samples of Klein Bolayi showed implementation of pinching. One sample showed implementation of coiling as its forming method while the last one showed signs of a combination of both pinching and coiling. Forming methods overlap across both sites with the predominance of pinching visible at both Evelyn and Klein Bolayi. Klein Bolayi presents the only different forming method of coiling and a combination of pinching and coiling.

Relative firing conditions analysed at Evelyn showed signs of ceramics which underwent low firing temperatures with signs of uneven firing. Similarly at Klein Bolayi, ceramics show that low firing temperatures were implemented as well as signs

of uneven firing. The presence of uneven firing could possibly show the use of an open fire firing method having been used at both Evelyn and Klein Bolayi.

### **3. What assumptions can be made on the locality of the ceramics based on the local geology?**

The comparison of mineralogical compositions of Evelyn and Klein Bolayi to geological reports of the local area, shows an overlapping mineralogy. Similarities overlap in the presence of granite, granodiorite, and K-feldspar minerals which are formative of the Bulai pluton. Minerals including plagioclase, quartz, biotite, and hornblende overlap with that of the composition of the Bulai gneiss.

It is likely that fabric grog-quartz-feldspars, quartz-feldspars-mica and its sub-fabrics quartz-feldspars-mica with grog, and quartz-mica-feldspars were created using a local clay source bearing local geological features. Samples within these fabrics display the most similarities at an inter-site scale as well as with the local geology.

Loner fabric olivine basalt-quartz-feldspars is assumably not of a local origin as its distinguishing mineral, olivine basalt is not formative to the geological formations present within the local landscape of Evelyn and Klein Bolayi. Loner fabric olivine-quartz-biotite is also likely not of local origin as it bears olivine and schist, which has also not been outlined as formative to any geological features within the local landscape. Whether these fabrics were the result of trade, inter-group marriage, or made using a different clay source was undeterminable. They are however, unique to the other petrographic samples and employed either a different clay or different technology resulting in a different paste.

## **6.12 Summary**

Based on macroscopic, chemical, and mineralogical analysis it can be assumed that Evelyn and Klein Bolayi both shared a common source of clay for raw material procurement. This clay source, based on geological comparisons, was likely situated within the broader local region surrounding the sites and were accessible by both sites. If the sites were contemporaneously occupied by two different communities, this shows the shared interaction and shared access to resources within the region. Klein Bolayi,

does however show mineralogical as well as technological variations not present at Evelyn. This is seen through the implementation of the coiling method at Klein Bolayi in two samples which is not observed in samples of Evelyn. This is also seen through the two loner fabrics olivine basalt-quartz-feldspars, and olivine-quartz-biotite. The presence of olivine basalt, olivine, and schist is not observed in any other samples. These two fabrics also show presence of minerals not common within the local geology and are likely the result of ceramics which have not been produced within the immediate landscape.

## CHAPTER SEVEN – CONCLUSION

Based on the scope of analysis of ceramic technology at Evelyn and Klein Bolayi, the sites were likely to have used a shared clay source for ceramic production. This clay source was likely to have been situated within the region, based on the geological overlap observed within petrographic samples. This was shown in an overlap of the Bulai pluton, the Bulai gneiss, and less so in the Sand River gneiss.

Analysis shows that Evelyn had a fairly homogenous clay paste used with a similar chemical and mineralogical composition seen throughout the whole site. Technological features implemented at Evelyn were also seen as consist with the implementation of a pinching forming method, low firing temperatures, and grog tempering. Klein Bolayi, which shares an overlap in clay similarities to Evelyn, also showed clay and technological variation. Pinching was the dominant forming method present, while one sample showed the implementation of a coiling forming method. As this sample was considered to be of local origin, it is likely that the coiling was implemented at Klein Bolayi itself. Another sample showed the combined implementation of coiling and pinching. This sample did however belong to the loner fabric olivine-quartz-biotite which was more likely not made using local materials. The other loner fabric, olivine basalt-quartz-feldspars was also speculated to not be of local origin. Whether the two loner fabrics present at Klein Bolayi were the result of trade, or inter-group marriage cannot be speculated with full certainty. It is only known that these two samples were likely not produced using local materials.

Further petrographic analysis sampling specific trenches not covered within this research could be done to allow for a complete spatial analysis of the ceramic compositions of Evelyn and Klein Bolayi. This could determine if Evelyn consistently presents a homogenised ceramic paste. It could also determine whether the loner fabrics of Klein Bolayi appear more frequently throughout the site.

Since the onset of this research, a third site, EV03 within the Klein Bolayi Game Lodge was excavated in 2018. Further research of this site could benefit in the understanding of these closely situated sites. Petrographic analysis could be done to determine whether

EV03 shares mineralogical and technological relationships to that of Evelyn and Klein Bolayi. If a clay source could be identified within the region of Evelyn and Klein Bolayi, samples could be collected, fired and used to create petrographic samples. This could allow for a more accurate comparison of local clay as to locate an exact clay source which might have been exploited during the occupation of Evelyn and Klein Bolayi.

The application of portable x-ray fluorescence and petrography to the ceramics of Evelyn and Klein Bolayi has shown the importance of the application of a technological approach to ceramics.

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## **APPENDIX A**

### **PXRF DATA**

**Table 1: pXRF data in percentage**

| Sample | Site | Macro-<br>scopic<br>Fabric<br>Group | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe   | MgO  | K <sub>2</sub> O | Ca   | P    | Ti   | Ba    | S    | V    | Cr    | Mn   | Co    | Ni    | Cu    |
|--------|------|-------------------------------------|------------------|--------------------------------|------|------|------------------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 1      | EV02 | F                                   | 70,96            | 29,57                          | 3,01 | 2,26 | 2,04             | 2,15 | 0,09 | 0,27 | 0,076 | 0,04 | 0,01 | 0,008 | 0,05 | 0,005 | 0,006 | 0,006 |
| 2      | EV02 | H                                   | 73,60            | 19,56                          | 3,82 | 3,27 | 2,54             | 2,15 | 0,17 | 0,76 | 0,110 | 0,10 | 0,02 | 0,010 | 0,08 | 0,005 | 0,015 | 0,009 |
| 3      | EV02 | H                                   | 60,20            | 14,22                          | 5,43 | 6,46 | 1,97             | 4,83 | 0,20 | 0,61 | 0,058 | 0,05 | 0,02 | 0,021 | 0,12 | 0,006 | 0,025 | 0,009 |
| 4      | EV02 | H                                   | 60,16            | 14,88                          | 5,71 | 6,48 | 2,11             | 3,44 | 0,15 | 0,51 | 0,059 | 0,08 | 0,02 | 0,026 | 0,13 | 0,000 | 0,036 | 0,010 |
| 5      | EV02 | H                                   | 60,81            | 13,93                          | 5,44 | 5,98 | 2,08             | 3,21 | 0,14 | 0,56 | 0,058 | 0,07 | 0,02 | 0,026 | 0,12 | 0,006 | 0,026 | 0,010 |
| 6      | EV02 | H                                   | 67,35            | 17,66                          | 3,80 | 3,53 | 2,52             | 2,26 | 0,16 | 0,57 | 0,152 | 0,06 | 0,03 | 0,006 | 0,08 | 0,000 | 0,011 | 0,008 |
| 7      | EV02 | L                                   | 62,88            | 18,13                          | 3,72 | 3,05 | 2,79             | 4,35 | 0,49 | 0,57 | 0,167 | 0,06 | 0,02 | 0,005 | 0,08 | 0,006 | 0,011 | 0,007 |
| 8      | EV02 | H                                   | 69,28            | 28,31                          | 2,98 | 2,24 | 2,20             | 4,03 | 0,20 | 0,28 | 0,110 | 0,09 | 0,01 | 0,007 | 0,06 | 0,000 | 0,005 | 0,006 |
| 9      | EV02 | H                                   | 64,76            | 21,07                          | 4,38 | 3,87 | 3,36             | 2,75 | 0,27 | 0,64 | 0,177 | 0,06 | 0,02 | 0,006 | 0,08 | 0,006 | 0,005 | 0,006 |
| 10     | EV02 | L                                   | 59,17            | 15,46                          | 4,08 | 2,47 | 2,07             | 3,30 | 1,02 | 0,73 | 0,219 | 0,05 | 0,02 | 0,004 | 0,06 | 0,000 | 0,016 | 0,006 |
| 11     | EV02 | F                                   | 64,71            | 24,32                          | 2,67 | 2,17 | 2,38             | 3,53 | 0,11 | 0,26 | 0,077 | 0,05 | 0,01 | 0,008 | 0,06 | 0,005 | 0,006 | 0,007 |
| 12     | EV02 | F                                   | 66,88            | 17,29                          | 4,02 | 2,82 | 2,70             | 1,74 | 0,11 | 0,75 | 0,103 | 0,06 | 0,02 | 0,008 | 0,08 | 0,006 | 0,005 | 0,007 |
| 13     | EV02 | L                                   | 60,74            | 17,31                          | 3,44 | 3,46 | 3,01             | 2,51 | 0,19 | 0,53 | 0,141 | 0,08 | 0,02 | 0,004 | 0,06 | 0,004 | 0,004 | 0,006 |
| 14     | EV02 | L                                   | 62,97            | 15,06                          | 3,33 | 3,13 | 2,32             | 2,39 | 0,16 | 0,52 | 0,140 | 0,09 | 0,02 | 0,004 | 0,04 | 0,005 | 0,005 | 0,005 |
| 15     | EV02 | L                                   | 61,63            | 18,57                          | 3,84 | 4,08 | 3,06             | 2,73 | 0,20 | 0,61 | 0,165 | 0,05 | 0,02 | 0,007 | 0,08 | 0,005 | 0,006 | 0,007 |
| 16     | EV02 | L                                   | 58,12            | 15,45                          | 3,03 | 2,36 | 2,39             | 3,65 | 0,13 | 0,71 | 0,149 | 0,06 | 0,02 | 0,000 | 0,05 | 0,000 | 0,007 | 0,005 |
| 17     | EV02 | L                                   | 60,24            | 18,82                          | 4,17 | 4,45 | 2,93             | 2,40 | 0,20 | 0,68 | 0,152 | 0,06 | 0,02 | 0,006 | 0,08 | 0,000 | 0,006 | 0,006 |
| 18     | EV02 | H                                   | 63,95            | 23,24                          | 3,09 | 2,69 | 2,94             | 2,59 | 0,15 | 0,40 | 0,106 | 0,07 | 0,01 | 0,006 | 0,07 | 0,006 | 0,006 | 0,006 |
| 19     | EV02 | H                                   | 60,86            | 17,68                          | 4,19 | 2,75 | 2,58             | 2,79 | 0,25 | 0,69 | 0,175 | 0,05 | 0,02 | 0,000 | 0,05 | 0,005 | 0,004 | 0,005 |
| 20     | EV02 | H                                   | 61,31            | 19,15                          | 3,95 | 4,43 | 2,84             | 2,48 | 0,19 | 0,65 | 0,147 | 0,05 | 0,02 | 0,006 | 0,07 | 0,006 | 0,005 | 0,006 |
| 21     | EV02 | H                                   | 76,86            | 12,86                          | 3,33 | 2,38 | 1,65             | 4,25 | 0,21 | 0,60 | 0,145 | 0,05 | 0,02 | 0,004 | 0,04 | 0,000 | 0,006 | 0,005 |

|    |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 22 | EV02 | H | 71,23 | 19,68 | 3,41 | 2,82 | 2,77 | 3,09 | 0,17 | 0,75 | 0,164 | 0,04 | 0,02 | 0,004 | 0,05 | 0,000 | 0,003 | 0,005 |
| 23 | EV02 | L | 63,12 | 19,18 | 4,27 | 3,81 | 3,66 | 2,01 | 0,20 | 0,66 | 0,169 | 0,06 | 0,02 | 0,005 | 0,07 | 0,000 | 0,004 | 0,012 |
| 24 | EV02 | L | 64,36 | 16,63 | 3,78 | 2,39 | 2,71 | 2,12 | 0,10 | 0,67 | 0,189 | 0,06 | 0,02 | 0,004 | 0,05 | 0,000 | 0,003 | 0,005 |
| 25 | EV02 | L | 69,53 | 28,41 | 2,82 | 2,32 | 1,87 | 2,74 | 0,09 | 0,33 | 0,141 | 0,05 | 0,01 | 0,009 | 0,08 | 0,007 | 0,007 | 0,007 |
| 26 | EV02 | L | 68,37 | 22,30 | 2,39 | 2,14 | 1,77 | 4,22 | 0,09 | 0,27 | 0,115 | 0,09 | 0,01 | 0,007 | 0,05 | 0,000 | 0,004 | 0,005 |
| 27 | EV02 | L | 64,66 | 14,88 | 3,43 | 2,29 | 2,04 | 2,03 | 0,16 | 0,55 | 0,164 | 0,06 | 0,01 | 0,005 | 0,05 | 0,000 | 0,005 | 0,005 |
| 28 | EV02 | H | 64,10 | 20,88 | 2,81 | 3,52 | 2,11 | 3,18 | 0,12 | 0,40 | 0,141 | 0,06 | 0,01 | 0,006 | 0,06 | 0,004 | 0,005 | 0,006 |
| 29 | EV02 | H | 61,47 | 14,75 | 3,39 | 3,21 | 2,42 | 2,04 | 0,15 | 0,52 | 0,160 | 0,10 | 0,02 | 0,004 | 0,05 | 0,000 | 0,004 | 0,006 |
| 30 | EV02 | H | 70,03 | 20,39 | 4,06 | 4,21 | 3,21 | 2,48 | 0,31 | 0,63 | 0,159 | 0,04 | 0,02 | 0,005 | 0,07 | 0,000 | 0,005 | 0,006 |
| 31 | EV02 | H | 61,81 | 18,63 | 3,77 | 4,06 | 3,25 | 2,28 | 0,19 | 0,62 | 0,162 | 0,04 | 0,02 | 0,006 | 0,06 | 0,004 | 0,005 | 0,006 |
| 32 | EV02 | H | 57,50 | 17,58 | 3,86 | 4,02 | 2,42 | 2,78 | 0,18 | 0,63 | 0,147 | 0,04 | 0,02 | 0,008 | 0,06 | 0,000 | 0,005 | 0,006 |
| 33 | EV02 | I | 73,64 | 12,88 | 3,47 | 2,64 | 1,55 | 3,34 | 0,17 | 0,77 | 0,166 | 0,07 | 0,02 | 0,005 | 0,04 | 0,000 | 0,006 | 0,005 |
| 34 | EV02 | I | 69,07 | 17,42 | 6,18 | 8,62 | 2,24 | 2,26 | 0,24 | 0,44 | 0,062 | 0,04 | 0,02 | 0,032 | 0,15 | 0,009 | 0,025 | 0,017 |
| 35 | EV02 | K | 74,59 | 21,53 | 4,26 | 3,90 | 3,98 | 1,70 | 0,23 | 0,87 | 0,124 | 0,06 | 0,03 | 0,009 | 0,08 | 0,005 | 0,006 | 0,009 |
| 36 | EV02 | K | 61,51 | 19,50 | 4,30 | 3,53 | 2,49 | 5,04 | 0,29 | 0,83 | 0,183 | 0,02 | 0,03 | 0,005 | 0,05 | 0,000 | 0,003 | 0,007 |
| 37 | EV02 | K | 65,47 | 19,53 | 4,00 | 2,86 | 2,78 | 4,37 | 0,24 | 0,65 | 0,168 | 0,06 | 0,03 | 0,005 | 0,07 | 0,000 | 0,005 | 0,006 |
| 38 | EV02 | K | 67,33 | 21,21 | 4,08 | 3,25 | 2,34 | 1,95 | 0,11 | 0,59 | 0,096 | 0,04 | 0,01 | 0,010 | 0,08 | 0,006 | 0,008 | 0,009 |
| 39 | EV02 | K | 58,88 | 15,37 | 3,69 | 2,34 | 2,60 | 1,79 | 0,08 | 0,68 | 0,167 | 0,06 | 0,02 | 0,005 | 0,06 | 0,000 | 0,007 | 0,006 |
| 40 | EV02 | L | 51,80 | 15,71 | 3,83 | 3,59 | 1,95 | 2,78 | 0,14 | 0,56 | 0,121 | 0,05 | 0,01 | 0,006 | 0,07 | 0,000 | 0,005 | 0,005 |
| 41 | EV02 | L | 72,81 | 19,86 | 3,38 | 3,20 | 3,78 | 1,44 | 0,09 | 0,64 | 0,130 | 0,15 | 0,02 | 0,009 | 0,04 | 0,000 | 0,009 | 0,008 |
| 42 | EV02 | L | 67,72 | 22,43 | 3,38 | 3,46 | 4,09 | 2,44 | 0,15 | 0,61 | 0,173 | 0,06 | 0,02 | 0,005 | 0,06 | 0,000 | 0,004 | 0,005 |
| 43 | EV02 | L | 49,68 | 14,22 | 2,86 | 2,99 | 2,11 | 1,75 | 0,16 | 0,41 | 0,104 | 0,06 | 0,01 | 0,000 | 0,04 | 0,007 | 0,020 | 0,007 |
| 44 | EV02 | L | 68,00 | 22,11 | 3,56 | 3,42 | 3,93 | 2,21 | 0,20 | 0,65 | 0,193 | 0,03 | 0,02 | 0,005 | 0,07 | 0,000 | 0,004 | 0,006 |
| 45 | EV02 | F | 65,22 | 23,26 | 3,36 | 3,46 | 3,64 | 3,12 | 0,14 | 0,58 | 0,160 | 0,06 | 0,02 | 0,005 | 0,06 | 0,000 | 0,009 | 0,006 |

|    |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 46 | EV02 | F | 68,13 | 25,94 | 3,03 | 3,05 | 2,55 | 2,73 | 0,11 | 0,37 | 0,090 | 0,05 | 0,01 | 0,007 | 0,08 | 0,005 | 0,006 | 0,006 |
| 47 | EV02 | F | 72,84 | 20,87 | 3,49 | 3,30 | 2,78 | 2,07 | 0,15 | 0,66 | 0,131 | 0,06 | 0,02 | 0,008 | 0,08 | 0,006 | 0,009 | 0,007 |
| 48 | EV02 | F | 65,16 | 14,87 | 3,75 | 3,16 | 1,98 | 1,68 | 0,11 | 0,71 | 0,082 | 0,08 | 0,02 | 0,010 | 0,08 | 0,006 | 0,007 | 0,007 |
| 49 | EV02 | F | 75,38 | 19,97 | 4,88 | 3,54 | 2,87 | 2,44 | 0,24 | 0,81 | 0,104 | 0,09 | 0,03 | 0,008 | 0,08 | 0,000 | 0,034 | 0,011 |
| 50 | EV02 | G | 67,21 | 19,73 | 3,46 | 2,31 | 3,08 | 3,34 | 0,22 | 0,71 | 0,189 | 0,04 | 0,02 | 0,005 | 0,05 | 0,000 | 0,003 | 0,007 |
| 51 | EV02 | J | 68,95 | 16,73 | 3,03 | 2,05 | 2,48 | 1,48 | 0,09 | 0,66 | 0,080 | 0,04 | 0,02 | 0,008 | 0,05 | 0,000 | 0,006 | 0,007 |
| 52 | EV02 | G | 69,84 | 19,13 | 4,17 | 6,11 | 3,85 | 1,98 | 0,15 | 1,00 | 0,116 | 0,07 | 0,03 | 0,020 | 0,08 | 0,007 | 0,023 | 0,011 |
| 53 | EV02 | G | 54,13 | 16,27 | 3,69 | 2,42 | 2,67 | 3,57 | 0,24 | 0,50 | 0,171 | 0,10 | 0,02 | 0,000 | 0,04 | 0,000 | 0,012 | 0,005 |
| 54 | EV02 | M | 69,98 | 19,31 | 2,86 | 2,57 | 3,13 | 1,43 | 0,14 | 0,61 | 0,108 | 0,03 | 0,02 | 0,007 | 0,04 | 0,000 | 0,004 | 0,014 |
| 55 | EV02 | H | 56,68 | 16,13 | 4,23 | 4,25 | 2,24 | 2,21 | 0,17 | 0,62 | 0,135 | 0,03 | 0,01 | 0,006 | 0,07 | 0,005 | 0,005 | 0,007 |
| 56 | EV02 | H | 68,73 | 21,82 | 3,91 | 3,93 | 3,00 | 2,24 | 0,17 | 0,70 | 0,142 | 0,04 | 0,02 | 0,007 | 0,07 | 0,005 | 0,005 | 0,007 |
| 57 | EV02 | H | 66,89 | 22,89 | 4,12 | 2,73 | 2,88 | 2,71 | 0,20 | 0,78 | 0,150 | 0,05 | 0,02 | 0,000 | 0,05 | 0,004 | 0,006 | 0,005 |
| 58 | EV02 | H | 59,61 | 14,45 | 3,20 | 2,36 | 2,23 | 2,01 | 0,12 | 0,56 | 0,139 | 0,10 | 0,01 | 0,004 | 0,05 | 0,005 | 0,011 | 0,006 |
| 59 | EV02 | H | 68,33 | 21,24 | 3,94 | 2,23 | 2,68 | 1,83 | 0,18 | 0,71 | 0,151 | 0,04 | 0,02 | 0,000 | 0,04 | 0,000 | 0,005 | 0,005 |
| 60 | EV02 | L | 79,02 | 14,86 | 3,97 | 2,22 | 2,13 | 2,85 | 0,31 | 0,71 | 0,160 | 0,04 | 0,02 | 0,005 | 0,05 | 0,000 | 0,005 | 0,006 |
| 61 | EV02 | L | 65,90 | 19,66 | 4,44 | 3,07 | 1,89 | 4,05 | 0,23 | 0,85 | 0,170 | 0,04 | 0,02 | 0,006 | 0,06 | 0,000 | 0,006 | 0,006 |
| 62 | EV02 | L | 69,31 | 20,52 | 4,54 | 2,94 | 2,15 | 3,50 | 0,27 | 0,89 | 0,185 | 0,05 | 0,03 | 0,005 | 0,05 | 0,000 | 0,005 | 0,006 |
| 63 | EV02 | H | 63,41 | 19,29 | 4,12 | 2,23 | 2,30 | 2,82 | 0,18 | 0,91 | 0,205 | 0,04 | 0,03 | 0,006 | 0,06 | 0,000 | 0,006 | 0,005 |
| 64 | EV02 | L | 55,07 | 16,97 | 4,58 | 2,48 | 1,73 | 3,40 | 0,20 | 0,85 | 0,172 | 0,03 | 0,02 | 0,006 | 0,06 | 0,000 | 0,097 | 0,012 |
| 65 | EV02 | L | 70,21 | 21,31 | 3,79 | 3,54 | 3,10 | 2,23 | 0,24 | 0,62 | 0,187 | 0,04 | 0,02 | 0,004 | 0,08 | 0,000 | 0,005 | 0,007 |
| 66 | EV02 | H | 55,35 | 19,19 | 4,22 | 2,91 | 2,16 | 2,31 | 0,15 | 0,87 | 0,179 | 0,05 | 0,02 | 0,007 | 0,06 | 0,000 | 0,007 | 0,006 |
| 67 | EV02 | H | 67,68 | 20,99 | 4,23 | 4,35 | 3,02 | 2,51 | 0,21 | 0,67 | 0,172 | 0,05 | 0,02 | 0,005 | 0,08 | 0,005 | 0,006 | 0,007 |
| 68 | EV02 | L | 66,44 | 28,90 | 2,50 | 2,75 | 1,79 | 2,98 | 0,17 | 0,23 | 0,121 | 0,05 | 0,01 | 0,012 | 0,07 | 0,004 | 0,014 | 0,006 |
| 69 | EV02 | H | 48,46 | 14,64 | 3,27 | 2,81 | 1,98 | 2,13 | 0,18 | 0,50 | 0,144 | 0,04 | 0,01 | 0,000 | 0,05 | 0,000 | 0,005 | 0,004 |

