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Disclosing the provenance and production technology of Meroitic ceramics from Sedeinga (Northern Sudan)

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Abstract

This research offers a comprehensive examination of the Meroitic ceramics (3rd-4th century AD) discovered at the Sedeinga archaeological site in Northern Sudan. It primarily focuses on two critical aspects: the provenance of these ceramics and their production technology. The research is being undertaken to understand if these ceramics were produced at Sedeinga or at another production centre and subsequently transported into Sedeinga; and to identify the methods and production environment used to produce the pottery, specifically, the firing conditions.

Prior to the onset of this investigation, the ceramics at Sedeinga had been categorised macroscopically based on clay type and forming techniques, resulting in the classification of hand-made kaolinitic clay ceramics, wheel-made ceramics, and hand-made coarse Nile clay ceramics. These initial categorisations, established by Romain David and the Sedeinga Archaeological Unit (SEDAU), serve as the foundational framework for the scientific analysis.

The site of Sedeinga is a funerary necropolis and was excavated between 2009-2019 by the SEDAU. From the remains the site indicated a settlement of important people lived here during the Meroitic period, there were pyramidal superstructures and presumably wealthy good in the graves that were looted before the excavations took place. Sedeinga is located in an important area on the Nile as it is close to the Egyptian and Nubian border. No previous scientific research has been completed at Sedeinga, so this research hopes to shed light on the scientific background on the ceramics discovered at the site.

The research methods employed for this research included petrographic analysis, X-ray Powder Diffraction (XRPD) and X-ray Florescence (XRF). The petrographic analysis serves to identify the fabric and the major mineralogical inclusions of the clays. With the petrographic analysis a high amount of organic temper or its traces (empty voids) was found in the Nile-clay based pottery giving special attention to these type of samples. The results of this data was compared to clay thin sections from various location along the river Nile to find possible similarities. The XRPD analysis was used to describe the mineralogical phases present in the samples (qualitative analysis). The XRPD data was used to define a firing temperature range used for these ceramics. The results were compared to other XRPD data from various clay samples from the river Nile to discern any similarities. The XRF analysis was used to describe the chemistry found in the samples and group them, using statistical tools, according to their chemistry. The cluster analysis and a principal component analysis showed the clear distinction

between the samples, in agreement with also the petrographic observations. This data was also compared to Nile clay samples to aid in discerning their provenance.

These were the main techniques used, however Raman Spectroscopy was additionally tested on two of the samples to gain further insight on the firing temperature range on the basis of the spectroscopic response of the carbon inclusions related to the organic temper, though a comprehensive analysis of this data is deferred to future studies.

From the multi-analytical techniques used, two significant findings emerged. Firstly, that the provenance of the Nile-clay based ceramics is likely the White Nile, as indicated from both the petrographic and XRF data, suggesting a network of production and trade. Conversely, the kaolinitic clays lack a comparable raw material, but the absence of a local workshop or kiln at Sedeinga implies that they were produced elsewhere and subsequently traded to the site. This implies that all the examined ceramic samples were imported to Sedeinga, and there was no local production centre within the site. Additionally discovered through XRPD and Raman Spectroscopy was a consistent firing temperature range between 750-950°C across all of the samples. The samples were likely fired in a kiln with an oxidising atmosphere for an extended duration of time at this temperature.

Riassunto

Questa ricerca offre un esame completo delle ceramiche meroitiche (3rd-4th secolo AD) scoperte nel sito archeologico di Sedeinga nel nord di Sduan. Si concentra principalmente su due aspetti critici: la provenienza di queste ceramiche e la loro tecnologia di produzione. La ricerca è intrapresa per capire se queste ceramiche sono state prodotte a Sedeinga o in un altro centro di produzione e successivamente trasportate a Sedeinga, e per identificare i metodi e l'ambiente di produzione utilizzati per produrre la ceramica e nello specifico, le condizioni di cottura.

Prima dell'inizio di questa indagine, le ceramiche di Sedeinga erano state classificate macroscopicamente in base al tipo di argilla (macrofabric) e alle tecniche di formatura, risultando suddivise in ceramiche costituite da argilla caolinitica fatte a mano, e ceramiche costituite da argilla del Nilo grossolane e fatte a mano. Queste prime categorizzazioni, stabilite da Romain David e dall'Unità Archeologica di Sedeinga (SEDAU), servono come quadro fondamentale per l'analisi scientifica.

Il sito di Sedeinga è una necropoli funeraria ed è stato scavato tra il 2009-2019 dal SEDAU. Dai resti il sito indicava un insediamento di abitativo importante, occupato durante il periodo meroitico, e nel quale ci sono evidenze di sovrastrutture piramidali e presumibilmente beni ricchi nelle tombe che furono saccheggiate prima dell'inizio degli scavi. Sedeinga si trova in una zona importante sul Nilo principale in quanto è vicino al confine egiziano e nubiano. Nessuna ricerca scientifica precedente è stata eseguita sui materiali di Sedeinga, quindi questa ricerca spera di far luce sugli aspetti più scientifici della produzione delle ceramiche scoperte nel sito.

I metodi di ricerca impiegati per questa ricerca hanno incluso l'analisi petrografica, la diffrazione a raggi X delle polveri (XRPD) e la florescenza a raggi X (XRF). L'analisi petrografica serve a identificare la matrice e le principali inclusioni mineralogiche presenti nel corpo ceramico. Con l'analisi petrografica è stata rilevata un'elevata quantità di resti vegetali (o delle su tracce) nei campioni ceramici prodotti con argille del Nilo, prestando particolare attenzione a questo tipo di impasti. I risultati di questi dati sono stati confrontati con le sezioni sottili di argilla da varie località campionate lungo il fiume Nilo per identificare possibili somiglianze. L'analisi XRPD è stata utilizzata per descrivere le fasi mineralogiche presenti nei campioni. I dati XRPD sono stati utilizzati per definire entro quale intervallo di temperatura la ceramica si stata cotta.. L'analisi XRF è stata usata per descrivere la composizione chimica dei campioni e per raggrupparli secondo la loro composizione attraverso l'uso di strumenti

statistici. L’analisi di raggruppamento (cluster analysis) e delle componenti principali ha mostrato chiare distinzioni tra i campioni, in accordo con quanto osservato anche dal punto di vista petrografico. Questi dati sono stati anche confrontati con le composizioni chimiche di campioni di argille del Nilo per definirne la provenienza.

Queste erano le tecniche principali usate, tuttavia la spettroscopia di micro-Raman inoltre è stata provata su due dei campioni per ottenere ulteriore comprensione sulla gamma di temperature di cottura delle ceramiche basandosi sullo studio spettroscopico dei resti di carboni negli corpi ceramici con tempera vegetale, benchè un'analisi completa di questi dati sia rinviata agli studi futuri.

Dall’ approccio multi-analitico utilizzato nel presente lavoro sono emersi due risultati significativi. In primo luogo, che la provenienza della ceramica prodotta coni di argille del Nilo è stata identificata lungo il Nilo Bianco, come indicato sia dalle analisi petrografiche e chimiche, suggerendo una rete di produzione e commercio/distribuzione. Al contrario, le ceramiche prodotte con argille caolinitiche mancano di una materia prima comparabile, ma l'assenza di un'officina locale o di attestazioni di forni per la produzione ceramica a Sedeinga suggerisce che sono state prodotte altrove e successivamente portate/distribuite al sito al fine del rituale di sepoltura. Ciò implica che tutti i campioni di ceramica esaminati sono stati importati a Sedeinga e che non vi era un centro di produzione locale all'interno del sito. Inoltre, attraverso la spettroscopia XRPD e la spettroscopia Raman è stato definito un intervallo di temperatura di cottura costante tra 750-950 C per tutti i campioni. I campioni sono stati probabilmente cotti in un forno con un'atmosfera ossidante per una durata prolungata a questa relativamente bassa temperatura.

Introduction

1.1 Introduction

Ceramics serve as invaluable artifacts enabling archaeologists to glean extensive insights from a site about the prevailing society and environment. Ceramics are integral to the daily lives of these communities, that not only function as tools but also persist as evidence, offering a window into the past. This research plans to discover the provenance and production techniques of 58 ceramics samples from Sedeinga, northern Sudan. These samples were gathered by Romain David throughout excavations from 2009-2019 with the Sedeinga Archaeological Unit. Sedeinga is an important Meroitic necropolis (3rd/4th century BC) with tombs and pyramidal superstructures. It is from these funerary contexts that the ceramics studied here were excavated from.

Meroitic ceramics are well attested throughout Nubia during the Meroitic period, and they have an important impact on the archaeology of ancient Nubia. Nubia is a region along the Nile river encompassing the area between the first cataract of the Nile (southern Egypt) and the confluence of the Blue and White Niles (in Khartoum in central Sudan). The region hosted one of the earliest civilizations of ancient Africa, the Kerma culture (2500 BC and 1500 BC) with several empires, among which Kingdom of Kush was the most important since it conquered Egypt in the 8th century BC ruled the country as its 25th Dynasty.

The provenance and the production technology of these ceramics are vital for the improvement of knowledge and broadening of research of this region. Specifically the provenance and production technology of ceramics is crucial to understanding more about the use of ceramics and the society they were produced in. They can tell us a lot about the traditions and priorities of the society that created them, such as religion and the roles of men and women in the pottery production line. They can also give us an insight into what the pots were used for and therefore the eating and storing tendencies of these communities. Sedeinga is an important site historically as it is located near the Nubian limit and has a lot of potential in growing the ceramic knowledge in Lower Nubia.

Northern Sudan has been an important area of study for years because of its interaction with the Egyptians and as many of the sites have been abandoned since ancient times so there is a high potentiality for well-preserved sites. The constant research within Nubia gives a huge insight to the Meroitic communities and its influence over Sudan. This research will be compared to other sites throughout Nubia such as Musawwarat es-Sufra and Meroe, in order to determine if there are any correlation or interactions, such as trade with other societies.

Sedeinga has been studied archaeologically by Rilly and Frangciny (2013-2019) and by Romain David (PhD, 2012) specifically within ceramics. The ceramics in Sudan and in the Meroitic industry have been analysed for many years however Sedeinga has yet to have its ceramics scientifically analysed. Only in recent years the scientific analysis and archaeometry of sites in Sudan (comprising Mesolithic, neolithic and Meroitic pottery) has become more apparent, with research by the groups leaded by Maritan and Daszkiewicz and pioneering the progress in this area of research (Daszkiewicz et al. 2005; Daszkiewicz et al. 2016; Daszkiewicz & Schneider 2011; Daszkiewicz & Malykh 2017; Daszkiewicz & Wetendorf 2014; Näser, Daszkiewicz 2013; Maritan et al., 2023). The focus of this research has been in central Sudan, mainly Meroe and Mussawarat, and has been going on since the 1990's, so this study will to expand the use of scientific analysis in Sudanese ceramics studies. Sedeinga is one of the sites in Lower Nubia that has been more recently excavated so it is the perfect site for a more detailed scientific analysis to be conducted. Petrographic analysis, X-ray Powder Diffraction, and X-ray Florescence will be conducted as the scientific research and these techniques will be used to help discover the provenance and production technology of these ceramics. Scientific analysis is used to improve the knowledge of the ceramics from the archaeological point of view. The knowledge of a ceramic is limited if no scientific analysis is used. It can help get definitive answers about the provenance of the raw materials and techniques used to produce the ceramics.

Alongside the scientific analysis images were taken of all of the thin sections to show the fabric patterns and inclusions within the thin section. This was done with a microscope with a camera attached, which allowed for a clear and precise image to be taken highlighting important aspects of the samples. Macroscopic images of the samples were also taken using a stereo microscope to record the finer details of the ceramic bodies and surfaces that are difficult to capture with a regular camera. The stereomicroscope used was an Axiocam stereomicroscope available at the university of Padova and the Labscope app on a tablet to take and record the images. Additionally photos were taken in a lightbox setting which gave a macroscopic clear view of the patterned samples.

1.2 AIMS

This research has three primary objectives. These objectives aim to uncover the origin and manufacturing techniques used for the ceramics found in Sedeinga. To achieve these objectives, a range of multi-analytical methods will be employing, including mineralogy, petrography, and chemistry. There is already a basis of source material as Romain David has written a report suggesting Nile clay or kaolonitic clay for the ceramic body and has identified any technological production that is visible macroscopically (Appendix). Thin section analysis will be used for the petrographic study, and X-ray Powder Diffraction used for the mineralogical analysis and X-ray Fluorescence will be used to study the chemical composition. These are destructive techniques, so parts of the samples will be crushed however, the powder samples will be kept for any future study. Raman spectroscopy will also be employed for the firing temperature of these samples but will not be used for gathering any usable data.

The first aim is to identify the microscopic characteristics of the samples and categorise them according to these features. This will lead to a better understanding of the raw materials used and the firing conditions of the pottery. This can be achieved using all the techniques mentioned, with an emphasis on the petrographic study. A table will be completed outlining the main features seen microscopically and if there are any distinct features that could provide information on the provenance or production technology used in terms of production recipes.

The second aim is to try to identify the possible sources of the raw clay, and compare the outcomes with available data in literature on ceramic materials. This can lead to the provenance of the material and can help show if production was done locally at the site or if the vessels were imported. Comparing the results to other Meroitic samples can deduce if these samples were the common style in Meroitic Nubia and provide evidence if the vessels were made at a production centre elsewhere and traded into Sedeinga. If they have a common petrography or chemistry to other samples it can be concluded that these samples are not unique and belong to the wider Meroitic style found in sites.

The third aim for this study is to understand the production technology of the pottery and specifically at the firing conditions of the ceramics. The most common style of firing during the Meroitic period was using kilns over a long period of time. The firing length, temperature and conditions have an impact on the ceramics and gives us information about the potters technology at the time. The firing temperature is vital for discussing the production techniques used by the potters as there can be a lot of information acquired. The production technology is also an important factor in understanding the society of the time and we can do this by disclosing the production technology of the various groups in this study.

Seeing how the different ceramics were wheel-thrown or hand-made or with fine or coarse clay can tell us the preferred styles and techniques used by the potters. From the macroscopic study, there is already a suggested technique for building the pottery, wheel-thrown or hand-made, and if specific methods were used such as coiling techniques.

In summary, these objectives aspire to analyse the provenance and production technology employed for the ceramics discovered in Sedeinga during the Meroitic period. This research aims to contribute significantly to the broader field of Sudanese and Nubian archaeology. Specifically, it seeks to advance our understanding of ancient Nubian ceramic production techniques, thereby to add to the ever growing database. Additionally, it endeavours to shed light on the origin of the ceramics unearthed in Sedeinga, determining whether the site had its own production centre or if these ceramics were imported through trade.

2 Archaeological Background

2.1 Background on ceramics in Upper and Lower Nubia

Nubia is divided into three sections along the River Nile, Lower Nubia, Upper Nubia and Central Sudan. Geographically Lower Nubia is located between the first and second cataracts of the Nile, while Upper Nubia stretches from the second cataract to the fifth cataract (Török, 1997). From the fifth cataract to Khartoum the area is known as Central Sudan. The River Nile is divided by six cataracts and Sedeinga is located between the second and third cataract in Upper Nubia. (Figure 1). To gain a better understanding about the ceramics found and used at Sedeinga it is necessary to also have an understanding of the ceramics from the surrounding areas. Therefore, studying ceramics found in Lower Nubia, Upper Nubia and Central Sudan is vital to analyse and comprehend these samples fully, as this can lead to a better understanding of the ceramics from Sedeinga. Ceramic materials are abundant in most archaeological sites and they can offer valuable insight into societies and geographical contexts through analysis, and this is why they

Figure 1 - Map of Nubia divided by the cataracts with the location of the main archaeological sites (kindly provided by Romain David)

are so important to archaeologists (Adams, 1964). In Central Sudan, important sites such as Meroe and Musawwarat es-Sufra have provided essential data on ceramics from Sudan (Naser et al, 2021 and Robertson and Hill, 2002, 2004). Similarly, in Lower Nubia Qasr Ibrim and Sai Island in Upper Nubia have led to substantial information about the Meroitic sites and ceramics (Rose 1996, 1998, 2001, 2003, 2005, 2008 and Francigny 2008, 2009, and David 2009, 2010).

2.1.1 Lower Nubia

It is widely believed that Lower Nubia experienced a significant decline in its population during the Napatan period (6th - mid-3rd century BC), resulting in a near-depopulation of the region. Subsequent settlement in Lower Nubia did not occur until at least the 1st century BC, as noted by Török (1997). Prior to this resurgence, Lower Nubia remained sparsely inhabited, with minimal evidence of occupation during both the Napatan and early Meroitic periods, as indicated by Edwards (1996). The geographical area between the first and second cataracts of the Nile River served a dual role as a vital corridor connecting the Mediterranean to inland Africa and as a strategic buffer zone separating Egypt from the political dynamics of the Middle Nile Region (Török, 1997). Lower Nubia was a sought-after area as it had this strategic advantage and had access to Wadis Allaqi and Gabgaba (Török, 1997). Lower Nubia held significant strategic, political, and religious importance, leading to the establishment of settlements in the region, despite its limited agricultural potential (Török, 1997).

The first millennium AD marked a notable transformation in Lower Nubia, characterised by a substantial increase in population and the emergence of a prosperous province within the Meroitic Empire (Edwards, 1996 and Adams, 1977). The precise factors driving this population surge remain an understudied subject. Speculations have been made regarding the role of technological advancements, such as the *saqia* waterwheel, as well as the opportunities presented by local trade with Romano-Egyptians and long-distance trade (Edwards, 1996). However, these hypotheses lack substantial empirical support, emphasising the need for further research and excavations in Lower Nubia to substantiate claims of population growth (Edwards, 1996). Török (1997) employed the site of Nalote in the Karanog region as an illustrative example for estimating settlement populations, drawing from burial and cemetery data. The data indicated an average of 1.75 burials per grave, a pattern consistent with other Lower Nubian cemeteries dating from the 1st to 3/4th century AD (Török, 1997).

Based on cemetery data, an approximate range of 50 to 150 individuals per living generation was estimated. When compared to the population density of an Egyptian metropolis, which typically housed around 300 people per hectare, Lower Nubia's population could have ranged from 1,800 to 2,400 people. However, a more conservative estimate of a minimum of 1,000 individuals is considered a plausible approximation (Török, 1997).

Qasr Ibrim is a Meroitic site from Lower Nubia that was excavated from the 1990's to the mid 2000's. The site location was vital for the interaction between the two cultures of Egypt and Nubia, and the mixing of these regions is visible here. Qasr Ibrim is located near the first cataract, so it had a lot of influence from both Pharaonic Egypt and Nubia. This site was used and reused throughout a long time period, including the Meroitic period, which was an important time of growth. One of the only Meroitic temples in Northern Nubia was discovered here, consisting of a Kushite temple complex on the fortress mount of Qasr Ibrim (Rose, 2008). This Meroitic temple was used throughout the Meroitic period and even reused afterwards until at least the 5th century AD (Rose, 2008). The 1995/6 excavations focused on the site of the 'Church on the Point' which consisted of a church and a monastery. At this site a lot of ceramics were discovered, but out of their original context due to subsequent looting of the site (Rose, 1996). Around 60,000 pottery sherds were recorded at this time which were used to help dating the use of the church and monastery (Rose, 1996). The most common vessels discovered were of open forms, bowls and dishes, mainly food or display crockery (Rose, 1997). The excavations continued in the larger area with a post-Meroitic house being analysed but issues arrived as the water-level was rising causing damage to the site, and specifically the increase of the lake (Rose, 1998). However, excavations in the cellar of this structure produced complete intact pottery vessels and the cellar dated to the earlier post-Meroitic period (Rose, 1998). Later excavations in 2000 produced a large amount of Napatan pottery, with the majority of the vessels found were of local origin either hand-made or wheel-made (Rose, 2001). Some of the vessels are known from other cemetery sites in Nubia but the majority seems to be unique to Qasr Ibrim from the twenty-fifth Dynasty (Rose, 2001). The 2003 excavations focused on a wall painting in a small mud-brick temple in the southern area of the site. The temple was still in a good condition by the Meroitic Period so it was restored and incorporated into the main Meroitic temple (Rose, 2003). The date was gather from Meroitic graffiti scratched into the lowest layer of whitewash added to the walls during the restoration (Rose, 2003). Trenches around the temple brought about more Meroitic artefacts, such as a fragmentary wooden plaque which included animal imagery and a very faded Meroitic cursive text (Rose, 2005). Trench 27 was dated to between the late first century BC and the end of the first century AD, with upper deposits put down after it had gone out of use dating to the Meroitic Period (Rose, 2005). This shows us the distance the Meroitic ceramics travelled and how important they were all along the River Nile.

2.1.2 Upper Nubia

Sai Island is a site between the second and third cataracts in Upper Nubia and is located quite near to Sedeinga. Sai Island is an interesting site as it has a mix of Egyptian and Nubian culture and has evidence that for a while Sai Island was the Egyptian headquarters in Kush (Budka, 2014). The settlement has evidence of Meroitic life but also other periods of settlement, as five different occupation levels were discovered here with a lot of mixing and reusing of older material (Francigny, 2008).

Excavations were conducted at Sai between 2013-2017 by the Sai Island Archaeological Mission (SIAM) with a focus on the town and cemetery of the 18th Dynasty (Budka, 2014). As the 18th Dynasty was likely the main period of occupation it is important to understand the settlement at this time to understand the consequent Meroitic settlement. A high amount of ceramics were found at the site from the New Kingdom but also during the Meroitic and Post-Meroitic period (Budka, 2011). Post-Pharaonic ceramics accounted for a small amount of the pottery found, 25% in one deposit and 7% in another, with some Meroitic pieces included (Budka, 2011). The ceramics found in the settlement structures are majority of household use, such as vessels for drinking and storage (Budka, 2011). These ceramics are all manufactured in multiple Nile clay varieties and were wheel-made except for the large storage jars which were built using a coiling technique (Budka, 2011). There are many correlations with these vessels to pottery from Egypt with connections to Elephantine cooking pots (Budka, 2011). By the mid-18th Dynasty Sai had become one of the most important Egyptian centres in Upper Nubia with a mix of both Egyptian and Nubian style ceramics (D'Ercole, 2017). This shows the importance of the site even before the Meroitic period.

Sai Island is believed to have also been important in the Post-Meroitic period specifically in a funerary context for elite burials (Francigny, 2008). This funerary site was established around the 1st century AD with some pyramids for the elite people buried there (Francigny, 2009). At this site the Meroitic cemetery is located on a hillock, with a Christian cemetery to the West and Muslim burials over the entire area, sometimes over the Meroitic burials (Francigny, 2009). The graves had all been heavily looted, especially the pyramid superstructures and not many artefacts were found (Francigny, 2009). In a grave with no pyramid a long-necked globular bottle was discovered, and the painted decoration on it was dated to the 1st century AD (Francigny, 2009). Of the ceramics found during the first season of excavations there were three different fabric types of ceramics noted, first the Meroitic Ordinary Red Ware which usually had a red exterior slip and a white or red slip inside, with an abundance of vegetal matter and sometimes having painted decoration (David, 2009). The second fabric was imitating Aswan ceramics, made from a coarse alluvial clay with some calcareous inclusions and visible voids (David, 2009). The final fabric found was the Meroitic Fine White ware and the frequency of this ceramics suggests the wealth of the elite necropolis (David, 2009). There was a high amount of Pharaonic pottery found in these Meroitic contexts, and this is likely due to the site being used as a rubbish dump during the earlier Pharaonic times so they mixed together (David, 2010). With the information gathered from the seasons of excavations it shows that the majority of the ceramics are of late Meroitic date and this can give an estimation of the main Meroitic period of occupation.

Sedeinga is also located in Upper Nubia closer to the boarder of Lower Nubia and a variety of other sites which were also a very relevant site for Meroitic ceramics. Sedeinga is a somewhat recent site to be uncovered with the main excavations taking place in the past 15 years. The potentiality of the site was high and throughout the seasons produced a lot of knowledge about the ceramics in this area. More information about the ceramic industry in Sedeinga will be identified in more detail in the next chapters.

2.1.3 Central Sudan

Musawwarat es-Sufra was a significant site in Central Sudan for the production of Meroitic ceramics as there was a ceramic workshop discovered, known as the Great Enclosure. More recent excavations started in this site from 1995 onwards and focused on the Great Enclosure and the surrounding area. The Great Enclosure is comprised of multiple building complexes connected by passages and surrounded by walls, covering an area approximately 43,000 m^2 (Naser et al, 2021). During the 1997 excavations a dump of pottery sherds and potters tools were discovered at the Great Enclosure, suggesting it to be a potters workshop; with evidence of a potter's wheel being found in an earlier excavation (Naser et al, 2021). The ceramics here were mainly of a single local production and only a few different fabric types or wares were discovered (Naser et al, 2021). In 2013 work continued at this area, which included archaeological, geophysical, and ethnoarchaeological research methods, to understand the distribution of pottery from Musawwarat es-Sufra and its role in the social, political and economic world of the Meroitic Empire (Naser et al, 2021). From the archaeometric analysis they found that all the material was from the same local source, which up to this study had not been found in any other site in the Middle Nile Valley (Naser et al, 2021). The coarse ware from this group were made from wadi clays whereas the fine wares were made from recipes based on kaolinitic clays (Naser et al, 2021). Some of the ceramics analysed resulted in wadi clays low in potassium, likely of local production (Näser and Daszkiewicz, 2013).

The Kingdom of Kush, was a very important empire and period in economic and political aspects, especially when Meroe was the capital of Kush for 600 years (Robertson and Hill, 2002). Meroe is also located in Central Sudan and had a substantial influence on a wide range of settlements along the cataracts of the River Nile. The Meroitic period was during an era when the royal necropolis moved from Napata to Meroe in the early 3rd century BC and during this period there was the highest production and influence of the Meroitic ceramics. Ceramic types found during excavations at Meroe included cups, bowls, jars and bottles, and beakers (Edwards, 1999). The style here is quite different and only a small amount of handmade jars were found there with different surface treatment and decoration (Edwards, 1999). Meroe was an urban centre with a large population in a confined space and this was reflected in its architecture as it was built more for a working environment rather than religious monuments (Robertson and Hill, 2002). The majority of Meroitic pottery made was for utility purposes and were expected to be roughly used and have a short life span (Robertson and Hill, 2004). For the Meroitic ceramics there were three main sources of clay used, which Robertson and Hill (2004), referred to as a red/orange fired colour clay, a yellow/brown fired colour clay, and a white kaolin clay. The orange/red clay was suggested to come from the Nile, and the yellow/brown clay came from the wadis, the majority of the vessels were made from the yellow/brown fired clay (Robertson and Hill, 2004). Cracking was an issue for the Meroitic clays, and a way they attempted to prevent any cracking during drying was the addition of non-plastics inclusions, mainly chopped grass (Robertson and Hill, 2004). The potters used shredded grass to create a temper material, and this was added into the clay through wedging (Robertson and Hill, 2004). A mix of the Nile and wadi clays with some kaolin clay was also used to counteract the cracking during drying, as kaolin absorbs less water (Robertson and Hill, 2004). The white firing kaolin was used for delicate and highly decorated ware, also known as eggshell vessels (Robertson and Hill, 2004).

2.2 Background on Meroitic Ceramics

Ceramics were manufactured all over Nubia and Egypt, and this is evident with the many discoveries of kilns and deposits of unfired pottery waste clearly from the manufacturing stage (Adams, 1986a). It is believed that there were many local production centres up and down the Nile throughout Nubia producing mainly utility vessels such as storage jars and cooking pots, and then a few specific centres were creating the specialised hand-made ware and they were transported along the River Nile (Adams, 1986a). A centre of manufacturing Meroitic pottery was found at Qasr Ibrim with the overfired waste from vessels but no kilns were found at Qasr Ibrim. However, there were remains of a kiln discovered at Argin (Adams, 1986a) and at Musawwarat es-Sufra a workshop was found (Edwards, 1999). A kiln compound was discovered at Hamadab with one kiln was excavated in detail to understand more about the technology used in kiln usage (Nowotnick, 2022). The kiln used here was a vertical double-chamber kiln which was around two meters in diameter with two superimposed chambers (Nowotnick, 2022). The underground firing chamber was where the fire was lit and in the upper chamber was where the pottery and other objects were placed to be fired (Nowotnick, 2022). There are over twenty similar cylindrical kiln structures recorded in multiple Meroitic sites, including Meroe city, Kedurma and Wadi al Arab (Nowotnick, 2022).

Ceramics can be used as the main dating and chronology of a site as they are usually quite abundant, durable, and they have distinct and recognisable wares and designs during a limited time period (Adams, 1986b). Seriation is the most common way of dating ceramics, as with stratigraphy and superposition we can clearly see which pots are older or younger than other vessels (Adams, 1986b). With the data gathered by Adams, he deduced that the occupation of Meroitic sites in Lower Nubia occurred from 100 AD and was only for a brief period (Adams, 1986b). The collapse of the Kush Empire is dated to 350 AD with the invasion of Axumite, and this led to the end of the manufacturing of the Meroitic pottery possibly a few years after this date in Lower Nubia (Adams, 1986b).

2.2.1 Early Meroitic Period 3rd-1st century BC

In Sedeinga, there is evidence of ceramics from an early Napatan settlement, but the majority of the archaeological data suggests the last period of occupation was during the Meroitic period as the Napatan pottery was removed from the graves and scattered on the ground. The Early Meroitic period is from the 3rd-1st century BC, and these ceramics included black hand-made ceramics sometimes with impression decoration (David, 2019). They were produced using various hand-made ceramic techniques, including the coiling and paddle and anvil methods. The iconography of these ceramics include both impressed and incised patterns likely developed from local traditions and could be interpreted as an imitation of basketry or nets (David, 2019). The non-figurative motifs on these ceramics are signs and expressions of cultural identity and beliefs. The categories of the Meroitic repertoire could be used as iconographic signals and could be linked with different groups of potters; or the similarities between the motifs on ceramics and on tattooed bodies could show the shared cultural context of both decorative practices (David, 2019). It is common for paintings, impressions and patterns on ceramics to have a cultural and or religious significance, especially if we consider it in a funerary context as we have in Sedeinga. For this period, no workshop or production site has been identified for the Meroitic ceramics but from studies of these ceramics it is clear that the potters were specialised and skilled. We can assume that a large workshop was linked to a centralised distribution system for these ceramics as they are widely distributed along the River Nile. From the mid-2nd century a new technique of combining the coiling method with wheel-throwing was introduced. Then followed with the beginning of painted decoration, influenced by Hellenistic models, for example, wavy lines and floral motifs (Török, 2011). The influence of Ptolemaic Egypt on the ceramic production is due to the high number of contacts developed between the two kingdoms since the end of the 3rd century BC (David, 2019). During the second part of the 2nd century BC until the end of the 1st century BC, the number of wheel-thrown ceramics increased substantially. This could suggest that the potters became more skilled with the wheel and this improvement of techniques can be seen in the ceramics as the coils became less visible (David and Evina, 2016). The wheel-thrown pottery was likely in the same workshops and then distributed along the same network as the hand-made wares. However, there is a regional preference first noticed in funerary pottery, seen in Sedeinga where a predecessor of the long-necked bottles appear in multiple graves such as tomb II T 145 (David, 2019).

2.2.2 Classic Meroitic Period 1st century BC – 1st century AD

The next period of significance of Meroitic ceramics was from the 1st century BC to the 1st century AD, and this was the main period of production for Meroitic ceramics. This period introduced the fine ware industry and the first pottery composed of kaolinitic clay. The start of the production of the fine ware pottery is believed to have been a result of the trading of knowledge from the Roman Empire to the Meroitic Kingdom (David, 2019). The potters used the wheel-throwing technique to improve the ceramics with getting inspiration from the Roman ceramics, bronze and glass vessels and similarly found inspiration for their stamp decoration from Hellenistic techniques (David, 2019). With this connection the potters gained a lot of new knowledge about techniques and shapes used for ceramics and then adapted this knowledge to suit their own unique style. With these new vessels a lighter surface colour came about, and this became a popular medium to develop religions themes, which were influenced by Pharaonic, Ptolemaic and Romano-Egyptian liturgy and also local themes (David, 2019). There has been one workshop excavated that produced fine ware, which is located at Musawwarat es-Sufra. This can give an insight to the production organisation of these vessels; of which they were highly standardised ceramics and produced in a state-controlled structure, suggesting that they were connected to the Meroitic state (David, 2019). The religious iconography used from the North to South of the Meroitic territory are quite similar and show no regional preference and seem to follow approved models (David, 2019). The iconography is also very similar to the reliefs in funerary chapels and temples, which again share a similar structure, likely defined by religious authorities. However, even if there are clear links to a main production site, there are distinct typological variations in the vessels, likely due to regional production centres. The use of wheel-thrown ceramics were more common at this time and had a high significance in funerary contexts in Nubia, where hand-made vessels were practically replaced by wheel-thrown technology at the end of the 1st century AD. The change in the pottery assemblages reflect the situation of the entire Meroitic ceramic industry, the decrease in hand-made ware suggests a major change in funerary customs (David and Evina, 2016). The decrease of hand-made vessels may have also been due to economic reasons rather than cultural reasons, as the hand-made potters were likely unable to compete with the fast production of wheel-thrown productions. The wheel-thrown workshops were a faster production, low cost industry and were widely distributed throughout the region, making them more profitable. Also during this period there was a more apparent distinction between the productions in Nubia and Meroe and especially in the funerary context. Such a case is in the distribution of the long-necked bottles which are only known around the middle of Nubia which suggest their own local traditions (David, 2019). There is a visible influence of the Meroitic industry in the iconography painted on the wheel-thrown and fine-ware ceramics as they share the same motifs (David, 2019). From this we can conclude that the same group of people were producing the decoration for both the wheel-made and fine-ware ceramics. Additionally, we can also infer that different craftsmen were producing the ceramics and decorating the vessels. The economic wealth during this period is seen through the increasing amount of imported vessels coming from Roman Egypt (David, 2019).

2.2.3 Late Meroitic Period 2nd–3rd century AD

The last period of the Meroitic ceramic industry was from the 2nd-3rd century AD, which was the downfall of the Meroitic ceramics and the Meroitic Kingdom. The demise of the Meroitic Kingdom is clear through analysing the typology and iconography of the ceramics produced during this period. The fine-ware productions were replaced with cheaper imitations made from alluvial or mixed clay and were poorly decorated (David, 2019). There was a rapid decline in Nubia and only a few fine-ware cups appear in graves dated to the mid-3rd century AD (Török, 1997). However, there is evidence that a small number of productions of kaolinitic fine-ware prolonged their workshops in Lower Nubia into the Post-Meroitic period (Adams, 1986). This could be due to the continued support of local religious cults in Lower Nubia such as Kalabsha, unlike the rest of the region as the administrative and religious authorities disappeared (Török, 1997). At the same time the overall decoration of the Meroitic ceramics became gradually simpler and then completely disappeared in the 3rd century AD (David, 2019). This decline can be connected to the disappearance of the fine ware workshops as the craftsmen had both the painting and iconographic knowledge of the decoration of the ceramics. The simplification of the decoration and shapes of the ceramics lead to a crucial development of mass-production of these vessels. During the last centuries of the Meroitic Period there was a new version of standardisation in production. During this time in Sedeinga the red slip was burnished earlier than it used to be. The ceramics were burnished when the clay was still wet and this led to the glossy effect being diminished and the surface was rougher with some irregularities (David, 2019). The regionalisation of the ceramic production seemed to be finalised during the 3rd century AD even though it was only initiated a few centuries earlier. Within Nubia, the usual shapes of the ceramics lost their common traits that they once shared with the southern regions (David, 2019). For the imported material there is not a lot of information but it is suggested that there were frequent raids along the Egyptian and Meroitic border by the Blemmyan tribes, and this would have negatively impacted the movements of goods and merchants (David, 2019).

