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Evolution and Archaeometrical Fabric Characterisation of Narosura Pastoral Neolithic Pottery from Luxmanda Site in Mbulu Plateau North-Central Tanzania

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DEDICATION

This work is dedicated to my parents: Mzee Timothy Luomba Ombori and Mama Phoebe A. Nyamanga, whose affection, love, encouragements and prayers of day and night make me able to get such success and honour despite the challenges we have been through.

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I feel indebted to my family and parents for the support, love and trust they showed me during the years I spent in abroad and not at home.

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Abstract

This study characterises the Narosura pastoral Neolithic (PN) pottery fabric from Luxmanda site (ca. 3000-2900 B.P) and compare with local raw clay sources within the Mbulu plateau in the North-Central Tanzania. The pottery samples used in this study were collected from RAPT 2018 excavation campaigns and the raw clay materials were obtained through survey. The pottery samples fabric characterisation and raw clay analysis were both assessed through microscopic and macroscopic analysis, respectively. In macroscopic analysis, typological (Narosura pottery), soil wet sieve (raw clay) and ethnography (contemporary pottery manufacturing) analysis were used. For microscopic analysis, petrography, scanning electron microscopy (SEM), and X-ray diffraction (XRD) were combined to characterize the mineralogical components and chemical variation of both Narosura pottery and clay sources to determine the sources of raw materials used in making pottery found in the Luxmanda site.

The results of the aforementioned studies showed that, the mineralogical and geochemical composition between the raw clay materials and the Narosura PN pottery samples paste are similar. The implication of this study can therefore be suggested that even though different raw clay sources might have been used for making Narosura PN pottery, but a closer homogeneity with local geology indicate that they were produced from the raw clay material derived from similar parent rocks as reflected in the Mbulu plateau geology. The mineralogical and geochemical composition findings from this study on both the raw clay and the Narosura PN pottery samples fabric analysis also support and confirm that pottery from Luxmanda site were locally made not imported outside the Mbulu plateau region as they reflect local geology. Even though it has been long upheld that the spread of Neolithic pottery found in northern parts of Tanzania were brought through migration of earlier pastoralists from the core in southern Kenya, this study however challenges this notion by demonstrating that the Luxmanda pottery were locally made with the clay resources found within the vicinity of Mbulu plateau. The contemporary ethnographic study also revealed that there are several local clay sources suitable for making pottery within Mbulu plateau and are still used by the Mbulu plateau potters.

The Narosura PN pottery sample fabric colour variability and the appearance multiple colourations of dark to light (firing clouding) identified in this study also revealed that the firing low and in reducing condition with uncontrolled firing process state. In addition, the lack of calcite (CaCO3) to decompose and the existence of mineralised plant substances in the pottery samples also supported low firing. The presence of some minerals of some minerals like fresh quartz, primary calcite and lack of vitrification in most of Narosura PN pottery samples proved that the firing temperature did not exceed 1000° C.

The macroscopic and microscopic analysis in study proved that the majority of the pottery were built by coils in bowls with thin wall and slabs in vessels with thick walls such as cooking and storage pots. The continuous use of coiling method in majority of the pottery samples indicated conservativeness and that the technology of manufacture had changed very little with time. It is also an imprint suggesting that the potter’s skills were inherited and maintained through time. The nature of aplastic inclusions such as tempering materials and voids also indicated the potter’s artistic standardisation and technological standards in the raw clay processing pottery manufacturing.

This study combined both the traditional archaeological pottery study techniques and the archaeometric, the combination opened new horizons for understanding Narosura PN pottery tradition. Finally, this study recommend that future studies should continue to focus on

mineralogical and geochemical analysis of the Pastoral Neolithic pottery sites within Tanzania and East Africa in general to establish database for future reference.

Riassunto

Questo studio caratterizza il fabric delle ceramiche del del Neolitico pastorale Narosura (PN) del sito di Luxmanda (ca. 3000-2900 a.C.) e lo confronta con le fonti locali di argilla grezza nell'altopiano di Mbulu nella Tanzania centro-settentrionale. I campioni di ceramica utilizzati in questo studio sono stati raccolti dalle campagne di scavo RAPT 2018 e i materiali di argilla grezza sono stati ottenuti tramite sondaggio. La caratterizzazione del fabric dei campioni di ceramica e l'analisi dell'argilla grezza sono state entrambe valutate attraverso l'analisi microscopica e macroscopica, rispettivamente. Nell'analisi macroscopica, sono state utilizzate analisi tipologiche (ceramica di Narosura), di setaccio del suolo umido (argilla grezza) e etnografiche (fabbricazione contemporanea della ceramica). Per l'analisi microscopica, la petrografia, la microscopia elettronica a scansione (SEM) e la diffrazione dei raggi X (XRD) sono state combinate per caratterizzare i componenti mineralogici e la variazione chimica sia della ceramica Narosura che delle fonti di argilla per determinare le fonti delle materie prime utilizzate nella produzione della ceramica trovata nel sito di Luxmanda.

I risultati dei suddetti studi hanno mostrato che la composizione mineralogica e geochimica tra i materiali argillosi grezzi e i campioni di ceramica di Narosura PN siano simili. Questo studio può quindi ha permesso di definire che, anche se diverse fonti di argilla grezza potrebbero essere state utilizzate per la fabbricazione delle ceramiche Narosura PN, una più stretta omogeneità con la geologia locale, indica che sono state prodotte da materiale argilloso grezzo derivato da rocce madri simili, come si riflette nella geologia dell'altopiano di Mbulu. I risultati della composizione mineralogica e geochimica di questo studio sia sull'argilla grezza che sull'analisi del fabric dei campioni di ceramica Narosura PN supportano e confermano che le ceramiche del sito di Luxmanda sono state prodotte localmente e non importate da fuori della

regione dell'altopiano di Mbulu in quanto riflettono la geologia locale. Anche se è stato a lungo sostenuto che la diffusione della ceramica neolitica trovata nelle parti settentrionali della Tanzania sia stata portata attraverso la migrazione dei pastori precedenti dal nucleo del Kenya meridionale, questo studio sfida questa nozione dimostrando che la ceramica di Luxmanda è stata fatta localmente con le risorse di argilla trovate nelle vicinanze dell'altopiano di Mbulu. Lo studio etnografico contemporaneo ha anche rivelato che ci sono diverse fonti locali di argilla adatte alla produzione di ceramiche all'interno dell'altopiano di Mbulu e sono ancora utilizzate dai vasai dell'altopiano di Mbulu.

La variabilità del colore del tessuto del campione di ceramica Narosura PN e la comparsa di colorazioni multiple da scure a chiare (offuscamento da cottura) identificate in questo studio, hanno anche rivelato che la cottura è stata bassa e in condizioni di riduzione con un processo di cottura incontrollato. Inoltre, la mancanza di calcite (CaCO3) da decomposizione e l'esistenza di sostanze vegetali mineralizzate nei campioni di ceramica hanno ulteriormente confermatoo la cottura a basse temperature. La presenza di alcuni minerali come il quarzo fresco, la calcite primaria e la mancanza di vetrificazione nella maggior parte dei campioni di ceramica di Narosura PN hanno dimostrato che la temperatura di cottura non ha superato i 1000° C.

L'analisi macroscopica e microscopica hanno dimostrato che la maggior parte delle ceramiche sono state costruite da bobine in ciotole con pareti sottili e lastre in vasi con pareti spesse come pentole da cucina e da conservazione. L'uso continuo del metodo di avvolgimento nella maggior parte dei campioni di ceramica indicava la conservatività e che la tecnologia di fabbricazione era cambiata molto poco nel tempo. È anche un'impronta che suggerisce che le abilità del vasaio sono state ereditate e mantenute nel tempo. La natura delle inclusioni aplastiche come i materiali di rinvenimento e i vuoti indica anche la

standardizzazione artistica dei vasai e gli standard tecnologici nella lavorazione dell'argilla grezza per la produzione della ceramica.

Questo studio ha combinato sia le tradizionali tecniche di studio della ceramica archeologica che l'archeometria, la combinazione ha aperto nuovi orizzonti per la comprensione della tradizione ceramica di Narosura PN. Infine, questo studio raccomanda che gli studi futuri continuino a concentrarsi sull'analisi mineralogica e geochimica dei siti ceramici del Neolitico Pastorale in Tanzania e in Africa orientale in generale per stabilire un database di riferimento futuro.

Abbreviations

PN	Pastoral Neolithic
masl	Meter Above Sea Level
A.D	Anno Domini
BP	Before Present
KM	Kilometre
mya	Million Years Ago
SPN	Savanna Pastoral Neolithic
mm	Millilitre

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CHAPTER ONE: 1

1.1. Background Information

Pottery manufacturing is among the dominant vital crafts of Holocene prehistoric communities. It is one of the most ubiquitous surviving archaeological remain recovered from excavations. Pottery (sherds) remains has been utilized by archaeologists in reconstruction of the human settlements, patterns of lifestyle, manufacturing methods, technology, art, trade, and exchange among ancient and contemporary societies. Worth mentioning is its use in relative dating, pottery (sherds) samples can be used as a marker for dating archaeological sites and the associated materials (Shepard 1985). Due to this fact, pottery has served for a long as fundamental start line of communal identification and analysis of the archaeological analysis site.

Like in other parts of the world, in East African archaeology, pottery have remained to be a vital archaeological material for establishing relative chronology and understanding different cultural traditions. Based on pottery typology, archaeologists working in East African Neolithic have significantly for long time assigned (classified) the similarities and differences observed in Pastoral Neolithic (PN) pottery to different traditions (ware) such as Kansyore ware (dates fall between 8200 and 2400 BP), Nderit ware (dates from 7000 to 1500 BP), Narosura ware (dates from 2700 to 1400 BP), Maringishu ware (date to 1700 BP), Elmenteitan (remnant) ware (date from 3300 to 1300 BP), and Akira ware from 1900 to 1200 BP (Mturi, 1986; Mehlman, 1989; Karega-Munene 1996, 2002; Lane, 2011; Grillo et al. 2020).

Despite the massive contribution of the above Neolithic pottery taxonomies and chronology research in East African archaeology. For many years, the formal typological (i.e., form, shape, types, decoration motifs etc) approach has been the predominant method of studying and interpreting Neolithic pottery in East Africa and Tanzania in particular (see Posnansky 1967; Ordner, 1972; Sutton 1973; Wandiba, 1977, 1980; Bower et al. 1977; Bower and Nelson 1978; Collett and Robertshaw 1983; Robertshaw et al 1989; Amborse, 1984; Bower 1985; Barthelme 1985 Mturi, 1986; Mehlman, 1989; Chami, 2001a; Chami and Kwekason, 2003; Prendergast et al, 2013; Ashley and Grillo, 2015; Grillo et al. 2020). This has left a side the scientific approaches that employ technological advances to offer the results that have been impossible to obtain with traditional typological studies (Rice, 1987). Although the application of scientific (archaeometrical techniques) approaches in archaeology dates backs more than a half century ago (Shepard, 1942; Sayre and Dobson, 1957; Peacock, 1971). In East Africa, the experimental research into actual ancient pottery manufacturing techniques by scientific methods (petrography, mineralogy and chemistry) still attracts very little attention, because this part of scientific approaches requires some expertise in natural sciences of which is almost distant to most archaeologists with background in social sciences.

1.2. Statement of the Problem

In Tanzania pottery (sherds) is the most archaeological remain recovered in many sites' contexts. However, until recently much of the research on archaeological Neolithic pottery has only focused on the outward appearance (typological) of stylistic attributes, while neglecting pottery technology (Prendergast et al, 2013; Ashley and Grillo, 2015). Notwithstanding, in recent years, there has been a quest of applying scientific (archaeometrical) methodological approaches as an effort to characterise and understand technological networks of Neolithic pottery production, function and exchange in and across East Africa and Tanzania respectively (Lane, 2011; Prendergast et al, 2013; Ashley and Grillo, 2015). This research study, therefore, applies archaeometrical (petrography and geo-chemical analysis) scientific approaches to characterise Narosura Pastoral Neolithic pottery type and compare to the potential sources of raw clay materials in the immediate environment. To better understand the manufacturing techniques employed in the production of Narosura Pastoral Neolithic pottery in Luxmanda site within the Mbulu plateau of North-Central region Tanzania. The combination of techniques can allow to delve further into the technical dimension of pottery production that have not been addressed by the past typological studies. The morphological approach does not allow to distinguish local production from imported artefacts.

1.3. Research Objectives

1.3.1. General objectives of the Study

The overall major objective of this study was archaeometric (petrography and geo-chemical) characterisation of Narosura Pastoral Neolithic pottery and compare to potential sources of raw clay materials in their immediate environment. To develop a better understanding of the pottery provenance in Luxmanda site, Mbulu Plateau of the North-Central Tanzania.

1.3.2. Specific Objectives

The study had the following specific objectives:

a. to establish the possible raw clay sources used for pottery manufacturing.
b. to determine the pottery fabric paste inclusions;
c. to identify techniques used for manufacturing;
d. to analyse the pottery firing conditions; and
e. to assess if the pottery were locally made or imported to the site.

1.4. Research Questions

This study was guided by answering the following research questions:

a. Which kind of clay was used to manufacture the Narosura Neolithic pottery material (where does the clay(s) used come from)?
b. How were the Narosura Neolithic pottery tempered?
c. How were they shaped/made (the technique of building pottery)?
d. How were they fired?
e. Was the pottery locally made or imported to the site?

1.5. Significance of the Study

This study contributes to the growing number of research study on Pastoral Neolithic in East Africa with reference to Narosura Pastoral Neolithic (NPN) pottery wares. Archaeometric analytical techniques applied in this work offers new dimensions to the study of Neolithic pottery by focusing on fabric paste material characterisation. This research also marks the foremost time in which

NPN pottery in Tanzania analysed by archaeometric scientific approaches rather than the long-standing typological approaches. In line with that, the fabric pastes characterisation approach that is adopted in here, bears new insight into the Narosura pottery technology and geochemical characteristics. Thus, a better conception and understanding of Neolithic pottery traditions. Additionally, this research brands the relevance of information obtainable by a multi-analytical approach to deeply understand the complexity of the pottery objects and provide insights on production technology which has an indispensable role in pottery manufacturing. Moreover, the results from this study also form a new comparative database for future Neolithic pottery archaeometrical and geochemical studies in East Africa.

1.6. Theoretical Framework

There are several theories which are applied in ceramic studies. Earlier frameworks argue in cultural-historical approach that developed in the mid to late nineteenth century (post-Darwin and the Industrial Revolution). The theory is primarily based on the concept that different, yet distinct cultural groups may be recognised by their materials culture (Renfrew and Bahn 1996). According to proponents of this theory, any changes seen in historical societies' materials were either viewed as the result of either diffusion or migration while other human behaviours like independent development of ideas were overlooked. Subsequently, ceramics became the main tools used to trace and classify social interactions as well as cultural connections in this model (Ford, 1938; Griffin, 1952; Phillips, 1970). Elsewhere, Rouse (1939) proposes cultural-historic classification system that is evident and provides a detailed of artifact classification.

Matson (1965) introduced ceramic ecological theory that became dominant framework in ceramic studies of the 1980's although the theory had its roots from cultural ecology, neo-evolution and neo-functionalism theories (see Steward, 1965; Arnold, 1999; Rice 1984, 1996). The framework argued on the influence of the potter's environmental settings that determine/limiting his or her technological choices. Matson (1965) perceive that, the roles played by the climate, landscape, and geographical locations in the manufacturing of ceramics should be identification. For instance, many scholars suggest based on cultural ecology framework, that the technological choices made by potters could respond more to environmental issues (i.e., such as raw material availability and their quality) than to social factors (see Arnold, 1999; Matson, 1965; Rice, 1996). This model was later supported by proponents of behavioural archaeology who added that ceramic ecologists should also focus on ceramic production and use or performance base on ethnography and experimental settings (Schiffer and Skibo, 1997; Stark, 1999). Even though, the underlying approaches did not wholly develop to a sufficient cohesive framework that could stand for theoretical gaps for ceramic research (Schiffer and Skibo, 1997; McGuire, 1995; Stark 2003).

In the late 20th (twentieth) and 21st (twenty first) centuries, new theoretical approaches were introduced. This was in line with the new development in science and technology that made a more increasingly sophisticated in-depth theoretical analytical approaches possible. For example, the Binfordians' and Behavioural approach was heavily influenced by application of science in archaeology (Renfrew and Bahn 1996, 2008; David, 1992). The proponents of Binfordians' theory perceive and contend that archaeology is science and thus archaeological record must be studied scientifically in archaeological theory building (Binford, 1977, 1983, 2001; Longacre, 1991:1; Longacre and Skibo, 1994a). The idea later leads to the application of scientific analysis like chemical and mineralogical analysis that can now be performed on ceramic materials to reveal a wide range of information.

On the other hand, behavioural approach proponents also generally centre their ceramic research into ceramic taphonomy. Their main goal is on establishing relationships concerning the supra-cultural, mechanical, physical, and/or chemical properties of artifact production, use, and discard. This group also borrow methods from materials science and ceramic engineering and use a cultural materialist framework (Renfrew and Bahn 1996, 2008; Binford, 2001). Generally, the two approaches advocate and emphasise the use of rigorous methodology, controlled experimental approaches, and the use of ethno-archaeological settings as actual laboratories for refining and enhancing the interpretation of data produced through the use of analytical techniques (Binford, 1977, 1983, 2001; Renfrew and Bahn 1996, 2008). The current study, therefore, combined the cultural-historical approach, Binfordian and Behavioral model to have a holistic view of Narosura pastoral Neolithic pottery from Luxmanda in the Mbulu plateau of the North-Central Tanzania.

1.7. Organisation of the thesis

This thesis is presented in a paper-style from chapter 4 to chapter 10; the chapters have been written with the intention of future submission to publications, therefore some ideas and discussions are somehow recurrent. The chapters are as follows: Chapter 2 represents the physiographic setting of the study area. A review of literary works on Neolithic tradition of East Africa in general and Tanzania in particular, is presented in Chapter 3. Materials and methods are dealt with in Chapter 4. This is followed by Chapter 5 that characterise on the typology of Narosura pottery samples used in this study. A detailed petrographic thin section characterisation of the Narosura pottery is articulated in Chapter 6. The fabric pastes elemental composition of the Narosura pottery determined by Scanning Electron Microscope (SEM) is presented in Chapter 7. Chapter 8 represents X-RAY Diffraction Characterisation of the Narosura pottery and the raw clay samples. Chapter 9 highlights the characteristics of raw clay samples analysed by wet sieving method. Chapter 10 is on the raw clay procurement and contemporary pottery making perspectives. Chapter 11 ends with overall conclusions of the study and future prospective.

NOTE: Due to outbreak of Covid-19 pandemic some lab work were done late and others like X-RAY Fluorescence for elemental analysis were postponed.

CHAPTER TWO: 2

PHYSIOGRAPHIC SETTINGS OF THE STUDY AREA

2.0. Introduction

This chapter provides description of the physiographic settings of the study area. It covers several important aspects of Luxmanda, including its location, chronology, geology, geomorphology, climatic, environment, inhabitants, and social cultural and economic activities. The chapters also describe the general climatic condition and geoformation of the Mbulu plateau in the north central Tanzania. This area is characterized to Mobile pastoralism, that is the earliest form of food production, remained one of the most important ancient subsistence strategies in Africa (Goldstein, 2020) and the pottery used in the technological processes are poorly understood despite their high cultural role.

2.1. Study Area and Chronology

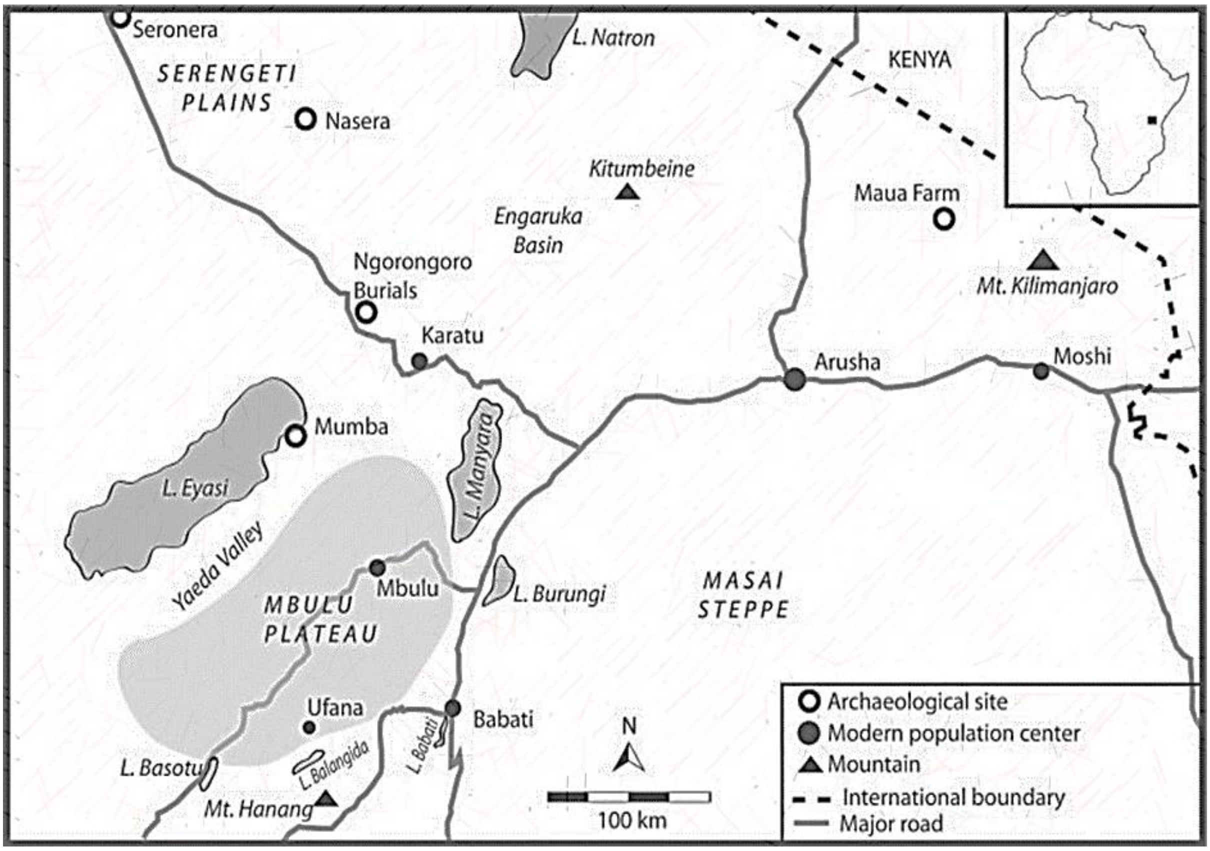
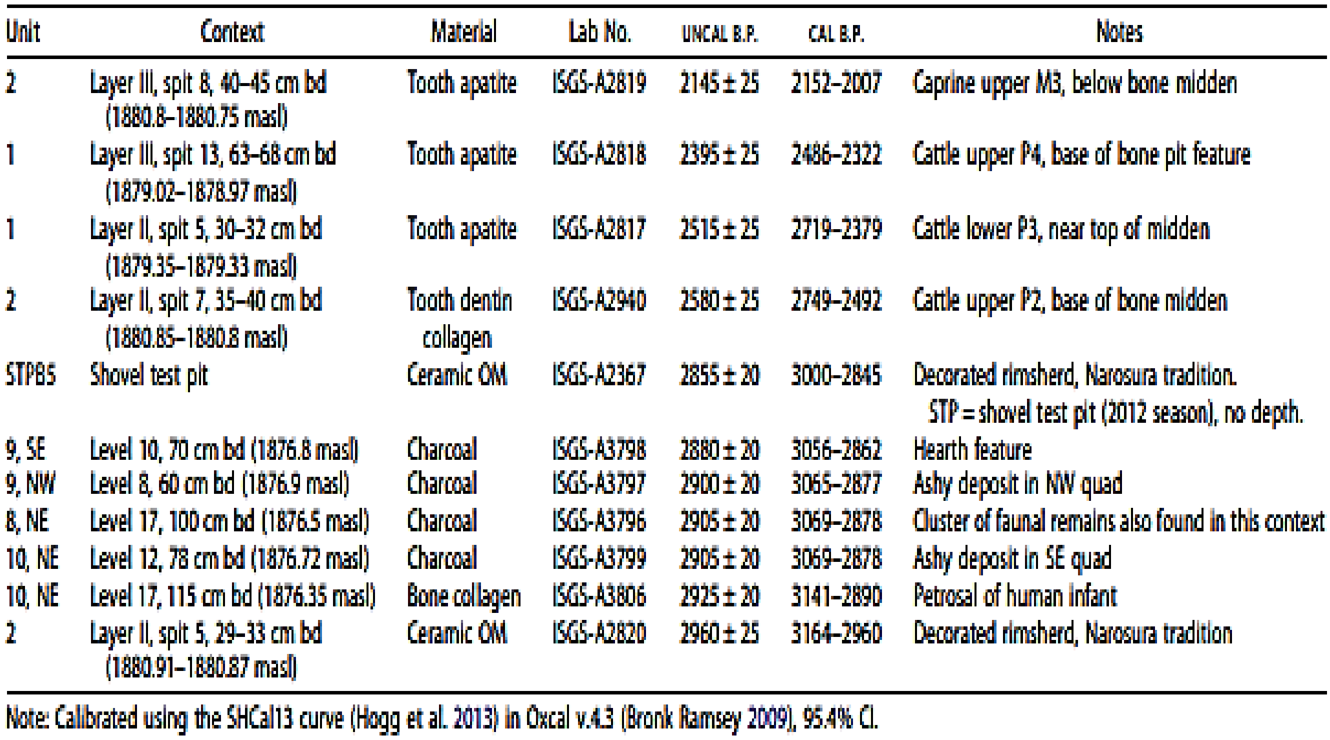


Figure 2.1: Map of the Crater Highlands (Northern Gregory Rift) in Tanzania, showing key landmarks and archaeological sites. After Prendergast et al. (2013).

Luxmanda site is located in the crater highlands region of Tanzania and is found in Luxmanda village (Ufana ward) on the southern edge of the Mbulu plateau in Babati District, Manyara Region (Figure 2.1). The site is one of the Savanna Pastoral Neolithic (SPN) sites in East Africa (see Table 2.2 for the site's spatial distribution). It was discovered in 2011, since then a few studies have been conducted that established the chronological sequence to ca. 3000-2900 CAL B.P (with the exception of four tooth sample dates: Table 2.1) that fall within the SPN sites of East Africa. The site is close to distinctive and prominent landforms, such as alkaline Lake Balangida and the extinct volcano Mount Hanang (1531 and 3420 metres above sea level, respectively) (Grillo et al., 2018; Table 2.1). The main hydrological surface drainage in Luxmanda is the perennial Ufana River, approximately two (2) km from the village, and several seasonal springs that provide the nearest fresh water (Grillo et al. 2018).

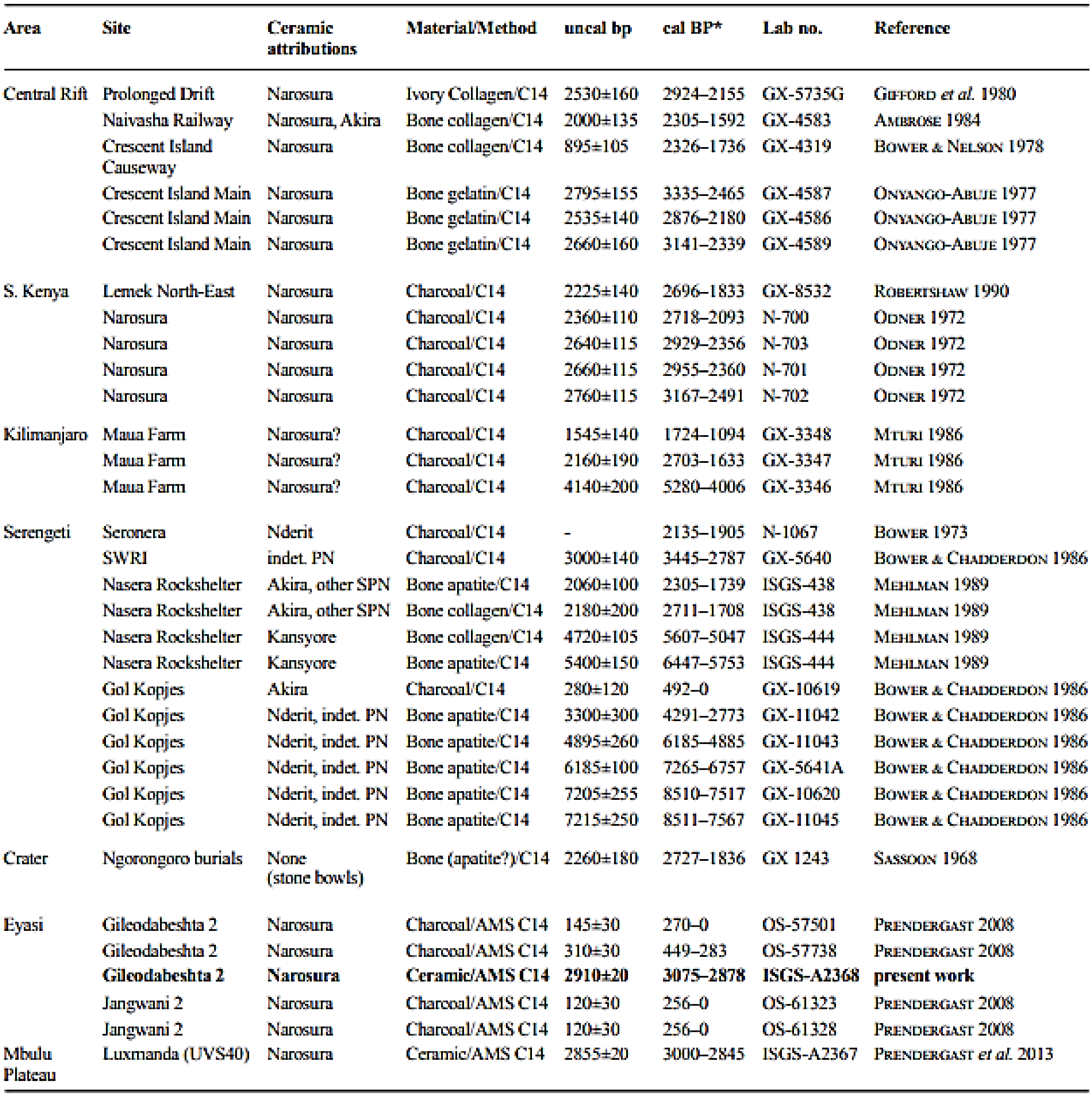
Table 2.1: Accelerator Mass Spectrometry (AMS) radiocarbon dates from Luxmanda adapted from Grillo et al. (2018:109).



Unit	Context	Material	Lab No.	UNCAL B.P.	CAL B.P.	Notes
2	Layer III, spit 8, 40–45 cm bd (1880.8–1880.75 masl)	Tooth apatite	ISGS-A2819	2145 ± 25	2152–2007	Caprine upper M3, below bone midden
1	Layer III, spit 13, 63–68 cm bd (1879.02–1878.97 masl)	Tooth apatite	ISGS-A2818	2395 ± 25	2486–2322	Cattle upper P4, base of bone pit feature
1	Layer II, spit 5, 30–32 cm bd (1879.35–1879.33 masl)	Tooth apatite	ISGS-A2817	2515 ± 25	2719–2379	Cattle lower P3, near top of midden
2	Layer II, spit 7, 35–40 cm bd (1880.85–1880.8 masl)	Tooth dentin collagen	ISGS-A2940	2580 ± 25	2749–2492	Cattle upper P2, base of bone midden
STPB5	Shovel test pit	Ceramic OM	ISGS-A2367	2855 ± 20	3000–2845	Decorated rimsherd, Narosura tradition. STP = shovel test pit (2012 season), no depth.
9, SE	Level 10, 70 cm bd (1876.8 masl)	Charcoal	ISGS-A3798	2880 ± 20	3056–2862	Hearth feature
9, NW	Level 8, 60 cm bd (1876.9 masl)	Charcoal	ISGS-A3797	2900 ± 20	3065–2877	Ashy deposit in NW quad
8, NE	Level 17, 100 cm bd (1876.5 masl)	Charcoal	ISGS-A3796	2905 ± 20	3069–2878	Cluster of faunal remains also found in this context
10, NE	Level 12, 78 cm bd (1876.72 masl)	Charcoal	ISGS-A3799	2905 ± 20	3069–2878	Ashy deposit in SE quad
10, NE	Level 17, 115 cm bd (1876.35 masl)	Bone collagen	ISGS-A3806	2925 ± 20	3141–2890	Petrosal of human infant
2	Layer II, spit 5, 29–33 cm bd (1880.91–1880.87 masl)	Ceramic OM	ISGS-A2820	2960 ± 25	3164–2960	Decorated rimsherd, Narosura tradition

Note: Calibrated using the SHCal13 curve (Hogg et al. 2013) in Oxcal v.4.3 (Bronk Ramsey 2009), 95.4% CI.

Table 2.2: Spatial-chronological distribution of Neolithic and Narosura pastoral Neolithic pottery ware sites across East Africa: 'Radiometric dates from selected Stone Age ceramic sites in Kenya and Tanzania (*Radiocarbon dates, except for Seronera, calibrated using the ShCal13 curve in OxCal version 4.2, 2-sigma range). After Prendergast (2014).



Area	Site	Ceramic attributions	Material/Method	uncal bp	cal BP*	Lab no.	Reference
Central Rift	Prolonged Drift	Narosura	Ivory Collagen/C14	2530±160	2924–2155	GX-5735G	Gifford *et al.* 1980
	Naivasha Railway	Narosura, Akira	Bone collagen/C14	2000±135	2305–1592	GX-4583	Ambrose 1984
	Crescent Island Causeway	Narosura	Bone collagen/C14	895±105	2326–1736	GX-4319	Bower & Nelson 1978
	Crescent Island Main	Narosura	Bone gelatin/C14	2795±155	3335–2465	GX-4587	Onyango-Abuje 1977
	Crescent Island Main	Narosura	Bone gelatin/C14	2535±140	2876–2180	GX-4586	Onyango-Abuje 1977
	Crescent Island Main	Narosura	Bone gelatin/C14	2660±160	3141–2339	GX-4589	Onyango-Abuje 1977
S. Kenya	Lemek North-East	Narosura	Charcoal/C14	2225±140	2696–1833	GX-8532	Robertshaw 1990
	Narosura	Narosura	Charcoal/C14	2360±110	2718–2093	N-700	Odner 1972
	Narosura	Narosura	Charcoal/C14	2640±115	2929–2356	N-703	Odner 1972
	Narosura	Narosura	Charcoal/C14	2660±115	2955–2360	N-701	Odner 1972
	Narosura	Narosura	Charcoal/C14	2760±115	3167–2491	N-702	Odner 1972
Kilimanjaro	Maua Farm	Narosura?	Charcoal/C14	1545±140	1724–1094	GX-3348	Mturi 1986
	Maua Farm	Narosura?	Charcoal/C14	2160±190	2703–1633	GX-3347	Mturi 1986
	Maua Farm	Narosura?	Charcoal/C14	4140±200	5280–4006	GX-3346	Mturi 1986
Serengeti	Seronera	Nderit	Charcoal/C14	-	2135–1905	N-1067	Bower 1973
	SWRI	indet. PN	Charcoal/C14	3000±140	3445–2787	GX-5640	Bower & Chadderdon 1986
	Nasera Rockshelter	Akira, other SPN	Bone apatite/C14	2060±100	2305–1739	ISGS-438	Mehlman 1989
	Nasera Rockshelter	Akira, other SPN	Bone collagen/C14	2180±200	2711–1708	ISGS-438	Mehlman 1989
	Nasera Rockshelter	Kansyore	Bone collagen/C14	4720±105	5607–5047	ISGS-444	Mehlman 1989
	Nasera Rockshelter	Kansyore	Bone apatite/C14	5400±150	6447–5753	ISGS-444	Mehlman 1989
	Gol Kopjes	Akira	Charcoal/C14	280±120	492–0	GX-10619	Bower & Chadderdon 1986
	Gol Kopjes	Nderit, indet. PN	Bone apatite/C14	3300±300	4291–2773	GX-11042	Bower & Chadderdon 1986
	Gol Kopjes	Nderit, indet. PN	Bone apatite/C14	4895±260	6185–4885	GX-11043	Bower & Chadderdon 1986
	Gol Kopjes	Nderit, indet. PN	Bone apatite/C14	6185±100	7265–6757	GX-5641A	Bower & Chadderdon 1986
	Gol Kopjes	Nderit, indet. PN	Bone apatite/C14	7205±255	8510–7517	GX-10620	Bower & Chadderdon 1986
	Gol Kopjes	Nderit, indet. PN	Bone apatite/C14	7215±250	8511–7567	GX-11045	Bower & Chadderdon 1986
Crater	Ngorongoro burials	None (stone bowls)	Bone (apatite?)/C14	2260±180	2727–1836	GX 1243	Sassoon 1968
Eyasi	Gileodabeshta 2	Narosura	Charcoal/AMS C14	145±30	270–0	OS-57501	Prendergast 2008
	Gileodabeshta 2	Narosura	Charcoal/AMS C14	310±30	449–283	OS-57738	Prendergast 2008
	Gileodabeshta 2	**Narosura**	**Ceramic/AMS C14**	**2910±20**	**3075–2878**	**ISGS-A2368**	**present work**
	Jangwani 2	Narosura	Charcoal/AMS C14	120±30	256–0	OS-61323	Prendergast 2008
	Jangwani 2	Narosura	Charcoal/AMS C14	120±30	256–0	OS-61328	Prendergast 2008
Mbulu Plateau	Luxmanda (UVS40)	Narosura	Ceramic/AMS C14	2855±20	3000–2845	ISGS-A2367	Prendergast *et al.* 2013

2.2. Geology and Geomorphology

Luxmanda’s geology is described and generally characterised based on the Mbulu Plateau Neocene Age rift faulting and volcanic activity that took place 3-4 million years ago (Selby and Thomas, 1963). Le Gall et al. (2008) have distinguished rift system from N to S into three structural domains (Figure 2.2) as follows:

1) The Magadi–Natron rift system is a NS-oriented depression, 50–80 km-wide, occupied by Late Miocene–Present volcanic directly overlying metamorphic basement rocks of the Proterozoic Belt (Baker et al., 1971, Fairhead et al., 1972). Its overall structure evolves southwards from an asymmetrical graben basin to a E-facing half-graben bounding to the W by a double system of normal faults (Ol Donyo Ogol and Natron master faults).