|    |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 70 | EV02 | H | 69,47 | 21,46 | 3,83 | 3,52 | 3,12 | 2,16 | 0,22 | 0,64 | 0,206 | 0,03 | 0,02 | 0,005 | 0,08 | 0,005 | 0,004 | 0,007 |
| 71 | EV02 | H | 66,33 | 16,80 | 3,14 | 2,83 | 3,14 | 2,06 | 0,14 | 0,51 | 0,182 | 0,05 | 0,02 | 0,000 | 0,06 | 0,004 | 0,004 | 0,006 |
| 72 | EV02 | H | 69,82 | 19,03 | 3,85 | 3,08 | 2,50 | 2,07 | 0,15 | 0,55 | 0,208 | 0,03 | 0,02 | 0,006 | 0,07 | 0,005 | 0,005 | 0,007 |
| 73 | EV02 | L | 60,14 | 17,19 | 3,12 | 2,74 | 2,66 | 3,16 | 0,17 | 0,75 | 0,184 | 0,04 | 0,02 | 0,000 | 0,05 | 0,000 | 0,004 | 0,005 |
| 74 | EV02 | L | 70,65 | 19,99 | 4,01 | 3,13 | 2,58 | 2,39 | 0,16 | 0,72 | 0,227 | 0,03 | 0,02 | 0,000 | 0,08 | 0,005 | 0,005 | 0,006 |
| 75 | EV02 | L | 74,40 | 18,68 | 3,23 | 2,65 | 2,40 | 3,77 | 0,23 | 0,67 | 0,187 | 0,11 | 0,02 | 0,005 | 0,05 | 0,000 | 0,004 | 0,005 |
| 76 | EV02 | H | 65,98 | 19,86 | 3,65 | 3,28 | 2,68 | 2,41 | 0,25 | 0,61 | 0,182 | 0,03 | 0,02 | 0,005 | 0,06 | 0,000 | 0,005 | 0,006 |
| 77 | EV02 | H | 68,49 | 21,34 | 3,89 | 4,04 | 3,32 | 2,39 | 0,21 | 0,66 | 0,149 | 0,03 | 0,02 | 0,005 | 0,07 | 0,000 | 0,005 | 0,006 |
| 78 | EV02 | H | 63,37 | 14,41 | 3,21 | 2,75 | 2,40 | 1,69 | 0,12 | 0,57 | 0,145 | 0,06 | 0,01 | 0,000 | 0,05 | 0,000 | 0,004 | 0,005 |
| 79 | EV02 | H | 74,68 | 19,07 | 4,68 | 2,55 | 2,43 | 2,18 | 0,66 | 0,69 | 0,080 | 0,04 | 0,02 | 0,006 | 0,08 | 0,007 | 0,005 | 0,010 |
| 80 | EV02 | L | 65,39 | 19,49 | 4,08 | 2,52 | 3,06 | 4,63 | 0,83 | 0,81 | 0,200 | 0,16 | 0,03 | 0,004 | 0,06 | 0,000 | 0,006 | 0,006 |
| 81 | EV02 | L | 64,87 | 17,01 | 3,45 | 2,54 | 2,41 | 2,78 | 0,20 | 0,60 | 0,134 | 0,04 | 0,02 | 0,000 | 0,04 | 0,000 | 0,003 | 0,005 |
| 82 | EV02 | F | 76,64 | 29,12 | 2,18 | 2,33 | 3,45 | 1,71 | 0,16 | 0,24 | 0,044 | 0,08 | 0,01 | 0,007 | 0,04 | 0,004 | 0,008 | 0,006 |
| 83 | EV02 | H | 76,04 | 19,84 | 4,50 | 2,30 | 4,27 | 1,90 | 0,63 | 0,79 | 0,082 | 0,12 | 0,02 | 0,008 | 0,08 | 0,000 | 0,005 | 0,009 |
| 84 | EV02 | H | 60,83 | 17,26 | 3,42 | 2,53 | 2,20 | 2,70 | 0,14 | 0,58 | 0,143 | 0,04 | 0,02 | 0,000 | 0,06 | 0,000 | 0,005 | 0,005 |
| 85 | EV02 | H | 66,19 | 21,45 | 4,40 | 4,56 | 2,63 | 2,66 | 0,23 | 0,68 | 0,159 | 0,05 | 0,02 | 0,008 | 0,08 | 0,000 | 0,007 | 0,007 |
| 86 | EV02 | H | 60,14 | 15,67 | 3,55 | 3,27 | 2,44 | 2,63 | 0,16 | 0,60 | 0,177 | 0,04 | 0,02 | 0,007 | 0,06 | 0,000 | 0,004 | 0,005 |
| 87 | EV02 | H | 74,42 | 18,13 | 4,10 | 3,20 | 3,05 | 1,77 | 0,18 | 0,79 | 0,141 | 0,07 | 0,02 | 0,009 | 0,09 | 0,005 | 0,009 | 0,008 |
| 88 | EV02 | H | 72,40 | 27,75 | 2,74 | 2,69 | 1,93 | 3,32 | 0,15 | 0,29 | 0,114 | 0,05 | 0,01 | 0,007 | 0,07 | 0,004 | 0,007 | 0,006 |
| 89 | EV02 | L | 72,27 | 19,31 | 4,23 | 3,81 | 2,77 | 2,28 | 0,19 | 0,65 | 0,178 | 0,05 | 0,02 | 0,005 | 0,07 | 0,006 | 0,010 | 0,007 |
| 90 | EV02 | L | 60,29 | 19,65 | 4,46 | 2,45 | 2,89 | 3,72 | 0,34 | 0,83 | 0,170 | 0,02 | 0,03 | 0,006 | 0,05 | 0,000 | 0,005 | 0,005 |
| 91 | EV02 | H | 67,23 | 23,03 | 3,69 | 3,38 | 3,10 | 3,20 | 0,19 | 0,62 | 0,125 | 0,06 | 0,02 | 0,005 | 0,06 | 0,000 | 0,008 | 0,006 |
| 92 | EV02 | H | 67,53 | 20,98 | 3,73 | 3,41 | 3,21 | 2,31 | 0,18 | 0,62 | 0,173 | 0,02 | 0,02 | 0,005 | 0,07 | 0,000 | 0,004 | 0,006 |
| 93 | EV02 | L | 79,08 | 20,42 | 3,29 | 3,57 | 4,15 | 1,45 | 0,09 | 0,72 | 0,126 | 0,08 | 0,02 | 0,011 | 0,05 | 0,006 | 0,009 | 0,008 |

|     |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|-----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 94  | EV02 | L | 66,48 | 18,17 | 3,55 | 2,41 | 2,50 | 3,11 | 0,23 | 0,68 | 0,170 | 0,06 | 0,02 | 0,005 | 0,05 | 0,000 | 0,011 | 0,005 |
| 95  | EV02 | L | 56,96 | 17,12 | 4,39 | 3,25 | 1,75 | 4,88 | 0,16 | 0,79 | 0,190 | 0,04 | 0,03 | 0,006 | 0,06 | 0,000 | 0,009 | 0,006 |
| 96  | EV02 | L | 69,22 | 21,68 | 4,25 | 2,64 | 2,48 | 3,53 | 0,17 | 0,83 | 0,219 | 0,04 | 0,03 | 0,006 | 0,05 | 0,000 | 0,006 | 0,005 |
| 97  | EV02 | L | 67,05 | 16,54 | 3,77 | 3,09 | 2,09 | 5,11 | 0,24 | 0,76 | 0,204 | 0,02 | 0,02 | 0,000 | 0,05 | 0,000 | 0,007 | 0,005 |
| 98  | EV02 | H | 67,60 | 16,84 | 3,45 | 3,61 | 2,82 | 1,67 | 0,16 | 0,54 | 0,158 | 0,06 | 0,02 | 0,005 | 0,06 | 0,000 | 0,004 | 0,006 |
| 99  | EV02 | H | 68,54 | 19,12 | 3,89 | 2,81 | 2,75 | 2,30 | 0,19 | 0,64 | 0,160 | 0,06 | 0,02 | 0,005 | 0,06 | 0,007 | 0,004 | 0,009 |
| 100 | EV02 | I | 68,32 | 29,70 | 2,44 | 3,05 | 3,15 | 3,22 | 0,16 | 0,22 | 0,112 | 0,05 | 0,00 | 0,013 | 0,05 | 0,005 | 0,014 | 0,007 |
| 101 | EV01 | C | 59,21 | 19,81 | 4,16 | 5,62 | 1,42 | 5,85 | 0,13 | 0,49 | 0,080 | 0,03 | 0,02 | 0,007 | 0,05 | 0,005 | 0,008 | 0,012 |
| 102 | EV01 | E | 57,39 | 16,61 | 4,78 | 2,34 | 1,72 | 2,04 | 0,09 | 0,90 | 0,141 | 0,12 | 0,02 | 0,006 | 0,05 | 0,000 | 0,005 | 0,007 |
| 103 | EV01 | E | 68,98 | 18,16 | 4,39 | 3,48 | 2,23 | 1,93 | 0,08 | 0,61 | 0,128 | 0,05 | 0,02 | 0,012 | 0,09 | 0,005 | 0,008 | 0,010 |
| 104 | EV01 | E | 59,53 | 24,03 | 2,08 | 2,68 | 1,55 | 5,45 | 0,12 | 0,19 | 0,100 | 0,04 | 0,02 | 0,006 | 0,06 | 0,005 | 0,007 | 0,009 |
| 105 | EV01 | E | 64,27 | 18,91 | 3,48 | 3,59 | 3,08 | 2,87 | 0,19 | 0,56 | 0,179 | 0,05 | 0,02 | 0,000 | 0,05 | 0,000 | 0,008 | 0,009 |
| 106 | EV01 | A | 67,34 | 16,41 | 3,77 | 2,79 | 3,35 | 1,93 | 0,25 | 0,73 | 0,107 | 0,08 | 0,02 | 0,009 | 0,07 | 0,000 | 0,006 | 0,009 |
| 107 | EV01 | A | 55,46 | 17,54 | 4,90 | 2,86 | 1,94 | 2,90 | 0,10 | 0,75 | 0,173 | 0,07 | 0,02 | 0,008 | 0,05 | 0,000 | 0,007 | 0,007 |
| 108 | EV01 | A | 66,26 | 18,43 | 4,77 | 3,83 | 2,40 | 3,55 | 0,16 | 0,76 | 0,152 | 0,03 | 0,02 | 0,008 | 0,09 | 0,007 | 0,007 | 0,010 |
| 109 | EV01 | A | 55,52 | 18,94 | 3,36 | 2,43 | 2,40 | 2,33 | 0,18 | 0,52 | 0,165 | 0,07 | 0,02 | 0,000 | 0,04 | 0,000 | 0,003 | 0,007 |
| 110 | EV01 | B | 66,94 | 21,09 | 3,94 | 2,33 | 2,68 | 2,79 | 0,28 | 0,64 | 0,201 | 0,05 | 0,03 | 0,000 | 0,04 | 0,000 | 0,004 | 0,006 |
| 111 | EV01 | B | 64,35 | 21,47 | 4,60 | 4,15 | 2,52 | 3,81 | 0,53 | 0,77 | 0,185 | 0,09 | 0,03 | 0,000 | 0,05 | 0,000 | 0,006 | 0,006 |
| 112 | EV01 | B | 61,15 | 24,53 | 6,48 | 1,99 | 1,97 | 1,71 | 0,17 | 0,95 | 0,189 | 0,07 | 0,03 | 0,007 | 0,05 | 0,007 | 0,008 | 0,006 |
| 113 | EV01 | C | 55,72 | 18,81 | 5,05 | 3,09 | 1,97 | 2,67 | 0,11 | 0,72 | 0,172 | 0,06 | 0,02 | 0,007 | 0,05 | 0,000 | 0,008 | 0,006 |
| 114 | EV01 | C | 62,47 | 20,38 | 5,34 | 2,81 | 1,94 | 3,06 | 0,13 | 1,10 | 0,191 | 0,03 | 0,04 | 0,006 | 0,07 | 0,006 | 0,007 | 0,009 |
| 115 | EV01 | C | 61,51 | 21,43 | 3,81 | 2,40 | 2,60 | 2,96 | 0,22 | 0,91 | 0,177 | 0,06 | 0,02 | 0,000 | 0,05 | 0,000 | 0,003 | 0,007 |
| 116 | EV01 | C | 52,12 | 15,45 | 4,82 | 2,67 | 1,39 | 2,55 | 0,07 | 0,68 | 0,158 | 0,05 | 0,02 | 0,007 | 0,05 | 0,000 | 0,010 | 0,009 |
| 117 | EV01 | E | 65,14 | 17,92 | 4,00 | 4,38 | 1,81 | 2,01 | 0,12 | 0,66 | 0,088 | 0,04 | 0,02 | 0,008 | 0,07 | 0,007 | 0,009 | 0,009 |

|     |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|-----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 118 | EV01 | E | 59,67 | 19,08 | 4,52 | 2,55 | 1,92 | 2,20 | 0,20 | 0,63 | 0,147 | 0,07 | 0,02 | 0,005 | 0,04 | 0,000 | 0,008 | 0,010 |
| 119 | EV01 | E | 70,31 | 17,15 | 4,49 | 3,58 | 2,16 | 1,72 | 0,07 | 0,64 | 0,155 | 0,08 | 0,02 | 0,014 | 0,10 | 0,007 | 0,009 | 0,012 |
| 120 | EV01 | E | 60,15 | 19,47 | 5,03 | 2,93 | 2,33 | 2,63 | 0,11 | 1,13 | 0,205 | 0,05 | 0,04 | 0,005 | 0,07 | 0,000 | 0,007 | 0,007 |
| 121 | EV01 | E | 63,08 | 17,12 | 5,38 | 2,44 | 2,21 | 1,58 | 0,07 | 0,75 | 0,139 | 0,06 | 0,02 | 0,007 | 0,04 | 0,000 | 0,008 | 0,008 |
| 122 | EV01 | C | 62,91 | 25,31 | 3,73 | 2,20 | 2,78 | 2,40 | 0,20 | 0,72 | 0,147 | 0,05 | 0,02 | 0,005 | 0,05 | 0,006 | 0,005 | 0,015 |
| 123 | EV01 | C | 60,72 | 19,85 | 5,25 | 3,22 | 1,40 | 2,00 | 0,10 | 0,82 | 0,123 | 0,05 | 0,02 | 0,006 | 0,04 | 0,000 | 0,014 | 0,007 |
| 124 | EV01 | C | 67,11 | 17,20 | 4,14 | 3,85 | 2,16 | 1,55 | 0,08 | 0,75 | 0,082 | 0,04 | 0,02 | 0,011 | 0,07 | 0,005 | 0,014 | 0,012 |
| 125 | EV01 | E | 62,94 | 20,33 | 4,56 | 3,43 | 2,19 | 3,89 | 0,24 | 0,86 | 0,140 | 0,06 | 0,03 | 0,000 | 0,05 | 0,006 | 0,013 | 0,006 |
| 126 | EV01 | E | 55,75 | 20,90 | 5,56 | 2,58 | 2,34 | 2,02 | 0,11 | 0,94 | 0,198 | 0,05 | 0,03 | 0,005 | 0,05 | 0,006 | 0,015 | 0,008 |
| 127 | EV01 | E | 74,58 | 22,13 | 3,97 | 4,49 | 2,84 | 2,25 | 0,18 | 0,74 | 0,082 | 0,03 | 0,02 | 0,009 | 0,08 | 0,006 | 0,005 | 0,010 |
| 128 | EV01 | E | 66,72 | 26,13 | 3,30 | 3,04 | 2,47 | 2,79 | 0,19 | 0,45 | 0,059 | 0,03 | 0,01 | 0,014 | 0,08 | 0,006 | 0,011 | 0,009 |
| 129 | EV01 | E | 77,24 | 19,02 | 5,07 | 2,49 | 0,47 | 1,41 | 0,05 | 0,80 | 0,018 | 0,05 | 0,03 | 0,018 | 0,03 | 0,006 | 0,032 | 0,017 |
| 130 | EV01 | C | 69,06 | 24,88 | 4,60 | 1,84 | 2,55 | 2,33 | 0,29 | 0,82 | 0,148 | 0,06 | 0,03 | 0,005 | 0,04 | 0,000 | 0,026 | 0,008 |
| 131 | EV01 | C | 63,56 | 25,35 | 5,47 | 2,58 | 2,59 | 2,54 | 0,13 | 1,08 | 0,161 | 0,04 | 0,04 | 0,006 | 0,05 | 0,000 | 0,010 | 0,007 |
| 132 | EV01 | C | 64,86 | 25,21 | 3,50 | 2,31 | 3,06 | 2,52 | 0,23 | 0,72 | 0,139 | 0,05 | 0,02 | 0,000 | 0,05 | 0,000 | 0,007 | 0,006 |
| 133 | EV01 | C | 70,32 | 31,06 | 2,41 | 2,78 | 3,10 | 3,53 | 0,18 | 0,33 | 0,076 | 0,07 | 0,01 | 0,009 | 0,04 | 0,000 | 0,010 | 0,009 |
| 134 | EV01 | C | 71,34 | 26,21 | 5,06 | 2,73 | 3,04 | 2,24 | 0,12 | 1,16 | 0,195 | 0,06 | 0,04 | 0,006 | 0,05 | 0,000 | 0,011 | 0,007 |
| 135 | EV01 | C | 53,91 | 19,92 | 6,15 | 4,68 | 1,53 | 4,69 | 0,21 | 0,78 | 0,162 | 0,03 | 0,03 | 0,005 | 0,05 | 0,000 | 0,006 | 0,011 |
| 136 | EV01 | C | 60,32 | 18,02 | 5,68 | 3,24 | 1,64 | 3,11 | 0,09 | 1,05 | 0,142 | 0,03 | 0,03 | 0,008 | 0,06 | 0,000 | 0,006 | 0,007 |
| 137 | EV01 | C | 59,75 | 19,02 | 4,97 | 3,40 | 1,98 | 2,70 | 0,08 | 0,87 | 0,146 | 0,04 | 0,02 | 0,006 | 0,05 | 0,000 | 0,008 | 0,006 |
| 138 | EV01 | C | 61,63 | 22,72 | 3,34 | 2,79 | 3,05 | 2,31 | 0,24 | 0,59 | 0,154 | 0,04 | 0,02 | 0,000 | 0,04 | 0,000 | 0,007 | 0,009 |
| 139 | EV01 | D | 52,80 | 18,22 | 5,62 | 5,76 | 1,17 | 2,92 | 0,12 | 0,49 | 0,043 | 0,04 | 0,02 | 0,030 | 0,11 | 0,008 | 0,021 | 0,013 |
| 140 | EV01 | B | 74,59 | 23,93 | 4,69 | 5,05 | 2,37 | 2,57 | 0,14 | 0,80 | 0,088 | 0,03 | 0,03 | 0,006 | 0,09 | 0,007 | 0,007 | 0,011 |
| 141 | EV01 | A | 63,32 | 22,56 | 3,35 | 2,24 | 2,90 | 2,68 | 0,22 | 0,56 | 0,169 | 0,06 | 0,02 | 0,000 | 0,04 | 0,000 | 0,004 | 0,012 |

|     |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|-----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 142 | EV01 | A | 71,37 | 28,03 | 3,15 | 4,06 | 1,79 | 3,94 | 0,11 | 0,37 | 0,091 | 0,04 | 0,02 | 0,010 | 0,06 | 0,005 | 0,005 | 0,009 |
| 143 | EV01 | A | 75,42 | 21,46 | 3,84 | 4,79 | 2,69 | 1,94 | 0,09 | 0,76 | 0,091 | 0,04 | 0,02 | 0,010 | 0,07 | 0,004 | 0,008 | 0,008 |
| 144 | EV01 | E | 57,66 | 17,89 | 4,89 | 3,84 | 1,84 | 3,13 | 0,12 | 0,80 | 0,160 | 0,04 | 0,02 | 0,006 | 0,05 | 0,000 | 0,004 | 0,006 |
| 145 | EV01 | E | 48,46 | 14,91 | 4,61 | 5,62 | 1,34 | 3,71 | 0,14 | 0,83 | 0,149 | 0,07 | 0,03 | 0,005 | 0,06 | 0,000 | 0,006 | 0,006 |
| 146 | EV01 | E | 69,11 | 27,60 | 3,46 | 2,17 | 1,68 | 2,43 | 0,22 | 0,45 | 0,089 | 0,09 | 0,01 | 0,007 | 0,06 | 0,000 | 0,010 | 0,010 |
| 147 | EV01 | E | 71,96 | 29,13 | 2,56 | 3,27 | 1,99 | 3,79 | 0,29 | 0,24 | 0,068 | 0,09 | 0,01 | 0,014 | 0,09 | 0,005 | 0,012 | 0,008 |
| 148 | EV01 | E | 57,72 | 21,40 | 4,83 | 2,02 | 3,04 | 2,20 | 0,16 | 0,75 | 0,193 | 0,04 | 0,02 | 0,006 | 0,04 | 0,000 | 0,004 | 0,006 |
| 149 | EV01 | E | 61,80 | 23,20 | 3,55 | 2,03 | 2,50 | 2,39 | 0,18 | 0,62 | 0,145 | 0,05 | 0,02 | 0,000 | 0,04 | 0,000 | 0,005 | 0,007 |
| 150 | EV01 | C | 62,22 | 19,93 | 3,95 | 3,51 | 3,03 | 1,59 | 0,13 | 0,74 | 0,138 | 0,05 | 0,02 | 0,008 | 0,06 | 0,000 | 0,005 | 0,007 |
| 151 | EV01 | C | 63,94 | 25,66 | 3,67 | 2,08 | 2,69 | 2,43 | 0,22 | 0,91 | 0,136 | 0,05 | 0,03 | 0,004 | 0,05 | 0,000 | 0,011 | 0,006 |
| 152 | EV01 | C | 68,28 | 19,33 | 3,84 | 3,56 | 2,48 | 2,16 | 0,17 | 0,73 | 0,117 | 0,04 | 0,02 | 0,008 | 0,09 | 0,006 | 0,020 | 0,008 |
| 153 | EV01 | C | 73,14 | 16,96 | 2,79 | 2,45 | 2,08 | 1,83 | 0,12 | 0,56 | 0,095 | 0,04 | 0,02 | 0,009 | 0,05 | 0,006 | 0,008 | 0,008 |
| 154 | EV01 | C | 62,98 | 21,84 | 5,91 | 4,99 | 1,75 | 3,21 | 0,20 | 0,96 | 0,162 | 0,04 | 0,03 | 0,008 | 0,05 | 0,000 | 0,012 | 0,008 |
| 155 | EV01 | C | 72,43 | 20,67 | 2,92 | 2,30 | 1,68 | 2,59 | 0,09 | 0,33 | 0,060 | 0,04 | 0,01 | 0,010 | 0,07 | 0,005 | 0,015 | 0,008 |
| 156 | EV01 | C | 55,04 | 24,43 | 2,10 | 2,57 | 1,01 | 3,49 | 0,06 | 0,34 | 0,052 | 0,05 | 0,01 | 0,005 | 0,04 | 0,000 | 0,004 | 0,008 |
| 157 | EV01 | B | 47,53 | 17,42 | 7,39 | 2,28 | 2,39 | 2,00 | 0,18 | 0,72 | 0,149 | 0,05 | 0,02 | 0,008 | 0,05 | 0,000 | 0,006 | 0,008 |
| 158 | EV01 | C | 62,94 | 20,58 | 4,53 | 2,09 | 2,32 | 2,77 | 0,19 | 0,76 | 0,157 | 0,05 | 0,02 | 0,004 | 0,05 | 0,000 | 0,007 | 0,006 |
| 159 | EV01 | E | 63,57 | 19,33 | 3,89 | 4,43 | 2,99 | 2,52 | 0,21 | 0,68 | 0,175 | 0,04 | 0,02 | 0,005 | 0,06 | 0,000 | 0,005 | 0,006 |
| 160 | EV01 | E | 62,99 | 23,34 | 4,79 | 1,98 | 2,95 | 4,03 | 0,23 | 0,80 | 0,167 | 0,06 | 0,03 | 0,006 | 0,05 | 0,000 | 0,021 | 0,007 |
| 161 | EV01 | E | 63,90 | 25,30 | 2,66 | 2,42 | 1,73 | 2,33 | 0,08 | 0,25 | 0,085 | 0,04 | 0,00 | 0,007 | 0,06 | 0,005 | 0,014 | 0,007 |
| 162 | EV01 | E | 63,20 | 21,99 | 3,17 | 2,04 | 2,97 | 1,95 | 0,15 | 0,54 | 0,126 | 0,05 | 0,02 | 0,000 | 0,03 | 0,000 | 0,008 | 0,006 |
| 163 | EV01 | E | 61,76 | 18,84 | 2,59 | 2,68 | 2,51 | 4,37 | 0,18 | 0,36 | 0,115 | 0,06 | 0,01 | 0,004 | 0,04 | 0,000 | 0,008 | 0,006 |
| 164 | EV01 | E | 63,63 | 18,41 | 4,53 | 3,12 | 2,20 | 1,63 | 0,18 | 0,75 | 0,091 | 0,04 | 0,02 | 0,011 | 0,08 | 0,007 | 0,007 | 0,009 |
| 165 | EV01 | E | 68,03 | 25,23 | 3,79 | 1,58 | 2,31 | 1,98 | 0,15 | 1,16 | 0,151 | 0,06 | 0,03 | 0,004 | 0,05 | 0,000 | 0,007 | 0,008 |