2.2.4 FINAL REMARKS

With this there is a general overview of the Meroitic ceramic industry and its changes over time. Specifically about how the industry grew and fell in the Nubian and Meroe regions, how the shape and decoration changed with the changing economic landscape and its distribution. Adam (1986b) created a typology of Nubian ceramics and put Meroitic ware within the groups of D.1 hand-made, M and N.1 Nubian ware, and A.1 Aswan ware. The D.1 Meroitic were the earliest wares considered by Adams (1986b) with a date around 100-350 AD, and include three different slip colours, red, black and cream, like what we have in this study. Adams subdivided the group D.1 ware into H1, H9, H11, and H12, which each had differing characteristics from each other during this time period (Adams, 1986b). The decoration style for the group used both painted and incised techniques, with the most common style using rectilinear and geometric patterns (Adams, 1986b). The hand-made Meroitic wares of D.1 are thin-walled unburnished walls, mainly used for pots and jars and then also much thicker burnished walled primarily used for bowls and other small form vessels (Adams, 1986b). Decoration with incisions is quite common in all the types but only Ware H12 has painted decoration (Adams, 1986b). The ware colours include black, red and cream, some with all three colours, some with just one, with and without slips, and some decoration. All these domestic wares were hand-made and of a medium to very coarse fabric, and the most common forms were plain bowls, pots, jars, and basins (Adams, 1986b). Comparing this to the samples from Sedeinga we can see that the colours and designs seem to be similar, and we can put them into these groups quite easily. The ceramics during the Meroitic period throughout Nubia changed and improved and declined in quality. This can reflect the society of this time and inform the archaeologist about the economic situation of the time and the production skills and level these potters acquired. This background can give us a basis for the progressions of the ceramics at Sedeinga and a likely time frame for these vessels.

2.3 ARCHAEOLOGICAL BACKGROUND AND MATERIALS OF SEDEINGA

The samples being analysed in this study were gathered during an excavation at the site of Sedeinga, Sudan, consisting of 58 pieces of ceramic ware. During the first season of excavations in 2009 a proposed date of occupancy between the 1st and 3rd century AD was suggested (Rilly and Francigny, 2010). This can provide some context to the site and give a framework for relating the ceramics to other sites of the same time period. The entire Napatan and Meroitic necropolis in Sedeinga that is being surveyed here covers an area approximately 650x450m (Figure 2) (Rilly and Francigny, 2011). Excavations at the site of Sedeinga have been going on for multiple years, over many seasons of field work. The new season of work began in November 2009 when the Sedeinga Archaeological Unit (SEDAU) was created, a French mission that began a new archaeological excavation campaign (Rilly and Francigny, 2010). This was the revival of fieldwork in the Meroitic necropolis after seven years of a break from the previous team conducted by Mrs Berger-el Nagar. The main area of this previous fieldwork was around the Temple of Queen Tiyi and focused on Meroitic tombs with pyramidal superstructures (Rilly and Francigny, 2010). An important thing to disclose about Meroitic archaeology is that it has favoured the excavation of cemeteries rather than urban areas so the majority of our knowledge is on funerary ceramics and not common ware; and that Meroitic is a chronological rather than a cultural description of the ceramics (David, 2019). As previously mentioned, the Meroitic period refers to the time when the Empire of Kush was governed in the city of Meroe, so therefore all the Meroitic pottery is pottery which was created or used during the period when the capital of the Empire of Kush

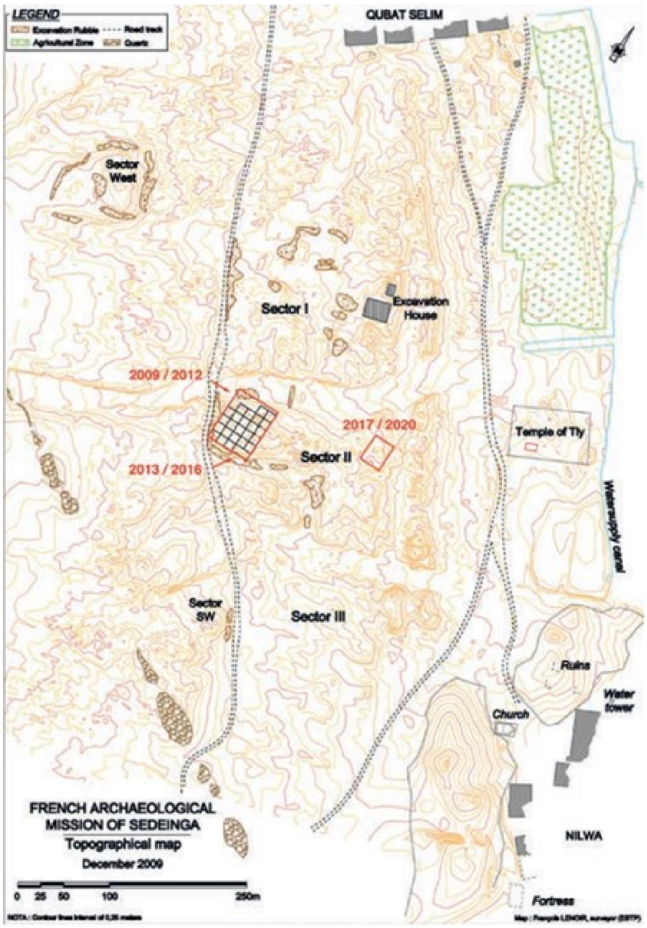


Figure 2 - Topographical map of the archaeological site at Sedeinga (from Rilly and Francigny 2011)

was at Meroe (Adams, 1973). The entire field work seasons were excavating cemeteries, specifically tombs and pyramids and analysing the material left in them.

2.3.1 First Year of Excavations

The SEDAU began their excavations and focused on the graves following the west-east row of pyramids, however, due to robbers the graves were highly disturbed and heavily looted (Rilly and Francigny, 2010). Only bone fragments and potsherds were left, albeit in a highly disturbed context. Ceramic potsherds were not found in their original context and very little material was found *in situ*. It is important to note that the majority of the graves were already disturbed and reused during Meroitic times causing most of the material to be *ex situ*; and then in modern times looting and robbing also occurred causing more disruption to the material. With the artefacts that remained in the graves it was clear that the area was quite poor, however they did include good quality ceramics including some of the painted or stamped fine ware (Rilly and Francigny, 2010).

During the Napatan period, the local rulers who held power in Sedeinga were buried under large pyramids in Sector W and the eastern part of Sector 1; however, the local community were buried in pit-graves in the western part of Sector 3 (Rilly and Francigny, 2011). This shows the difference in funerary customs for the elite and local citizens, giving us an insight to the societies using these ceramics. In the Meroitic period, smaller pyramids were built east of the Napatan pyramids in Sector 2 for the Meroitic princes (Rilly and Francigny, 2011). However, it is still difficult to designate specific time periods for many areas, due to the reuse of many graves and the multi-age material found in the same graves (Rilly and Francigny, 2011). In Sector 2 it was discovered that the family customs of the time was to bury the deceased in the same area of previous ancestors, so multiple generations would be buried together (Rilly and Francigny, 2012). This suggests a high respect for ancestors and the importance of burial traditions of the families. Similarly, many of the pyramid monuments were restored and slightly cleaned before the reuse of them by the new generations, showing a sign of respect for the dead, an example of this custom is seen in Pyramid 233 (Rilly and Francigny, 2012). Another example is in tomb II T 337 where a broken Napatan offering-table and a slab of schist were added into the ceiling to reinforce the structure before it was used for a new burial (Rilly and Francigny, 2018). It shows that even if it is easier to build a new burial chamber they would restore and use the older one, suggesting a deeper meaning and practice for the reuse of graves.

2.3.2 SECOND YEAR OF EXCAVATIONS

The next season of the excavation and field work was from November to December 2010, continuing on from the last season. During this fieldwork two more Neolithic sites were uncovered with prehistoric and protohistoric remains including pottery assemblages (Rilly and Francigny, 2011). Three new sites that were excavated during this period were from the north-western end of the site and the western part of sector 3, and they contained pottery material which could be assigned to a Pre-Kerma group (Rilly and Francigny, 2011). However, the term Pre-Kerma was used here in accordance with the culture known in the Pre-Kerma site and the assemblages found in Sedeinga have a slightly different profile, which is actually closer to the material of the same period in Sai Island (Rilly and Francigny, 2011). During this season three other sites with the same material were found in the north-western end of the site and the western part of Sector 3, they included sherds with herringbone patterns or zigzag motifs (Rilly and Francigny, 2011). In Sectors 1 and 3 a general inspection of the surface pottery spread was completed, which with previous excavations allowed for a more accurate picture of the chronological distribution of the graves in the necropolis (Rilly and Francigny, 2011). During this field work approximately 1,600 potsherds were analysed, 165 had a detailed description made of them, and an additional two dozen objects were drawn with complete profiles (Rilly and Francigny, 2011). The material was scattered between both the surface deposit and burials due to looting, and this caused difficulty in reassembling the fragments as they were all mixed (Rilly and Francigny, 2011). The looting and disturbing of the graves led to only a few pottery items that were commonly used for funerary purposes to be located in its, presumably original context (Rilly and Francigny, 2011). A benefit of this year was that some of the profiles drawn in the previous season could be completed with the additional parts found in the new graves. Additionally, a high amount of sherds from handmade domestic ware vessels were found, mainly found in the surface deposits and the descendaries (Rilly and Francigny, 2011). However, a significant portion of the domestic ware could be intrusive, the limited types of containers could suggest a different type of earthenware designated to be placed on top of the graves as a post-burial offering (Rilly and Francigny, 2011). This is only a hypothesis as there is no archaeological evidence for this, even if it is a ritual that happens today in Sudan (Rilly and Francigny, 2011). Not a lot of funerary ware was found apart from the above mentioned domestic ware and this could be due to the poverty of the area and to the heavy pillaging of the graves (Rilly and Francigny, 2011). Looking at the design, many of the potsherds lost their original slip due to heavy weathering caused by the summer rains; half of the catalogued sherds were found as shapeless fragments (Rilly and Francigny, 2011). A large amount of the pottery found in this season were of bowls and beakers with a red slip inside and outside, or a whitish slip on the inner surface (Rilly and Francigny, 2011). Similarly, many fragments of white fine-ware beakers with painted motifs or stamps were found (Rilly and Francigny, 2011). However, mixed in with this assemblage were earlier items, such as mini *lekythos*, dating from the Early to Classical Meroitic, this suggests that they likely originate from the same time as the structures during the early period and were reused again for late burials (Rilly and Francigny, 2011). Again showing evidence of reuse of the sites and specifically of the graves in the later periods.

2.3.3 Third Year of Excavations

The third season of fieldwork at Sedeinga took place in late 2011 and expanded the site from the two previous excavations with an additional two sondages dug in the areas south of the Temple of Tiye and another two in the easternmost part of Sector two, amounting to four sondages being opened (Rilly and Francigny, 2012). In one of the tombs during this excavation, tomb II T 219, a near complete fine ware bottle was discovered which was decorated with a frieze of unidentified designs, suggesting to resemble double axes and small stars (Rilly and Francigny, 2012). The design and shape of the bottle suggests a forming date of 1st century AD (Rilly and Francigny, 2012). In the area of this grave many potsherds of handmade ceramics were found, likely from the same time period (Rilly and Francigny, 2012). A small bottle was found in tomb II T 238, likely of Post-Meroitic or Christian date but there were many materials there, suggesting that it covers many periods, it also included cooking-pots from the Christian period (Rilly and Francigny, 2012). Not a lot of information were given about the ceramics found during this excavation season as an offering table and a funerary stela were discovered and the main focus was given to them.

2.3.4 Fourth Year of Excavations

The fourth season of excavations, which took place in 2012, focused on the chronology of the burials, the journey of development of the necropolis in sector 2, a row of Kushite pyramids, and a new area called Sector 4 located 1.5km west of the necropolis as a new road was going to be built so they needed to do a salvage operation (Rilly and Francigny, 2013).

During this season, not a lot of advances were made as they were focusing on Sector 2 and Sector 4, working mainly on tomb IV T 1 (Rilly and Francigny, 2013). In this tomb a pottery sherd from a cup and fragments associated with charcoal were found. This charcoal lead to a C14 date of 43 BC with 95% probability which corresponds to their architectural comparison (Rilly and Francigny, 2013). In another tomb, II T 242, two well preserved *lecythi* were discovered, but not much else was found due to the repeated robbing of the site (Rilly and Francigny, 2013). Also discovered in this tomb was an upper part of a 'torpedo' amphora which gave a date between the 6th and mid-3rd century BC and is usually associated in Nubia with Napatan sites (Rilly and Francigny, 2013). Accordingly this area of the necropolis is suggested to be covering the transition between the late Napatan and early Meroitic period (Rilly and Francigny, 2013). With the main focus on the chronology and development of the area and a long time spent on the grave IV T 1 only a limited amount of information was included about the ceramics as there weren't many sherds found in this location.

2.3.5 FINAL EXCAVATION

The final paper written about the excavations at Sedeinga in 2018 included information from the five seasons of field work from 2013 to 2017 and focused on the topochronology of the Kushite necropolis and on the transition from the Napatan period to the Meroitic period (Rilly and Francigny, 2018). In tomb II T 302 there were numerous Napatan pottery sherds, and a fragment of a Meroitic bowl with a polished red slip in the neighbouring grave II T 303 (Rilly and Francigny, 2018). In tomb II T 303 many ceramics from different time periods were discovered. Napatan sherds were found in the chamber and descendary of the grave with two pieces belonging to a ceramic offering table (Rilly and Francigny, 2018). Additionally, parts of a painted Meroitic jar and Meroitic bowls with polished red slips were found in the funerary or descendary of the tomb (Rilly and Francigny, 2018). With the ceramic analysis they found three successive burials in the grave, from the Napatan, Classic Meroitic, and Late Meroitic periods, showing the reuse of this grave and is evidence of the reusing of graves in this area (Rilly and Francigny, 2018). In tomb II T 355, the ceramic sherds were mainly Napatan in date found in the descendary of the grave, and also found in the descendary were two fragments of a handmade Meroitic jar (Rilly and Francigny, 2018). Additionally, fragments of a Meroitic jar and a long-neck bottle were found in both the funerary chamber and descendary (Rilly and Francigny, 2018). From the ceramic analysis of Romain David at least two successive burials can be suggested, one from the Napatan period and another from Late Meroitic centuries (Rilly and Francigny, 2018). Ceramics from the Classical Meroitic period were also found but as their presence were only in the descendary it could be possible that they came from tomb II T 303. In the final tomb recorded here, grave II T 410, Napatan ceramic potsherds were scattered in both the funerary chamber and the descendary, and fragments of an egg-shaped Meroitic jar in the descendary (Rilly and Francigny, 2018).

2.4 FINDINGS

The main aspects to focus on from this description of the excavations at Sedeinga are that the ceramics were all found in disturbed funerary contexts scattered throughout many graves, and that they include material from Napatan and Meroitic times. Here (Figure 3) is a sketch of the graves from the SEDAU showing the locations of the ceramics samples used in this study. Added in the appendix is a copy of the report David gave numbering the ceramic sherds used here and to which grave they correspond to (appendix).

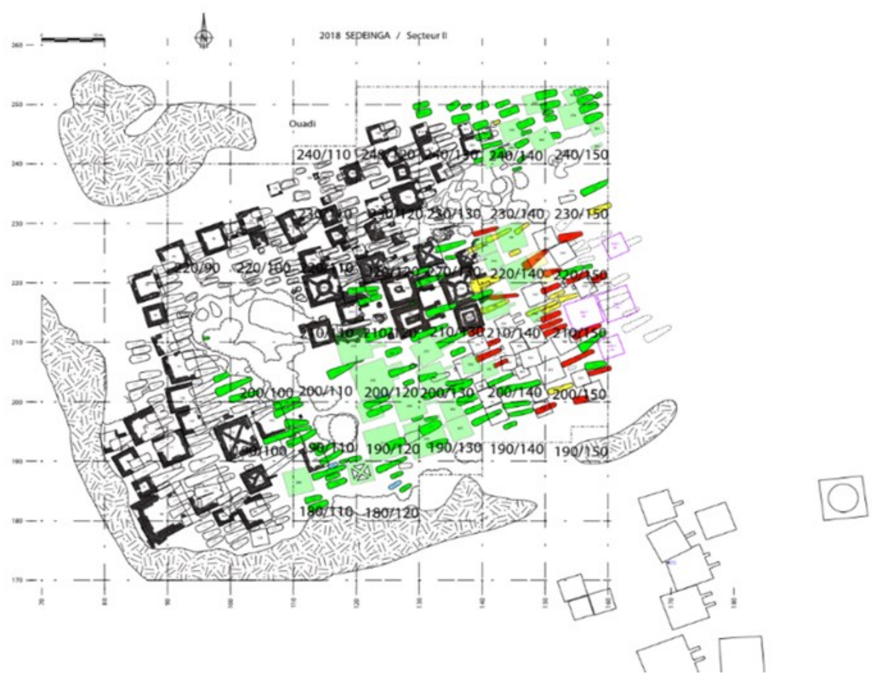


Figure 3 – Images of the graves plan from the excavations that the ceramic pottery were collected from. V.Francigny/©SEDAU

From 2018 to 2020 Romain David compiled his information on the ceramics of the site and created a more precise documentation of the collection (Rilly, Francigny and David, 2020). He also included sketches of vessels found at the excavations. One important element he noted on the Late Napatan burials in Sector II was that the ceramics had a relatively coarse appearance which are generally more related to the ceramics found in settlements rather than in burials (Rilly, Francigny and David, 2020). This could suggest that they used the same pottery for everyday use and for funerary rituals, therefore no division of specialisation for ritual pottery. However, it is important to note that there might have been higher quality pottery in the graves but they could have been looted by grave robbers. Some Egyptian imports and local imitations were also found, but these have a clear contrast with the Meroitic ceramics. These ceramics are of poor quality, poor finish and poor state of preservation and this makes them “barriers to the classification of Napatan ceramics" (Rilly, Francigny and David, 2020). There is a large typology but they all seem to be quite standardised and even if there is a high frequency of some forms like the bowls and jars with thick bases, there is a suggested degree of specialisation (Rilly, Francigny and David, 2020). One of the more notable assemblages was one that consisted of bowls and jars with a surface that is covered with a thick and browned red slip (Rilly, Francigny and David, 2020). It is difficult to give a precise chronology to these ceramics even if they are all linked to Napatan tombs because of the multiple reuses and the plundering of the tombs (Rilly, Francigny and David, 2020).

2.4.1 Typology

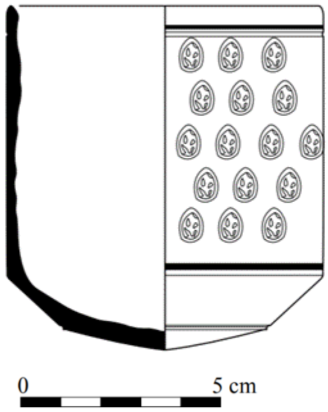
The typology created by David and Evina (2009) is vital for the initial grouping and dividing of the ceramics found at Sedeinga, but the first general typology and classification system of archaeological ceramics from Sudan was devised by Adams (1964).

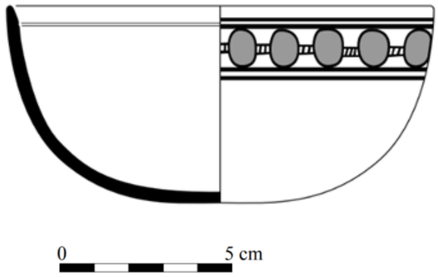
According to Adams, a classification is defined as a generic and include terms to be used for conceptual systems, whereas a typology is a particular type of classification, one for sorting items into mutually exclusive categories (Adams 1988). Typologies are commonly used over classifications as a starting point for comparisons and statistical generalisations (Adams 1988). For a well organised typology there are certain features it must adhere to, such as having a rigid system, be comprehensive and have mutually exclusive categories (Adams, 1988). Adams firstly focused on the fabric, form and style, then subsequently studied the recurring combination of fabric, forms, style, colours and surface treatment; and these combinations were divided as wares (Adams, 1964). Each of these characteristics are highly important to understanding and distinguishing the ceramics, and are defined as follows. Fabric is made up of the internal and structural properties of the pottery which are usually invisible to the eye (Adams, 1964). Form is the size and shape of the vessels, which are usually decided on for functional and aesthetic uses (Adams, 1964). Style is the surface decoration and has no real functionality and is purely for aesthetic purposes (Adams, 1964). Colour is one of the factors that is highly independent and variable, and is strongly influenced by the chemistry of the clay, pigments used, and conditions of firing (Adams, 1964). All of these aspects differentiate the ceramics and can allow us to interpret the use and meaning of the ceramics. These specific recurring characteristics are related to the cultural traditions and available raw materials, causing pottery to be related to ethnic and geographic factors (Adams, 1964). The created typology consisted of four typologies which included five fabric, ninety-four forms, and twelve typologies all within the five ware groups (Adams, 1964). With this classification, it can give a basis for categorising the ceramics from Sedeinga.

The ceramic typology created by David and Evina for Sedeinga occurred during the first season of excavations, and was established from the pottery sherds collected from the surface excavations. The lack of ceramic material found, only about 800 sherds that consisted of only about 100 forms, shows the poverty of this area (Rilly and Francigny, 2010). The limited number of ceramics and forms suggest that there were not many types and styles of pottery and they likely often reused pots so they could use the one pot for multiple functions. A preliminary search showed at least 15 fabrics, however, some are only represented by one sherd. With this the main collections were divided into four groups, “Meroitic Fine-ware, Wheel-made quite fine common ware, Wheel-made coarse ware, and Handmade ware” (Rilly and Francigny, 2010). Also found in some graves were some Egyptian, Napatan and Christian intrusive material however this could be related to the proximity to the Temple of Tiyi, the Napatan tombs and the Christian church (Rilly and Francigny, 2010). To also help create a preliminary typology a description and drawings of the diagnostic sherds was undertaken, and during this season 41 different forms were recognised (Rilly and Francigny, 2010). Using this analysis they found that the materials used for funerals in Sedeinga were ceramics of common types in Nubia during the Meroitic period, and the form, motifs and shapes have parallels in other necropolises such as Missiminia or Sai, so it could be determined as being included in a homogeneous regional material (Rilly and Francigny, 2010). Also if some of the material is contemporary with ceramics from other sites it could provide more knowledge for a more accurate chronology and could suggest a connection of ceramic knowledge and trade.

Figure 4 - Photo taken under the stereomicroscope of some of the ceramic decorations observed for the samples of Sedeinga: From top to bottom sample, 4 (stamped ware), 9 (painted ware), 46 (red-slipped ware).

Looking at the 58 samples from Sedeinga within colour and decoration it can be split into, red slip, decorated or undecorated; thirty-four have a red slip, twenty-two are decorated and four have no decoration. The decoration includes, painting, stamping, coatings and impressions on the ceramic surface. Some examples of the decorated ware include stamping, painting, and red slip (Figure 4) from this collection, samples four, nine and forty-six (Figure 4). With the petrographic analysis a classification and grouping of the samples will be done. The sketches from the SEDAU also highlight the details on the ceramics and show the presumed shape of the entire body. With this he divided them into three groups, of fine ware pottery, wheel-made Nile pottery, and hand-made Nile pottery. These sketches can give a clearer picture of the ceramics used and of the production technology of the site. The analysis of the chemical characteristics could help identify the sources of the different kinds of clays used. Such as, in the fine ware group David put sample groups SED 004, 005 and 009, all of which are thought to be kaolonitic clays; one sketch of each group is added below (Figure 5). The Nile-clay ware groups are SED 001, 002, 011 and 012, which are all mainly homogenous clays wheel-made and either using a moulded method, coiled techniques or a paddle and anvil method. These groups consist of various shapes, such as bowls, bottles and jars, that are decorated and/or non-decorated (Figure 6). Images of some of the ceramics found were also photographed on site showing the size and shape varieties within the samples (Figure 6).





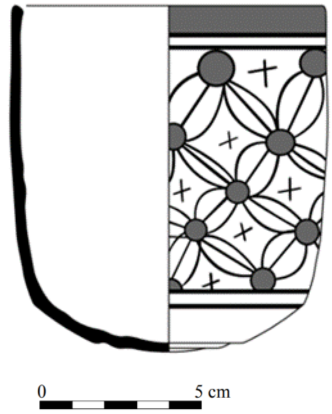
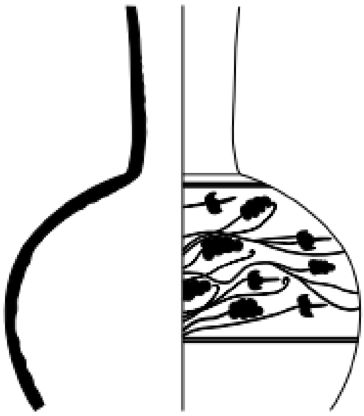
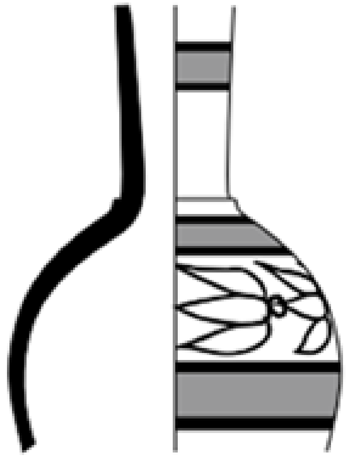


Figure 5 - Examples of the fine ware groups SED 004, 005, and 009. From left to right Sample 4 goblet, 9 bowl, and 14 goblet. © R. David/SEDAU

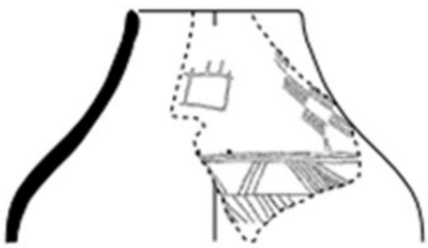


II T 212 Cd 01



II T 089 Cc 01

II T 187 Cc 01



II T 083 Cs 03

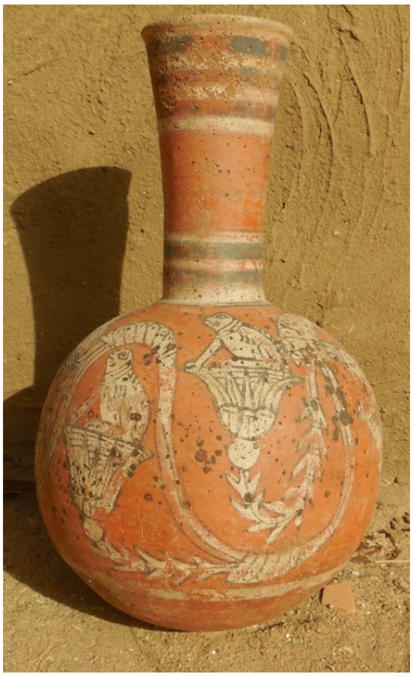


Figure 6 - Examples of the Nile-clay ware groups SED 001, 002, 011, and 012. Top row L-R Sample 24 bottle, sample 51 bottle. Bottom row L-R sample 42 bowl and sample 58 jar. ©R. David/SEDAU. Also images of vases from the site provided by Romain David.

Adams mentioned that when classifying pottery in entirely empirical terms commonly known categories are used, such as families, ware groups and wares (Adams, 1973). However, when looking at pottery manufacturing in social and economic terms we have to look at industries, which are a recognisable society with common economic and social factors (Adams, 1973). However, this is not applicable when talking about the Meroitic industry as its influence is too large and too long a period for it to be entirely one industry. Therefore, Meroitic Nubia has different wares and groups, and industries in a social and economic context (Adams, 1973). For the latter half of the Meroitic period Adams identified three industries, the Nubian hand-made ware, Nubian wheel-made wares and imported wheel-made wares (Adams, 1973). These were divided on the basis of them being stylistically different but also due to them being made by different people for different purposes (Adams, 1973). The impact of location, and specifically on the cataracts, is very apparent with the distribution of wheel-thrown pottery in Nubia, Egyptian ware is often found in Lower Nubia however above the second cataract they are rare luxury goods (Adams, 1973). From the distribution of the Nubian wheel-thrown ceramics on the cataracts it can be determined that the Nubian industry was centred around the north, likely influenced by Egypt (Adams, 1973). In Lower Nubia it is different as local wheel-made wares were highly predominant over Egyptian and local hand-made wares (Adams, 1973).

Differentiating ceramics can be done by multiple aspects of variability, such as methods of manufacture, materials employed, vessel forms, surface finish, colour and style of decoration, and these can give indications of different areas of provenance (Adams, 1973).

These variations can indicate a region of origin and could be caused by a cultural and or an environmental impact. The raw material, such as the clay deposits, are also usually from a local source and can give chemical information on the provenance of the material. Distinguishing wheel-thrown ceramics that were from post-pharaonic Nubia or imported from Egypt were separated by four main characteristics, fabric, finish and decoration, forms, and distribution (Adams, 1973). The typology that David and Evina created for the ceramics found at the Sedeinga excavations will be compared to the scientific results achieved here to decide if the groups created from the thin sections and XRF data coincide with the data from the original typology. The 58 samples chosen for analysis were picked on the basis of the macroscopic features as defined by Romain David. He gave 7 classification fabrics and named them SED 001, SED 002, SED 004, SED 005, SED 009, SED 011, SED 012. Groups SED 004, 005 and 009, are the fine ware samples and all suggested to be kaolonitic-clay based ware. Groups SED 001, 002 and 0012 are Nile-clay based samples but wheel-thrown productions which are all similar but could be divided more with the petrographic analysis. The final group is SED 011 that consists again of Nile-clay based samples but are hand-made productions, using techniques such as moulded and coiled, and the paddle and anvil method. Later these groups will be compared to the scientific data to see if they are chemically and mineralogically similar or not. This typology is the basis of the study for analysing these ceramics, and can give information on the provenance and production technology for these ceramics..

2.4.2 DESCRIPTION OF CERAMICS

Referring back to the D.I Meroitic Group previously mentioned, during the Meroitic period there were four principal hand-made wares. The most common style was a thin-walled and completely undecorated vessels mainly used for bag-shaped storage jars, Ware H1 (Adams, 1986a). A slightly less common style was Ware H12 which has simple painted deigns only on the neck or shoulders of the jars while the bottom sections were un-slipped and undecorated (Adams, 1986a). A third common ware was made up of a thick-walled with an all over burnished slip in black, red or white, consisting of mainly bowls, which sometimes had incised decoration in very simple rectilinear patterns, known as Ware H9 (Adams, 1986a). H11 is the hand-made Meroitic ware in this group that is very distinct from the rest. It is thin walled, quite hard, and highly burnished black ware, decorated with incised or comb-pricked designs filled with white pigment (Adams, 1986a). As this group of wares (H11) is rather unique and rare it suggests the possibility that these vessels are specialised products and could have been traded from distant regions (Adams, 1986a).

Nubian wheel-made wares were also present in Upper Nubia but as there is a gap in the archaeological record in resettlement of Lower Nubia and therefore no examples of wheel-made Napatan or early Meroitic ware. These styles of pottery just appeared in Lower Nubia from the moment of the resettlement with no signs of a gradual development of the style and process (Adams, 1986a). Then during the Meroitic period in Lower Nubia the Meroitic wheel-made wares consist of groups Family M and Group N.I, there was a great diversity in the pottery suggesting a coexistence of many different manufacturing centres (Adams, 1986a). The Family M wares were made using fine residual clays and Group N.I used Nile mud for the material of the pottery (Adams, 1986a). Within these groups there were four basic decorated wares, consisting of eggshell white ware, ordinary white ware, eggshell red ware and ordinary red ware (Adams, 1986a). The white wares were almost always highly decorated but the red wares had little decoration and sometimes no decoration at all (Adams, 1986a). There was also a difference in the vessel forms for the separate colours, the red wares were usually cups, bowls and bottles, while the white wares were also used for many different forms (Adams, 1986a). There were another two red wares in the Meroitic pottery that were likely created in specialised centres (Adams, 1986a). The first style, R33 is only known as jars and bottles with no decoration except a very fine black and white stripes on a red background, and the other style R34 happens on a variety of forms all similar to the contemporary Aswan pottery (Ware R30) but made from Nile mud (Adams, 1986a). There are many collections and examples of Meroitic pottery and as they are so abundant it is difficult to split them into individual groups. The Meroitic ware have historical and taxonomic problems as not much importance was put into their place or origin, manufacture and the identity of the potters making them (Adams, 1986a). The Group-X replaced the Meroitic pottery after 350 AD, and there is little continuity seen, as the Meroitic pottery is mainly white and well decorated while the Group-X pottery is commonly red with simple lines and spots or not decorated at all (Adams, 1986a). This complete change in style and decoration has always hypothesised that the Group-X ware people were outlanders who took over Meroitic Nubia (Adams, 1986a).

2.4.3 SEDEINGA COLLECTION

In total there are 58 ceramic samples collected from Sedeinga, and these samples can be divided by description into decorated ware, red slip ware and no decoration (Table 1). The kaolinitic clay samples have a light pink tint to the ceramic and are light and thin in composition. The Nile clay samples have a dark brown intense body. The colour of the ceramic body in general is due to the abundance of iron and organic material, the firing atmosphere and the length of firing (Quinn, 2013).

The painted decorated ware mostly consists of the thin kaolonitic-based ware with some on the red slip ware. Additionally some of the kaolinitic-clay based and Nile-clay based ware samples have impressions and some samples with no red slip. The painted decoration on the kaolonitic-clay based ware varies from lines to shapes, border lines and flowers, and other patterns. Impressions were found on the kaolonitic-clay based and the Nile-clay based samples, they were delicate with comb stamps, leaves and triangles with intricate designs and maybe ankh shapes (Figure 7). From this we can see the craftsmen were very detailed and they put a lot of effort into designing these pots. Most of the decoration on the ceramics consisted of a red slip, and then the second most common was painted ware, there were many with a base of red slip with additional painting, or painted ceramics with stamps. There were only a few without a red slip or painted decoration, with either just impressions or no decoration at all, mostly the coarse ware.

Decoration	**Sample number**
Painted	1,8,9,10,11,12,13,14,16,17
Painted & Stamped	2,3,4
Red Slip & Painted	6,22,26,51
Red Slip	5,18,19,20,21,23,25,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42, 43,44,45,46,47,48,49,50, 52
Impression	7,54,55,56
None	15,24,53,57,58

Table 1 – Description of decoration on the Sedeinga samples

The decoration within the fine kaolonitic-based ware is quite varied and with the most detail, such as sample 3 (Figure 7). The painting on the ceramics consist of black, white and red/orange pigment, sometimes the patterns are linear and in some cases they are intricate patterns with a high amounts of detail. Details of the painted designs can be seen in sample 10 and the use of colour is visible in sample 11 (Figure 7). The level of effort and skill needed for creating these ceramics could suggest a certain level of specialisation, however, it is unsure if these vessels were decorated elsewhere or at Sedeinga. As there has been no evidence for a workshop in Sedeinga it is likely to assume that they were decorated elsewhere. The coarser Nile-clay based ware is more simple, twenty-eight out of the fifty-eight samples just have a red slip, and only six have a form of other decoration on them. The red slip ware is mostly just the slip and they lack any other decoration, only four in total have extra designs on them. If we recall that these ceramics were all found in funerary contexts, we can study them with their use for ritual functions or as treasures or offerings to be buried with the deceased. The decorated fine ware could have been perceived as prestigious ware and was deliberately chosen or purposefully made for funerary customs.