2) The 200 × 50 km transverse volcanic belt extending at N80°E from the Ngorongoro crater to the Kilimanjaro includes numerous (< 20) volcanic edifices, and their extensively distributed effusive and air-fall material, that were emplaced during the time interval 8 Ma–Present.

3) The Eyasi, Manyara and Pangani fault systems form the main diverging rift structures of the 300 km-wide NTD sensu stricto which is underlain by Precambrian basement rocks of the Mozambique Belt (E) and the Archaean Tanzanian craton (W). Major fault-bounded half-graben basins, ~ 3 km-deep, are only documented along the Eyasi and Manyara structures (Foster et al., 1997). Most of fault structures are difficult to be directly dated by radiometric methods because of the lack of volcanic association.

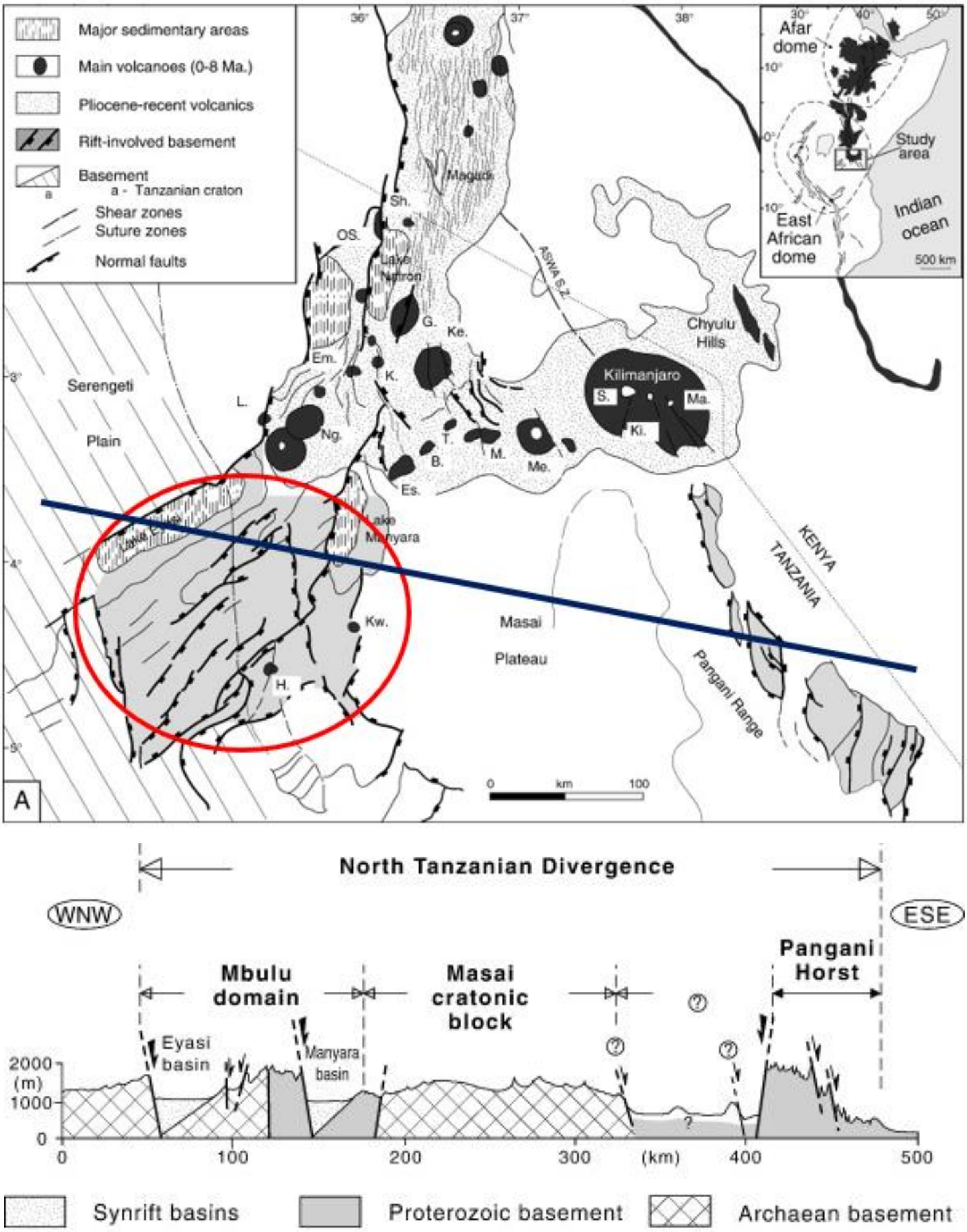


Figure 2.2: The area of interest is delimited in red in the geological-structural schematic map of Le Gall et al. (2008).

The Neocene age faulting activity caused large blocks of granite basement rock to be raised up to form plateaus, valleys and escarpments, to mention a few, in the area. The Mbulu plateau is separated from the eastern branch of the East African Rift valley system by the Balangida escarpment (Foster et al., 1997). The formation of the rift valley and the adjacent uplands in the area was also due to faulting and earth movements (Figure 2.2 and 2.3), which were accompanied by volcanic activity that resulted in the eruption and growth of several mountains on the Mbulu plateau, for example Mountain Hanang (Selby and Thomas, 1963; Foster et al., 1997). The volcanic dust from these mountains was carried down the mountainside to some several localities and accumulated to form calcareous crystalline tuff and extensive deposits of soil. However, the topography of the area varies from the high mountains in the north, through the low mountains and foothills in the central parts to plains in the east and west of the site (Selby and Thomas, 1963; Loth, 1986; Foster et. al.,1997; Loth, 1999).

Lake Eyasi is south of Ngorongoro Highlands, lies within a region of internal drainage. The Basin is primarily a semi-arid region with sparse vegetation and characterised by low rainfall and high daily temperatures. The lake is very shallow so it dries up during the dry season, leaving a thin crust of salts. It occupies an area of 1350 km2 during a “good” rainy season, covering all the “salt-flats” with the mean surface area of 1050 km2. Almost all the streams and rivers, except those associated with springs, are ephemeral. Springs contribute a significant amount of water into the lake. The quality of the spring water varies from saline water to fresh water (Mabulla, 1996).

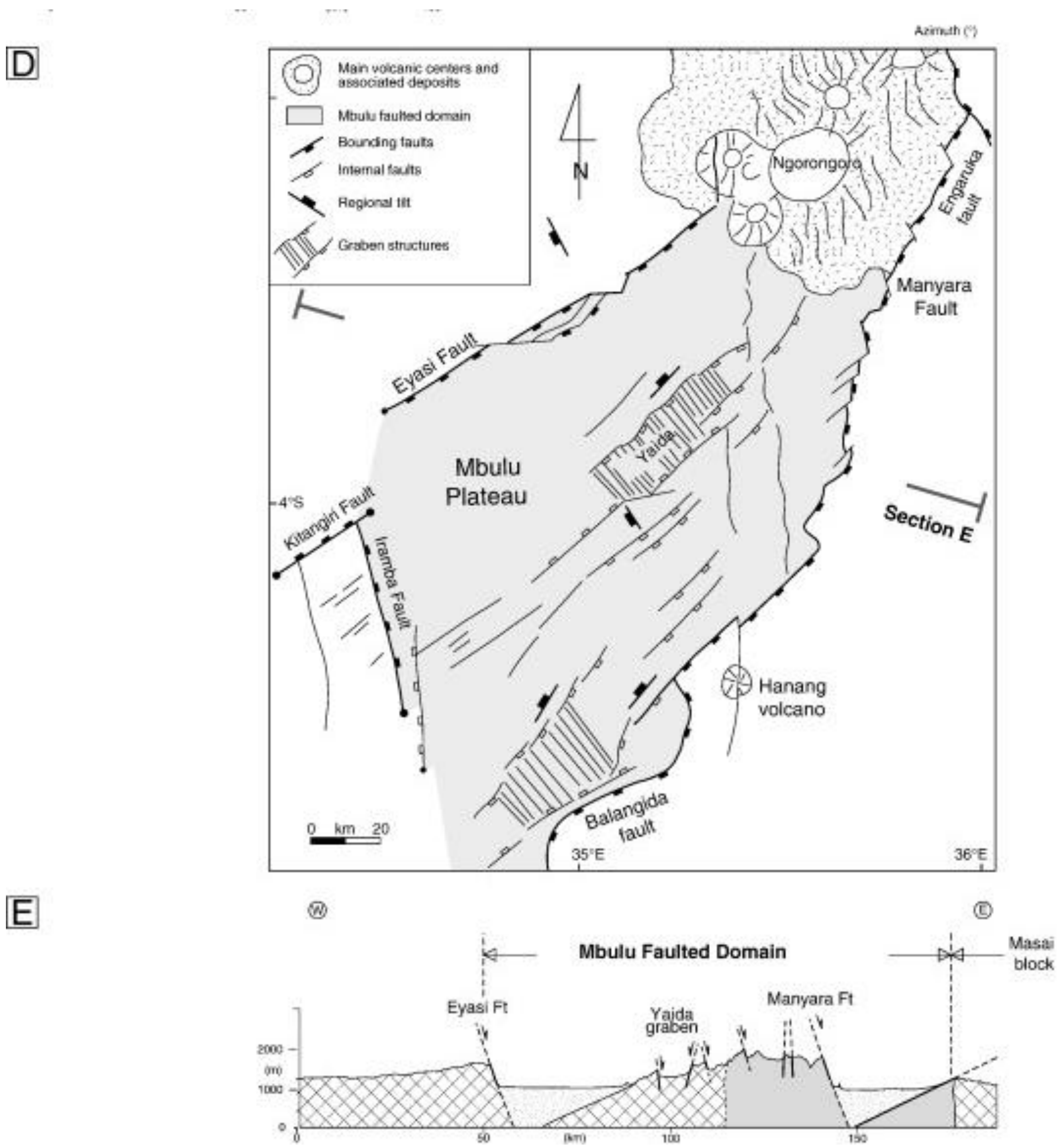


Figure 2.3: Geometrical features of rift fault patterns in the Magadi–Natron and Mbulu extended zones (Le Gall et al., 2008).

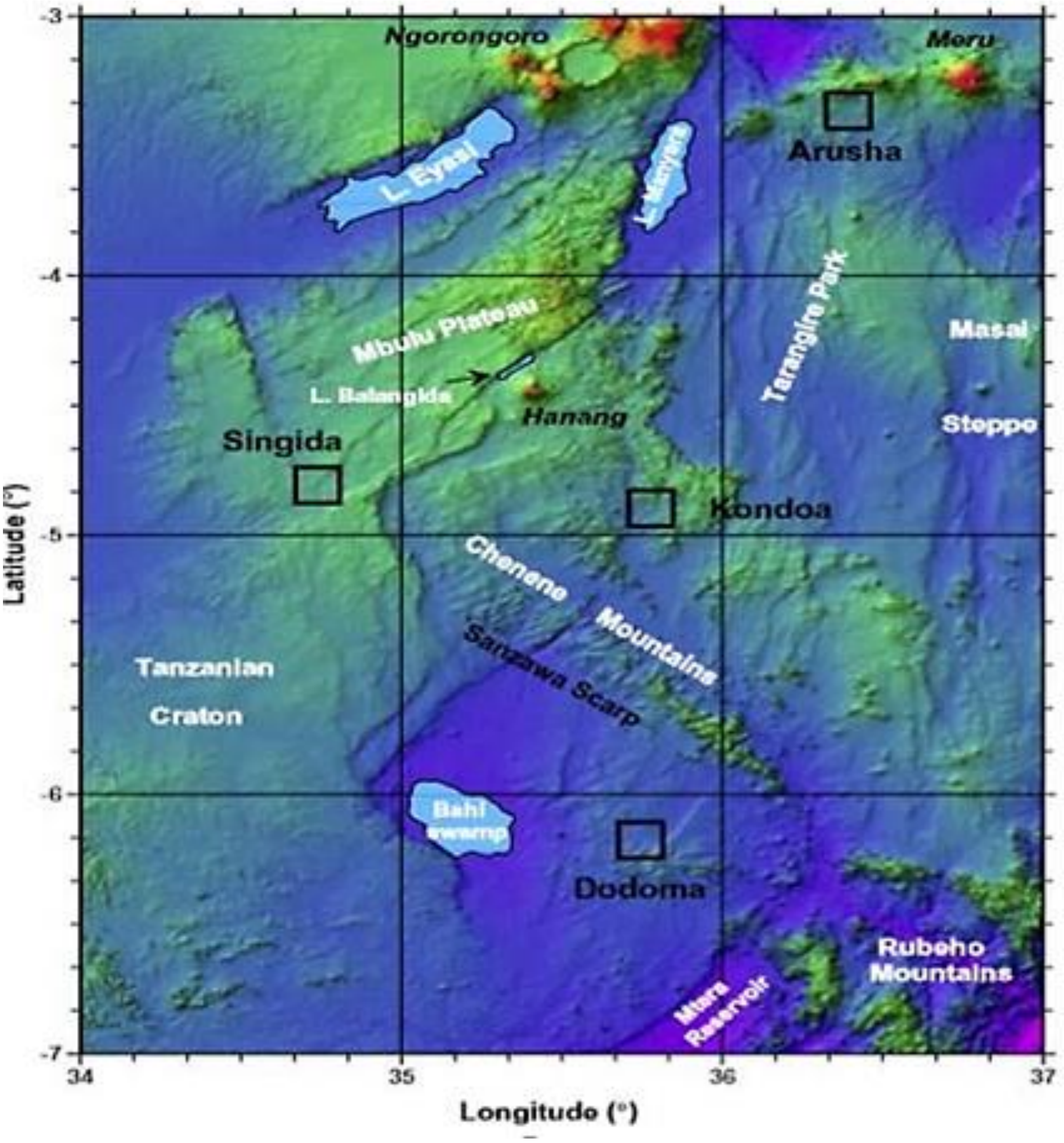


Figure 2.2: Digital elevation map showing the location of Mbulu plateau in latitude/longitude (°). Data are from the 90-m resolution SRTM 2004.

2.3. Climate

The climate of the Luxmanda site on Mbulu plateau varies from mild, and generally warm to temperate. A lot of rain falls in the summer season, but very little in the winter. The maximum temperature in March, the hottest month, is on average 19.0 °C, and the minimum temperature on average is 14.4 °C in July, the coldest month of the year. This type of climate is described and characterised by the Köppen-Geiger climate classification system as a tropical wet and dry, or savanna, climate (‘Aw’/Cwb) (Hudak, 1999; Bachofer et al., 2014), with an annual temperature averaging 17.5 °C and annual rainfall averaging 994 mm in Mbulu (Mabulla, 1996; Figure 2.3) and in the area of the Lake Eyasi the annual average rainfall is about 450 mm ranging from 300 to 600 mm. The mean monthly temperature ranges from 25 to 30 °C (Yanda et al., 2005).. Therefore, Luxmanda has a moist climate, which is ideal for farming and grazing (Grillo et al., 2018).

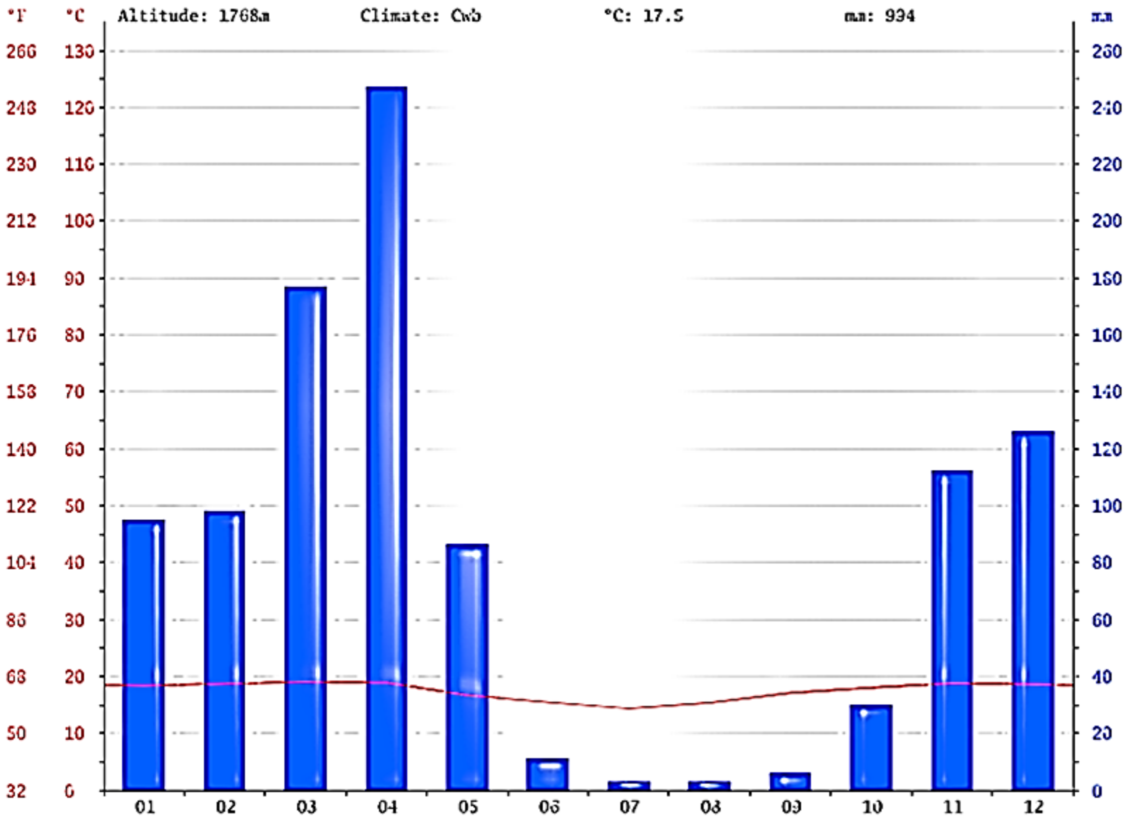


Figure 2.3: Climate Graph showing that precipitation is lowest in July, with an average of 3 mm. Most of the precipitation here falls in April, averaging 247 mm, Adapted from: https://en.climate-data.org/africa/tanzania/manyara/mbulu-765648/#climate-table.

2.4. Vegetation Cover

The Luxmanda landscape, part of the Mbulu savanna plateau in north-central Tanzania, is generally covered by thorny shrubs, grassland, bushes, trees and forests. The most common tree species on the east African savanna are those of the *Acacia* genus and *Baobab* genus (Hudak, 1999). Currently, the site lies on a series of farm plots that have been partly destroyed by traditional agricultural activities (Grillo et al., 2018; Figure 2.4). According to the interviews, many changes in land cover (vegetation) in Luxmanda began in the 1970s due to adoption of the Tanzanian government policy of ujamaa, which resulted in the destruction of the ancient vegetation that provided numerous wildlife with a habitat (Butz, 2009). The vegetation also provided the inhabitants with forage for their livestock, agricultural land, firewood, building materials and medicinal plants (Ibrahim, 1997). The topography of this area varies from mountainous (2,000 metres) to the lower-lying savanna (1,000 metres) (encyclopedia.com).

Figure 2.4: Part of Luxmanda village Topography.

2.5. Main Economic Activities

The Mbulu plateau, and Luxmanda in particular, is the home of the Iraqw'ar Da/aw people, who mainly practise agro-pastoralism (Lawi, 1999; Grillo et al., 2018). Their main livelihood activities are large-scale/subsistence farming and intensive subsistence pastoralism. Agricultural activities include both crop production and livestock keeping. It is estimated that 95% of the inhabitants grow both cash and food crops, although other small-scale entrepreneurship and employment were observed (URT, 2012; Babati District Profile, 2012). Due to the cool moist climate, Luxmanda is ideal for livestock keeping and agriculture (Grillo et al., 2018).

2.5.1. Agriculture

The most arable Luxmanda village land is predominantly owned and used for small-scale subsistence farming. It is estimated that 3-4 acres per household are used for growing food crops near the settlements. Large-scale farming also takes place for the cultivation of cash crops, which along with food crops, comprise maize, paddy, seed beans, millet, sorghum, cassava, banana, leguminous crops, sweet and Irish potatoes, various fruits, vegetables, *simsim*, coffee, sugarcane, cotton, groundnuts, sunflower and wheat (URT, 2012; Babati District Profile, 2012). Generally, village land is regularly used for farming, although grazing, forestry, water catchment conservation also prevails.

2.5.2. Livestock Keeping

In Luxmanda, livestock are kept primarily for milk, beef, traction (mainly oxen), manure and as a source of income. The main domestic livestock are cattle, goats, sheep, donkeys, chickens and pigs. According to Grillo et al. (2018:104), the 2012 census (observed in the Ufana Council ward office) showed that goats (Capra hircus) dominated the livestock (61%), followed by cattle (B. taurus or taurus/indicus crossbreeds) (17%), sheep (Ovis aries) (17%), and donkeys (Equus asinus) (5%). Maize and beans are the dominant crops in the region, with supplementary cultivation of African cereals like sorghum and millet (URT, 2012).

2.7. Chapter Conclusion

The chapter presented an overview of the physiographic setting of the study area and the socio-economic activities at Luxmanda. In the physiographic set-up, the study area, chronology, geology, geomorphology, vegetation cover (fauna and flora), and climate have been presented. The site area (village) is also drained by a significant perennial river Ufana (supplying water to a wide area) and several other seasonal tributaries that form the hydrological zones, making it a favourable habitat for the people. The socio-economic activities presented includes agriculture (both small and large scale) and livestock keeping for subsistence purposes.

CHAPTER THREE: 3

LITERATURE REVIEW

3.0. Introduction

This chapter reviews the literature on the Neolithic period of East Africa, as well as archaeological research conducted on the Neolithic pottery tradition (ware) of East Africa, and Tanzania in particular. The review starts by highlighting the different typo-taxonomies assigned to Neolithic pottery and the major concern of the author concerning the classification and naming of the Neolithic tradition/ware. The chapter also reviews what has been written about the development of Narosura Pastoral Neolithic (PN) pottery that forms the key area of research of this study.

3.1. The General View of the Neolithic period in East Africa

Neolithic is a general term that refers to the earliest complex culture that appeared sites in southern Kenya and northern Tanzanian in East Africa dated around 3500 BC. It represents the earliest evidence of pre-Iron Age food-producing (herding) societies there (Owen et al. 1982, Marshall et al. 1984). Although it is not known whether they also cultivated plants, the earliest sites on the plains of northern Kenya have produced artefacts (stone bowls and pottery) associated with the Neolithic culture. Domesticated sheep and goats are also represented in the sites (Ovis and Capri) in Ileret on the north-eastern shore of Lake Turkana (Owen et al. 1982; Marshall et al., 1984; Barthelme, 1985). Similar pottery associated with this complex culture has also been reported on the western shore of Lake Turkana. Fish were also an important source of food for the early Ileret herders (Owen et al., 1982; Marshall et al. 1984; Barthelme, 1985). Some scholars suggest that the climatic conditions in East Africa in the past forced people to adopt a nomadic and pastoral way of life, while farming took place in the highlands of southern Kenya and northern Tanzania before the beginning of the iron-working age in East Africa (Phillipson, 1984; Gifford-Gonzalez 1998). Bower and Nelson (1978) hint that domestic animals in this region were probably herded and might have appeared much earlier in the archaeological record before the beginning of the iron-working period, but this has now been discounted (Owen et al. 1982; Robertshaw and Collet, 1983; Bower, 1991; Marshall, 2000). Generally, what has been referred to collectively as the Neolithic age in East Africa (Kenya and Tanzania) has been named the Pastoral Neolithic (PN) tradition in acknowledgment of the fact that the people were herders, although whether they were typical pastoralists is debated. This interpretation eventually led to the establishment of a division in the PN pottery into different types of ware, such as Elementeitan, Kansyore, Nderit, Narosura, Oldishi, Olmange and Oltome.

3.2. Foundation of East Africa Neolithic period

The term Neolithic was first used in the archaeological context by John Walter Gregory, who was a geologist working in the Rift Valley system in East Africa (Wandiba, 1977; Mturi, 1986). During this time, Gregory used the term only to explain the obsidian artefacts found on the Athi plains of the Kikuyu Escarpment near Lake Baringo in present day Kenya. Later on, the term was also adopted to describe isolated findings of polished stone axe-heads, stone bowls, and bored or stone rings that had been made in various parts of the country (Hobley, 1913; Dobbs, 1914; 1918; Wandiba, 1977). Lubbock (1872) pointed out that, in European and Near Eastern archaeology, the same term was also used to refer to cultures connected with polished stone artefacts. The term continued to be used in East Africa until the early 20th century when it was then used to identify both cultures with domestic animals and plants (Burkitt, 1925; Childe, 1953). However, developments in Neolithic research in East Africa between the 1950s and 1970s witnessed a change in the title from Neolithic to Pastoral Neolithic to encompass herding as a subsistence strategy as well as plants, wild animals and fish (Karage-Munene, 2003). Since then, the two terms (Neolithic and Pastoral Neolithic) have been used interchangeably, although Neolithic infers a more diversified subsistence economy based on rearing domestic animals and cultivating crops.

3.3. The Pioneers of Systematic Neolithic Research in East Africa

Systematic archaeological work in East Africa began in 1931 with Louis Leakey's expedition to East Africa. His first systematic work covered the Lake Nakuru-Naivasha basin in the Kenyan Rift Valley (L. Leakey, 1931). Although the purpose of his expedition was not to focus on the Neolithic period, the recovery of artefacts associated with it, such as polished stones, human remains and pottery, suggested the existence of a Neolithic culture in the region. Based on these finds, Leaky later managed to classify and name the three cultural traditions as Njoroan (after a farm near Njoro in Kenya), Gumba A and Gumba B (after mythical people called Gumba by the Kikuyu in the central part of Kenya) (L. Leakey, 1931; Muriuki, 1974; Kusimba and Kusimba 2003). According to Leakey (1931), the three identified cultures discovered in the area were simply considered descendants of the Mesolithic cultures of Kenya Wilton and Elementeitan. As a result, the term Njoroan culture was removed from the regional terminology, due to the failure to discover more sites with the same culture.

Nonetheless, subsequent research carried out on the Ugandan and Kenyan sides of the Lake Victoria region suggested two other Neolithic cultures, namely the Tumbian and Kenya Wilton C Neolithic cultures, with the Tumbian culture divided into the Proto, Lower, Middle and Upper cultural phases (L. Leakey 1931). The upper phase was later renamed Lupemban and the other three phases were called the Sangoan Culture (L. Leakey, 1931; Leaky and Cole, 1959). However, putting the taxonomical system into phases later led to major difficulties in clearly separating the phases, as well as the one refined and proclaimed the Sangoan-Lupemban culture of the middle Stone Age (Nelson and Posnasky, 1970; Ambrose, 1984; McBreaty, 1986). In contrast, Nelson and Posnasky (1970) contended that the term Wilton culture is not directly related to East Africa, and so it should not be used to describe the Neolithic culture of East Africa (Ambrose 1984).

Likewise, research in the Uganda region also created three Neolithic cultures, such as Kagerean (on a site on the banks of the river Kagera), Wilton Neolithic A and Wilton Neolithic B (in the Nsogezi rock shelter and Chui cave on the

Uganda-Kenya border). The first of these phases was mainly characterized based on artefacts such as choppers, scrapers and flakes. The second phase was identified by the presence of pottery, scrapers, back blades and crescents, while the last phase was classified according to the discovery of scrapers, burins and crescents (Wayland, 1934; O'Brien,1939). Based on subsequent research studies, the continued existence of the Kagerean and Wilton culture was not supported, due to the lack of artefacts as evidence (Nelson and Posnansky, 1970).

Because of the problems associated with the above taxonomical characterisations, the use of *fossiles directeurs* was unavoidable, and they remained the only data providing a direct link to studies on Neolithic cultures in East Africa, although in Europe and the Near East direct evidence of food production using domestic animals and plants was constantly used to identify Neolithic cultures (Childe, 1953; Mallear, 1965; Renfrew 1972; Phillipson, 1980; Thomas, 1988; 1991).

3.4. Reasons for Denying the Existence of East African Neolithic Culture

Although East Africa has been claimed to be the cradle of humanity based on the astonishing discoveries made by Leakey and other researchers in the Olduvai Gorge and other sites in East Africa (Cole, 1963), the existence of a Neolithic culture in East Africa revealed by research conducted in the region in the mid-20th century was not accepted by all scholars and, surprisingly, some of them even questioned and totally rejected its existence (Posnasky, 1967; Bower, 1991; Karega-Munene, 1996; 2002). For example, Posnasky (1967a:644) pointed out that the use of the term Neolithic culture was inappropriate for East Africa due to the lack of evidence of the widespread use of stone implements by settled agricultural societies. Surprisingly, they even went as far as to justify this claim without looking at the indisputable evidence of food production discovered at that time from Hyrax hill in Kenya (M. Leakey 1945, Leaky and Leaky, 1950). Although use of the term Neolithic was rejected, some researchers later indignantly maintained that there were a few indications of stock keeping before the Iron Age (Cole, 1963:49). On the other hand, some researchers argued that the Neolithic culture could be subsumed in the Later Stone Age of East Africa (Cole, 1963; Sutton, 1966). The failure to value the East African Neolithic culture was also prevented by the researchers' failure to recognize the usefulness of pottery and other biological remains as evidence of the Neolithic culture. These denial views were also favoured to the degradation of the organic material useful to geochronological measurements, for example the acidic soils nature favourable to degradation of bones, wood and other vegetable remains. As a result, such remains were simply discarded in the field (Soper and Golden, 1969), or treated casually and dropped quickly in a bag and either forgotten about or briefly described (Posnasky, 1962:273).

3.5. The Renaming of East African Neolithic Culture to Pastoral Neolithic (PN)

Rigorous advances made in faunal analysis, initiated by studies in the 1970s and 1980s on Neolithic herding, confirmed the existence of pre-Iron Age food producers in East Africa (Cole, 1963; Kusimba and Kusimba, 2003; Grillo et al. 2018). The Neolithic period in East Africa was then renamed 'Pastoral Neolithic' (PN) to refer to "Pastoral Neolithic cultures that used Later Stone Age technologies, but they relied economically on domestic cattle and sheep/goats" (Bower et al. 1977:119; Grillo et al. 2018). Kusimba and Kusimba (2003) suggested that the predominance of cattle and sheep/goats in animal assemblages revealed the existence of a specialized pastoralist economy in the area (i.e., like that of today's Maasai and other pastoralists in East Africa) and the lack of domestic plant remains in the assemblages influenced the name of PN. Sites in the south-western and central rift valley in Kenya have produced *fossiles directeurs*, pottery and faunal remains that were used as evidence for the existence of the PN culture (Odner, 1972; Bower et al., 1977; Onyango-Abuje, 1977a; 1980; Kusimba and Kusimba, 2003). Despite the important contribution of these sites, none of them produced evidence of either domestic or wild plants (Kusimba and Kusimba, 2003).

3.6. Temporal and Regional Extent of Pastoral Neolithic Culture in East Africa

The temporal and regional extent of the PN culture in East Africa is quite complex, as chronometric dates do not show a definite north/south trend for the appearance of domestic animals in East Africa (Grillo et al. 2018; Prendergast et al. 2019). This still needs to be scientifically demonstrated to discover the chronometric movement of these specialized pastoralists. To look at the temporal difference between each site a general review of regional findings is used and the data broken down into areas where the PN culture has been discovered.

The current archaeological evidence suggests that the PN era was probably between ~5000–1200 BP (Grillo et al., 2018; Prendergast et al., 2019). Ancient DNA studies on an area near Lake Turkana in Kenya have provided the earliest known evidence of animal domestication in sub-Saharan Africa (Prendergast et al., 2019). Although previous evidence places the appearance of domestic animals in East Africa from around 5000-4000 BP in Kenya, the sites of Ileret, Dongodien and Gaji 2 in northern Kenya on the eastern part of Lake Turkana have yielded evidence of domestic animals (i.e., cattle and sheep/goats) dated to 4500-3400 BP (Barthelme, 1985; Philipson 1973; Marshall 1986, 1994). In central Kenyan sites, the evidence suggests the appearance of domestic animals between 3000 and 2000 BP along the central Rift Valley area (Bower et al. 1977; Onyango-Abuje, 1977b; Ambrose, 1985; Gifford, 1985), while the Enkapune ya Muto site west of Lake Naivasha in Kenya places sheep/goat domestication to 4000 BP, the oldest date known in Kenya (Marean, 1992a). The areas around the Lake Victoria basin to the west of the Rift Valley at Gogo also date the appearance of cattle and sheep/goats to 3400-2000 BP (Marshall, 1986; Karega-Munene, 1993; 1996; 2002). To the east of the central Rift Valley, domestic faunal have been dated to about 3300 BP at Lukenya Hill in Kenya (Nelson and Kimengich, 1984).

In Tanzania, the evidence is limited to Maua sites on the slopes of Kilimanjaro and Serengeti Plain in northern Tanzania, where domestic faunal have been dated to between 4200 BP and 1500 BP (Mturi, 1986; 1998; Prendergast, et al., 2013), as well as Eyasi Basin, Ngorongoro Crater Burial Mounds in northern Tanzania and of recent is Luxmanda site in north central Tanzania (Langley, et al. 2019; Prendergast, et al., 2013; Grillo, et al., 2018). The recent discovery of Luxmanda site in northern Tanzania has also produced evidence of animal domestication, dating to between 3,200 and 2,900 years ago (cal. 3000 BP). The presence of this PN open-air site suggests that the regional extent of Neolithic PN sites has not been well established, and there are probably many more sites throughout a large part of East Africa waiting to be discovered (Prendergast et al., 2013; Grillo, et al., 2018). Therefore, the temporal and regional extent of these specialized Neolithic pastoralists required a scientific demonstration in order to understand the chronometric evidence outlined above. As the outlined chronometric dates do not show a definite north south trend for the appearance of domestic animals in East Africa.