|     |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|-----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 166 | EV01 | E | 60,16 | 23,29 | 6,69 | 2,02 | 1,56 | 1,80 | 0,19 | 1,00 | 0,156 | 0,08 | 0,03 | 0,007 | 0,05 | 0,000 | 0,007 | 0,007 |
| 167 | EV01 | A | 62,40 | 22,30 | 2,56 | 2,46 | 1,97 | 3,06 | 0,35 | 0,18 | 0,079 | 0,07 | 0,01 | 0,011 | 0,08 | 0,005 | 0,008 | 0,008 |
| 168 | EV01 | C | 69,25 | 24,95 | 3,72 | 1,84 | 2,10 | 2,21 | 0,31 | 0,52 | 0,098 | 0,10 | 0,02 | 0,007 | 0,05 | 0,005 | 0,012 | 0,008 |
| 169 | EV01 | C | 64,86 | 25,28 | 3,64 | 2,00 | 2,44 | 2,53 | 0,26 | 0,59 | 0,138 | 0,05 | 0,02 | 0,000 | 0,03 | 0,000 | 0,003 | 0,006 |
| 170 | EV01 | C | 53,00 | 18,63 | 5,16 | 1,91 | 2,06 | 1,79 | 0,22 | 0,76 | 0,163 | 0,09 | 0,02 | 0,005 | 0,05 | 0,000 | 0,005 | 0,007 |
| 171 | EV01 | C | 66,36 | 29,10 | 4,04 | 1,98 | 2,98 | 2,19 | 0,24 | 0,74 | 0,170 | 0,06 | 0,03 | 0,005 | 0,04 | 0,005 | 0,003 | 0,007 |
| 172 | EV01 | C | 65,75 | 17,77 | 6,56 | 3,73 | 1,82 | 3,13 | 0,26 | 0,94 | 0,072 | 0,12 | 0,03 | 0,016 | 0,12 | 0,009 | 0,017 | 0,015 |
| 173 | EV01 | C | 62,91 | 24,45 | 3,65 | 2,44 | 2,50 | 2,07 | 0,12 | 0,71 | 0,169 | 0,03 | 0,02 | 0,005 | 0,04 | 0,000 | 0,003 | 0,005 |
| 174 | EV01 | E | 64,43 | 18,78 | 3,81 | 2,05 | 2,48 | 2,40 | 0,11 | 0,72 | 0,149 | 0,05 | 0,02 | 0,005 | 0,05 | 0,000 | 0,015 | 0,007 |
| 175 | EV01 | E | 63,24 | 19,40 | 3,81 | 2,20 | 2,19 | 3,24 | 0,22 | 0,75 | 0,234 | 0,13 | 0,03 | 0,007 | 0,05 | 0,000 | 0,018 | 0,007 |
| 176 | EV01 | E | 65,37 | 20,96 | 4,55 | 3,53 | 3,16 | 3,08 | 0,37 | 0,93 | 0,160 | 0,11 | 0,02 | 0,006 | 0,08 | 0,005 | 0,011 | 0,008 |
| 177 | EV01 | E | 58,83 | 19,76 | 5,09 | 2,41 | 1,69 | 1,97 | 0,08 | 0,87 | 0,131 | 0,04 | 0,02 | 0,006 | 0,04 | 0,000 | 0,020 | 0,007 |
| 178 | EV01 | E | 64,52 | 17,34 | 4,16 | 2,25 | 1,86 | 3,66 | 0,26 | 0,74 | 0,140 | 0,07 | 0,02 | 0,005 | 0,04 | 0,000 | 0,020 | 0,008 |
| 179 | EV01 | E | 69,05 | 22,59 | 2,96 | 2,73 | 1,69 | 3,54 | 0,32 | 0,46 | 0,125 | 0,07 | 0,02 | 0,010 | 0,08 | 0,006 | 0,010 | 0,007 |
| 180 | EV01 | C | 63,80 | 18,43 | 6,34 | 3,74 | 2,04 | 3,03 | 0,34 | 0,95 | 0,078 | 0,07 | 0,03 | 0,017 | 0,12 | 0,007 | 0,016 | 0,014 |
| 181 | EV01 | C | 64,35 | 14,20 | 2,45 | 1,89 | 2,34 | 1,55 | 0,07 | 0,76 | 0,154 | 0,05 | 0,01 | 0,005 | 0,04 | 0,000 | 0,009 | 0,006 |
| 182 | EV01 | C | 56,05 | 16,19 | 3,89 | 1,85 | 2,01 | 2,72 | 0,38 | 0,61 | 0,138 | 0,05 | 0,02 | 0,005 | 0,04 | 0,005 | 0,016 | 0,006 |
| 183 | EV01 | C | 67,79 | 17,13 | 3,92 | 4,63 | 2,36 | 1,91 | 0,18 | 0,70 | 0,078 | 0,06 | 0,02 | 0,014 | 0,07 | 0,007 | 0,017 | 0,010 |
| 184 | EV01 | C | 69,31 | 19,64 | 5,03 | 2,73 | 2,05 | 2,74 | 0,19 | 0,83 | 0,162 | 0,29 | 0,03 | 0,006 | 0,05 | 0,006 | 0,009 | 0,008 |
| 185 | EV01 | E | 70,61 | 25,77 | 2,92 | 2,79 | 1,67 | 3,94 | 0,32 | 0,30 | 0,098 | 0,10 | 0,01 | 0,010 | 0,08 | 0,005 | 0,013 | 0,008 |
| 186 | EV01 | E | 62,84 | 13,54 | 4,80 | 3,88 | 1,45 | 3,59 | 0,30 | 0,48 | 0,082 | 0,13 | 0,01 | 0,019 | 0,07 | 0,000 | 0,017 | 0,008 |
| 187 | EV01 | E | 69,65 | 14,33 | 4,58 | 3,89 | 1,60 | 2,88 | 0,37 | 0,51 | 0,084 | 0,06 | 0,02 | 0,019 | 0,06 | 0,007 | 0,017 | 0,008 |
| 188 | EV01 | E | 67,50 | 19,21 | 4,86 | 4,69 | 3,18 | 1,90 | 0,20 | 0,79 | 0,100 | 0,20 | 0,02 | 0,019 | 0,09 | 0,006 | 0,012 | 0,007 |
| 189 | EV01 | E | 60,86 | 17,85 | 3,97 | 3,63 | 3,59 | 2,78 | 0,33 | 0,57 | 0,139 | 0,12 | 0,02 | 0,000 | 0,06 | 0,000 | 0,006 | 0,007 |

|     |      |   |       |       |      |      |      |      |      |      |       |      |      |       |      |       |       |       |
|-----|------|---|-------|-------|------|------|------|------|------|------|-------|------|------|-------|------|-------|-------|-------|
| 190 | EV01 | E | 55,28 | 17,95 | 4,76 | 4,70 | 2,42 | 3,89 | 0,22 | 0,77 | 0,161 | 0,06 | 0,03 | 0,006 | 0,05 | 0,000 | 0,008 | 0,006 |
| 191 | EV01 | E | 71,39 | 28,65 | 2,71 | 2,47 | 2,03 | 2,90 | 0,07 | 0,27 | 0,111 | 0,05 | 0,01 | 0,007 | 0,07 | 0,005 | 0,010 | 0,007 |
| 192 | EV01 | E | 62,48 | 22,76 | 2,69 | 2,87 | 1,51 | 2,73 | 0,09 | 0,35 | 0,095 | 0,04 | 0,01 | 0,008 | 0,05 | 0,004 | 0,008 | 0,007 |
| 193 | EV01 | E | 63,14 | 20,25 | 5,42 | 2,87 | 2,08 | 1,85 | 0,09 | 0,95 | 0,179 | 0,04 | 0,03 | 0,005 | 0,05 | 0,000 | 0,022 | 0,007 |
| 194 | EV01 | E | 72,73 | 30,41 | 2,84 | 3,24 | 1,39 | 3,34 | 0,15 | 0,25 | 0,087 | 0,03 | 0,00 | 0,015 | 0,10 | 0,005 | 0,013 | 0,008 |
| 195 | EV01 | B | 62,68 | 21,26 | 6,11 | 2,21 | 1,70 | 2,13 | 0,18 | 0,85 | 0,137 | 0,04 | 0,03 | 0,005 | 0,05 | 0,000 | 0,012 | 0,006 |
| 196 | EV01 | B | 64,96 | 22,34 | 4,93 | 3,14 | 2,51 | 1,65 | 0,18 | 0,79 | 0,177 | 0,06 | 0,02 | 0,005 | 0,05 | 0,008 | 0,007 | 0,007 |
| 197 | EV01 | C | 59,33 | 19,11 | 4,40 | 3,06 | 3,20 | 2,90 | 0,15 | 0,69 | 0,189 | 0,08 | 0,02 | 0,005 | 0,04 | 0,000 | 0,007 | 0,005 |
| 198 | EV01 | C | 60,21 | 15,29 | 5,32 | 2,66 | 1,69 | 3,59 | 0,19 | 1,26 | 0,093 | 0,05 | 0,03 | 0,008 | 0,10 | 0,007 | 0,009 | 0,014 |
| 199 | EV01 | C | 69,94 | 26,87 | 3,55 | 2,43 | 2,74 | 1,88 | 0,11 | 0,56 | 0,178 | 0,04 | 0,02 | 0,006 | 0,04 | 0,004 | 0,005 | 0,007 |
| 200 | EV01 | C | 59,39 | 20,82 | 3,77 | 5,33 | 1,08 | 6,22 | 0,11 | 0,46 | 0,079 | 0,03 | 0,02 | 0,007 | 0,05 | 0,005 | 0,006 | 0,007 |

**Table 2: pXRF data in percentage (trace elements)**

| Sample | Site | Macro-<br>scopic<br>Fabric<br>Group | Zn    | Ga    | As    | Rb    | Sr    | Y     | Zr    | Nb    | La    | Ce    | Ta    | Hg    | Pb    | Th    | Pd    |
|--------|------|-------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1      | EV02 | F                                   | 0,006 | 0,001 | 0,000 | 0,005 | 0,020 | 0,001 | 0,001 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,000 | 0,002 |
| 2      | EV02 | H                                   | 0,009 | 0,001 | 0,000 | 0,009 | 0,030 | 0,002 | 0,024 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,003 | 0,002 |
| 3      | EV02 | H                                   | 0,008 | 0,001 | 0,001 | 0,005 | 0,023 | 0,001 | 0,009 | 0,001 | 0,000 | 0,000 | 0,000 | 0,001 | 0,001 | 0,001 | 0,002 |
| 4      | EV02 | H                                   | 0,010 | 0,001 | 0,000 | 0,006 | 0,020 | 0,001 | 0,009 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,001 |
| 5      | EV02 | H                                   | 0,010 | 0,001 | 0,000 | 0,006 | 0,019 | 0,002 | 0,009 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,000 |
| 6      | EV02 | H                                   | 0,011 | 0,001 | 0,000 | 0,007 | 0,035 | 0,002 | 0,021 | 0,001 | 0,016 | 0,026 | 0,003 | 0,001 | 0,001 | 0,003 | 0,001 |
| 7      | EV02 | L                                   | 0,010 | 0,001 | 0,001 | 0,007 | 0,037 | 0,002 | 0,028 | 0,001 | 0,021 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 8      | EV02 | H                                   | 0,006 | 0,001 | 0,000 | 0,005 | 0,031 | 0,001 | 0,006 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 9      | EV02 | H                                   | 0,011 | 0,002 | 0,000 | 0,008 | 0,041 | 0,003 | 0,019 | 0,001 | 0,016 | 0,024 | 0,003 | 0,001 | 0,002 | 0,003 | 0,000 |
| 10     | EV02 | L                                   | 0,010 | 0,001 | 0,001 | 0,005 | 0,063 | 0,002 | 0,064 | 0,001 | 0,023 | 0,024 | 0,002 | 0,001 | 0,001 | 0,002 | 0,001 |
| 11     | EV02 | F                                   | 0,006 | 0,001 | 0,000 | 0,005 | 0,019 | 0,001 | 0,002 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 12     | EV02 | F                                   | 0,008 | 0,001 | 0,000 | 0,010 | 0,027 | 0,003 | 0,024 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,001 |
| 13     | EV02 | L                                   | 0,009 | 0,001 | 0,000 | 0,008 | 0,036 | 0,003 | 0,030 | 0,001 | 0,000 | 0,023 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 14     | EV02 | L                                   | 0,007 | 0,001 | 0,000 | 0,006 | 0,035 | 0,002 | 0,036 | 0,001 | 0,000 | 0,020 | 0,002 | 0,001 | 0,001 | 0,002 | 0,001 |
| 15     | EV02 | L                                   | 0,010 | 0,001 | 0,000 | 0,008 | 0,038 | 0,003 | 0,020 | 0,001 | 0,016 | 0,023 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |
| 16     | EV02 | L                                   | 0,006 | 0,001 | 0,000 | 0,006 | 0,044 | 0,002 | 0,062 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 17     | EV02 | L                                   | 0,011 | 0,001 | 0,000 | 0,007 | 0,038 | 0,002 | 0,031 | 0,001 | 0,015 | 0,019 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 18     | EV02 | H                                   | 0,007 | 0,001 | 0,000 | 0,007 | 0,026 | 0,002 | 0,017 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 19     | EV02 | H                                   | 0,007 | 0,001 | 0,000 | 0,006 | 0,046 | 0,002 | 0,042 | 0,001 | 0,000 | 0,022 | 0,003 | 0,001 | 0,001 | 0,000 | 0,000 |
| 20     | EV02 | H                                   | 0,010 | 0,001 | 0,000 | 0,007 | 0,038 | 0,003 | 0,034 | 0,001 | 0,018 | 0,029 | 0,003 | 0,000 | 0,001 | 0,003 | 0,002 |
| 21     | EV02 | H                                   | 0,006 | 0,001 | 0,000 | 0,003 | 0,032 | 0,002 | 0,038 | 0,001 | 0,000 | 0,000 | 0,002 | 0,000 | 0,001 | 0,001 | 0,001 |
| 22     | EV02 | H                                   | 0,007 | 0,001 | 0,000 | 0,006 | 0,033 | 0,002 | 0,042 | 0,001 | 0,000 | 0,027 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 23     | EV02 | L                                   | 0,010 | 0,001 | 0,001 | 0,008 | 0,040 | 0,002 | 0,025 | 0,001 | 0,000 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 24     | EV02 | L                                   | 0,006 | 0,001 | 0,000 | 0,006 | 0,040 | 0,002 | 0,040 | 0,001 | 0,019 | 0,019 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |

|    |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 25 | EV02 | L | 0,006 | 0,001 | 0,000 | 0,005 | 0,028 | 0,001 | 0,007 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 26 | EV02 | L | 0,005 | 0,001 | 0,000 | 0,004 | 0,024 | 0,001 | 0,002 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,003 |
| 27 | EV02 | L | 0,007 | 0,001 | 0,000 | 0,005 | 0,039 | 0,002 | 0,039 | 0,001 | 0,018 | 0,024 | 0,003 | 0,001 | 0,001 | 0,002 | 0,002 |
| 28 | EV02 | H | 0,007 | 0,001 | 0,000 | 0,005 | 0,032 | 0,001 | 0,023 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 29 | EV02 | H | 0,009 | 0,001 | 0,000 | 0,007 | 0,039 | 0,002 | 0,039 | 0,001 | 0,000 | 0,022 | 0,002 | 0,000 | 0,001 | 0,002 | 0,000 |
| 30 | EV02 | H | 0,011 | 0,001 | 0,000 | 0,007 | 0,035 | 0,003 | 0,022 | 0,001 | 0,017 | 0,024 | 0,003 | 0,001 | 0,002 | 0,003 | 0,000 |
| 31 | EV02 | H | 0,009 | 0,001 | 0,000 | 0,008 | 0,042 | 0,002 | 0,025 | 0,001 | 0,016 | 0,022 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 32 | EV02 | H | 0,009 | 0,001 | 0,000 | 0,006 | 0,044 | 0,002 | 0,048 | 0,001 | 0,000 | 0,020 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 33 | EV02 | I | 0,007 | 0,001 | 0,000 | 0,004 | 0,036 | 0,002 | 0,041 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 34 | EV02 | I | 0,011 | 0,001 | 0,000 | 0,008 | 0,015 | 0,002 | 0,005 | 0,000 | 0,015 | 0,029 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 35 | EV02 | K | 0,010 | 0,001 | 0,000 | 0,011 | 0,026 | 0,002 | 0,015 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,000 |
| 36 | EV02 | K | 0,008 | 0,001 | 0,000 | 0,005 | 0,052 | 0,002 | 0,050 | 0,001 | 0,017 | 0,027 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 37 | EV02 | K | 0,007 | 0,001 | 0,000 | 0,006 | 0,041 | 0,002 | 0,049 | 0,001 | 0,000 | 0,021 | 0,002 | 0,001 | 0,001 | 0,003 | 0,000 |
| 38 | EV02 | K | 0,008 | 0,001 | 0,000 | 0,007 | 0,023 | 0,002 | 0,016 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 39 | EV02 | K | 0,008 | 0,001 | 0,000 | 0,007 | 0,039 | 0,002 | 0,036 | 0,001 | 0,000 | 0,034 | 0,003 | 0,001 | 0,002 | 0,001 | 0,002 |
| 40 | EV02 | L | 0,010 | 0,001 | 0,001 | 0,007 | 0,041 | 0,002 | 0,050 | 0,001 | 0,000 | 0,021 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 41 | EV02 | L | 0,007 | 0,001 | 0,000 | 0,010 | 0,024 | 0,002 | 0,018 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,000 |
| 42 | EV02 | L | 0,009 | 0,001 | 0,000 | 0,009 | 0,039 | 0,002 | 0,024 | 0,001 | 0,000 | 0,022 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 43 | EV02 | L | 0,010 | 0,001 | 0,000 | 0,007 | 0,027 | 0,003 | 0,018 | 0,001 | 0,000 | 0,019 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 44 | EV02 | L | 0,009 | 0,001 | 0,000 | 0,009 | 0,044 | 0,002 | 0,019 | 0,001 | 0,015 | 0,028 | 0,003 | 0,001 | 0,001 | 0,004 | 0,001 |
| 45 | EV02 | F | 0,008 | 0,001 | 0,000 | 0,008 | 0,042 | 0,002 | 0,020 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 46 | EV02 | F | 0,007 | 0,001 | 0,000 | 0,006 | 0,025 | 0,002 | 0,009 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 47 | EV02 | F | 0,008 | 0,001 | 0,000 | 0,009 | 0,030 | 0,002 | 0,020 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,001 |
| 48 | EV02 | F | 0,006 | 0,001 | 0,000 | 0,009 | 0,024 | 0,002 | 0,017 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,001 |
| 49 | EV02 | F | 0,010 | 0,001 | 0,000 | 0,008 | 0,028 | 0,003 | 0,013 | 0,001 | 0,014 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 50 | EV02 | G | 0,007 | 0,001 | 0,000 | 0,006 | 0,039 | 0,002 | 0,051 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |
| 51 | EV02 | J | 0,006 | 0,001 | 0,000 | 0,010 | 0,021 | 0,002 | 0,030 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,001 |
| 52 | EV02 | G | 0,008 | 0,001 | 0,000 | 0,009 | 0,035 | 0,002 | 0,020 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |

|    |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 53 | EV02 | G | 0,008 | 0,001 | 0,001 | 0,006 | 0,053 | 0,002 | 0,042 | 0,001 | 0,000 | 0,022 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 54 | EV02 | M | 0,006 | 0,001 | 0,000 | 0,009 | 0,024 | 0,002 | 0,031 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |
| 55 | EV02 | H | 0,011 | 0,001 | 0,000 | 0,007 | 0,034 | 0,003 | 0,025 | 0,001 | 0,000 | 0,021 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 56 | EV02 | H | 0,010 | 0,001 | 0,000 | 0,007 | 0,034 | 0,002 | 0,023 | 0,001 | 0,000 | 0,022 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 57 | EV02 | H | 0,008 | 0,001 | 0,000 | 0,007 | 0,031 | 0,002 | 0,040 | 0,001 | 0,000 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,002 |
| 58 | EV02 | H | 0,007 | 0,001 | 0,000 | 0,006 | 0,033 | 0,002 | 0,046 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 59 | EV02 | H | 0,007 | 0,002 | 0,000 | 0,006 | 0,027 | 0,002 | 0,043 | 0,001 | 0,000 | 0,025 | 0,003 | 0,000 | 0,001 | 0,003 | 0,001 |
| 60 | EV02 | L | 0,007 | 0,001 | 0,000 | 0,004 | 0,035 | 0,002 | 0,037 | 0,001 | 0,021 | 0,028 | 0,003 | 0,001 | 0,001 | 0,001 | 0,001 |
| 61 | EV02 | L | 0,008 | 0,001 | 0,000 | 0,004 | 0,045 | 0,002 | 0,041 | 0,001 | 0,017 | 0,024 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 62 | EV02 | L | 0,009 | 0,001 | 0,000 | 0,004 | 0,043 | 0,002 | 0,038 | 0,001 | 0,018 | 0,023 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 63 | EV02 | H | 0,008 | 0,001 | 0,000 | 0,005 | 0,044 | 0,002 | 0,067 | 0,001 | 0,000 | 0,025 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 64 | EV02 | L | 0,008 | 0,001 | 0,000 | 0,004 | 0,053 | 0,003 | 0,055 | 0,001 | 0,022 | 0,026 | 0,003 | 0,001 | 0,001 | 0,001 | 0,001 |
| 65 | EV02 | L | 0,011 | 0,001 | 0,000 | 0,008 | 0,037 | 0,002 | 0,022 | 0,001 | 0,017 | 0,021 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |
| 66 | EV02 | H | 0,009 | 0,002 | 0,000 | 0,006 | 0,050 | 0,002 | 0,051 | 0,001 | 0,017 | 0,000 | 0,004 | 0,001 | 0,001 | 0,003 | 0,000 |
| 67 | EV02 | H | 0,012 | 0,002 | 0,000 | 0,008 | 0,037 | 0,003 | 0,026 | 0,001 | 0,018 | 0,025 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 68 | EV02 | L | 0,005 | 0,001 | 0,000 | 0,003 | 0,024 | 0,001 | 0,004 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 69 | EV02 | H | 0,009 | 0,001 | 0,000 | 0,007 | 0,044 | 0,002 | 0,049 | 0,001 | 0,016 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 70 | EV02 | H | 0,011 | 0,001 | 0,000 | 0,008 | 0,037 | 0,002 | 0,024 | 0,001 | 0,018 | 0,022 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 71 | EV02 | H | 0,008 | 0,001 | 0,000 | 0,007 | 0,037 | 0,002 | 0,024 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 72 | EV02 | H | 0,011 | 0,001 | 0,000 | 0,007 | 0,037 | 0,002 | 0,022 | 0,001 | 0,020 | 0,030 | 0,003 | 0,001 | 0,002 | 0,003 | 0,002 |
| 73 | EV02 | L | 0,006 | 0,001 | 0,000 | 0,006 | 0,047 | 0,003 | 0,062 | 0,001 | 0,015 | 0,021 | 0,003 | 0,000 | 0,001 | 0,002 | 0,002 |
| 74 | EV02 | L | 0,010 | 0,002 | 0,000 | 0,006 | 0,037 | 0,002 | 0,023 | 0,001 | 0,019 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 75 | EV02 | L | 0,007 | 0,001 | 0,000 | 0,005 | 0,042 | 0,002 | 0,042 | 0,001 | 0,000 | 0,021 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 76 | EV02 | H | 0,009 | 0,001 | 0,000 | 0,006 | 0,037 | 0,002 | 0,032 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 77 | EV02 | H | 0,010 | 0,001 | 0,000 | 0,007 | 0,040 | 0,003 | 0,023 | 0,001 | 0,000 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,002 |
| 78 | EV02 | H | 0,007 | 0,001 | 0,000 | 0,006 | 0,037 | 0,002 | 0,051 | 0,001 | 0,000 | 0,020 | 0,002 | 0,000 | 0,001 | 0,001 | 0,001 |
| 79 | EV02 | H | 0,012 | 0,001 | 0,000 | 0,006 | 0,029 | 0,002 | 0,011 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,000 |
| 80 | EV02 | L | 0,009 | 0,001 | 0,000 | 0,006 | 0,068 | 0,002 | 0,039 | 0,001 | 0,017 | 0,021 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |

|     |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 81  | EV02 | L | 0,007 | 0,001 | 0,000 | 0,005 | 0,031 | 0,001 | 0,037 | 0,001 | 0,000 | 0,021 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 82  | EV02 | F | 0,007 | 0,001 | 0,000 | 0,006 | 0,012 | 0,001 | 0,001 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 83  | EV02 | H | 0,010 | 0,001 | 0,000 | 0,007 | 0,026 | 0,003 | 0,016 | 0,001 | 0,000 | 0,000 | 0,002 | 0,000 | 0,001 | 0,001 | 0,000 |
| 84  | EV02 | H | 0,007 | 0,001 | 0,000 | 0,006 | 0,035 | 0,002 | 0,044 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,001 |
| 85  | EV02 | H | 0,013 | 0,001 | 0,000 | 0,007 | 0,039 | 0,003 | 0,020 | 0,001 | 0,015 | 0,023 | 0,003 | 0,001 | 0,002 | 0,003 | 0,000 |
| 86  | EV02 | H | 0,008 | 0,001 | 0,000 | 0,007 | 0,044 | 0,002 | 0,039 | 0,001 | 0,016 | 0,022 | 0,003 | 0,001 | 0,002 | 0,001 | 0,002 |
| 87  | EV02 | H | 0,009 | 0,001 | 0,000 | 0,007 | 0,028 | 0,002 | 0,018 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 88  | EV02 | H | 0,006 | 0,001 | 0,000 | 0,005 | 0,023 | 0,001 | 0,003 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,002 |
| 89  | EV02 | L | 0,010 | 0,001 | 0,000 | 0,007 | 0,035 | 0,002 | 0,024 | 0,001 | 0,000 | 0,024 | 0,003 | 0,001 | 0,002 | 0,003 | 0,001 |
| 90  | EV02 | L | 0,008 | 0,001 | 0,000 | 0,005 | 0,043 | 0,002 | 0,046 | 0,001 | 0,017 | 0,022 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 91  | EV02 | H | 0,009 | 0,001 | 0,000 | 0,006 | 0,038 | 0,002 | 0,017 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 92  | EV02 | H | 0,010 | 0,002 | 0,000 | 0,008 | 0,037 | 0,002 | 0,024 | 0,001 | 0,000 | 0,023 | 0,003 | 0,001 | 0,001 | 0,002 | 0,001 |
| 93  | EV02 | L | 0,007 | 0,001 | 0,000 | 0,009 | 0,023 | 0,002 | 0,015 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,002 |
| 94  | EV02 | L | 0,007 | 0,001 | 0,001 | 0,006 | 0,044 | 0,002 | 0,040 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,002 | 0,002 |
| 95  | EV02 | L | 0,009 | 0,001 | 0,001 | 0,004 | 0,056 | 0,002 | 0,044 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 96  | EV02 | L | 0,008 | 0,001 | 0,000 | 0,005 | 0,049 | 0,002 | 0,040 | 0,001 | 0,016 | 0,025 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 97  | EV02 | L | 0,007 | 0,001 | 0,000 | 0,004 | 0,052 | 0,002 | 0,048 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 98  | EV02 | H | 0,009 | 0,001 | 0,000 | 0,007 | 0,030 | 0,002 | 0,019 | 0,001 | 0,017 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,002 |
| 99  | EV02 | H | 0,009 | 0,001 | 0,000 | 0,007 | 0,041 | 0,002 | 0,028 | 0,001 | 0,017 | 0,027 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 100 | EV02 | I | 0,005 | 0,001 | 0,000 | 0,004 | 0,020 | 0,001 | 0,003 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 101 | EV01 | C | 0,006 | 0,001 | 0,000 | 0,003 | 0,027 | 0,002 | 0,009 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,001 | 0,001 |
| 102 | EV01 | E | 0,007 | 0,001 | 0,000 | 0,004 | 0,042 | 0,002 | 0,050 | 0,001 | 0,000 | 0,020 | 0,002 | 0,001 | 0,001 | 0,002 | 0,001 |
| 103 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,007 | 0,022 | 0,002 | 0,015 | 0,001 | 0,000 | 0,025 | 0,002 | 0,001 | 0,002 | 0,001 | 0,001 |
| 104 | EV01 | E | 0,005 | 0,001 | 0,000 | 0,004 | 0,028 | 0,001 | 0,006 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 105 | EV01 | E | 0,010 | 0,001 | 0,000 | 0,008 | 0,041 | 0,002 | 0,039 | 0,001 | 0,000 | 0,020 | 0,002 | 0,001 | 0,001 | 0,002 | 0,000 |
| 106 | EV01 | A | 0,008 | 0,001 | 0,000 | 0,008 | 0,022 | 0,003 | 0,025 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,000 |
| 107 | EV01 | A | 0,008 | 0,001 | 0,000 | 0,005 | 0,050 | 0,003 | 0,051 | 0,001 | 0,014 | 0,024 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 108 | EV01 | A | 0,010 | 0,001 | 0,000 | 0,007 | 0,030 | 0,003 | 0,018 | 0,001 | 0,014 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,000 |