Figure 7 - Photographs of some of the decoration of the fine ware. Top to bottom sample 3, 10, and 11

The most common decoration for these samples is a red slip with only a few with additional decoration. The red slip samples are presumably all of the Nile-clay based production of both wheel-made and hand-made ceramics. The samples have a red slip on the outer layer and are undecorated on the inside of the ceramic (Figure 8, sample 46), a high number of these samples also have a dark or black ceramic body, indicating a low firing temperature and from the thin sections we can see some of these samples have organic remains preserved in them. Some of the red slips also have additional paintings on them, the extra decoration is somewhat common with many samples having both slip and paint, or stamps and paintings on them (table 1). Additionally, there are some samples with no decoration at all, but some of the samples with no slip or paint have incisions accounting for minimal decoration. Fine ware ceramics from Musawwarat also included painting and stamp patterns have some parallels to ceramics found at Sedeinga. In particular, sample 2 (Figure 8) from Sedeinga is very similar to a stamped ceramic found in the 224 courtyard (Figure 8) (Edwards, 1998). The shape is similar to an ankh but with a solid circular top, and then in the Musawwarat sample it also has vertical lines above it. Both of the samples are of fine ware and have a red rim stripe (Figure 8 sample 2 from Sedeinga and Edwards, 1999 sample 2) on the vessels which shows some correlations between the designs at both sites. This is another indication for trade of ceramics vessels within the Meroitic landscape or a trade of motifs and designs by potters along the Nile. This could suggest that the craftsmen at Sedeinga saw these designs on the one pot and then used them separately on two pots so to have some difference in the decoration.

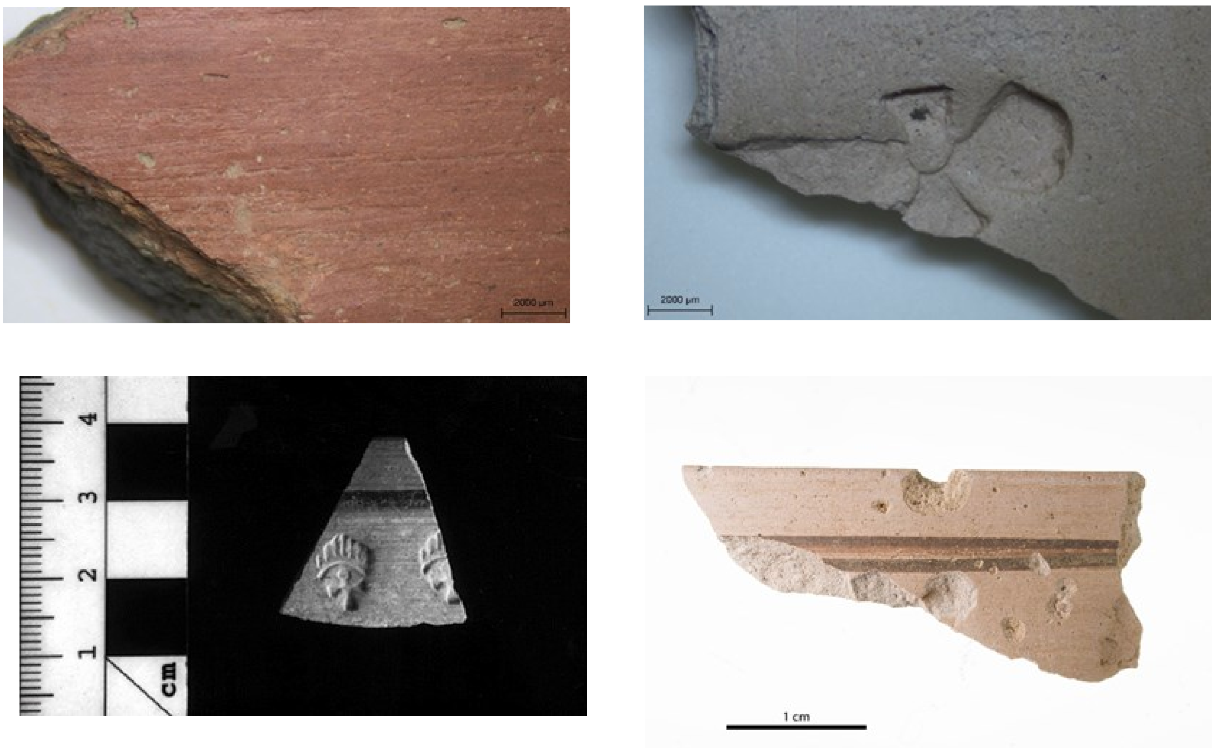


Figure 8 – Top row: L-R sample 46, 2. Bottom row: L-R sample from Edwards 1999 and Sedeinga sample 2

Comparing styles and forms within Nubia gives us an insight to the differences and similarities in the multiple local productions throughout Nubia. The style can also be distinct to an area, so it can provide us information about the potters and community that made them. However, we cannot fully understand the entire characteristics of the ceramics without scientific analysis and studying the raw material of the vessels. Scientific analysis together with the information from the surface analysis can give us a very wide and detailed description about the ceramics.

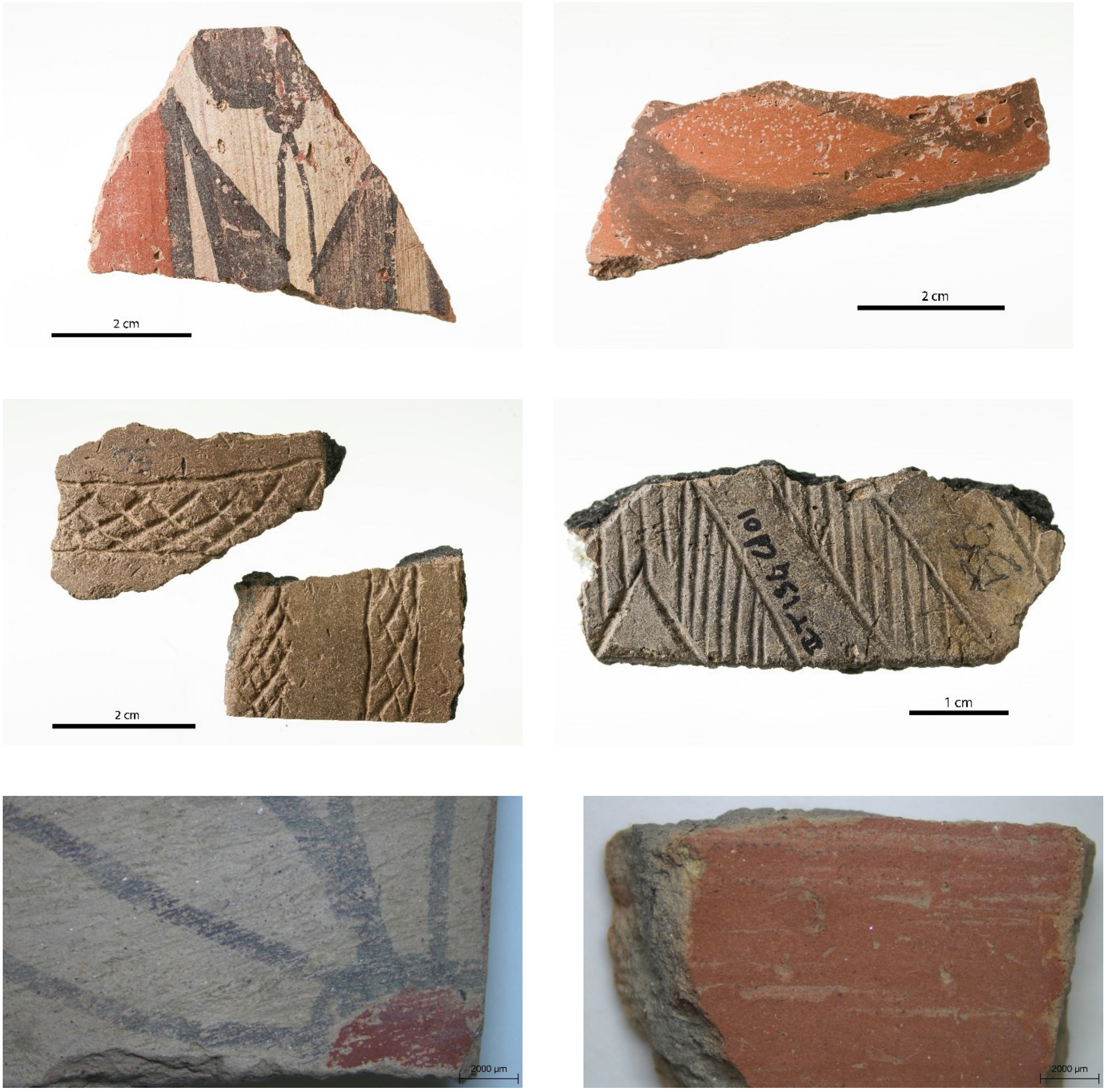


Figure 9 - Photographs and photographs from the stereomicroscope of the samples. Top L-R sample 22 and 26 – red slip with paint. Middle row L-R Sample 54 and 56 – impressed ware. Bottom row L-R sample 14 with painted decoration and sample 28 with a red slip

2.5 Geological setting

The geology of the area is also an important factor when trying to define the provenance of ancient ceramic and therefore to identify is local raw materials were used. The geological setting can help with the provenance of the raw clay and therefore where it was produced, locally or if it was imported ware. The geology of Nubia is underlaid by the African shield, composed mostly of Precambrian metamorphic and intrusive basement rocks, and Nubian sandstone, with the Nile running through it causing Nile alluvium clay (Mason and Grzymski, 2009). A map is included here which shows the geology of Sudan that includes Sedeinga, which is shown to have a Precambrian geology (Figure 10) (Maritan et al, 2023).

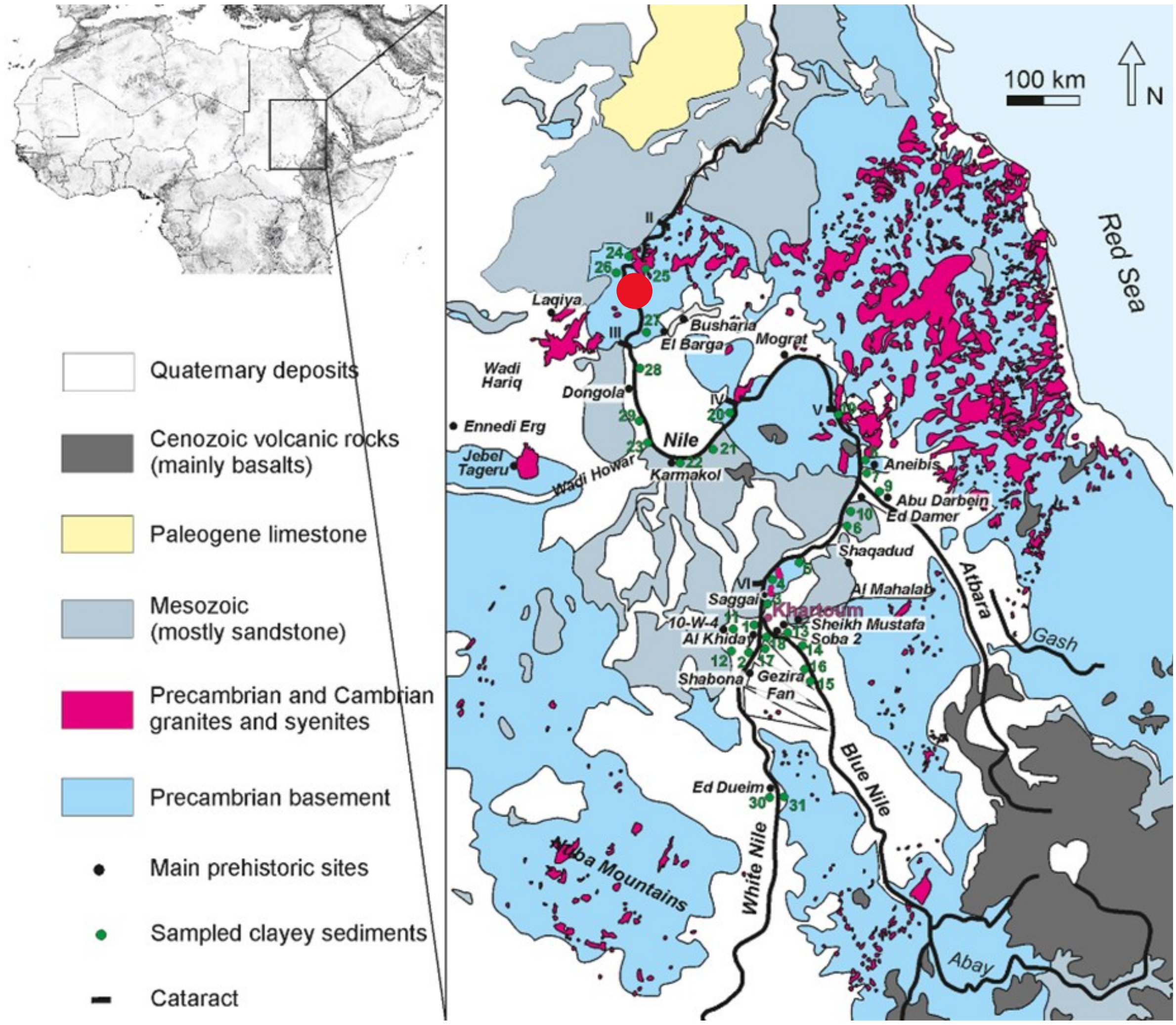


Figure 10 - Map of geological setting of Sudan from Maritan et al. 2023 – Red dot indicates location on Sedeinga

The Precambrian basement complex, also known as the Pan-African basement, is composed of igneous, high-grade metamorphic, and sedimentary rocks, and some Cambrian intrusive rocks (Maritan et al, 2023). The basement complex is overlain by the Mesozoic sedimentary sequences and are mainly represented by the Nubian sandstone formation and by Cenozoic volcanic rocks locally (Maritan et al, 2023). There are extensive Quaternary deposits near the river systems and in the large areas around it, formed by gravels, sands and clayey material (Maritan et al, 2023). There are also kaolonitic-clay deposits interbedded with the sandstone in the Shendi Formation (Ting and Humphis, 2017). An important factor of the geology is the Nile River and its evolution is always changing the landscape. The Nile basin drains about one tenth of the African continent and the evolution of the drainage network reflects the changes in erosion and sedimentation, and major changes in vegetation and climate (Woodward et al. 2007). The drainage basin and its major tributaries consist of several different sub-catchments, the White Nile, the Blue Nile, the Atbara, and the desert Nile (Maritan et al, 2023). As each of the sub-catchments drain into specific geological bedrocks and have different water sources causing the loads and deposits to have specific mineralogical, sedimentological, and geochemical properties (Maritan et al, 2023). The White Nile basin consists of clayey deposits rich in rounded monocrystalline quartz and limited number of feldspar; and then the Blue Nile ones contain abundant mafic volcanic grains, biotite and feldspar, while the Atbara River carries volcanic rock fragments, olivine and augite (Ting and Humphis, 2017). The alluvium of the Nile after the confluence of the Blue and White Nile is generally more homogeneous and contains minerals such as quartz, feldspars, plagioclase, mafic minerals and basic rocks fragments (Maritan et al, 2023). The importance of knowing the varieties of composition of the sediments along the Nile River is high so different raw materials locations can be known. With this there is a base knowledge about the soils and geology at Sedeinga and can give us a base knowledge for this study.

3 Petrographic Analysis

3.1 Description of method

Petrographic analysis was the first technique conducted on these samples, which consists of data gathered from thin sections under a polarised-light microscope about the ceramic body. It can disclose the fabric and inclusions found in the ceramics and lead towards discovering the provenance of the raw material (Maritan, 2023). More information that can be gathered from thin section analysis can include the raw material processing, firing temperature and information on the slip and decoration of the ceramic (Quinn, 2013). Petrographic analysis consists of using a polarised-light microscope to look at thin sections, and here specifically of ceramics samples. The use of describing a thin section for a ceramic sample was first proposed by Whitbread (1989) and later developed by Quinn (2013). Petrographic studies are used to focus on the composition of the ceramic bodies of the samples with less attention on the slip or coating of the ceramics (Quinn, 2013). The thin sections are 30µm thick and then this slice of the ceramic is fixed onto a glass microscope slide (Quinn, 2022). The thin sections from Sedeinga were analysed using an petrographic light Olympus microscope with magnifications of 4x-40x with plane polarised light (PPL) and crossed polarised light (XPL). The XPL settings produce optical effects that can help with mineral identification (Quinn, 2022). When examining the thin section of a ceramic, multiple different aspects of the pottery can be seen. First, there is the ceramic body, which encompasses everything apart from the added slip or decoration. Then within the ceramic body there is the clay matrix or micromass which consists of a fine-grained material less than 10 µm in size (Quinn, 2022). This is formed by fine silt and the fired clay fraction that forms the base of the ceramic body, the matrix can be described according to its optical state and orientation. Next are the inclusions, which are made up of grains of minerals and rocks larger than 10 µm (Quinn, 2022). They can be individually identified and classified, then described in terms of their size, size-distribution, and shape. Voids are another characteristic of a thin section which are spaces that remain unoccupied in the micromass. Then outside the ceramic body there can be a coating (in this case study a slip or a painted decoration), which is a type of coating produced by an aqueous suspension of clay, and a glaze, which is a thin, glassy layer fused to the surface of a ceramic body through firing. In general, all ceramic thin sections are described by these features, in both plain-polarised light and cross-polarised light. These characteristics and others such as decoration, will be employed to divide the samples into distinct groups. These groups will subsequently be compared to other data sources from ancient Nubia in order to identify any potential parallels with other clay bodies and similarity between the Sedeinga collection to ascertain their similarity. This aims to provide an understanding of the provenance of the raw material. It is worth noting that the dataset comprises 57 thin sections; however, a thin section for sample 6 was not prepared.

Voids are gaps within a thin section where there are cut pores within the sample (Quinn, 2013). Voids are highly important within the ceramics as they influence aspects of the physical property of the vessel, such as its weight, thermal conductivity, toughness, insulation and permeability (Quinn, 2013). Voids can be created during the processing stage and during their accumulation. They can also be caused during the drying stage of production by the shrinkage of clay as it releases its absorbed water (Quinn, 2013). Rapid drying and shrinkage can also cause cracking, especially in fine ceramics. Voids are usually formed from either the burning of organic material, over-firing causing bloating pores, or during the firing process causing physical shock (Quinn, 2022). It is important to note that some of the voids also could have been created during the preparation of the thin section, if completed poorly. This can lead to some discrepancies within the statistics. Some are clearly identified as inclusions accidentally removed during the thin section making process but also some voids are due to the complete burning of organic material which can be identified from the shape of the void. Voids are described by the shape and size using prerequisites from soil micromorphology, such as ‘channels’ and ‘vughs’ (Quinn, 2013).

The colour of the clay in thin sections is determined by multiple factors, mainly the types and amount of clay minerals present, the abundance of organic material, the amount and oxidation of iron and the presence of other particles (Quinn, 2013). However, colour is also influenced by the firing technology and the post-depositional affects (Quinn, 2013).

The process of petrographic analysis focuses on the matrix, inclusions, and other material found in the thin sections. The petrographic analysis of these samples resulted in a table comprising of all the key information, this table can give a quick overview of the important aspects of the contents of each of the thin sections and help group similar ceramics together (appendix). The main characteristics that we can see from the table includes the shape and size of inclusions, the optical state of the matrix, and the amount of minerals and organic material.

3.2 Characteristics of thin sections

An overall view of the samples show some similarities within the entire collection. The coarse fine ratio (c:f) for all the samples are either open spaced or double spaced with a c:f quantity between 10%-30%. The samples are all quite similar within the fine ware and coarse ware groups, the majority of them have a strial b-fabric and unimodal grain-size distribution. The shapes of the inclusions are also all similar, being mostly subangular in shape. However, the designs of the surface of the vessels are varied, with slips, painted surfaces or incisions, and this could suggest a different workshop solely for the decoration. The similar fabric within the kaolinitic-clay based and Nile-clay ware groups suggest that the respective groups were manufactured in the same workshop.

Analysing the kaolinitic-clay based thin sections there is an average 10-15% course-fine fraction, and an average size of inclusions around 30µm with mainly quartz and small amounts of plagioclase, K-feldspar and biotite in a variety of sections. When we compare this to Mason and Grzimsky study (2009) it seems similar to the Meroe kaolinitic petro-fabric, they suggest that its source is from the Precambrian Shield, that we know from the previous chapter includes Sedeinga, so this suggests the theory that the raw material of these samples are from this geological source.

The coarse ware samples, have a higher course-fine fraction ratio, from 20%-30% and an average size of inclusions around 30µm-40µm. The main inclusions are quartz, plagioclase, K-feldspar and muscovite, and in the coarse ware there are a lot of organic remains, in the form of undisturbed organic material, phytoliths, carbon residues, and burnt organic remains. This group used a temper with plant remains and no addition of minerals, therefore there is likely no mineralogical changes as there is no mineralogical temper.

3.2.1 Petrographic Groups

Romain David divided the material in 5 groups depending on the production type and the decoration style, the Nile-clay based samples are labelled SED 001, SED 002, SED 011 and SED 012, and the kaolinitic-clay based samples are labelled SED 004, SED 005 and SED 009 (appendix). The 57 samples with thin sections can be divided into groups determined through the previously defined characteristics of petrographic analysis. Dividing the samples can help show the variety of samples and the difference in the multiple production styles. The collection can be first divided between the kaolinitic- and Nile-clay based samples, splitting the first 18 samples apart from the rest. Then these groups can be subsequently subdivided into more definitive groups based on the previously defined factors. Within the kaolinitic-clay based fine wares there are four sub-groups and the Nile-clay based medium ware has six sub-groups. Using petrographic analysis we can divide the samples by the information gathered microscopically.

3.2.2 Fine Ware

The first group from the petrographic analysis is the fine ware group and is composed of all the kaolinitic-clays based ware, named Group 1. The first sub-group is 1A, a very fine ware, consisting of samples 1-7. The samples are all open spaced, have a 10-20% c:f ratio and the average inclusions are around 40µm in size. There are small amounts of inclusions present, with mainly quartz and small amounts of other minerals. They are all optically active and all have a very similar fabric, also to note that sample 4 has a piece of chamotte in the fabric (Figure 11).

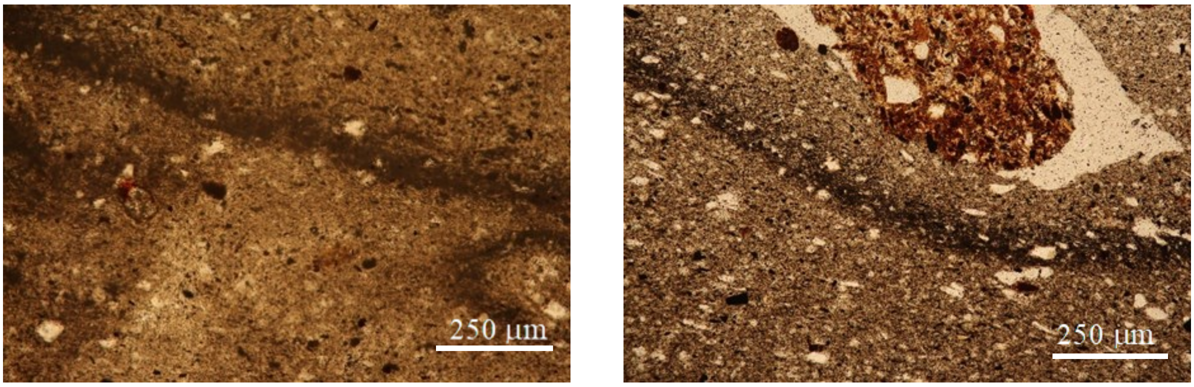
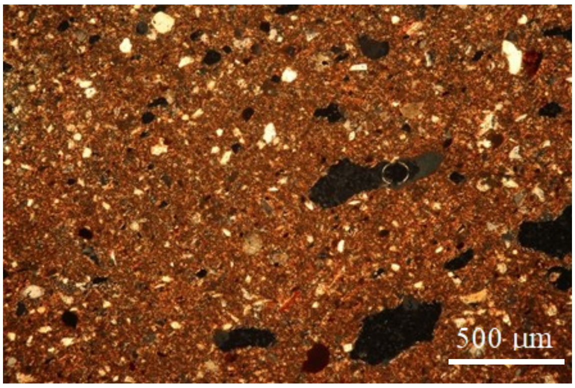


Figure 11 – Photomicrographs of group 1A in plain-polarised light of kaolinitic-clay based potsherds (left: sample 7; right sample 4 with inclusion of chamotte

The next fine ware group is 1B consisting of samples 8-12, with sample 8 having some more coarse grains compared to the others. These samples have an average inclusion size of 40µm and a c:f average of 15% and are optically active with a small amount of inclusions (Figure 12). Sample 8 has an average inclusion size of 70 µm so clearly more coarse in comparison to the rest of the group, this is important and can be analysed further with XRPD and XRF analysis.



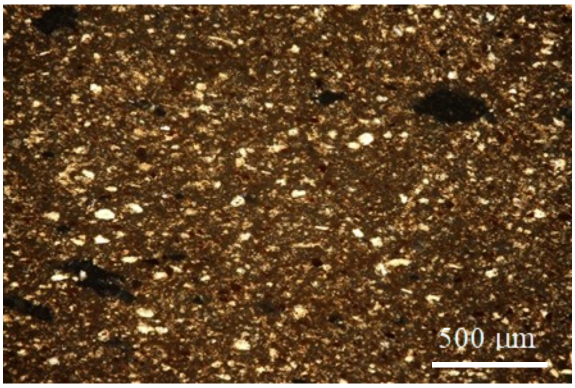
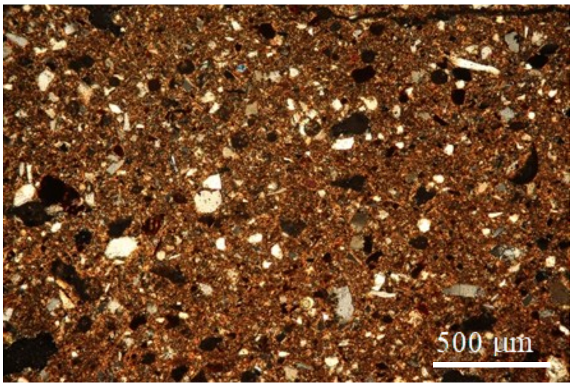


Figure 12 - Photomicrographs of group 1B in crossed-polarised light of kaolinitic-clay based potsherds: left: sample 8; right: and 12.

Group 1C are samples of fine ware with more abundant fine inclusions which include samples 13-17. Again these samples are all similar in the fabric, however sample 14 is slightly more coarse with larger inclusions, the c:f ratio in sample 14 is 30% but the other samples have a 10% c:f ratio (Figure 13). There are a small number of inclusions, mainly found are quartz and biotite. The average size of the inclusions is between 30-40µm and they are all unimodal in distribution. There is a clear distinction between sample 14 and the others within the size and spatial distribution on the inclusions. Sample 14 can also be noted as slightly different, similar to sample 8 and be studied further with XRPD and XRF.



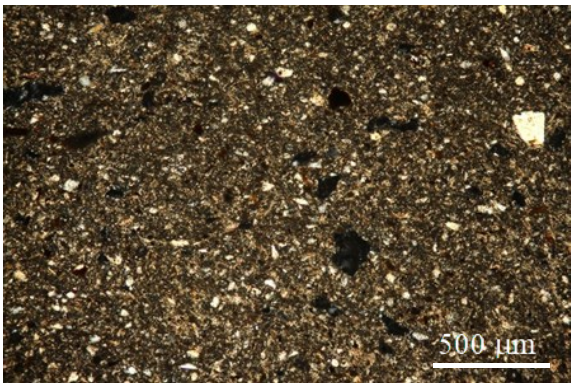


Figure 13 - Photomicrographs of group 1C in crossed-polarised light of kaolinitic-clay based potsherds: left: sample 14; right: sample 17.

The final group in this Fine Ware group is group 1D and is only sample 18 as it is a medium-fine ware and petrographically different compared to the other kaolinitic-clay based samples. Sample 18 is double spaced and not optically active, unlike the other samples. Its average size of inclusions is 50µm and interestingly it is the only kaolinitic-clay based sample with vegetal remains. Sample 18 is clearly very different petrographically to the other kaolinitic samples, so with the other data we can determine if there are any chemical or mineralogical differences and how this influences the changes within the petrography.

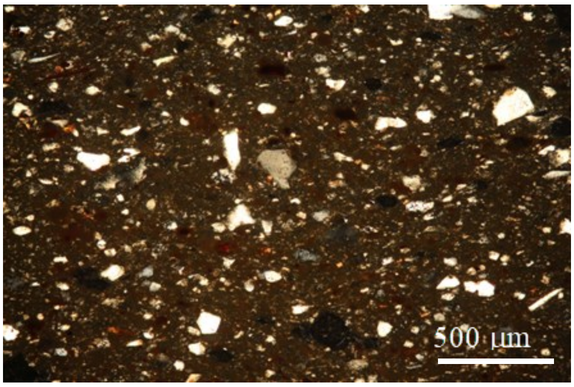


Figure 14 - Photomicrograph of group 1D in crossed-polarised light of sample 18 with coarser inclusions

3.2.3 Medium-Fine Ware with Vegetal Temper

The next group of thin sections is the Nile-clay based ware samples which are coarser and have a medium-fine ware fabric with vegetal temper, named Group 2. The first sub-group is 2A which includes samples with a unimodal grain-size distribution of inclusions with some large grains and few small inclusions, samples 19-21, 39, 43-45. Samples 19, 43 and 45 are all double spaced whereas the other samples all have a singled spaced distribution (Figure 15), however they all contain organic material. Samples 39, 43-45 all contain higher amounts of organic temper or its traces after partial decomposition/burning compared to samples 19-21,

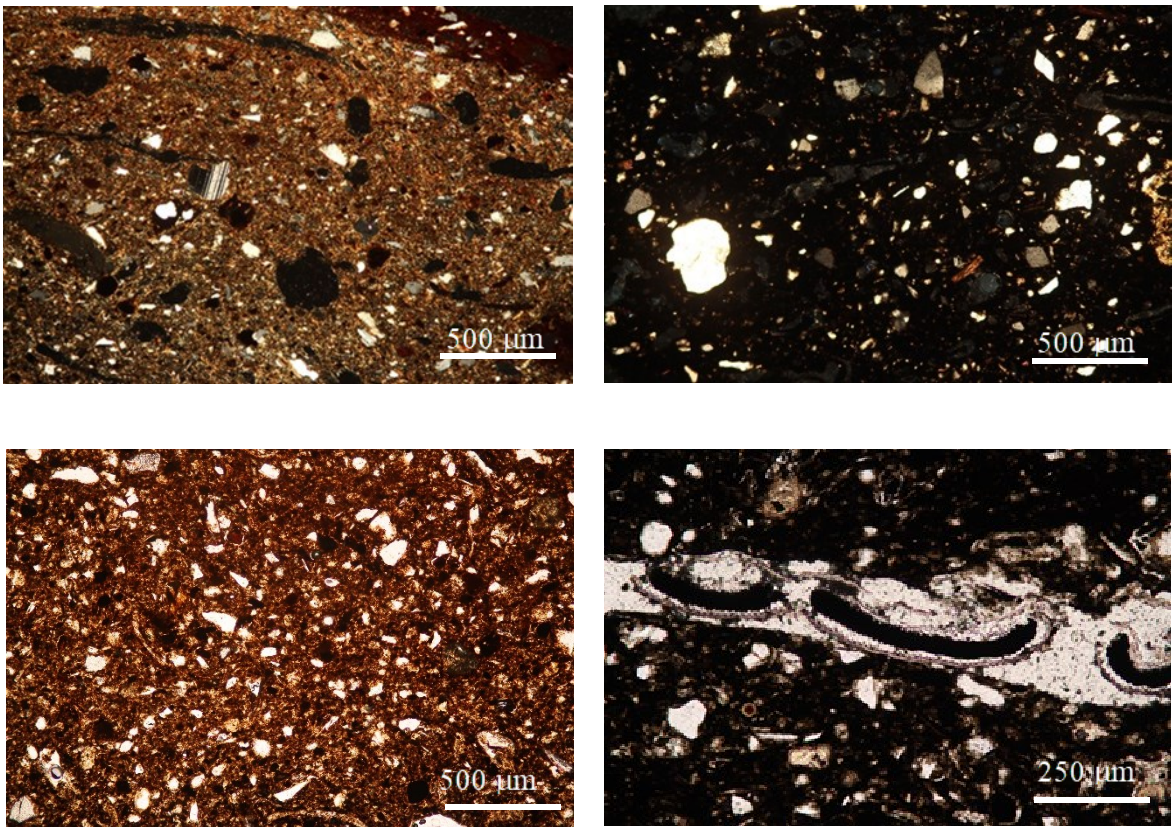


Figure 15 - Photomicrographs of group 2A of Nile-clay based potsherds. Top: images in crossed-polarised light: L-R: sample 19, sample 21. Bottom: images in plain-polarised light: L-R: sample 45, samples 43 with remains of organic material

however samples 43 has a lot of well-preserved organic remains. Also, with the Nile-clay based samples there is an increase of inclusions in the ceramic body, as seen in the petrographic table (appendix). A higher variety of inclusions are found in the samples, such as plagioclase, biotite and pyroxenes.

The next group is 2B which like 2A have a unimodal grain-size distribution but the samples have more fine inclusions with fewer large inclusions. This group includes samples 22-25, and 29-31, 46-48 and 53. These samples all have a 20% c:f ratio apart from samples 47 and 53, and an average size of inclusions is around 40µm and there is again a high amount of vegetal material within the samples. A lot of the organic material is well preserved such as monocot leaves and bulliform cells and then some burned organic material leaving residues of carbon behind, but more detail on the organic material will be reviewed in the next section. In these samples there are some rock fragments found and some chamotte pieces also found (Figure 16). Some of the surface designs, such as a red slip is visible on the thin section, such as sample 25 (Figure 17) which shows a clear distinction between the ceramic body and the red slip.

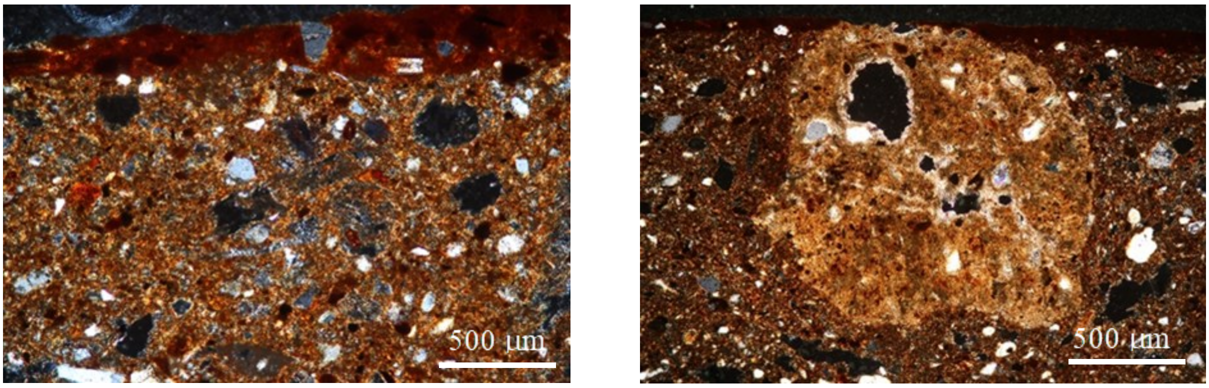


Figure 16 - Photomicrographs of group 2B in crossed-polarised light of potsherds of group 2A. L-R sample 25, sample 29 with a rock fragment.