3.7. East African Neolithic Cultures Based on Evidence from Pottery Studies

The work of archaeologists in the 1960s was the first attempt to synthesize East African Neolithic cultures using pottery as evidence of the PN culture. It replaced the previously known artefacts, *fossiles directeurs*, which were used to gain an understanding of the PN culture. Classification of the PN culture based on pottery resulted in placing it in three categories, designated Classes A, B and C (Sutton 1973), which were further divided and referred to as Ware. For instance, Class A, which is considered to be the oldest culture and was probably created by hunter gathers, was associated with Elementeitan pottery. The second class, Class B, included Gumban and Hyrax Ware pottery, while Class C pottery consisted of floral decorations on Lanet and some Guban B pottery. The author also considered Class C to be the youngest because of its apparent association with sedentary communities with iron-working knowledge (Sutton, 1973). Although most of the pottery used in creating these classes included Neolithic, Iron Age Lanet Ware (Posnansky 1967), the results of the above classification rendered many differences in the classes, thus making it more difficult to compare them. Apart from that, the chronological scheme used to classify the pottery (i.e*.,* class A being the oldest, followed by class B, and class C) lacked chronological evidence to support the proposal. Although the proposed approach had some inherent problems, no attempts were made to correlate the classes with other dates known, such as those from Njoro River Cave in Kenya (Wandiba, 1977).

The second attempt to reclassify Neolithic pottery was made in the 1970s in the southern part of the Rift Valley sites in East Africa, which mainly focused on examining pottery attributes, such as firing condition, decorative techniques and motifs, vessel shapes and other features like lugs, handles, spouts and knobs (Wandiba, 1977, 1980). This resulted in the recognition of five (5) Ware groups termed Nderit Ware, Narosura Ware, Remnant Ware (Elmenteitan), Maringishu Ware, and Akira Ware, which were called after the names of the respective sites found in northern and southern Kenya, the Kenyan Central Rift Valley, and Northern Tanzania (Wandiba, 1977, 1980). Henceforth, another scheme followed, which again reordered pottery Ware starting from the oldest Nderit Ware to Kansyore Ware, Narosura Ware, Akira Ware and Maringishu Ware (Bower et al., 1977).

Later on, other classification attempts were made to group the Neolithic pottery based on a cluster of variables, such as decoration and vessel form, and the relationship between Neolithic sites was examined. As part of the study, the link between their economy, chronology, pottery, lithic artefacts and geographical distribution was also established. With these classification results, two changes in pottery nomenclature were made that replaced the term Ware with Tradition and the renaming of the Wares. The first recommendation (i.e., from using “ware” to “tradition”) was made because it was believed that tradition cannot be recognized from a site containing a single type (Collett and Robertshaw 1983:121). The second recommendation was the renaming of the Wares. For example, Kansyore Ware has been renamed Oltome Tradition, Narosura Ware has been renamed Oldishi Tradition, and

Maringishu Ware has been renamed Olmalenge Tradition (Sutton, 1973; Mturi, 1986; Robertshaw, et al., 1989).

The recommendation of two classification systems was preferred and is referred to in the work of Sutton (1973), Mturi (1986) and Wandiba (1977; 1980). However, despite the contradiction posed by the above classifications and renaming as well as lack of clearly defined chronology, the Neolithic pottery groupings like Nderit Ware, Narosura Ware, Maringishu Ware, Akira Ware and Kansyore Ware are commonly suggested and have continued to be used by most archaeologists working on East African Neolithic pottery (Ambrose, 1984, Barthelme, 1985; Bower 1985, 1991; Bower, et al., 1977, Mehlman, 1989; Mturi, 1986; Grillo, et al., 2020).

3.8. Narosura Pastoral Neolithic Pottery

The pottery attributed to Narosura PN pottery has been identified along the Eastern Rift Valley of Kenya and Tanzania (Bower and Nelson, 1978; Ordner, 1972). Ordner (1972:62) describes Narosura assemblage as being mainly characterised by comb-stamping or line incisions, which are occasionally crossed by horizontal lines or divided by zigzags, and narrow-mouthed bowls, bowls with slightly everted rims and beaker-like vessels. Previously, the distribution of Narosura settlements was only thought to have occurred in the eastern branch of the Rift Valley between Lake Nakuru and Eyasi (Ordner, 1972). This distribution was later modified after the discovery of Narosura, a site to the west of Kilimanjaro containing PN pottery (Mturi, 1998). Chami (2001a) and Chami and Kwekason (2003) also reported the presence of the same tradition on the southern coast of Tanzania. Recently, Prendergast et al. (2013) also reported a Narosura PN pottery site at Luxmanda on the southern part of Mbulu plateau.

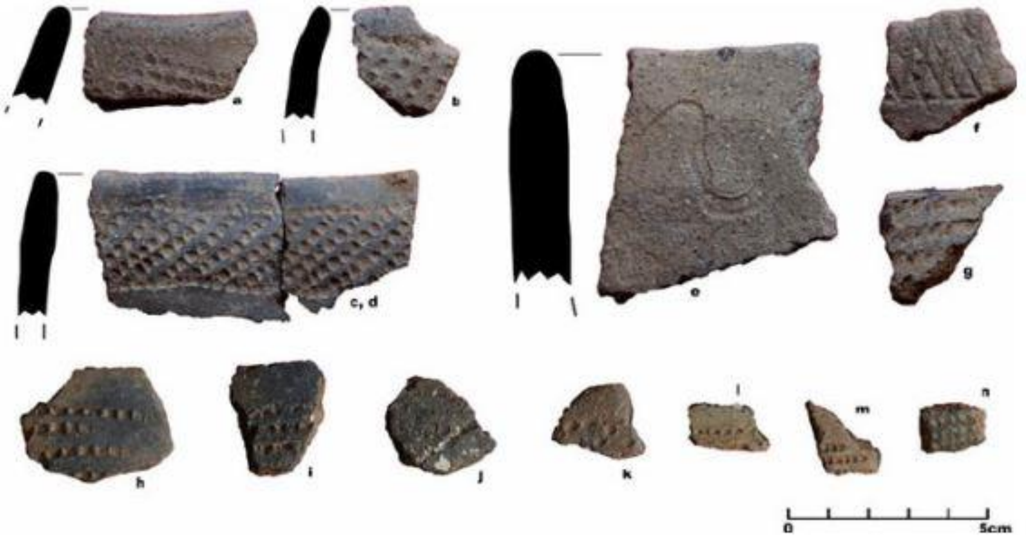


Figure 3.1: Decorated pottery of Narosura Ware: a-g collected from the surface and h-n recovered from test pit B5 at Luxmanda. After Prendergast et al. (2013).

The existence of a site like Narosura implies that the PN people had spread from the Rift Valley crater highlands to the adjacent hinterland down to the southern coast of Tanzania (Mturi, 1998; Chami, 2001a; Chami and Kwekason, 2003; Prendergast et al., 2013). However, the variants of Narosura tradition have been the subject of debate among scholars working on PN pottery, for which different terminologies have been used (Odner, 1972:71-73; Robertshaw, 1990). Over the decades, PN researchers considered the Narosura people to be pastoralists because they relied substantially on domestic stock for their livelihood in the crater highlands and adjacent regions (Bower and Nelson, 1978; Robertshaw, 1990, Prendergast, 2008; Prendergast et al., 2013; Lane, 2011; Ashley and Grillo, 2015). The findings reported in Chami (2001a); Chami and Kwekason (2003) on the southern coast of Tanzania and in Zanzibar certainly contradict the evidence, and so it is questionable whether the coastal Narosura people were pastoralists due to the lack of domesticated stock in the layers associated with the Narosura period that dates to the last millennium BC (Chami and Kwekason, 2003).

Against this background, previous studies have mostly relied on typological approaches and establishing chronological schemes to classify PN pottery, thereby failing to use scientific methods to characterize and interpret PN pottery. Hence, the application of typological, petrographic, and geo-chemical approaches in this study will successfully obtain higher levels of information on technological practices that address social issues on how Narosura PN pottery was made and used, rather than just sticking to classification.

3.9. Chapter Conclusion

This chapter has reviewed the studies on the Neolithic period in East Africa and has sought to classify the PN pottery. The review has also identified how and why typological approaches were used to characterise PN pottery as Ware, which was renamed Tradition, and why this renaming took place. The chapter also introduced the current state of research on PN pottery. The works discussed above have all contributed to providing an understanding of the Neolithic culture and of PN pottery. Despite the limitations of their approaches, they have made a valuable contribution to our knowledge of the chronology (though not well defined) of the Neolithic period in East Africa and Tanzania in particular. The chapter ends by stating that this study is based on the application of combining the typological, ethnographic and scientific material-based approaches to analyse how the pottery was made and used.

CHAPTER FOUR: 4

MATERIALS AND METHODS

4.0. Introduction

The chapter describes materials and research methods used in collection and analysis data for this study from Luxmanda site in the Mbulu plateau region of Tanzania. The chapter also outlines the sampling procedure used to collect the pottery samples from RAPT (Research on the Archaeology of Pastoralism in Tanzania) 2018 excavations campaign at Luxmanda site, raw clay material samples collected, survey and ethnographic research (2018 and 2019) on the Mbulu plateau. The details analytical experimental set-ups and conditions are another component of this chapter. Moreover, the macroscopic and microscopic methods for assessing typology (morphology, decoration motifs, and fabric colour) and wet soil sieving (raw clay materials) are described, as the methods for analysing the petrography (thin-section) and and geo-chemistry (SEM and XRD) of the entire Narosura PN pottery fabric are enlightened.

4.1. Sampling Procedure and Sample Size

Based on the aim and nature of this study, both random (probability) and non-random (non-probability) sampling techniques were employed to select the samples. In random (probability), simple random technique was used to select pottery sherds from ten (10) units (i.e. unit number 15, 16, 17, 18, 19, 20, 21, 24, 25, and 26) of the 2018 RAPT (Research on the Archaeology of Pastoralism in Tanzania) excavation collection. In which a total of one hundred (100) pottery sherds were selected based on the units' arbitrary stratigraphic levels. Using an arbitrary stratigraphy levels of five (5) cm splits, uneven arbitrary levels numbers (i.e. level 3, 5, 7, 9, and 11) were used to sample ten (10) pottery sherds per excavation unit.

Among the ten (10) pottery sherd sampled from each excavation unit, two (2) were decorated sherds and eight (8) were undecorated sherds selected by non-random (judgmental) sampling technique Therefore, only samples regarding the above series and sequence with a few adjustments that were necessary were selected for this study. The aim of selecting samples using this strategy was to inquire into the macro or micro-spatial distribution of pottery technologies and chronology representations. This strategy was adopted to avoid selecting pottery sherds from the same vessels with a heterogeneous fabric colour. As several authors have pointed out (Gibson and Woods, 1990; Spataro, 2002; Weymouth, 1973), that prehistoric ceramics fired at low temperatures and with high porosity also have greater fabric heterogeneity.

In addition, sixteen (16) localities with raw clay material were also sampled for provenance purposes. All possible clay sources within a radius 30 km from Luxmanda site were identified and sampled for the purpose of ascertaining the raw clay source for the Narosura PN pottery in the Mbulu plateau region. This was done as a complementary criterion in the sampling strategy that are usually considered when selecting pottery and other clay materials (Arnold 1985; Rice, 1987).

4.2. Methods for collecting Research Materials

4.2.1. Excavation

The pottery sherds analysed in this work came from the RAPT 2018 field excavations campaigns (n=100 sherds) of all the pottery material recovered at Luxmanda site, and fifteen (n=15) additional sherds from 2017 field excavation campaigns at Eyasi-Mumba site. These fifteen (15) pottery sherds samples were only added to this study for comparison purposes due to this site’s proximity (80 km) to Luxmanda site. The aim of comparing them was to find out whether or not these pottery sherds came from the raw clay material found on Mbulu plateau. However, the selection of pottery sherds was guided by the following criteria. First, to obtain a profile of the Narosura tradition/ware, which had been recorded in 2017 at Luxmanda, sherds were chosen from different quadrants of the excavation units and at arbitrary levels. This also help to establish a clear representation of the Narosura tradition/ware typo-chronology. Second, although both diagnostic and non-diagnostic sherds were sampled for technological interest, pottery sherds showing particular diagnostic features, such as rims, colour, decorative motifs and size, were preferred. Third, sherds were selected from a limited rage of shapes, such as small and large bowls (slightly restricted to open mouth) and pots (cooking/serving based on blackening of the surface), as well as coarse to fine body sherds for morphological characterisation (Chapter 5).

4.2.2. Survey and Ethnography

The raw clay materials and ethnographic data were collected through archaeological survey and ethnographic techniques. The main objective of the survey and ethnography in this study were twofold. First, was to identify localities with the possible raw clay materials sources for making Narosura PN pottery within and outside the Ufana valley. Second, was to collect raw clay samples from these localities identified in the vicinity of site and from the areas mentioned by contemporary potters as sources of raw clay materials for pottery making. Prior to surveying possible potential raw material sources for pottery making, a preliminary ethnographic survey was conducted on contemporary potters and indigenous people at the site and around the Mbulu escarpment. The best time and meeting point with potters was at the weekly markets (*Gulio* in *Swahili*) where they brought their pots to sell. The information provided by the contemporary potters and local people on raw clay material sources was vital for identifying the raw clay material sites discussed in this work (chapter 7, 8 and 9). As noted in conversation with potters, that not all clays were used for pottery making, therefore, this strategy was deliberately chosen in order to identify the possible raw clay sources used for Narosura PN pottery making.

4.3. Materials Analysis Methods

Since all pottery assemblage recovered at Luxmanda site represent only Narosura PN pottery tradition/ware, ceramic ecology approaches (typology, petrography, geochemical and ethnography) was adopted by this study for pottery analysis (see Matson, 1965a; Maniatis, 2009). A common aspect of the study of ancient pottery technology is investigating the different properties of natural clays (especially the chemical composition and the proportion of natural nonplastic micro-inclusions) and identifying deliberately added (temper) or natural occurring inclusions (Maniatis, 2009). This can be obtained using physical, chemical, mineralogical and elemental analyses. These techniques were primarily developed in the natural sciences, and currently have been carefully used in archaeology to the study and interpret the ancient ceramic's technology and materials (Arnold 1985; Rice, 1987; Orton, et al. 1993; Peterson and Betancourt, 2009; Quinn 2013). The methods used for analysis in this study included both macroscopic and microscopic analysis. The two methods are therefore, grouped into two components (characterisation and provenance) phases. Characterisation phase in this study combines multiple analytical techniques to describe and classify physical, chemical, and mineralogical variations within Luxmanda pottery sherds and the raw clay samples in the neighbouring areas within the Mbulu plateau. The latter provenance phase compares the pottery sherds and the clay data (plastic clay (matrix) and aplastic inclusions or temper) to identify the sources of the raw materials used to manufacture pottery. In addition, an ethnography also was undertaken to document the contemporary pottery manufacturing processes in the Mbulu plateau.

4.3.1. Macroscopic Analysis

4.3.1.1. Typological Analysis

Prior to macroscopic typological analysis, a total of one hundred (n=100) Narosura PN pottery sherds samples from Luxmanda site for typological, petrographical and geochemical analysis were individually described, photographed, and recorded in Excel spreadsheet. This was followed by a preliminary macroscopic typological examination that was done by looking at their (pottery sherds) general morphological, fabric colour and decorative motifs. The pottery sherds photos were taken with a normal *Samsung SM – G928F Dpi 96 and Dino–capture 2.0 photo camera*. Since all the pottery sherds from this site represented only a single ware/tradition (Narosura PN), therefore, illustrations of the decorative motifs, and the drawing of the rim profiles as well as rim morphology were done to determine the vessels form for the diagnostic sherd's samples with either rims or decorative motifs. The sherds were typological analysed in two stages using two different methods. The first was by looking carefully with the naked eye at the surfaces and fresh fractures of pottery samples. In the second stage, both a hand-held lens and an OPTIKA B-600POL-I microscope were used to identify the forming techniques, inclusions, and nature of decorative motifs.

4.3.2. Microscopic Analysis

The detailed microscopic analysis in this study was preceded by a primarily microscopic analytical examination on all pottery sherds samples to determine and select few samples for petrography and geochemical analysis. Microscopic observation of the fabric characteristics of the pottery sherds was carried out using an OPTIKA B-600POL-I polarised microscope installed. The aim of these observations was to understand the fabric variability and thus enclosing out the best and important analytical method based on samples constitutes. Based on the observations, petrography (thin section), scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence microscopy (XRF) analytical methods were chosen for pottery sherds samples from Luxmanda site and few sherds from Eyasi-Mumba sites for comparison. In addition, the raw clay samples from the Mbulu plateau were also examined by wet soil analysis method.

4.3.2.1. Petrographic Analysis

A petrographic analysis is a traditional technique used in the geosciences. It was developed by geologists to identify minerals in rocks. In archaeology, petrographic analysis is not new to the study of archaeological ceramics, and it has received more attention as it is applied to interesting and diverse archaeological problems. Archaeologists use it to study the minerals that occur in prehistoric clay matrices transformed by heat to a rocklike state (Peterson and Betancourt, 2009; Quinn 2013). This analysis entails studying thin-sections of the pottery pieces with a traditional light microscope. The petrography of archaeological ceramics involves the describing, classifying and interpreting ceramic pastes using techniques derived from those used to describe rocks (petrography). The primary research tool is the petrographic, or polarising microscope and the ceramics are examined as thin sections, prepared from slices or fragments of pot which are fixed to glass slides and abraded until they are a standard thickness (0.03 mm) (Whitbread 1996; Reedy 1994; 2008; Peterson, 2009; Quinn 2013). At this thickness, many of the more common minerals become translucent, and may be identified based on their characteristic optical properties, such as colour, refractive index, and cleavage (fracture pattern) (Reedy, 1994). As light from this specialized microscope passes through a mineral, it produces optical properties unique to that mineral. Birefringence and pleochroism are two such properties used to identify minerals, while physical properties such as cleavage and relief are also important discriminators. Several references fully explain these properties and relate them to specific minerals and rocks (Rice, 1987; Whitbread 1996; Tite, 1992; Reedy 1994; 2008; Peterson, 2009; Peterson and Betancourt, 2009; Quinn 2013).

4.3.2.2. X-Ray Diffraction (XRD) Analysis

X-ray diffraction (XRD) analysis is a technique used in materials science to determine the crystallographic structure of a material (Moore and Reynolds, 1997; Truker, 1988). XRD works when X-ray beams are habitually fired at a sample, and the source of the X-ray beam progressively turns, and when the beams interact at a certain angle with a mineral a diagnostic diffraction pattern is produced and measured by a detector (Tucker, 1988; Moore and Reynolds, 1997). All minerals have a unique X-ray diffraction pattern based on their crystal structure (Rice, 2015; Peacock, 1970). XRD can be used to minerals in the sample either quantitatively or qualitatively. It is particularly very useful when measuring the concentration of clay minerals in samples when used on fine fractions (Tucker, 1988). In pottery studies, X-ray diffraction analysis is widely used to study the effect of heat on minerals found in pottery and synthetic ceramic materials (Shepard 1985:147). The crystal structure of minerals allows XRD to describe the chemical properties of different minerals and traces. This allow XRD to yield data on the mechanical and heat treatments to which artifacts are subjected during their manufacturing processes. The presence or absence of some minerals indicated in analytical techniques like petrography or chemical analysis can be verified by XRD analysis (Tite 1972; Tite, 1999). In this study, XRD analytical technique was used to verify the presence of pottery fabric minerals that were not identified in petrography and SEM.

4.3.2.3. Scanning Electron Microscopy (SEM-EDS/EDAX)

Scanning electron microscopy coupled with energy dispersive spectrometry (SEM-EDS) provides qualitative and quantitative details regarding the chemical and mineral structures of the samples to be studied. Furthermore, it allows for the visual inspection of microstructure diagrams with high magnification up to 100,000 times. SEM can check the degree of vitrification, due to the temperature at which the pottery was fired, such as the vitreous phase and the development of the pore structure. The energy diffusion X-ray spectroscopy attached to SEM also determines the chemical composition of the matrix and the chemistry of the clay (Tite, 1992). The basic principle of a microscope (SEM) is that a sample observed from a series of lenses magnifies the image of visible light. However, the SEM does not provide a true picture of the specimen, but it produces an electronic map of the sample shown on the cathode ray tube. In addition, an electron beam is generated above the microscope with an electron gun. The microscope has a perpendicular path, allows the electron beam to pass, and is usually kept under vacuum. When the ray begins to travel, it passes through electromagnetic fields and lenses, where it is aimed at the sample. When this ray hits the sample, electrons and x-rays are removed from the sample. The detectors assemble these X-rays, back-scattering electrons, and secondary electrons, where they are transformed into signals, displayed on a monitor screen (Pollard and Heron, 2008:46–49). The vacuum and electron conditions are required to perform SEM analysis so the sample should be dry and conductive. For non-metallic material sometimes coating (usually applied using a spray applicator) with a thin layer of conductive material, such as carbon or gold, is required to allow the conductivity of the sample. Therefore, the development of vitrification of microstructures can be investigated and the pore expansion time can be evaluated. Subsequently, the information on the heating temperature can be also obtained. Henceforth, the chemical composition of the clay material used in the production of the pottery sample can also possible detected (Goodhew et al. 2000; Pollard and Heron, 2008). The samples for this study were not coated with an electron-beam layer due to the quick conductivity.

4.3.2.4. Raw Clay Wet Sieve Analysis

A wide variety of wet and dry sieving analysis techniques are used in the clay analysis to separate clay from non-clay material. The sieving removes the non-clay concentrates from the clay, and the sieved materials are then classified by size, making it easier to further examine the non-clay materials under a microscope. Clay and non-clay samples residues derived from wet or dry sieving can be further processed by concentration techniques in fractions. The wet sieve analysis method involves mixing the sample while spraying water on it or suspending it in water. It is usually agitated manually using a wet washing screen under running water from either a tap under water or dispensed from a spray device (Allman and Lawrence, 1972; Green, 2001). The mesh sizes for these screens are normally selected based on research requirements for particle sizes to retain analysis. In this method, the entire sample is placed in a pan, cover with water and rinse manually. The wastewater is drained to a wet sieve and more water is added to the pan. This process continues until the wastewater is relatively clean. Aggregate washing device saves time and increases repeatability by mechanizing this process. The wet runoff materials are therefore filtered with a standard sieve screen placed next to a drain or fitted with a drain pan (Green, 2001). Wet sieving is an ideal process to use with raw clay materials with high granular friction and containing a lot of fine material, which makes dry sieving difficult (Miller, 1989), because the clay and fine materials can stick together in clusters with non-clay materials, preventing an accurate assessment. Wet sieving is therefore useful for separating non-clay particles from clay materials. In this study, wet sieving analysis was performed with two purposes in mind. First, it was performed to determine mineral fractions retained on sieves; and Second, it was used as a method of non-clay sample materials preparation that allowed later mineral particle size analysis to be performed more easily and accurately.

4.4. Chapter Conclusion

Both probability (random) and non-probability (non-random) strategies were used to select samples for this study, which ensured good representation of the sample materials and to avoid bias in the selection of the pottery sherds. The data used in this research were mainly collected through surveys (which sought to document all places with raw clay and potters’ localities), previous excavations campaigns (which sought to collect pottery sherds samples) in Luxmanda (2018) and Eyasi-Mumba (2017) sites, and from ethnography (which documented the contemporary pottery manufacturing processes). In the ethnographic enquiry, about 15 potters conversant with raw clay sources within Mbulu plateau were visited and deliberately interviewed. Analytical procedures for pottery samples data followed several schemes for pottery fabric macroscopic and microscopic analysis developed for typology, petrography, and geochemical analysis.

CHAPTER FIVE: 5

TYPO-TECHNOLOGICAL ANALYSIS OF NAROSURA PASTORAL NEOLITHIC POTTERY WARE FROM LUXMANDA

5.0. Introduction

This chapter describes the typo-technological characterization of Narosura Pastoral Neolithic (PN) pottery samples recovered and collected from the 2018 field excavations at Luxmanda site. The primary aim of this analysis was to identify and describe the key typo-technological attributes (rim profile and lip morphology, fabric colour and inclusions, and decorative motifs) of the Narosura PN pottery samples collected from Luxmanda site that forms part of this study. The basic intention of this chapter is therefore to describe the above attributes types rather than ascertaining their chronological relationship with other Narosura PN pottery sites in East Africa.

5.1. Material Analysis Procedures and Methods

All the diagnostic and undiagnostic pottery sherds (n=100) were analysed and given a unique artefact number based on their excavation unit quadrant and level. The attributes of each piece were recorded on an Excel spreadsheet using a coding system based on the criteria outlined above. The information recorded for each pottery sherd sample included contextual information, sherd dimensions (maximum length, width, and thickness in millimetres recorded using digital Vernier Callipers), and pottery sherds fabric matrix attributes description done by looking at their morphological features, colour, nature of surface treatment and decoration types, overall texture and hardness.

5.2. Typological Analysis Results

5.2.1. Decoration motifs and Placement techniques

Decorative motifs are formed when single or several decorative elements are combined together in different ways (Figure 5.2). Decoration placement refers the position where decorative treatments are embellished on the vessel (Rice, 1987). The decorative placement or treatments can be placed on lip, rim, neck, shoulder and on body of a vessel (Figure 5.3). Pottery decoration can also occur on the exterior or interior of vessels. Several varieties of decorative motifs of the selected Narosura PN pottery sherds samples from Luxmanda were identified and recorded (Figure 5.2 and 5.3). Based on the decorative elements parameters and by considering placement techniques, seven categories of pottery decorative motifs techniques were ascertained and described herein, following decorative motifs scheme described by Odner (1972) at Narosura site in the southern highlands of Kenya. The categories of techniques included punctating (12%), stamping dots (18%), slips/paint (19%), burnish/grooves (16%), stabs (14%), graphite (9%), and incisions (12%), often occurring in combination (Figure 5.1). The decorative pattern of the selected pottery sample exhibited both single and multiple elements of decorative motifs. For the most part, decoration motifs were either restricted on, or immediately below the rim, and on the neck or shoulder (Figure 5.2 and 5.3).

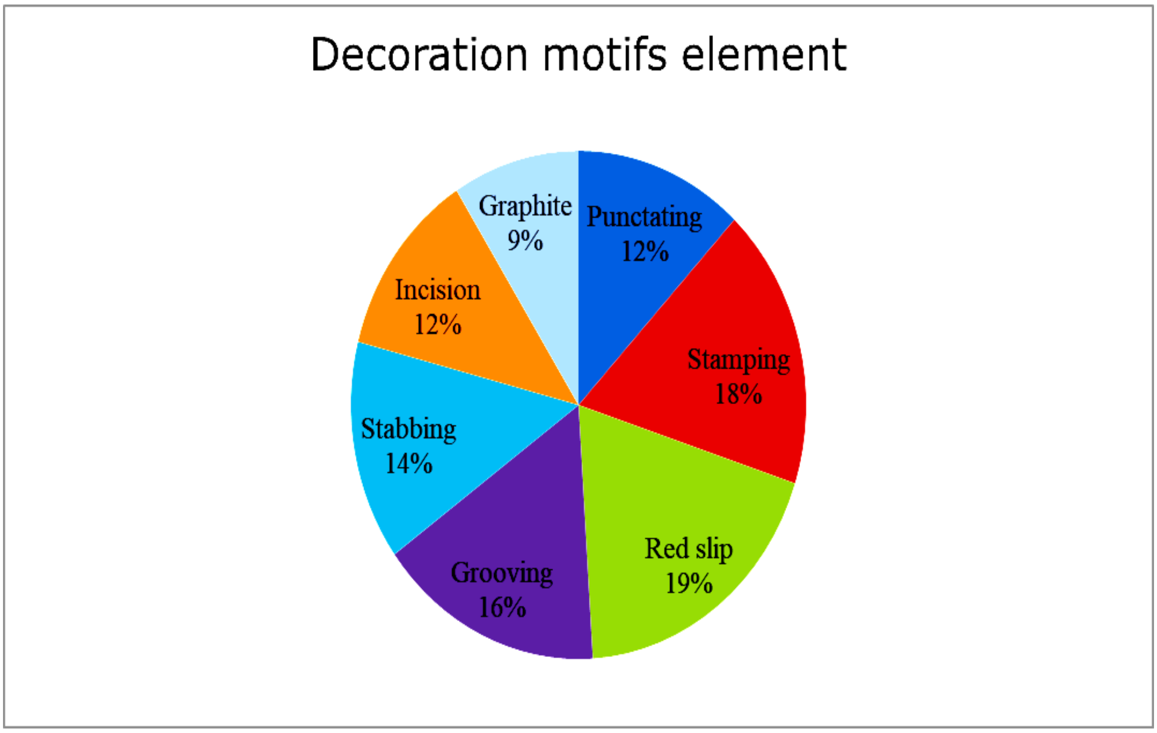
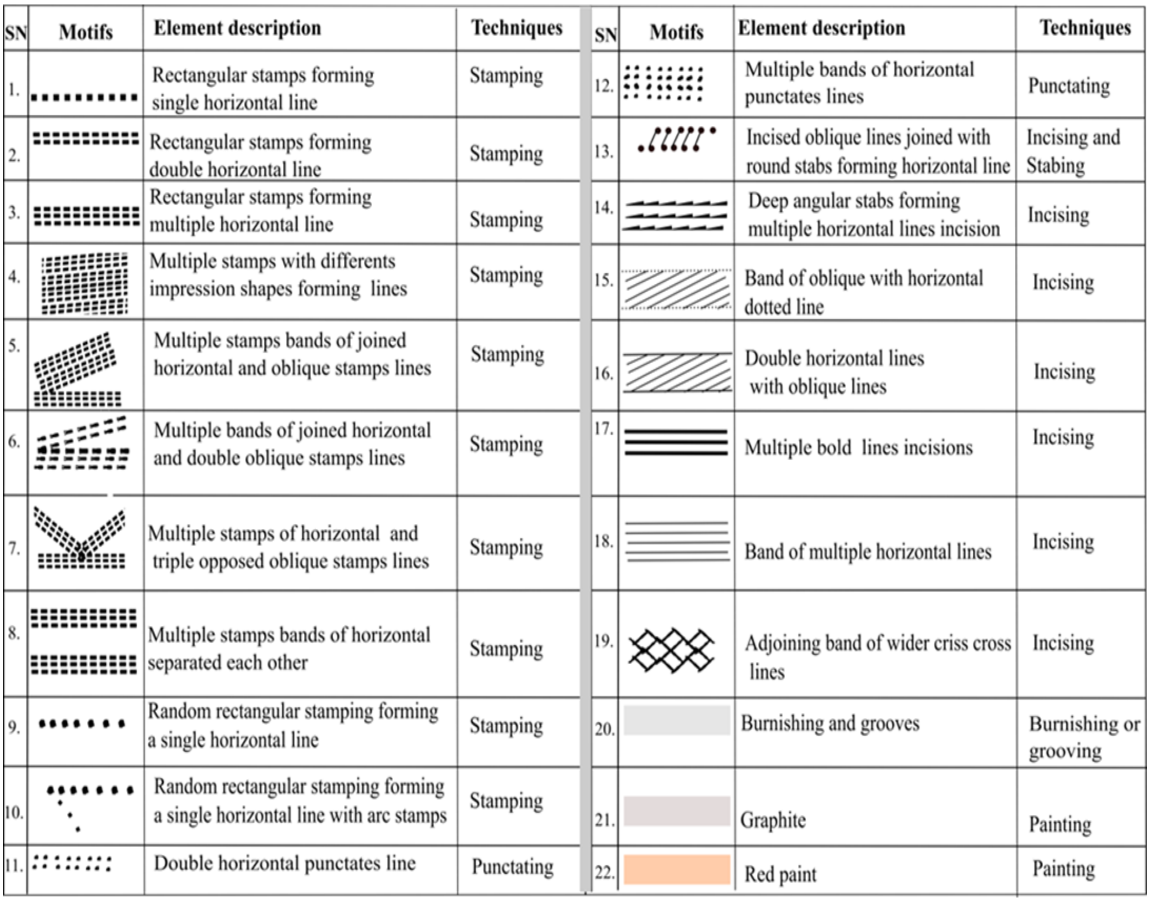


Figure 5.1: Frequency Pattern of decoration motifs



SN	Motifs	Element description	Techniques	SN	Motifs	Element description	Techniques
1.		Rectangular stamps forming single horizontal line	Stamping	12.		Multiple bands of horizontal punctates lines	Punctating
2.		Rectangular stamps forming double horizontal line	Stamping	13.		Incised oblique lines joined with round stabs forming horizontal line	Incising and Stabing
3.		Rectangular stamps forming multiple horizontal line	Stamping	14.		Deep angular stabs forming multiple horizontal lines incision	Incising
4.		Multiple stamps with differents impression shapes forming lines	Stamping	15.		Band of oblique with horizontal dotted line	Incising
5.		Multiple stamps bands of joined horizontal and oblique stamps lines	Stamping	16.		Double horizontal lines with oblique lines	Incising
6.		Multiple bands of joined horizontal and double oblique stamps lines	Stamping	17.		Multiple bold lines incisions	Incising
7.		Multiple stamps of horizontal and triple opposed oblique stamps lines	Stamping	18.		Band of multiple horizontal lines	Incising
8.		Multiple stamps bands of horizontal separated each other	Stamping	19.		Adjoining band of wider criss cross lines	Incising
9.		Random rectangular stamping forming a single horizontal line	Stamping	20.		Burnishing and grooves	Burnishing or grooving
10.		Random rectangular stamping forming a single horizontal line with arc stamps	Stamping	21.		Graphite	Painting
11.		Double horizontal punctates line	Punctating	22.		Red paint	Painting

Figure 5.2: Decorative motifs, elements, and techniques

5.2.2. Pottery Surface Treatment Patterns

Macroscopic analysis identified three types of Narosura PN pottery sherds surface treatments, such as hand smoothed, polished/slipped, and wiped with a tool to enhance the surface of pottery. The criteria for hand smoothed surface were veiled if the pottery sherds surface was smooth and had no wiping marks. While, for polished/slipped surface treatments, if the pottery sherds were highly smoothed and lustrous. Lastly, for wiped surface treatment if the pottery sherds were smoothed and display any wiping marks. Moreover, the surface treatments observed were further classified in three categories depending on their place of occurrence. These included interior surface treatment, exterior surface treatment, and rim surface treatments.

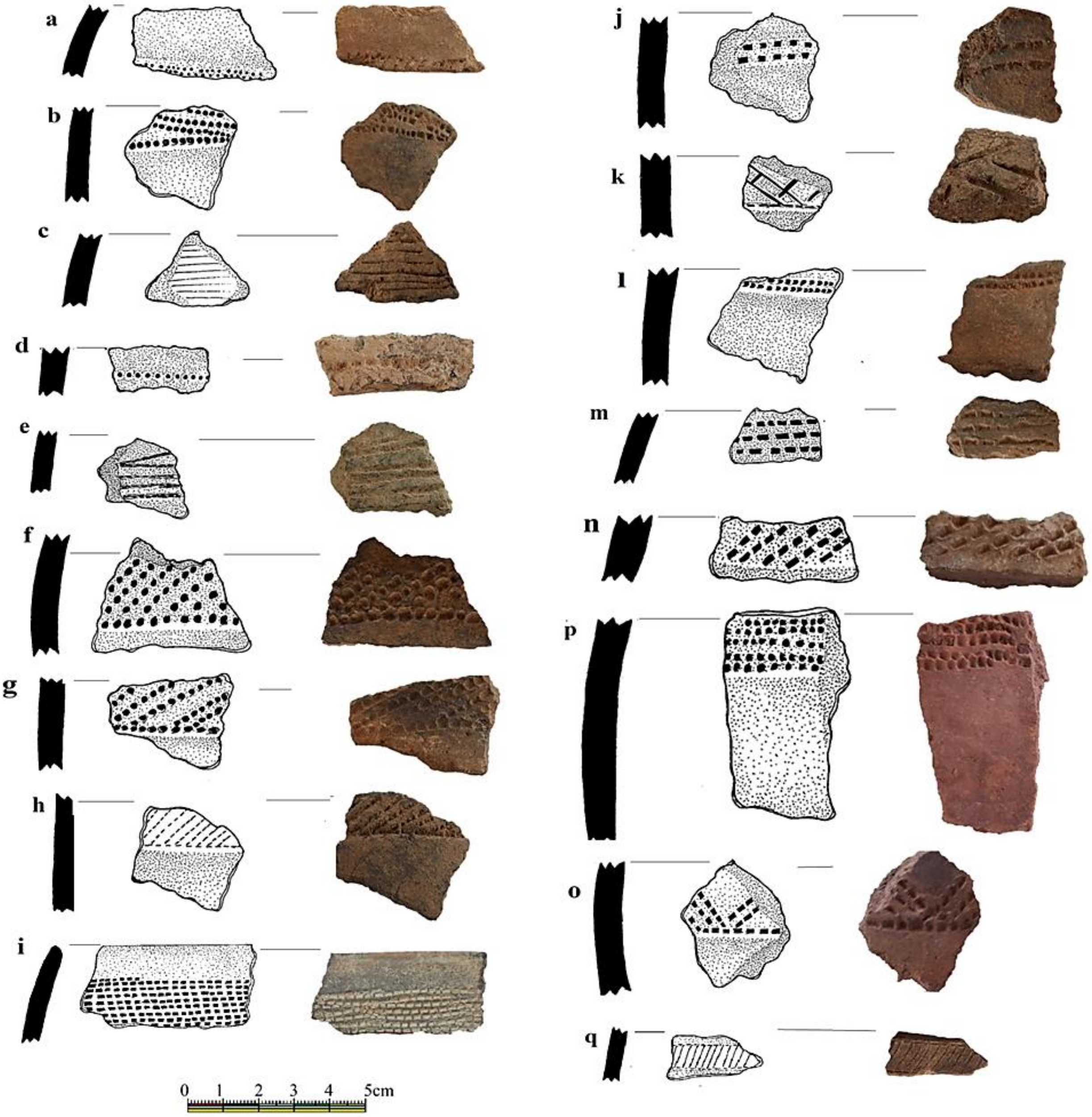


Figure 5.3: Decorative Motifs (a-q) of Narosura PN Pottery identified from the 100 sherds selected from Luxmanda site 2018 field excavations. Illustrations by Hitson Pazza.