|     |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 109 | EV01 | A | 0,007 | 0,001 | 0,000 | 0,007 | 0,034 | 0,002 | 0,056 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,003 | 0,002 |
| 110 | EV01 | B | 0,007 | 0,001 | 0,000 | 0,006 | 0,038 | 0,002 | 0,044 | 0,001 | 0,022 | 0,000 | 0,003 | 0,001 | 0,001 | 0,003 | 0,002 |
| 111 | EV01 | B | 0,008 | 0,001 | 0,000 | 0,005 | 0,055 | 0,002 | 0,037 | 0,001 | 0,000 | 0,020 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 112 | EV01 | B | 0,009 | 0,002 | 0,000 | 0,004 | 0,040 | 0,003 | 0,036 | 0,001 | 0,015 | 0,038 | 0,004 | 0,001 | 0,001 | 0,002 | 0,000 |
| 113 | EV01 | C | 0,008 | 0,002 | 0,000 | 0,004 | 0,052 | 0,003 | 0,034 | 0,001 | 0,014 | 0,023 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 114 | EV01 | C | 0,008 | 0,001 | 0,000 | 0,004 | 0,051 | 0,003 | 0,057 | 0,001 | 0,015 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 115 | EV01 | C | 0,008 | 0,001 | 0,000 | 0,006 | 0,042 | 0,002 | 0,044 | 0,001 | 0,019 | 0,023 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 116 | EV01 | C | 0,008 | 0,001 | 0,000 | 0,004 | 0,047 | 0,003 | 0,061 | 0,001 | 0,019 | 0,034 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 117 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,008 | 0,033 | 0,002 | 0,019 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 118 | EV01 | E | 0,008 | 0,002 | 0,000 | 0,005 | 0,039 | 0,002 | 0,030 | 0,001 | 0,015 | 0,023 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 119 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,007 | 0,024 | 0,002 | 0,018 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,000 |
| 120 | EV01 | E | 0,007 | 0,001 | 0,000 | 0,005 | 0,051 | 0,002 | 0,059 | 0,001 | 0,017 | 0,024 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 121 | EV01 | E | 0,007 | 0,001 | 0,000 | 0,007 | 0,028 | 0,006 | 0,027 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,001 | 0,001 |
| 122 | EV01 | C | 0,010 | 0,002 | 0,000 | 0,008 | 0,033 | 0,002 | 0,051 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 123 | EV01 | C | 0,009 | 0,002 | 0,000 | 0,003 | 0,040 | 0,003 | 0,037 | 0,001 | 0,000 | 0,019 | 0,003 | 0,001 | 0,002 | 0,000 | 0,000 |
| 124 | EV01 | C | 0,009 | 0,001 | 0,001 | 0,010 | 0,021 | 0,002 | 0,022 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,001 |
| 125 | EV01 | E | 0,009 | 0,001 | 0,000 | 0,005 | 0,044 | 0,003 | 0,042 | 0,001 | 0,017 | 0,026 | 0,002 | 0,001 | 0,002 | 0,002 | 0,000 |
| 126 | EV01 | E | 0,007 | 0,002 | 0,000 | 0,006 | 0,057 | 0,003 | 0,040 | 0,001 | 0,019 | 0,028 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 127 | EV01 | E | 0,009 | 0,001 | 0,000 | 0,010 | 0,029 | 0,002 | 0,015 | 0,001 | 0,000 | 0,021 | 0,002 | 0,001 | 0,002 | 0,002 | 0,002 |
| 128 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,005 | 0,026 | 0,001 | 0,008 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 129 | EV01 | E | 0,007 | 0,001 | 0,000 | 0,002 | 0,007 | 0,002 | 0,004 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,000 |
| 130 | EV01 | C | 0,008 | 0,001 | 0,001 | 0,006 | 0,041 | 0,002 | 0,048 | 0,001 | 0,015 | 0,026 | 0,003 | 0,001 | 0,001 | 0,003 | 0,001 |
| 131 | EV01 | C | 0,007 | 0,002 | 0,000 | 0,006 | 0,041 | 0,002 | 0,038 | 0,001 | 0,015 | 0,021 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 132 | EV01 | C | 0,009 | 0,002 | 0,000 | 0,007 | 0,035 | 0,002 | 0,047 | 0,001 | 0,015 | 0,000 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 133 | EV01 | C | 0,005 | 0,001 | 0,001 | 0,006 | 0,022 | 0,002 | 0,015 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 134 | EV01 | C | 0,008 | 0,002 | 0,000 | 0,006 | 0,052 | 0,003 | 0,047 | 0,001 | 0,016 | 0,035 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 135 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,004 | 0,075 | 0,003 | 0,041 | 0,001 | 0,018 | 0,026 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 136 | EV01 | C | 0,008 | 0,001 | 0,000 | 0,004 | 0,056 | 0,003 | 0,066 | 0,001 | 0,019 | 0,021 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |

|     |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 137 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,004 | 0,054 | 0,003 | 0,058 | 0,001 | 0,000 | 0,028 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 138 | EV01 | C | 0,007 | 0,002 | 0,000 | 0,007 | 0,041 | 0,002 | 0,053 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,004 | 0,001 |
| 139 | EV01 | D | 0,009 | 0,001 | 0,000 | 0,004 | 0,018 | 0,002 | 0,012 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,000 |
| 140 | EV01 | B | 0,010 | 0,001 | 0,001 | 0,008 | 0,030 | 0,003 | 0,016 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,002 | 0,001 |
| 141 | EV01 | A | 0,008 | 0,002 | 0,000 | 0,007 | 0,038 | 0,002 | 0,045 | 0,001 | 0,021 | 0,026 | 0,003 | 0,001 | 0,001 | 0,002 | 0,001 |
| 142 | EV01 | A | 0,006 | 0,001 | 0,000 | 0,005 | 0,026 | 0,001 | 0,003 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,001 |
| 143 | EV01 | A | 0,008 | 0,001 | 0,000 | 0,009 | 0,038 | 0,002 | 0,016 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,002 | 0,001 |
| 144 | EV01 | E | 0,007 | 0,001 | 0,000 | 0,005 | 0,055 | 0,003 | 0,044 | 0,001 | 0,000 | 0,029 | 0,003 | 0,001 | 0,002 | 0,001 | 0,001 |
| 145 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,005 | 0,068 | 0,003 | 0,060 | 0,001 | 0,016 | 0,028 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 146 | EV01 | E | 0,006 | 0,001 | 0,001 | 0,005 | 0,055 | 0,001 | 0,011 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 147 | EV01 | E | 0,005 | 0,001 | 0,000 | 0,004 | 0,026 | 0,001 | 0,001 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 148 | EV01 | E | 0,007 | 0,002 | 0,000 | 0,007 | 0,043 | 0,002 | 0,051 | 0,001 | 0,015 | 0,024 | 0,003 | 0,001 | 0,002 | 0,003 | 0,000 |
| 149 | EV01 | E | 0,007 | 0,002 | 0,000 | 0,006 | 0,030 | 0,002 | 0,052 | 0,001 | 0,015 | 0,024 | 0,003 | 0,001 | 0,002 | 0,003 | 0,002 |
| 150 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,008 | 0,032 | 0,002 | 0,033 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 151 | EV01 | C | 0,007 | 0,002 | 0,000 | 0,007 | 0,030 | 0,002 | 0,038 | 0,001 | 0,000 | 0,024 | 0,004 | 0,000 | 0,002 | 0,003 | 0,000 |
| 152 | EV01 | C | 0,008 | 0,001 | 0,001 | 0,009 | 0,030 | 0,002 | 0,026 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 153 | EV01 | C | 0,006 | 0,001 | 0,000 | 0,006 | 0,022 | 0,002 | 0,014 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 154 | EV01 | C | 0,009 | 0,002 | 0,000 | 0,004 | 0,050 | 0,003 | 0,033 | 0,001 | 0,000 | 0,029 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 155 | EV01 | C | 0,005 | 0,001 | 0,000 | 0,004 | 0,020 | 0,001 | 0,015 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 156 | EV01 | C | 0,004 | 0,001 | 0,000 | 0,002 | 0,022 | 0,001 | 0,009 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,001 |
| 157 | EV01 | B | 0,007 | 0,002 | 0,000 | 0,006 | 0,040 | 0,002 | 0,045 | 0,001 | 0,000 | 0,017 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 158 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,006 | 0,036 | 0,002 | 0,045 | 0,001 | 0,016 | 0,019 | 0,003 | 0,001 | 0,002 | 0,002 | 0,001 |
| 159 | EV01 | E | 0,010 | 0,001 | 0,000 | 0,008 | 0,039 | 0,002 | 0,031 | 0,001 | 0,000 | 0,024 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 160 | EV01 | E | 0,007 | 0,001 | 0,001 | 0,007 | 0,041 | 0,002 | 0,035 | 0,001 | 0,016 | 0,027 | 0,003 | 0,001 | 0,002 | 0,003 | 0,000 |
| 161 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,005 | 0,020 | 0,001 | 0,007 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,000 | 0,001 |
| 162 | EV01 | E | 0,008 | 0,002 | 0,000 | 0,007 | 0,027 | 0,002 | 0,038 | 0,001 | 0,014 | 0,018 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 163 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,005 | 0,037 | 0,001 | 0,025 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 164 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,008 | 0,026 | 0,003 | 0,026 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,000 |

|     |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 165 | EV01 | E | 0,006 | 0,002 | 0,000 | 0,006 | 0,029 | 0,002 | 0,051 | 0,001 | 0,000 | 0,000 | 0,004 | 0,001 | 0,002 | 0,002 | 0,000 |
| 166 | EV01 | E | 0,012 | 0,002 | 0,000 | 0,004 | 0,040 | 0,003 | 0,039 | 0,001 | 0,021 | 0,032 | 0,004 | 0,001 | 0,002 | 0,002 | 0,000 |
| 167 | EV01 | A | 0,005 | 0,001 | 0,000 | 0,003 | 0,027 | 0,001 | 0,003 | 0,000 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 168 | EV01 | C | 0,006 | 0,001 | 0,000 | 0,005 | 0,042 | 0,002 | 0,017 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |
| 169 | EV01 | C | 0,008 | 0,002 | 0,000 | 0,006 | 0,031 | 0,002 | 0,038 | 0,001 | 0,000 | 0,020 | 0,003 | 0,001 | 0,002 | 0,002 | 0,001 |
| 170 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,006 | 0,049 | 0,002 | 0,045 | 0,001 | 0,015 | 0,027 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 171 | EV01 | C | 0,008 | 0,002 | 0,000 | 0,006 | 0,033 | 0,002 | 0,035 | 0,001 | 0,000 | 0,025 | 0,003 | 0,001 | 0,001 | 0,003 | 0,000 |
| 172 | EV01 | C | 0,010 | 0,001 | 0,000 | 0,005 | 0,027 | 0,003 | 0,014 | 0,001 | 0,016 | 0,000 | 0,002 | 0,000 | 0,001 | 0,002 | 0,000 |
| 173 | EV01 | C | 0,006 | 0,002 | 0,000 | 0,006 | 0,036 | 0,002 | 0,045 | 0,001 | 0,000 | 0,021 | 0,004 | 0,001 | 0,001 | 0,003 | 0,002 |
| 174 | EV01 | E | 0,009 | 0,001 | 0,001 | 0,006 | 0,039 | 0,002 | 0,044 | 0,001 | 0,019 | 0,020 | 0,002 | 0,001 | 0,001 | 0,002 | 0,002 |
| 175 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,005 | 0,048 | 0,002 | 0,047 | 0,001 | 0,015 | 0,018 | 0,003 | 0,001 | 0,000 | 0,003 | 0,000 |
| 176 | EV01 | E | 0,012 | 0,001 | 0,000 | 0,008 | 0,043 | 0,002 | 0,033 | 0,001 | 0,017 | 0,024 | 0,003 | 0,001 | 0,002 | 0,002 | 0,000 |
| 177 | EV01 | E | 0,007 | 0,002 | 0,000 | 0,004 | 0,041 | 0,003 | 0,035 | 0,001 | 0,014 | 0,021 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 178 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,005 | 0,041 | 0,003 | 0,041 | 0,001 | 0,000 | 0,023 | 0,003 | 0,001 | 0,002 | 0,002 | 0,002 |
| 179 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,004 | 0,039 | 0,001 | 0,013 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,002 |
| 180 | EV01 | C | 0,010 | 0,001 | 0,000 | 0,006 | 0,028 | 0,002 | 0,016 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,000 |
| 181 | EV01 | C | 0,004 | 0,001 | 0,000 | 0,006 | 0,033 | 0,001 | 0,066 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,003 | 0,002 |
| 182 | EV01 | C | 0,010 | 0,001 | 0,001 | 0,005 | 0,044 | 0,003 | 0,050 | 0,001 | 0,000 | 0,025 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 183 | EV01 | C | 0,009 | 0,001 | 0,000 | 0,008 | 0,029 | 0,002 | 0,018 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,002 | 0,001 | 0,000 |
| 184 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,004 | 0,054 | 0,002 | 0,030 | 0,001 | 0,000 | 0,022 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 185 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,004 | 0,054 | 0,001 | 0,009 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 186 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,004 | 0,053 | 0,002 | 0,018 | 0,001 | 0,000 | 0,000 | 0,000 | 0,001 | 0,001 | 0,000 | 0,000 |
| 187 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,004 | 0,038 | 0,001 | 0,014 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |
| 188 | EV01 | E | 0,011 | 0,001 | 0,000 | 0,009 | 0,042 | 0,002 | 0,016 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,002 | 0,001 | 0,002 |
| 189 | EV01 | E | 0,011 | 0,001 | 0,000 | 0,009 | 0,047 | 0,002 | 0,031 | 0,001 | 0,000 | 0,021 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 190 | EV01 | E | 0,008 | 0,001 | 0,000 | 0,004 | 0,062 | 0,003 | 0,045 | 0,001 | 0,018 | 0,030 | 0,003 | 0,001 | 0,001 | 0,001 | 0,000 |
| 191 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,005 | 0,022 | 0,001 | 0,003 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,000 | 0,003 |
| 192 | EV01 | E | 0,006 | 0,001 | 0,001 | 0,004 | 0,024 | 0,001 | 0,007 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,000 | 0,002 |

|     |      |   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----|------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 193 | EV01 | E | 0,007 | 0,002 | 0,000 | 0,005 | 0,043 | 0,003 | 0,046 | 0,001 | 0,018 | 0,023 | 0,003 | 0,001 | 0,002 | 0,001 | 0,000 |
| 194 | EV01 | E | 0,006 | 0,001 | 0,000 | 0,003 | 0,029 | 0,001 | 0,003 | 0,000 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,000 | 0,002 |
| 195 | EV01 | B | 0,009 | 0,002 | 0,000 | 0,004 | 0,037 | 0,003 | 0,033 | 0,001 | 0,017 | 0,024 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 196 | EV01 | B | 0,007 | 0,002 | 0,000 | 0,006 | 0,038 | 0,002 | 0,040 | 0,001 | 0,014 | 0,022 | 0,003 | 0,001 | 0,002 | 0,002 | 0,001 |
| 197 | EV01 | C | 0,007 | 0,002 | 0,000 | 0,005 | 0,047 | 0,002 | 0,050 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 198 | EV01 | C | 0,008 | 0,001 | 0,000 | 0,005 | 0,021 | 0,003 | 0,025 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,000 |
| 199 | EV01 | C | 0,007 | 0,001 | 0,000 | 0,006 | 0,032 | 0,002 | 0,034 | 0,001 | 0,000 | 0,000 | 0,003 | 0,001 | 0,001 | 0,002 | 0,000 |
| 200 | EV01 | C | 0,006 | 0,001 | 0,000 | 0,003 | 0,029 | 0,001 | 0,010 | 0,001 | 0,000 | 0,000 | 0,002 | 0,001 | 0,001 | 0,001 | 0,001 |

## **APPENDIX B**

# **PETROGRAPHIC REPORTS**

## SAMPLE 4

Site: Klein Bolayi

Macroscopic Fabric Group: H

Petrographic Fabric: Loner fabric olivine-quartz-biotite

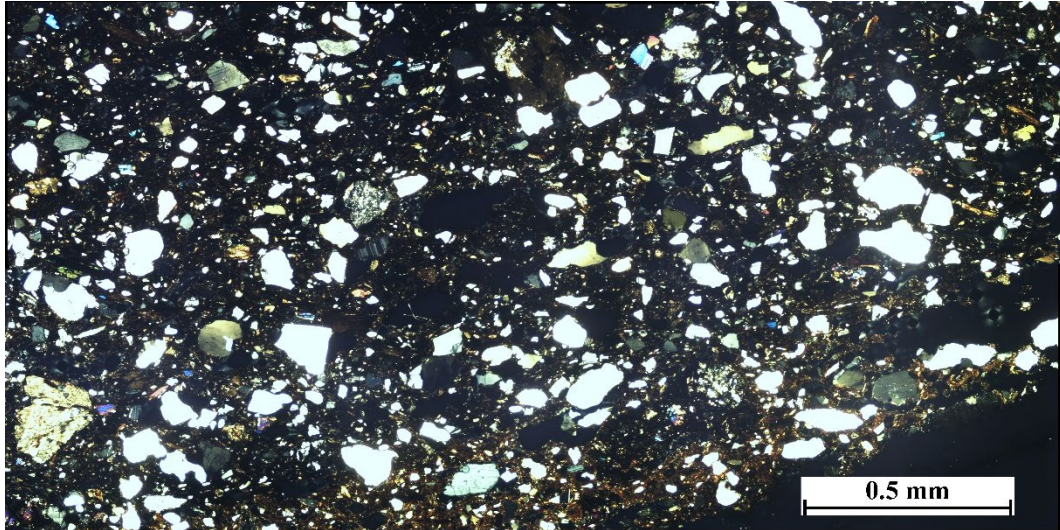


Figure 1: Sample 4 in XPL

### Mineralogy

Quartz (10%, frequency: few) – predominantly coarse silt to very fine sand inclusions present. Some quartz grains show fractures with slight fills. Grains exhibit undulose extinction and have sharp boundaries throughout.

Inclusion size range:

- 0.16mm x 0.13mm, angular with high sphericity
- 0.09mm x 0.09mm, angular with high sphericity
- 0.07mm x 0.03mm, sub-rounded with low sphericity

Biotite (7%, frequency: few) – euhedral, coarse sand to fine sand laths which are visible throughout. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.20mm x 0.04mm, tabular shape
- 0.15mm x 0.01mm, lath shape
- 0.07mm x 0.02mm, tabular shape

K-Feldspar (6%, frequency: few) – euhedral and anhedral inclusions, predominantly medium silt to very fine sand. 90° cleavage angles are visible. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.15mm x 0.03mm, very angular with low sphericity

- 0.07mm x 0.03mm, angular with low sphericity
- 0.02mm x 0.02mm, equant shape

Olivine (4%, frequency: very few) – very fractured olivine of medium silt to medium sand is present in the sample. Boundaries are diffuse throughout.

Inclusion size range:

- 0.034mm x 0.28mm, angular with high sphericity
- 0.15mm x 0.11mm, sub-angular with high sphericity
- 0.08mm x 0.05mm, sub-rounded with low sphericity

Plagioclase (3%, frequency: very few) – coarse silt to very fine sand inclusions found through the sample. Boundaries are sharp to diffuse throughout.

Inclusion size range:

- 0.11mm x 0.04mm, very angular with high sphericity
- 0.08mm x 0.04mm, sub-rounded with low sphericity
- 0.04mm x 0.02mm, sub-angular with low sphericity

Hornblende (3%, frequency: very few) – subhedral, coarse silt to very fine sand inclusions are present. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.10mm x 0.04mm, angular with low sphericity
- 0.04mm x 0.02mm, angular with low sphericity
- 0.03mm x 0.02mm, sub-angular with high sphericity

Clinopyroxene (2%, frequency: rare) – subhedral, medium silt and coarse silt grains visible in the sample. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.05mm x 0.04mm, elongate shape
- 0.04mm x 0.01mm, angular with low sphericity
- 0.03mm x 0.01mm, elongate shape

Clay pellets (1%, frequency: rare) – coarse silt inclusions of clay pellets are found through the sample. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.09mm x 0.06mm
- 0.07mm x 0.04mm
- 0.04mm x 0.03mm

Opaque minerals (1%, frequency: rare) – medium silt to coarse silt grains present in the sample. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.03mm x 0.01mm, sub-rounded with low sphericity
- 0.02mm x 0.01mm, sub-rounded with low sphericity

- 0.01mm x 0.01mm, sub-rounded with low sphericity

Schist (<1%, frequency: rare) – three foliated inclusions of schist present in the sample. Inclusions are of very fine sand and fine sand sizes. Boundaries are clear to diffuse in all inclusions.

Inclusion size range:

- 0.20mm x 0.15mm, angular with low sphericity
- 0.14mm x 0.08mm, angular with low sphericity
- 0.08mm x 0.08mm, angular with high sphericity

### **Voids** (8%)

Meso and micro planar voids as well as meso and micro vugh voids are present in the sample.

Size range of planar voids:

- 0.11mm x 0.02mm
- 0.05mm x 0.01mm
- 0.04mm x 0.01mm

Size range of vugh voids:

- 0.26mm x 0.13mm
- 0.17mm x 0.08mm
- 0.04mm x 0.02mm

### **Clay Matrix** (55%)

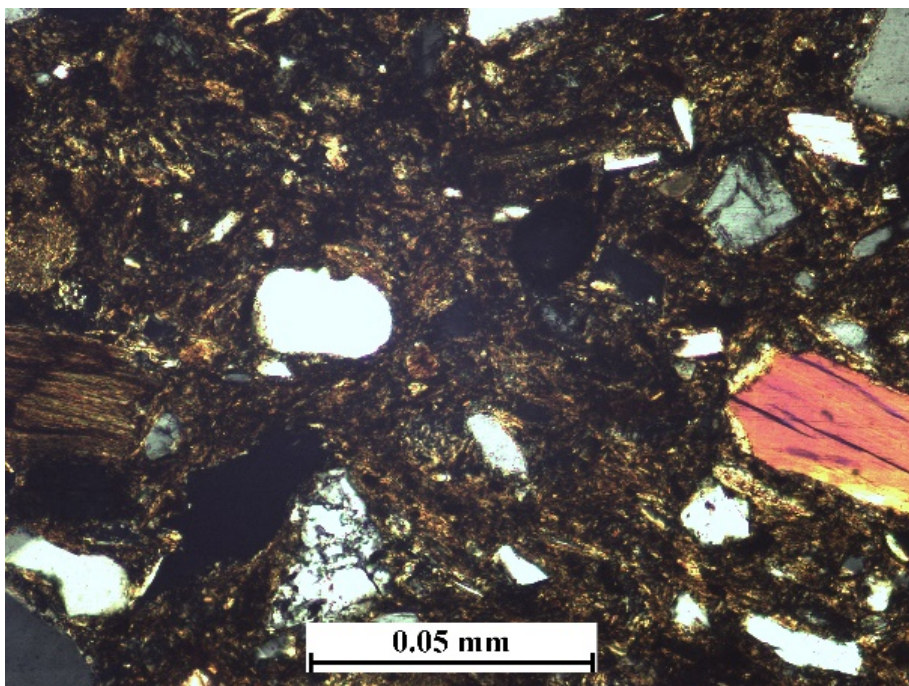


Figure 2: Clay matrix in XPL

The clay matrix is orange-brown in colour with high optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being slightly less optically active due to uneven firing. The plastic inclusions of the clay matrix are equal biotite laths and quartz grains.

### **Mineral Orientation**

Mineral orientation in the sample shows flowing half circles along with alternating random orientations in some sections. This points to the combined use of pinching and coiling as a forming method.

## SAMPLE 11

Site: Klein Bolayi

Macroscopic Fabric Group: F

Petrographic Fabric: Quartz-feldspars-mica

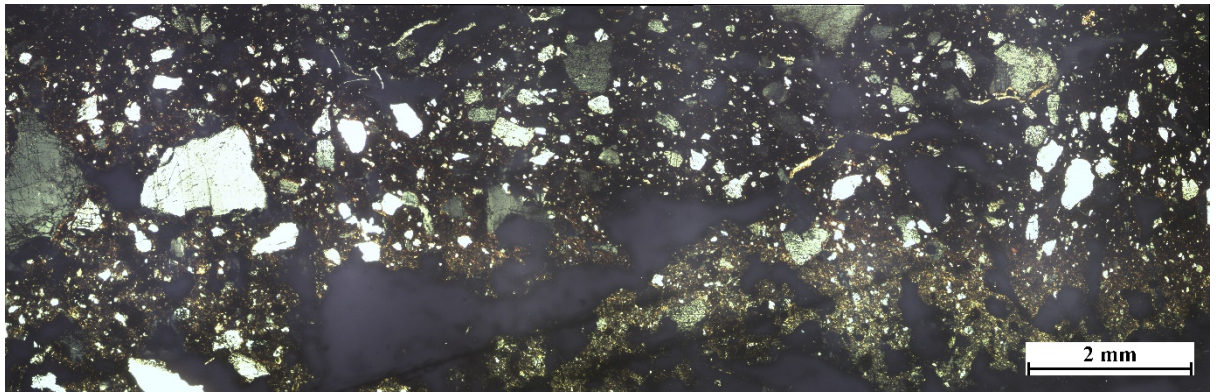


Figure 3: Sample 11 in XPL

### Mineralogy

Quartz (10%, frequency: few) – coarse silt to very coarse sand quartz grains throughout the sample. Undulose extinction is visible in the grains. Boundaries are sharp throughout.