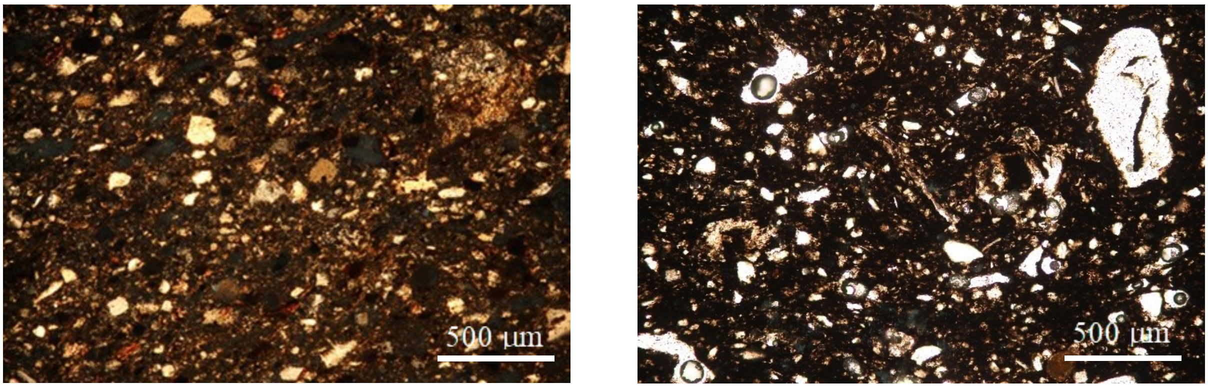


Figure 17 - Photomicrographs of potsherds of group 2B. L-R: crossed-polarised light sample 22, plain-polarised light: sample 46

The next groups is 2C which has a unimodal grain-size distribution with fewer small inclusions and more larger ones. This group includes samples 26-28, 32-37, and 40-42. These samples are mainly open spaced, optically active, have a c:f ratio around 20% and the average size of inclusions are 40µm. There are some organic remains in these samples also, mainly carbon residues and some well-preserved material in the black core of the ceramics (Figure 18).

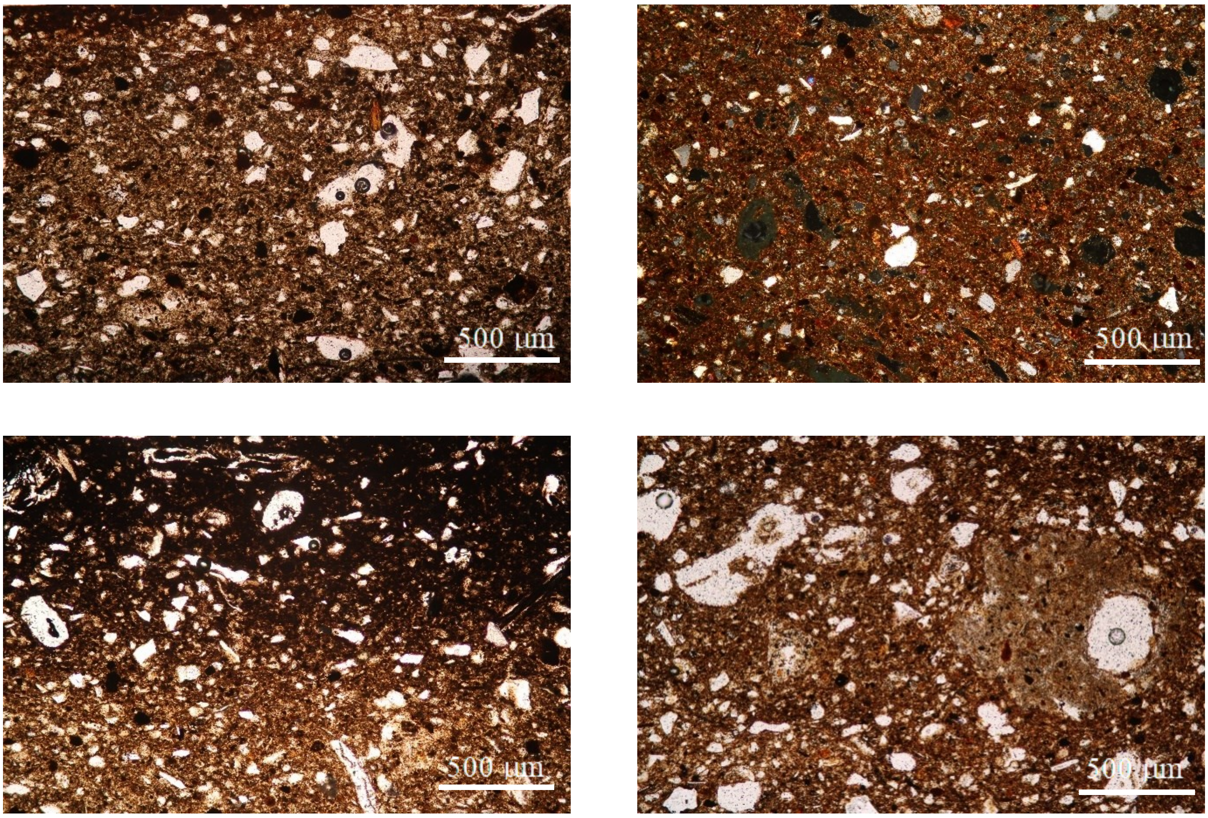


Figure 18 - Photomicrographs of potsherds of group 2C. Top: left: sample 28 (taken in plain-polarised light), right: sample 34 (taken in crossed-polarised light). Bottom: left; sample 35 (taken in plain-polarised light); right: sample 41 (taken in plain-polarised light).

The next group is 2D, which only includes two samples, 38 and 57. They have a unimodal grain-size distribution with more abundant inclusions. Sample 38 is double spaced, with a 30% c:f ratio and 50µm average size of inclusions, and the organic temper was completely burned with some surviving as carbon residues. Sample 57 is single spaced with a 40% c:f ratio and the inclusion average size is 40µm with well-preserved organic material. The abundance of inclusions in these samples are what group them together, and the similarities in the fabric (Figure 19).

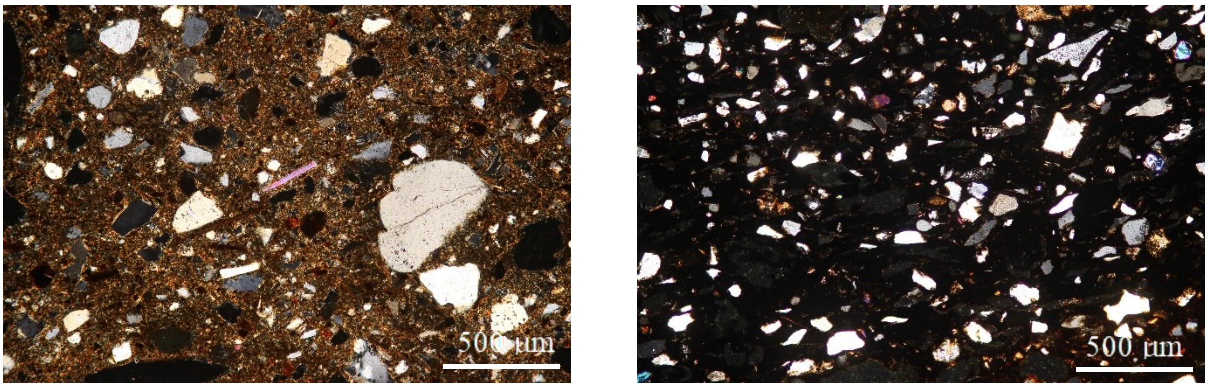


Figure 19 - Photomicrographs in crossed-polarised light of potsherds of group 2D. L-R: sample 38, sample 57.

Group 2E is the next group, which includes samples with a bimodal grain-size distribution and a lot of large inclusions. The samples included in this group are 51-52, 54-56 and 58. These have a mix of open spaced and double spaced, with 20%-30% c:f ratio with abundant well-preserved remains of organic material (Figure 20). The samples mainly do have a red slip and either have impressions, painted designs or no designs at all.

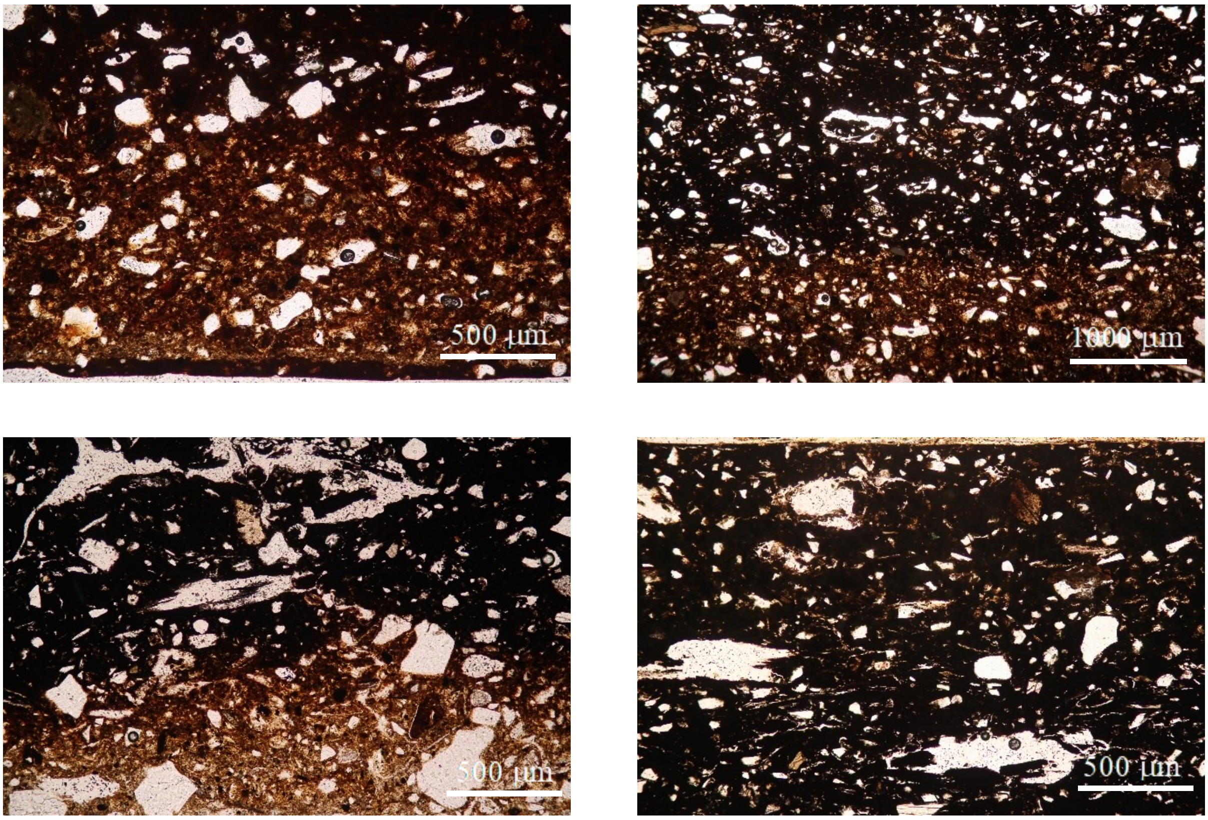


Figure 20 – Photomicrographs in crossed-polarised light of potsherds of group 2E Top: left: sample 51; right sample 54. Bottom: left: sample 55; right: sample 56

The final group of the samples is 2F, which included samples 49 and 50. They have a unimodal grain-size distribution with abundant inclusions. They have a little amount of organic material, and if any they are not well-preserved. There is an evident difference between the outer and inner section of the ceramic body (Figure 21). The size and abundance of the inclusions are visible and show the similarities in the samples.

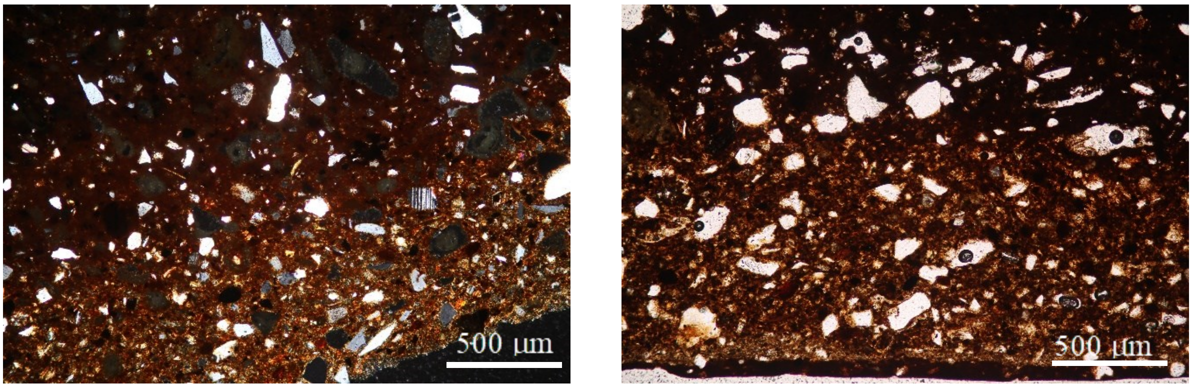


Figure 21 - Photomicrographs in crossed-polarised light of potsherds of group 2F. Left: sample 49, right: sample 50.

Overall, there are four sub-groups in the fine ware samples, and six sub-groups in the medium-ware samples. However, the differences within these sub-groups are quite small and show that these samples are very similar to each other petrographically. This suggests that all the Nile-clay based samples are highly likely produced with the same raw material and the same is for the kaolinitic-clay based samples. To understand more about the characteristics of these thin sections, the organic inclusions and mineral inclusions are discussed in more detail in the next section.

3.2.4 ORGANIC MATERIAL

Plant matter is also found in ceramic bodies but as they are composed of cellulose, such as plant stems and leaves, they are usually destroyed during the firing process (Quinn, 2022). However, ceramics in low firing temperatures can leave behind charred carbonised inclusions in the shape of the vegetal material or intact plant remains (Quinn, 2022). If a void from the burnt material is left it can sometimes lead to identifying the material, such as grass fragments having elongated and curved voids (Quinn, 2022). Within the Sedeinga ceramics, there are vegetal materials within the core of the Nile clay samples and is an important factor to consider when studying these ceramics. There are copious examples of organic material in these thin sections and this high amount of well-preserved organic material is a major characteristic of this collection, 32 out of the 57 samples include traces of organic (vegetal) remains. There is a clear trend in the samples having organic inclusions from samples 18 to 58, matching all the Nile-clay based samples previously established. The organic material here could be well-preserved in the ceramic due to the low firing temperature and the conditions the vessels were fired in. This can later be compared to the results from the XRPD data analysis to see if this theory is plausible.

In many of the samples there is a visible black area in the middle of the cross section of the vessel (Figure 22). It is in these areas of the ceramic body that the remains of vegetal materials, voids from burnt organic material, bulliform cells in monocot leaves and grass material are found. With the very high amounts of vegetal remains in the vessels it can only be assumed that the organic material was deliberately added by the potter during the production stage of the ceramic to likely act as a drying agent. However, in some samples, such as 18 and 19, there are very small amounts of organic matter suggesting that it was not deliberately added. This could be accounted for by the potter using grass to clean their hands while working and the residue from this was transferred into the clay at the time of forming or if loose organic material was around the production centre and it was blown into the workshop and onto the surface of the clay while being worked.

Also discovered through the petrographic study were some carbon

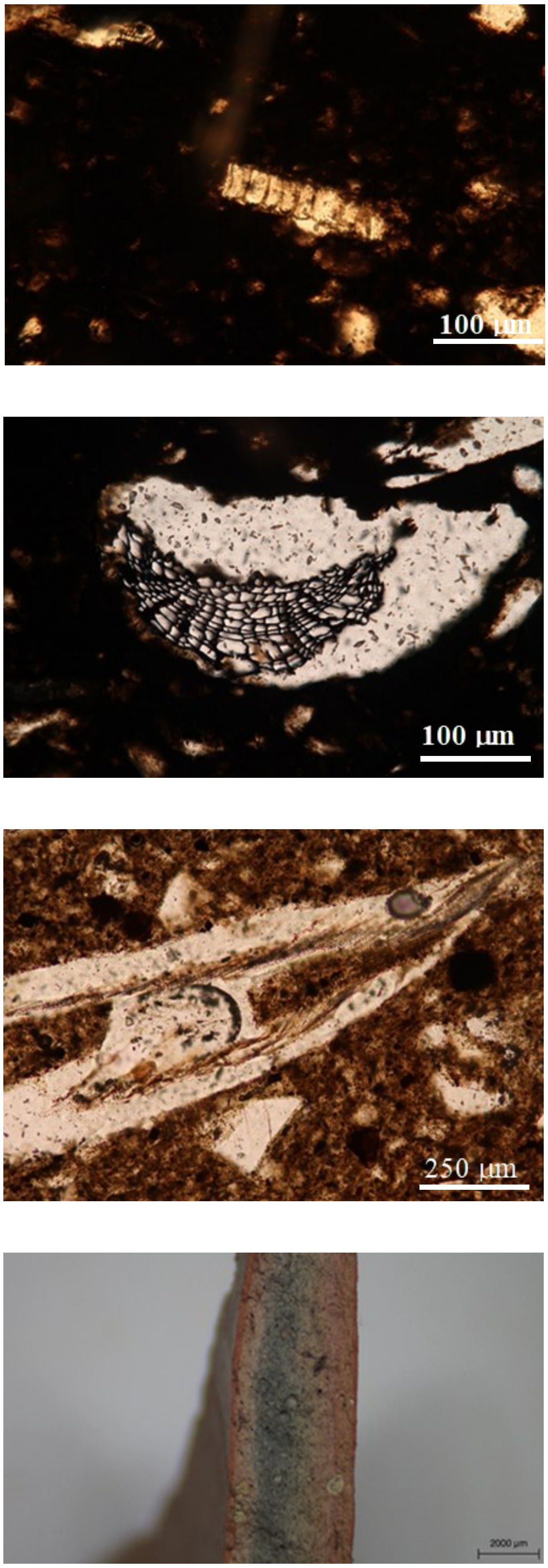


Figure 22 – Photomicrograph of organic remains as observed microscopically (in plain-polarised light) and photo from the stereomicroscope on the fresh cut. From top to bottom: sample 23, 54, 36, 47

residues. Plant matter is usually destroyed during the firing process but they are not always, such as if the pots were fired at a low temperature, which leaves behind charred carbonised black inclusions (Quinn, 2013) (Figure 23 also the second in Figure 22). In some cases it is possible to see the structure of the vegetal remains which partially carbonised. Carbon rings are the result of the burning of organic material which causes smoke to be trapped in the ceramic matrix and cause these voids with carbon residues on the edges of them. These carbon residues are usually found closer to the edges of the ceramics as they would have had a higher temperature than the middle section of the ceramic (Figure 23).

In some samples there is also this brown cell organic material which is an unusual form of organic material. This could be a factor of a low firing temperature as a thin layer of the organic grass or organic matter that hasn't been burned yet into the cell form such as sample 54 (Figure 23).

Another style of organic material discovered in these samples were phytoliths (Figure 23). Phytoliths are microscopic silica bodies which usually are the shape of the cells in or around where they were deposited, meaning they can also preserve variable plant anatomy (Neumann et al., 2019). Phytoliths could be caused by a phytolith rich plant found at the source of the raw material, such

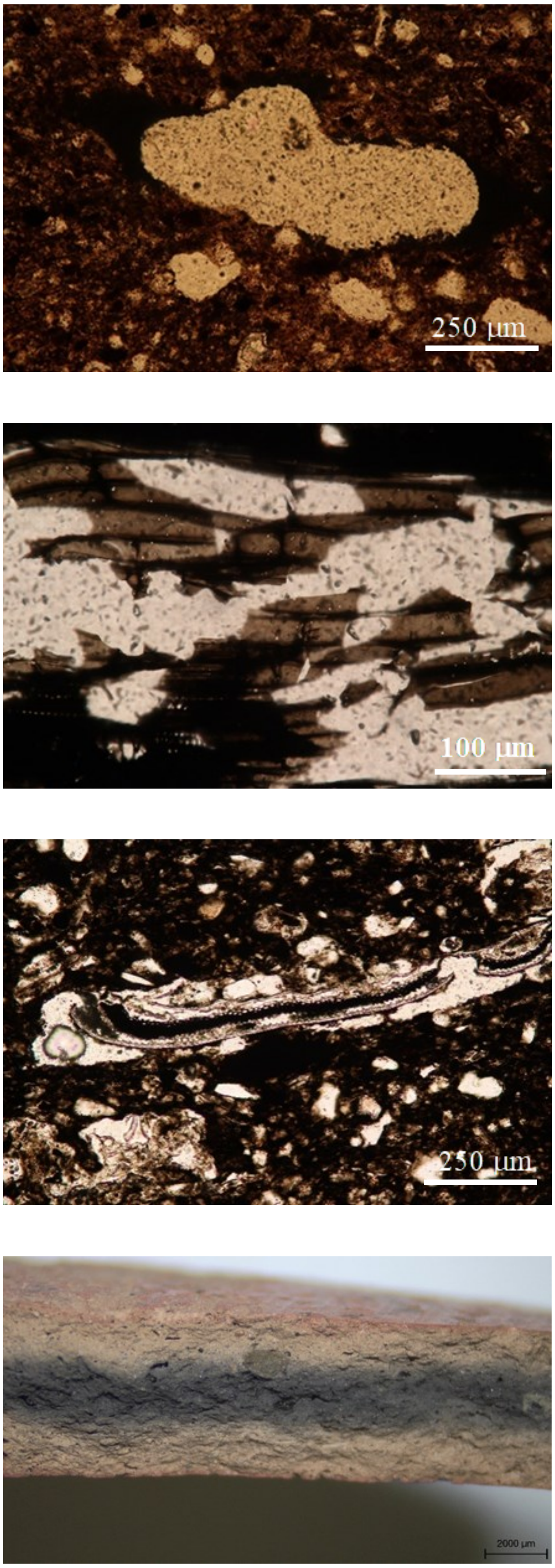


Figure 23 - Photomicroscope of organic remains (in plain-polarised light) and photo from the stereomicroscope on the fresh cut. From top to bottom: sample 24, 56, 43, 37.

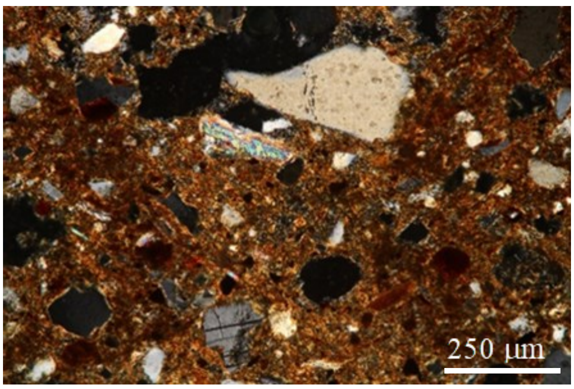
as papyrus, supporting the claim that this clay could be from the River Nile (Mason and Grzimsky, 2009). However, they are usually hard to decipher which type of plant as many shapes are similar in multiple taxa so they generally cannot be identified to a single taxon (Neumann et al., 2019). Phytoliths are important aspects of organic material as they can disclose the type of plants added to the clay and can lead to a better understanding of the firing conditions of the ceramic. The presence of phytoliths has an impact on the firing temperature as plant material usually begins to char around 360°C, however the presence of silica within the plant cell can increase the survival during higher firing temperatures as well as repeated re-heating during functional use (Tomber et al., 2011).

Plant fragments from the *Poaceae* or grass family will usually start to burn around 600-800°C however, this can change with the presence of silica (Tomber et al., 2011). Phytoliths are usually discovered in the oxidised layer of the ceramic, as they will not be blurred by the charred vegetal remains in the reductive layer (Vrydaghs, 2016). The oxidised layer is usually red in colour and have low quantities of vegetal material (since the rest burnt out leaving voids) and are the outside of the ceramic, whereas the reductive layer is an inner black layer rich in vegetal remains, like these Nile clay samples from Sedeinga (Figure 23) (Vrydaghs, 2016).

To further study these remains, especially those partially preserved as burnt material, Raman Spectroscopy will be conducted to gather more information on the firing temperature based on the carbon order vs. disordered ratio

3.2.5 Mineralogical Inclusions

Other materials excluding organic remains were found in some of the samples, including mineral inclusions, some natural glass, chamotte pieces, and fragments of rocks. Mineral and rock inclusions are generally the most common type of inclusions in ceramics,



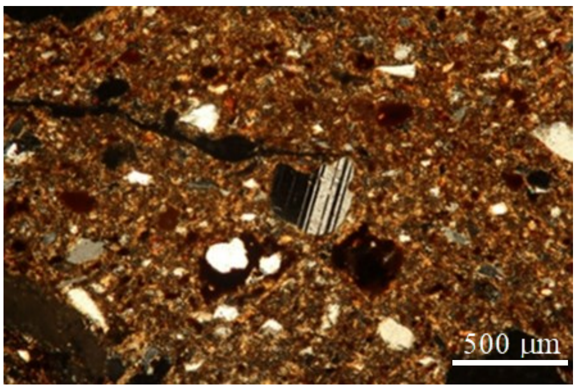
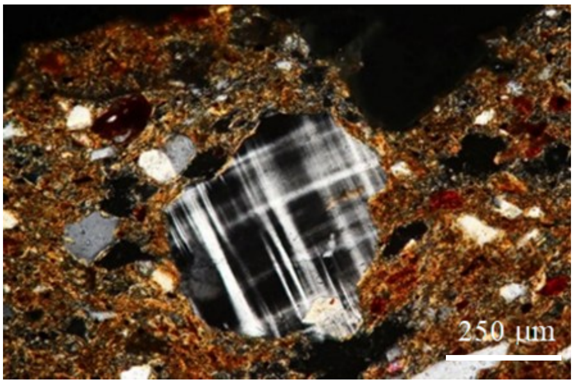


Figure 24 – Photomicrograph in crossed-polarised light of inclusions: top: plagioclase (sample 19); bottom: muscovite (sample 38).

usually from the bed rock near the raw material and eroded, transported and deposited material for sedimentary clays (Quinn, 2013). A lot of mineral inclusions appear in ceramics such as, quartz, feldspars and micas which are usually the most common (Quinn, 2013). From the table (appendix) we can see that there is a high variety of inclusions, for example quartz, plagioclase and K-feldspars are found in many of the samples and then biotite, muscovite, olivine, pyroxenes, amphiboles, chlorite and opaque minerals are found in lesser amounts (Figure 24). Other mineral inclusions including muscovite and biotite (Figure 25).



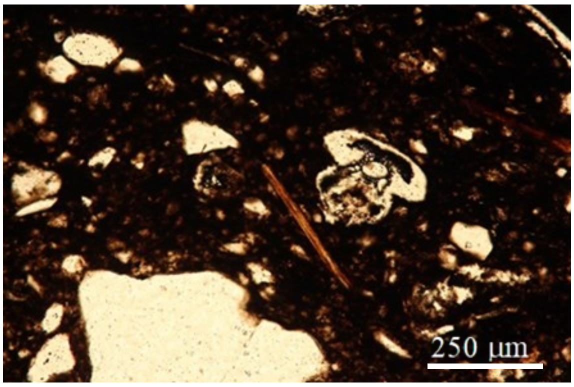
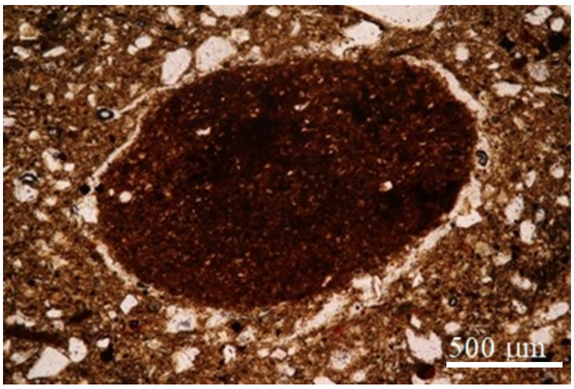


Figure 25 - Photomicrograph in crossed-polarised light of inclusions: left: feldspar (sample 42); plain-polarised light: right: biotite (sample 42)

Another interesting type of inclusion in some of the samples are fragments of chamotte or grog, pieces of fired clay material. Aplastic inclusions of synthetic material can also appear within the ceramic, known as grog or chamotte which is fired ceramic material which has been purposefully crushed and added during the manufacturing process (Quinn, 2013). This can help with the composition of the clay give it a more heterogenous matrix, and the addition of chamotte can also be due to the potter purposefully adding ceramic to the paste as a temper. Tempering is the process when potters choose to add particular matter to their paste, such as in



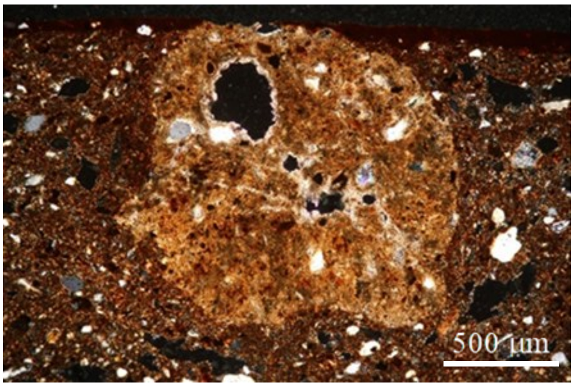


Figure 26 - Photomicrograph in plain-polarised light of inclusions: left: chamotte (sample 38); crossed-polarised light: right: rock fragment (sample 29)

this case recycling ceramics and adding them to the paste or organic material as mentioned previously (Quinn, 2013). Rock fragments are also common in these samples, sedimentary rock fragments are found as they are a hard rock and not crushed or broken up during the clay processing. In particular fragments of mudstone and siltstone are reported in Figure 26.

3.2.6 Slips and Coatings

Also through the petrographic analysis we can look at the slip, designs and coatings on the samples. A slip is an opaque coating which does not vitrify during firing and is usually formed by a finer suspension than the body of the ceramic. A red slip, which most of these ceramics have, are usually obtained using a Fe-rich clay fired in oxidising conditions. Slips are usually darker in colour and less porous than the body, a painted layer can also be analysed. Sample 8 (Figure 27) has a red painted layer which is seen here on the thin section analysis. The red colour on the ceramic is visible on the edge of the thin section, in a dark red colour. There is an even layer of the red which is very homogenous and adheres well to the ceramic body. As we can see from these slips in plain polarised light and in cross-polarised light there is a clear difference in the slip and the ceramic body.

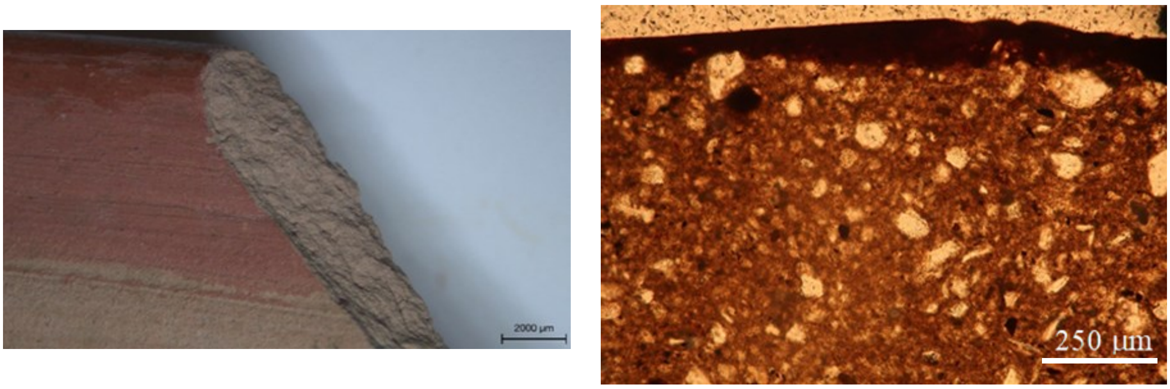


Figure 27 - Photo of the fresh cut and photomicrograph in plain-polarised light (sample 8)

Looking at different samples, such as sample 24, there is a very different outer layer to the ceramic. In the macroscopic view there is a white/grey layer on top of a light red layer of the ceramic body. With analysis on the thin section we can see the distinct layers, and that the white outer layer is full of inclusions (Figure 28), so it could be a different clay paste was used as a slip to decorate the ceramic vessel. Sample 30 (Figure 28) has a red slip which is visible microscopically, however it also shows some inclusions within the slip, but this could just suggest that some loose ceramic body got into the slip while it was being applied. With theses we can distinctly see the difference between the different styles of surface decoration. This could be an example of different workshops being employed for these vessels or that many styles of decoration were in use at the same time.

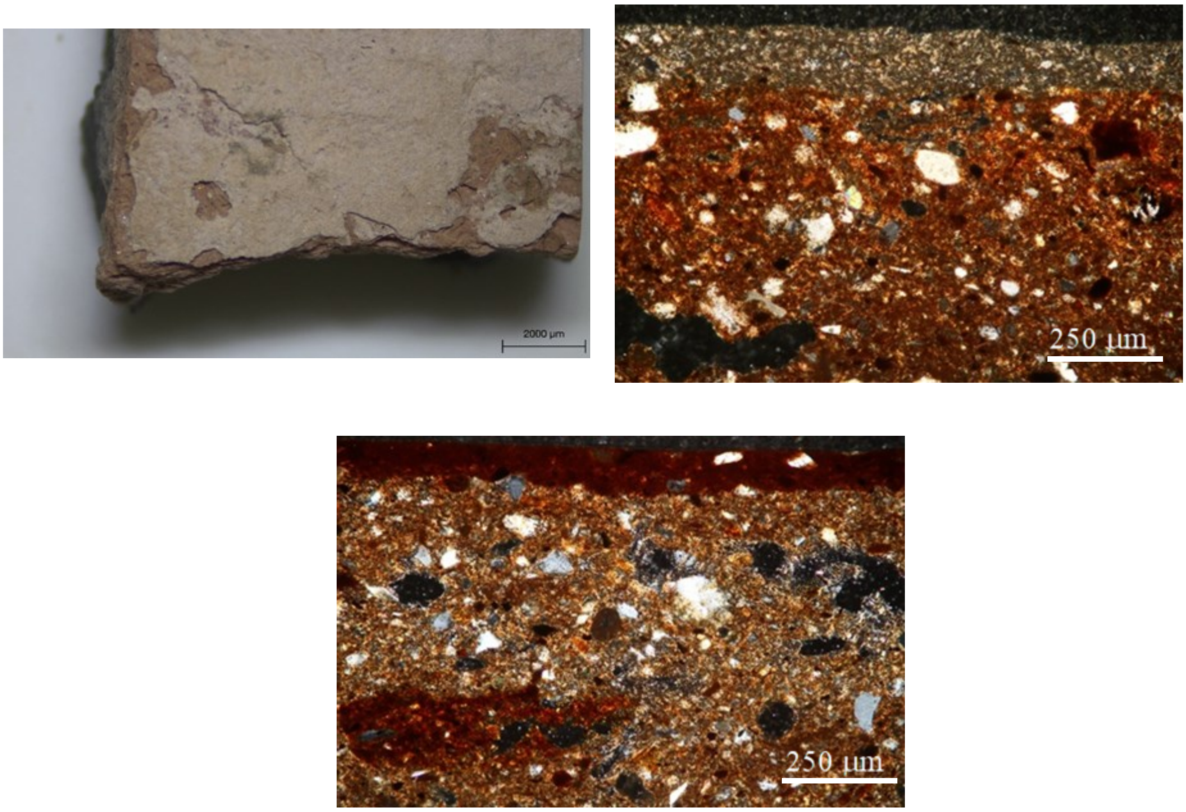


Figure 28 – Photo of outer layer (sample 24) and photomicrograph in crossed-polarised light: top: clay-based slip (sample 24); bottom: red slip (sample 30)

3.3 Results

With this first analysis of the ceramics from Sedeinga we can understand a lot about the environment these vessels were produced in and the materials that were used to produce them. It is clear that these samples are common with each other and the two main groups are likely produced in the same workshop/area, respectively. The information from the petrographic analysis (table in appendix) indicates that similar minerals and inclusions are common in the samples belonging to the two main groups, supporting these claims. Gathering the data together in the table we can quickly see similarities and differences within the samples. We can see that organic material is a huge characteristic of these samples and there are a variety of well-preserved and burned organic material. We can use this data to further compare with the other types of analysis being conducted in this study. The petrography of these samples can give us starting information to find the origins of these clays.