5.2.3. Pottery Sherds Colour

A range of pottery sherds colours from the samples were observed. Basically, the colours of a few samples were similar, although some variations were observed in the colour distributions across the samples on the exterior and interior surface and in the core. In order to maintain consistency in the assessment of colour, the core, interior and exterior surface colours were determined and recorded using the Munsell soil colour chart (Munsell, 1994). Following the observed variation in the colour pottery sherds, the analysis is divided into three sub-sections (core colour, interior surface colour and exterior surface colour) based on the sherds' profile.

5.2.3.1. Core Colour

A fresh breakage was initiated on the pottery sherds core from the cross section where a core effect is available. The section of the core showed distinct colours from the surface and the margins or interior. The colour of most of the pottery sherds core exhibits black, very dark gray, dark gray and very dark grayish brown colours. For light-coloured pottery sherds, the colours such as brown, yellowish brown, dark brown, grayish brown, very dark grayish brown, reddish gray, very dark brown, reddish yellow, very pale brown, and light olive brown were also observed in the core (Figure 5.4).

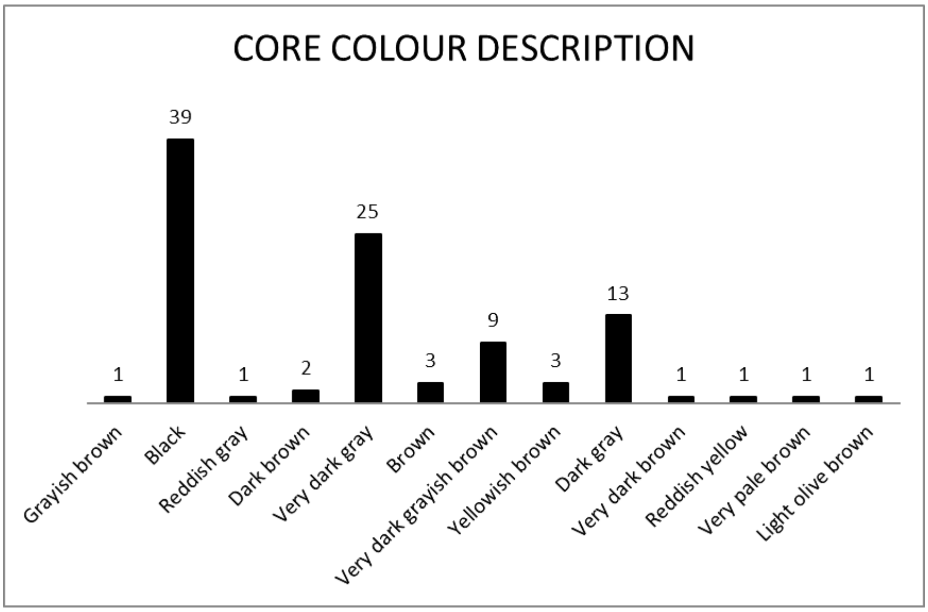


Figure 5.4: Core colour of pottery sherd samples frequency distribution.

5.2.3.2. Interior Surface Colour

The colours of the interior surface of the pottery sherds analysed varied significantly, although the ones most occurring were brown, dark gray and grayish brown. However, other colours were also observed, such as dark grayish brown, very dark grayish brown, very dark gray, gray, yellowish brown, black, light yellowish, light olive brown, pale brown, light brownish gray, very pale brown, redish brown, pale yellow and pale brown (Figure 5.5).

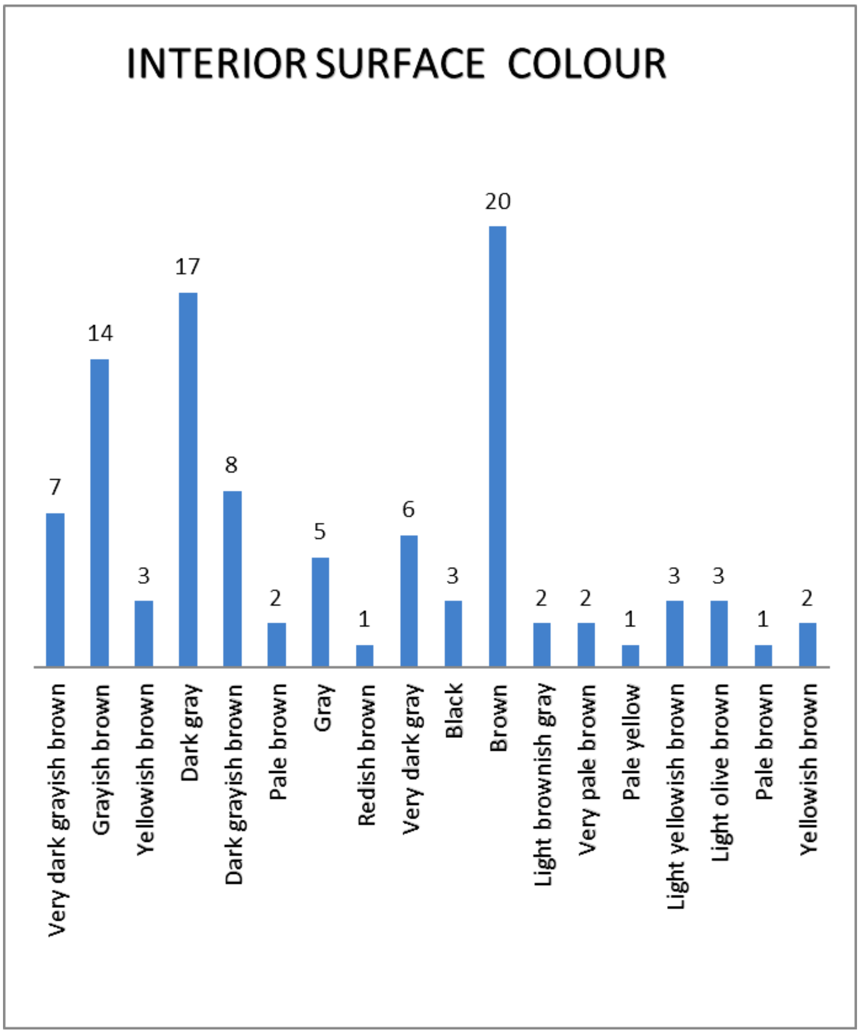


Figure 5.5: Interior surface colour of pottery sherds frequency distribution.

5.2.3.3. Exterior Surface Colour

The exterior surface of the pottery sherds comprised of several colours such as brown, very dark gray, dark gray, grayish brown, light yellowish brown, pale brown and dark grayish brown that were more common in the samples analysed. Although, other colours like light brownish gray, yellowish brown, light olivine brown, reddish yellow, dark brown, very dark grayish brown, dark olive brown, srong brown, light brown, reddish brown and black were also attested in small quantities in the samples (Figure 5.6).

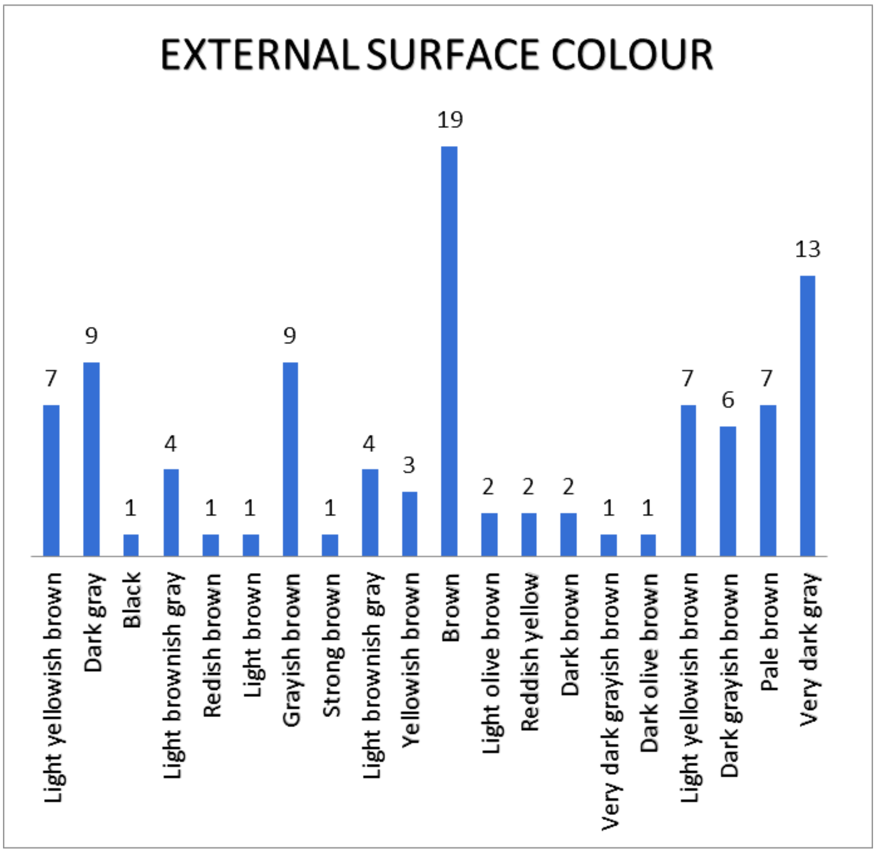


Figure 5.6: Exterior surface colour of pottery sherds frequency distribution

5.2.4. Morphological Parts of Pottery sherds

5.2.4.1. Rim Profiles and Lip Morphology

The rim is defined as the margin of the vessel orifices and may be functional and/or decorative (Rice, 1987). The rim serves to strengthen and orifice vessels for the functional purposes of pouring, lifting, and retaining liquids or may be decorative. A rim sherd can also be used to discern the type of vessel, its diameter and general shape. There are almost infinite number of shapes of rim profiles, but a more limited numbers of lips (Shepard, 1968; Rice, 1987). The formation of different shapes/types of rims raises a technical question as to whether they were formed by adding a coil of clay or by manipulating the edge of the vessel wall. The analysis of rims from the Narosura PN pottery samples collected from Luxmanda indicated that rims were of four distinctive types or forms (flared rim B; in-turned rim C, D, G & H; out-turned rim A & F;

and up-turned rim E), with four classes of lips morphology (rounded lip G & H, squared lip E & F, Everted lip A & B, and pointed lip C & D) (Figure 5.7 and 5.8).

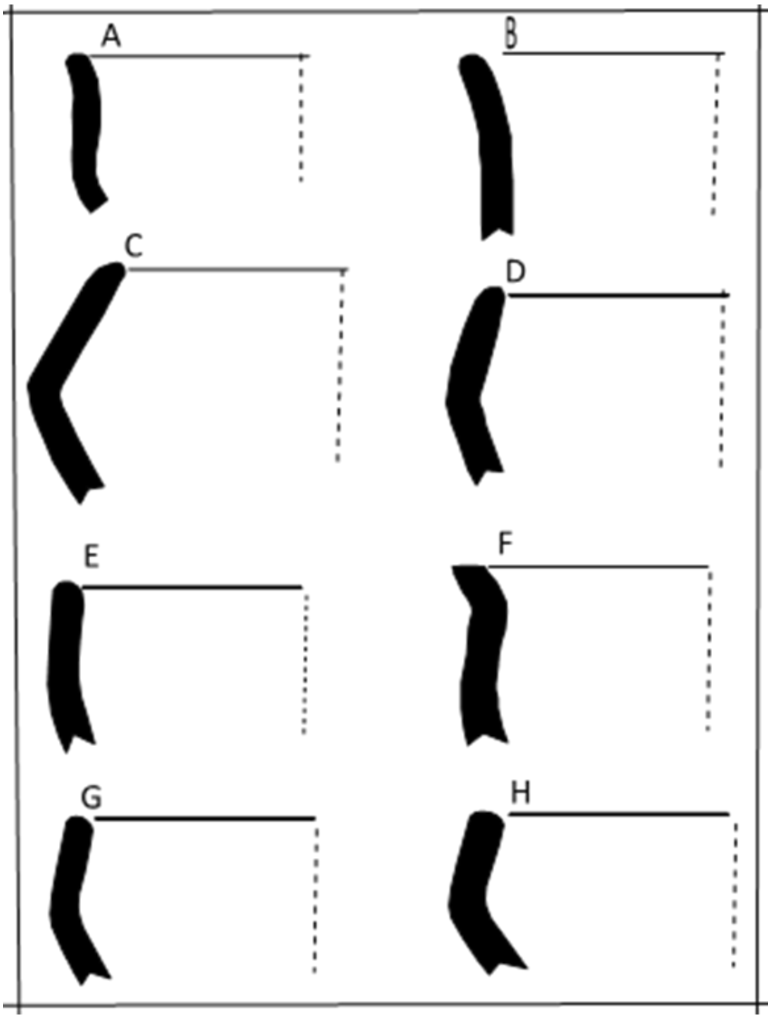


Figure 5.7: A-H illustrated rim profiles.

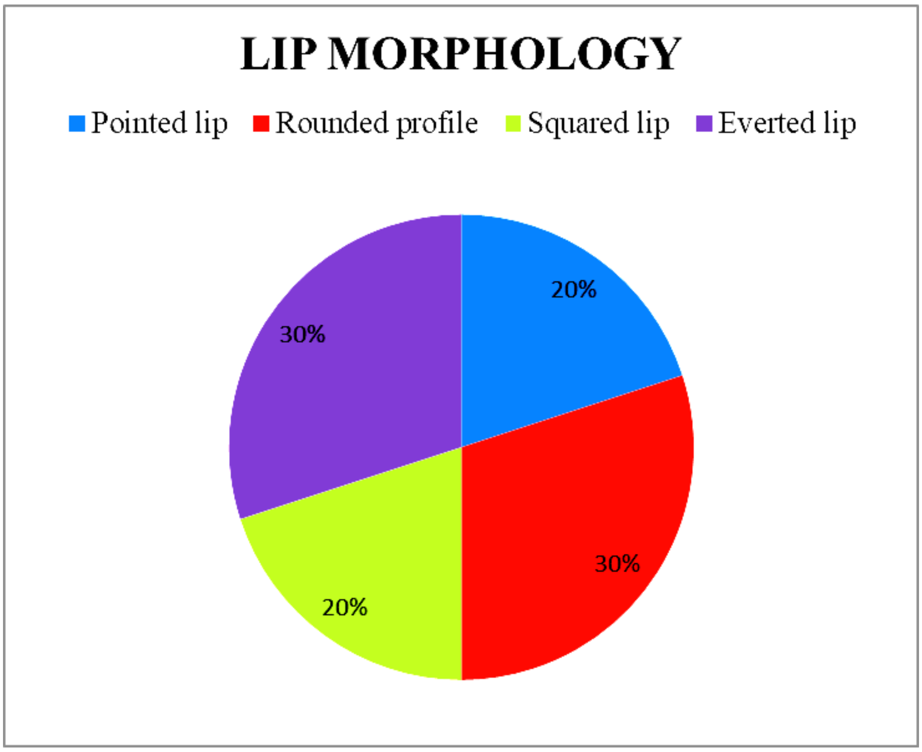


Figure 5.9 Lip Morphology frequency Observed.

5.3. Discussion

5.3.1. Manufacturing Techniques

The presence of visible coils after fresh breakage on several Narosura PN pottery sherds samples suggests that the coiling technique was mostly used to manufacture the pottery, whilst other techniques like hand pushing of clay with paddle in slab building also exists. The profiles of the rims also revealed that several types of bowls and cooking pots were made. Chami (1994) and Pikirayi (1993) noted that up-turn rims suggest open bowls, in-turn rims suggest restricted or hemispherical bowls, and flared rims suggest independent restricted pots. Therefore, according to the rim profiles observed above, the Luxmanda pottery assemblage consisted of all four vessel shapes categorized in Chami's (1994) model, which comprise dependent restricted pots, independent restricted pots, restricted and open bowls. The decorative treatments observation also indicates several aesthetic advancement and functional aspects. For instance, the micro-analysis of the decorative motifs showed a lack of standardization skills in decorating the pots, as the decorations appears to be of different sizes in same place. The use of paint (red paint and graphite) is more related to both aesthetic (initial steps towards artistic change) and functional aspects. Shepard (1968) argues that the method of surface finishing depends on the purpose of the vessel and whether or not it is to be decorated. The presences of surface treatments in the interior and exterior pottery sherds samples indicates that the pottery vessels were manufactured for the purpose of both cooking and serving.

5.3.2. Pottery Firing

Potter firing involves applying heat to clay vessels when dry, which normally results into the chemical alterations (mineralogical and microstructural modification) of the clay material and the loss of clay plasticity, thereby producing a hard and durable pottery vessel (Shepard, 1968; Rice, 1987; Quinn, 2003). The type of raw material used, the maximum temperature attained, the firing duration, atmosphere and firing structure are among the factors influencing the appearance and structure of the pottery (Rice, 1987). With reference to pottery sherds from Luxmanda, the firing of pottery is determined based on pottery matrix colour. Rice (1987) noted that the difference in the pottery colour may be due to presence or absence of air circulation in the firing atmospheres (oxidizing and reducing). An oxidizing atmosphere exists when oxygen is present in the firing chamber, while reducing atmosphere exists when little oxygen is present. Therefore, the firing atmosphere affects vessel colour, hardness, porosity, and shrinkage (Shepard, 1968; Rice, 1987; Quinn, 2003). According to Shepard (1956), potters may control firing atmosphere in several ways, such as opening or sealing the firing facility so that less oxygen enters the firing chamber, thereby allowing free flow of oxygen in the firing chamber. Pottery with light colours (oxidising atmosphere) are produce during firing when the oxygen is abundantly available and the carbon present in the vessels body and fuels are consumed. Similarly, pottery with black or dark brown colours (reducing atmosphere) are produced in the oxygen-poor atmospheres, whereby the carbon in the vessel body is not lost, and carbon from fuels may be deposited on the vessel surface, making it black (Rye 1981). With regard to the multiple colours of the core, interior and exterior surfaces of the pottery sherds analysed, it is likely that the Narosura PN pottery at Luxmanda were fired in a reducing atmosphere (environments). The presence of pottery sherds with black, dark gray and very dark grayish brown core colours suggests a low firing temperature, while pottery sherds with both light and dark colours imply to uncontrolled firing environment. However, the blackening of the pottery sherds interior and exterior surface suggests that vessels were multiple used in cooking and serving.

5.4. Chapter Conclusion

The typological data analysed and discussed in this chapter have provided useful information on pottery production and firing at Luxmanda site. The typological analysis of Narosura PN pottery sherds suggests the presence of mixed high to low pottery firing, as well as multipurpose use of pots for both cooking and serving. The treatment and placement of ceramic decorative motifs further suggest that they lacked aesthetic standardization, because several motifs had significant variations, while a few pottery sherds revealed some important aspects of sophistication that implies to a major specialization in pottery surface finishing. Although the repetition of some decorative motifs on several sherds reveals the same typology, it also suggests that the ancient society maintained its own identity in pottery production. Hence, the new typological data provides not only an understanding of ancient pottery technology, but also the socio-cultural implications.

CHAPTER SIX: 6

THE PETROGRAPHIC CHARACTERIZATION OF THE NAROSURA PASTORAL NEOLITHIC POTTERY FROM LUXMANDA IN THE MBULU PLATEAU NORTHERN TANZANIA

6.0. Introduction

The chapter outlines the petrographic characteristic of Narosura pastoral Neolithic pottery recovered from excavations in 2018 at Luxmanda site in the Mbulu plateau of northern Tanzania. The pottery sherds are characterised based on thin-section analysis. This characterisation is based mostly on the mineralogy and texture of non-plastic inclusions, and comparison to petrographic features of clay minerals outcropping in the area (Ganbat et al., 2021). This provides a general concept of the clay paste preparation techniques. This chapter also represent the first petrographic analytical and interpretation data derived from Narosura pastoral Neolithic pottery in Tanzania. The focus of the study was on the nature of clay matrix and more conspicuous aplastic inclusions in order to detect composition and alterations, important microstructural and textural evidence hence deducing the geological sources of the raw materials and the forming technique used to manufacture the Narosura pastoral Neolithic pottery.

6.1. Petrographic features of clay minerals in relation to pottery matrix

Clayey sediments for the pottery are localized in depressed areas due to the presence of rift basins affecting the southern sector of the western flank of the Gregory Rift (Dawson, 1992; Chorowicz, 2005). The region is underlain by mostly Precambrian metamorphic rocks (quartzites, limestones, schists, gneisses and migmatites) that outcrops in the North Eastern sector. Geochemically, the granitoid rocks outcropping in the area are characterized by High-K, calc-alkaline fingerprint. The minerals of degradation of these rocks are involved in the Quaternary lacustrine and fluvial deposits, formed in a semi-arid environment. The weathering of metamorphic lithologies is in slightly to strongly acid conditions favourable to the formation of kaolinite from smectite and in these clay minerals matrices relics of the following rocks are observed by Ganbat et al (2021):

a. Metagranite, porphyroblastic, lepidoblastic, granoblastic in texture contained potassic feldspar-microcline, rich in albite plagioclase, quartz, biotite and sometime hornblende. Metamorphic minerals are epidote, chlorite and garnet. Accessory minerals are muscovites, zircon, apatite, sphene and opaque minerals. Poikiloblastic texture is presented by idioblastic microcline megacrysts with cross-hatched twinning containing relicts of quartz and, plagioclase within idioblastic microcline megacrysts with cross-hatched twinning. Subidioblastic to xenoblastic potassic feldspar-microcline with cross-hatched and simple twinning occurs as porphyroblastic minerals. The K-feldspars exhibit cross-hatched and pericline twinning, as the result of monoclinic orthoclase or sanidine transforming to microcline. Plagioclase markedly altered to smectite clay minerals and biotite to epidote. Porphyroblastic garnet with skeletal texture contained ilmenite, clinozoisite as an inclusion (for a critique see Ganbat et al., 2021: Fig. 3c). Quartz, biotite, muscovite forms shape preferred orientations.

b. Granoporphyry, porphyritic, hypocrystalline in texture, composed of phenocrysts-potassium feldspar, quartz, plagioclase and cryptocrystalline groundmass minerals altered in clay minerals, which consist of felsic minerals, devitrified volcanic glass, biotite and accessory and secondary minerals such as epidote, zircon and apatite. The phenocrysts, mainly idiomorphic, variably exhibit corroded embayment of rhyolitic quartz. Feldspars are altered to clay minerals, displays faint Carlsbad and cross-hatched twinning. Some megacrystals contained plagioclase, zircon, epidote, and altered biotite. Plagioclase crystals sericitized. Biotite often lobed in the periperhy of phenocrysts and altered to sericite and epidote.

c. Metagranodiorite, lepidoblastic, granoblastic in texture comprised of hornblende, biotite, plagioclase rich in An, potassic feldspar, small amount of quartz, zircon and apatite. Epidote, garnet, and clinozoisite occur as metamorphic mineral. Idio- to subidioblastic hornblende crystals demonstrates clear diamond-shape cleavage, often clustered with biotite laths. This association is largely replaced by felty masses of epidotes.

Possibly, by result of breakdown of anorthite formed albite and clinozoisites; magmatic hornblende lattice break-off formed epidotes.

d. Metamonzodiorite, porphyroblast, lepidoblastic in texture, consisted of potassic feldspar, plagioclase, quartz, hornblende, biotite and muscovite. Accessory minerals are titanite, apatite, zircon, rutile. Metamorphic minerals are epidote and kyanite. Microcline and plagioclases occur as porphyroblastic minerals. Two types of quartz are observed: porhyroblastic and interstitial. Porphyroblastic grains surrounded by micas and hornblende which defines schistosity of sample. Plagioclase saussuritizated largely replacing by felty masses of epidote, muscovite. Metamonzogranite can have weakly foliated, hypidiomorphic granular in texture.

6.2. How Petrography Works/Operates

A petrographic analysis is a traditional technique used in the geosciences. It was developed by geologists to identify minerals in rocks. In archaeology, petrographic analysis is not new to the study of archaeological ceramics and it has received more attention as it is applied to interesting and diverse archaeological problems. Archaeologists use it to study the minerals that occur in prehistoric clay matrices transformed by heat to a rocklike state (Peterson and Betancourt, 2009; Quinn 2013). This analysis entails studying on polished cross thin sections of the pottery pieces with a traditional light microscope in order to characterize the fabrics of the ceramic paste and minerals and rocks aplastic inclusions. The petrography of archaeological ceramics involves the description, classification and interpretation of ceramic pastes using techniques derived from those used to describe rocks (petrography). The primary research tool is the petrographic, or polarising, microscope and the ceramics are examined as thin sections, prepared from slices or fragments of pot which are fixed to glass slides and abraded until they are a standard thickness (0.03 mm) (Whitbread 1996; Reedy 1994; 2008; Peterson, 2009; Quinn 2013). At this thickness, many of the more common minerals become translucent, and may be identified based on their characteristic optical properties, such as colour, refractive index, and cleavage (fracture pattern) (Reedy, 1994). As light from this specialized microscope passes through a mineral, it produces optical properties unique to that mineral. Birefringence and pleochroism are two such properties used to identify minerals, while physical properties such as cleavage and relief are also important discriminators. Several references fully explain these properties and relate them to specific minerals and rocks (Rice, 1987; Whitbread 1996; Reedy 1994; 2008; Peterson, 2009; Peterson and Betancourt, 2009; Quinn 2013).

6.3. Material Analysis Procedures and Methods

Petrographic analysis method was conducted to thirteen Narosura PN pottery sherds from both Luxmanda (n=11 sherds) and Mumba Eyasi (n=2) sites, respectively. The samples for Mumba-Eyasi site were only included in this study for the purpose of affirming if there is probably link between the two sites due to their closer temporal and spatial similarity connection in terms of Narosura PN pottery Ware. For Luxmanda site, eleven (11) pottery sherds were selected from 2018 RAPT field campaigns for fabric thin section analysis (Table 6.0 and Figure 6.0). The selected Narosura PN pottery sherds samples for thin sections were first impregnated in vacuum with a mixture from five parts of Hardrock 554 epoxy resin and one part of Hardrock 554 hardener. The process of epoxy impregnation also stabilizes the samples in a plastic form resin to help them withstand the later cutting and polishing. The mounted samples were then sliced to produce a flat surface to fix on the petrographic glass microscope slides, which were later grounded with a diamond lap/abrasive powder to prepare a standard thin-section of 30 µm (see Whitbread 1996; Reedy 1994; 2008; Peterson, 2009; Quinn 2013). The thin-section slides were first prepared and analysed by petrographic equipment facility at University of Ferrara Geology Section of Department of Physics and Earth Sciences, and later were submitted for a more detailed confirmatory petrographic analysis using a Leica DM 750 polarizing light microscope with a digital camera attached at the African Minerals and Geosciences Centre (AMGC) Laboratory in Dar es Salaam, Tanzania (www.seamic.org). The minerals were studied in plane and cross polarized light, hereafter referred to as PPL and XPL respectively, as well as reflected light for the opaque minerals.

A camera mounted to the microscope was used to take pictures of the minerals and Atlas of rocks was used to identify the pottery sherds minerals, rock types and textures.

The fabric grouping and petrographic description were performed based upon the nature of the inclusions, clay matrix, grogs, and voids (Quinn, 2013, 44-68, 73–79, 83-100). Whitbread (1996) and Quinn (2013) systems criteria were used to characterize and describe the pottery fabrics compositional, textural (Mathew et.al., 1991) and shape to detect the presence of specific practices, such as clay mixing and the addition of different types of temper (Quinn 2013, 156–171).

Table 6.0: Petrographic thin section samples distribution

Site	Thin Section Number	Sample Designation	Excavation Unit	Level
Luxmanda	1	1302A	18	3
Luxmanda	2	1245	17	9
Luxmanda	3	1453	19	11
Luxmanda	4	1002	15	3
Luxmanda	5	2036	25	9
Luxmanda	6	1505	20	5
Luxmanda	7	1012	15	5
Luxmanda	8	1102	16	3
Luxmanda	9	1970	24	13
Luxmanda	10	2102B	26	3
Mumba II Eyasi	11	Z 0.52	19	10D
Mumba II Eyasi	12	Z 0.56	19	9C
Luxmanda	13	1620	21	9

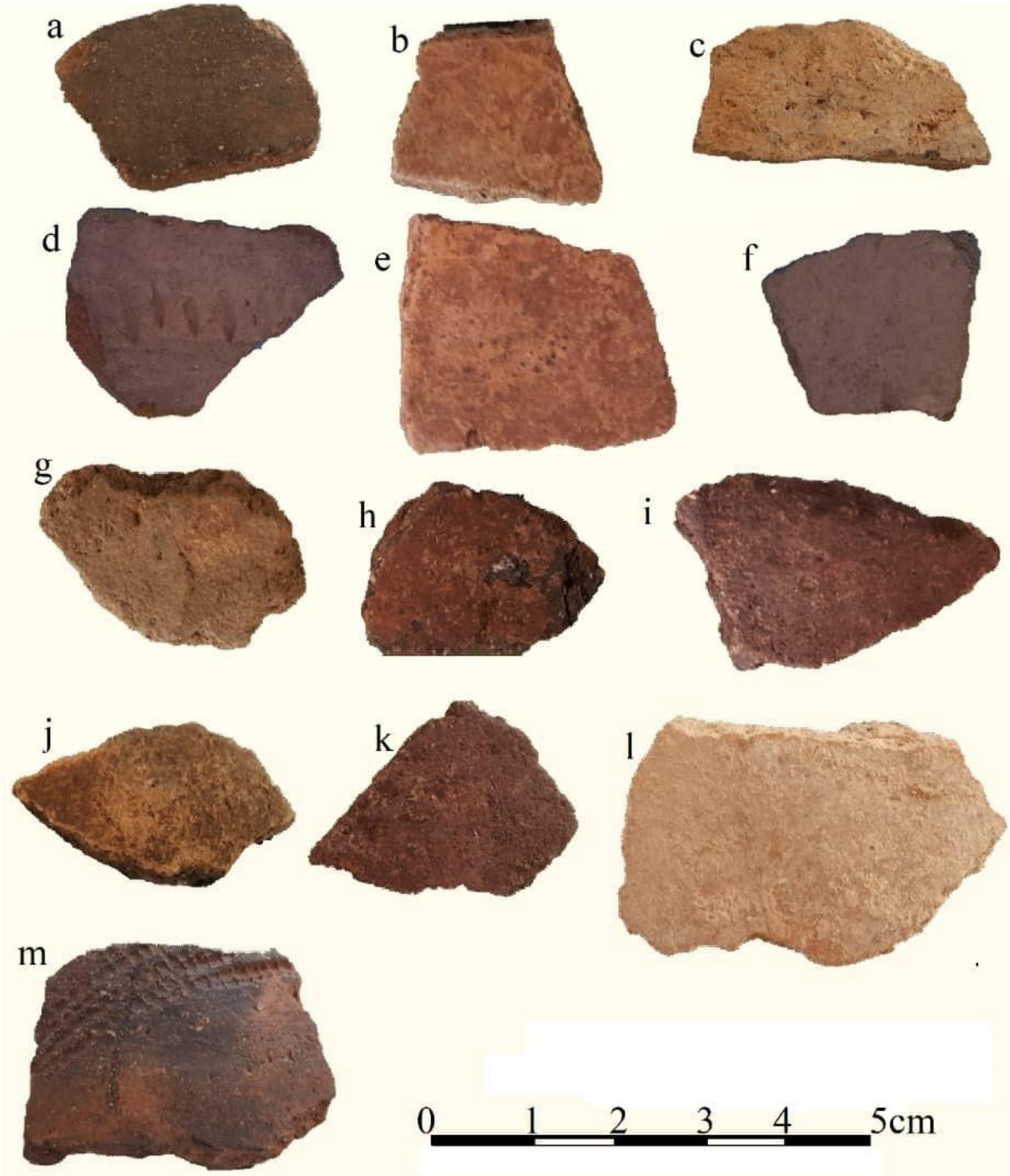


Figure 6.0: a (1002), b (1012), c (1970), d (Z 056), e (2036), f (Z 052), g (1453), h (2102), i (1505), j (1620), k (1302A), l (1245), m (1102). A-M: selected Narosura pottery sherds samples for petrographic thin section analysis.

6.4. Petrographic Thin-Sections Analysis Results

To describe the mineralogical composition of ancient ceramics, the material of the fine grained clay matrix has to be distinguished from the comparatively coarse grained inclusions, which was either added to the clay to improve its properties for shaping and baking or which has already been part of the clay as a residue from the original rock from which the clay developed (Riederer, 2004:145). In this study, the Narosura PN pottery fabric paste material were performed by distinguishing the ceramics on the basis of the main categories of matrix colours including buff, grey, pale red, black and into plastic or malleable and aplastic or non-plastic component based on their component characteristics (see Quinn, 2013:53). The plastic and non-plastic materials component make up the entire pottery matrix called paste (Quinn, 2013). The pottery plastic paste material component are predominately clay minerals and mostly consist of the clay minerals which react to changes in temperature. The process destroys the optical characteristics of the original clay thus thwarting the detection of the original clay (Rice, 1987:38). The petrographic observation of matrix has given the degree of sintering. In the buff pottery type the colour varies from beige to deep beige, while the red colour shades are pale red, and the grey colour also vary from deep grey to anthrax grey. On the other hand, aplastic material component comprised of non-clay mineral and rock fragments that can be identified through petrographic observation (Quinn, 2013). The crystal shape (angular, subangular, subround and round), size, and distribution of aplastic material were evaluated in this study. The presence of minerals, colour (textural and optical characteristics) and temper (intentionally added materials both organic and synthetic original) were also the evaluated (Whitbread 1996; Reedy 1994; Peterson and Betancourt, 2009; Quinn, 2013; see Table 6.1 and 6.2). The petrographic analysis results highlighted some main pottery fabric minerals, matrix, and inclusions. The analysis of the thin sections allowed to create a new subdivision of the material based on its main rock minerals (Table 6.2), fabric matrix and crystal contents distributional size (Table 6.1).