Inclusion size range:

- 1.64mm x 0.45mm, angular with low sphericity
- 0.67mm x 0.51mm, very angular with high sphericity
- 0.05mm x 0.03mm, sub-rounded with high sphericity

K-Feldspar (9%, frequency: few) – euhedral and anhedral, fine sand to coarse sand grains found throughout the sample. Boundaries are sharp throughout.

Inclusion size range:

- 1.68mm x 0.95mm, angular with low sphericity
- 0.13mm x 0.05mm, tabular shape, likely sanidine
- 0.11mm x 0.02mm, lath

Plagioclase (5%, frequency: few) – subhedral and euhedral very fine sand inclusions. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.18mm x 0.12mm, elongate shape
- 0.10mm x 0.07mm, sub-rounded with low sphericity
- 0.08mm x 0.06mm, sub-angular with low sphericity

Hornblende (2%, frequency: very few) – subhedral very fine sand inclusions. Distinctive 120° cleavage angles are visible. Boundaries are mostly diffuse.

Inclusion size range:

- 0.17mm x 0.04mm, tabular shape
- 0.11mm x 0.05mm, angular with low sphericity
- 0.05mm x 0.02mm, sub-rounded with low sphericity

Opaque minerals (2%, frequency: very few) – coarse silt grains with some presenting an elongate shape. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.05mm x 0.03mm, elongate shape
- 0.04mm x 0.02mm, elongate shape
- 0.02mm x 0.02mm, sub-angular with high sphericity

Clay pellets (1%, frequency: rare) – a few clay pellets can be seen within the sample. All clay pellets are compositionally similar. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.32mm x 0.04mm
- 0.28mm x 0.08mm
- 0.06mm x 0.03mm

Biotite (<1%, frequency: rare) – low amounts of euhedral very fine sand inclusions. Sharp boundaries throughout.

Inclusion size range:

- 0.13mm x 0.03mm, tabular shape
- 0.11mm x 0.01mm, lath shape
- 0.05mm x 0.01mm, tabular shape

Muscovite (<1%, frequency: rare) – euhedral very fine sand inclusions. Clear to sharp boundaries throughout.

Inclusion size range:

- 0.12mm x 0.03mm, tabular shape
- 0.09mm x 0.02mm, lath shape
- 0.07mm x 0.002mm, lath shape

### **Voids (10%)**

Macro and meso planar voids as well as macro and meso vugh voids are present. Sample is also highly eroded.

Size range of planar voids:

- 2.62mm x 0.16mm
- 0.30mm x 0.03mm
- 0.08mm x 0.01mm

Size range of vugh voids:

- 1.20mm x 0.92mm
- 0.52mm x 0.14mm
- 0.12mm x 0.10mm

### **Clay Matrix (58%)**

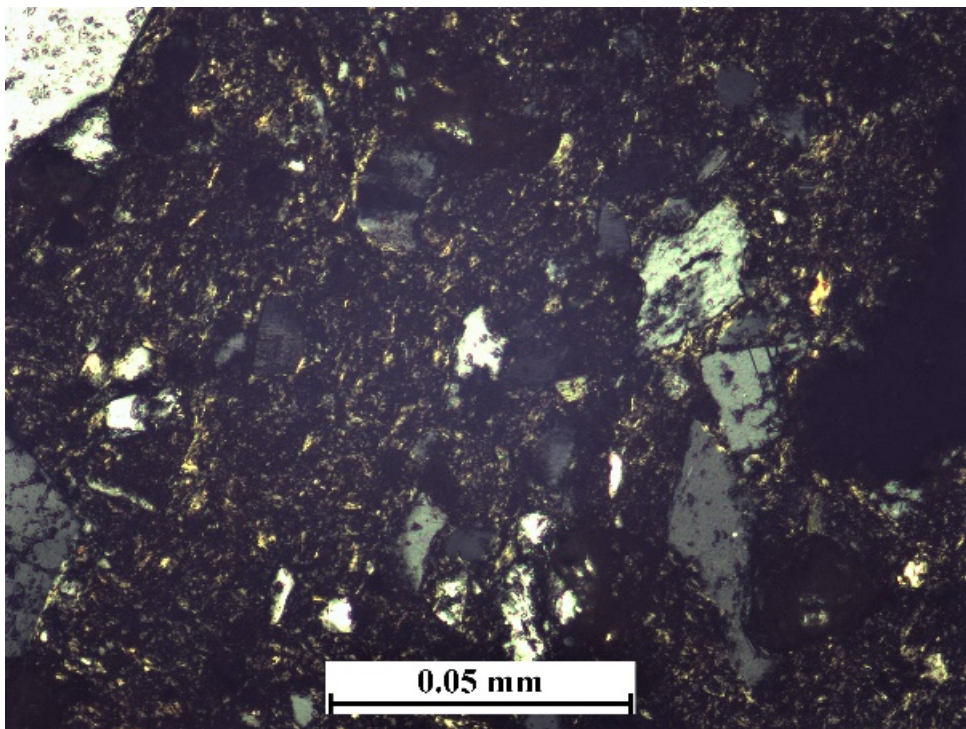


**Figure 4: Clay matrix in XPL**

The clay matrix is dark reddish-brown in colour with fine silt quartz and some biotite and muscovite laths throughout the matrix. Moderate optical activity hints at low firing temperatures with the bottom half, and extending into the whole left side of the sample shows higher optical activity as a result of uneven firing.

### **Mineral Orientation**

The minerals in the sample are randomly orientated and show signs of pinching as the forming method applied.

## SAMPLE 34

Site: Klein Bolayi

Macroscopic Fabric Group: I

Petrographic Fabric: Sub-fabric quartz-mica-feldspars

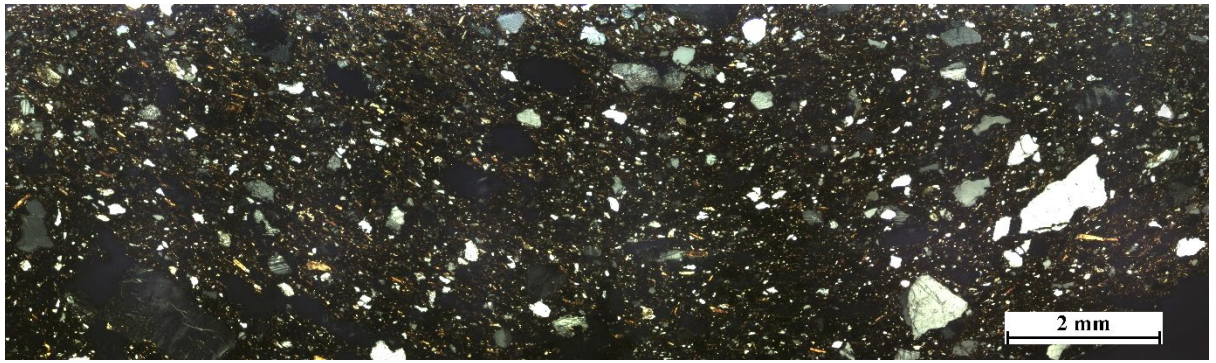


Figure 5: Sample 34 in XPL

### Mineralogy

Quartz (10%, frequency: few) – coarse silt to medium sand grain inclusions. Undulose extinction is visible. Boundaries are clear to sharp throughout. Two grains have a visible bleb texture present.

Inclusion size range:

- 0.38mm x 0.17mm, angular with low sphericity
- 0.21mm x 0.19mm, angular with high sphericity
- 0.04mm x 0.03mm, sub-rounded with high sphericity

Biotite (9%, frequency: few) – euhedral very fine sand and fine sand inclusions. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.32mm x 0.04mm, tabular shape
- 0.23mm x 0.03mm, lath shape
- 0.12mm x 0.01mm, lath shape

Plagioclase (5%, frequency: very few) – subhedral to anhedral very fine sand and fine sand inclusions. Boundaries are sharp throughout.

Inclusion size range;

- 0.26mm x 0.21mm, angular with high sphericity
- 0.08mm x 0.07mm, angular with high sphericity
- 0.08mm x 0.05mm, tabular shape

K-Feldspar (5%, frequency: very few) – euhedral and anhedral very fine sand, medium sand and very coarse sand. Boundaries are sharp throughout.

Inclusion size range:

- 2.16mm x 0.78mm, tabular shape
- 0.74mm x 0.66mm, sub-angular with low sphericity
- 0.10mm x 0.03mm, tabular shape

Muscovite (3%, frequency: very few) – euhedral very fine sand muscovite laths are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.17mm x 0.02mm, lath shape
- 0.16mm x 0.01mm, lath shape
- 0.15mm x 0.01mm, lath shape

Opaque minerals (3%, frequency: very few) – coarse silt grains are present throughout the sample. Roundness and sphericity varies greatly throughout the grains. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.09mm x 0.05mm, rounded with low sphericity
- 0.03mm x 0.02mm, angular with high sphericity
- 0.03mm x 0.01mm, sub-rounded with low sphericity

Grog (<1, frequency: rare) – a single grog inclusion, which is more visible in plane polarized light. The grog has a circle of shrinkage present around it and has a discordant feature. The inclusion is 0.21mm x 0.14mm in size.

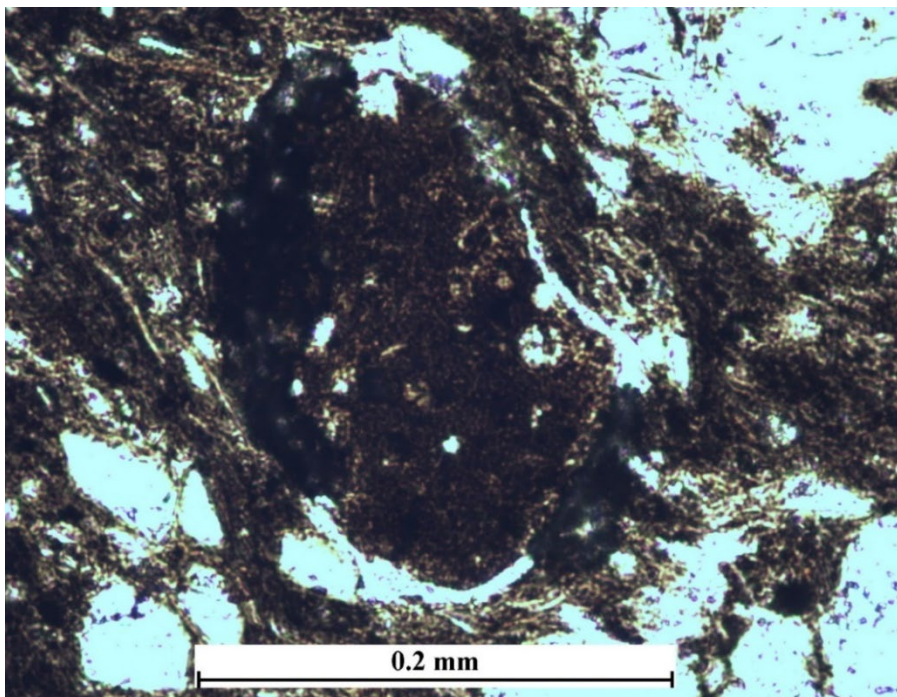


Figure 6: grog inclusion in PPL

Granite (<1%, frequency: rare) – a single coarse grain granite inclusion comprised of quartz, k-feldspar, plagioclase and mica as the accessory mineral. The k-feldspar of the granite has a visible bleb texture. The inclusion is 0.95mm x 0.60mm in size and is sub-angular with low sphericity.

### **Voids** (10%)

Meso planar voids as well as meso and macro vugh voids are present in the sample. Voids do not have a distinct orientation.

Size range of planar voids:

- 0.66mm x 0.06mm
- 0.42mm x 0.03mm
- 0.18mm x 0.01mm

Size range of vugh voids:

- 0.68mm x 0.54mm
- 0.19mm x 0.08mm
- 0.06mm x 0.05mm

### **Clay Matrix** (55%)

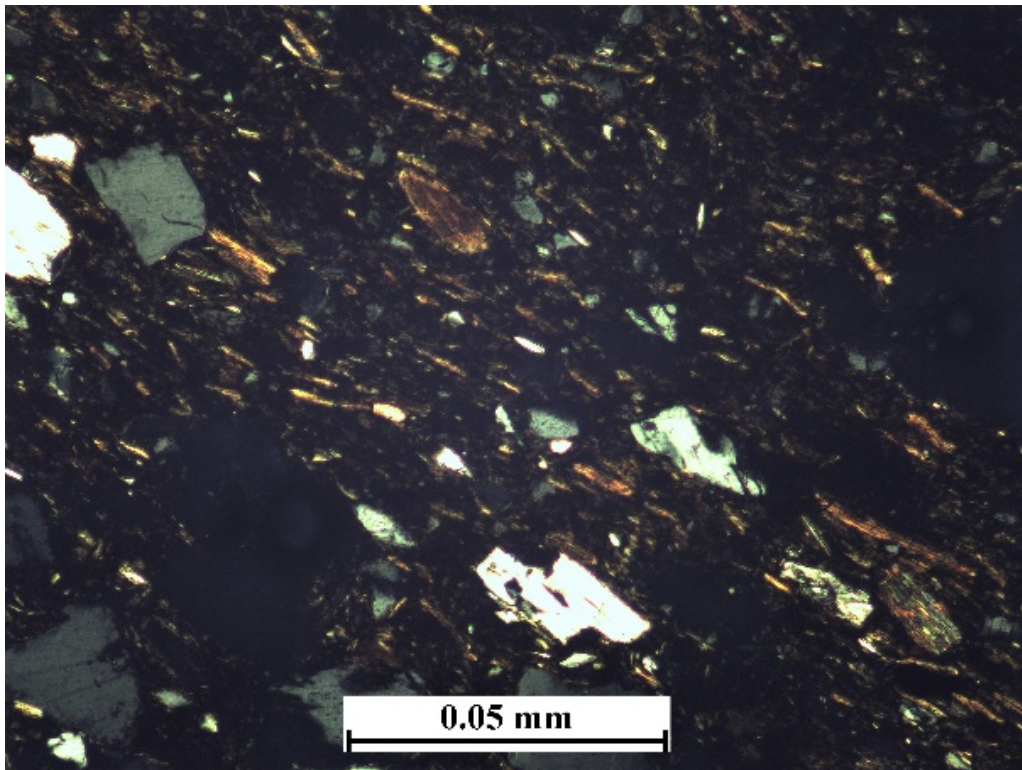


Figure 7: Clay matrix in XPL

The clay matrix is reddish-orange-brown in colour with an abundance of both biotite and muscovite laths as well as fine silt quartz throughout the matrix. Moderate optical activity hints at low firing temperatures with the centre having slightly higher activity due to uneven firing.

### **Mineral Orientation**

Minerals are orientated in flowing half circles throughout the sample. This shows the use of coiling as the forming method.

## SAMPLE 36

Site: Klein Bolayi

Macroscopic Fabric Group: K

Petrographic Fabric: Quartz-feldspars-mica

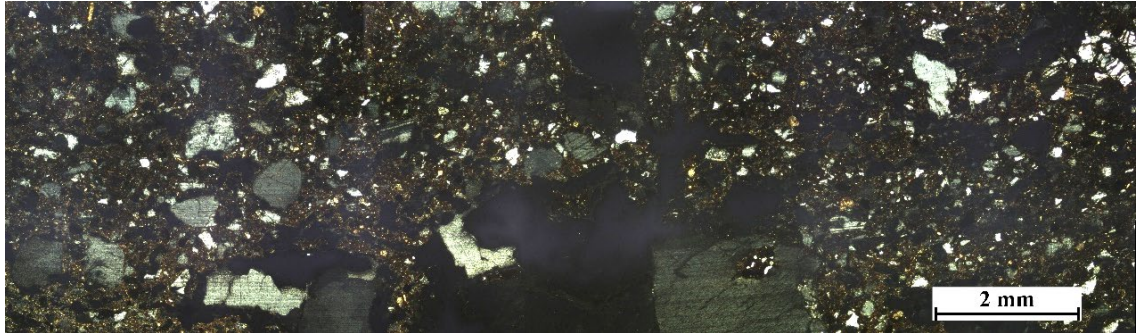


Figure 8: Sample 36 in XPL.

### Mineralogy

K-Feldspar (13%, frequency: few) – euhedral and anhedral grains, predominantly medium sand with some very coarse sand. 90° cleavage angles are visible. Boundaries are sharp to clear throughout.

Inclusion size range:

- 1.1mm x 0.42mm, tabular shape, likely sanidine
- 0.31mm x 0.30mm, angular with high sphericity
- 0.06mm x 0.02mm, tabular shape

Quartz (10%, frequency: few) – predominantly very fine sand quartz grains with some coarse sand grains. Some quartz grains show fractures with slight fills. Grains exhibit undulose extinction and have sharp boundaries throughout.

Inclusion size range:

- 0.63mm x 0.58mm, rounded with high sphericity
- 0.16mm x 0.08mm, sub-angular with low sphericity
- 0.04mm x 0.03mm, sub-angular with low sphericity

Opaque minerals (3%, frequency: very few) – very fine sand inclusions, most inclusions are either spherical or sub-rounded and slightly elongate. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.16mm x 0.03mm, slightly tabular shape
- 0.13mm x 0.07mm, sub-rounded with low sphericity
- 0.04mm x 0.02mm, elongate shape

Clay pellets (3%, frequency: very few) – clay pellets are found spread throughout the sample. All clay pellets seem to be of a similar composition.

Inclusion size range:

- 1.13mm x 1.09mm
- 0.27mm x 0.17mm
- 0.09mm x 0.07mm

Plagioclase (3%, frequency: very few) – low amounts of medium sand inclusions spread through the sample. Boundaries are sharp to diffuse throughout.

Inclusion size range:

- 0.44mm x 0.45mm, equant shape
- 0.26mm x 0.18mm, sub-angular with high sphericity
- 0.25mm x 0.21mm, sub-angular with high sphericity

Biotite (2%, frequency: very few) – euhedral, fine sand biotite laths which are not part of the clay matrix are visible throughout. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.24mm x 0.02mm, lath shape
- 0.20mm x 0.01mm, lath shape
- 0.08mm x 0.01mm, lath shape

Hornblende (1%, frequency: rare) – subhedral, very fine sand to fine sand inclusions. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.16mm x 0.04mm, angular with low sphericity
- 0.1mm x 0.14mm, angular with high sphericity
- 0.12mm x 0.05mm, angular with low sphericity

Clinopyroxene (<1%, frequency: rare) – subhedral, coarse silt grains visible in sample. Boundaries are mostly diffuse throughout.

Inclusion size range:

- 0.06mm x 0.02mm, angular with low sphericity
- 0.04mm x 0.04mm, equant shape
- 0.04mm x 0.03mm, equant shape

Granodiorite (<1%, frequency: rare) - one very coarse sand inclusion with a composition of plagioclase, quartz, minor k-feldspar and accessory minerals of hornblende and mica. Inclusion is 2.41mm x 0.86mm in size with clear to merging boundaries. All quartz and feldspars are fractured and filled by mica.

### **Voids** (10%)

Macro and meso planar voids as well as macro and meso vugh voids with a few mega vugh voids are present in the sample. Voids do not have a distinct orientation due to the erosive nature of the sample.

Size range of planar voids:

- 0.82mm x 0.07mm
- 0.39mm x 0.03mm
- 0.16mm x 0.01mm

Size range of vugh voids:

- 3.57mm x 0.67mm
- 1.85mm x 0.53mm
- 0.09mm x 0.05mm

### **Clay Matrix** (55%)

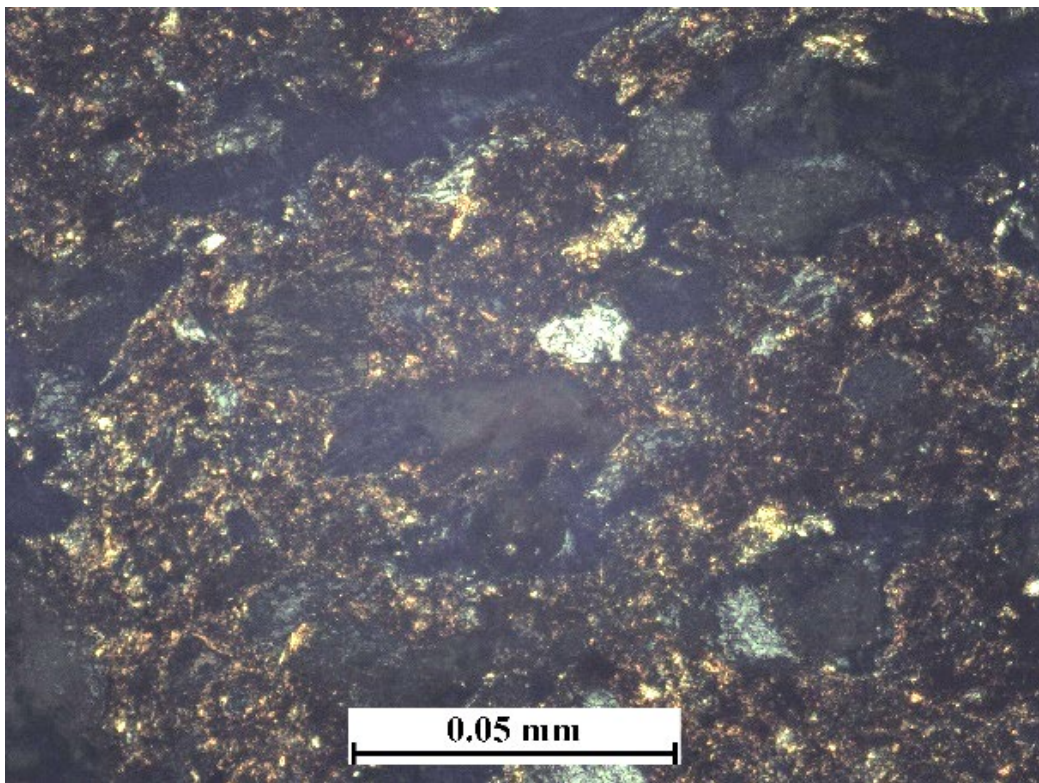


**Figure 9: Clay matrix in XPL**

Clay matrix is reddish brown in colour with both biotite and muscovite laths and fine silt quartz throughout the matrix. The outer edges of sample have higher optical activity levels than the centre, due to uneven firing and a low firing temperature. Smaller clay pellets (<0.02mm) of the same composition as the larger ones are visible throughout the entire matrix.

### **Mineral Orientation**

The minerals in the sample are randomly orientated and show signs of pinching as the forming method used.

## SAMPLE 51

Site: Klein Bolayi

Macroscopic Fabric Group: J

Petrographic Fabric: Grog-quartz-feldspars

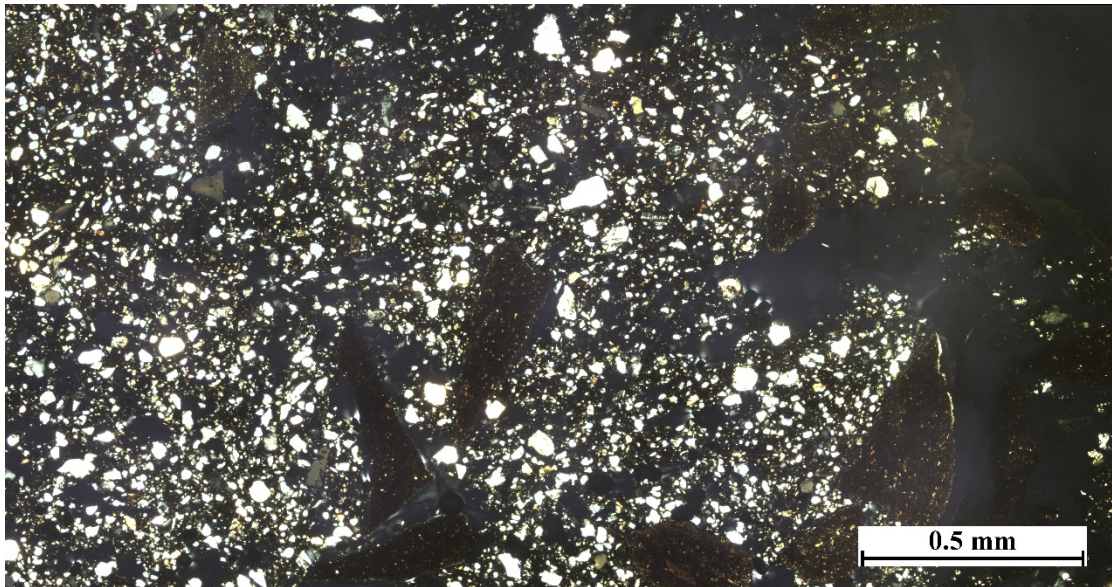


Figure 10: Sample 51 in XPL

### Mineralogy

Quartz (13%, frequency: few) – very fine sand, fine sand and lesser amount of medium sand grain inclusions are present. Undulose extinction is visible in the quartz grains. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.50mm x 0.29mm, sub-angular with low sphericity
- 0.24mm x 0.15mm, angular with low sphericity
- 0.14mm x 0.07mm, sub-angular with low sphericity

Grog (10%, frequency: few) – the sample has a total of 40 grog inclusions spread throughout the sample. All grog inclusions seems to be of similar composition throughout the whole sample. All grog inclusions are mostly clustered in the bottom left corner of the sample. All grog inclusions are likely a result of the same relic vessel.