As mentioned previously, the main clay sources from the riverbanks along the Nile are the Blue Nile, White Nile and Main Nile (Maritan et al., 2023). We can compare the data from each location to see if they match with the Sedeinga Nile-clay based samples. Clay from the White Nile petrographically has a homogenous groundmass, with rounded to well-rounded quartz grains, plagioclase, K-feldspar, white mica, biotite, amphiboles and small carbonate inclusions (Maritan et al., 2023). The groundmass in the Sedeinga Nile coarse ware samples are similar to the White Nile samples and have similar inclusions present, however, the White Nile samples are more coarse and have larger inclusion sizes. They seem similar to the Sedeinga samples so they could possibly be made from clay from the White Nile area. The samples from the Blue Nile have inclusions of quartz associated with alkali feldspar, plagioclase, amphiboles, pyroxenes, weathered biotite, volcanic rock fragments and white mica flakes (Maritan et al., 2023). These thin sections are very different from the Sedeinga samples, therefore likely that the Sedeinga samples are not made with clay from the Blue Nile, the eastern bank are well-sorted, fine-sand and silt sized inclusions, and on the western bank are poorly-sorted with inclusions up to 600μm (Maritan et al., 2023). The final clay samples are from the Main Nile, after the confluence between the White and Blue Nile, and this clay has a small amount of inclusions. These inclusions include quartz, biotite, white mica, opaque minerals, K-feldspar, plagioclase, clinopyroxene, amphibole, volcanic rock fragments, weathered olivine, and limestone fragments (Maritan et al., 2023). Again these samples are not similar to the samples collected at Sedeinga, one sample is similar to the fine ware clay from Sedeinga but not similar enough to be the raw material source, but we can gain more conclusive information from the XRPD data. From this the most likely source would be the White Nile, the inclusions are similar as well as the fabric colour (Figure 29). With this data it is best to compare to the other analytical techniques to see if any other techniques show similarities between the Sedeinga samples and the White Nile clay samples.

Obviously it is important to say that the clayey materials supplied along the Nile system (Maritan et al., 2023) we not treated at all, but thin section. Therefore, both quantity and size of inclusions, as well as the relative abundance of the various mineral and rock inclusions, can vary even within the same river branch, since affected by depositional factors. Moreover, the comparison with the studied ceramics has to consider also the possibility that the clayey materials used for the ceramic productions were processed by depuration, therefore with elimination part of the sand and silt inclusions.

Comparing the kaolinitic-clay based ware of Sedeinga, with the Meroe kaolinitic petrofabrics analysed by Mason and Grzimsky (2009), some differences are noted This resulted in a grain size around 0.03mm with around 20-22% of the sample composed of quartz with small amounts of muscovite, feldspars and traces of plagioclase, amphiboles and clinopyroxenes. These examined samples were also white-bodied and are likely clays from the Precambrian Shield though this is not definite (Mason and Grzimsky, 2009). The Meroe samples had a petrofabric of inclusions of subrounded/subangular silt with a mean grain-size of about 0.02mm with 4-6% quartz with 1-3% of plagioclase, clinopyroxene and phytoliths (Mason and Grzimsky, 2009). There were also small amounts of biotite, amphiboles and basalt rock fragments. The inclusions and micromass do not fit into the same category as the kaolinitic-clay based samples from Sedeinga, so it is likely that these samples are not from the same production centre.

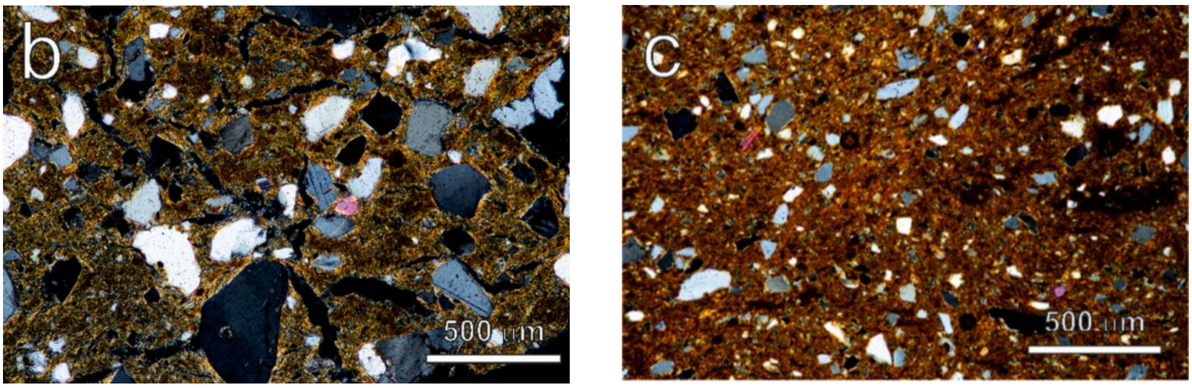


Figure 29 – Photomicrographs of inclusions from the White Nile clay samples from Maritan et al. 2023

4 X-Ray Powder Diffraction Analysis

4.1 DESCRIPTION OF METHOD

X-ray Powder Diffraction (XRPD) is used to give a description of synthetic and natural materials, and is a vital technique for the identification of crystalline compounds (Artioli, 2010). XRPD is used to identify the minerals present in a sample and can group similar mineralogically based samples. This can provide information on of the raw material of the ceramics and interpret a firing temperature range. XRPD analysis is a very popular and commonly used technique which has data available for most known inorganic compounds and minerals (Artioli, 2010).

For the XRPD analysis the entire collection of the 58 Sedeinga samples were analysed. A sample size of 1 gram was needed from each sample to conduct the XRPD analysis. First a piece of a ceramic was picked and if needed broken to create a smaller piece so to keep as much of the original ceramic as possible. Then the piece was sanded down using the Dremel micro-drill to remove the dirt and outer layer or slip so there would not be any contamination and to receive results from just the ceramic body. Secondly, an agate pestle and mortar was used to hand grind the samples down into a fine material suitable for the XRPD machine. Between each sample the mortar was cleaned so no cross contamination would occur. After this, the samples were loaded onto spinning steel back-loading sample holders.

The mineralogical composition was determined by X-Ray Powder Diffraction with a PANalytical X'Pert PRO diffractometer in Bragg-Brentano geometry equipped with a cobalt X-ray tube and a X'Celerator detector. The working conditions were CoKa radiation, 40 kV voltage, 30 mÅ current, 3-70° 2θ range, step size 0.02° and 1s counts per step. The mineral phases were identified using the X'Pert HighScore Plus software. The XRPD data were then statistically treated by cluster analysis according to the procedure proposed by Maritan et al. (2015). After the analysis was completed a diffractogram was achieved with the results and analysed using HighScore Plus, which distinguished the mineral phases present in each of the samples.

4.2 XRPD FOR THE FIRING TEMPERATURE ANALYSIS

XRPD was conducted on these samples to discuss the mineral phases and to distinguish the firing temperature of the ceramics at the time of production. The study of thermal behaviours can provide information on the production technology and firing regime (Holakooei et al., 2014). XRPD is used for the estimation of the firing temperature due to the fact that the mineralogical composition of clays changes during firing (Holakooei et al., 2014; Maritan, 2023). The firing temperature can be determined due to the minerals present or the lack of certain minerals. Firing experiments can show the temperatures minerals survive in and the atmospheric conditions the ceramics were fired in, and even the difference between type of firing, such as pit-firing reducing conditions or an oxidising kiln environment (Maritan et al., 2015). The phase analysis can show which minerals are present in the samples. This style of analysis can give a firing temperature range for ceramics and can be used along with other techniques to refine the firing range.

It is proposed that the samples from Sedeinga were fired in a kiln, as that was the style during the Meroitic period, in an oxidising atmosphere over a long period of time. If these ceramics were fired in updraught kilns as previously hypothesised, the highest temperatures reached lies around 900-1150°C, as the kilns walls usually vitrify and melt beyond that temperature (Nowotnick, 2022). These kilns are advantageous to use as they can keep a steady temperature for a long period of time, which these ceramics indicate they were fired in (Nowotnick, 2022). From the colouring on the ceramics it is believed that they were fired in low temperatures for a long period of time.

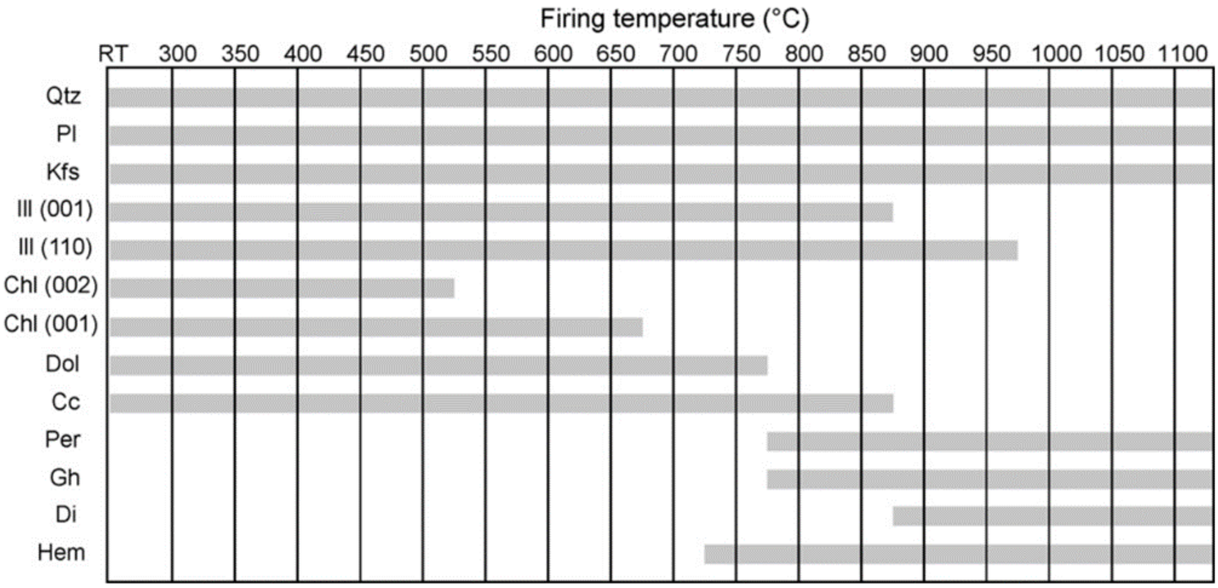


Figure 30 - Firing temperatures certain minerals can survive or decompose in from Nodari et al. (2007).

To disclose the firing temperatures using XRPD analysis the minerals discovered can be used to suggest a temperature range. Minerals detected in the XRPD can be compared to graphs such as (Figure 31) that show which minerals of a starting clay survive and decompose in certain temperature ranges and new ones form (Nodari et al. 2007). This graph can be applied to the XRPD results from the Sedeinga samples to achieve a firing temperature range. The more comprehensive representations of the firing dynamics by Gliozzo (2020) (Figure 30 for the illite stability) shows the phase stability according to the clay composition. For instance, the presence of illite/muscovite (also microscopically observed in the samples form Sedeinga) indicate an average of 950°C for the highest temperature that illite will survive in.

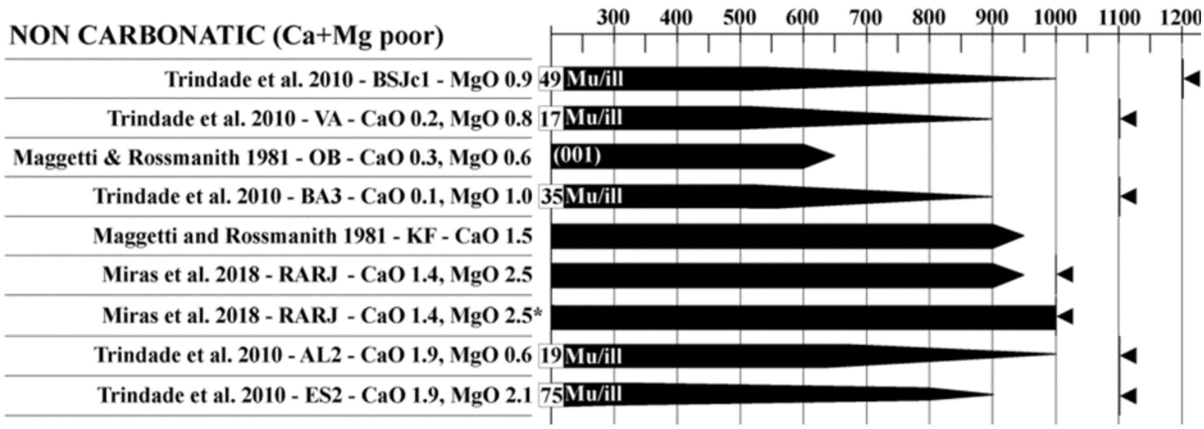


Figure 31 - Temperatures Muscovite/Illite survived at in pervious experiments from Gliozzo (2020)

4.3 RESULTS

The XRPD data was first gathered into a dendrogram of the cluster analysis to define the collection into sub-groups and see the similarities or differences between the samples (Figure 31), as suggested by Maritan et al (2015) . Cluster analysis of XRPD data in particular is very useful tool to use as it easy to use for the description of the structure of the dataset and cluster together the homogeneous subsets of the samples (Maritan et al., 2015). The dendrogram representing the cluster analysis is composed of branches which the height between to clusters in directionally proportional to the degree of dissimilarity between them (Maritan et al., 2015). When using XRPD analysis on ceramics it is important to note that there are many aspects that affect the mineralogical affinities between samples, mostly about the raw materials used and the firing conditions of the ceramics (Martian et al., 2015). The cluster analysis of these samples from the site of Sedeinga was performed using the position and intensity of the minerals, the Euclidean distance as the metric measurement of distance between the pairs of observations and the average link criterion determining the distance between sets of observations as a function of the pairwise distances between observations. This criteria was chosen in accordance to the evaluation proposed by Piovensan et al. (2013). Euclidean distance was used here instead of squared Euclidean distance as the squared distance is more suited to further apart samples which is not the case here. Similarly, the average link method was the preferred method used as it is widely used for cluster analysis.

The samples are labelled individually and divided by the fabric categories created by Romain David. Within the cluster analysis there are five clusters identified, suggesting similar mineral phases present (Figure 32). Clusters 1 and 5 obtain nearly all of the kaolinitic-clay based samples, apart from samples 8 and 14 which are in cluster 4. However, these samples have already been recognised as different to the other kaolinitic-clay based samples from the petrographic analysis. Clusters 2, 3, and 4 include the Nile-clay based samples except for sample 46 which is an outlier. Samples 8 and 14 were previously noted in the petrographic analysis to be slightly more coarse than the other samples, so this XRPD data is showing similar results, suggesting that maybe these two kaolinitic-clay based samples are also related to the coarse ware samples. This could be due to the type of kaolinitic clay used, which mineralogically has similar characteristics to the Nile clay. This can also be compared to the XRF analysis to see if there is any correlation between the samples chemically.

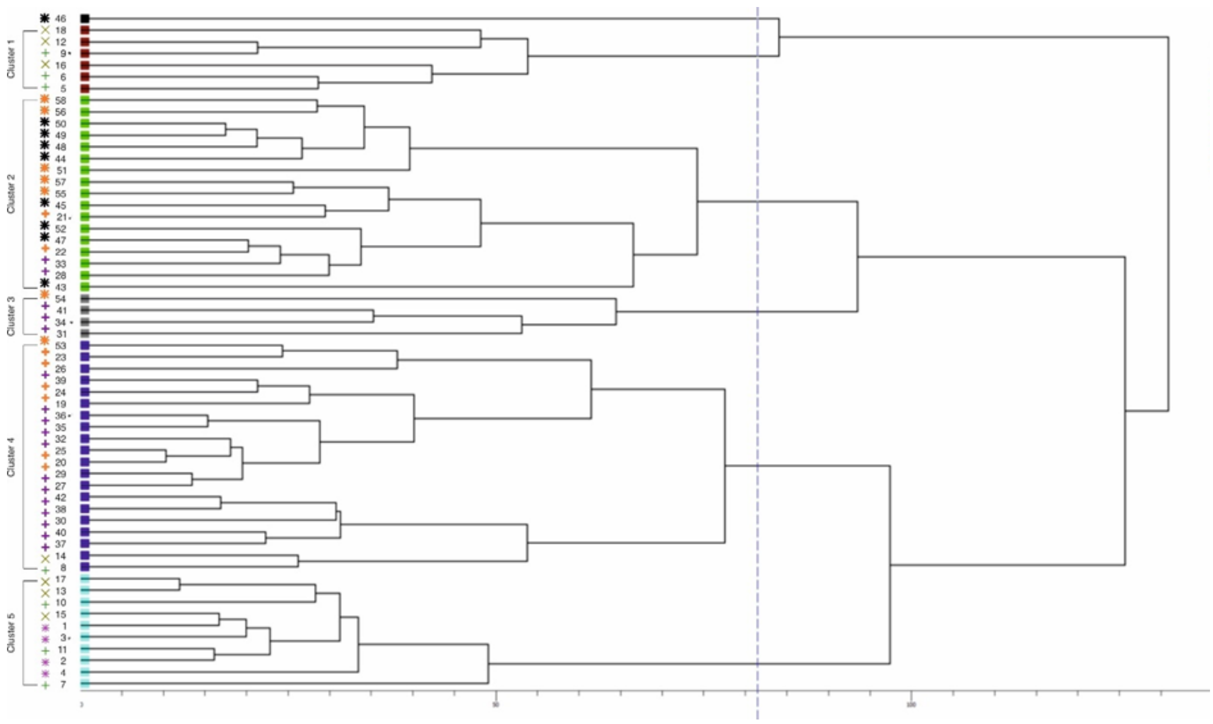


Figure 32 – Dendrogram obtained from the cluster Analysis of XRPD data on Sedeinga samples

Continuing onto the individual XRPD dendrogram, one sample from each group was chosen. An average from each cluster group was identified by the programme and is noted by an asterisk beside the sample number in the cluster analysis dendrogram. These average samples of the groups will be used as the identifier for each group and will be studied rather than the entire group.

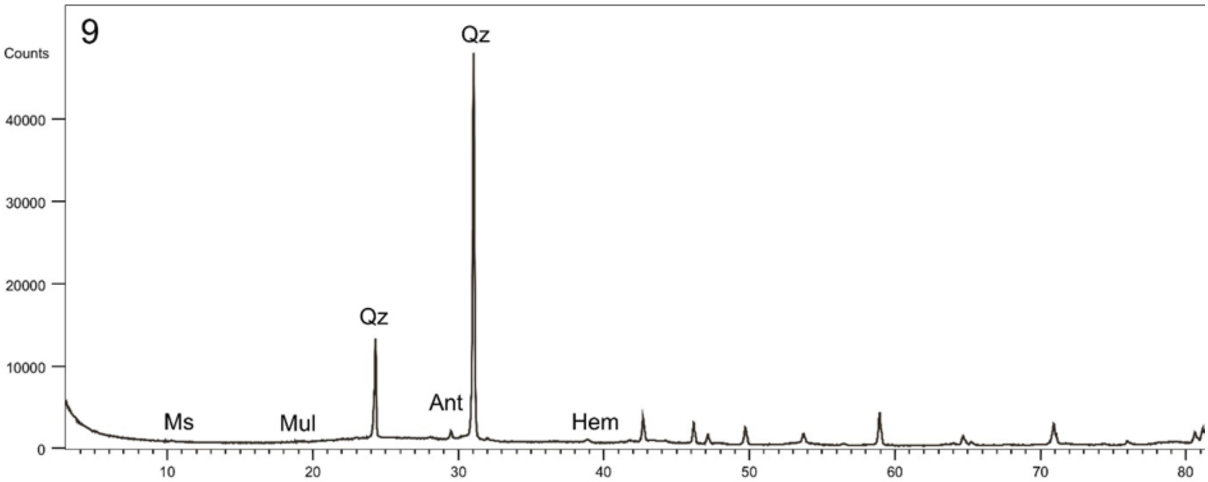


Figure 33 - XRPD pattern of sample 9, representative of cluster 1. Mineral abbreviations: Qz: quartz; Ms: muscovite/illite; Hem: hematite; Ant: anatase; Mul: mullite.

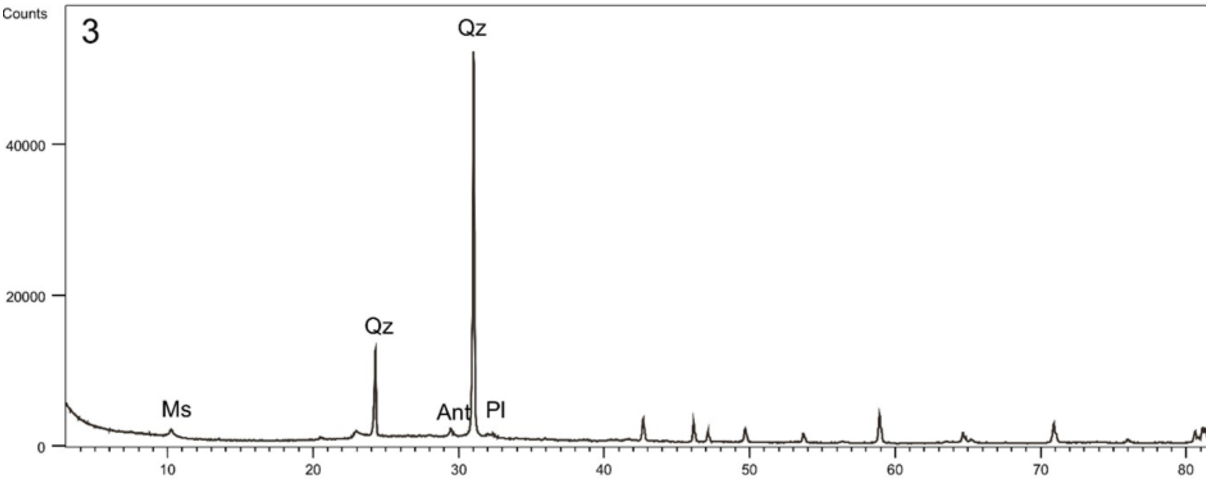


Figure 34 - XRPD pattern of sample 3, representative of cluster 5. Mineral abbreviations: Qz: quartz; Ms: muscovite/illite; Ant: anatase, Pl: plagioclase.

The XRPD pattern of sample 9 (average for cluster 1) is characterised by quartz hematite, mullite, muscovite/illite and anatase (Figure 33). It reflects the mineralogical phases in the kaolinitic-rich clay and its transformation during firing. The occurrence of mullite is due to the kaolinite transformation at temperature exceeding 900°C. Cluster 5 also contains the kaolinitic clay with sample 3 as the average (Figure 34), and is similar to sample 9 but it has a plagioclase and anatase peak but the hematite and mullite peaks are not present. It is slightly different from the other kaolinitic samples but is still related in composition as the peaks and counts are similar. When muscovite/illite is present the temperature of heating lower than 950°C as according to Figure 31,. This suggests that are samples were likely not fired over 950°C as muscovite is still present. Hematite is present in sample 9, and this usually forms in oxidising conditions above 700-750°C if there is sufficient amounts of iron present in the clay (Quinn, 2013). So this suggest of a firing range at least between 700°C-950°C as muscovite and hematite are both present in graph 9. Muscovite is present in sample 3 so we can also suggest a maximum temperature for this around 950°C.

The Nile clay samples are all within clusters 2, 3, and 4, excluding sample 46 as mentioned before. Cluster 2 is based on sample 21, and again has the large quartz peak with muscovite, plagioclase and amphibole peaks (Figure 35). The addition of amphiboles in the graph and the higher amount of peaks are the main differences here from the kaolinitic-clay based samples. This suggests the high variety of minerals in the Nile clays.

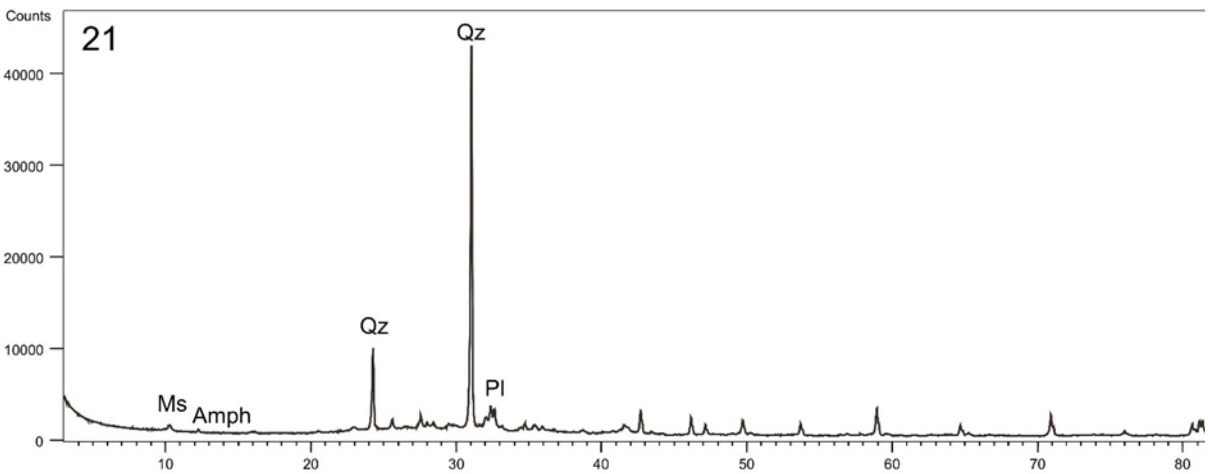


Figure 35 - XRPD pattern of sample 21, representative of cluster 2. Mineral abbreviations: Qz: quartz; Ms: muscovite/illite; Amph: amphibole; Pl: plagioclase.

Cluster 3 only has a small number of samples with sample 34 being the representative patter (Figure 36). This is quite different from the previous patterns, the quartz peak is much lower, and contain s K-feldspar and pyroxenes. In the dendrogram we can see that this group is the smallest cluster, accounting for only four samples. There is no evidence in the petrographic analysis to suggest a difference, so it seems that they are just mineralogically different. The low amount of quartz could be an indicator of a low count of minerals in the ceramic body.

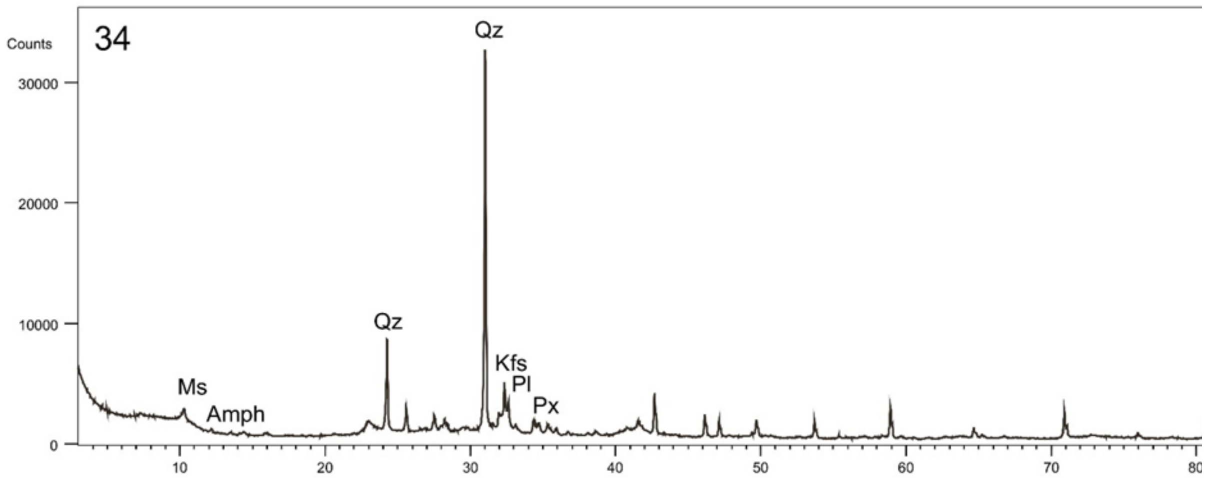


Figure 36 - XRPD pattern of sample 34, representative of cluster 3. Mineral abbreviations: Qz: quartz; Ms: muscovite/illite; Amph: amphibole; Kfs: K-feldpsar; Pl: plagioclase; Px: pyroxene.

In cluster 4, the representative sample is 36 rich in quartz with plagioclase, muscovite and pyroxene peaks (Figure 37). This cluster has the majority of the samples consisting of the Nile-clay based samples and the two kaolinitic samples, 8 and 14. These kaolinitic samples clearly have a mineralogical phase more similar to the Nile-clay based samples, since the inclusions are those accounting more for the mineral composition, being the kaoline decomposed and therefore not affecting the pattern and suggest a more coarse ware body than fine ware as suggested by the clay source. The muscovite again gives a maximum firing

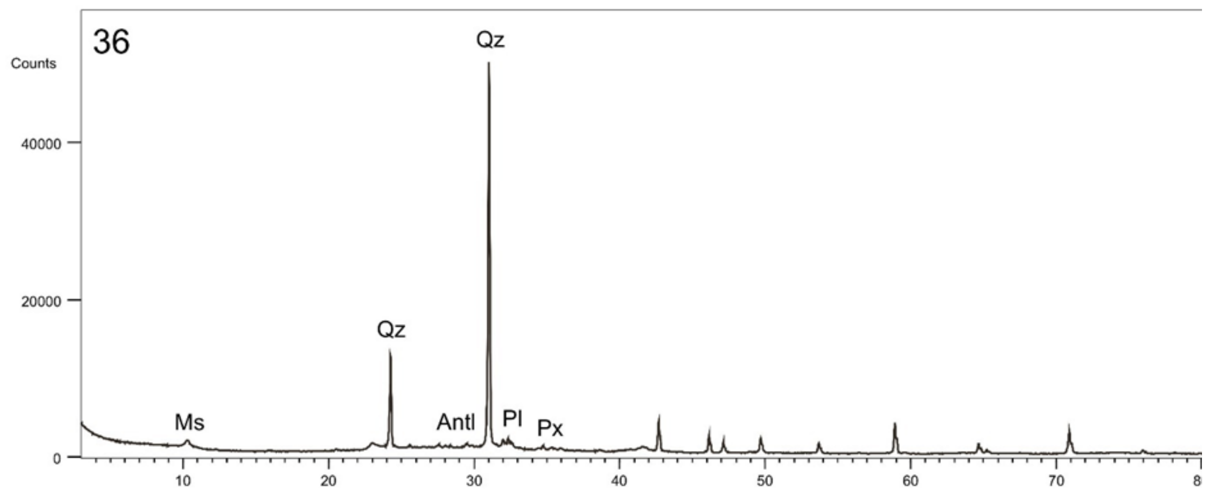


Figure 37 - XRPD pattern of sample 36, representative of cluster 4. Mineral abbreviations: Qz: quartz; Ms: muscovite/illite; Ant: anatase, Pl: plagioclase; Px: pyroxene.

temperature of 950°C, and it is likely that this temperature max range is similar for all the samples.

The three clusters containing the Nile-clay based samples are all quite similar and suggest a common raw material source for these samples, and from the petrographic analysis the ceramics have a fairly homogenous body. Sample 46 is an outlier from all the other samples, with very high quartz peaks and no other mineral phases detected, probably related to higher firing temperature which decomposed the other phases present in the raw material (Figure 38).

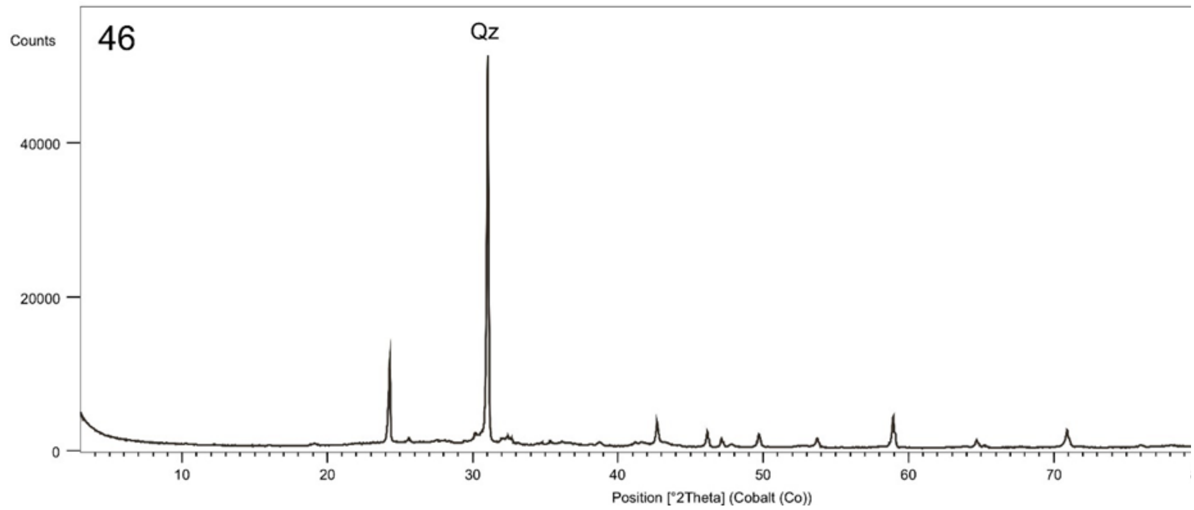


Figure 38 - XRPD pattern of sample 46, outlier. Mineral abbreviations: Qz: quartz

The XRPD analysis of the samples from Sedeinga shows that these samples are all quartz based and only have a small amount of differing minerals, as the results of a use of a non-calcareous clay containing also very limited types of inclusions. Meaning that a prior knowledge of the samples is needed before XRPD, specifically a known classification of the samples by their petrographic composition if coarse-grained, which was obtained in this study (Martian et al., 2015). Going into the XRPD analysis the coarse Nile wares were already divided into petrographic sub-groups and used as a basis of this analysis.