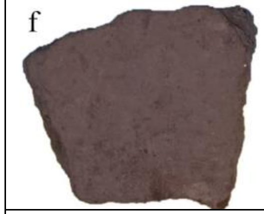
Table 6.1 Minerals, Clay matrix and Particulate Inclusions present in the pottery sherds thin sections samples

Main mineral inclusions and rock fragments identified by optical microscopy in thin-sections				
Sample Designation	**Thin Section Laboratory Number**	**Minerals identified in thin sections**		
		Inclusions	**Fabric Matrix Colour**	**Description and Distribution of Inclusion (sizes, shape and frequency)**
1302A 	1	This sample is representative of a pottery group has the high variability in all-textural and compositional characteristics. The structure of matrix is main yellow – brawn hyporystalline, and the red matrix rich in iron varies its texture from hyporystalline to microgranular. The matrix host aplastic inclusions with bimodal grane size distribution. Large inclusions are polygenic, mainly of granite and gneiss rocks and subordinate are the limestone grain. The strained grains of quartz do not have uniform extinction (undulose extinction for their metamorphic genesis), microcline, perthitic K-feldspars and plagioclase feldspar, subordinated with fine to medium grains of sericitic feldspar. Strong pleochroic yellow - brown biotite have green hues (incipient alteration in chlorite)	Pale red -brown to dark brown, parallel- Strongly elongated macropores probably due to relics of organic stems and calcination of carbonates	50-60% matrix derived to clay minerals. The non-clay components have low gran size selection with high proportions of coarse sand and relatively low proportions of fine sand and silt, average abundant are largest inclusions up to 4 mm (fine gravel). This non clay components marked by sub-angular metamorphic rock fragments composed of quartz and muscovite added as temper (possibly gneiss) and rounded plutonic rock fragments (probably granite), subordinate are the limestone grains. Also, fine grains of grog temper materials are fired ceramic inclusion materials intentionally crushed (pulverised) and added to the pottery plastic clay paste during pottery manufacturing process are observed in 5% amount
1245 	2	Fine Vegetal Tempered black Fabric This pottery are characterized by vesiculate vitrophyric matrix. The macro voids are prevalently linear in the matrix with a parallel stretch to the walls, with shape	From deep brown with red shades to very dark brown and black shades, strong fabric outlined by colour bands, Discontinuity fractures system	50-60% matrix derived to clay minerals. The non-clay components have a gran size average selection with high proportions of coarse sand and largest inclusions up to 4 mm (gravel) and rare largest inclusions up

		ratio from 0.05 mm to 2 mm that are due to vegetal materials and partially filled by secondary calcite. The high elongation of voids is probably due to organic material (dung, straw etc) of different origin used as plasticiser to improve workability and thermal shock resistance and toughness thereby preventing the propagation of cracks generated by the differential expansion of interior and exterior vessel walls upon heating or cooling Inclusions are felsic, and mainly composed to mega - grains of quartz and Sanidine subordinated with highly weathered perthitic K-feldspar and plagioclase feldspar, mica (biotite). Sericitization of feldspars.	parallel to the colour banded fabric.	to 4mm. The non-clay components marked by rounded plutonic rock fragments (probably granite, composed of quartz, feldspar and muscovite.
1453 g 	3	The pastes of antracite black colour have high sintering of matrix in a reducing atmosphere. However, it must be borne in mind that calcareous lumps in Ca-rich clay can prevent the formation of hematite crystals by fixation of Fe in the network of newly formed calcareous silicate and alumino-silicate minerals, consequently inhibiting the generation of a red colour in the fired pottery (Rice, 1987, 336). Inclusions are mainly of megacrystals quarts and feldspar, some grain have highly weathered perthitic K-feldspar, microcline, plagioclase feldspar subordinated with fine green and brown biotite. Sericitization of feldspars. The presence of hematite is locally observed both in the matrix and in the	Deep brown to very dark brown to black, strong fabric outlined by colour bands, Discontinuity fractures system flowing within the bands. The flow texture is also exhibit by the rest of the grain inclusions.	40-50% matrix derived to clay minerals. The distribution of grain size of non-clay minerals is bimodal with mainly fine rounded sand and the size angular inclusions largest up to 4 mm (very fine gravel) are on average abundant. Macro pores are observed probably produced by the use of the mixture with macerated vegetable substance to improve plasticity while micro and nano pore are rare for the high sintering grade of matrix

		altered granules		
1002 a 	4	The red ware pastes are high sintering matrix rich in iron oxide (Fe2O3) minerals may be present in clays used as the raw material in the production of pottery, these minerals can also appear during the firing of pottery as a product of the destruction of Fe-containing minerals present in the raw material and recrystallisation of secondary crystals. In an oxidising atmosphere, hematite crystals can be formed, which is responsible for the red colour of the pottery. Large inclusions mainly consisted of plagioclase, weathered feldspar subordinated with very fine quartz with strained extinction (under 20x obj.), hematite (brown).	Pale brown with some areas showing dark brown spots. Discontinuity fractures. The fabric shows a well-developed parallel orientation system of both the grains and the Discontinuity fractures.	55-65% matrix derived to clay minerals. The macro voids are high and have prevalently linear orientation in the matrix with a parallel stretch to the walls, with shape ratio from 0.05 mm to 1 mm that are due to vegetal materials and largest pores are partially filled by secondary calcite. The high elongation of voids is probably due to organic material (dung, straw etc) of different origin used as plasticiser to improve workability and thermal shock resistance and toughness thereby preventing the propagation of cracks generated by the differential expansion of interior and exterior vessel walls upon heating or cooling. Poorly sorted angular to sub angular silt to sand sized non-plastic inclusions. The rare largest inclusions are up to 3.5mm.
2036 e 	5	The structure of matrix varies from hyporystalline to glassy with elonged inclusions of iron hydroxides, Large inclusions are mainly of weathered feldspar subordinated with very fine quartz, microcline, plagioclase, epidote, iron oxide. Epidotization of feldspars.	pale brown with some areas showing very dark brown. Fabric outlined by colour bands. Voids, Discontinuity fractures in parallel and non-parallel orientation. Pseudomorphs of iron oxide after feldspar.	50-60% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. The largest inclusions above 4mm are composed of quartzite and gneiss gravels. The sintering temperature produced a partial destabilization of the granules. Relict of Biotite and Muscovite crystals are present. Fine grain of grog temper materials are

				fired ceramic inclusion materials intentionally crushed (pulverised) and added to the pottery plastic clay paste during pottery manufacturing process are observed
1505 	6	Large inclusions are mainly of quartz, weathered feldspar (plagioclase and perthite), sericite, pseudomorphs of iron oxide after feldspar. Sericitization of feldspars.	Very dark brown, partly show pale brown and colour band fabric, parallel and non-parallel Discontinuity fractures, parallel orientation of feldspar grains and Discontinuity fractures.	40-50% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. The largest inclusions measure above 4mm.
1012 	7	Main inclusions are medium to very fine grains of weathered feldspars, hematite (brown), plagioclase. Sericitization of feldspars.	Pale brown to dark brown, slight colour band fabric, Discontinuity fractures, parallel orientated grains, void filled with iron oxide.	50-60% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. The largest inclusions are up to 3.5mm.
1102 	8	Large inclusions are grog tempers of rock fragments (i) Feldspars enclosing finer grains of feldspar (ii) Fibrous green grain enclosing green and blueish biotite laths; grogs of pre-existing pottery (fibrous textured, brown); subhedral weathered feldspar stained with iron oxide, medium to fine grain weathered feldspar, iron oxide (black crystals). Epidotization of feldspars.	Dark red brown to black, parallel, and non-parallel Discontinuity fracture system, grogs	30-40% matrix derived to clay minerals, inhomogeneous, round to sub-round, euhedral to subhedral inclusions. Largest inclusion above 4mm. Rock inclusions (non-plastic component consists of medium-grade metamorphic rocks derived from sedimentary rocks (metapelites and metabasites) for which they are of different origin from the rest of the ceramics studied Fine grain of grog temper materials are fired, ceramic inclusion materials intentionally crushed (pulverised) and added to the pottery plastic clay paste during pottery manufacturing process are observed

1970 	9	Large inclusions composed of weathered feldspars, very fine mica	Pale brown to very dark brown to black, partly colour bands fabric, Discontinuity fractures, iron oxide melts	50-60% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. Largest grain up to 3.5mm.
2102B 	10	Large inclusions are mainly weathered feldspars subordinated with iron oxide grains (black)	Dark brown to very dark brown to black, randomly oriented Discontinuity fractures, voids filled with iron oxide	40-50% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. Largest grain measure above 4mm.
Z 0.52 	11	Large inclusions are mainly weathered feldspars subordinated with fine grained quartz, epidote. Epidotization of feldspars.	Dark brown to black, parallel flow textured Discontinuity fracture system, voids	30-40% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. Largest grain measures up to 2mm.
Z 0.56 	12	Large inclusions are mainly weathered feldspars subordinated with biotite (dark green) and iron oxide (black), epidote (yellowish green).	Pale brown, Discontinuity fractures	50-60% matrix derived to clay minerals, poorly sorted angular to sub angular silt to sand sized inclusions. Largest grain measures up to 3.5mm.
1620 	13	Large inclusions are mainly weathered feldspars	Pale red brown to dark brown, Discontinuity fractures, voids, grog temper composed of feldspars, quartz, and iron oxide	40-50% matrix derived to clay minerals, more poorly sorted angular to sub angular silt to sand sized inclusions. Largest grain measures up to 3.5mm. high percentage of non-plastic component consisting of large granules of granite rocks

6.4.1. Aplastic Inclusion Material Component Categories

The Aplastic or non-clay materials component were separated into three categories constituents: this included mineral grains or fragments of rock, grog, and voids. The general petrographic characterisation of aplastic materials observed in Narosura PN pottery from both Luxmanda (thin-section no. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13) and Eyasi-Mumba (thin section no. 11 and 12) sites are presented by photomicrographs (images) in Figure 6.1 to 6.26. The attempt to classify and characterise the aplastic materials herein were made according to the criteria and scheme developed for the ceramic petrographic thin-section analyses (see Whitbread 1996; Reedy 1994; Peterson and Betancourt, 2009; Quinn, 2013). The thin section photomicrograph (images) presented in this chapter were taken at x100 magnification.

6.4.1.1. Mineral grains Inclusions

Mineral grains inclusions in the samples were separated as follows: quartz, k-feldspar, plagioclase, Iron oxides, microcline, mica, epidote, calcite, biotite, and hematite (see Figure 6.1-6.14 photomicrographs). The most occurring minerals are indicated by red colour x mark (Table 6.2).

Thin Section Number	Sample Designation	Q	K	Pl	Cal	FeO	Ep	Mic	Bio	Mi	He	Gg	V
1	1302A	X	X	X	X			X	X				X
2	1245	X	X	X						X			
3	1453	X	X	X				X	X				
4	1002	X	X	X							X		
5	2036	X	X	X			X	X					
6	1505	X	X	X		X							
7	1012		X	X		X					X		X
8	1102		X			X	X		X			X	
9	1970		X			X				X			
10	2102B		X			X			X				
11	Z 0.52	X	X				X						
12	Z 0.56		X			X	X		X				
13	1620		X			X						X	X

Table 6.2: Thin section analysis of samples. Q=Quartz; K=K-Feldspar; Pl=Plagioclase; FeO=Iron Oxide; Mic=microcline; Mi=Mica; Ep=Epidote; Cal= Calcite; Bio=Biotite, Hematite; Gg=Grog*; V= Voids. *Grog is a technical term that indicates the use of shredded pottery in the raw materials.

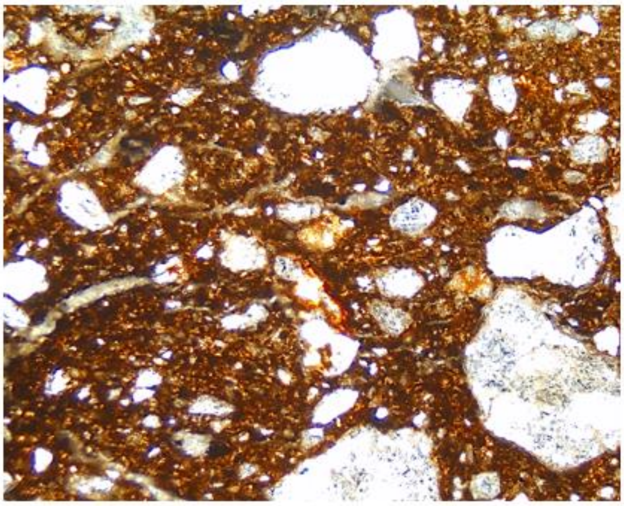


Figure 6.1 C: Sample no. 1, Discount fractures, perthitic K-feldspar, iron oxide stains on quartz grains and surrounding quartz grains.

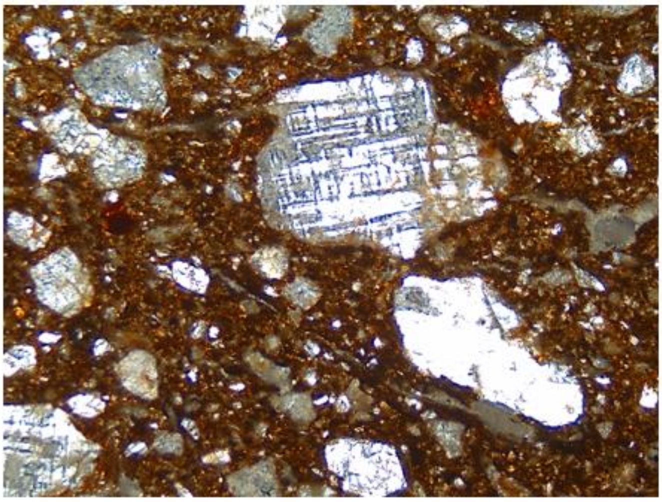


Figure 6.1 D: Sample no. 1, Perthitic K-Feldspar stained with iron oxide grain texture, silt to sand sized quartz grains.

Figure .6.1 C: Smple no.1, Discount fractures, perthitic K- feldspar, iron oxide stinson quartz grains nd surrounding quartz grains on sand sized quartz grains.

Figure 6.1 D: Sample no.1, perhitic – K- Feldspar stained with iron oxide grain texture, silt t

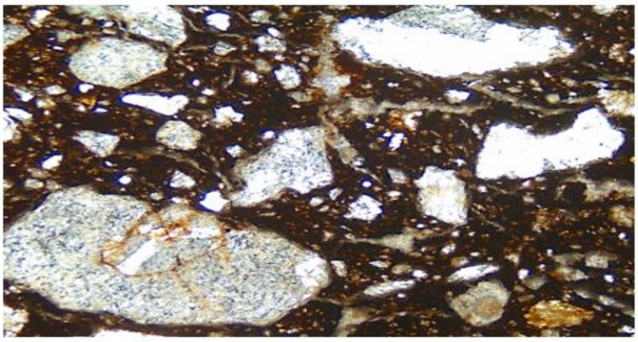


Figure 6.2 A: Sample no. 2, Sericitic feldspar (yellowish), highly weathered pathetic K-feldspar, discount fractures.

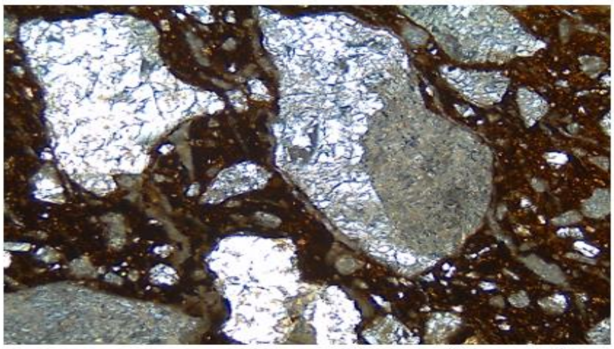


Figure 6.2 B: Sample no. 2, Highly weathered feldspars, discount fractures.

Figure 6.2 A: Small no.2, Sericitic feldspar (Yellowish) highly weathered pathetic K-feldspar, discount fractures

Figure 6.2 B: Sample no.2, Highly weathered feldspars, discount fractures

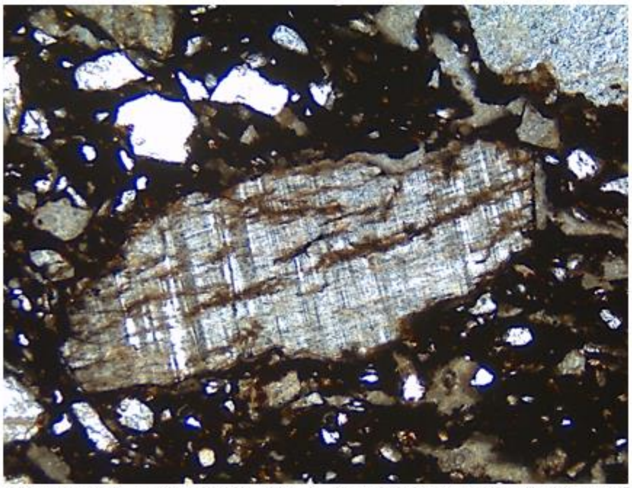
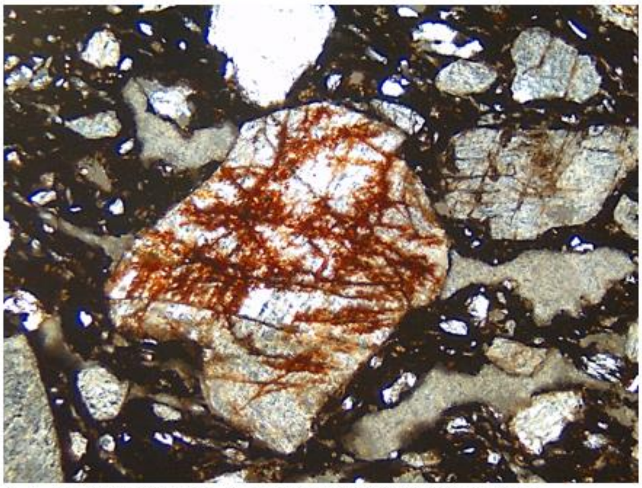


Figure 6.3 A: Sample no. 3, Microcline with strings of iron oxide (dark brown – magnetite/hematite) cutting across the exsolution lamellae.



6.3 B: Sample no. 3, Sericitized feldspar with crisscrossing strings of iron oxide (reddish brown hematite).

Figure 6.3 A: Sample no 3, Microcline with strings of iron oxide (dark brown – magnetite/hematite) cutting across the exsolution lamellae.

6.3 B: Sample no.3, Sericitized feldspar with crisscrossing strings of iron oxide (reddish brown hematite)

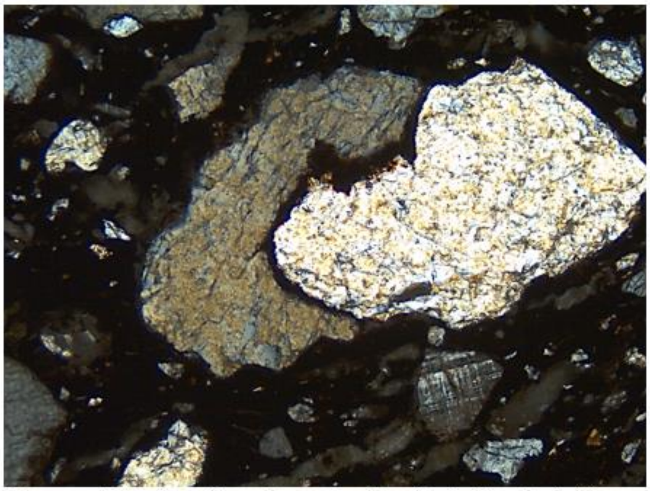


Figure 6.3 C: Sample no. 3, Sericitized feldspar. Originally seems to be a single crystal which was invaded with iron oxide melting that caused it to split in two. Perthitic feldspars.

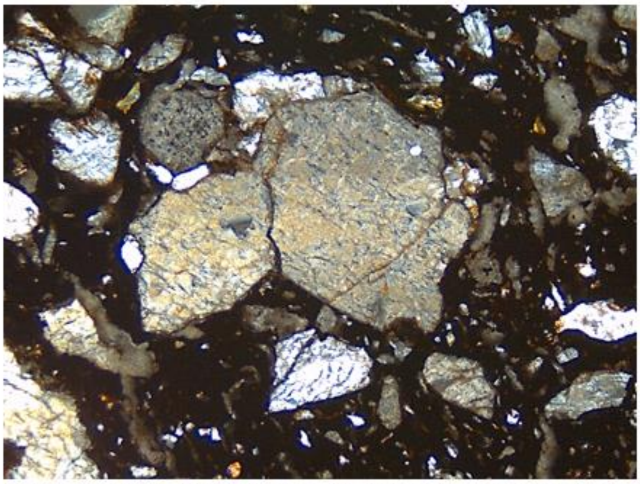


Figure 6.3 D: Sample no. 3, Iron oxide melts filling fractures in the sericitized feldspars.

Figure 6.3 C: Sample no 3, Sericitized feldspar

Figure 6.3 D: Sample no. 3: Iron oxide melts filling fractures in the sericitized feldspars.

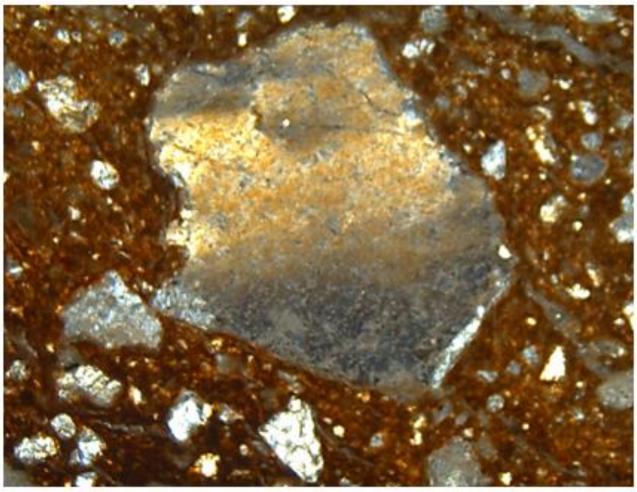


Figure 6.4 A: Sample no. 4, Highly weathered plagioclase feldspar.

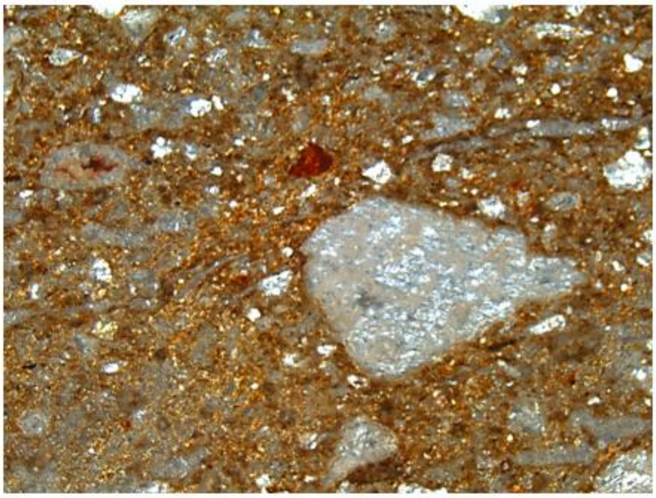


Figure 6.4 B: Sample no. 4 Hematite (brown), discontinuity parallel fractures.

Figure 6.4 A: Sample no.4, Highly weathered plagioclase feldspar.

Figure 6.4 B: Sample no. 4 Hematite (brown), discontinuity parallel fractures.

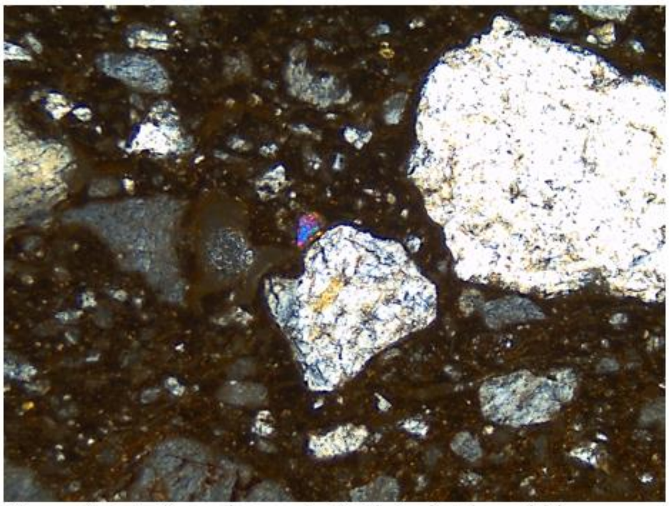


Figure 6.5 A: Sample no. 5, Epidote (pink and blue birefringent colours).

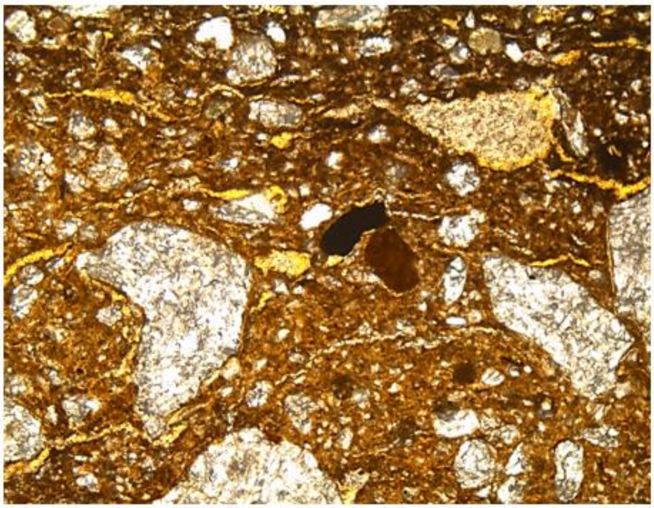


Figure 6.5 B: Sample no.5, Parallel and non-parallel discontinuity fractures, pseudomorphs of iron oxide after feldspar grains (PPL) (the black one with a slight bend).

Figure 6.5 A: Sample no.5, Epidote (pink nd blue birefringent colours.

Figure 6.5 B: Sample no.5, Parallel nd non – parallel discontinuity fractures, pseudomorphs of iron oxide after feldspar grains (PPL) (the black one with a slight bend)

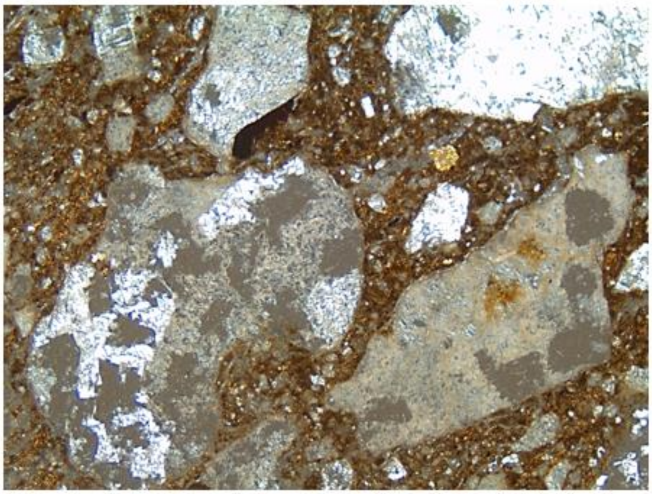


Figure 6.6: Sample no. 6, Weathered plagioclase feldspar with grayish inclusions (XPL).

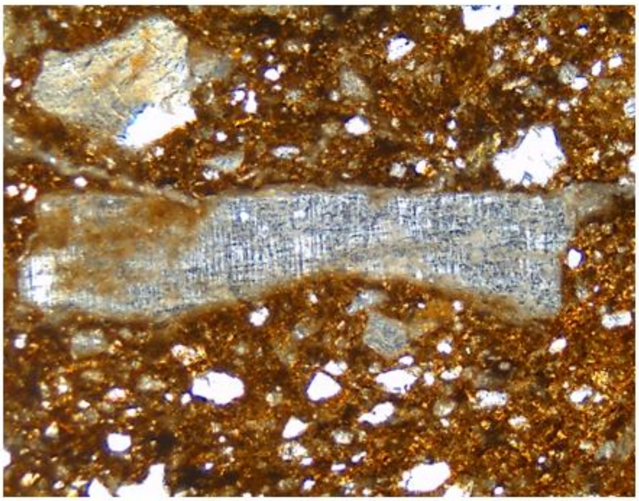


Figure 6.7: Sample no. 7, Weathered perthitic feldspar, weathered plagioclase feldspar. The plagioclase is undergoing sericitization.

Figure 6.6: Sample no. 6, Weathered plgioclase feldspr with grayish inclusions (XPL).

Figures 6.7: Sample no.7, Weathered perthitic feldspar, weathered plagioclase feldspar.

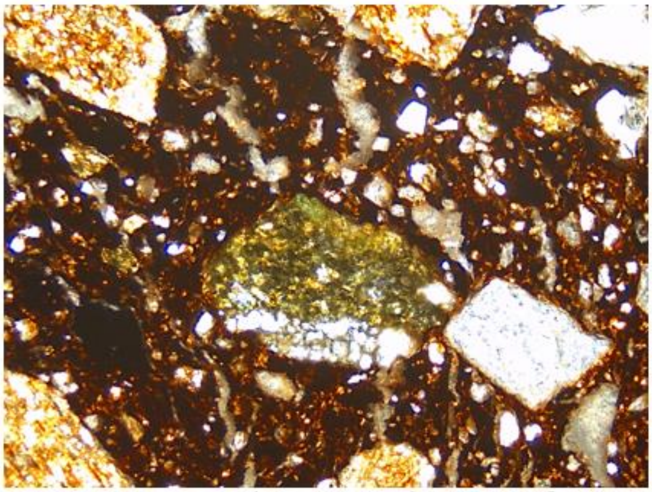


Figure 6.8 A: Sample no. 8, Epidotization of feldspar, iron oxide (black).

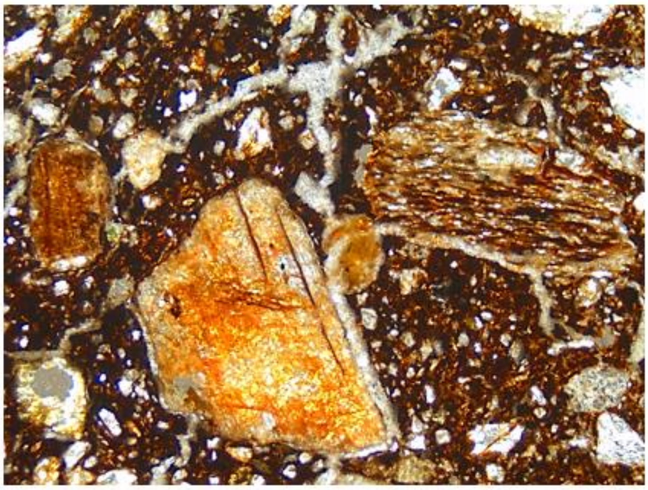


Figure 6.8 B: Sample no.8, Subhedral weathered feldspar stained with iron oxide. Carbonate are observed in the macropore and/or in the cracks that borders the large grains

Figure 6.8 A: Sample no. 8, Epidotization of feldspar, iron oxide (black).

Figure 6.8 B: Sample no.8, Subhedral weathered feldspar stained with iron oxide.

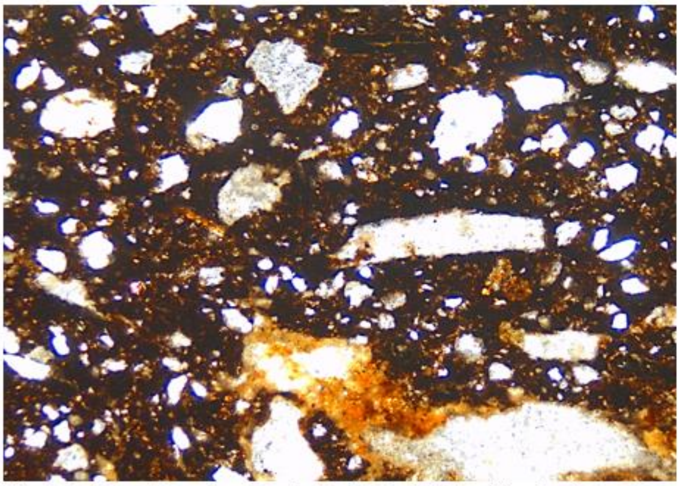


Figure 6.9: Sample no. 9, Euhedral to subhedral weathered feldspars, iron oxide melt (yellowish brown), very fine mica with pink birefringent seen in the lower left side of the image.

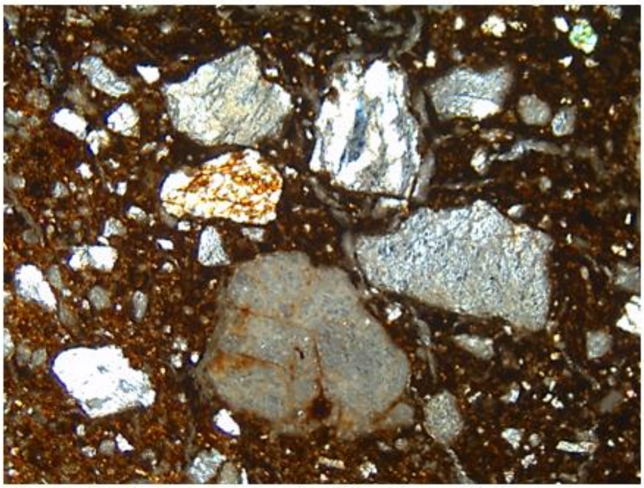


Figure 6.10: Sample no.10, Weathered feldspars.

Figure 6.9: Sample no.9, Euhedral to subhedral weathered feldspars,iron oxide melt (yellowish brown),very fine mica with pink birefringent seen in the lower left side of the image.

Figure 6.10: Sample no.10, Weathered feldspars

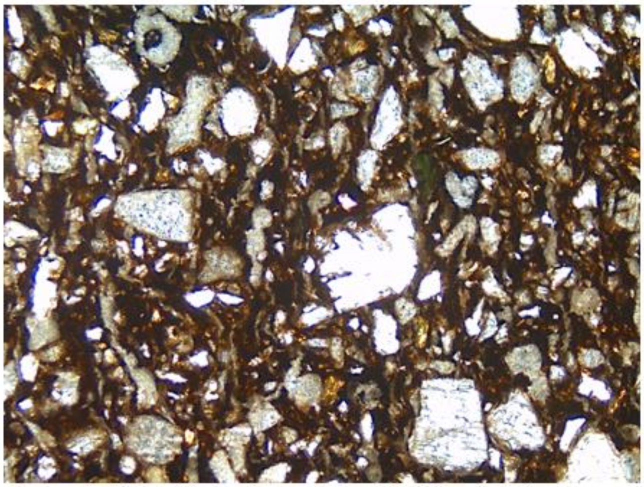


Figure 6.11 A: Sample no. 11, Epidotes (pink, yellowish - 3 grains), biotite (green), discount fractures. Non-plastic components consisting of monomineral granules of well-selected medium sands

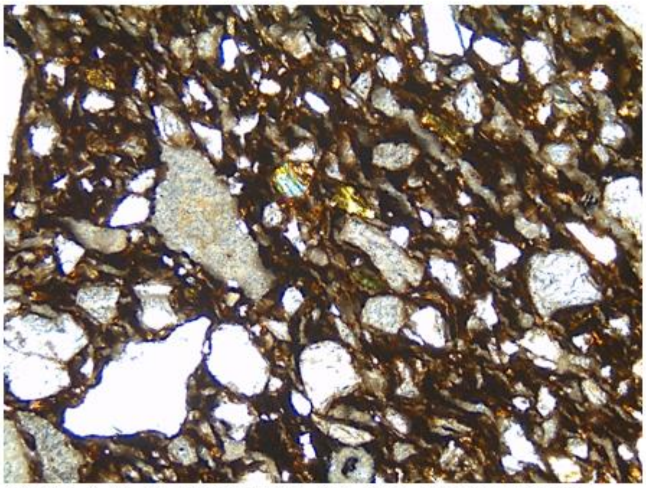


Figure 6.11 B: Sample no. 11, Fine grained quartz, epidote, parallel orientation of grains and discount fractures. Fine Vegetal Tempered black Fabric This pottery are characterized by vesiculate vitrophyric matrix.

The macro voids are prevalently linear in the matrix with a parallel stretch to the walls, with shape ratio from 0.05 mm to 0.5 mm that are due to vegetal materials and partially filled by secondary calcite. The high elongation of voids is probably due to organic material (dung, straw etc) of different origin used as plasticiser to improve workability and thermal shock resistance and toughness thereby preventing the propagation of cracks generated by the differential expansion of interior and exterior vessel walls upon heating or cooling.

Figure 6.11 A: Sample no.11, Epidotes (pink, yellowish – 3 grains), biotite (green), discount fractures.

Figure 6.11 B: Sample no.11, Fine grained quartz,epidote, parallel orientation of grains and discount fractures.

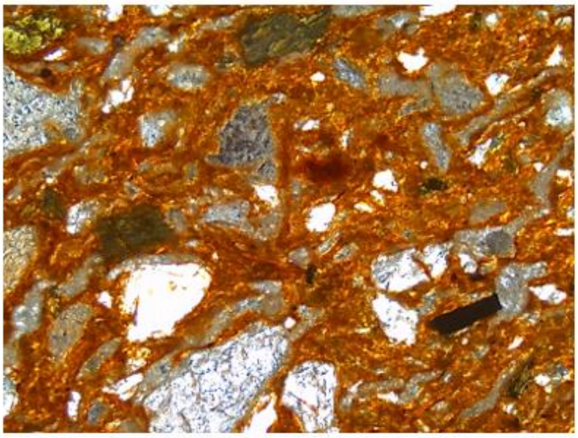


Figure 6.12: Sample no. 12, Weathered feldspars, biotite (green), iron oxide (black), epidote (light green), partially parallel orientation of grains.