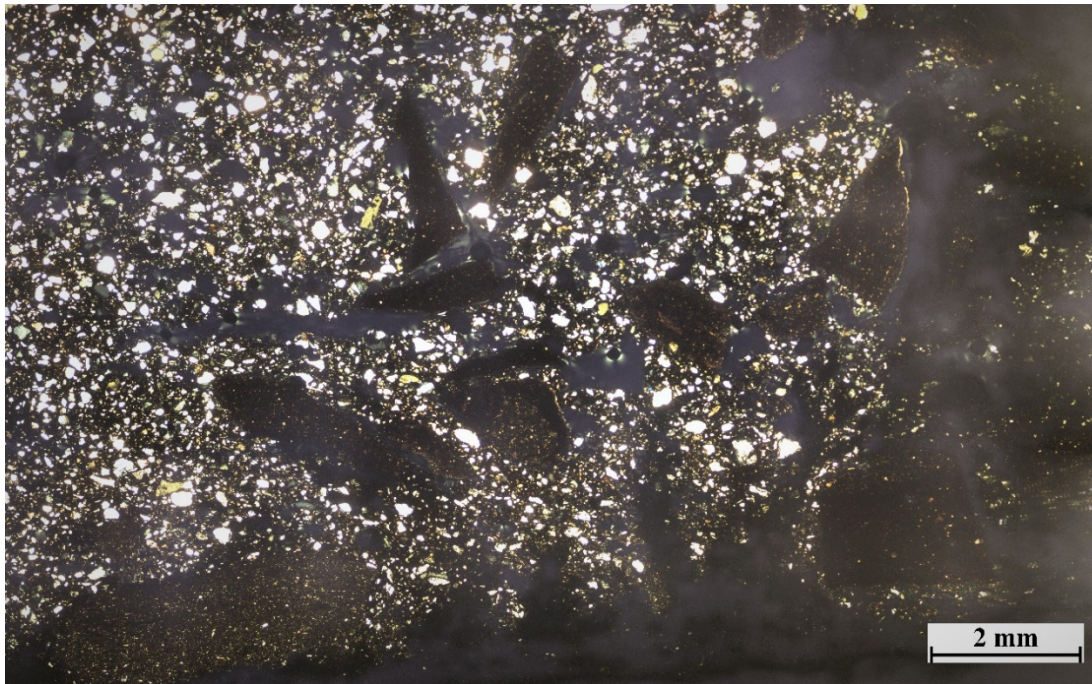


**Figure 11: Grog cluster in XPL**

Inclusion size range:

- 4.19mm x 1.29mm
- 2.05mm x 1.80mm
- 1.50mm x 0.65mm
- 1.48mm x 0.57mm
- 0.59mm x 0.29mm

K-Feldspar (7%, frequency: few) – euhedral and subhedral medium silt to very fine sand grains are present. Boundaries are sharp throughout.

Inclusion size range:

- 0.17mm x 0.12mm, angular with high sphericity
- 0.07mm x 0.02mm, lath shape
- 0.06mm x 0.02mm, tabular shape

Opaque minerals (3%, frequency: very few) – coarse silt grains are present throughout the sample. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.08mm x 0.05mm, sub-rounded with high sphericity
- 0.06mm x 0.06mm, equant shape
- 0.06mm x 0.05mm, sub-rounded with high sphericity

Plagioclase (3%, frequency: very few) – euhedral and subhedral coarse silt and very fine sand inclusions are present. Boundaries are sharp throughout.

Inclusion size range;

- 0.08mm x 0.06mm, angular with low sphericity
- 0.07mm x 0.05mm, elongate shape
- 0.06mm x 0.06mm, equant shape

Clinopyroxene (1%, frequency: rare) – euhedral coarse silt to fine sand grains are present. Boundaries are diffuse to clear throughout.

Inclusion size range:

- 0.11mm x 0.11mm, equant shape
- 0.10mm x 0.04mm, elongate shape
- 0.04mm x 0.04mm, equant shape

Muscovite (<1%, frequency: rare) – euhedral very fine sand laths are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.16mm x 0.02, lath shape
- 0.13mm x 0.01mm, lath shape
- 0.06mm x 0.01mm, lath shape

### **Voids** (10%)

The sample displays macro and meso planar voids as well as macro and meso vugh voids.

Size range of planar voids:

- 0.31mm x 0.04mm
- 0.09mm x 0.02mm
- 0.04mm x 0.01mm

Size range of vugh voids:

- 1.24mm x 0.83mm
- 0.33mm x 0.12mm
- 0.11mm x 0.06mm

### **Clay Matrix (53%)**

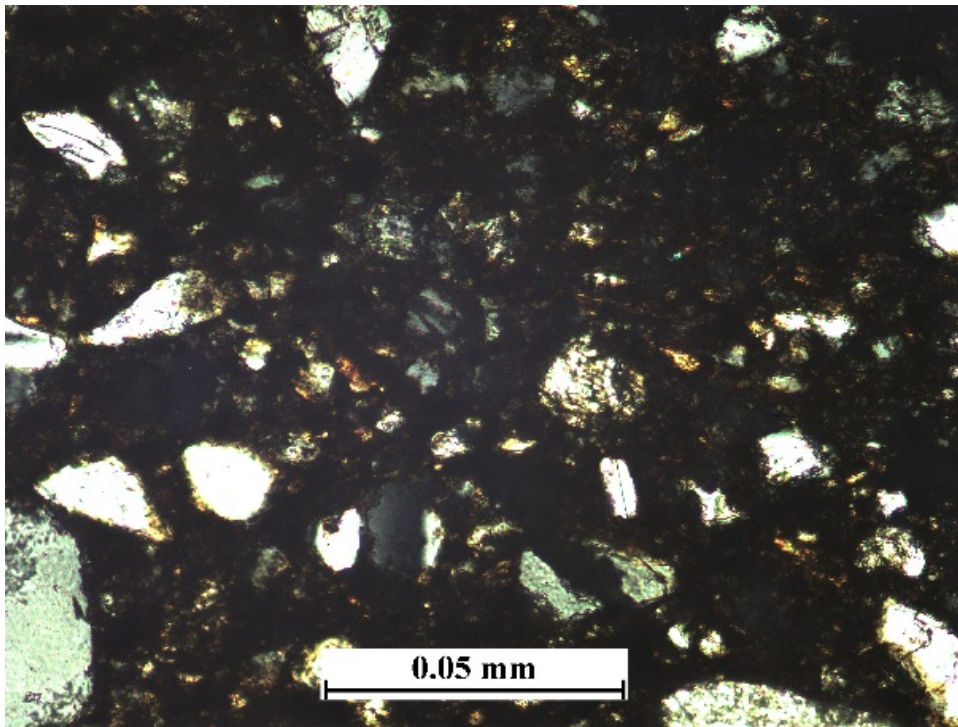


**Figure 12: Clay matrix in XPL**

The clay matrix is dark red-brown in colour with plastic quartz and k-feldspar laths with lesser amounts of mica laths. Moderate to low optical activity indicates low firing temperature. The top half of the sample shows slightly higher levels of optical activity which is likely a result of uneven firing temperatures.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 52

Site: Klein Bolayi

Macroscopic Fabric Group: G

Petrographic Fabric: Loner fabric olivine basalt-quartz-feldspars



Figure 13: Sample 52 in XPL

### Mineralogy

Quartz (12%, frequency: few) – predominantly medium silt to very fine sand inclusions present. Grains exhibit undulose extinction and have sharp boundaries throughout.

Inclusion size range:

- 0.41mm x 0.31mm, angular with high sphericity
- 0.33mm x 0.22mm, sub-angular with high sphericity
- 0.05mm x 0.02mm, sub-angular with low sphericity

Olivine basalt (10%, frequency: few) – poikilitic textured olivine basalt is found throughout the sample of fine sand to coarse sand grained inclusions. The olivine basalt is comprised of olivine, plagioclase laths, clinopyroxene and laths of opaque minerals.

Inclusion size range:

- 0.57mm x 0.36mm, angular with low sphericity
- 0.32mm x 0.28mm, very angular with high sphericity
- 0.16mm x 0.14mm, angular with high sphericity

K-Feldspar (6%, frequency: few) – euhedral and anhedral inclusions, medium silt to very coarse sand grain inclusions are present in the sample. 90° cleavage angles are visible. Boundaries are sharp to clear throughout.

Inclusion size range:

- 1.17mm x 0.22mm, tabular shape, likely sanidine
- 0.23mm x 0.02mm, lath shape
- 0.11mm x 0.07mm, sub-angular with low sphericity

Plagioclase (3%, frequency: very few) – subhedral to anhedral very fine sand to coarse sand inclusions are present in the sample. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.64mm x 0.60mm, angular with low sphericity
- 0.50mm x 0.38mm, sub-rounded with low sphericity
- 0.15mm x 0.10mm, sub-angular with low sphericity

Biotite (3%, frequency: very few) – euhedral, coarse silt to fine sand laths which are visible throughout. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.20mm x 0.01mm, lath shape
- 0.15mm x 0.02mm, lath shape
- 0.16mm x 0.02mm, tabular shape

Opaque minerals (1%, frequency: rare) – medium silt to coarse silt grains present in the sample. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.30mm x 0.01mm, sub-rounded with low sphericity
- 0.02mm x 0.01mm, sub-rounded with low sphericity
- 0.01mm x 0.01mm, sub-rounded with low sphericity

Muscovite (1%, frequency: rare) – euhedral fine silt to very fine sand inclusion are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.11mm x 0.02mm, tabular shape
- 0.07mm x 0.02mm, tabular shape
- 0.05mm x 0.01mm, lath shape

Hornblende (<1%, frequency: rare) – subhedral, coarse silt to very fine sand inclusions are present. Boundaries are diffuse throughout.

Inclusion size range:

- 0.13mm x 0.08mm, prismatic shape
- 0.12mm x 0.04mm, prismatic shape
- 0.10mm x 0.09mm, angular with high sphericity

### **Voids** (8%)

Macros and meso planar voids as well as meso vugh voids are present in the sample.

Size range of planar voids:

- 0.97mm x 0.07mm
- 0.30mm x 0.04mm
- 0.09mm x 0.03mm

Size range of vugh voids:

- 0.20mm x 0.11mm
- 0.10mm x 0.05mm
- 0.08mm x 0.05mm

### **Clay Matrix** (56%)

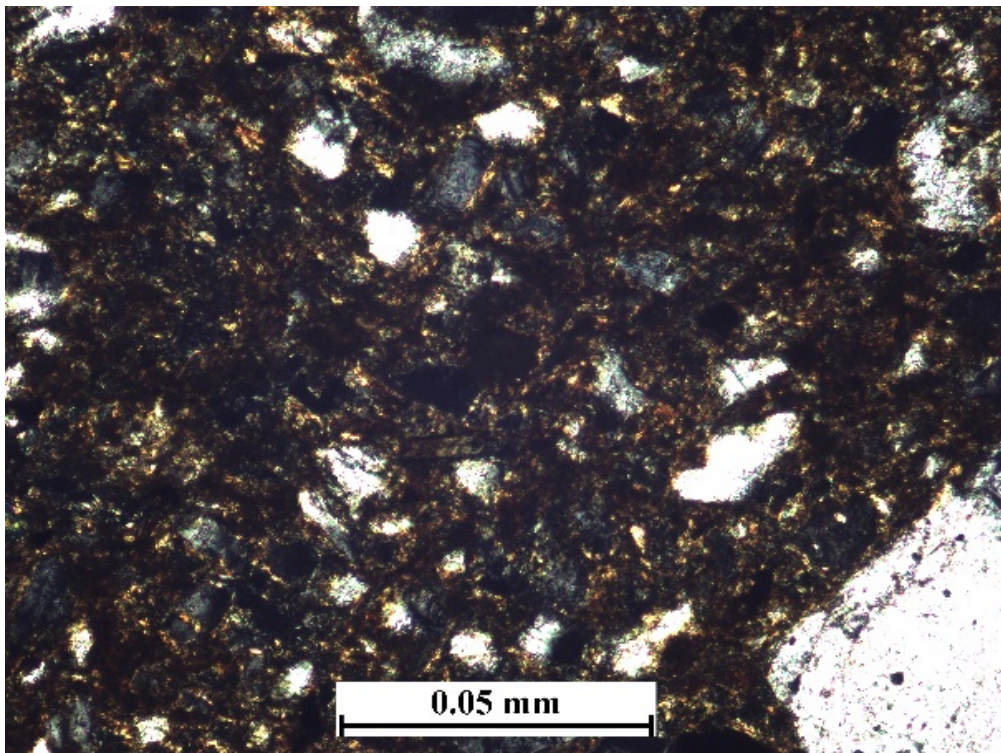


**Figure 14: Clay matrix XPL**

The clay matrix is orange-brown in colour with high optical activity due to low firing temperatures. The plastic inclusions of the clay matrix are predominantly quartz with small amount biotite laths.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 54

Site: Klein Bolayi

Macroscopic Fabric group: M

Petrographic Fabric: Grog-quartz-feldspars

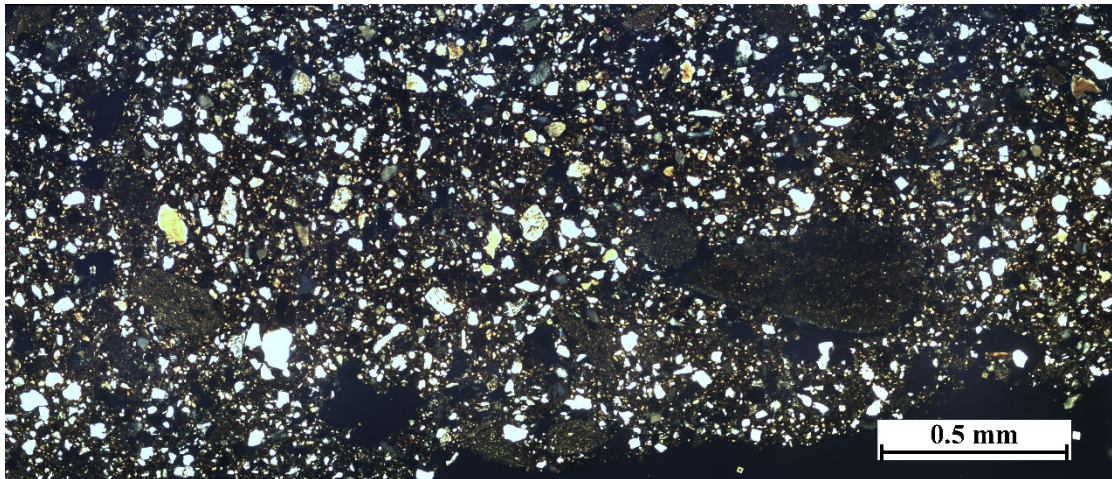


Figure 15: Sample 54 in XPL

### Mineralogy

Quartz (10%, frequency: few) - grain size varies largely from coarse silt grains to medium sand. Undulose extinction is visible in the inclusions. Boundaries are sharp throughout.

Inclusion size range:

- 0.15mm x 0.19mm, angular with high sphericity.
- 0.06mm x 0.05mm, sub-rounded with low sphericity.
- 0.43mm x 0.28mm, angular with high sphericity.

Grog (9%, frequency: few) – the sample has a total of 47 grog inclusions spread throughout the sample. The bottom, right corner has a cluster of 15 grog inclusions. All grog seems to be of similar composition throughout the whole sample. All grog inclusions are likely a result of the same relic vessel.

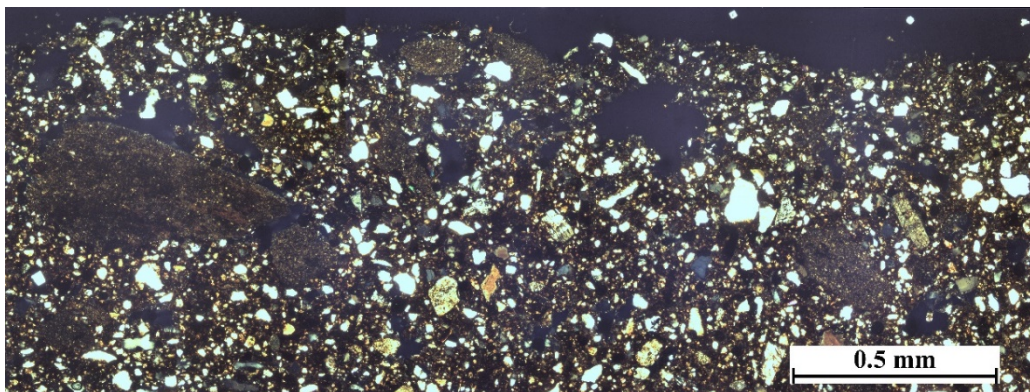


Figure 16: Grog cluster in XPL

Inclusion size range:

- 2.73mm x 1.14mm
- 2.66mm x 1.35mm
- 0.86mm x 26mm
- 0.70mm x 0.42mm
- 0.27mm x 0.15mm

K-Feldspar (7%, frequency: few) - subhedral and anhedral inclusions. Grain sizes vary from coarse silt to medium sand. 90° cleavage angles are visible. Some grains show signs of fracturing. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.40mm x 0.38mm, very angular with high sphericity
- 0.19mm x 0.15mm, very angular with high sphericity
- 0.08mm x 0.03mm, very angular with low sphericity

Plagioclase (5%, frequency: few) - euhedral and subhedral fine sand grains are found throughout the sample. Boundaries are sharp throughout.

Inclusion size range:

- 0.21mm x 0.15mm, sub-angular with low sphericity
- 0.10mm x 0.15mm, sub-angular with high sphericity
- 0.27mm x 0.09mm, tabular shape

Muscovite (3%, frequency: very few) – euhedral coarse silt and very fine sand inclusions are present in the sample. These inclusions are larger than the muscovite laths present within the clay matrix. Boundaries are clear throughout

Inclusion size range:

- 0.11mm x 0.06mm, tabular shape
- 0.05mm x 0.01mm, lath
- 0.04mm x 0.004mm, lath

Microcline (2%, frequency: very few) – subhedral, fine sand grains present in the sample. Characteristic tartan twinning is visible in the inclusions. Boundaries are sharp throughout.

Inclusion size range:

- 0.22mm x 0.12mm, very angular with low sphericity
- 0.19mm x 0.11mm, angular with low sphericity
- 0.18mm x 0.14mm, sub-angular with low sphericity

Opaque minerals (1%, frequency: rare) – very fine sand inclusions are present in the sample. Majority of the inclusion have a higher sphericity but have not distinctive shape. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.27mm x 0.11mm, angular with low sphericity
- 0.13mm x 0.10mm, angular with high sphericity
- 0.10mm x 0.05mm, sub-angular with high sphericity

Clinopyroxene (1%, frequency: rare) – subhedral and anhedral grains of fine sand are present in the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.16mm x 0.04mm, sub-rounded with low sphericity
- 0.13mm x 0.08mm, very angular with low sphericity
- 0.12mm x 0.10mm, equant shape

Hornblende (>1%, frequency: rare) – subhedral, very fine sand grains present in the sample. Parallel cleavage system and 120° angle cleavages are visible. Boundaries are clear throughout.

Inclusion size range:

- 0.10mm x 0.06mm, sub-angular with low sphericity
- 0.12mm x 0.03mm, sub-rounded with low sphericity
- 0.07mm x 0.05mm, sub-angular with low sphericity

Biotite (>1%, frequency: rare) – euhedral fine sand and medium sand grains are present in the sample. Boundaries are clear throughout.

Inclusion size range:

- 0.35mm x 0.12mm, tabular shape
- 0.29mm x 0.05mm, tabular shape
- 0.10mm x 0.03mm, lath shape

### **Voids** (10%)

The sample has a combination of macro and meso planar voids as well as macro and meso vugh voids. Majority of the voids are vugh voids.

Size range of planar voids:

- 0.95mm x 0.19mm
- 0.17mm x 0.03mm
- 0.15mm x 0.02mm

Size range of vugh voids:

- 1.01mm x 0.57mm
- 0.44mm x 0.19mm
- 0.18mm x 0.09mm

### **Clay Matrix (50%)**

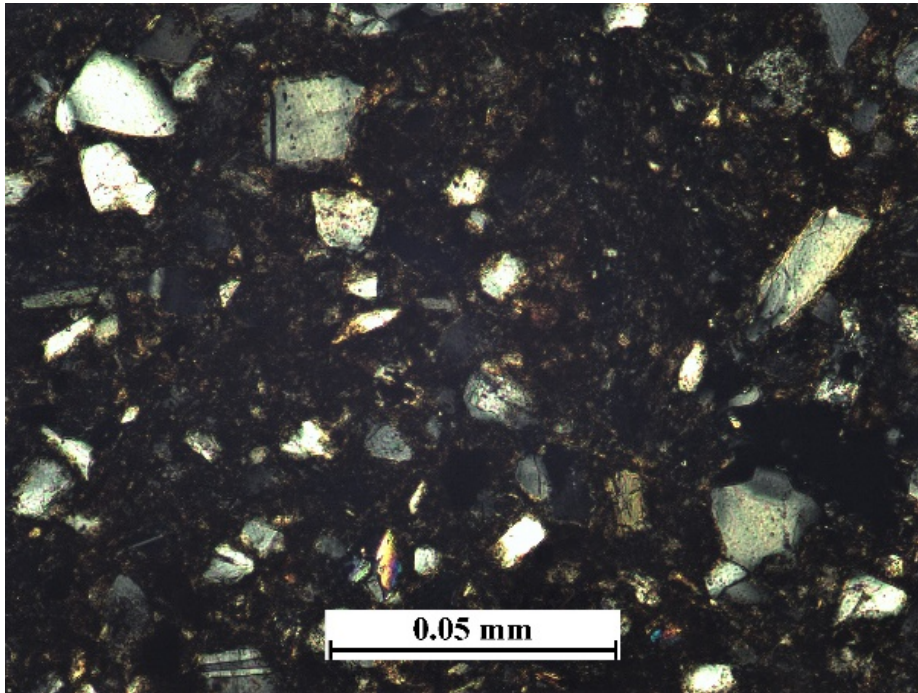


**Figure 17: Clay matrix in XPL**

The clay matrix is dark reddish-brown in colour with both biotite and muscovite laths and fine silt quartz throughout the matrix. High optical activity indicates a low firing temperature. The bottom half of the sample shows higher levels of optical activity which is likely a result of uneven firing temperatures.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 72

Site: Klein Bolayi

Macroscopic Fabric Group: H

Petrographic Fabric: Quartz-feldspars-mica

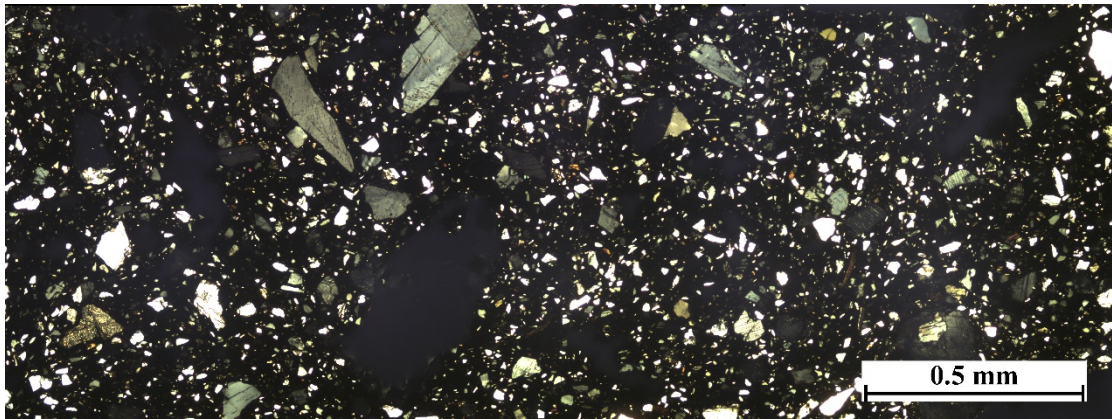


Figure 18: Sample 72 in XPL

### Mineralogy

Quartz (13%, frequency: few) – predominantly coarse silt to fine sand present in the sample. Grains exhibit undulose extinction and have sharp boundaries throughout.

Inclusion size range:

- 0.28mm x 0.17mm, very angular with low sphericity
- 0.07mm x 0.06mm, angular with high sphericity
- 0.03mm x 0.03mm, very angular with high sphericity

K-Feldspar (10%, frequency: few) – euhedral and anhedral inclusions, predominantly coarse silt to fine sand. 90° cleavage angles are visible. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.27mm x 0.18mm, sub-rounded with low sphericity
- 0.15mm x 0.07mm, angular with low sphericity
- 0.09mm x 0.04mm, angular with low sphericity

Biotite (5%, frequency: few) – euhedral, fine silt to very fine sand laths which are visible throughout. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.07mm x 0.02mm, lath shape
- 0.06mm x 0.01mm, lath shape
- 0.04mm x 0.01mm, lath shape

Plagioclase (3%, frequency: very few) – medium silt to very fine sand inclusions found through the sample. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.10mm x 0.05mm, sub-rounded with low sphericity
- 0.07mm x 0.05mm, sub-rounded with high sphericity
- 0.01mm x 0.01mm, angular with high sphericity

Opaque minerals (3%, frequency: rare) - medium silt to coarse silt grains present in the sample. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.04mm x 0.04mm, equant
- 0.03mm x 0.01mm, sub-rounded with low sphericity
- 0.01mm x 0.01mm, sub-rounded with high sphericity

Hornblende (2%, frequency: very few) – euhedral and subhedral, fine silt to coarse silt inclusions are present. Many hornblende inclusions are fractured. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.06mm x 0.02mm, angular with low sphericity
- 0.05mm x 0.05mm, equant shape
- 0.02mm x 0.01mm, angular with low sphericity

Granite (<1%, frequency: rare) - two very fine sand inclusions are present in the sample. The granite is comprised of quartz, K-feldspar, plagioclase, with mica as the accessory mineral.