The XRPD data gathered shows us the similarities and differences in the mineralogical phases of the samples and can define a firing temperature range for the ceramics. From the minerals present and absent from the samples a firing range has been determined between 750-950°C. The ceramics were likely fired in a kiln in oxidising conditions, therefore the firing process was not short. Since the Nile-clay based ceramics have still a lot of vegetal remains or their burnt structure, especially in the core, it can be deduced that the firing was not enough long to completely burn them. Moreover, the oxygen was not able to go through the ceramic thickness, dure to its low porosity, scarce inclusion content and high plasticity. The core of the vessels were not oxidised and heated enough leaving behind the black coloured core and this allowed the organic material to survive.

5 Chemical composition: X-ray Fluorescence

5.1 Description of Method

X-ray fluorescence spectroscopy (XRF) is a very common technique used in cultural heritage for the elemental analysis of materials. It is based on the emitting of fluorescence photons in the X-ray region and these secondary X-rays represent the characteristics of the atom and are used to identify and quantify the chemical elements (Artioli, 2010). This technique is used to identify the elemental composition and the quantitative analysis of a range of inorganic materials. XRF data and in particular their statistical treatment is here used to identify homogeneous groups of samples in terms of chemistry, groups that can be identified on the dendrogram and principal-component plots. As the samples were already crushed for the XRPD analysis we could use the powder form of the material for a more precise XRF analysis. XRF is commonly used on archaeological ceramics to identify the areas of activity and to determine the raw material provenance (Hunt and Speakman, 2014). XRF is commonly used for ceramics in conjunction with XRPD and optical microscopy analysis as together they can give information about the sedimentary rocks source, manufacturing techniques and the purification process of the raw material (Acquafredda, 2019).

The chemical composition of the ceramic bodies of the samples was determined by X-ray Fluorescence Spectrometry on a WDS Panalytical Zetium sequential spectrometer. The instrument, operating in vacuum conditions, is equipped with a 2.4 kW Rh X-ray tube, 5 analyzer crystals (LiF220, LiF200, Ge, PE, PX1), 3 detectors (gas flow proportional counter, scintillator and sealed Xe), 2 collimators (150 μm and 550 μm), 4 filters (Al 200 μm, Al 750 μm, Brass 100 μm and Brass 400 μm) and a sample changer for 16 sample holders. Fot the chemical analysis, beads were prepared from sample powder after calcination and mixed with $Li_2B_4O_7$, at a dilution ratio of 1:10, using a Claisse Eagon 2 fusion instrument (running at a maximum temperature of 1150°C). Quantitative chemical analyses of major and minor (wt% of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5) and trace elements (ppm of S, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Nd, Pb, Th and U) were carried out. Loss on ignition (LOI) was determined heating the samples in a furnace at 860 ◦C for 20 minutes, and then at 980°C for 2 hours. A set of geological standards, as analytically tested by the international scientific community (Govindaraju, 1994), were used for calibration;

they were supplied by the following agencies: USGS (United States Geological Survey, Reston, USA), CRPG (Centre de Recherches Pétrographiques et Géochimiques, France), ANRT (Associa- tion Nationale de la Recherche Technique, Paris, France), GIT-IWG (Groupe International de Travail - International Working Group, France), RIAP (Research Institute of Applied Physics, Irkutsk, Russia), GSJ (Geological Survey of Japan, Japan), MINTEK (Council for Mineral Technology, South Africa) and WIHG (Wadia Institute of Himalayan Geology, India). The geological international standards were used to measure the following major, minor and trace element: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K e P (expressed in oxide %), and Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Nd, Pb, Th and U (expressed in part per million ppm).

Chemical data were processed with standard statistical tools such as Principal Component Analysis (PCA) and cluster analysis (CA) with Statgraphics® Centurion XVI software. The cluster analysis calculates the similarity or distance between pairs of samples (Smith, 1997), whereas the principal component analysis determines which of the variables (chemical elements) are responsible of the variability of the system.

5.2 Results

The chemical data (table in appendix) was gathered from the XRF machine and statically analysed.

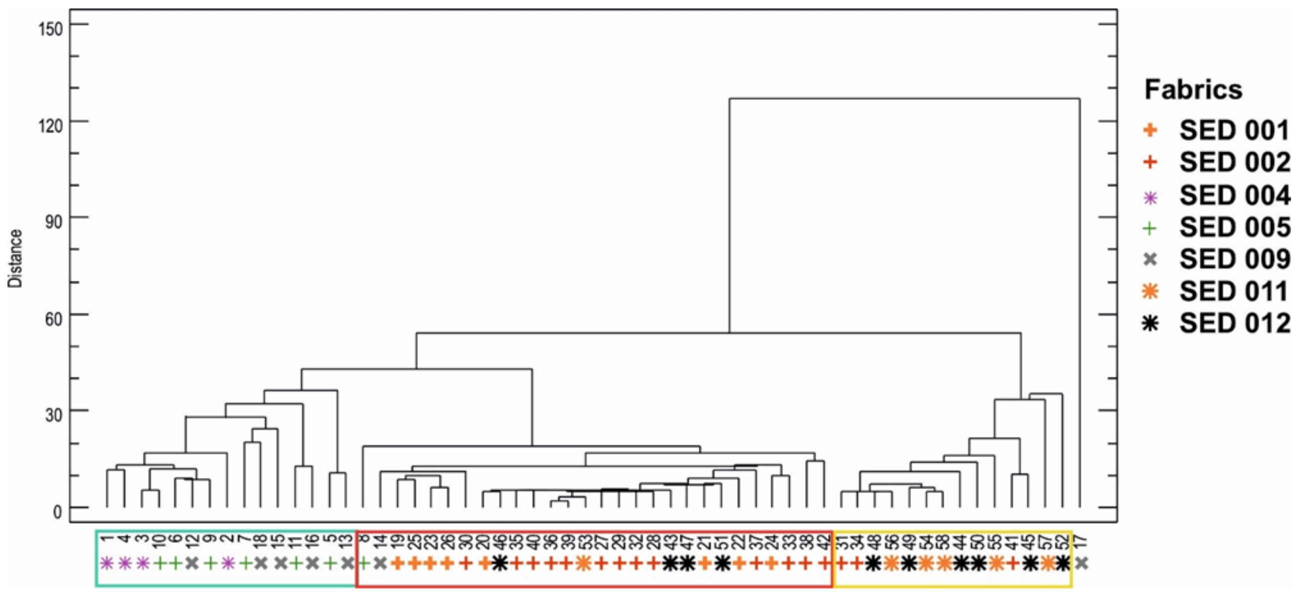


Figure 39 - Dendrogram obtained by the cluster analysis of Sedeinga samples, performed on all the dataset and using the Square Euclidean Distance and the Average Linkage method.

The cluster analysis show that samples divided in three clear groups and one outlier (Figure 39).

The first cluster (highlighted by a green frame in Figure 39) consist of solely kaolinitic-clay based potsherds, and fifteen out of the eighteen samples.. From the dendrogram we can see that the distance within this group is low in terms of dissimilarity level, suggesting that there are minor differences within the raw material used to produce such pieces of ware. This suggests that these samples are very similar chemically and are likely from the same source. Comparing to the petrographic groups these samples are all in Group 1 as they are all fine ware.

The second cluster (highlighted by an orange frame in Figure 39) consists of the majority of the Nile-clay based samples and two kaolinitic-clay based samples (8 and 14). These samples all seem to be very close on the dendrogram and are tightly grouped together. Samples are 8 and 14 are also petrographically quite different from the other kaolinitic-clay based samples, since they are coarser and closer petrographically to the Nile-clay based samples. They clearly have a chemical signature closer to the coarse ware samples as well. This has similar results to the XRD data which includes these kaolinitic samples in cluster 4 alongside the other Nile clay samples. These samples could possibly be mixed clay with kaolinitic clay and Nile clay resulting in chemical and mineralogical analysis closer to the Nile samples even though they have the physical body and colour of the kaolinitic-clay based samples.

The third cluster (highlighted by a yellow frame in Figure 39) consists of Nile-clay based samples which all have a high organic material count. The production technology is probably similar as they have similar XRPD and XRF results, so this could suggest that they were formed and produced with the same material probably within a single workshop. There is a low dissimilarity level between these samples so it suggests that they are still quite similar and there are likely only minor differences.

Finally there is the outlier, which is sample 17, this is completely different from all the other samples. It is not chemically similar to any of the samples, however petrographically it does not look very different from the other kaolinitic samples and also in terms of XRPD it isn't different. Looking at the principal component diagram sample 17 is located in the top left hand corner (Figure 40). It is clear that this sample has similar elements to the kaolonitic clays but just higher amounts of the elements. We can see that sample 17 has high amounts of Nd, Pb and Al, and the other kaolinitic samples just have lower amounts of these chemicals.

The score and loading plot of the principal component analysis (Figure 40) shows each of the samples in comparison to the chemical elements analysed by XRF. Here, there is a clear distinction between the kaolinitic-clay based and the Nile-clay based potsherds.

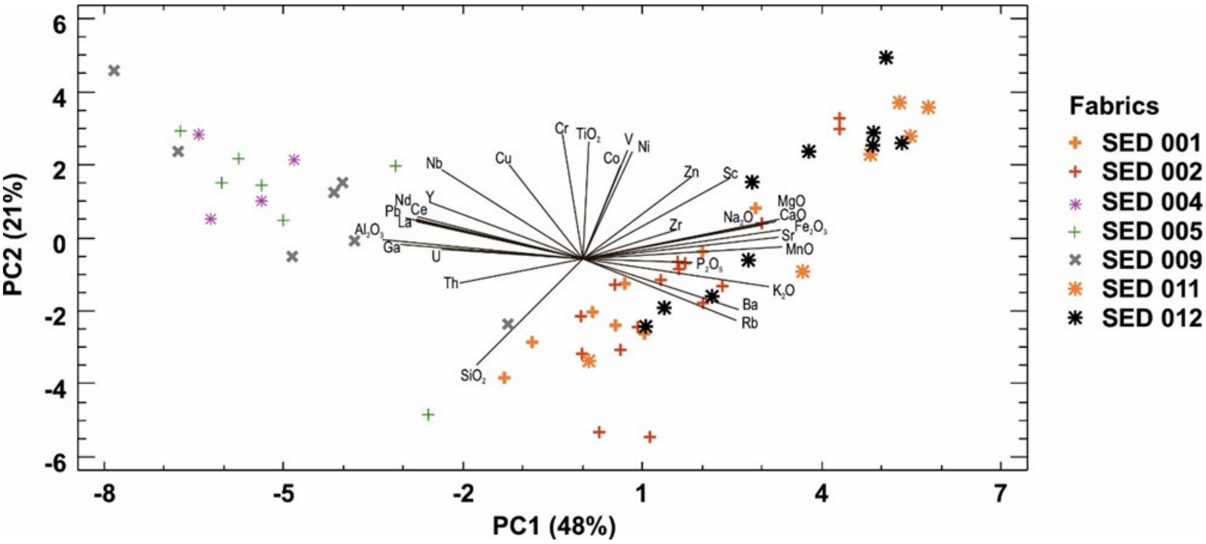


Figure 40 - Score and loading plot of the PC1 and PC2 obtained by the principal component analysis of Sedeinga samples. PC1 and PC2 account for the 48% and the 21% of the total variance, respectively.

The kaolinitic-clay based pots (labelled SED 004, 005 and 009) are all located at negative value of PC1 being richer in Al, Pb, Nb, Ce, Y, La, Ga, U and Nd than the other samples . They are all clustered together, therefore the chemistry in all the kaolinitic samples are similar and then likely from the same raw material. The outlier sample 17 is on its own and it is clear that samples is chemically different and distinctive from all the other samples (unlike in the petrographic and XRPD analysis) for it higher Y content.

The Nile-clay based samples are all at positive PC1 values and are characterised by a higher content in Si, Mg, Na, K, Ca, Fe.

In order to understand the provenance of the samples produced using the Nile-clay, we can compare them to clay samples from along the River Nile (Maritan et al, 2023). The principal component analysis (Figure 41) highlights the Sedeinga samples are chemically close to some of the White Nile, White Nile- Gezira and Main Nile clays, suggesting that the pottery found in Sedeinga could possibly be from the White Nile or Main Nile (near the confluence with the Blue Nile) region. This result is also confirmed by the cluster analysis (Figure 42), which indicates a was completed with the Sedeinga Nile clay samples and the samples from along the Nile show that samples from the White Nile show similarities and the White Nile samples are the most related to the Sedeinga samples.

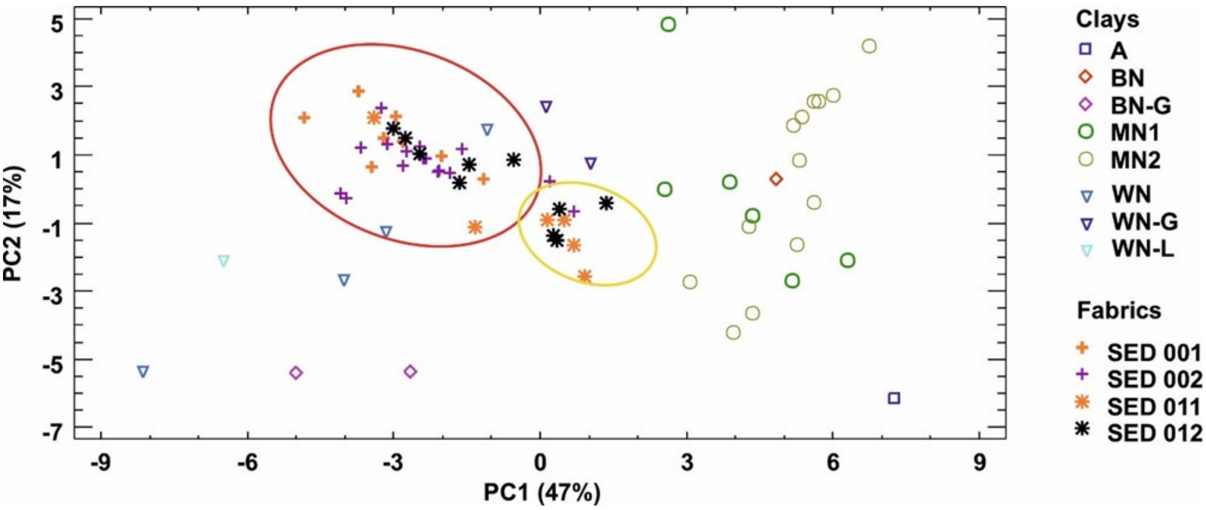


Figure 41 - Score plot of the PC1 and PC2 obtained by the principal component analysis performed on the Nile-clay based potsherds from Sedeinga and the Nile-system clays (Maritan et al. 2023). Abbreviations: A: Atbara; BN: Blue Nile; BN-G: Blue Nile -Gezira; MN1: Main Nile 1 (after the confluence with the blue Nile and before that of Atbara); MN2: Main Nile 2 (after the confluence with Atbara); WN: White Nile; WN-G: White Nile-Gezira; WN-L: White Nile Pleistocene lakes.

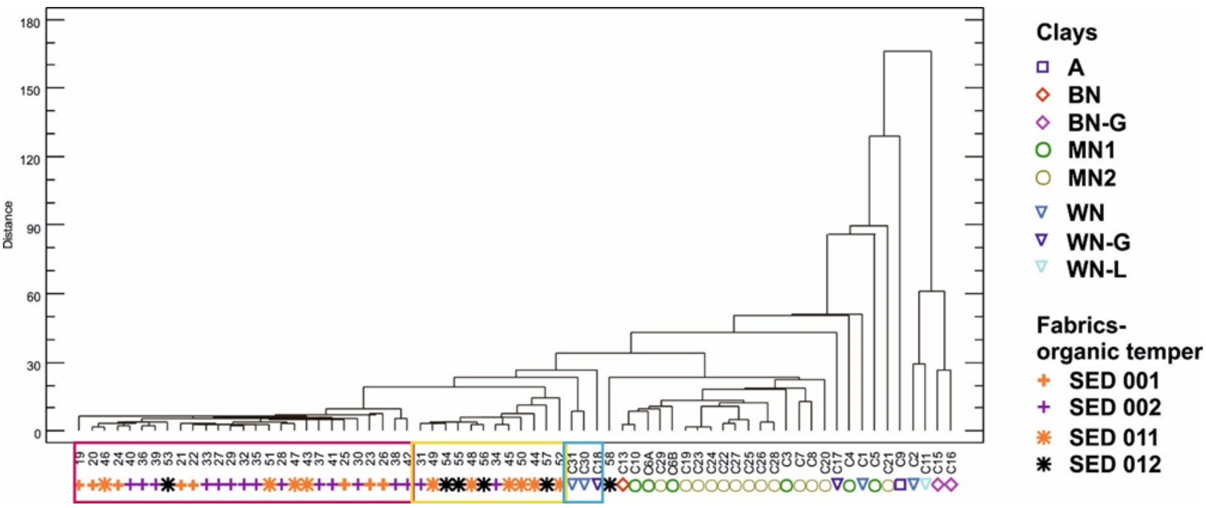


Figure 42 - Dendrogram obtained from the Cluster analysis on the Nile-clay based samples from Sedeinga samples and from the Nile system clays (Maritan et al. 2023). Abbreviations: A: Atbara; BN: Blue Nile; BN-G: Blue Nile -Gezira; MN1: Main Nile 1 (after the confluence with the blue Nile and before that of Atbara); MN2: Main Nile 2 (after the confluence with Atbara); WN: White Nile; WN-G: White Nile-Gezira; WN-L: White Nile Pleistocene lakes.

From the petrographic study the Sedeinga samples were closest to the White Nile samples, and again from the XFR data the Sedeinga samples are closest to the White Nile clays. The evidence from the analyses point towards the Sedeinga Nile samples originating from the White Nile area.

These results clearly indicates that the ceramic materials found in Sedeinga, at least those obtained from the Nile clay were not locally produced but imported from central Sudan, possibly from the White Nile or Main Nile 1 region. Differences between the Nile clay and the ceramic materials in terms of chemistry and therefore the luck of a clear overlapping might be related to chemical changes due to the clay processing. Therefore, in order to define if the ceramics found in Sedeinga could have come from the central Sudan, chemical data were compared with those of Meroitic pottery from a series of sites located along the Main Nile, between the 6th cataract and the Atbara (Figure 43). This data clearly shows the high chemical similarities between the Sedeinga samples and the analysed samples from central Sudan. The sites compared to the Sedeinga samples are all important sites of the Meroitic period and have the potentiality to have been the major production centres during this time. From this comparison of the Nile-clay based ceramics and the ceramics from central Sudan ceramics, and the data gathered from the other techniques it shows that the Sedeinga ceramics were produced elsewhere and traded into the site. It also shows that the Nile-clay based ceramics from all of

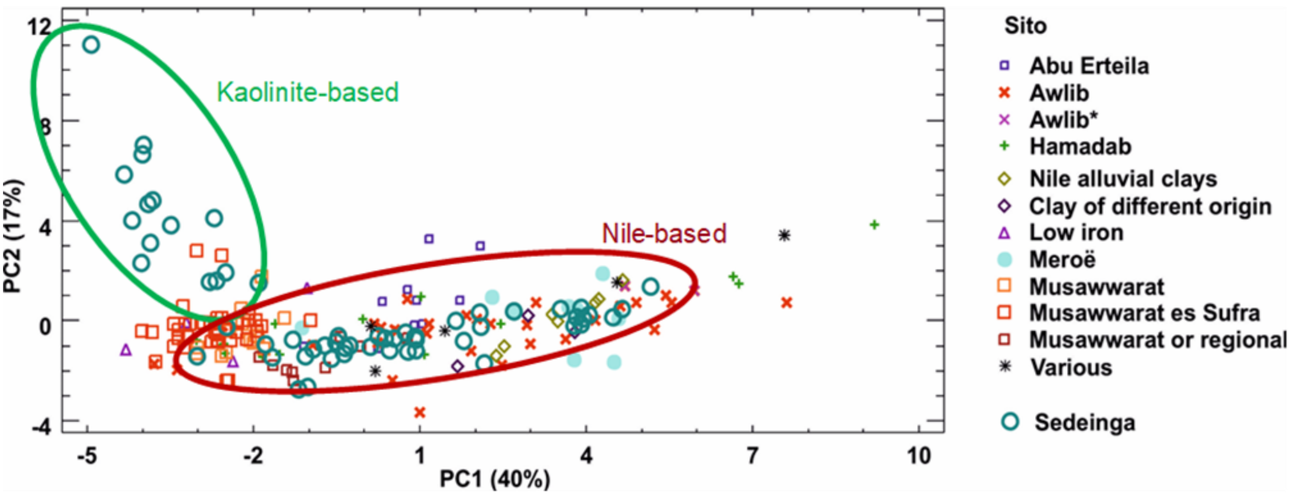


Figure 43 - Loading plot of the PC1 and PC2 obtained from the principal component analysis performed on the pottery from Sedeinga and from the Meroitic production sites of Abu Erteila, Awlib, Hamabad, Meroë, Musawwarat in central Sudan (Daszkiewicz et al. 2005; Daszkiewicz et al. 2016; Daszkiewicz & Schneider 2011; Daszkiewicz & Malykh 2017; Daszkiewicz & Wetendorf 2014; Näser, Daszkiewicz 2013). Green and red circles comprise the kaolinitic-clay based and the Nile-clay based ware of Sedeinga, respectively.

the sites are all very similar, and a common recipe was likely used for the ceramics found at the multiple sites.

6 Further Study

6.1 Raman Spectroscopy on carbon remains

Raman spectroscopy is another form of analysis that can be applied to these samples to gather more information on the firing temperature and on the organic materials. Within this research there was not enough time to also complete a full Raman analysis on the samples and interpret the results. Therefore, Raman Spectroscopy was conducted on two of the samples to deduce if a future study on these samples would be worthwhile. The Raman analysis was conducted the samples which had carbon residues and samples that had well preserved organic vegetal remains. Raman analysis can also show more details in the mineralogical assemblage leading to more information on the provenance of the raw material (Medeghini et al., 2014). Raman spectroscopy is an ideal analysis method because it is non-destructive, has high spatial and spectral resolution, and ease of use on unprepared samples (Medeghini et al., 2014). There are some issues with using Raman spectroscopy, such as if the ceramic has a fine texture and high purification degree as it can cause problems with the identification of mineral phases, whereas coarse-grain pottery with a low vitrification degree give a clear identification of mineral phases (Medeghini et al., 2014). In cases where the ceramic has a fine texture and high purification degree other analytical techniques need to be used in conjunction with Raman to describe the technological manufacturing (Medeghini et al., 2014).

The Micro-Raman analysis was completed in the Geoscience Department of the University of Padova. The instrument consists of a Raman Witec alpha 300 R and Zeiss microscope attached (10x, 20x, 50x LD, 50x, 100x obj.s), with 532nm lasers, 785nm lasers, and Spectrometer 1: UHTS 600 (VIS) (with 2 spectrographs), Spectrometer 2: UHTS 400 (NIR) (with 2 spectrographs). It has a motorised xy-sample scanning stage for confocal Raman imaging, TrueSurface microscopy and automated measurements routines (50x50 mm 2 travel range in reflection builds; Software controlled) and uses a Windows PC with 2 software: Control Five (operate system) + Project Five (data treatment).

For this analysis only two samples were analysed and this will leave room for future analysis to be conducted on the other samples. The main aim of this analysis was to see if any information about the firing temperature could be gathered and to compare it to the XRPD results. The chosen samples were 19 and 56, sample 19 had a limited amount of organic remains with some carbon, and sample 56 had an abundant number of organic remains. The analysis started with the thin section of sample 19, however there were some issues getting clear results. The organic remains in sample 19 were just too thin to get a clear analysis and the resin of the thin section caused discrepancies and the bands we needed were very unclear within the results. Some results were achieved but it was very difficult to obtain them due to the difficulty finding the organic material. With the larger vegetal remains in sample 56 the analysis would be easier to obtain. This analysis had much better results, as there were larger and clearer organic material all over the sample. However there were still some issues with the resin of the thin section so it was decided to use some of the actual ceramic material.

The Raman was then used on the fresh cut of the body so as not to analyse the coating. From this there were excellent results obtained, there were clear areas of organic remains visible. The analysis programme showed the two clear bands of carbon, the defect band (D) and the graphite band (G), around 1350 cm-1 and 1580 cm-1 respectively on the graph, usually following this pattern from Deldicque et al. (2016) (Figure 44). The G band divided by the D band gives the ratio that can be used to estimate the firing temperature.

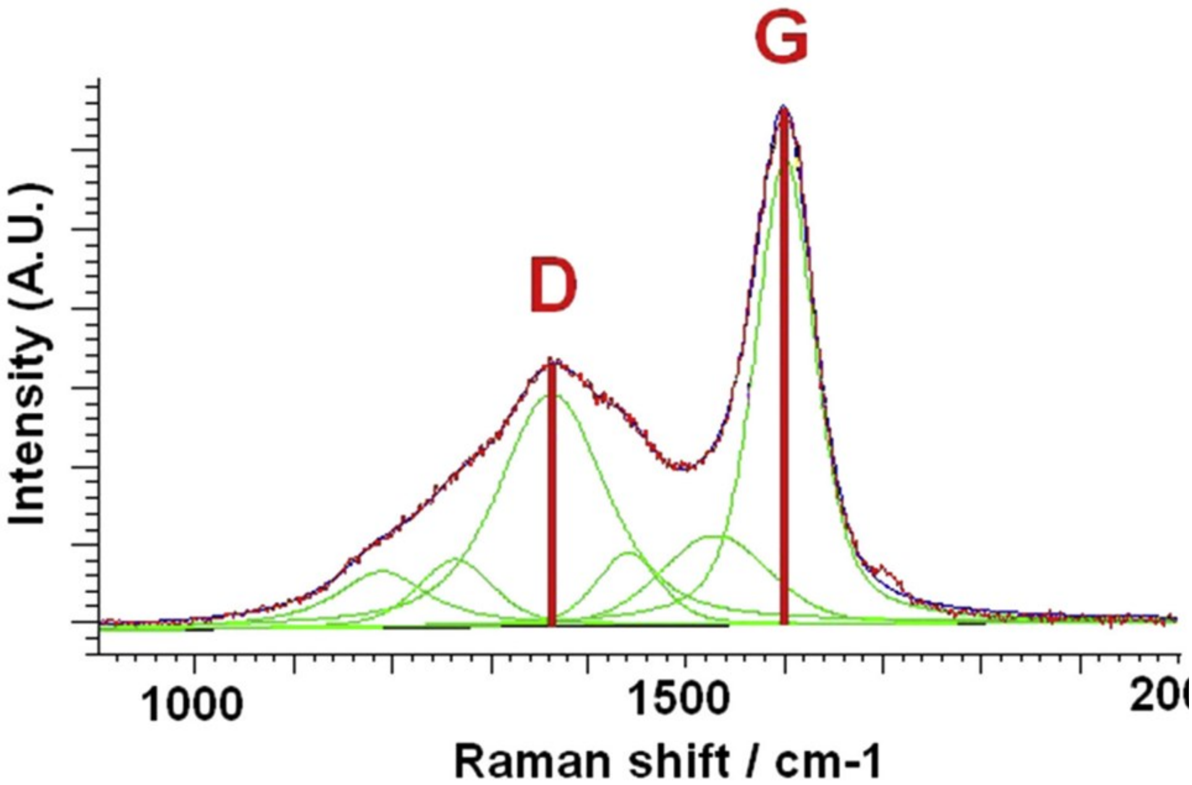


Figure 44 - Raman Spectroscopy graph highlighting the defect band and graphite band - Deldicque et al. (2016)

Multiple points were used to take data for the Raman analysis and these created graphs which were analysed on SpectraGryph 1.2. The height of the D band and G band were measured and divided to find the height ratio and compare the calibration curves (Figure 45) by Deldicque et al. (2016), obtained for firing of pine wood with different firing rates (1 hour in blue, 6 hours in red and 12 hours in green). This is the burning of pine wood but this can still be compared to the data gathered from the Sedeinga samples to see where they lie. The ratios for sample 19 mainly is between 0.73 and 0.94, excluding the outliers 0.59 and 0.99, suggesting a temperature range between 700-1100°C, which is slightly higher than the range from the XRPD data. However, as mentioned before sample 19 was difficult to get clear results from, so this might not be the best example to use for the overall data. Sample 56 had more graphs produced which achieved a much more closer number range. The ratios were between 0.67-0.87, indicating 700-950°C which is much closer to the XRPD data. Further analysis can be completed to study the firing temperature and the length of firing. This preliminary research shows that this analysis technique has a high potential for future research.

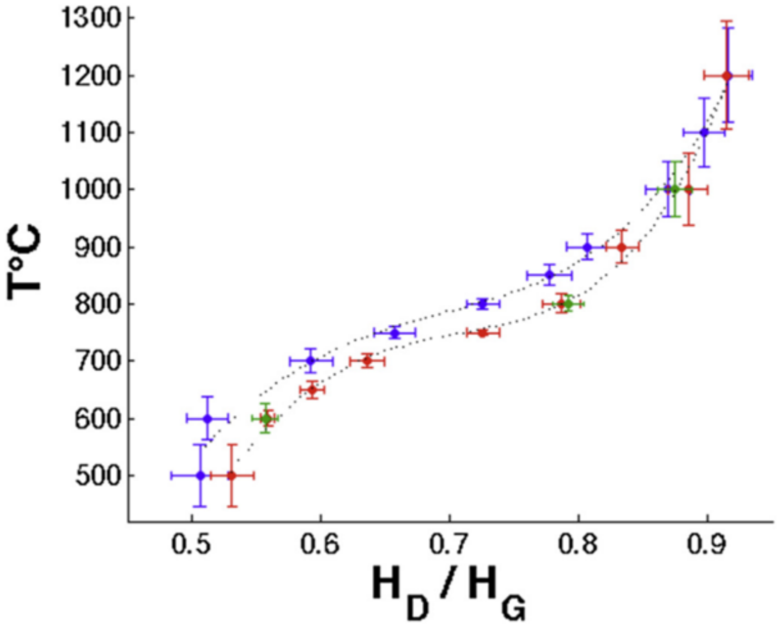


Figure 45 - Ratios plotted on graph from Deldicque et al. (2016)

All of the samples have a substantial potential for Raman analysis as a lot of them contain very well preserved organic material. This is a highly advantageous opportunity for future research to obtain more information on the material composition and on the firing conditions of these ceramics. Raman spectroscopy was not carried out here for all the samples mainly due to the time constraints and analytical workload. Future Raman analysis should be compared to the data from XRPD from this research to see if similar temperature ranges are found or if even a more refined range can be discovered.

7 Conclusion

7.1 RESULTS

This research was conducted to disclose the provenance and production technology of Meroitic ceramics found in Sedeinga. Three techniques were used to solve this which were petrographic analysis, X-ray powder diffraction (XRPD) for the mineralogical composition, and X-ray fluorescence (XRF) for the chemical analysis. The use of multiple analytical techniques allows for the acquisition of a substantial body of scientific knowledge pertaining to the production technology and origin of the ceramics found in Sedeinga. Notably, X-ray Powder Diffraction (XRPD), X-ray Fluorescence (XRF), and Petrographic analysis are particularly advantageous methodologies for addressing these fundamental inquiries (Maritan, 2023).

One of the principal objectives of this study was to disclose the provenance of the kaolinitic-clay based fine ware and Nile-clay based ware discovered at Sedeinga. Based on the research findings, it is highly probable that the Nile clay ware originated from central Sudan, implying that this pottery was both manufactured and traded into the Sedeinga site. The absence of any definitive workshop or kiln evidence at Sedeinga further supports the proposition that the pottery was produced at external locations. The petrographic comparison between the Sedeinga samples and the White Nile samples are similar but not extremely related, this gave the first hint that the raw material may come from this source or a nearby area. The majority of the evidence came from the XRF analysis which showed a correlation with the cluster analysis. Chemically the Sedeinga group and the White Nile group were similar and by far the closest of all the sample groups, and are very closed to some of the Main Nile 1. Comparison with Maritan et al. (2023) proved invaluable to this analysis and showed that a large and comprehensive database is vital when discussing the provenance of material.

Thanks to the comparison with the Meroitic production of central Sudan, it was possible to define that the Nile-clay based ceramics found in Sedeinga were traded from central Sudan and not produced locally at Sedeinga.

The provenance of the kaolinitic ware remains undetermined within the scope of this study; however, insights garnered from personal communication with Romain David have pointed to a potential source. Approximately 1 kilometre west of the necropolis, a granite outcrop with a distinctive purple hue was identified, bearing similarity to samples 1-4 (SED 004) of the kaolinitic clay. It is possible that this granite outcrop may serve as a plausible source of the kaolinitic clay, although it must be noted that no research has been carried out on this sample so this potential source of the raw material cannot be certain. Moreover, the absence of identifiable workshops on-site raises the possibility that the clay may have been procured from an alternate source along the Nile and subsequently traded to Sedeinga. To establish a more definitive provenance for the kaolinitic raw material, further investigations into potential sources along the Nile are needed.

The petrographic analysis resulted in a understanding in the minerals present, the fabric types and importantly the vegetal remains found in the samples. As expressed before, thin section analysis can lead to a significant amount of information about the ceramic body. A petrographic study should always be conducted when it comes to studying the provenance of samples as the fabric and mineral inclusions can be compared to other samples. This analysis is often used for provenance as it deals with the geological characterisation and the nature of the raw material of the ceramic (Quinn, 2013). A reason that the Sedeinga Nile clay samples are believed to not have been produced locally is that it is assumed that potters did not travel long distances to obtain the raw material for the ceramics and that they used local natural deposits (Quinn, 2013). This also highlights the importance of XRF analysis as it can give a definitive and clear comparison between sources in a database. The XRF analysis led to a clearer understanding of the provenance of the raw material and gained insight into the chemistry of the samples.

Another objective was to discuss the production technology used for the creation of theses ceramics. With the Sedeinga samples the main production technology investigated was the firing temperatures employed for the production of the samples. From the data gathered all of the samples seems to have been fired between 750°C-950°C. The XRPD analysis was the main technique used for understanding the firing temperature for the Sedeinga samples. Comparing with data gathered from firing experiments a temperature range could be suggested by the minerals present in the XRPD graphs. The prior knowledge of minerals present in the samples from the petrographic analysis also proved useful with the identification of the minerals. Raman spectroscopy is another technique that can be used to prove the firing temperature range of a ceramic. From the two samples analysed a similar range to the XRPD was gathered, and proves that this might be a useful method to use in the future to understand more about the production technology. The colouring of the clay also suggests a low firing temperature as the ceramics have a black core. The kaolinitic ceramics are thinner so they do not have a black core but they also have a similar firing temperature range. Evidence from other studies shows that kilns with oxidising atmospheres were the firing structures used during the Meroitic period and likely the method used for these ceramics.

Using both XRPD and Raman a firing temperature could be disclosed, and using petrography and XRF a provenance could be disclosed. These techniques used in conjunction can solve these questions, and with more techniques more answers can be provided. Other production technologies such as the forming techniques of these samples were proposed by David and the SEDAU, dividing the Nile clay samples into wheel-made and hand-made productions. This can be discussed more in the future using techniques such as X-ray photogrammetry and a more specific study into the thin sections. A variety of analysis can give different information on the samples so it is worthwhile to use a broad spectrum of analysis techniques.