Massive vitrophyric matrix of red colors characterized moderately abundant porosity and coarse grain non plastic inclusions. They have a low amount of very fine quartz silt in an abundant matrix of highly sintered clay rich in oxeide and idroxide of iron. The fine matrixes was obtained from purified clay and the very low porosity of groundmass with a homogenous color is due to the high sintered procedure and the dispersion in the matrix of very fine quartz microlithes is homogeneous. These texture features proved a regular sintered structure of studied potteries.

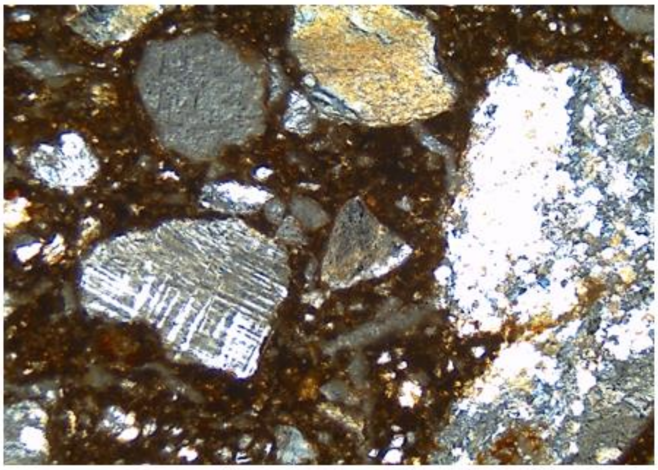


Figure 6.13: Sample no. 13, Weathered perthitic feldspars, discount fractures.

Figure 6.12: Sample no.12, Weathered feldspars, biotite(green),iron oxide (black), epidote (light green), partially parallel orientation of grains.

Figure 6.13: Sample no.13, Weathered perthitic feldspars, discount fractures.

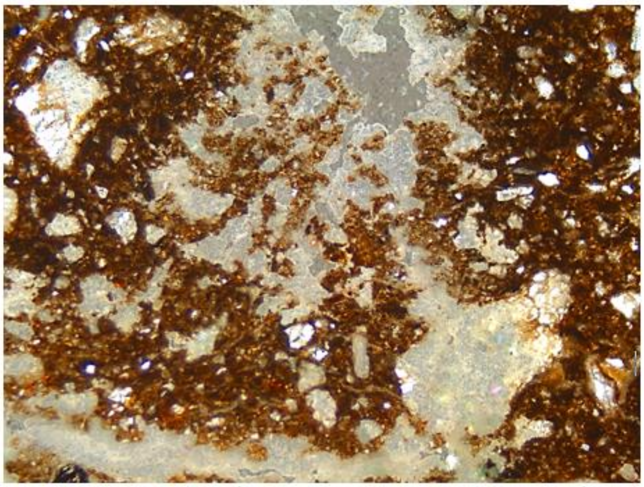


Figure 6.14 A: Sample no. 1, Limestone temper with voids in crossed polarized light (XPL).

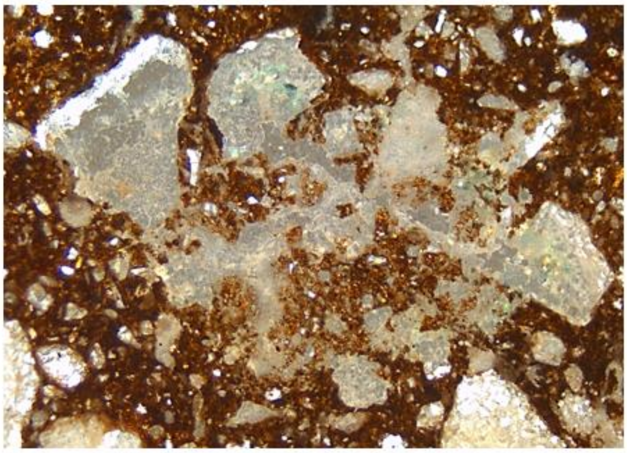


Figure 6.14 B: Sample no. 1, Limestone temper with voids in crossed polarized light (XPL).

Figure 6.14 A: Sample no.1, Limestone temper with voids in crossed polarized light (XPL)

Figure 6.14 B: Sample

6.4.1.2. Grog and Grit Temper Materials

Grog temper materials are fired ceramic inclusion materials (i.e., either old sherds or fire-hardened pieces of clay) (Figure 6.15 A) that are intentionally crushed (pulverised) and added to the pottery plastic clay paste during pottery manufacturing process (Whitbread, 1986; Quinn, 2013). The adding of grog by potters to the clay modify the clay’s workability or firing properties (Shepard, 1985; Rice, 1987:476; Herbert, 2009). On the other hand, Grit is a temper material comprising of crushed lithics (Figure 6.15 B), usually silicate-based lithics like granite, or feldspathic lithics, such as gabbro. Grit temper is distinguished from sand temper based on the size, angularity, and type of minerals existing in the grains (Reedy 2008: 133-139). The petrographic thin section observation of Narosura PN pottery samples revealed several grog and grit materials as seen in the following photomicrographs.

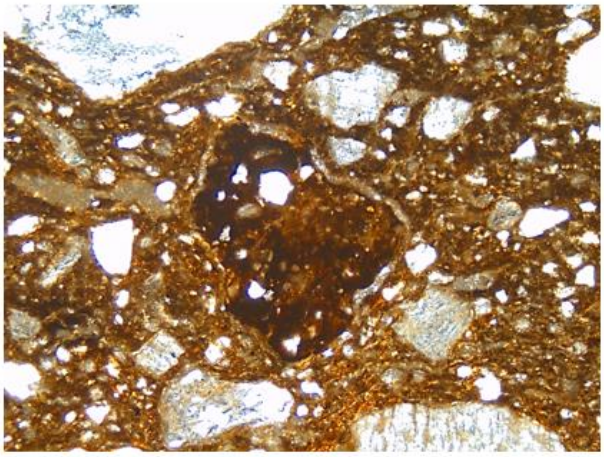


Figure 6.15 A: Sample no. 5, Grog of pre-existing pottery composed of iron oxide and feldspars.

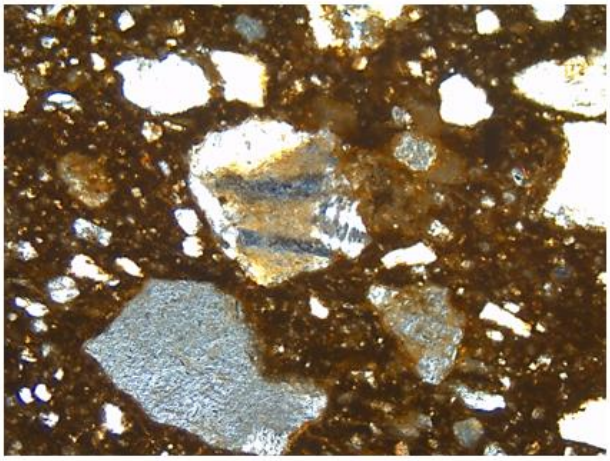


Figure 6.15 B: Sample no. 5, Grit temper of rock fragment (plagioclase and perthite) interlocking grains at the center of image.

Figure 6.15 A: Sample no.5, Grog of pre- existing pottery composed of iron oxide and feldspars.

Figure 6.15 B: Sample no.5, Grit temper of rock fragment (plagioclase and perthite) interlocking grains at the center of image.

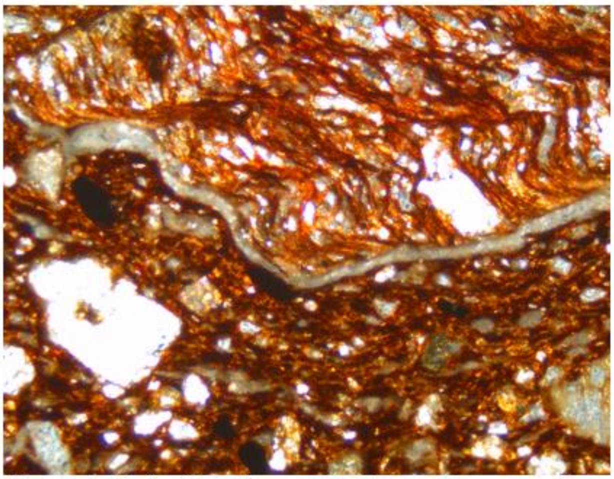


Figure 6.16 A: Sample no. 8, Grogs of pre-existing pottery (Fibrous textured, brown).

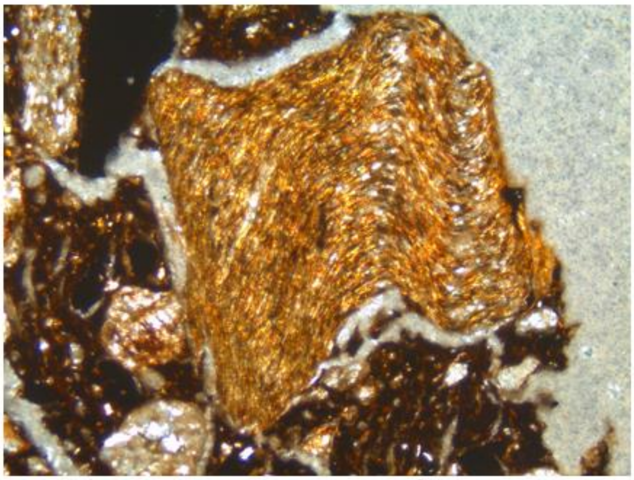


Figure 6.16 B: Sample no. 8, Grogs of pre-existing pottery (Fibrous textured – yellowish brown), iron oxide (black).

Figure 6.16 A: Sample no.8, Grogs of pre-existing pottery (Fibrous textured, brown)

Figure 6.16 B: Sample no.8, Grogs of pre-existing pottery (Fibrous textured- yellowish brown), iron oxide (black).

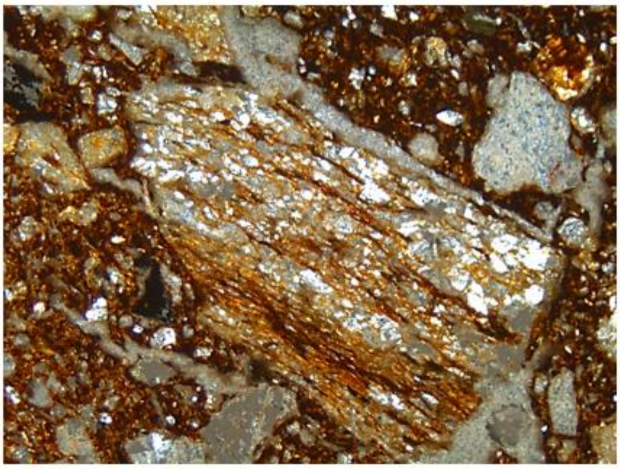


Figure 6.16 C: Sample no. 8, Grit tempers of rock fragments (Feldspars enclosing finer parallel oriented grains of feldspar with iron oxide strings).

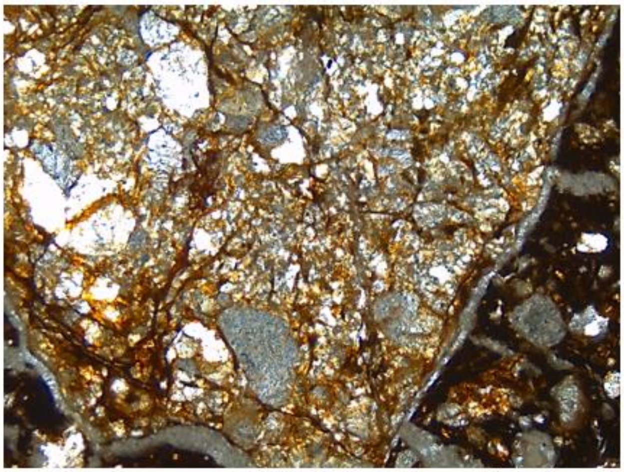


Figure 6.16 D: Sample no. 8, Grit tempers of rock fragments (Feldspars enclosing finer randomly oriented grains of feldspar with iron oxide strings).

Figure 6.16 C: Sample no.8, Gift tempers of rock fragments (Feldsprs enclosing finer parallel oriented grains of feldspar with iron oxide strings).

Figure 6.16 D: Smple no.8, Gift tempers of rock fragments (Feldspars enclosing finer randomlly oriented grains of feldspr with iron oxide strings).

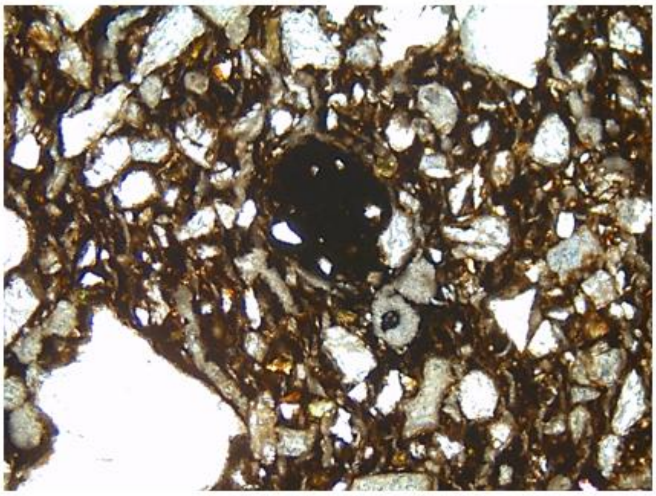


Figure 6.17: Sample no. 11, Grit of rock fragment (iron oxide, feldspar), and void (gray) filled with iron oxide (black).

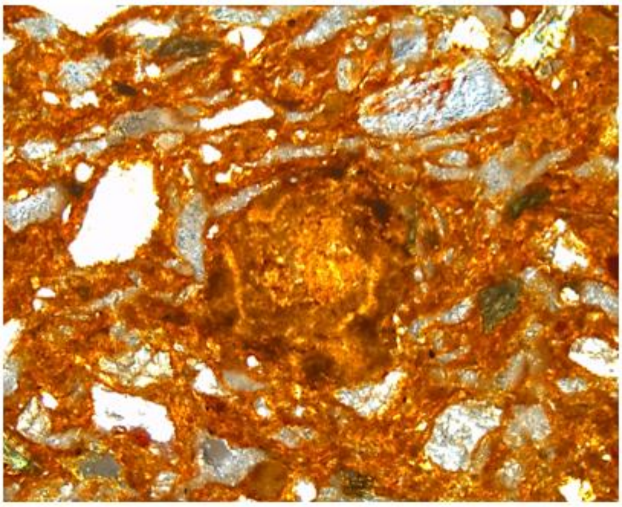


Figure 6.18: Sample no. 12, Grog of pre-existing pottery (roundish yellowish brown at the center of image) surrounded by parallel orientation of grains.

Figure 6.17: Sample no.11, Grit of rock fragment (iron oxide, feldspar). And void (gray) filled with iron oxide (black).

Figure 6.18: Sample no 12, Grog of pre-existing pottery (roundish yellowish brown at the centre of image) surrouned by parallel orientation grains

6.4.1.3. Voids Materials (Non-mineral phases)

Voids refers to holes or pores in thin section that dissects in ceramic samples. They influence the key physical properties of ceramics such as weight, toughness, thermal conductivity, permeability, and insulation (Shepard, 1956, 125-126; Quinn, 2013, 61). According to Peterson and Betancourt (2009:13) and Reedy (2008, 191-193), voids number, shapes and size of pores are indicatives of the way in which the ceramic fabric was prepared, or they occur due to release of gas or shrinkage of clay during drying and firing of ceramic materials. Quinn (2013, 61) also noted that, voids can either be present in the raw clay materials used to produce the ceramic or may be introduced at several stages in the life history of the artefact. The voids or pores encompassing pottery fabric can be detected in thin sections. During microscopic examination of the Narosura PN pottery thin sections material samples several voids were noticed as follows (Figure 6.19-26).

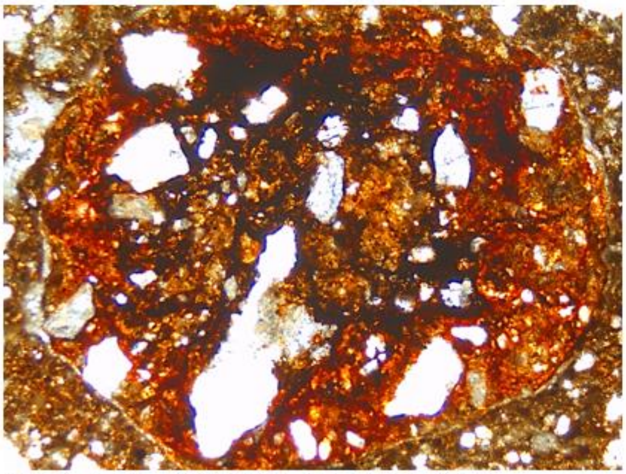


Figure 6.19: Sample no. 13, A ring voids surrounding grog temper composed of feldspars, quartz, and iron oxide.

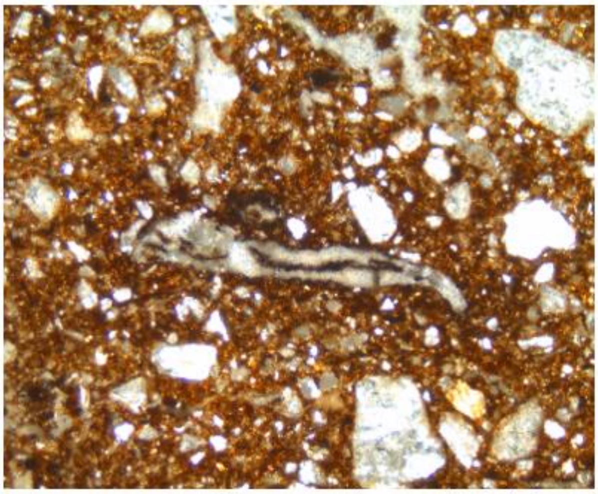


Figure 6.20: Sample no. 1, Elongated void (gray) at centre of image filled with iron oxide (black).

Figure 6.19: Sample no.13, A ring voids surrounding grog temper composed of feldsprs, quartz, and iron oxide

Figure 6.20: Sample no.1, Elongated void (gray) at centre of image filled with iron oxide (black)

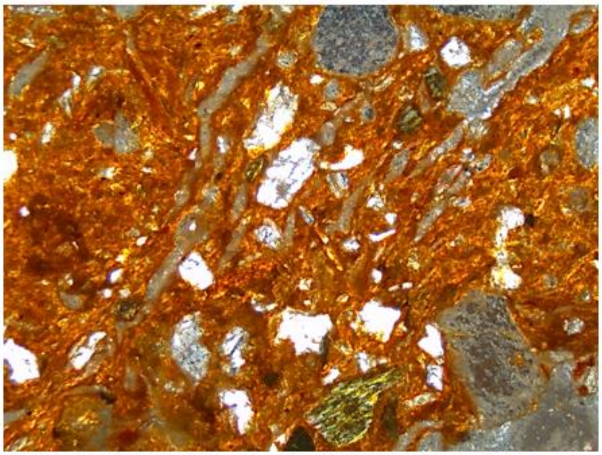


Figure 6.21: Sample no. 12, Parallel linear elongated voids discontinuity fractures likely caused by pressure during forming.

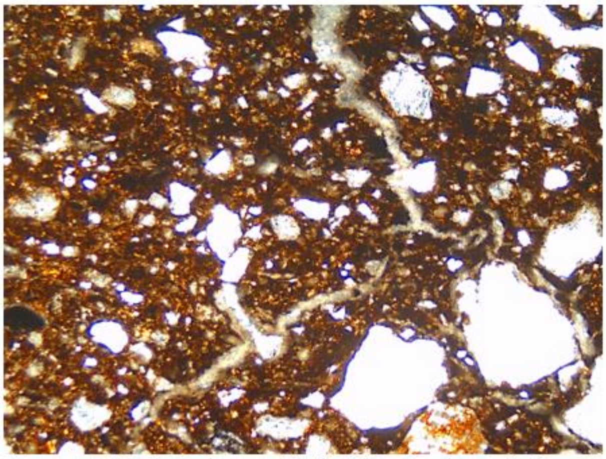


Figure 6.22: Sample no. 10, Randomly elongated branching, and ring Voids oriented discontinuity fractures associated with some inclusions.

Figure 6.21: Sample no.12, Parallel linear elongated voids discontinuity fractures likely caused by pressure during forming

Figure 6.22: Sample no.10, Rndomly elongated branching, nd ring voids oriented discontinuity fractures ssocited with some inclusions

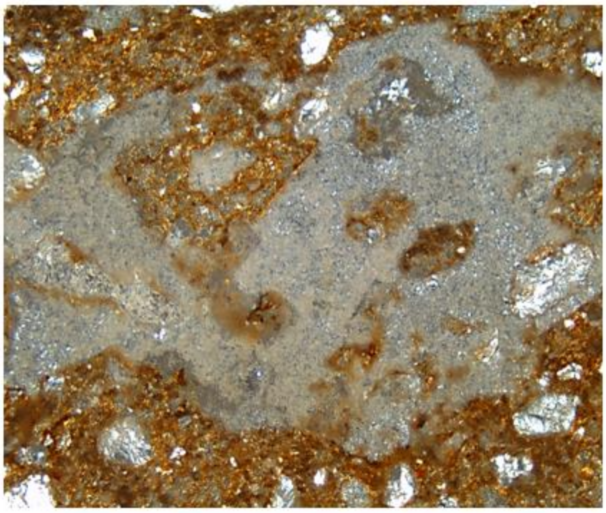


Figure 6.23: Sample no. 4, a large delta-like irregular shaped Voids appears to have experienced some melting. *Quinn (2013) termed it as Vughs voids.

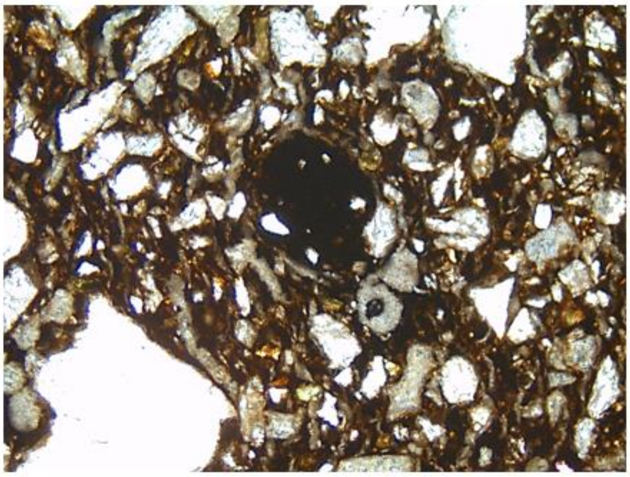


Figure 6.24: Sample no.11, Randomly vesicles and channels shaped Voids (gray) associated with rock (grit) inclusion (iron oxide, feldspar) in concentric coil. *see Stoops (2003, Figure 5.6,64).

Figure 6.23: Sample no.4, a large delt-like irregular shaped Voids appears to hve experienced some melting.

Figure 6.24:Sample no.11,Randomly vesicles and channels shaped Voids (gray)associatedwith rock (gift) inclusion (iron oxide, feldspar) in concentric coil.

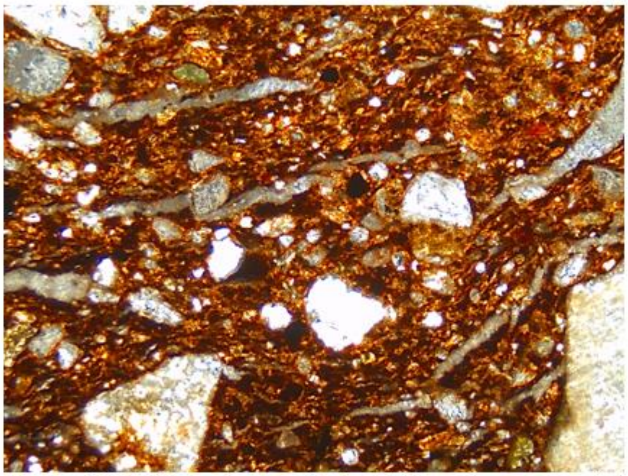


Figure 6.25: Sample no. 8, Parallel and non-parallel planar* voids discontinuity fracture system. *see Stoops (2003, Figure 5.6,64).

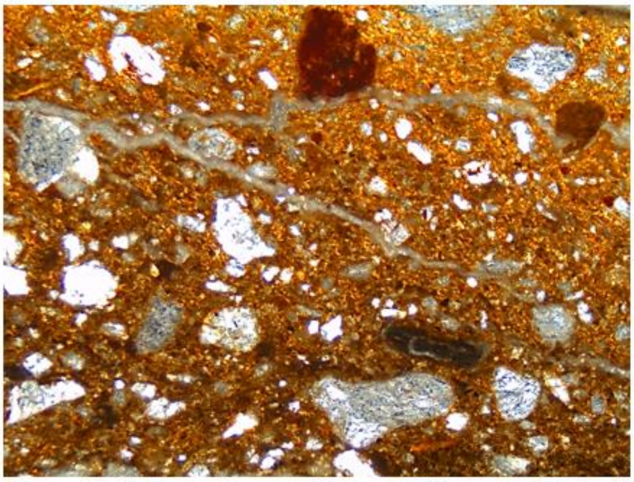


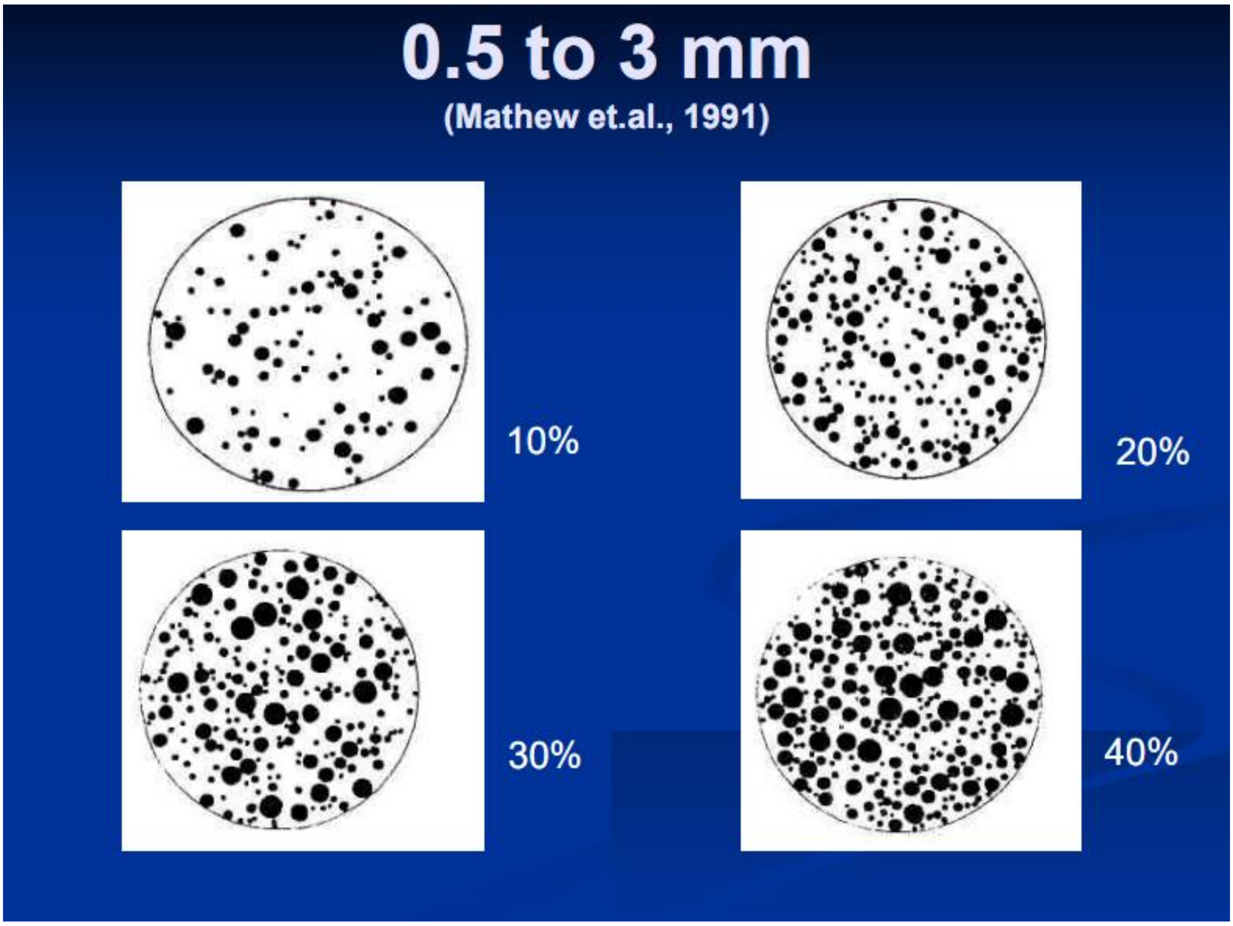
Figure 6.26: Sample no.7, Linear voids associated with Hematite (brown) and other inclusions, Void filled with iron oxide (black).

Figure 6.25: Sample no.8, Parallel and non –parallel planar* voids discontinuity fracture system.

Figure 6.26: Sample no.7, Linear voids associated with Hematite (brown) and other inclusions, void filled with iron oxide (black)

6.4.1.4. The Relative Abundance of Aplastic Inclusions

The relative abundance of non-plastic inclusions texture (grain size, grain shape and frequency) was determined based manual method by visually comparing overall grain area within the field of thin sections view (Mathew et.al., 1991; see Table 6.1 and Figure 6.27).



0.5 to 3 mm

(Mathew et.al., 1991)

Figure 6.27: Visual comparison chart for estimation of percentage area.

6.5. Discussion

6.5.1. Clay Paste Preparation Techniques

The results from this study suggest that both natural and modified clay were used for production Narosura PN pottery at Luxmanda. The petrographic observation made revealed different texture of both aplastic and aplastic inclusions. Based on the texture of the inclusions, their shapes differ in various stages from round to sub round and it is more likely that inclusion occurred naturally in the clay paste. Apart from that, the presence of angular to sub angular of the paste grains shapes were also observed that suggests the intentional adding of temper materials in the clay during pottery manufacturing. According to Stoltman (2001:301–305), the difference between deliberately added and naturally occurring materials in a paste can be problematic in ceramic analysis. To avoid such problems in ceramic paste analysis, Rice (2015:205) suggests the categories of inclusions that can be stated clearly to have been added to clays rather than occurring naturally are grog (angular fragments of crushed fired clay), quantities of volcanic rocks, and many kinds of organic matter. Basing on such tenets it is clearly that the Narosura PN potters added temper such as grog (fired clay mixed with iron oxide)/grit (crushed lithic materials) and other materials like organic matter. Voids were also evidenced from petrographic thin-sections samples (Figure 6.14-6.29) presented in this chapter. The variations observed in the tempering material grain sizes likely depended on the potters' standards (Figure 6.16 C) and method of paste preparations rather than the nature of tempering materials. In general, the raw clay material used for the production of the Narosura PN pottery appear to have been obtained and mixed from multiple (primary and secondary) sources due to the presence of round to sub round and angular to sub angular grains observed in thin-section. The primary geological sources are indicated by the angularity of the majority of the grains while secondary sources are derived from pre-existing rocks by weathering, redistribution, and deposition. The secondary source hypothesis is also supported by the presence of round to sub round nature of some of the grains.

6.5.2. Inclusion Particles Mineral Composition

The most on Narosura PN pottery samples were found to have rock and mineral inclusions. The major minerals across the pottery samples were quartz, feldspar, K-feldspar, and plagioclase. The other secondary minerals were iron oxide, microcline, mica, epidote; calcite, biotite, hematite, and other opaque minerals fragments (see Table 6.1 and 6.2). It was also a bit difficult to separate some inclusions mineral from some of the petrographic samples due to their conjugation in single aggregates form. For instance, some minerals like feldspar in quartz plus feldspar rock fragments formed K-feldspar (microcline), other samples also had both feldspar and plagioclase minerals. It was generally not possible to distinguish between plagioclase and alkali feldspar microscopically. The feldspar minerals were heavily weathered and altered as indicated by the presence of sericites and epidote minerals alterations. In addition to that, feldspar and quartz fragments also showed some graphic texture. The presence of graphic texture observed in some samples and abundance of K-feldspar suggests that the rock fragments are derived from an intermediate to felsic plutonic (granitic rocks) source (Harold, 1921). These mineral fragments are native to the Mbulu plateau region and well seen in the local soils. Except, for sample no. 1 containing limestone temper probably exotic minerals or rock fragments not seen locally in the Mbulu escarpment therefore, hypothesised to have been imported to the site (Figure 6.14 A and B) or formed due to calcite transformation into caustic lime at temperatures around 700°C (Riederer, 2004). On the basis of the composition of minerals, it is possible that the same or at the least very similar sources of the raw clay were used for manufacturing of Luxmanda Narosura PN pottery.

6.5.3. Pottery Manufacturing Methods

The thin-section study successfully identified a variety of manufacturing or shaping tecno-approaches. The paste mineral inclusions in sample showed admixture of sizes from fine, rounded, subround, angular and sub angular of both natural and additives inclusions mineral fragments. This indicates that the paste recipes were either collected naturally or added to clay with little or no purification. The workability and purity of the clay only noticed with the use of added tempers. A lack of clear internal preferred orientation of grains and the randomly distributed porosity also revealed that a minimum of working was done during the shaping process for Narosura pottery from Luxmanda site. Even though, a moderate degree of standardization of workability on paste recipes grains and purity of the clay for the Narosura PN pottery at Eyasi-Mumba site can be suggested (photomicrographs Figure 6.11A and B). The petrographic thin-section analysis suggests coiling, slabbing, and pitching as method of Narosura PN pottery shaping/manufacturing at Luxmanda. Quinn (2013:13) contends that, coiling method involves the sequential construction of a pottery vessels by means of successive coils or rope of clay that are rolled out by hands and applied in a circular movement. The coils are then joined in succession by bonding each coil to the next by wetting and smearing with hands. This method produces a concentric orientation (vertical sections) and strong preferred orientation parallel to the vessels wall (horizontal sections) inclusions and voids that are identified in petrography (Quinn, 2013; Thér, 2016). The thin-section characterisation of samples exhibits and support that coiling, slabbing and pitching techniques were used in both Luxmanda (Figure 6.8 A, Figure 6.2 A, Figure 6.16 A) and Eyasi-Mumba (Figure 6.24) sites. Although coiling formed by hand with clay anvil pitching was predominant for Narosura PN at Luxmanda.

6.5.4. Firing Processes

Firing is the most important process in ceramic production as it transformed pottery clay to irreversible hard ceramic structure. Though, the changes in pottery during firing are not only influenced by maximum temperature, but also the duration of firing in which the pottery soaks in maximum temperature (Quinn, 2013). The degree of possible equivalent firing temperature was estimated qualitatively by observing the thermal induced changes in clay matrix and specific mineral inclusions. The main target was explicitly on whether the clay matrix had been partially vitrified, whether calcite had been thermally dissociated, and whether there have been thermal adjustments obvious in minerals such as quartz. Petrographic thin-section evaluation on samples revealed that the firing was low and occurred in a reducing atmosphere. Thus, producing pottery with multiples colours with reduced iron oxides and microscopic quantities of carbon from organic matter (Table 6.1) as seen in the samples. Worth noting here, is the existence of both light and dark colours (oxidation and Reducing conditions) on a single sample (Table 6.1) that denotes firing clouding (Quinn, 2013; Reedy, 2008), and it is a results of pottery position to fuel source and ventilation during firing. The presence of frequent patches of oxidized materials in samples also confirmed that the firing conditions had been not nicely controlled. However, carbonised (black) spots and many voids (Figure 6.19-26) in most of the samples also applauds that many organic inclusions were burnt out of the clay fabric during firing respectively (Whitbread, 1982; Reedy, 2008). Nevertheless, following the presence of irregular dark areas observed in all of the samples investigated could highly indicate that reduced and perhaps organic rich zones were present. The lack of calcite disintegration (Figure 6.14 A and B) additionally suggests a low firing temperature and that pottery sherds did not reached high temperatures above 1000°C. A more detailed aspect of multiple colours for all samples is well articulated in chapter four of this thesis.