Inclusion size range:

- 0.17mm x 0.11mm, sub-angular with low sphericity
- 0.13mm x 0.10mm, angular with high sphericity

Granodiorite (<1%, frequency: rare) - a single medium sand granodiorite inclusion is present in the sample. The inclusion is comprised of plagioclase, quartz, K-feldspar, and mica as the accessory mineral.

Inclusion size range:

- 0.52mm x 0.18mm, angular with low sphericity

### **Voids** (10%)

Meso planar voids as well as meso and micro vugh voids are present in the sample.

Size range of planar voids:

- 0.47mm x 0.01mm
- 0.45mm x 0.08mm
- 0.29mm x 0.02mm

Size range of vugh voids:

- 0.54mm x 0.25mm
- 0.22mm x 0.15mm
- 0.04mm x 0.03mm

### **Clay Matrix** (54%)

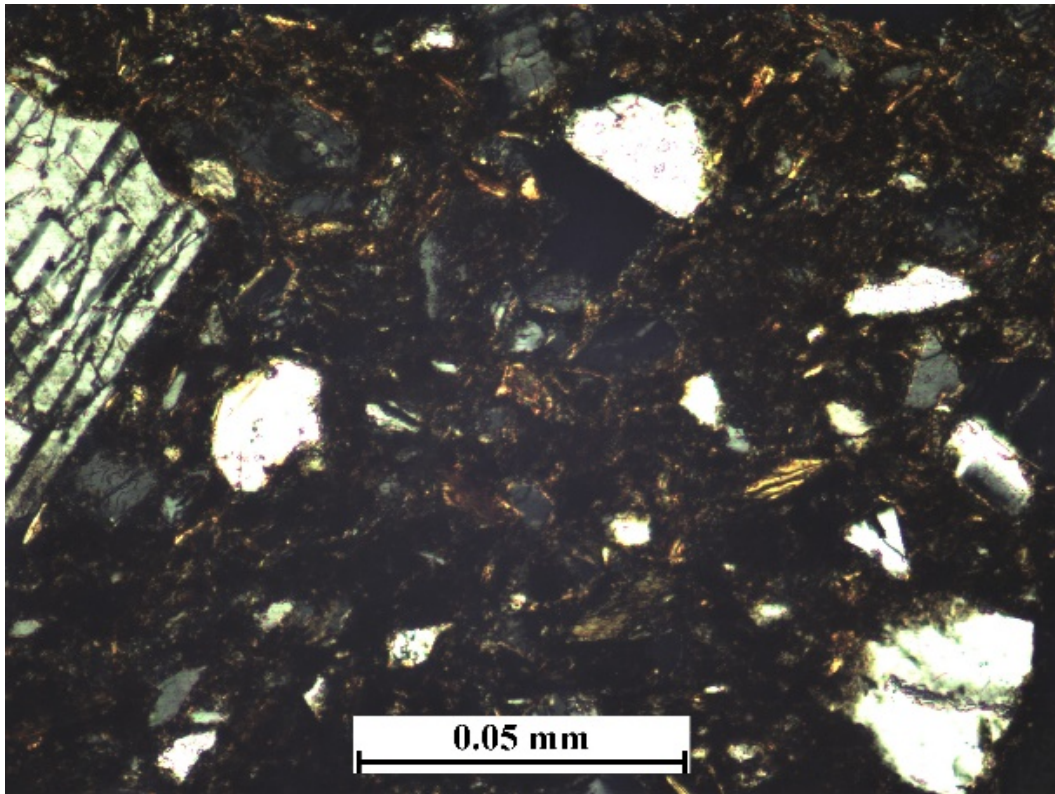


**Figure 19: Clay matrix XPL**

The clay matrix is dark reddish-brown in colour with high optical activity. Variation in optical activity is present with the centre being less optically active due to uneven firing. The plastic inclusions of the clay matrix are equally quartz and biotite laths.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 74

Site: Klein Bolayi

Macroscopic Fabric group: L

Petrographic Fabric: Sub-fabric quartz-feldspars-mica with grog

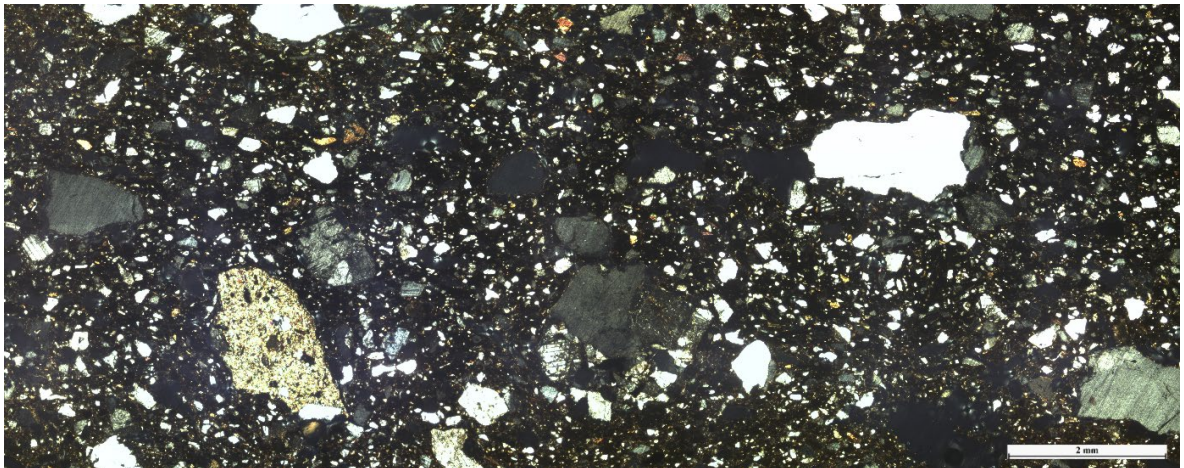


Figure 20: Sample 74 in XPL

### **Mineralogy:**

Quartz (12%, frequency: few) – coarse silt to very fine sand inclusions. Inclusions display undulose extinction. Larger grains have visible fractures which have been filled by the surrounding clay matrix. Boundaries are sharp throughout.

Inclusion size range:

- 0.74mm x 0.67mm, very angular with high sphericity
- 0.09mm x 0.06mm, sub-angular with high sphericity
- 0.04mm x 0.02mm, sub-rounded with low sphericity

Plagioclase (10%, frequency: few) - subhedral, fine sand to medium sand inclusions are found in this sample. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.78mm x 0.49mm, sub-angular with low sphericity
- 0.24mm x 0.15mm, sub-rounded with low sphericity
- 0.10mm x 0.10mm, equant shape

K-Feldspar (7%, frequency: few) – anhedral and subhedral, very fine sand to very coarse sand grains present. Boundaries are sharp to clear throughout.

Inclusion size range:

- 1.76mm x 1.48mm, angular with high sphericity
- 0.95mm x 0.63mm, sub-rounded with low sphericity
- 0.19mm x 0.11mm, angular with low sphericity.

Opaque minerals (3%, frequency: very few) – coarse silt to fine sand inclusions are present. Inclusions all have high sphericity. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.22mm x 0.13mm, sub-angular with high sphericity
- 0.08mm x 0.05mm, angular with high sphericity
- 0.03mm x 0.02 mm, rounded with high sphericity

Granite (1%, frequency: rare) – coarse sand to very coarse sand inclusions are visible in the sample. The granite inclusions are comprised of k-feldspar, plagioclase and mica as the accessory mineral. Boundaries are sharp to clear throughout.

- 2.07mm x 0.71mm, very angular with low sphericity
- 1mm x 0.45mm, sub-angular with low sphericity
- 0.90mm x 0.77mm, angular with high sphericity

Biotite (1%, frequency: rare) – euhedral medium silt to very fine sand inclusions are present. Boundaries are sharp throughout.

Inclusion size range:

- 0.18mm x 0.06mm, tabular
- 0.17mm x 0.02mm, lath
- 0.15mm x 0.01mm, lath

Hornblende (1%, frequency: rare) – subhedral and anhedral medium silt to very fine sand inclusions. Distinctive 120° cleavage angles are visible. Boundaries are sharp throughout.

Inclusion size range:

- 0.20mm x 0.09mm, angular with low sphericity
- 0.18mm x 0.07mm, angular with low sphericity
- 0.12mm x 0.05, angular with low sphericity

Clay pellets (<1%, frequency: rare) - Clay pellets can be found spread throughout the sample. All clay pellets seem to be of the same composition.

Inclusion size range:

- 0.74mm x 0.29mm
- 0.50mm x 0.42mm
- 0.34mm x 0.21mm

Granodiorite (<1%, frequency: rare) - A single very coarse sand inclusion 1.97mm x 1.84mm in size comprised of plagioclase, quartz, k-feldspar, and hornblende and mica as accessory minerals. Inclusion is very angular with high sphericity and clear boundaries.

Grog (<1%, frequency: rare) – a single grog inclusion, 1.88mm x 1.25mm in size, is visible in the sample. Quartz and mica aplastic inclusions can be seen within the grog.

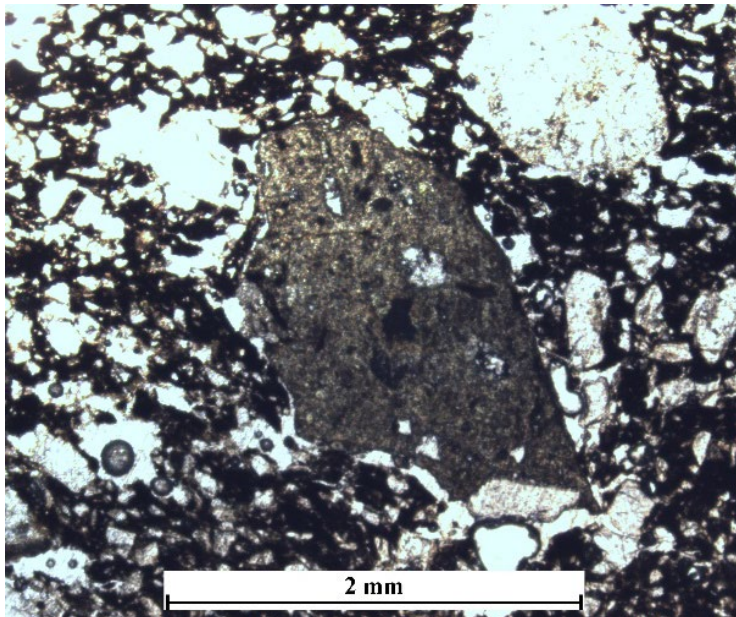


Figure 21: Grog in PPL

### Voids (8%)

Meso planar voids as well as meso and macro vugh voids are present in the sample. Voids do not have a distinct orientation.

Size range of planar voids:

- 0.28mm x 0.06mm
- 0.24mm x 0.05mm
- 0.22mm x 0.03mm

Size range of vugh voids:

- 0.86mm x 0.64mm
- 0.84mm x 0.46mm
- 0.26mm x 0.15mm

### **Clay Matrix (55%)**

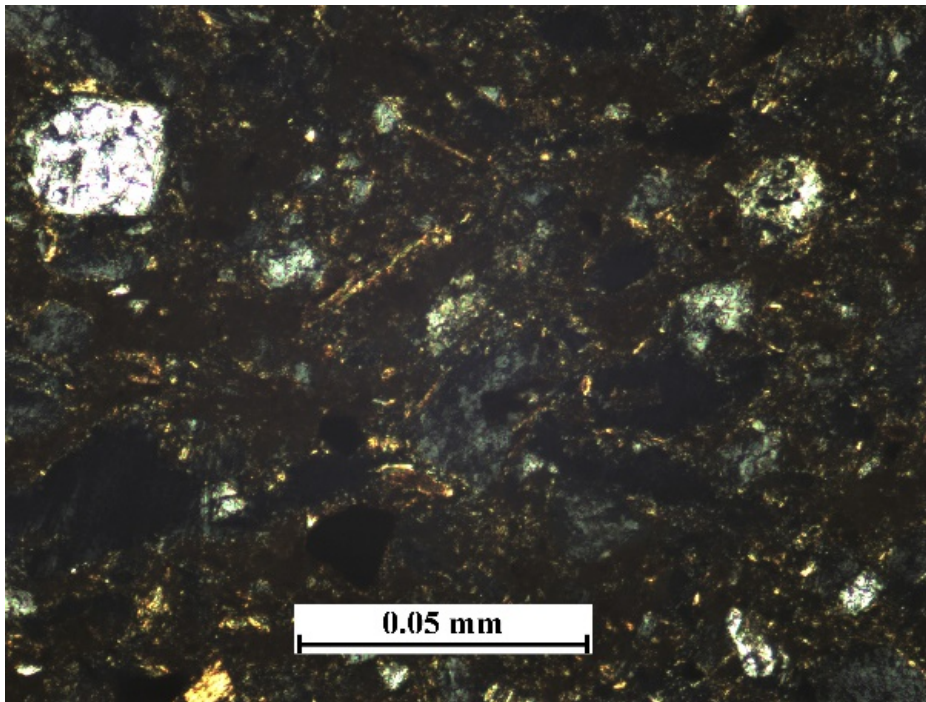


**Figure 22: Clay matrix in XPL**

The clay matrix is reddish-brown with moderate optical activity as a result of low firing temperatures. Variation in optical activity is present with the centre being less optically active due to uneven firing. The plastic inclusions of the clay matrix are biotite and muscovite laths as well as quartz grains.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 109

Site: Evelyn

Macroscopic Fabric Group: A

Petrographic Fabric: Quartz-feldspars-mica

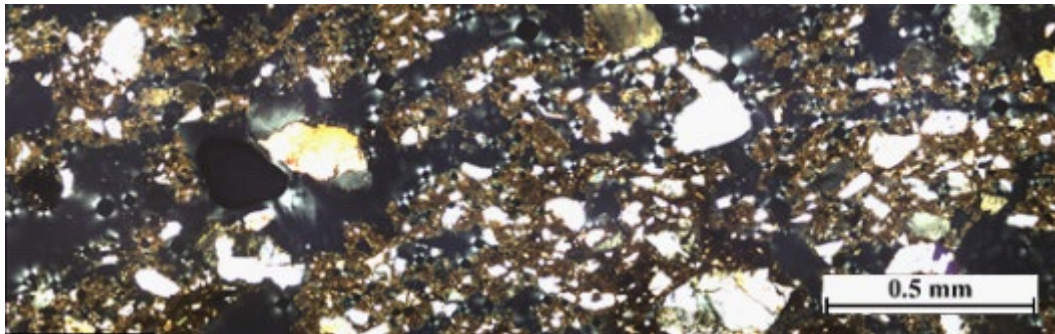


Figure 23: Sample 109 in XPL

### Mineralogy

Quartz (12%, frequency: few) – fine silt to granule size inclusions are present. Larger quartz grains all show visible undulose extinction. Borders are sharp throughout.

Inclusion size range:

- 3.41mm x 1.41mm, angular with low sphericity
- 0.32mm x 0.15mm, angular with low sphericity
- 0.01mm x 0.01mm, sub-angular with high sphericity

K-Feldspar (9%, frequency: few) – subhedral and anhedral very fine sand to coarse sand inclusions are present. Majority of the inclusions are fractured with some being slightly filled by the clay matrix. Borders are sharp throughout.

Inclusion size range:

- 0.74mm x 0.69mm, equant shape
- 0.57mm x 0.08mm, tabular shape, likely sanidine
- 0.08mm x 0.07mm, angular with high sphericity

Plagioclase (5%, frequency: few) – euhedral and subhedral very fine sand to medium sand inclusions are present. Some inclusions are fractured and are partially replaced. Borders are clear to sharp throughout.

Inclusion size range:

- 0.53mm x 0.15mm, elongate shape
- 0.19mm x 0.18mm, angular with high sphericity
- 0.15mm x 0.09mm, elongate shape

Biotite (3%, frequency: very few) – euhedral very fine silt to very fine sand inclusions are present. Distinctive bird's eye distinction is visible throughout. Borders are sharp to clear throughout.

Inclusion size range:

- 0.19mm x 0.04mm, tabular shape
- 0.10mm x 0.01mm, lath shape
- 0.06mm x 0.005mm, lath shape

Hornblende (3%, frequency: very few) – subhedral very fine sand to fine sand inclusions are present. Inclusions show distinctive 120° angle cleavage. Borders are mostly diffuse throughout.

Inclusion size range:

- 0.23mm x 0.11mm, angular with low sphericity
- 0.15mm x 0.03mm, angular with low sphericity
- 0.11mm x 0.06, elongate shape

Opaque minerals (2%, frequency: very few) – coarse silt to very fine sand inclusions. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.13mm x 0.11mm, equant shape
- 0.11mm x 0.04mm, sub-rounded with low sphericity
- 0.03mm x 0.01mm, sub-angular with low sphericity

Granite (1%, frequency: rare) – two coarse grain inclusions are present in the sample. The granite is comprised of quartz, k-feldspar, plagioclase and mica as the accessory mineral. Boundaries are clear throughout.

Inclusion size range:

- 1.95mm x 1.27mm, sub-angular with low sphericity
- 1.36mm x 0.91mm, angular with high sphericity

Granodiorite (1%, frequency: rare) – a single granule inclusion is visible within the sample. The granodiorite is comprised of quartz, plagioclase, and small amounts of k-feldspar with mica as the accessory mineral. The quartz is fractured and slightly filled. Boundaries are clear.

Inclusion size range:

- 3.04mm x 2.32mm, angular with low sphericity

Clay pellets (1%, frequency: rare) – some noticeable clay pellets with clear boundaries are found throughout. All pellets seem to be of similar compositions.

Inclusion size range:

- 0.58mm x 0.45mm
- 0.27mm x 0.14mm
- 0.11mm x 0.09mm

### **Voids** 15%

High percentage of voids is due to erosion of the ceramic. There are macro and meso planar voids as well as mega, macro and meso vugh voids.

Size range of planar voids:

- 1.01mm x 0.08mm
- 0.53mm x 0.02mm
- 0.09mm x 0.02mm

Size range of vugh voids:

- 3.99mm x 1.53mm
- 0.36mm x 0.15mm
- 0.07mm x 0.04mm

### **Clay Matrix** 48%

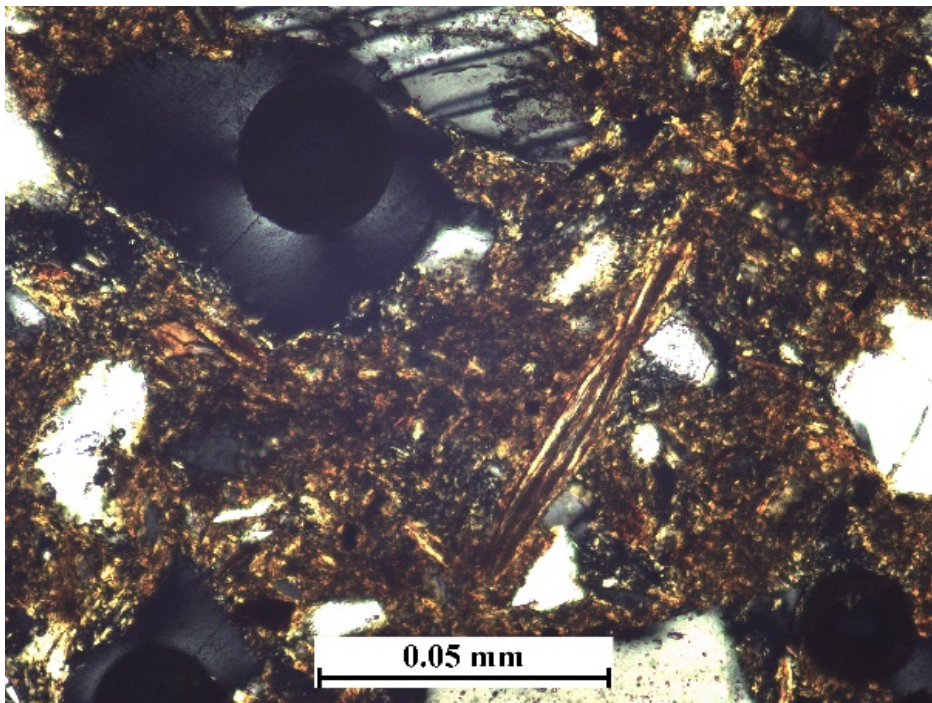


Figure 24: Clay matrix in XPL

The clay matrix is dark reddish-brown with moderate optical activity due to low firing temperatures. Variation in optical activity is visible with higher optical activity in the bottom half of the sample as a result of uneven firing. The plastic inclusions of the clay matrix are predominantly biotite and muscovite lathes with smaller amounts of quartz and clay pellets ( $<0.02\text{mm}$ ) mixed into the clay matrix.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 137

Site: Evelyn

Macroscopic Fabric Group: C

Petrographic Fabric: Sub-fabric quartz-feldspars-mica with grog

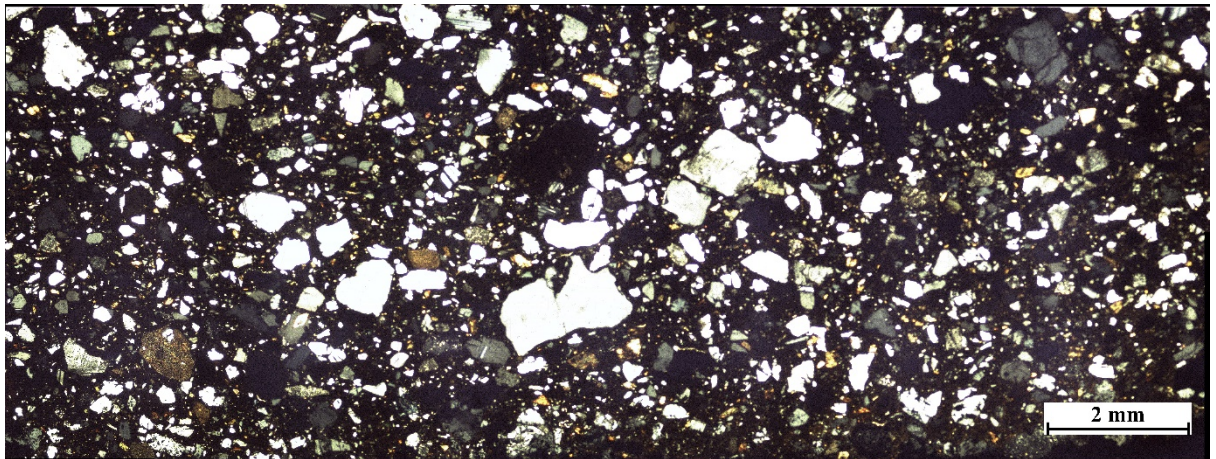


Figure 25: Sample 137 in XPL

### Mineralogy

Quartz (10%, frequency: few) – very fine sand to medium sand grains are present throughout the sample. Undulose extinction is visible in all the grains. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.63mm x 0.32mm, angular with low sphericity
- 0.39mm x 0.19mm, angular with low sphericity
- 0.07mm x 0.05mm, angular with low sphericity

K-Feldspar (7%, frequency: few) – subhedral and anhedral coarse silt to coarse sand inclusions are present. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.96mm x 0.34mm, sub-rounded with low sphericity
- 0.47mm x 0.38mm, sub-angular with low sphericity
- 0.12mm x 0.03mm, tabular

Plagioclase (6%, frequency: few) - anhedral fine sand grains are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.65mm x 0.30mm, sub-angular with low sphericity
- 0.25mm x 0.17mm, sub-angular with low sphericity

- 0.17mm x 0.13mm, sub-angular with low sphericity

Hornblende (4%, frequency: very few) – euhedral and anhedral very fine silt to very fine sand grains are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.16mm x 0.06mm, tabular shape
- 0.17mm x 0.15mm, angular with high sphericity
- 0.06mm x 0.06mm, prismatic shape

Clay pellets (2%, frequency: very few) – clay pellets are found spread throughout the sample. All the clay pellets seem to be of the same the same composition.

Inclusion size range:

- 0.78mm x 0.59mm
- 0.40mm x 0.26mm
- 0.26mm x 0.18mm

Opaque minerals (2%, frequency: very few) – very fine sand and fine sand grains are present in the sample. Roundness and sphericity varies greatly. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.22mm x 0.19mm, sub-angular with low sphericity
- 0.08mm x 0.07mm, angular with high sphericity
- 0.06mm x 0.06mm, sub-rounded with high sphericity

Biotite (1%, frequency: rare) – euhedral medium silt to very fine sand laths are present in the sample. Distinctive bird's eye extinction is visible. Boundaries are sharp throughout.

Inclusion size range:

- 0.11mm x 0.01mm, lath
- 0.07mm x 0.02mm, lath
- 0.07mm x 0.01mm, lath

Granite (>1%, frequency: rare) – two granite inclusions of coarse sand and granule grain sizes are present in the sample. The granite is comprised of k-feldspar, quartz, plagioclase and mica as the accessory mineral. Boundaries are sharp throughout.

Inclusion size range:

- 0.76mm x 0.42mm, sub-angular with high sphericity
- 2.32mm x 2.07mm, angular with high sphericity

Grog (<1%, frequency: rare) - a single grog inclusion, which is more visible in plane polarized light. The inclusion is 0.43mm x 0.29mm in size. Aplastic inclusions are

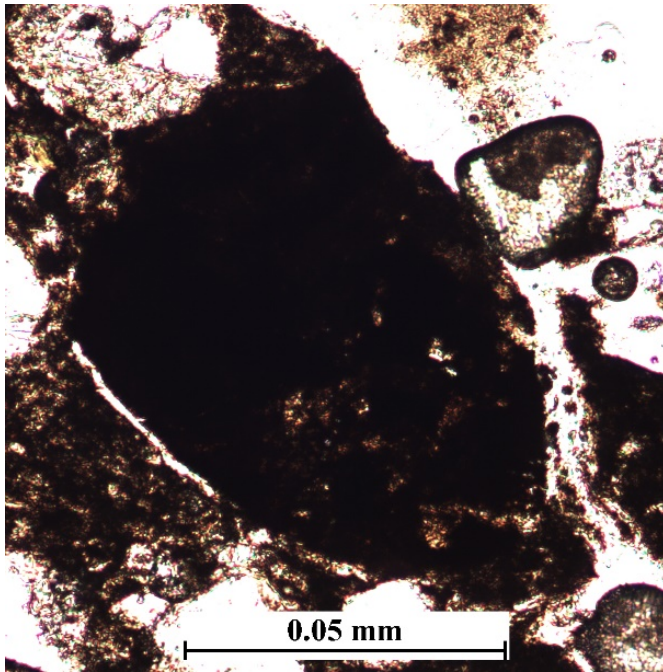


Figure 26: Grog in PPL

### **Voids** (13%)

Meso and macro planar voids as well as meso vugh voids are present in the sample. Voids do not have a distinct orientation.