In conclusion, this comprehensive study has delved into the detailed characteristics of ceramics discovered at the Sedeinga archaeological site, shedding light on their production technology, provenance, and the broader socio-economic context of ancient Nubia. Through the meticulous application of various analytical techniques, we have gained valuable insights into the provenance of the ceramics and the firing temperatures during their creation. Furthermore, this research has not only contributed to the evolving database of knowledge but has also illuminated the interconnectedness of Sedeinga with different communities along the Nile. However, it is evident that more inquiries remain and further research should be carried out to explore more aspects of Sedeinga.

References

ADAMS W. Y., 1964, *AN INTRODUCTORY CLASSIFICATION OF MEROITIC POTTERY, KUSH*.

ADAMS W.Y., 1973, *POTTERY, SOCIETY, AND HISTORY IN MEROITIC NUBIA*, KENTUCKY

ADAMS W.Y., 1977, *NUBIA: CORRIDOR TO AFRICA*. LONDON

ADAMS W. Y., 1986A, *CERAMIC INDUSTRIES OF MEDIEVAL NUBIA PART 1*, KENTUCKY

ADAMS W. Y., 1986B, *CERAMIC INDUSTRIES OF MEDIEVAL NUBIA PART 2*, KENTUCKY

ADAMS W. Y., 1988, *ARCHAEOLOGICAL CLASSIFICATION: THEORY VERSUS PRACTICE*, "ANTIQUITY", VOL 62 NO. 234, PP. 40-56 DOI: HTTPS://DOI.ORG/10.1017/S0003598X0007349X

ARTIOLI G. 2010, *SCIENTIFIC METHODS AND CULTURAL HERITAGE: AN INTRODUCTION TO THE APPLICATION OF MATERIAL SCIENCE TO ARCHAEOMETRY AND CONSERVATION SCIENCE*, OXFORD.

BUDKA, J., 2011. *THE EARLY NEW KINGDOM AT SAI ISLAND: PRELIMINARY RESULTS BASED ON THE POTTERY ANALYSIS (4TH SEASON 2010),* "SUDAN & NUBIA", VOL 15, PP. 23-33.

BUDKA J., 2014, *THE NEW KINGDOM IN NUBIA: NEW RESULTS FROM CURRENT EXCATIONS ON SAI ISLAND*, "EGITTO E VICINO ORIENTE", VOL. 37, PP.55-87. DOI 10.12871/9788674150144

DASZKIEWICZ M, BOBRYK E, SCHNEIDER G., 2005, *ARCHAEOLOGICAL STUDY OF POTTERY FABRIC FROM AWLIB, SUDAN*, "GDAŃSK ARCHAEOLOGICAL MUSEUM AFRICAN REPORTS", VOL: 3, PP. 67-78

DASZKIEWICZ M, SCHNEIDER G., 2011, *KERAMIK AUS MEROË UND HAMADAB. BERICHT ÜBER DIE ERSTEN ERGEBNISSE ZUR KLASSIFIZIERUNG DURCH NACHBRENNEN (MGR-ANALYSE) UND CHEMISCHE ANALYSE (WD-RFA)*, ARCHÄOLOGISCHER ANZEIGER, VOL: 270, PP. 247-265

DASZKIEWICZ M, MALYKH S,. 2017, *POTTERY SAMPLES RECOVERED FROM ABU ERTEILA (SUDAN) – CORRELATION OF MACROSCOPICALLY IDENTIFIED FABRICS WITH LABORATORY-DEFINED RAW MATERIAL GROUPS*, "STUDIA EUROPAEA GNESNENSIA", VOL: 15, PP. 9-35. DOI: 10.14746/SEG.2017.15.1

DASZKIEWICZ M, WETENDORF M, BOBRYK E, SCHNEIDER G., 2016, *MUSAWWARAT ES-SUFRA – IN SEARCH OF CERAMIC RAW MATERIALS,* "NOVENSIA 27", WARSAW

DASZKIEWICZ M, WETENDORF M,. 2014 , A NEW SERIES OF LABORATORY ANALYSES OF COARSE WARES FROM 'POTTERY COURTYARD' 224 OF THE GREAT ENCLOSURE IN MUSAWWARAT ES-SUFRA (SUDAN), "HEFT", VOL. 25, PP. 99-104

DAVID R. 2009, *THE MEROITIC NECROPOLISES OF SAI ISLAND: FIRST REPORT ON CERAMIC MATERIAL FROM MEROITIC CEMETERY 8-B-5.A*, "SUDAN & NUBIA", VOL 13, PP. 97-100.

DAVID R., 2010. *THER MEROITIC NECROPOLISES OF SAI ISLAND: SECOND REPORT ON THEIR CERAMICS FROM THE MEROITIC CEMETERY 8-B-5.A,* "SUDAN & NUBIA", VOL. 14, PP. 60-62

DAVID R., 2012. *LA CÉRAMIQUE FUNÉRAIRE DE L'ÉPOQUE MÉROÏTIQUE*, UNPUBLISHED PHD THESIS, UNIVERSITÉ PAUL VALÉRY MONTPELLIER 3.

DAVID R. 2019, *CERAMIC INDUSTRIES OF MEROITIC SUDAN*, IN D. RAUE (ÉD.), "HANDBOOK OF ANCIENT NUBIA", PP. 875-895. DOI: HTTPS://DOI.ORG/10.1515/9783110420388-035

DAVID R., EVINA M. 2016, *INTRODUCTION À L'ÉVOLUTION DES CHAÎNES OPÉRATOIRES DES CÉRAMIQUES MÉROÏTIQUES,* "DOTAWO: A JOURNAL OF NUBIAN STUDIES", VOL. 3; DOI: HTTPS://DOI.ORG/10.2307/JJ.2353939.8

DELDICQUE D., ROUZAUD JN., VELDE B. 2016, *A RAMEN – HRTEM STUDY OF THE CARBONIZATION OF WOOD: A NEW RAMAN-BASED PALEOTHERMOMETER DEDICATED TO ARCHAEOMETRY*, "CARBON", VOL:102, PP. 319-329; HTTP://DX.DOI.ORG/10.1016/J.CARBON.2016.02.042

D'Ercole G., Budka J., Sterba J,H., Garcea E,A., Mader D. 2017, The successful 'recipe' for a long-lansting tradition: Nubian ceramics assemblages from Sai Island (northern Sudan) from prehistory to the New Kingdom, "Antiquity", vol: 91, pp.24-42. Doi: https://doi.org/10.15184/aqy.2016.262

Edwards D.N., 1996, *The Archaeology of the Meroitic State: New perspectives on its social and political organisation.* Cambridge

Edwards D.N., 1999, *Musawwat Es Sufra II: A Meroitic Pottery Workshop at Musawwarat es Sufra*, Berlin

Francigny V., 2008, The Meroitic Temple at Sai Island, in "*The Kushite World: Proceedings of the 11th International Conference for Meroitic Studies*" , eds Zach M H. Vienna

Francigny V., 2009, *The Meroitic Necropolises of Sai Island: First Season at the Meroitic Cemetery 8-B-5.A*, "Sudan & Nubia", Vol 13, pp. 92-96.

Maritan L., 2023, *Ceramics: Chemical and Petrographic Analysis,* Reference Module in Social Sciences; https://doi.org/10.1016/B978-0-323-90799-6.00020-3.

Maritan L., Gravagna E., Cavazzini G., Zerboni A., Mazzoli C., Grifa C., Mercurio M., Mohamed A., Usai D., Salvatori S. 2023, *Nile River clayey materials in Sudan: Chemical and isotope analysis as reference data for ancient pottery provenance studies*, "Quaternary International", vol. 657, pp. 50-66. Doi: https://doi.org/10.1016/j.quaint.2021.05.009

Maritan L., Holakooei P., Mazzoli C. 2015, Cluster analysis of XRPD data in ancient ceramics: What for?, "Applied Clay Science", vol.114, pp.540-549

Mason R., Grzymski K. 2009, Petrography of Pottery from Meroe, Sudan, "Sudan & Nubia", vol 13, pp. 87-92

Naser C., Daszkiewicz M. 2013, *New Data from the Ceramic Workshop in Courtyard 224 of the Great Enclousure in Musawwarat Es Sufra*, Heft, Vol 24, pp. 15-22.

Naser C., Metendorf M., Dasziewicz M., Schnieder G. 2021, *Understanding Meroitic Pottery and Its Production – Research Design and Methodology of an Interdisciplinary Research Project*, in Meyer C. (eds), *Approaching Economic Spaces: Methods and Interpretation in Archaeometric Ceramic Analysis*, Berlin, pp. 87-111

Nelson K. 2002, *Holocene Settlement of the Egyptian Sahara: The Pottery of Nabta Playa*, Texas

Neumann K., Stromberg C., Ball T., Albert RM., Vrydaghs L, Cummings LS. 2019, *International Code for Phytolith Nomenclature (ICPN) 2.0*, Annals of Botany, Vol 124, pp. 189-199. http://www.academic.oup.com/aob

Nodari L., Marcus E., Maritan L., Mazzoli C., Russo U. 2007, *Hematite nucleation and growth in the firing of carbonate-rich clay for pottery production*, “European Ceramic Society”, vol: 27, pp.4665-4673; doi:10.1016/j.jeurceramsoc.2007.03.031

Nowotnick U. 2022, *Ceramic technology, production and use in an urban settlement on the Middle Nile: the pottery assemblage from Late Meroitic Hamadab, Sudan (2nd to 4th Century A.D.)*, Berlin

Piovesan, R., Dalconi, C., Maritan, L., Mazzoli, C. 2013, *X-ray powder diffraction clustering and quantitative phase analysis on historic mortars*, “European Journal of Mineralogy”, vol 25, pp 165-175, doi: https://doi.org/10.1127/0935-1221/2013/0025-2263

Rilly C., Francigny V. 2010*, Excavations at Sedeinga. A New Start*, “Sudan & Nubia”; vol14, pp. 62-68

RILLY C., FRANCIGNY V. 2011, *THE LATE MEROITIC CEMETRY AT SEDEINGA. CAMPAIGN 2010,* "SUDAN & NUBIA", VOL. 15, PP. 72-79;

RILLY C., FRANCIGNY V. 2012, *EXCAVATIONS OF THE FRENCH ARCHAEOLOGICAL MISSION IN SEDEINGA, 2011 SEASON*, "SUDAN & NUBIA", VOL. 16, PP. 60-71

RILLY C., FRANCIGNY V. 2013, *SEDEINGA 2012: A SEASON OF UNEXPECTED DISCOVERIES*, "SUDAN & NUBIA", VOL. 17, PP. 61-65

RILLY C., FRANCIGNY V. 2018, *CLOSER TO THE ANCESTORS. EXCAVATIONS OF THE FRENCH MISSION IN SEDEINGA 2013-2017*, "SUDAN & NUBIA", VOL 22, PP. 65-74

RILLY C., FRANCIGNY V., DAVID R. 2020, *COLLECTIVE GRAVES AND BA-STATUES. THE 2018 AND 2019 CAMPAIGNS AT SEDEINGA*, "SUDAN & NUBIA", VOL 24, PP.72-90

ROBERTSON J., HILL E. 2002, *TECHNOLOGY AND SOCIETY: AN INTERPRETATION OF MEROITIC SOCIAL STRUCTURE DEVELOPED FROM AN ANALYSIS OF CERAMICS*, IN HARRISON R., GILLESPIE M., PEURAMAKI-BROWN M. (EDS), *EUREKA!! THE ARCHAEOLOGY OF INNOVATION & SCIENCE*, CALGARY, PP. 194-204

ROBERTSON J., HILL E. 2004, *THE MEROITIC POTTERY INDUSTRY*, IN: SHINNIE, PETER LEWIS / ANDERSON, JULIE RENEE (EDS.): THE CAPITAL OF KUSH 2. MEROË EXCAVATIONS 1973–1984. MEROITICA. SCHRIFTEN ZUR ALTSUDANESISCHEN GESCHICHTE UND ARCHÄOLOGIE 20. WIESBADEN: HARRASSOWITZ, P. 109–136

ROSE P. ET AL., 1996, *FIELDWORK, 1995-6: MEMPHIS, SAQQARA, NORTH SAQQARA, TELL EL-AMARNA, BUTO, GEBEL DOKHAN, QASR IBRIM*, "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL. 82; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822111

ROSE P. ET AL., 1997, *FIELDWORK, 1996-7: MEMPHIS, SAQQARA, TELL EL-AMARNA, MONS PORPHYRITES, QASR IBRIM*, "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL. 83; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822456

ROSE P. ET AL., 1998, *FIELDWORK, 1997-8: DELTA SURVEY, MEMPHIS, SAQQARA, TELL EL-AMARNA, GEBEL DOKHAN, QASR IBRIM*, "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL. 84; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822201

ROSE P. ET AL., 2001, *FIELDWORK, 2000-01: SAIS, TELL MUTUBIS, DELTA SURVEY, MEMPHIS, TELL EL-AMARNA, QASR IBRIM,* "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL. 87; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822367

ROSE P. ET AL., 2003, *FIELDWORK, 2002-03: DELTA SURVEY, MEMPHIS, TELL EL-AMARNA, QASR IBRIM,* "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL. 89; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822489

ROSE P. ET AL., 2005, *FIELDWORK, 2004-05: SAIS, MEMPHIS, SAQQARA BRONZES PROJECT, TELL EL-AMARNA, TELL ELAMARNA GLASS PROJECT, QASR IBRIM,* "THE JOURNAL OF EGYPTIAN ARCHAEOLOGY", VOL 91; DOI: HTTPS://WWW.JSTOR.ORG/STABLE/3822391

ROSE P., 2008, *THE MEROITIC TEMPLE COMPLEX AT QASR IBRIM*, "EGYPT EXPLORATION SOCIETY", VOL 41, PP. 383-385, DOI: HTTPS://DOI.ORG/10.1086/666880

SMITH L.M.V., 1997, *CLAY SOURCES FOR MEROITIC FINEWARES*, "AZANIA", VOL. 32 PP.77-92, DOI: HTTPS://DOI.ORG/10.1080/00672709709511588

TING C., HUMPHRIS J. 2017, *THE TECHNOLOGY AND CRAFT ORGANISATION OF KUSHITE TECHNICAL CERAMIC PRODUCTION AT MEROE AND HAMADAB, SUDAN*, "JOURNAL OF ARCHAEOLOGICAL SCIENCE: REPORTS", VOL 17, PP. 34-43; DOI: HTTP://DX.DOI.ORG/10.1016/J.JASREP.2017.09.017

TOMBER R., CARTWRIGHT C., GUPTA S. 2011, *RICER TEMPER: TECHNOLOGICAL SOLUTIONS AND SOURCE IDENTIFICATION IN THE INDIAN OCEAN*, "JOURNAL OF ARCHAEOLOGICAL SCIENCE", VOL 38, PP. 360-366. DOI:10.1016/J.JAS.2010.09.014

TÖRÖK L., 1997, *THE KINGDOM OF KUSH: HANDBOOK OF THE NAPATAN-MEROITIC CIVILIZATION,* LEIDEN.

TÖRÖK L., 2011. *HELLENIZING ART IN ANCIENT NUBIA 300 BC–AD 250 AND ITS EGYPTIAN MODELS*. LEIDEN; BOSTON: BRILL.

VRYDAGHS L., 2016, *PHYTOLITH ANALYSIS OF CERAMIC THIN-SECTIONS. FIRST TAPHONPMICAL INSIGHTS FROM EXPERIMENTS WITH VEGETAL TEMPERING*, IN SIBBESSON E., JERVIS B., COXSON S. (EDS.) *INSIGHT FROM INNOVATION: NEW LIGHT ON ARCHAEOLOGICAL CERAMICS*, OXFORD, PP. 57-73

QUINN P. S., 2013. *CERAMIC PETROGRAPHY: THE INTERPRETATION OF ARCHAEOLOGICAL POTTERY & RELATED ARTEFACTS IN THIN SECTION*. ARCHAEOPRESS. OXFORD. HTTPS://DOI.ORG/10.2307/J.CTV1JK0JF4

QUINN P. S., 2022. *THIN SECTION PETROGRAPHY, GEOCHEMISTRY AND SCANNING ELECTRON MICROSCOPY OF ARCHAEOLOGICAL CERAMICS*. ARCHAEOPRESS. OXFORD. HTTPS://DOI.ORG/10.2307/J.CTV2NWQ8X4

WOODWARD, J.C., MACKLIN, M.G., KROM, M.D. AND WILLIAMS, M.A.J., 2007. *THE NILE: EVOLUTION, QUATERNARY RIVER ENVIRONMENTS AND MATERIAL FLUXES*. IN A. GUPTA (ED.) *LARGE RIVERS*, PP.261-292. HTTPS://DOI.ORG/10.1002/9780470723722.CH13

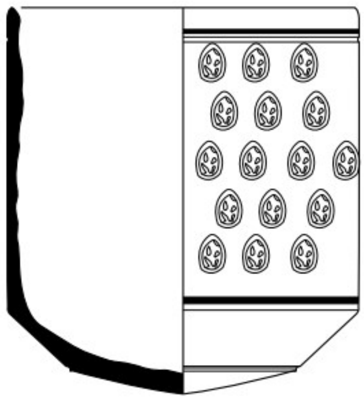
Appendix

<u>List of samples from Sedeinga given by Romain David. ©SEDAU</u>

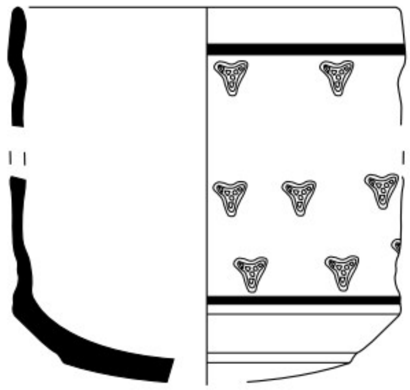
	Number of excavation	Description
FINE WARE SAMPLES - KAOLINITIC CLAY		
1	II T 192 Cd 02	Fine Ware sherds (SED 004)
2	II T 178 Cd 02	Fine Ware sherds (SED 004)
3	II T 196 Cd 01	Fine Ware sherds (SED 004)
4	II T 203 Cd 02	Fine Ware sherds (SED 004)
5	II T 203 Cd 01	Fine Ware sherds (SED 005 ?)
6	II T 214 Cd 01	Fine Ware rim (SED 005)
7	II T 209 Cd 01	Fine Ware sherds (SED 005)
8	II T 194 Cd 02	Fine Ware sherds (SED 005)
9	II T 206 Cd 01	Fine Ware sherds (SED 005)
10	II T 176 Cd 01	Fine Ware sherds (SED 005)
11	II T 188 Cd 01	Fine Ware sherds (SED 005)
12	II T 194 Cd 01	Fine Ware sherds (SED 009)
13	II T 211 Cd 01	Fine Ware sherds (SED 009)
14	II T 215 Cd 02	Fine Ware sherds (SED 009)
15	II T 224 Cd 01	Fine Ware sherds (SED 009)
16	II T 272 Cc 01	Fine Ware sherds (SED 009)
17	II T 089 Cs 04	Fine Ware sherds (SED 009)
18	II T 093 Cd 02	Fine Ware sherds (SED 009)
NILE CLAY SAMPLES - WHEEL-MADE PRODUCTIONS		
19	II T 213 Cs 02	Nile clay sherds (SED 001)
20	II T 089 Cs 01	Nile clay sherds (SED 001)
21	II T 092 Cd 01	Nile clay sherds (SED 001)
22	II T 184 Cd 02	Nile clay sherds (SED 001)
23	II T 188 Cd 03	Nile clay sherds (SED 001)
24	II T 212 Cd 01	Nile clay sherds (SED 001)
25	II 210/100 Cs 07	Nile clay sherds (SED 001)
26	II T 179 Cd 02	Nile clay sherds (SED 001)

27	II 230/120 Cs 03	Nile clay sherds (SED 002)
28	II T 179 Cd 01	Nile clay sherds (SED 002)
29	II 220/100 Cs 03	Nile clay sherds (SED 002)
30	II T 248 Cd 03	Nile clay sherds (SED 002)
31	II T 225 Cd 01	Nile clay sherds (SED 002)
32	II T 216 Cd 03	Nile clay sherds (SED 002)
33	II T 213 Cs 01	Nile clay sherds (SED 002)
34	II T 211 Cd 02	Nile clay sherds (SED 002)
35	II T 194 Cd 03	Nile clay sherds (SED 002)
36	II T 192 Cd 01	Nile clay sherds (SED 002)
37	II T 089 Cd 08	Nile clay sherds (SED 002)
38	II T 091 Cc 02	Nile clay sherds (SED 002)
39	II T 093 Cd 01	Nile clay sherds (SED 002)
40	II T 099 Cd 01	Nile clay sherds (SED 002)
41	II T 145 Cd 02	Nile clay sherds (SED 002)
42	II T 187 Cc 01	Nile clay sherds (SED 002)
43	II T 115 Cd 01	Nile clay sherds (SED 012)
44	II 220/100 Cs 02	Nile clay sherds (SED 012)
45	II 230/110 Cs 04	Nile clay sherds (SED 012)
46	II 230/120 Cs 10	Nile clay sherds (SED 012)
47	II 220/100 Cs 04	Nile clay sherds (SED 012)
48	II T 145 Cd 01	Nile clay sherds (SED 012)
49	II T 215 Cd 01	Nile clay sherds (SED 012)
50	II T 090 Cd 02	Nile clay sherds (SED 012)
51	II T 089 Cc 01	Nile clay sherds (SED 012)
52	II T 076 Cd 01	Nile clay sherds (SED 012)
NILE CLAY SAMPLES - HAND-MADE PRODUCTIONS		
53	II T 238 Cc 15	Nile clay sherds (SED 011)
54	II T 238 Cc 08	Nile clay sherds (SED 011)
55	II T 192 Cd 03	Nile clay sherds (SED 011)
56	II T 134 Cd 01	Nile clay sherds (SED 011)
57	II T 108 Cd 01	Nile clay sherds (SED 011)
58	II T 083 Cs 03	Nile clay sherds (SED 011)