6.6. Chapter Conclusion

The petrographic thin-section provided a range of useful information about the nature of raw material, aplastic remains and the technological paste preparation of Narosura PN pottery. The fabric characterisation made accounts for local sources of the raw clay for pottery making in Luxmanda within the Mbulu plateau. This adds new insights and evidence on the ancient potters' knowledge and behaviour towards the preparation of the clay paste (adding tempering materials-organic, grogs, grits etc), forming and firing of the pottery vessels. Generally, the petrographic analysis data interpreted confirm the provenance of the Narosura PN pottery at Luxmanda site. The data analysed and interpreted herein will therefore form the first petrographic database for Tanzania and the future comparative studies with Narosura PN pottery sites in Tanzania and East Africa.

CHAPTER SEVEN:7

SCANNING ELECTRON MICROSCOPY (SEM-EDS/EDAX) CHARACTERISATION OF NAROSURA POTTERY FROM LUXMANDA SITE ON THE MBULU PLATEAU

7.1. Introduction

This chapter presents the compositional and microstructural analysis of Narosura PN pottery from Luxmanda by scanning electron microscopy coupled with energy dispersive spectrometry (SEM-EDS/EDAX). The compositional and microstructural analysis of PN pottery was done to address two aspects: first was to collect information pertaining to the texture and composition of the Narosura PN pottery paste; and second was to ascertain on Narosura PN pottery matrix markers to establish the provenance, and any possible alteration process. In particular, this chapter seeks to provide an understanding of the chemical composition of individual minerals in Narosura PN pottery sherds paste, as well as the possible occurrence and identification of diverse recipes from which Narosura PN pottery at Luxmanda was produced.

7.2. Material Analysis procedure and Methods

A total of twenty-four (24) samples were selected for scanning electron microscopy coupled with energy dispersive spectrometry (SEM-EDS/EDAX) for compositional analysis (Table 7.1; Figure 7.1). The strategy used was to randomly select two pottery sherds (i.e. decorated/non-decorated) from each excavation unit sampled bag containing ten (10) Narosura PN pottery sherds. Before accurate observation of the internal morphology of the samples by SEM-EDS/EDAX, each pottery sherd sample was cut and polished on a flat glass using silicon carbide powder to create a flat analytical surface. Due to the nature of the pottery sherds samples, no epoxy resin was used to harden the samples because there was no crushing of the samples that took place. After polishing the pottery sherds, they were thoroughly cleaned with a brush and water to remove the silicon carbide powder used for polishing. Since the samples were to be studied in high vacuum, careful drying of them at a maximum temperature of 35 C for 30 minutes in a vacuum drying oven was recommended in order to avoid delays in the SEM analysis as much as possible, although some modern SEMs can work with rather low vacuum, which alleviates this problem. The samples were not coated, and the microanalysis were carried out under variable pressure. The samples were therefore attached to the target holder by a conducting glue and analysed by SEM-EDS Zeiss EVO (MA 15) 50 scanning electron microscope equipped with an INCA Energy 300 Oxford EDS microanalysis system using 18 kV, 0.12 nA, 100 s counting time and 8.5 mm working distance (Figure 7.0). Elemental data were prepared using the INCA Energy 300 software, calibration was carried out by cobalt, and the obtained data were normalised to 100%. The chemical composition of the samples was studied by EDS/EDAX (Table 7.2).

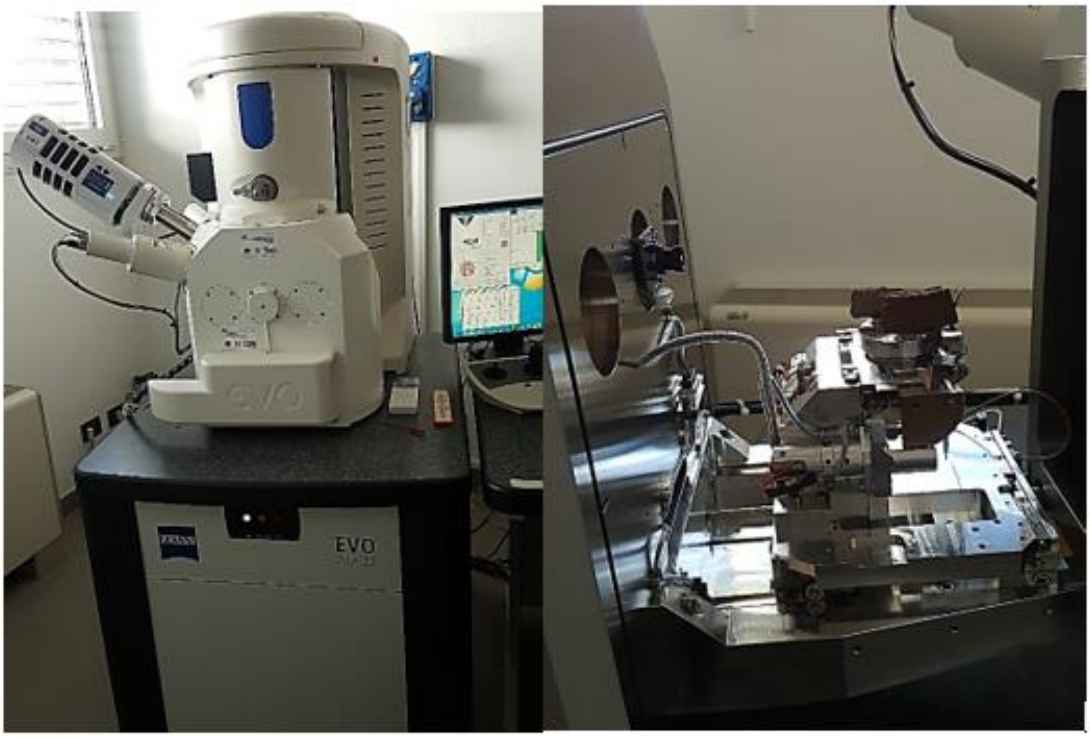


Figure 7.0: SEM-EDS Zeiss EVO (MA 15) 50 scanning electron microscope equipped with an INCA Energy 300 Oxford EDS microanalysis system.

Table 7.1: Physical attributes of designated Narosura PN pottery sherd samples.

s/n	site	sample designation	fabric colour *MUNSEL		
			core	internal	external
1	Luxmanda	2149	black	very pale brown	light yellowish brown
2	Luxmanda	1140	brown	brown	strong brown
3	Luxmanda	1114	very dark gray	grayish brown	grayish brown
4	Luxmanda	2111	black	dark gray	grayish brown
5	Luxmanda	1015	very dark gray	brown	brown
6	Luxmanda	1012	dark gray	yellowish brown	pale brown
7	Luxmanda	1431	very dark grayish brown	grayish brown	brown
8	Luxmanda	1327	very dark gray	dark grayish brown	grayish brown
9	Luxmanda	1450	dark gray	pale yellow	light olive brown
10	Luxmanda	1340	black	very dark gray	dark greyish brown
11	Luxmanda	1502	black	brown	reddish yellow
12	Luxmanda	1616	very pale brown	yellowish brown	light yellowish brown
13	Luxmanda	1513	black	pale yellow	light brownish gray
14	Luxmanda	1613	very dark gray	dark grayish brown	dark grayish brown
15	Luxmanda	Surface collection	black	dark grayish brown	dark grayish brown
16	Luxmanda	2002	yellowish brown	light yellowish brown	brown
17	Luxmanda	2015	black	dark grayish brown	grayish brown
18	Luxmanda	1206	very dark gray	very dark grayish brown	dark grayish brown
19	Luxmanda	1234	very dark gray	dark gray	grayish brown
20	Luxmanda	1912B	black	very dark grayish brown	very dark gray
21	Luxmanda	1906	very dark gray	light olive brown	grayish brown
22	Mumba II Eyasi	Z 0.63 20/11D	black	light brownish gray	gray
23	Mumba II Eyasi	Z 0.67 20/11D	gray	brown	gray
24	Mumba II Eyasi	Z. 0.51 19/9D2	dark gray	reddish brown	reddish gray

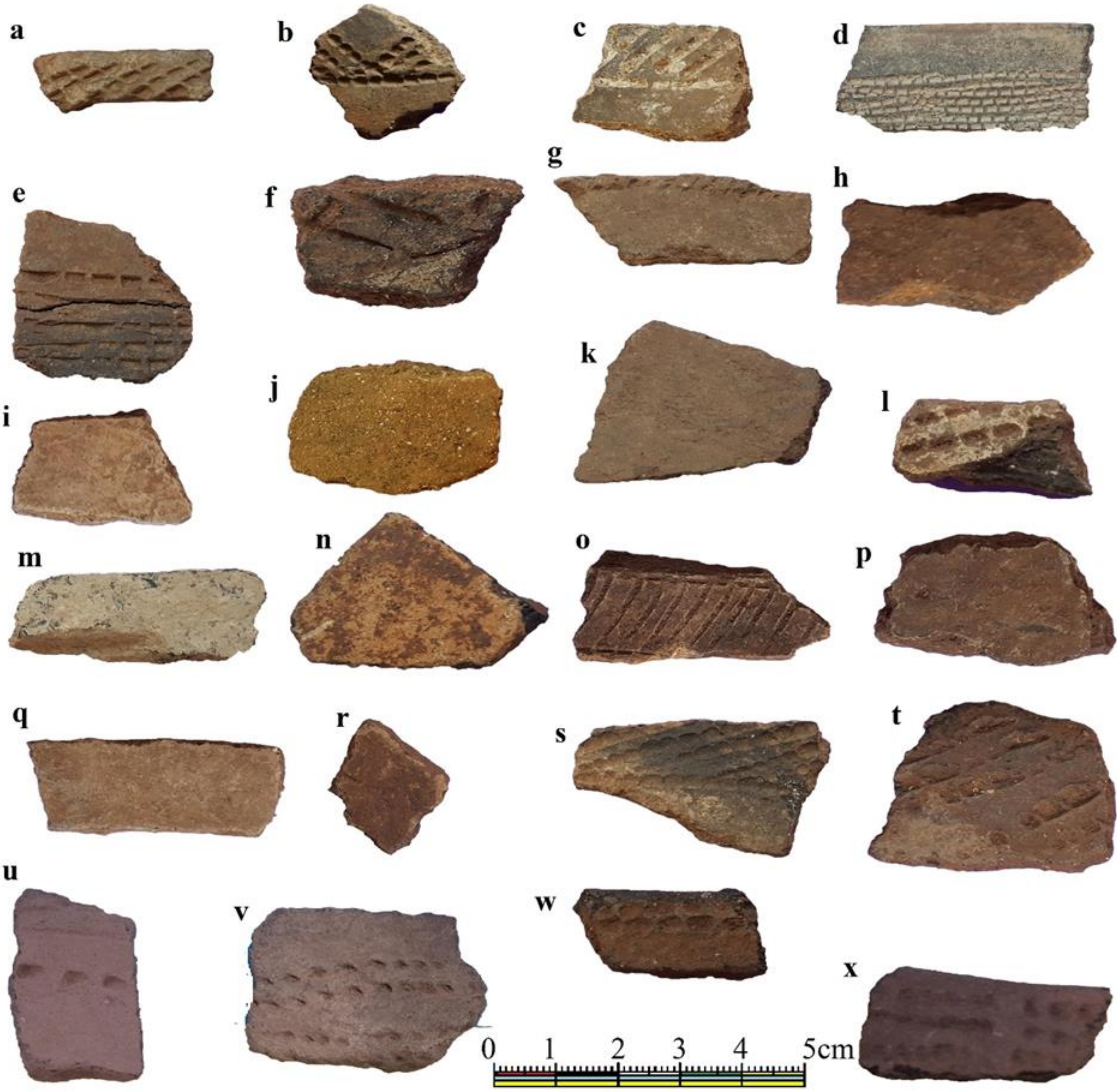


Figure 7.1: Pottery sherds Sample for SEM-EDS analysis A (1114), B (1327), C (1234), D (Surface) E (1015), F (1912), G (1450), H (2002), I (1012), J (1206), K (1431), L (1513), M (1140), N (1502), O (1616), P (1613), Q (2149) R (1906), S (1340), T (2111), U (Z.051 19/9D), V (Z.067 20/11D), W (2015), X (Z. 063 20/11D).

7.3. SEM-EDS/EDAX Analysis Results

SEM-EDS analysis revealed that the pottery material matrix of all investigated Narosura PN pottery samples, mainly constitutes of C, O, Na, Mg, Al, Si, P, S, K, Ca, Ti, Fe, Cl, Mn and Ba elements. The dominant matrix in the observed samples is composed of Si, O, C, Al and Fe and are of very large percentage (Table 7.2.). The concentration of C is probably due to the presence of organic carbon. Generally, the samples indicated that the materials could be rich in potassium feldspar, sodium feldspar or calcium feldspar (KAlSi3O8 – NaAlSi3O8 – CaAl2Si2O8). A detailed description and composition analysis of each pottery sample is presented below.

Table 7.2: Elemental analysis data for the selected Narosura PN pottery samples as acquired by EDAX.

Sample name	**C**	**O**	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**K**	**Ca**	**Ti**	**Mn**	**Fe**	**Ba**	**Total**
Z.063	9.37	55.39	0.94	0.96	5.63	19.04	0.11			1.9	1.6	0.39	-	4.66		100
Z.051	7.88	54.41	1.36	1.25	5.14	21.85	0.06	0.06	0.05	1.38	1.0	0.52	-	5.02		100
1206	8.47	45.99	0.48	0.41	4.52	32.89	0.27			1.3	1.01	0.61		4.04		100
1234	9.33	48.82	0.47	0.5	5.56	28.45				1.95	1.01	0.52		3.41		100
1327	11.44	58.17	0.48	0.37	6.71	16.53	0.46			1.11	1.34	0.34		3.03		100
1431	8.7	48.54	0.4	0.75	9.34	21.53	0.57			1.93	1.74	0.67	0.33	5.94		100
1340	12.19	58.31	0.09	0.53	5.55	13.44	1.83	0.04		0.85	3.72	0.34	0.15	2.95		100
1513	6.99	53.25	0.64	0.6	8.74	20.04	0.81		0.18	2.41	0.75	0.37		4.3	0.94	100
1613	7.87	53.94	0.68	0.25	7.56	19.09	1		0.12	1.89	1.15	0.9		4.25	1.3	100
1616	9.1	56.03	0.5	0.25	5.18	20.84	1.05		0.07	2.28	0.92		2.7	1.09		100
1906	10.92	58.38	0.55	0.33	4.48	20.11	0.37			1.45	0.61	0.45		2.36		100
2015	4.85	51.76	5.9	0.52	8.11	23.85	0.47			0.6	0.89	0.25		2.82		100
2002	5.94	52.15	0.58	0.3	10.03	20.95	0.11		0.05	3.44	0.65	0.94		4.86		100
2149	9.17	47.64	0.25	0.92	10.07	21.14	0.57			2.35	1.42	0.79		5.68		100
2111	9.49	53.39	0.22	0.2	3.43	30.27	0.16			0.51	0.43	0.19		1.71		100
1140	13.85	48.03	0.39	0.8	7.02	19.86	0.36			1.81	3.05	0.59		4.24		100
1114	8.16	53.34	0.32	0.7	8.14	20.48	1.2			1.79	1.48	0.53		3.87		100
1012	12.47	45.18	0.15	0.68	9.16	16.61	2.34	0.1		1.5	5.48	0.69	0.34	5.21		100
1015	7.3	49.1	0.37	0.7	8.91	21.92	0.59	0.07		2.54	1.8	0.77		5.93		100

C=Carbon, O=Oxygen, Na=Sodium, Mg=Magnesium, Al=Aluminium, Si=Silicon, P=Phosphorus, S=Sulphur, Cl=Chlorine, K=Potassium, Ca=Calcium, Ti=Titanium, Mn=Manganese, Fe=Iron, Ba=Barium

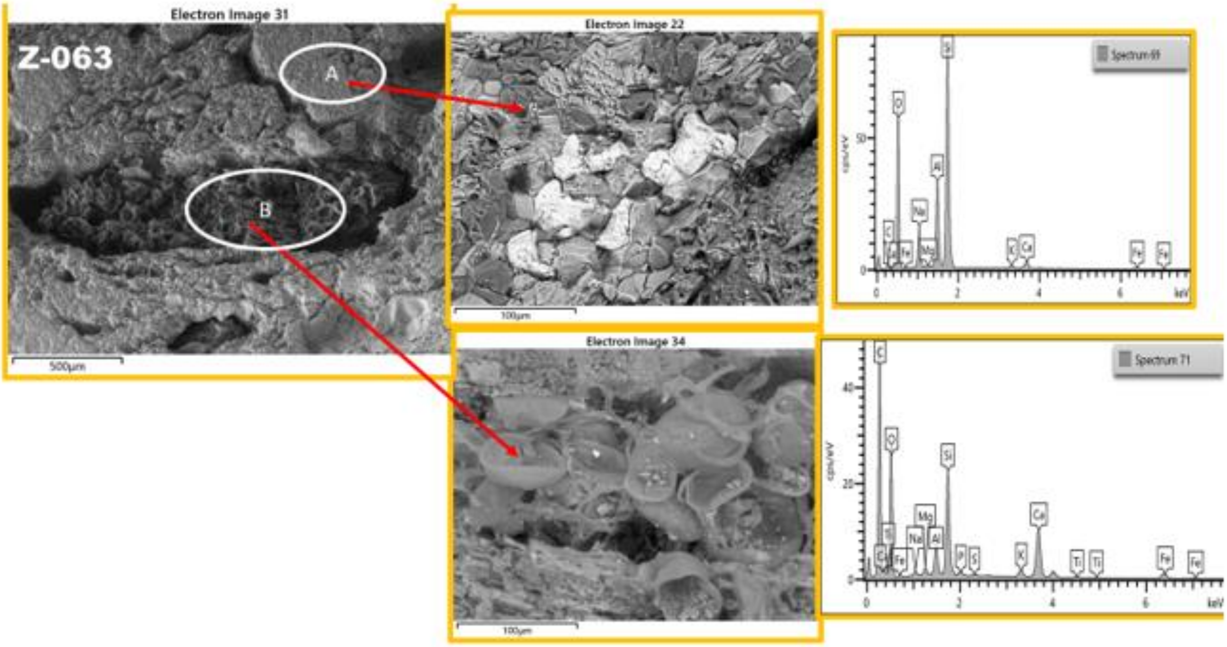


Figure 7.2: Sample Z 0.63 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

Z. 063: The sample showed the presence of fine particles with different morphologies. It can be seen that the sample exhibits irregular particles (A) and spherical plate like–particles (B). EDAX analysis revealed that the sample contain C, O, Na, Mg, Al, Si, P, S, K, Ca, Ti and Fe elements. Thus, the materials could be potassium feldspar, sodium feldspar or calcium feldspar ($KAlSi_3O_8$ – $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$). Further analysis, of the samples at higher magnifications indicates that part A lacks Ti, P and S whilst part B contains all of the above-mentioned elements. Part B is also very rich in C and O while part A has less C and O and plenty of metals. This indicate that the clay materials for making pottery were obtained from different sources (Figure 7.2).

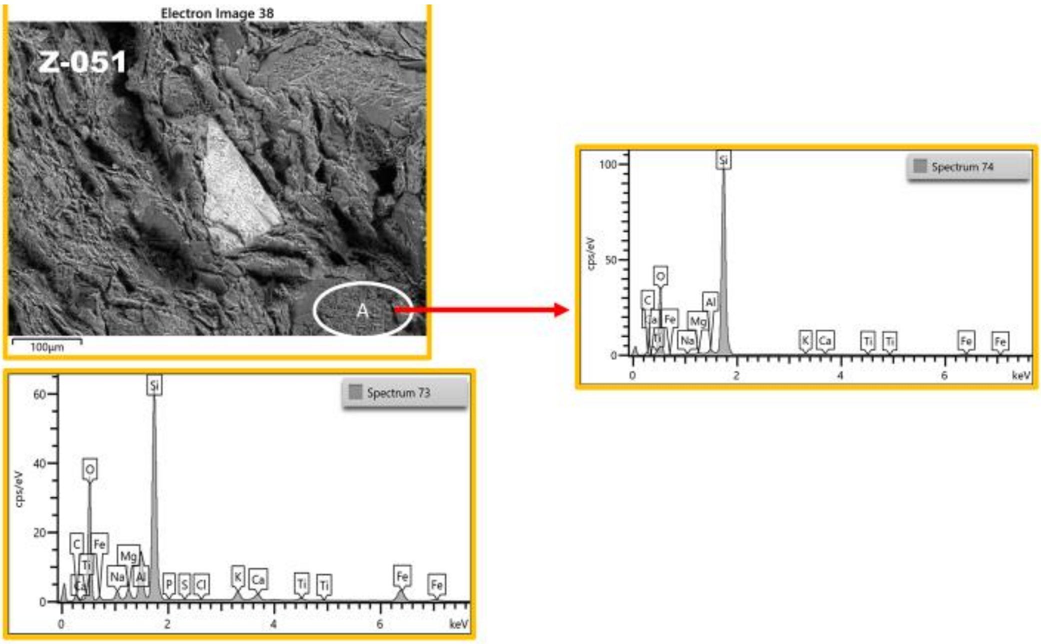


Figure 7.3: Sample Z 0.51 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

Z.051: The sample shows the presence of fine particles with different morphologies and a porous structure with distinct inclusions that seem to lack phosphorus, sulphur and chlorine elements. EDAX analysis reveals the presence of C, O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti and Fe elements (Figure 7.3).

1015: The sample shows the presence of fine and interconnected irregular particles. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, S, K, Ca, Ti and Fe elements (Figure 7.4).

1114: The sample shows the presence of fine and interconnected surface. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.4).

1140: The sample shows the presence of fine irregular particles. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.4).

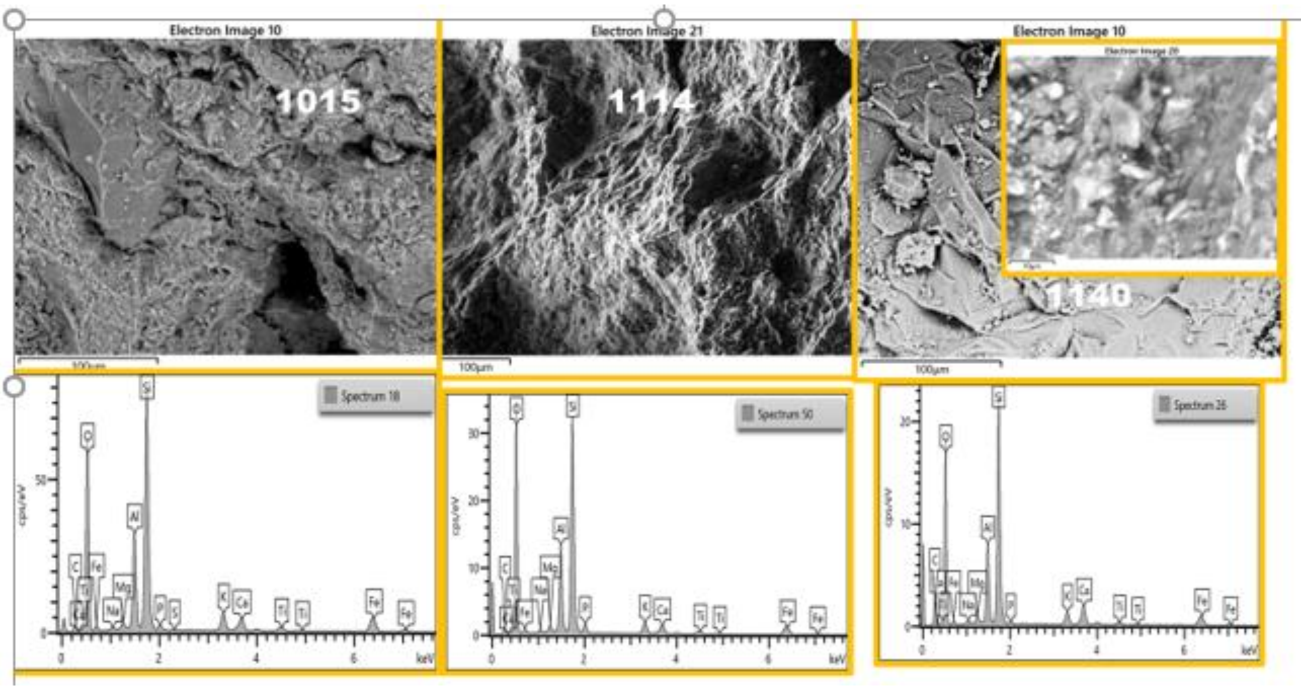


Figure 7.4: Samples 1015, 1114 and 1140 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

2111: The sample shows the presence of small spherical aggregates. Higher magnified images show the presence of porous structures. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.5).

2149: The sample shows the presence of small spherical and rod-like aggregates. Higher magnified images show the presence of spherical. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.5).

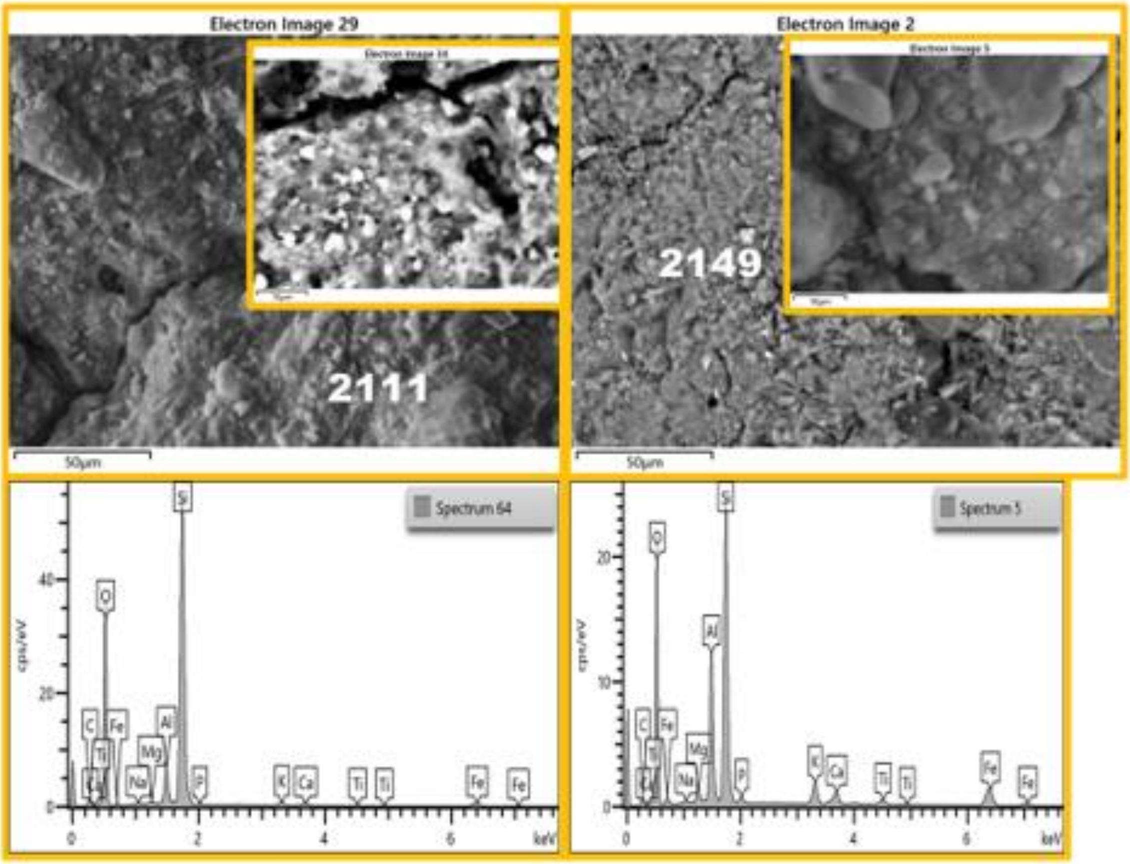


Figure 7.5: Samples 2111 and 2149 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

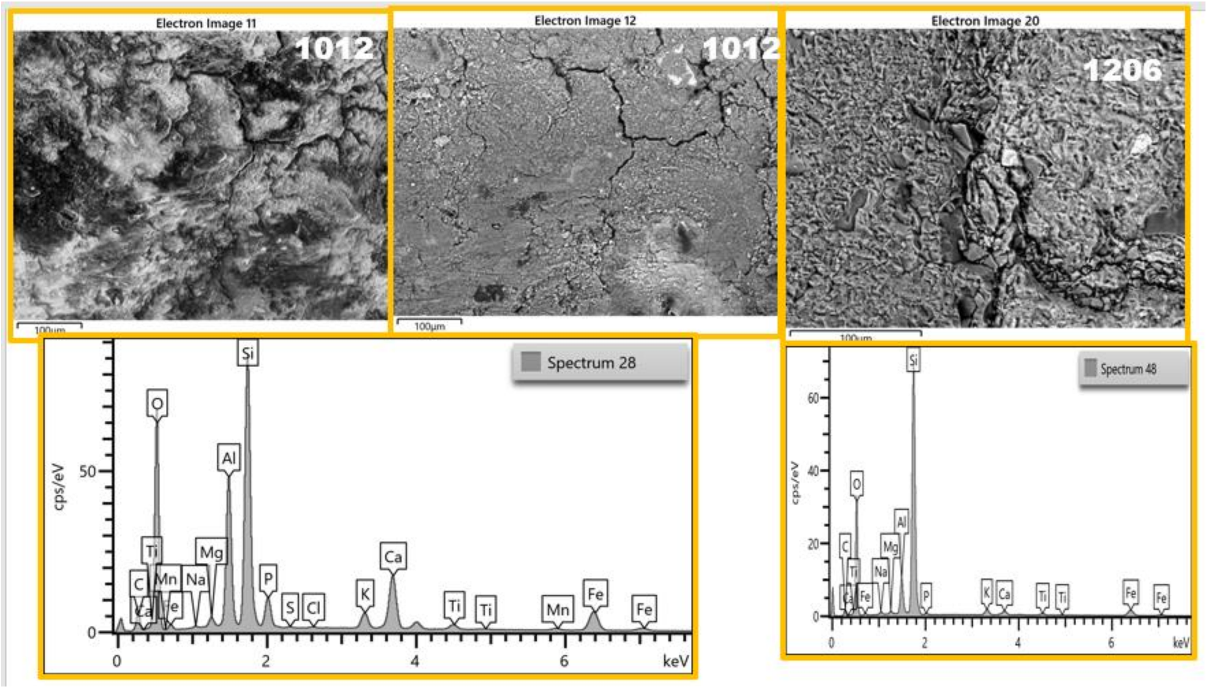


Figure 7.6: Samples 1012 and 1206 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

1012: The sample shows the presence of irregular structures. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, S, Cl, Mn, K, Ca, Ti and Fe elements (Figure 7.6).

1206: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.6).

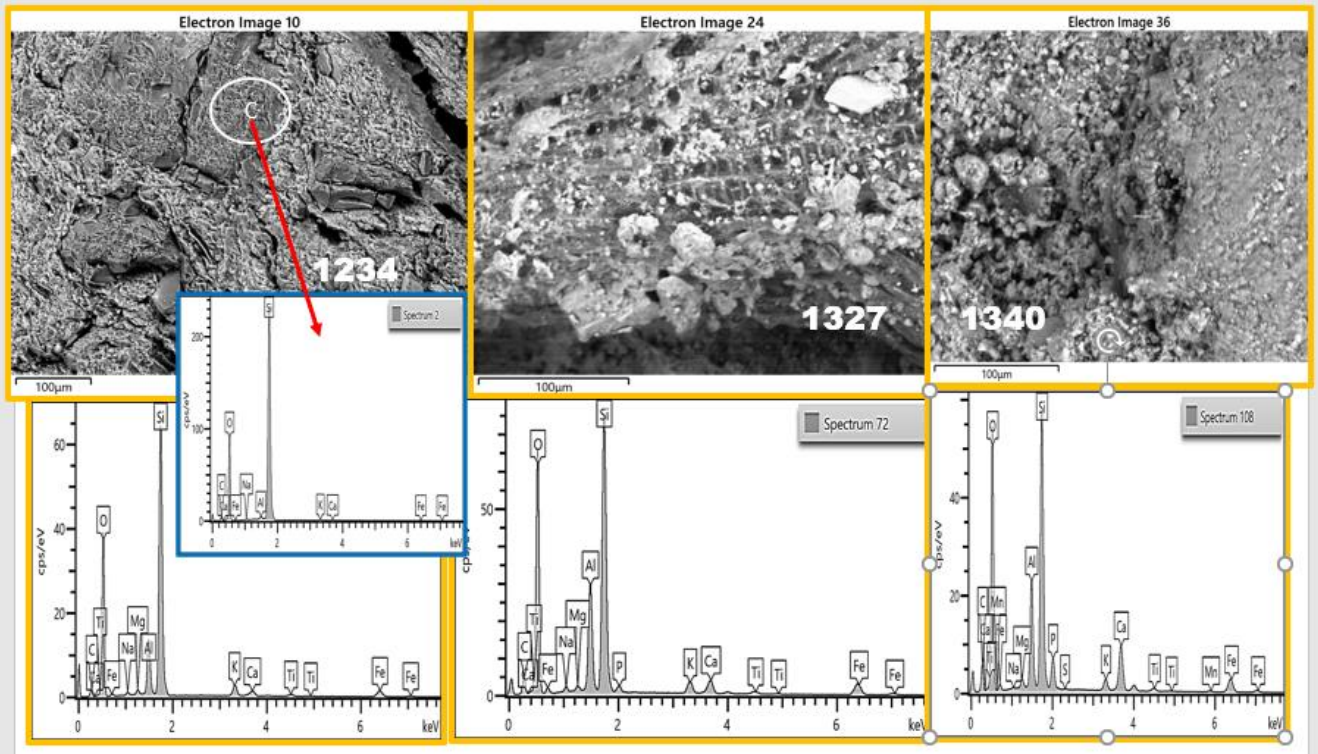


Figure 7.7: Samples 1234, 1327 and 1340 SEM micrograph images and energy dispersive x-ray (EDS/EDAX) spectra.

1234: The sample shows the presence of various structures with inclusions. Higher magnified images show the presence of porous structures. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Al, Mg, Si, K, Ca, Ti and Fe elements. Thus, the sample lacks P, S and Mn elements. EDAX spectrum shows that inclusions (C) lack Mg and Ti elements. Furthermore, these inclusions have very high concentration of Si and O (probably quartz) and the abundance of other elements is decreased (Figure 7.7).

1327: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements. In some cases, the presence of S and Cl (fiber like structures) was evident and suggests the structures of the mineralized plant remains (Figure 7.7 image 24).

1340: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, S, K, Ca, Ti and Fe elements. No evidence of inclusions (Figure 7.7).