Size range of planar voids:

- 1.39mm x 0.12mm
- 0.43mm x 0.04mm
- 0.22mm x 0.01mm

Size range of vugh voids:

- 0.62mm x 0.19mm
- 0.47mm x 0.22mm
- 0.25mm x 0.11mm

### **Clay Matrix** (54%)

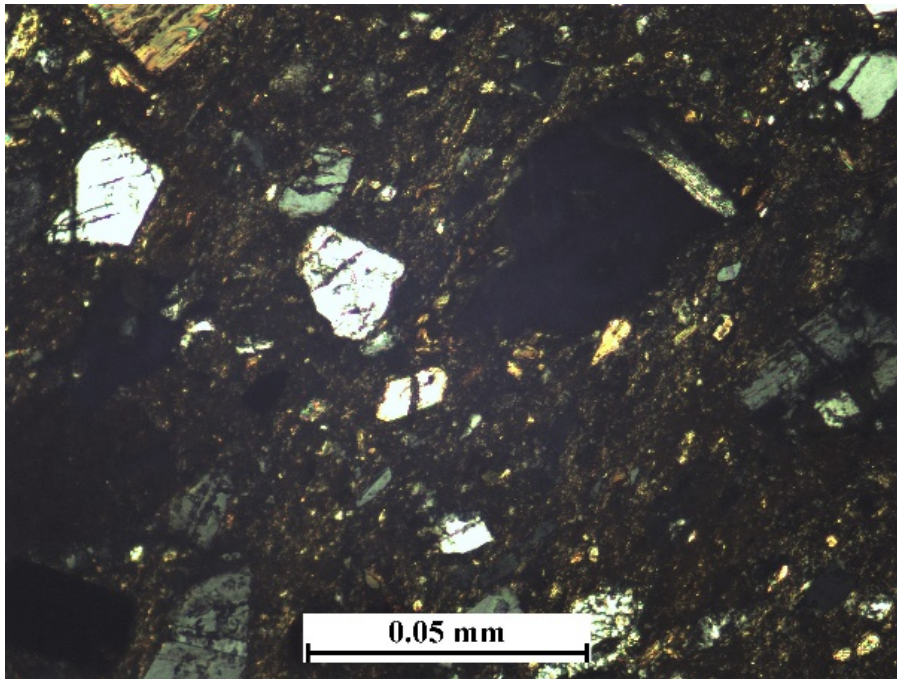


**Figure 27: Clay matrix in XPL**

The clay matrix is dark brownish-red with present optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix shows an abundance of hornblende as well as mica laths and quartz grains.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 139

Site: Evelyn

Macroscopic fabric group: D

Petrographic Fabric: Quartz-feldspars-mica

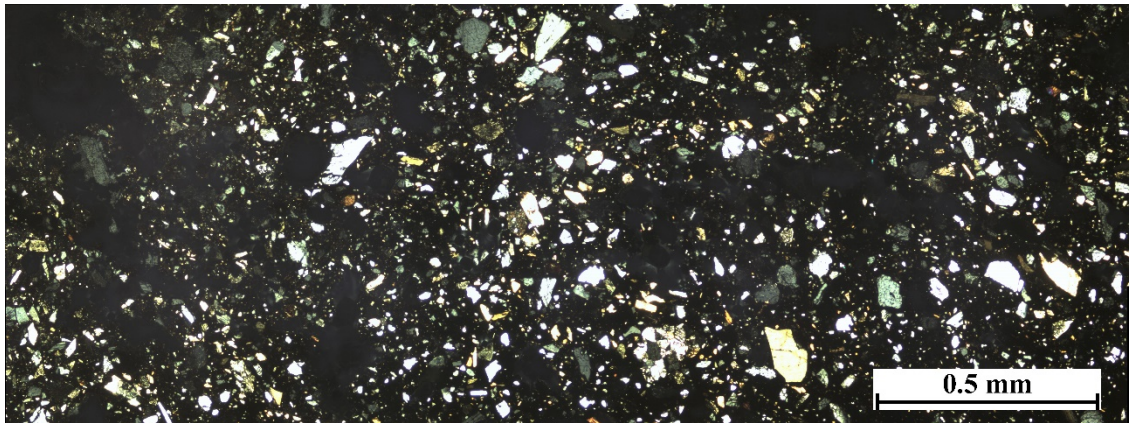


Figure 28: Sample 139 in XPL

### Mineralogy:

K-Feldspar (13%, frequency: few) – euhedral and anhedral inclusions, predominantly medium silt to very fine sand. 90° cleavage angles are visible. Boundaries are sharp to clear throughout.

Inclusion size range:

- 0.09mm x 0.05mm, very angular with low sphericity
- 0.08mm x 0.07mm, very angular with high sphericity
- 0.02mm x 0.02mm, sub-angular with high sphericity

Quartz (8%, frequency: few) – coarse silt to very fine sand inclusions present. Grains exhibit undulose extinction and have sharp boundaries throughout.

Inclusion size range:

- 0.13mm x 0.07mm, sub-angular with low sphericity
- 0.07mm x 0.04mm, very angular with low sphericity
- 0.03mm x 0.03mm, angular with high sphericity

Biotite (3%, frequency: very few) – euhedral, fine silt to coarse silt laths which are visible throughout. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.04mm x 0.01mm, tabular shape
- 0.03mm x 0.01mm, tabular shape
- 0.04mm x 0.005mm, lath shape

Hornblende (3%, frequency: very few) – subhedral, medium silt to very fine sand inclusions are present. Boundaries are clear to diffuse throughout.

Inclusion size range:

- 0.09mm x 0.04mm, elongate
- 0.04mm x 0.02mm, sub-rounded with low sphericity
- 0.02mm x 0.02mm, sub-angular with high sphericity

Plagioclase (1%, frequency: rare) – medium silt to very fine sand inclusions found through the sample. Boundaries are sharp to diffuse throughout.

Inclusion size range:

- 0.07mm x 0.03mm, angular with low sphericity
- 0.03mm x 0.01mm, sub-angular with low sphericity
- 0.02mm x 0.01mm, sub-rounded with low sphericity

Opaque minerals (1%, frequency: rare) – very fine silt to coarse silt grains present in the sample. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.03mm x 0.02mm, elongate
- 0.01mm x 0.01mm, rounded with high sphericity
- 0.01mm x 0.004mm, elongate

Clay pellets (<1%, frequency: rare) – a few clay pellets can be seen within the sample. All clay pellets are compositionally similar.

Inclusion size range:

- 0.04mm x 0.04mm
- 0.03mm x 0.02mm
- 0.03mm x 0.01mm

### **Voids** (15%)

The sample displays micro planar voids and meso vugh voids. The sample has a high percentage of voids due to high erosion within the sample.

Size range of planar voids:

- 0.05mm x 0.01mm
- 0.04mm x 0.01mm
- 0.03mm x 0.005mm

Size range of vugh voids:

- 0.36mm x 0.20mm
- 0.32mm x 0.27mm
- 0.08mm x 0.06mm

### **Clay Matrix (55%)**

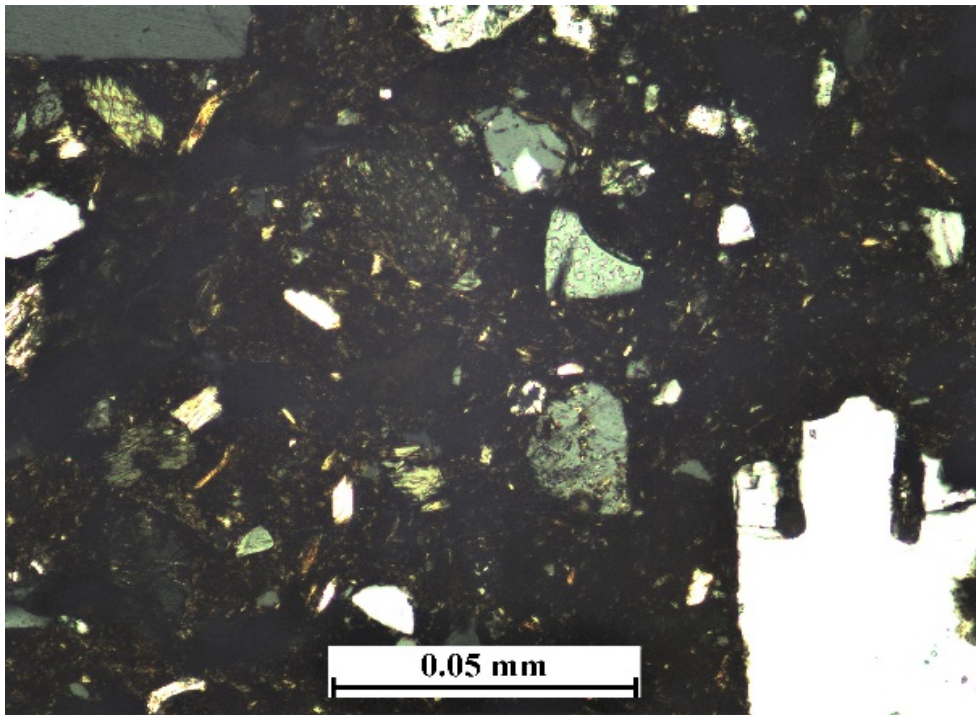


**Figure 29: Clay matrix XPL**

The clay matrix is dark reddish orange-brown with present optical activity. Variation in optical activity is present with the top half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix include K-feldspar laths, quartz and lower amounts of biotite laths.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 144

Site: Evelyn

Macroscopic Fabric Group: E

Petrographic Fabric: Quartz-feldspars-mica

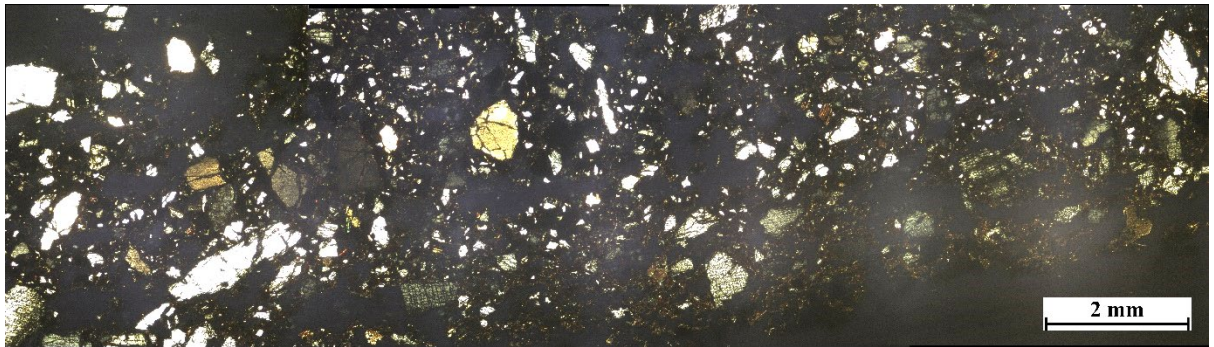


Figure 30: Sample 144 in XPL

### Mineralogy

Quartz (10%, frequency: few) – mostly medium sand grains with some very coarse sand grains and coarse silt. Grains show undulose extinction. Majority of the quartz grains are fractured. Boundaries are sharp throughout.

Inclusion size range:

- 0.91mm x 0.53mm, angular with low sphericity
- 0.51mm x 0.25mm, sub-angular with low sphericity
- 0.20mm x 0.13mm, sub-angular with high sphericity

K-Feldspar (10%, frequency: few) – large size variation across the sample of subhedral to euhedral coarse sand, medium sand and very fine sand inclusions. Boundaries are sharp throughout.

Inclusion size range:

- 1.82mm x 0.61mm, elongate shape
- 0.48mm x 0.46mm, equant shape
- 0.12mm x 0.08mm, sub-angular with high sphericity

Plagioclase (3%, frequency: very few) – subhedral fine sand and medium sand inclusions are present. Most of the inclusions are fractured but not filled. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.68mm x 0.59mm, sub-angular with low sphericity
- 0.55mm x 0.44mm, angular with high sphericity
- 0.18mm x 0.12mm, equant shape

Opaque minerals (3%, frequency: very few) – mostly coarse silt inclusions as well as very fine sand inclusions are present. Most inclusions have a high sphericity. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.09mm x 0.07mm, sub-angular with high sphericity
- 0.08mm x 0.03mm, sub-angular with low sphericity
- 0.07mm x 0.06mm, sub-rounded with high sphericity

Hornblende (2%, frequency: very few) – low amounts of euhedral and anhedral very fine sand fine sand inclusions are visible in the sample. Boundaries are clear throughout.

Inclusion size range:

- 0.35mm x 0.13mm, sub-angular with low sphericity
- 0.13mm x 0.06mm, elongate shape
- 0.14mm x 0.07mm, elongate shape

Clay pellets (1%, frequency: rare) – some clay pellets with a high optical activity are visible within the sample. All clay pellets seem to be of similar composition.

Inclusion size range:

- 0.74mm x 0.59mm
- 0.33mm x 0.22mm
- 0.23mm x 0.18mm

Granite (>1%, frequency: rare) – a single very coarse sand inclusion is present. Inclusion is comprised of quartz, k-feldspar, plagioclase, and mica as the accessory mineral. The grain has visible fractures which are slightly filled by the mica. The inclusion is 1.58mm x 1.29mm in size and is angular with high sphericity with clear boundaries.

### **Voids** (15%)

This high percentage of voids also included the voids which are as a result of the eroded nature of the ceramic sherd. Of the natural voids there are mega and meso planar voids as well as macro and meso vugh voids. The voids do not have a distinct orientation.

Size range of planar voids:

- 2.17mm x 0.26mm
- 0.35mm x 0.05mm
- 0.38mm x 0.06mm

Size range of vugh voids:

- 2.10mm x 0.70mm
- 1.15mm x 1.02mm
- 0.09mm x 0.05mm

**Clay matrix 56%**

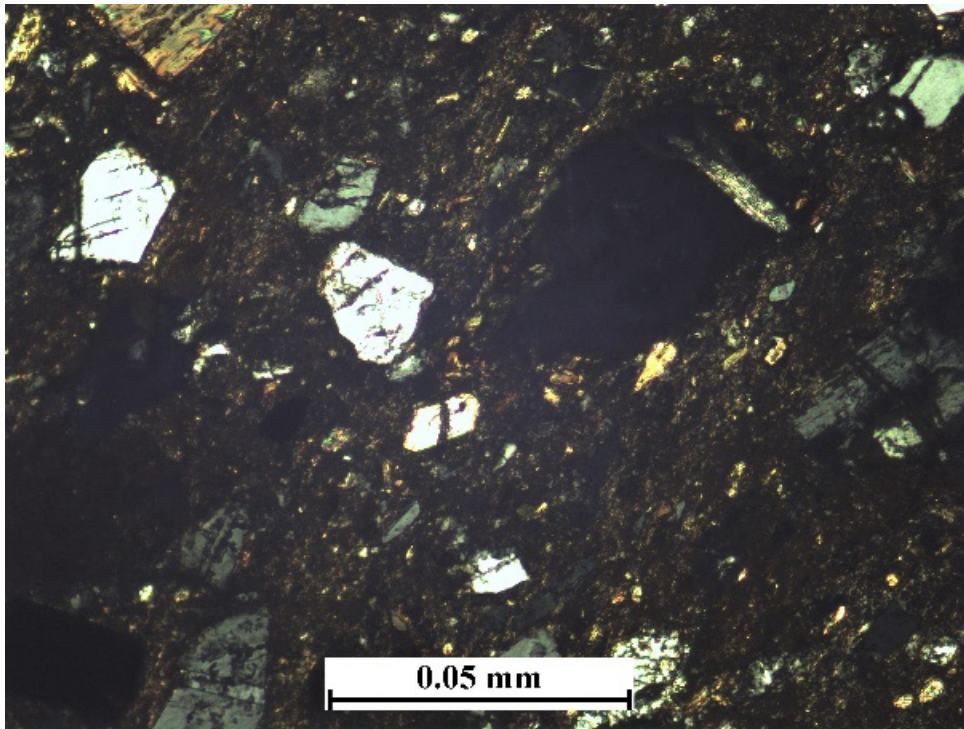


**Figure 31: Clay matrix in XPL**

The clay matrix is reddish-orange-brown in colour with moderate optical activity likely due to low firing temperatures. Variation in optical activity with a less optically active clay matrix centre shows signs of uneven firing. The plastic inclusions of the clay matrix are predominantly biotite and muscovite laths with smaller amounts of quartz grains and clay pellets.

**Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.

## SAMPLE 157

Site: Evelyn

Macroscopic Fabric Group: B

Petrographic Fabric: Sub-fabric quartz-feldspars-mica with grog

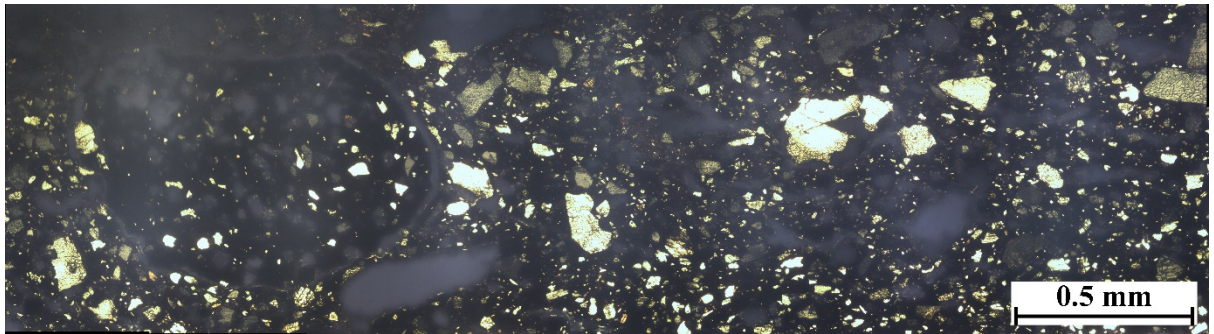


Figure 32: Sample 157 in XPL

### Mineralogy

Quartz (10%, frequency: few) – coarse silt to fine sand grain inclusions. Undulose extinction is visible. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.24mm x 0.20mm, sub-angular with high sphericity
- 0.08mm x 0.07mm, sub-angular with high sphericity
- 0.03mm x 0.01mm, sub-rounded with low sphericity

K-Feldspar (10%, frequency: few) – euhedral and anhedral coarse silt to medium sand grains are present. Boundaries are sharp throughout.

Inclusion size range:

- 0.47mm x 0.38mm, angular with high sphericity
- 0.18mm x 0.05mm, elongate
- 0.02mm x 0.02mm, very angular with high sphericity

Opaque minerals (5%, frequency: very few) – medium silt to coarse silt grains are present throughout the sample. Roundness and sphericity varies greatly throughout the grains. Accurate identification of exact minerals was not possible.

Inclusion size range:

- 0.09mm x 0.04mm, rounded with low sphericity
- 0.03mm x 0.03mm, angular with high sphericity
- 0.01mm x 0.01mm, angular with high sphericity

Plagioclase (3%, frequency: very few) – euhedral and subhedral coarse silt to fine sand grains are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.15mm x 0.11mm, sub-angular with low sphericity
- 0.08mm x 0.05mm, equant
- 0.03mm x 0.02mm, equant

Clay pellets (2%, frequency: very few) – clay pellets can be found spread throughout the sample. All clay pellets seem to be of the same composition.

Inclusion size range:

- 0.27mm x 0.20mm
- 0.25mm x 0.08mm
- 0.04mm x 0.03mm

Biotite (2%, frequency: rare) – euhedral very fine silt to medium silt grains are present. Boundaries are clear throughout.

Inclusion size range:

- 0.12mm x 0.03mm, lath shape
- 0.03mm x 0.01mm, tabular shape
- 0.04mm x 0.003mm, lath shape

Grog (1%, frequency: rare) – a single grog inclusion is found in the sample, 0.99mm x 0.64mm in size. There is a 0.02mm circle of shrinkage around the inclusion. Quartz and k-feldspar are visible within the grog as well as planar and vugh voids. The clay matrix of the inclusion lacks optical activity.

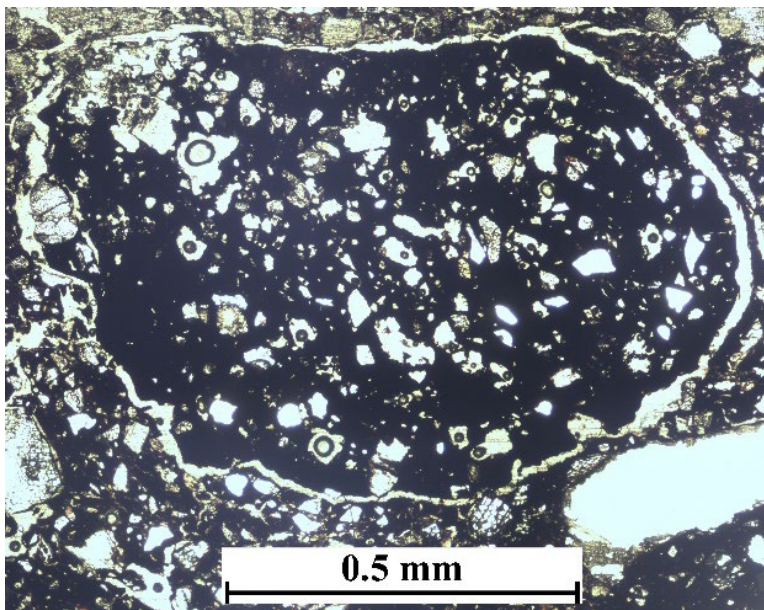


Figure 33: Grog in PPL

Hornblende (1%, frequency: rare) – euhedral and anhedral coarse silt grains are present throughout the sample. Boundaries are clear to sharp throughout.

Inclusion size range:

- 0.06mm x 0.04mm, angular with low sphericity
- 0.05mm x 0.03mm, elongate shape
- 0.04mm x 0.03mm, sub-angular with low sphericity

### **Voids** (10%)

Meso and macro planar voids as well as meso vugh voids are present in the sample. Voids do not have a distinct orientation.

Size range of planar voids:

- 0.96mm x 0.04mm
- 0.28mm x 0.03mm
- 0.10mm x 0.02mm

Size range of vugh voids:

- 0.20mm x 0.07mm
- 0.18mm x 0.08mm
- 0.06mm x 0.02mm

### **Clay Matrix** (56%)

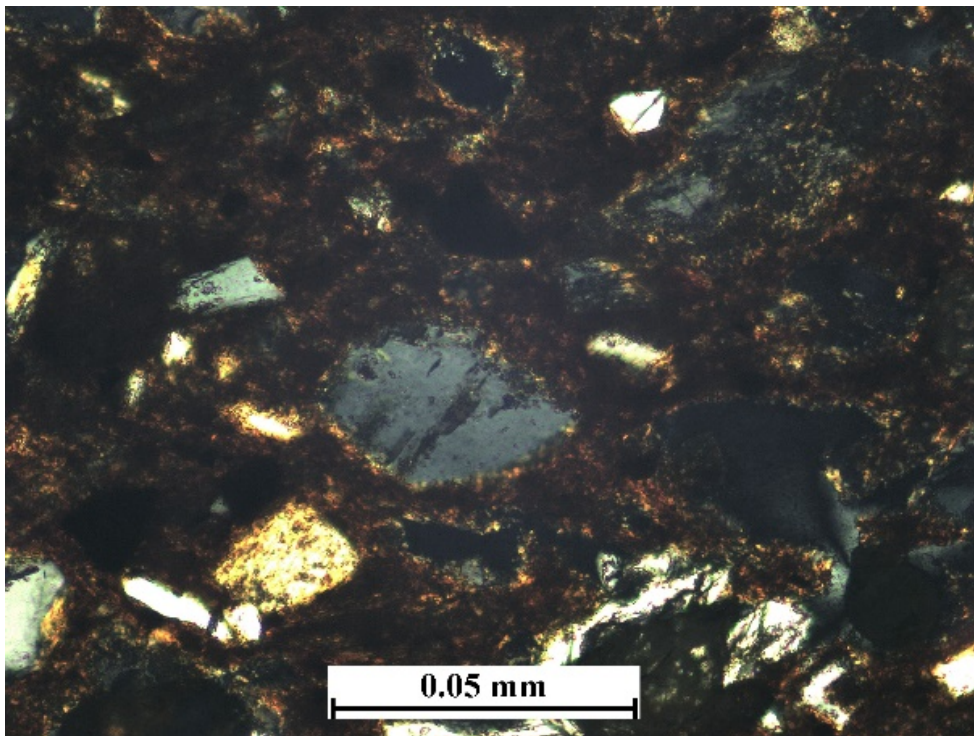


Figure 34: Clay matrix in XPL

The clay matrix is dark reddish-brown in colour with present optical activity as a result of low firing temperatures. Variation in optical activity is present with the bottom half being slightly more optically active due to uneven firing. The plastic inclusions of the clay matrix are quartz as well as lesser amounts of broken mica laths and clay pellets.

### **Mineral Orientation**

The mineral orientation of the sample shows signs of implementation of a pinching forming method.