Sketches of the samples from the ©SEDAU

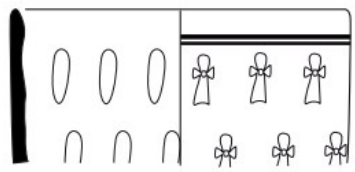


Sample 4



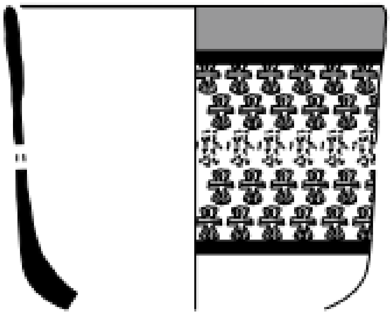
Sample 3

Sample 1

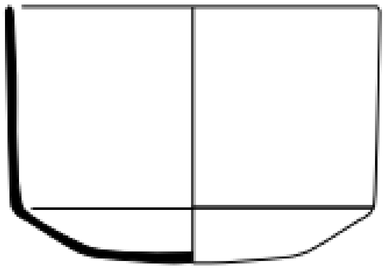


Sample 2

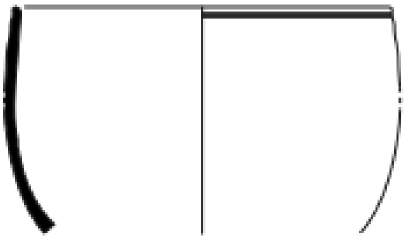
SED 004 - Ceramic samples



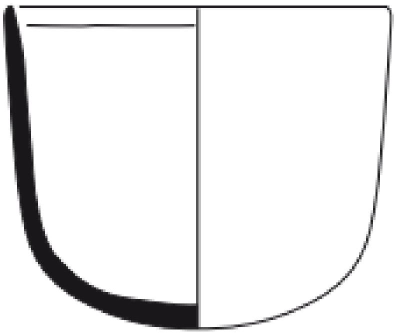
Sample 6



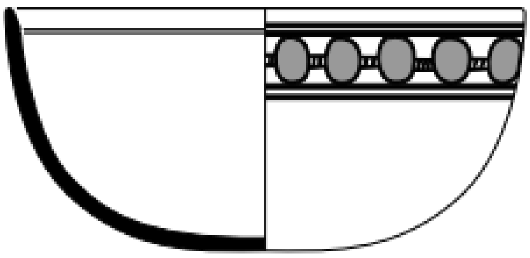
Sample 5



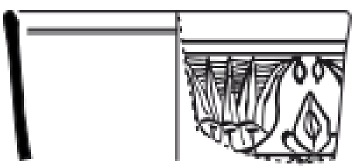
Sample 7



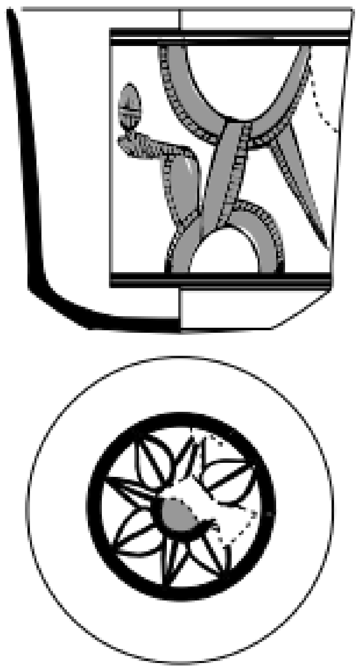
Sample 8



Sample 9

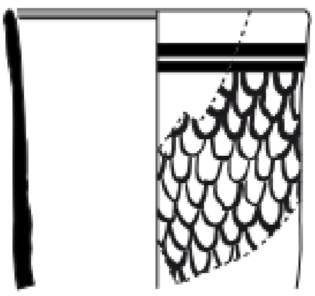


Sample 10

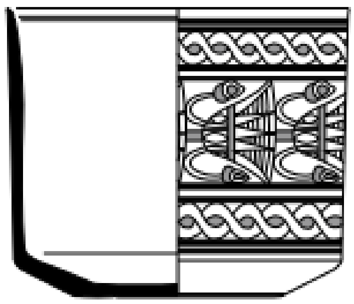


Sample 11

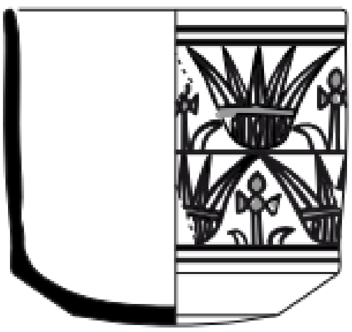
SED 005 - Ceramic samples



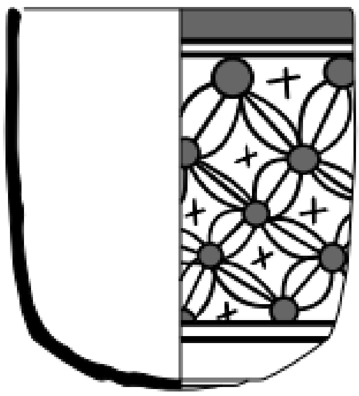
Sample 12



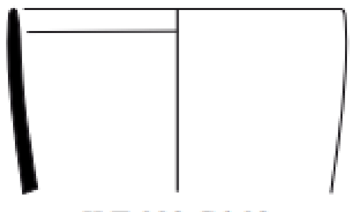
Sample 13



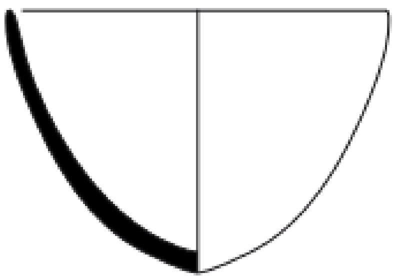
Sample 17



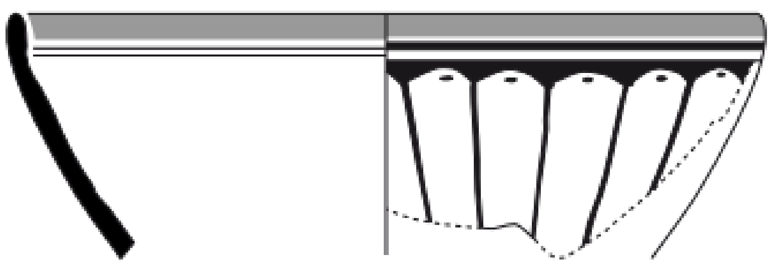
Sample 14



Sample 18

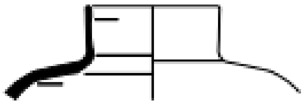


Sample 15

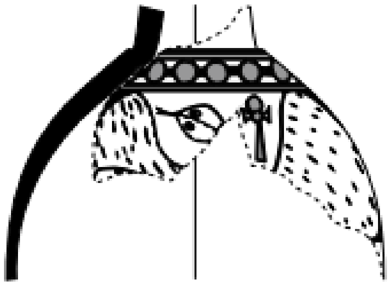


Sample 16

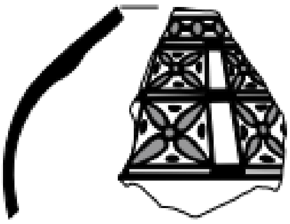
SED 009 - Ceramic samples



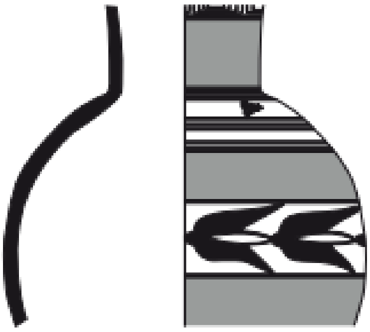
Sample 19



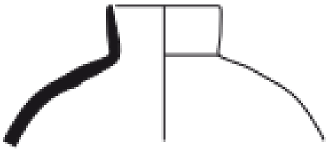
Sample 20



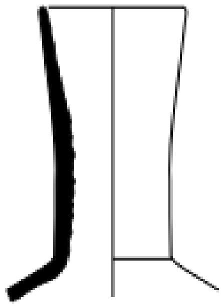
Sample 21



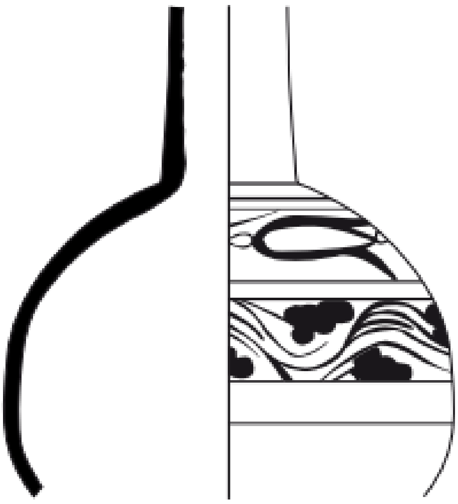
Sample 22



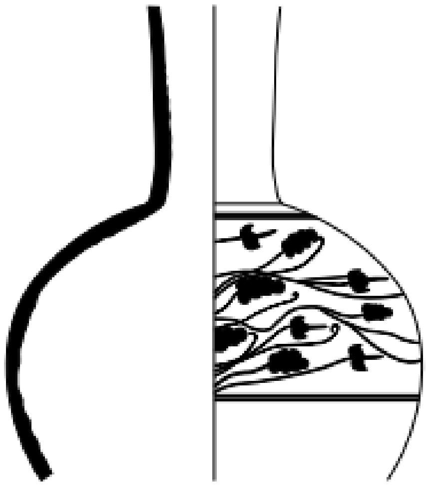
Sample 23



Sample 25

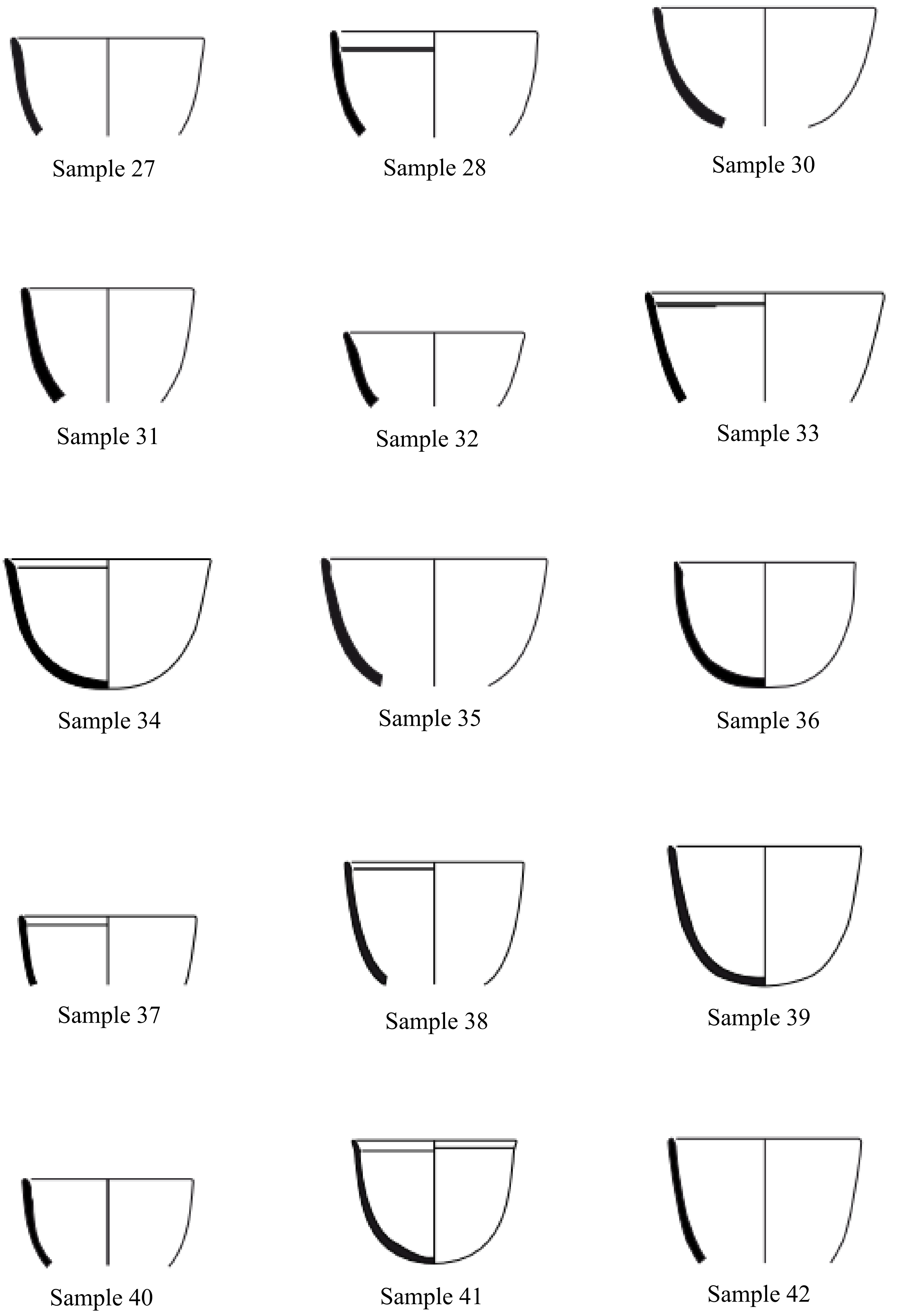


Sample 26

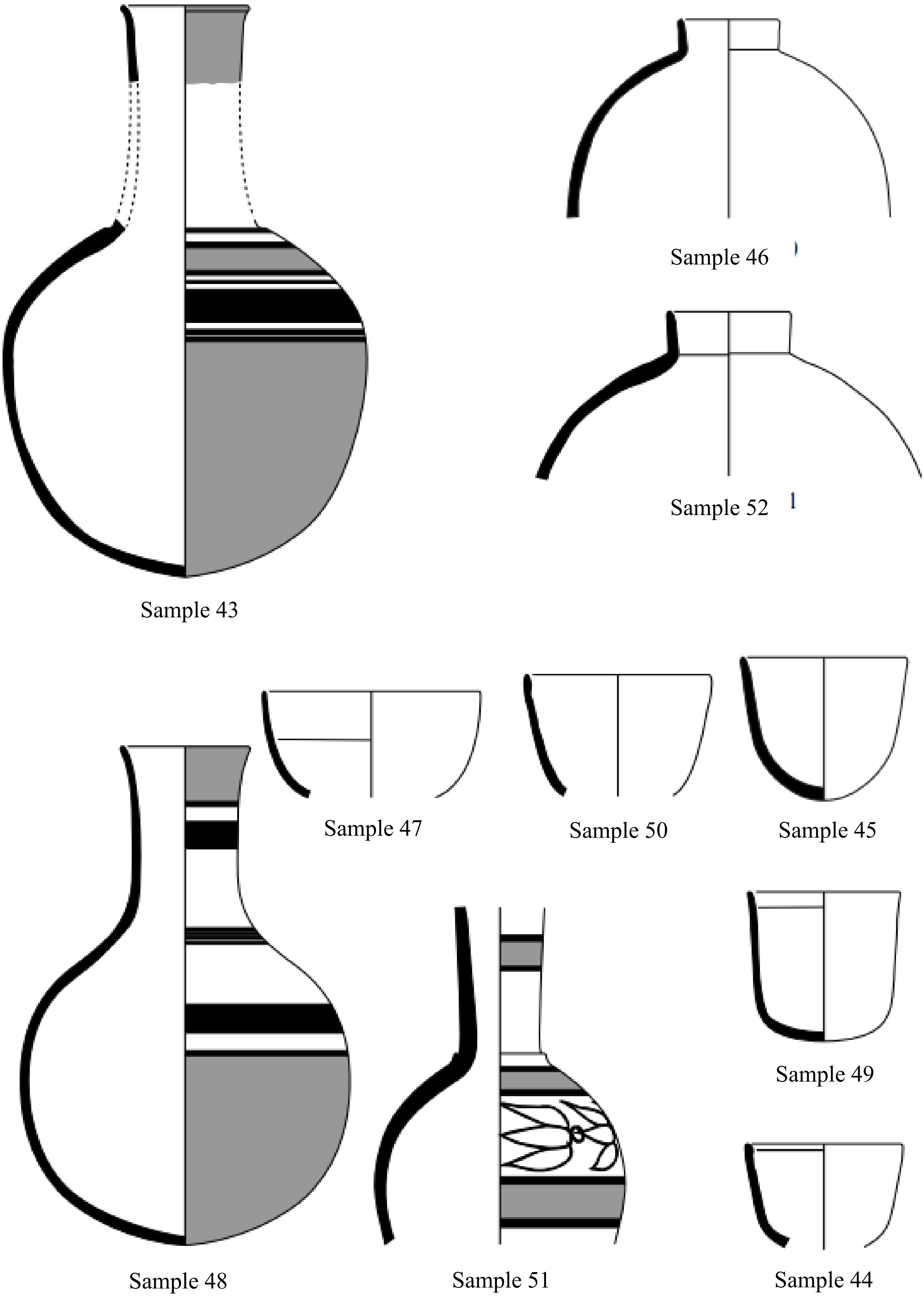


Sample 24

SED 001 - Ceramic samples

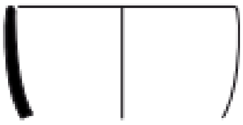


SED 002 - Ceramic samples

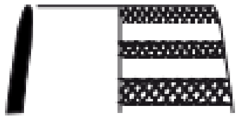


SED 012 - Ceramic samples

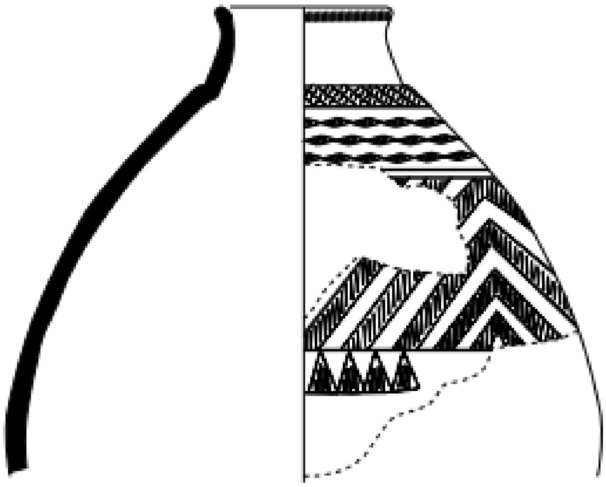
0 10 cm



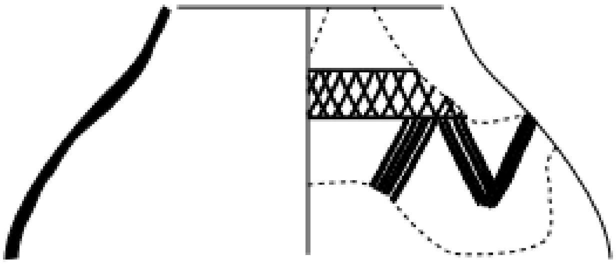
Sample 53



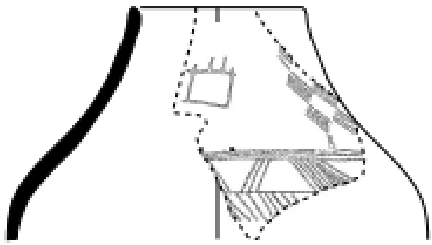
Sample 54



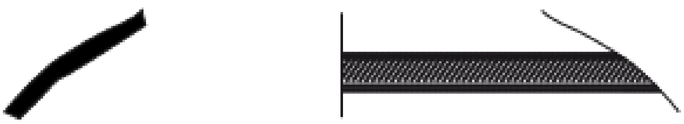
Sample 56



Sample 57



Sample 58



Sample 55

SED 011 - Ceramic samples

Petrographic Table

Sample	Decoration type	Petrographic Groups	c:f ratio	c:f quantity	Optical state
			10x		
1	painting	1A	open spaced	10%	optically active
2	painting & stamped	1A	open spaced	10%	optically active
3	painting & stamped	1A	open spaced	20%	optically active
4	painting & stamped	1A	open spaced	20%	optically active
5	red slip	1A	open spaced	10%	optically active
6	painting & stamped	No thin section			
7	lined impression	1A	open spaced	10%	optically active
8	painting	1B	open spaced	20%	slightly optically active
9	painting	1B	open spaced	15%	optically active
10	painting & lined impression	1B	open spaced	10%	slightly optically active
11	painting	1B	open spaced	15% (20% some places)	optically active
12	painting	1B	open spaced	15%	slightly optically active
13	painting	1C	open spaced	10%	optically active
14	painting	1C	double spaced	30%	optically active
15		1C	open spaced	10%	optically active
16	painting & lined impression	1C	open spaced	10%	optically active
17	painting	1C	open spaced	10%	optically active
18	red slip	1D	double spaced	20%	not optically active
19	red slip	2A	double spaced	20%	optically active
20	red slip	2A	open spaced	20%	optically active
21	painting & coating	2A	open spaced	20%	not optically active
22	painting	2B	single spaced	20%	optically active
23	red slip	2B	open spaced	10%	not optically active
24	coating	2B	open spaced	20%	optically active
25	red slip	2B	open spaced	20%	optically active
26	painting & red slip	2C	open spaced	20%	optically active (low)
27	red slip	2C	open spaced	20%	optically active
28	red slip & lined impression	2C	open spaced	20%	optically active (low)
29	red slip	2B	open spaced	20%	optically active
30	red slip (&dots?)	2B	open spaced	20%	optically active
31	red slip	2B	open spaced	20%	optically active
32	red slip	2C	open spaced	20%	optically active
33	slight red slip	2C	double spaced	30%	optically active
34	red slip	2C	open spaced	20%	optically active
35	red slip (&dots?)	2C	open spaced	20%	optically active
36	red slip	2C	open spaced	20%	optically active
37	red slip	2C	open spaced	20%	optically active
38	red slip	2D	double spaced	30%	optically active
39	red slip	2A	open spaced	20%	optically active
40	red slip	2C	open spaced	20%	optically active
41	red slip	2C	open spaced	20%	optically active
42	red slip	2C	open spaced	20%	optically active

43	red slip	2A	double spaced	20%	not optically active
44	red slip	2A	open spaced	20%	optically active
45	red slip	2A	double spaced	30%	optically active (low)
46	red slip	2B	open spaced	20%	not optically active
47	red slip	2B	open spaced	30%	optically active (low)
48	red slip	2B	open spaced	20%	not optically active
49	red slip	2F	double spaced	30%	not optically active
50	red slip	2F	open spaced	30%	not optically active
51	painting	2E	open spaced	30%	not optically active
52	red slip	2E	double spaced	30%	not optically active
53		2B	double spaced	30%	not optically active (low)
54	crossed impression	2E	double spaced	30%	not optically active (low)
55	arch impression	2E	open spaced	20%	not optically active
56	lined impression - pattern	2E	double spaced	20%	not opticaly active
57		2D	single spaced	40%	not optically active
58		2E	open spaced	25%	not optically active

Sample	B-fabric	Max inclusion size	Average inclusion size	Grain-size distibution	Shape
		10x	10x		
1	cross striated	120 µm	40µm	unimodal	subangular
2	strial	90µm	40µm	unimodal	subangular
3	strial	140µm	40µm	unimodal	subangular
4	strial	200µm	50µm	unimodal	subangular
5	strial	100µm	30µm	unimodal	subangular
6					
7	strial	200µm	30µm	unimodal	subangular
8	strial	210µm	70µm	unimodal	subangular
9	strial	230µm	30µm	unimodal	subangular
10	strial	150µm	40µm	unimodal	subangular
11	strial	220µm	40µm	unimodal	subangular
12	strial	100µm	40µm	unimodal	subangular
13	strial	300µm	40µm	unimodal	subangular
14	strial	300µm	50µm	unimodal	subangular
15	strial	100µm	30µm	unimodal	subangular
16	strial	300µm	30µm	unimodal	subangular
17	strial	350µm	40µm	unimodal	subangular
18	strial	950µm	50µm	unimodal	subangular
19	strial	750µm	50µm	bimodal	subangular
20	strial	650µm	40µm	unimodal	subangular
21	strial	600µm	50µm	unimodal	subangular
22	strial	250µm	50µm	unimodal	subangular
23	strial	400µm	40µm	unimodal	subangular
24	strial	200µm	40µm	unimodal	subangular
25	striated	400µm	50µm	unimodal	subangular
26	strial	600µm	40µm	unimodal	subangular
27	strial	350µm	40µm	unimodal	subangular
28	strial	200µm	30µm	unimodal	subangular
29	strial	1000-1005µm	40µm	unimodal	subangular
30	strial	520µm	40µm	unimodal	subangular
31	strial	600µm	40µm	bimodal	subangular
32	strial	550µm	40µm	unimodal	subangular
33	strial	350µm	40µm	unimodal	subangular
34	strial	520µm	50µm	unimodal	subangular
35	strial	340µm	40µm	unimodal	subangular
36	strial	900µm	50µm	bimodal	subangular
37	strial	380µm	50µm	unimodal	subangular
38	strial	820µm	50µm	unimodal	subangular
39	strial	800µm	30µm	unimodal	subangular
40	strial	340µm	30µm	unimodal	subangular
41	strial	300µm	40µm	unimodal	subangular
42	strial	550µm	40µm	unimodal	subangular
43	strial	520µm	30µm	unimodal	subangular
44	strial	580µm	40µm	unimodal	subangular
45	strial	650µm	40µm	unimodal	subangular

46	strial	780µm	30µm	unimodal	subangular
47	strial	480µm	40µm	unimodal	subangular
48	strial	650µm	40µm	unimodal	subangular
49	strial	980µm	30µm	unimodal	subangular
50	strial	620µm	40µm	unimodal	subangular
51	strial	950µm	30µm	unimodal	subangular
52	strial	650µm	30µm	unimodal	subangular subrounded
53	strial	550µm	30µm	unimodal	subangular
54	strial	250µm	40µm	bimodal	subangular
55	strial	700µm	40µm	unimodal	subangular
56	strial	300µm	40µm	unimodal	subangular
57	strial	450µm	40µm	unimodal	subangular
58	strial	450µm	40µm	unimodal	subangular

Sample	Organic material	Condition of organic temper		Voids
		Well preserved	Completely burned	
1				channels, elongated vughs, up to mm in size
2				vughs
3				vughs, planar voids
4				vughs and channels
5				vughs and channels
6				
7				vughs, complex packing voids
8				vughs, channels, simple packing voids
9				vughs, channels
10				vughs and channels
11				vughs, complex packing voids
12				vughs and channels
13				vughs and channels
14				vughs and complex packing voids
15				vughs, channels and complex packing voids
16				vughs and channels
17				vughs and channels
18	few			vughs, channels, complex packing voids
19	some	Well preserved		vughs, channels and complex packing voids
20	many	Well preserved	traces	vughs, channels and complex packing voids
21	many	Well preserved		vughs and channels
22	few	not well preserved		vughs and channels
23	some	not well preserved		vughs and channels
24	few (&1 carbon)	not well preserved		vughs, channels and complex packing voids
25	few and monocot leaves and carbon	not well preserved		vughs, channels and complex packing voids
26	some and carbon	Well preserved - monoclot leaves		simple packing voids and channels
27	some and carbon	well preserved where not oxidised	some burned and only void left	simple packing voids, channels and vughs
28	carbon		Completely burned	vughs
29	few and carbon	few poorly preserved	Completely burned	channels and vughs
30	bit of carbon		Completely burned	simple packing voids, vughs, channels
31	few and monoclot leaves	preserved		channels and vughs
32			burned chaff	channels and vughs
33	few			channels and vughs
34	bit of carbon		Completely burned	channels and vughs
35	some and carbon	well preserved	Completely burned	channels and vughs and complex packing voids
36	few and small carbon	very little preserved	Completely burned	channels, vughs and simple packing voids
37			Completely burned	channels, vughs and complex packing voids
38	bit of carbon		Completely burned	channels. vughs and complex packing voids
39	few and few carbon	poorly preserved	Completely burned	channels and vughs
40			Completely burned	channels and vughs

41	few carbon		Completely burned	channels,vughs and complex packing voids
42			Completely burned	channels, planes and vughs
43	some carbon	well preserved		channels and vughs
44	few	not well preserved		channels and vughs
45	few and carbon	not well preserved		channels and vughs
46	few	not well preserved		channel and vughs
47	few carbon	not well preserved		channels and vughs
48	few	not well preserved		channels and vughs
49	few	not well preserved		vughs and complex packing voids
50	few			channels and vughs
51	few	not well preserved		channels and vughs
52	many	well preserved		channels and vughs
53	few and few carbon		Completely burned	channels and vughs
54	many	well preserved		channels and vughs
55	many	well preserved		channels, planes and vughs
56	many	well preserved		channels, planes and vughs
57	many	well preserved		channels, planes and vughs
58	few	not well preserved	some burned and only void left	channels and vughs

	Material composition / Inclusions					
	Quartz	Plagioclase	Feldspar	Biotite	Muscovite	Olivine	Pyroxene
1	x	x	x	x	x		
2	x	x			x		x
3	x	x	x	x		x	x
4	x	x		x	x		x
5	x	x			x		
6							
7	x	x					
8	x	x	x		x		
9	x		x				
10	x	x		x			
11	x			x			
12	x	x			x		
13	x	x					x
14	x	x		x	x		x
15	x						
16	x			x			
17	x			x	x		
18	x		x				
19	xx	x		x	x		x
20	xx	x	x	x	x		x
21	xx	x			x	x	x
22	xx	x		x	x	x	x
23	xx		x		x		
24	xx	x	x		x		
25	xx	x	x		x		x
26	xx	x	x	x	x	x	x
27	xx	x	x		x		
28	xx	x	x	x		x	x
29	xx	x			x		x
30	xx	x	x	x	x		
31	xx	x	x	x	x		
32	xx	x	x	x	x		
33	xx	x	x	x	x	x	
34	xx	x	x		x		
35	xx		x		x		
36	xx	x	x		x		
37	xx	x	x	x	x		
38	xx	x	x	x	x	x	
39	xx	x	x		x		
40	xx	x	x		x		
41	xx	x	x		x		
42	xx	x	x	x	x		x
43	xx	x	x		x		
44	xx	x	x		x		
45	xx	x	x		x		

	Quartz	Plagioclase	Feldspar	Biotite	Muscovite	Olivine	Pyroxene
46	xx	x	x	x	x		
47	xx	x		x	x		x
48	xx	x		x	x		x
49	xx	x		x	x		x
50	xx	x	x		x		
51	xx	x	x	x	x	x	
52	xx	x		x	x		x
53	xx		x		x		
54	xx	x	x	x	x		x
55	xx	x	x	x	x		x
56	xx	x	x	x	x		
57	xx	x	x	x	x		
58	xx	x	x	x	x		

	amphiboles	chlorite	vegetal materials	opaque minerals	Glass	Ceramic	other
1				x			
2	x						illite
3	x				x		
4	x	x			x	x	
5		x		x			fragment of sedimentary rock
6							
7				x			
8				x			zircon
9				x			
10				x			zircon
11				x			fragment of ochre
12				x			
13				x			metamorphic quartz
14				x			secondary calcite
15	x			x			
16				x			
17				x			
18			x				fragment of bone
19	x	x	x	x			fragment of fine sandstone, carbonate mudstone, secondary calcite, ochre fragment
20			x	x			
21	x		x				
22			x	x			siliminite
23			x				some bone
24			x	x			dense mudstone
25			x	x			grain/seed void, 1.2mm. Fragment of sandstone
26			x	x			fragment of sandstone
27	x		x	x		x	sandstone
28	x						metamorphic rock and mudstone
29	x		x	x		x	secondary calcite
30	x			x			carbon and metaphorhic quartz
31	x		x	x			
32	x			x			ochre fragment
33	x		x	x			rock fragment
34	x			x			carbon
35	x			x			
36			x	x			carbon
37	x			x			
38	x			x		x	rock fragment
39	x		x	x			
40				x			
41	x			x			rock fragment
42				x			
43			x	x			
44				x			
45	x		x	x			carbon
46	x		x	x			

	amphiboles	chlorite	vegetal materials	opaque minerals	Glass	Ceramic	other
47	x		x	x			
48	x		x	x			
49	x		x	x			
50	x			x			rock fragment
51	x		x	x			
52	x		x	x			rock fragment
53			x	x			
54			x	x			
55	x		x	x			
56	x		x	x			
57	x		x	x			
58	x		x	x			

<u>XRF data</u>

Sample	Fabric	Petro	SiO_2	TiO_2	Al2O3	Fe2O3	MnO	MgO
1	SED 004	1A	65.97	1.78	26.29	3.89	0.02	0.06
2	SED 004	1A	66.34	1.69	25.93	3.85	0.05	0.08
3	SED 004	1A	67.25	1.73	25.52	3.42	0.03	0.29
4	SED 004	1A	65.91	1.64	25.86	4.20	0.02	0.09
5	SED 005	1A	67.85	2.00	25.50	4.07	0.02	0.01
6	SED 005	No thin section	66.91	1.68	25.17	3.86	0.04	0.35
7	SED 005	1A	63.85	2.10	30.91	2.80	0.01	0.01
8	SED 005	1B	70.54	1.47	21.77	3.46	0.04	0.45
9	SED 005	1B	66.77	1.68	26.37	4.42	0.03	0.10
10	SED 005	1B	66.23	1.74	26.90	3.62	0.03	0.21
11	SED 005	1B	68.33	1.73	25.76	2.99	0.03	0.39
12	SED 009	1B	67.10	1.72	26.58	3.39	0.03	0.01
13	SED 009	1C	68.32	1.96	25.01	3.40	0.02	0.01
14	SED 009	1C	69.38	1.58	21.10	4.53	0.05	0.50
15	SED 009	1C	67.01	1.69	26.48	3.29	0.02	0.01
16	SED 009	1C	68.54	1.76	26.43	2.76	0.02	0.33
17	SED 009	1C	65.87	1.71	26.42	2.95	0.02	0.23
18	SED 009	1D	65.32	1.97	27.13	3.26	0.04	0.46
19	SED 001	2A	67.14	1.58	20.00	6.16	0.08	1.10
20	SED 001	2A	67.31	1.52	19.58	6.62	0.11	1.06
21	SED 001	2A	64.72	1.73	18.00	8.39	0.13	1.99
22	SED 001	2B	66.11	1.71	18.60	7.03	0.12	1.48
23	SED 001	2B	67.82	1.47	20.84	5.22	0.06	0.57
24	SED 001	2B	67.75	1.52	19.75	6.69	0.10	0.93
25	SED 001	2B	66.02	1.58	19.82	6.68	0.09	1.13
26	SED 001	2C	68.50	1.50	20.75	6.19	0.08	0.76
27	SED 002	2C	65.81	1.63	19.04	7.32	0.12	1.23
28	SED 002	2C	67.30	1.58	19.13	6.59	0.10	1.49
29	SED 002	2B	65.16	1.58	19.69	7.00	0.09	1.16
30	SED 002	2B	68.79	1.47	20.26	5.46	0.05	0.90
31	SED 002	2B	61.74	1.89	17.37	9.75	0.16	2.27
32	SED 002	2C	65.96	1.63	19.02	7.35	0.12	1.27
33	SED 002	2C	66.21	1.61	18.76	6.69	0.12	1.44
34	SED 002	2C	62.47	1.87	17.51	9.28	0.16	2.24
35	SED 002	2C	65.74	1.59	19.74	7.19	0.10	1.17
36	SED 002	2C	67.14	1.55	20.38	6.56	0.09	1.01
37	SED 002	2C	65.22	1.65	19.31	6.81	0.11	1.38
38	SED 002	2D	71.12	1.31	17.34	5.28	0.10	1.06
39	SED 002	2A	68.15	1.53	19.59	6.06	0.10	1.00
40	SED 002	2C	66.69	1.54	20.69	6.55	0.10	0.95
41	SED 002	2C	64.32	1.70	18.85	7.52	0.14	1.58
42	SED 002	2C	72.27	1.31	17.47	5.30	0.09	1.04

43	SED 012	2A	66.65	1.59	19.06	7.07	0.13	1.26
44	SED 012	2A	60.03	2.04	16.50	10.70	0.19	3.10
45	SED 012	2A	62.79	1.82	18.01	8.68	0.13	2.15
46	SED 012	2B	66.73	1.57	19.94	6.81	0.10	1.03
47	SED 012	2B	66.24	1.57	18.67	7.00	0.14	1.40
48	SED 012	2B	62.74	1.89	15.99	9.51	0.14	2.80
49	SED 012	2F	64.11	1.93	16.37	9.16	0.17	2.36
50	SED 012	2F	61.80	1.83	16.15	8.83	0.16	2.59
51	SED 012	2E	65.48	1.63	16.95	7.92	0.14	2.19
52	SED 012	2E	64.72	1.73	18.31	7.51	0.11	1.99
53	SED 011	2B	68.18	1.45	19.98	6.08	0.11	0.75
54	SED 011	2E	61.67	1.95	15.76	10.26	0.14	2.80
55	SED 011	2E	62.51	1.80	16.08	9.97	0.14	2.36
56	SED 011	2E	62.44	1.81	15.99	9.76	0.14	2.66
57	SED 011	2D	67.12	1.45	14.51	7.96	0.15	2.11
58	SED 011	2E	63.18	1.99	15.68	10.25	0.14	2.76

Sample	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**Tot**	**L.O.I.**	**S**	**Sc**	**V**	**Cr**
1	0.74	0.95	0.61	0.44	100.75	4.98	67	18	188	132
2	0.62	0.63	0.66	0.25	100.10	3.37	34	18	200	137
3	0.70	0.85	0.68	0.10	100.57	3.51	79	19	190	145
4	0.50	0.82	0.59	0.11	99.74	3.54	162	19	186	140
5	0.34	0.63	0.53	0.20	101.15	2.06	49	21	146	129
6	0.94	0.51	0.75	0.24	100.24	1.78	51	20	152	140
7	0.57	0.82	0.29	0.14	101.50	4.04	21	19	192	153
8	0.84	0.93	1.08	0.13	100.71	4.84	52	13	139	114
9	0.31	0.51	0.70	0.11	101.00	1.50	41	22	158	143
10	0.37	0.75	0.69	0.28	100.82	4.60	31	19	192	145
11	0.58	0.76	0.78	0.15	101.50	2.98	57	20	181	144
12	0.29	0.32	0.57	0.14	100.15	1.77	34	18	146	146
13	0.71	0.80	0.63	0.39	101.25	4.30	72	21	152	132
14	1.21	0.53	1.15	0.19	100.22	4.48	79	19	145	113
15	0.50	1.13	0.34	0.06	100.53	3.55	86	19	190	136
16	0.41	0.29	0.80	0.15	101.49	1.53	24	18	146	146
17	0.60	0.63	0.70	0.20	99.33	2.66	33	20	148	147
18	0.87	0.68	0.71	0.20	100.64	1.74	42	21	160	156
19	1.75	1.08	0.99	0.37	100.25	3.25	302	21	145	124
20	1.65	0.89	1.19	0.23	100.16	3.75	134	18	153	119
21	2.66	1.13	1.29	0.45	100.49	2.84	13	24	177	133
22	2.20	1.26	1.27	0.24	100.02	2.53	106	22	165	152
23	1.20	0.79	1.14	0.38	99.49	4.66	81	17	143	116
24	1.56	0.93	1.24	0.70	101.17	2.83	68	21	146	118
25	2.04	1.51	1.17	0.31	100.35	4.39	510	21	163	126
26	1.08	0.85	1.18	0.23	101.12	2.23	80	20	155	119
27	2.23	1.35	1.15	0.27	100.15	4.61	177	22	164	125
28	2.18	1.09	1.46	0.40	101.32	2.14	148	25	155	127
29	2.58	1.41	1.17	0.28	100.12	6.55	216	22	161	125
30	1.47	1.26	1.07	0.21	100.94	5.74	132	21	143	113
31	3.58	1.70	1.15	0.30	99.91	7.28	169	28	186	147
32	2.35	1.36	1.15	0.26	100.47	4.75	394	23	169	122
33	2.30	1.27	1.29	0.66	100.35	3.69	157	21	151	136
34	3.84	1.58	1.28	0.31	100.54	5.84	271	31	184	146
35	1.66	1.26	1.12	0.26	99.83	4.24	62	20	171	123
36	1.76	1.08	1.16	0.28	101.01	4.47	117	23	150	116
37	2.12	1.72	1.20	0.20	99.72	5.36	332	21	163	130
38	1.89	1.18	1.13	0.25	100.6	4.31	136	16	125	99
39	1.65	0.94	1.15	0.36	100.53	3.03	190	20	143	117
40	1.64	0.90	1.16	0.34	100.56	5.17	157	20	155	119
41	2.75	1.75	1.16	0.21	99.98	6.19	1111	24	173	128
42	1.60	1.20	1.16	0.31	101.75	4.14	135	17	127	103
43	1.48	1.02	1.24	0.31	99.81	2.18	74	22	155	121
44	3.54	2.15	1.24	0.27	99.76	2.91	398	27	207	148
45	2.98	1.49	1.22	0.32	99.59	2.57	967	28	180	143
46	1.45	0.87	1.20	0.47	100.17	1.90	119	18	152	121

47	1.94	1.30	1.51	0.35	100.12	2.07	184	23	152	129
48	3.09	1.82	1.58	0.45	100.01	1.65	123	25	192	147
49	3.56	1.71	1.23	0.39	100.39	1.93	246	29	190	149
50	5.42	1.62	1.21	0.24	99.85	3.35	432	29	182	141
51	2.74	1.37	1.36	0.35	100.13	1.35	185	22	168	115
52	2.44	1.83	1.38	0.75	100.77	5.71	134	26	168	138
53	1.44	0.89	1.16	0.24	100.28	4.65	66	19	149	120
54	4.19	1.73	1.35	0.40	100.25	4.77	221	29	203	149
55	3.71	1.91	1.40	0.65	100.53	6.98	579	27	187	138
56	3.22	1.70	1.60	0.45	99.77	3.48	322	25	190	136
57	3.30	1.43	1.42	0.34	99.79	5.13	189	22	153	127
58	3.63	1.79	1.21	0.34	100.97	1.71	206	29	203	147

Sample	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb
1	26	42	45	58	19	26	95	88	310	24
2	46	51	90	55	23	28	87	109	292	24
3	36	71	70	48	18	31	86	146	305	25
4	20	35	40	39	23	27	75	84	280	23
5	15	35	33	87	18	24	68	59	361	26
6	38	48	59	68	21	34	102	141	292	23
7	18	47	30	74	26	19	67	47	330	28
8	15	27	17	38	18	58	113	48	323	16
9	33	45	78	56	21	32	66	106	295	24
10	42	64	67	56	23	30	73	137	291	25
11	56	94	48	88	21	40	90	57	312	21
12	47	52	92	68	24	30	61	140	299	25
13	12	27	18	51	17	23	129	54	351	25
14	32	54	32	82	15	44	129	41	325	15
15	30	46	37	70	23	19	85	26	284	18
16	43	95	37	117	23	39	72	61	305	23
17	34	79	86	106	23	35	110	244	285	32
18	18	36	47	74	27	29	107	64	364	22
19	22	39	28	70	11	41	201	37	310	15
20	29	43	32	65	16	59	151	36	307	17
21	34	65	44	89	9	57	232	35	345	16
22	28	46	32	72	12	59	195	36	362	14
23	16	30	30	58	15	63	150	33	287	15
24	28	40	33	71	12	59	202	36	316	14
25	27	47	38	68	15	60	172	42	289	14
26	28	36	34	59	15	65	140	49	305	15
27	27	47	39	73	11	54	219	37	317	16
28	28	47	34	72	11	63	211	35	311	13
29	25	43	38	69	14	59	214	36	306	17
30	21	35	29	59	14	55	279	36	305	14
31	37	70	48	100	11	51	324	36	319	21
32	30	47	38	75	12	54	220	36	319	19
33	32	46	32	71	12	57	243	34	313	13
34	38	67	49	90	7	54	292	37	335	21
35	28	46	40	69	14	55	181	34	317	15
36	26	41	34	66	13	54	191	37	298	15
37	30	47	36	66	15	53	214	35	305	15
38	23	31	29	60	2	52	177	31	311	14
39	24	40	30	65	15	56	164	34	304	15
40	25	43	39	66	17	61	156	38	303	16
41	31	54	39	70	9	55	246	38	318	15
42	23	31	27	63	11	54	179	30	307	9
43	28	43	30	69	11	63	148	37	344	15
44	45	77	51	104	12	52	295	36	361	21
45	34	62	44	89	10	60	257	36	330	22

46	27	44	31	73	15	64	174	34	301	14
47	27	48	38	73	6	61	188	34	345	12
48	38	70	42	99	11	57	276	32	337	18
49	37	69	46	101	5	48	298	36	358	15
50	34	61	42	85	9	47	285	34	365	16
51	32	53	36	85	6	51	214	31	310	17
52	40	79	43	102	2	51	223	37	314	17
53	24	33	31	58	12	56	198	37	297	14
54	38	71	49	107	2	48	352	32	338	15
55	39	73	50	110	10	53	318	34	314	14
56	39	69	45	102	8	55	283	34	345	17
57	29	53	31	96	11	50	299	31	393	14
58	45	74	51	107	5	50	300	35	315	19

Sample	Ba	La	Ce	Nd	Pb	Th	U
1	256	88	200	98	20	15	5
2	370	59	133	71	20	11	4
3	313	130	270	128	18	13	6
4	273	108	237	119	22	12	4
5	207	96	207	91	17	12	3
6	299	97	200	91	22	9	6
7	131	27	66	36	22	15	7
8	381	44	95	48	12	12	4
9	298	93	206	101	23	13	4
10	297	121	259	122	20	15	6
11	354	37	90	50	16	12	5
12	284	99	204	97	20	10	6
13	261	95	207	100	16	13	5
14	448	32	80	42	12	12	4
15	233	21	48	26	14	10	6
16	330	49	109	58	21	10	4
17	376	176	351	148	23	11	6
18	297	47	107	56	19	12	6
19	466	39	79	43	11	11	5
20	497	44	95	43	8	8	2
21	473	28	66	41	12	10	3
22	515	32	77	44	11	10	2
23	408	37	85	51	12	13	5
24	493	32	79	46	9	10	5
25	471	33	77	44	13	12	5
26	428	40	91	44	12	14	4
27	438	36	82	42	8	8	4
28	512	30	76	41	8	10	4
29	448	33	77	42	13	10	2
30	403	38	86	48	12	10	3
31	548	24	63	39	13	7	2
32	456	30	72	42	9	13	2
33	498	28	68	47	11	9	2
34	514	28	69	44	10	11	2
35	463	30	72	43	13	12	4
36	604	32	78	39	10	10	3
37	560	28	70	46	17	7	3
38	585	28	68	40	3	13	2
39	613	32	74	47	11	10	3
40	505	39	91	47	11	10	5
41	510	41	89	44	12	10	3
42	585	31	69	36	14	11	5
43	454	35	82	38	11	11	2
44	508	33	70	37	11	9	4
45	497	33	79	42	11	10	2
46	482	37	87	43	7	7	3

47	559	29	72	42	13	12	5
48	486	26	61	36	8	8	2
49	510	19	57	36	10	9	3
50	454	22	60	37	7	5	2
51	510	33	77	41	12	10	3
52	409	37	84	40	10	15	5
53	630	46	95	42	14	11	3
54	468	22	60	36	7	9	2
55	438	27	64	35	10	5	3
56	462	19	56	37	9	9	4
57	475	30	66	34	8	9	5
58	440	5	41	30	5	8	2

Raman data bands and ratios

Sample 19:

D band (cm^{-1})	G band (cm^{-1})	Ratio
1156.30	1225.70	0.943379
479.92	545.02	0.880555
2325.10	2569.30	0.904955
340.86	363.52	0.937665
377.94	641.69	0.588976
983.27	1351.90	0.727325
499.75	641.60	0.778912
1160.40	1171.2	0.990779
545.16	622.33	0.875998

Sample 56:

D band (cm^{-1})	G band (cm^{-1})	Ratio
1163.70	1447.40	0.803993
294.86	408.46	0.721882
993.68	1188.50	0.836079
148.82	179.74	0.827974
896.07	1125.70	0.796011
139.06	165.37	0.840902
294.39	337.90	0.871234
88.34	104.26	0.847353
230.72	266.81	0.864735
178.87	203.39	0.879443
247.80	354.83	0.698363
337.63	502.87	0.671406
130.33	146.20	0.89145
181.00	210.04	0.861741