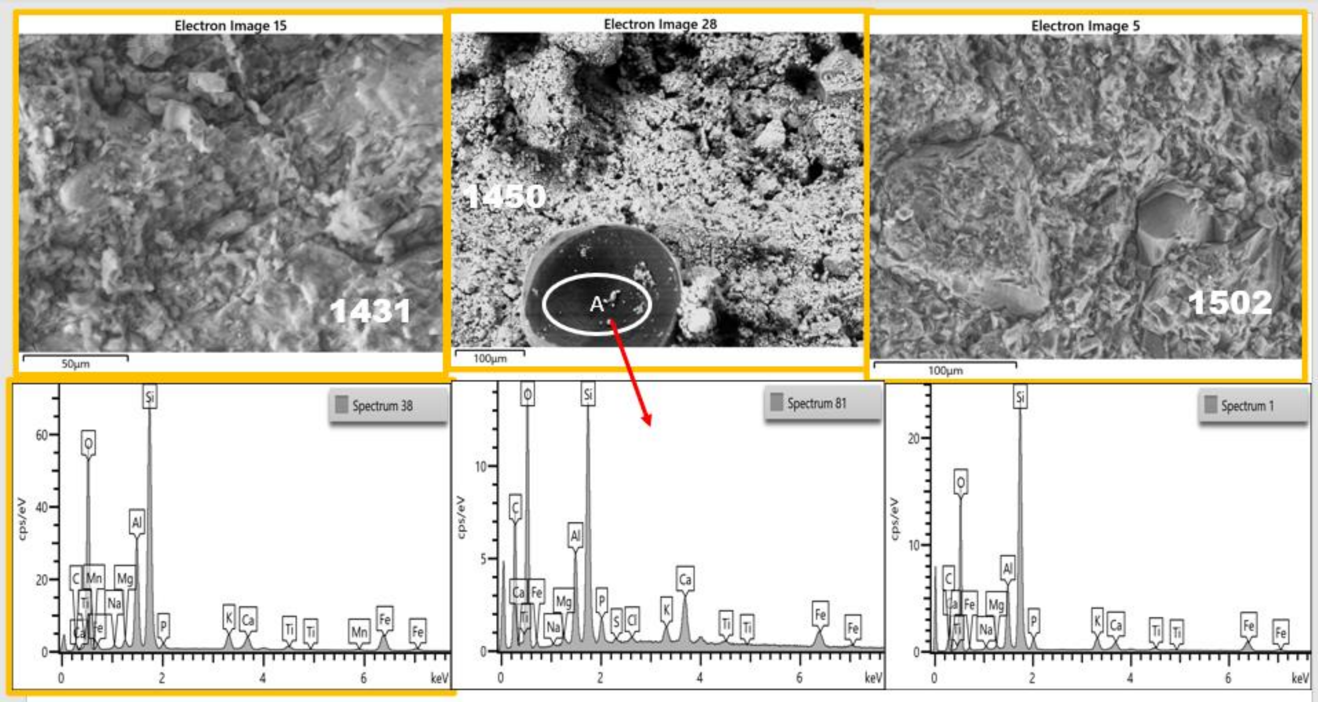


Figure 7.8: Samples 1431, 1450 and 1502 SEM micrograph images and energy dispersive x-ray (EDSE/DAX) spectra.

1431: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements. No evidence of inclusions (Figure 7.8).

1450: The sample shows the presence of small irregular aggregates with some areas show the presence of plate-like structures. Although there is evidence of inclusions, this needs to be further substantiated by EDAX analysis. EDAX analysis on the plate like-structure inclusions (A) shows the existence of mineral, i.e., C, O, Na, Mg, Al, Si, P, Cl, S, K, Ca, Ti and Fe elements with a very high concentration of Si and O and the abundance of other elements is decreased (Figure 7.8).

1502: The sample shows the presence of small irregular aggregates, with some areas showing the presence of plate like-structures. There is evidence of inclusions and EDAX analysis substantiates the existence mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements, with a very high concentration of Si and O (Figure 7.8).

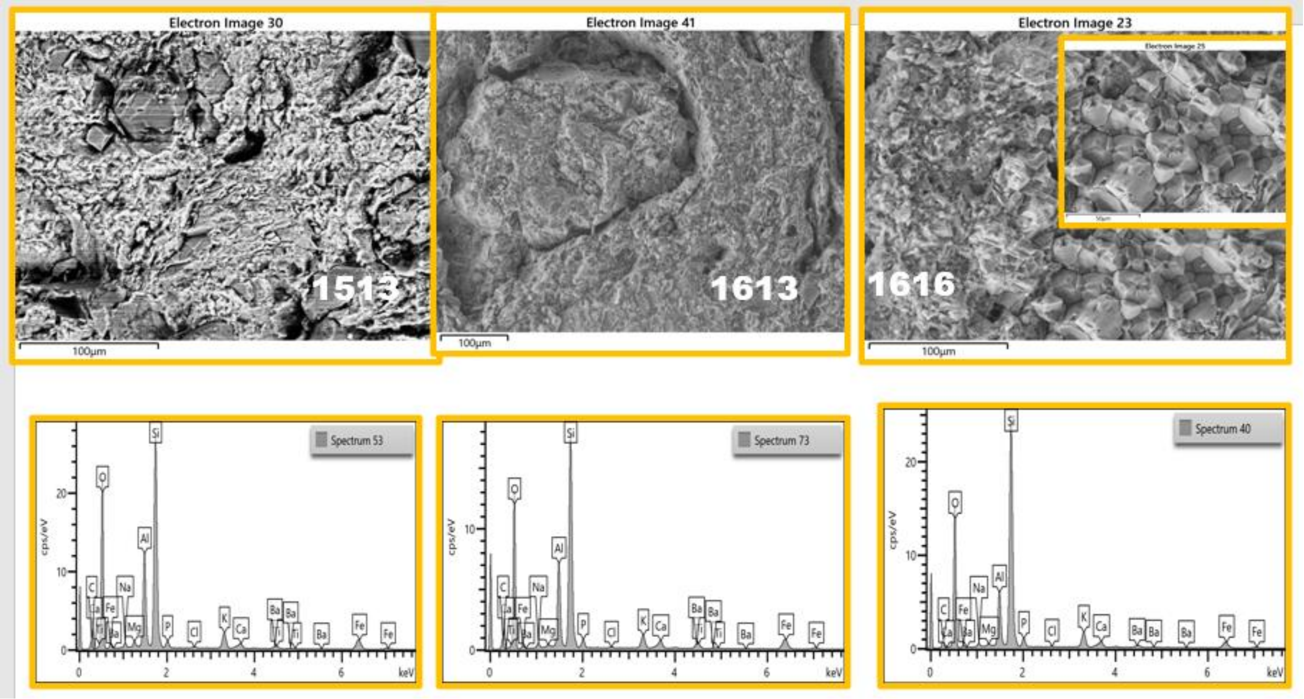


Figure 7.9: Samples 1513, 1613 and 1616 SEM micrograph images and energy dispersive x-ray (EDAX) spectra.

1513: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ba, Ti and Fe elements. The inclusions lack Ba and Ti elements (Figure 7.9).

1613: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ba, Ti and Fe elements. The inclusions lack Ba and Ti elements (Figure 7.9).

1616: The sample shows the presence of small regular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ba and Fe elements. In some cases, the sample shows the presence of Ti which has been ubiquitous for most of the samples. The inclusions lack Ti element (Figure 7.9).

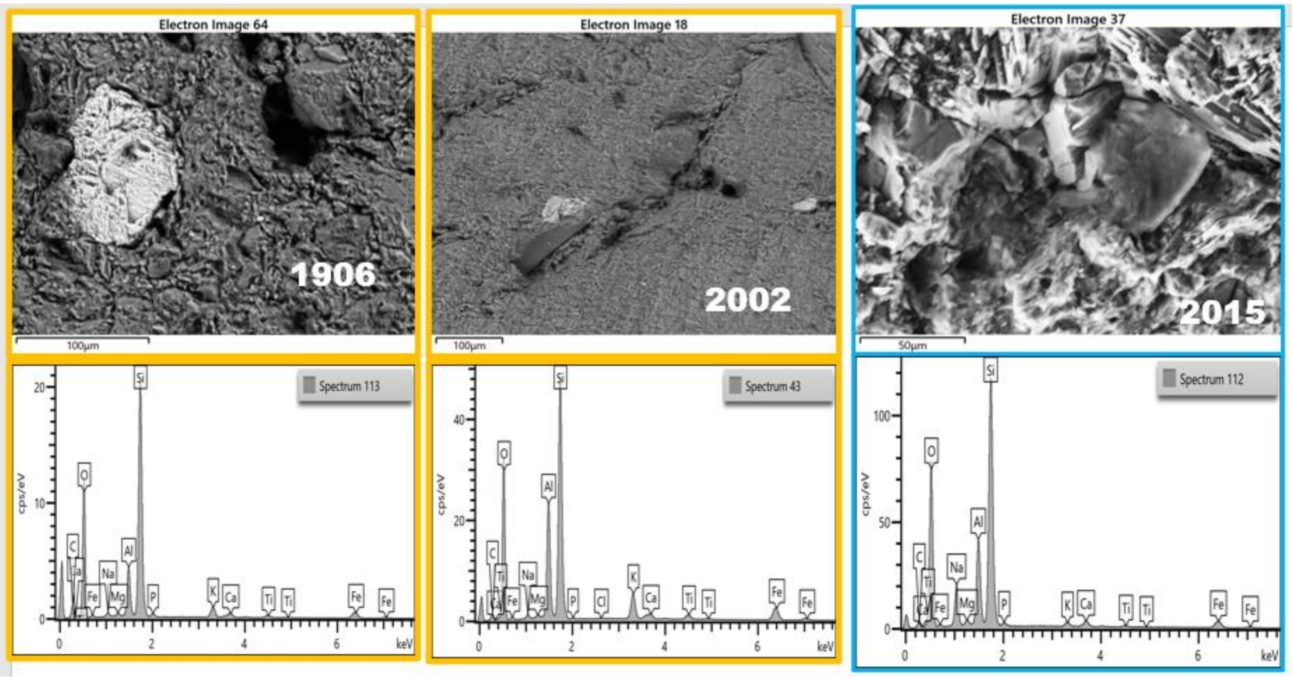


Figure 7.10: Samples 1906, 2002 and 1616 SEM micrograph images and energy dispersive x-ray (EDAX) spectra.

1906: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements (Figure 7.10).

2002: The sample shows the presence of small irregular aggregates. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements. The inclusions lack Ba and Ti elements (Figure 7.10).

2015: The sample shows the presence of large inclusions. EDAX shows the existence of normal ceramic mineral, i.e., C, O, Na, Mg, Al, Si, P, K, Ca, Ti and Fe elements. The inclusions lack Ti elements (Figure 7.10).

7.5. Discussion

The SEM/EDAX analysis shows the presence of various particles in the aggregate, with the texture being from fine to coarse and the shape from irregular to spherical, with large to small inclusions. The presence of both irregular and spherical aggregates of different sizes (fine and coarse) in most of the pottery samples indicates that the clay material had not been carefully sorted as shown in 1114 (Figure 7.4), 1431 (Figure 7.8), 1340 (Figure 7.7), and 1206 (Figure 7.6) or the clay material was just used as obtained from the source. On the other hand, samples that exhibits homegeinity in aggreagates with fine texture and small inclusions suggests that the clay material had been refined to remove the coaser grain fractions before the pottery was manufactured. This indicates that the potter intentionally selected the material due to standardization, and his specialization and experience in making pottery, as he bore in mind what the vessels would be used for. Rice, (1991:268) defines "standardization" as the relative degree of homogeneity or reduction in variability in the characteristics of an artifact, or the process of achieving that relative homogeneity. The underlying assumption of the degree of standardization or homogeneity in the vessels is that it reflects specialized production connected to a particular end use, while variation or relative heterogeneity is taken to indicate production for the household (Rice, 1991). Rice (1981) argues that, standardization in specialized archaeological ceramics production assemblages should be detected through standardization in raw-material composition and manufacturing technique. To substantiate this assumption, the degree of standardization should be ideally established by comparing the products of the same population and cultural tradition (Arnold and Nieves, 1992). In this regard, SEM/EDAX also showed that there were aspect clay mixing in production of the pottery. For examples sample Z.063, which display discrete clumps within the paste, suggests mixing of clay material obtained from different sources, as shown in the variation in the chemical composition (Figure 7.2).

The mineralogical composition of almost all the Narosura PN pottery sherds from Luxmanda was similar. The similarity in mineralogical composition between different pottery samples paste mainly for the most dominant ones like Si, O, C, Al and Fe elements permits to conclude that the raw clay material used to make the pottery were nearly the same (Table 7.2). The results of the SEM/EDAX analysis therefore clearly indicate that the majority of the pottery samples analysed were made of raw clay material of local origin. This might suggests that the raw clay used originated from similar parent rocks, although it could have been obtained from a different locality but within the same region. Furthermore, the presence of inclusions with major compositional differences in the pottery sample matrix suggests that inclusions were introduced to improve the plasticity of the raw clay material. Maniatis et al. (1988) and Tite (1999) maintain that the mechanical and thermal properties of ceramics can be modified strongly by introducing aplastic inclusions, whose concentration and size strongly affects these properties. This in combination with the raw materials availability in certain region leads to the greater understanding of the level of ancient ceramic technology and the social and economic implications related to it.

The mineralogical elements present and the microstructure texture of the Narosura PN pottery sample paste observed under SEM/EDAX provided information for determining the possible degree of firing temperature attain. Ceramic firing is one of the most essential stage responsible in transforming clay material into a hard, durable, and resistant ceramic artificial substance (Rice, 1987). Although it is hard to precisely state the exact temperatures at which firing reactions take place, these reactions are influenced by several factors such as duration and atmosphere of firing, chemical and mineralogical composition of the ceramic paste. Therefore, the clay matrix and the degree of contraction depend on the chemical and mineralogical composition, and the particle sizes. It also depends on the amount, type and size of accessory minerals and aplastic inclusions (Rice, 1987; Tite, 1999; Maniatis et al., 2002). Maniatis and Tite (1981) noted that, the ceramic microstructure analysis under SEM can offer various information on the degree of vitrification that can be used to estimate the firing temperature as well as the chemistry and type of the clay used and its refractory properties. However, a rough estimate compilation of the most frequent firing reactions that can be observed with increasing temperatures can simplified be summarized after Rice (1987), Maggetti (1982), Maniatis et al. (2002), as follows:

a. 100-200°C: Loss of water of formation – dehydration.
b. 200-400°C: Oxidation of organic material.
c. 450-600°C: Lost of water in the clay structure– dihydroxylation of clay minerals starts.
d. 550-750°C: β-quartz is formed at 573°C; calcite and micas begin to break down.
e. 750-850°C: Kaolinite and smectite lose their crystalline structure.
f. 850-1100°C: Calcite decomposes to lime (CaO) losing CO2, β-quartz can transform to Tridymite; complete destruction of most clay mineral structures, some illite may persist; depending on the elements available, high temperature phases such as wollastonite, gehlenite, diopside and anorthite as well as mullite and spinel may start to form; incipient vitrification.
g. >1100°C: Dissolving silica initiates further vitrification.

Based on microstructure SEM/EDAX analysis it can be suggested that pottery samples observed were lowly fired at a temperature not exceeding 1000°C, which is supported by the lack of vitrification shown in the SEM/EDAX images. Furthermore, low firing hypothesis is also supported with interestingly the presence of the remains of vegetable substances added to increase the workability, as observed on SEM microcope image in Figure 7.7 sample 1327 (Image 24) that indicates the structure of the mineralized plant remains. The intensities of some element’s peaks remain changing by the sintering. However, the continuous increase in the intensity of Si peak phase observed in all samples is probably after sintering as well as the early transformation signs of inception to further vitrification phase. Some parts of most pottery sherd samples also show heterogeneity in their microstructure texture, suggesting uncontrolled firing environment.

7.6. Chapter Conclusion

This chapter presented the SEM-EDS/EDAX chemical composition of Narosura PN pottery sherds samples from Luxmanda site on the Mbulu plateau in north-central Tanzania. The chemical composition observation identified broad similarity in the mineralogical composition, although with some slight difference in elements peaks that probably reflect variation in paste preparation and technology as well as type of the clay material used. The difference in microstructure texture, size and distribution of grains were also observed, which were attributed to potter's standardisation in clay processing for pottery making. Based on mineralogical composition of the samples and microstructure analysis, it is suggested that the pottery samples were fired at temperatures not exceeding 1000°C and in a reducing environment. The homogeneity of most of the pottery samples also indicate that the technology of manufacturing changed very little with time. The similarity in mineralogy and chemistry of the pottery samples paste also suggests that they were probably produced from clay material that originated from same parent rocks, but from a different locality within the same region.

CHAPTER EIGHT: 8

X-RAY POWDER DIFFRACTION (PXRD) FOR NAROSURA PASTORAL NEOLITHIC POTTERY AND THE RAW CLAY FROM THE MBULU PLATEAU IN NORTH-CENTRAL TANZANIA

8.0. Introduction

This chapter presents the X-ray powder diffraction (PXRD) data carried out at the Department of Geosciences, University of Roma that was performed on the Narosura PN pottery (sherds) and on raw clay material samples collected in the areas bordering the archaeological site to detect the mineralogical composition in both pottery sherds and raw clay material in order to assess the production technologies and the firing conditions. It was also performed as a confirmation test to identify the clay minerals in pottery paste that could not be identified by petrography. As noted by Moore and Reynolds (1997), clay minerals that cannot be identified by petrography can be identified based on their unique diffraction patterns that occur because of interlayer basal spacing in PXRD.

8.1. Materials Analysis Procedures and Methods

Twelve (12) samples of Narosura PN pottery sherds (n=4 from Luxmanda and Eyasi-Mumba sites) and raw clay (n=8 from Mbulu plateau/escarpment) were collected and sampled for XRD analysis (Table 8.1). The samples were prepared to powder form using smear method by using Laarmann LMMG-100 power mortar grinder install at the University of Ferrara, Department of Physical and Earth sciences (Figure 8.1). The method involved grinding the dry clay and pottery sherd with an electrical mortar and pestle until a fine uniform powder was attained. The grounded powder samples were then sent for PXRD analysis at the University of Roma using a Bruker AXS D8 Advance apparatus, operated in θ/θ geometry and transmission mode. Data were collected in step scan mode in the 5–145° 2θ angular range, 0.022° 2θ step size and 10s counting time. Peaks were identified using data in the XPowder diffraction software, PLV file format Ver. 3.0, exported by XPowder 12 Ver. 2014.04.30. The structures of the clay mineral peaks diffractograms graphs were further plotted with the Origin Pro 8.5 Analyzer software tool that provides an additional capability of finding and fitting multiple peaks in the spectra.

Table 8.1: Description of Raw Clay Samples Localities

Sample Lab ID	Clay/Pottery Locality Name	Colour Description
T001	Darwedick C	Gray clay with yellowish to milky fine particles
T002	Dareda	Yellowish brown clay
T003	Darwedick A	Yellowish brown clay
T004	Arri 2	Red clay
T005	Kirudiki	Dark gray clay
T006	Arri 1	Dark gray to black clay
T007	Sidigi A	Yellowish brown clay
T008	Sidigi B	Gray clay
T010	Eyasi-Mumba	Dark grayish brown pottery
T014	Eyasi-Mumba	Grayish brown pottery
1051	Luxmanda	Dark gray pottery
1524	Luxmanda	Light yellowish brown pottery

Figure 8.1: High Performance Electrical Mortar Grinder Laarmann LMMG-100 Universal for grinding solid materials into powder.

8.2. X-Ray Powder Diffraction Results

The study employed PXRD analysis to investigate the microstructure mineral composition of the archaeological pottery samples and the surrounding raw clay soil on Mbulu plateau. The chemical, mineralogical and structural investigation of ancient pottery can disclose the raw materials used in making such materials (provenance) and provide a broad understanding on the technological processes related to pottery manufacture and ceramic production at large (Tite, 1999; Quinn, 2003; Quinn and Benzonelli, 2018). Pottery materials are systematically investigated to identify their specific chemical composition, which could be related to the geology and geomorphology of the study region, to reveal the possible source of raw material for making pottery, and to differentiate locally pottery from imported pottery. The general understanding of these preparation techniques can be determined through studying the raw clay materials and respective pottery.

The PXRD analysis in general led to identification of the following minerals phases in both raw clay and pottery sherd materials: quartz, kaolinite, feldspars, plagioclase feldspar, hematite and calcite are the common minerals elements. The calcite may derive from the raw material (fragments of limestone and chalk composed of polycrystalline calcite for tempering the raw material during production of vessels and/ or carbonate rich clay raw materials), but also the Calcite can precipitate as secondary phase during burial of the ceramic. The XRF and petrographic analyses, coupled to XRD investigation have shown the primary origin of calcite is due to rich clay raw materials used to obtain sintering at lower firing temperatures (<800 °C) during the ceramics manufacture. Contrariwise, the potteries rich in Calcium but free-lime are formed above the de-carbonation temperature, the carbon dioxide gas (CO2) is released and the calcium of calcite decomposes it reacts with the silica to give the silicate phases of calcium. Under prolonged ceramic firing the de-carbonation takes place at temperatures between 600 and 800

°C, depending on the form of the calcite, the impact of the clay and the firing conditions (Shoval et al., 1993, Fabbri et al., 2014). Although, pyroxene, gehlenite, dolomite and illite minerals are also present in small densities (Figure 8.3; 8.4). The gehlenite in a thermometamorphic phase appears during the firing of ceramics at 800 °C (Dondi et al., 1998). The free CaO can reacts with free silica and alumina derived from decomposition of illite, the most abundant clay mineral, forming gehlenite according to the following reaction (Peters and Iberg, 1978) so the illite is a low temperature marker.

In specific, the predominant minerals content in the raw clay samples indicates that the composition of sample T001, T003, T005, T006, T007 and T008 are mainly quartz and alkali feldspars, while the presence of plagioclase, feldspar and hematite is observed in the T002 sample. Trindade et al 2009 have observed that the first transformation in the clay minerals during firing is the disappearance of goethite at 300 °C (lower heating temperature). Goethite becomes unstable at low temperatures (230–280 °C, according to Brindley and Brown, 1980) and decomposes to form hematite according to the reaction $2FeOOH \rightarrow Fe2O3 + H2O$. Although hematite could be identified in the PXRD pattern at 500 °C, well-crystallized hematite it is a significant component only after heating at 900 °C. On the other hand, T004 is also composed of kaolinite and quartz, pottery sherd samples 1051 and 1024 are also composed of quartz and alkali feldspars (Figure 8.2; 8.3; 8.4; 8.5), while sample T010 and T014 revealed the presence of illite mineral in high concentration among other minerals. Even though, the concentration of illite in sample 1051 and 1524 was small (Figure 8.4).

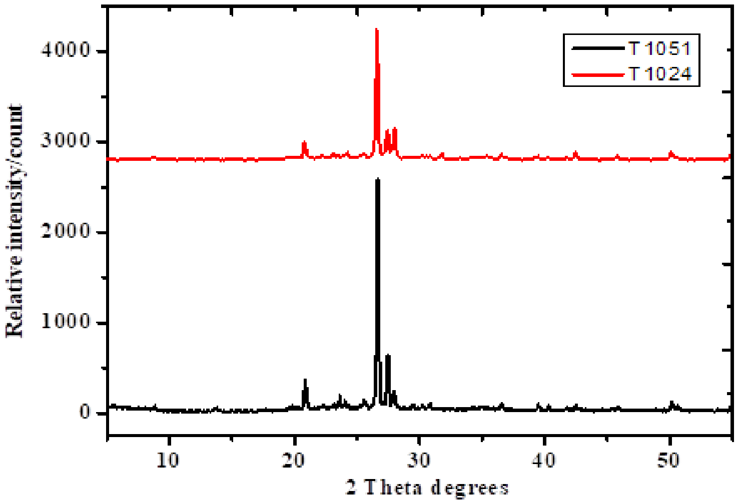


Figure 8.2: PXRD diffractograms of Luxmanda pottery samples.

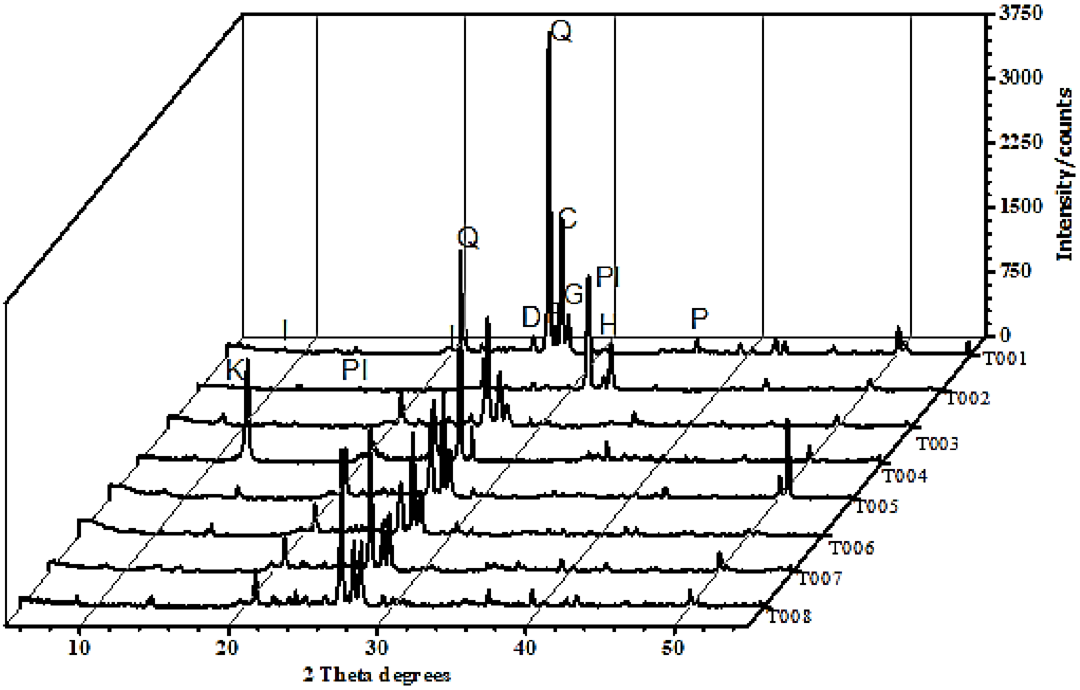


Figure 8.3: PXRD diffractograms indicating peak positions and minerals present in the raw clay soil samples collected from different locations on Mbulu plateau.

Q=quartz; K=kaolinite; F=feldspar; Pl=Plagioclase feldspar; H=Hematite; C=calcite; P=pyroxene; G=gehlenite; D=Dolomite; I= Illite.

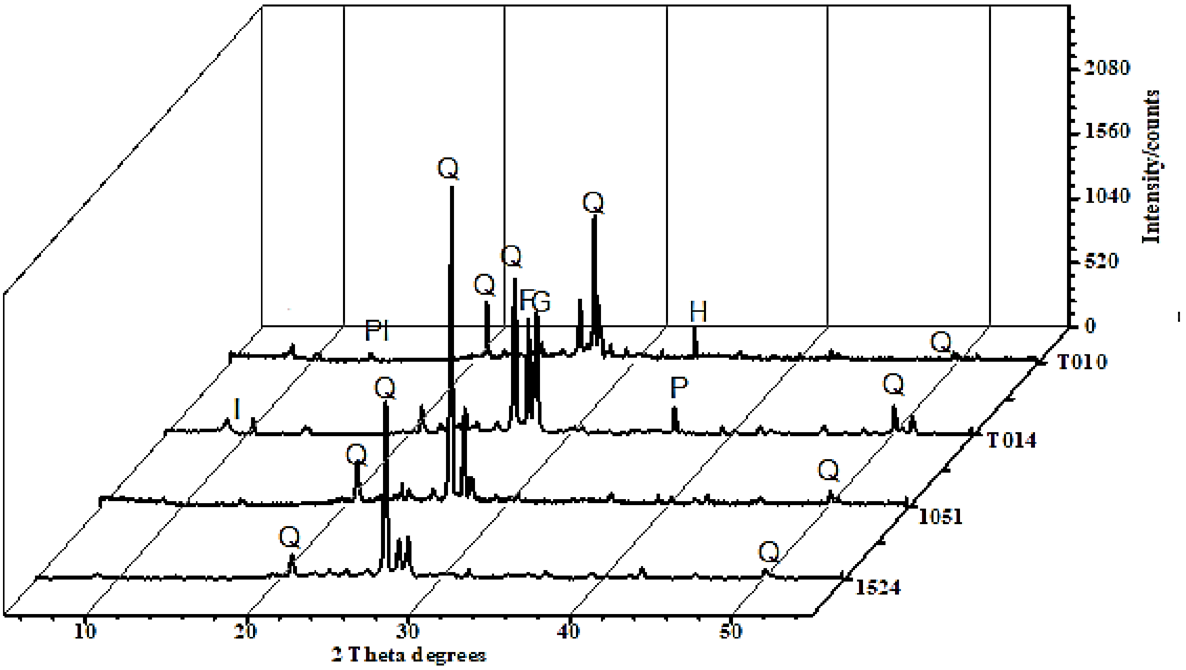


Figure 8.4: PXRD of pottery samples collected from Luxmanda (sample no. 1051 and 1524) and Eyasi-Mumba (sample no. T010 and T014) sites.

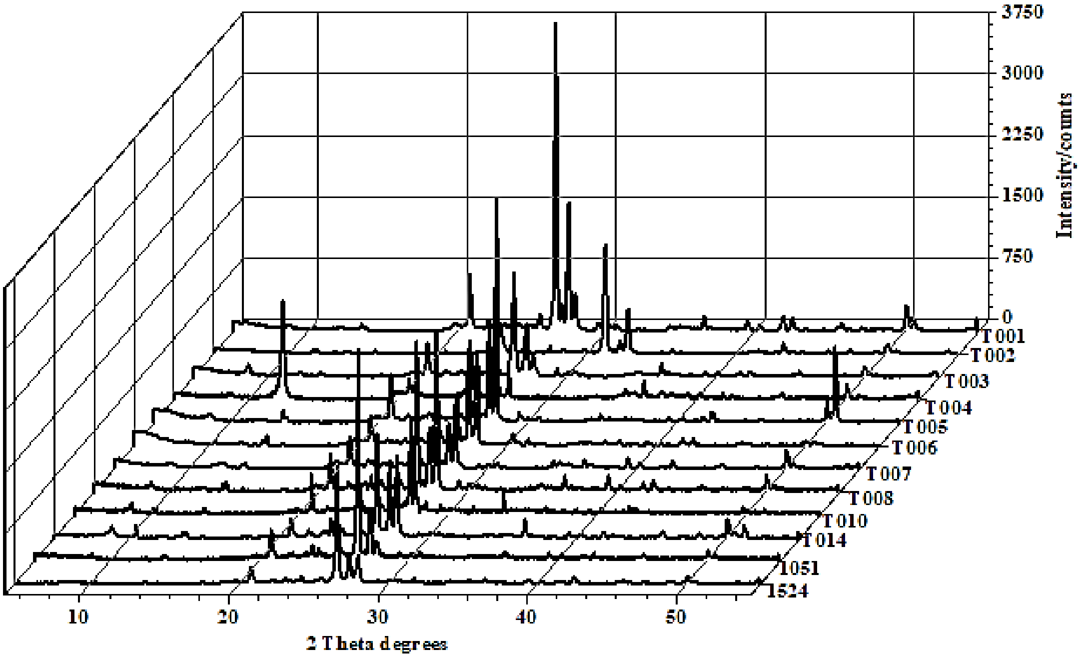


Figure 8.5: PXRD comparison of the raw clay soil samples and representative pottery materials.

8.3. Discussion

The PXRD diffractograms comparison of the raw clay materials and pottery samples presented in Figure 8.5 exhibited some difference, which may indicates the presence of different mineral elements in various concentrations (Figure 8.3, 8.4 and 8.5). The main identified minerals element concentration include quartz [SiO2], kaolinite [Al2Si2O5(OH)4], feldspars [(K,Na,Ca)AlSi3O8], plagioclase feldspar, hematite [Fe2O3], calcite [CaCO3], pyroxenic augite [(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)2O6], gehlenite [Ca2Al2SiO7], dolomite[CaMg(CO3)2]and illite [(K,H3O)(Al,Mg,Fe)2(Si,Al)4O10[(OH)2,(H2O)] (Iordanidis et al., 2009).

Based on the mineral composition, it could be ascertained that the raw clay samples T001, T003, T005, T006, T007 and T008 (Figure 8.3) were the possible source of raw materials for pottery sample 1051 and 1524 (see Table 8.1 for localities names). This is supported by the presence of the same mineral elements, namely quartz and alkali feldspars, in their mineralogical composition (Figure 8.4). The PXRD data also revealed that the samples exhibited similar diffractograms, indicating that pottery were probably made from the same source of materials. A compilation of the PXRD diffractograms for all samples is provided in Figure 8.5 for further comparisons. The presence of these elements is also consistent with the EDS results presented in chapter seven of this thesis.

Following the PXRD results, the firing temperatures attained during manufacturing process of Narosura PN pottery as part of manufacturing technology and their degradation were determined based on the presence or absence of some mineral in the composition (Quinn, 2003; Quinn and Benzonelli, 2018). Quinn and Benzonelli (2018) noted that the existence of certain minerals in samples can be used to interpret the firing process during manufacture of the ceramic materials. The PXRD results from this study indicated that quartz and feldspars were ubiquitous in the pottery samples, which is a clear indication that the pottery samples were fired at a temperature not exceeding 900°C during manufacturing of the pottery. According to Trindade et al., (2009), quartz decomposes gradually from 800°C to 1100°C, drastically diminishing at 1100°C, although other studies have also established that quartz mineral can be stable up to 1000°C temperature before decomposing (Castellanos, et al. 2012). Therefore, based on the abundance of quartz minerals in the pottery samples as the dominant mineral constituent among others, this is an indication that the Narosura PN pottery were possibly fired at a temperature below 1000°C. Furthermore, the presence of minerals such as illite that is stable up to temperature of 850° C is also indicative that the pottery samples were not fired at temperatures above 900°C. Castellanos, et. al. (2012) suggests that minerals such as illite, turn out to be progressively less crystalline, and the intensity of their lines slowly deteriorates and disappears between 900°C and 1000°C. Moreover, some scholars have observed that minerals such as calcite, dolomite and illite exist in a low firing temperature (Shimada et al, 2003; Iordanidis et al., 2009). Therefore, the presence of calcite and illite mineral in the pottery samples support a low firing less than 900°C temperature hypothesis.

8.4. Chapter Conclusion

PXRD data results discussed in this chapter have demonstrated that the Narosura PN pottery samples were mainly composed of quartz, feldspar, plagioclase, hematite, pyroxene, gehlenite and illite minerals (Figure 8.4). Following the composition of the raw clay and pottery materials observed in PXRD, it seems that the pottery samples from Luxmanda site were manufactured from the raw clay, probably of local origin, found in the Mbulu plateau region, which the geological in the area seems to support. This conclusion is in line with ethnographic data that points Darwedick (T001; T002) and Sidigi (T007; T008) as the nearest best raw clay sources mostly mined for pottery manufacturing, among others. As previously reported, the existence of certain minerals like quartz, feldspar and illite in samples were also used to establish and interpret the firing temperatures attained during the process of manufacturing the Narosura PN pottery. PXRD observation revealed that the pottery samples were generally fired at an estimated low temperature not exceeding 1000°C, thus suggesting a bonfire-firing process. The diffractometric analyses indicate that for the production technologies they used both low temperature forms and kilns that could exceed the temperature of 900 degrees, these conditions concern the ceramics rich in gehlenite and free of illite.

CHAPTER NINE: 9

THE MBULU PLATEAU RAW CLAY MINERALOGICAL ANALYSIS AND ITS IMPLICATION TO THE PROVENANCE OF NAROSURA PASTORAL NEOLITHIC POTTERRY FROM LUXMANDA SITE ON THE MBULU PLATEAU NORTH-CENTRAL TANZANIA

9.0. Introduction

This chapter presents a detail mineralogical analysis of the raw clay collected from the Mbulu plateau in the north-central Tanzania. The raw clay mineralogical was analysed to determine the concentration of the non-clay mineral content, the percentage of composition, and the grain size distribution in the raw clay. The study of the non-clay mineral content and distribution of the Mbulu raw clay material sources were useful for ascertaining the origin raw clay and provenance the archaeological Narosura PN pottery excavated at Luxmanda site.

9.1. Materials Analysis Procedures and Methods

The raw clay material samples for this study were collected in sixteen (16) localities, (Table 9.2; Figure 9.1), although the analysis concentrated on only eight (8) major sources from five villages areas (Table 9.1; Figure 9.2) identified by contemporary potters (for a critique, see chapter 10) as exceptional and active areas from where they currently obtain the raw clay for pottery making. The raw clay samples that were collected were first subjected to a standard Munsell soil colour chart (1994) to determine their colour when the clay was wet and later dry (Table 9.2). They were later analysed by wet soil sieve analysis to determine the mineralogical content of non-clay inclusions. A more general detailed analysis on the mineralogical composition of the sampled raw clay materials is discussed in chapter 7 and 8 in this thesis.

To determine the clay content, the type of non-clay minerals inclusions and their particle/grain size distribution. The samples were first homogenized then each divided into two halves. One half was stored for future reference and the second half was wet sieved (IS-2720, 1985). The wet soil sieve analysis method was chosen because it was an easier method to separate the raw clay aggregates so as to avoid any profound modification and identification of the non-clay mineral inclusions in the raw clay. The wet sieving was done in sieve with different particles size fractions 4000µm, 2000µm, 1000µm, 500µm, 250µm and 125µm. The grains were later examined using a KERN Optics Binocular Microscope mounted with a camera to discern the mineralogical composition, percentage by volume and maturity in each grain size.

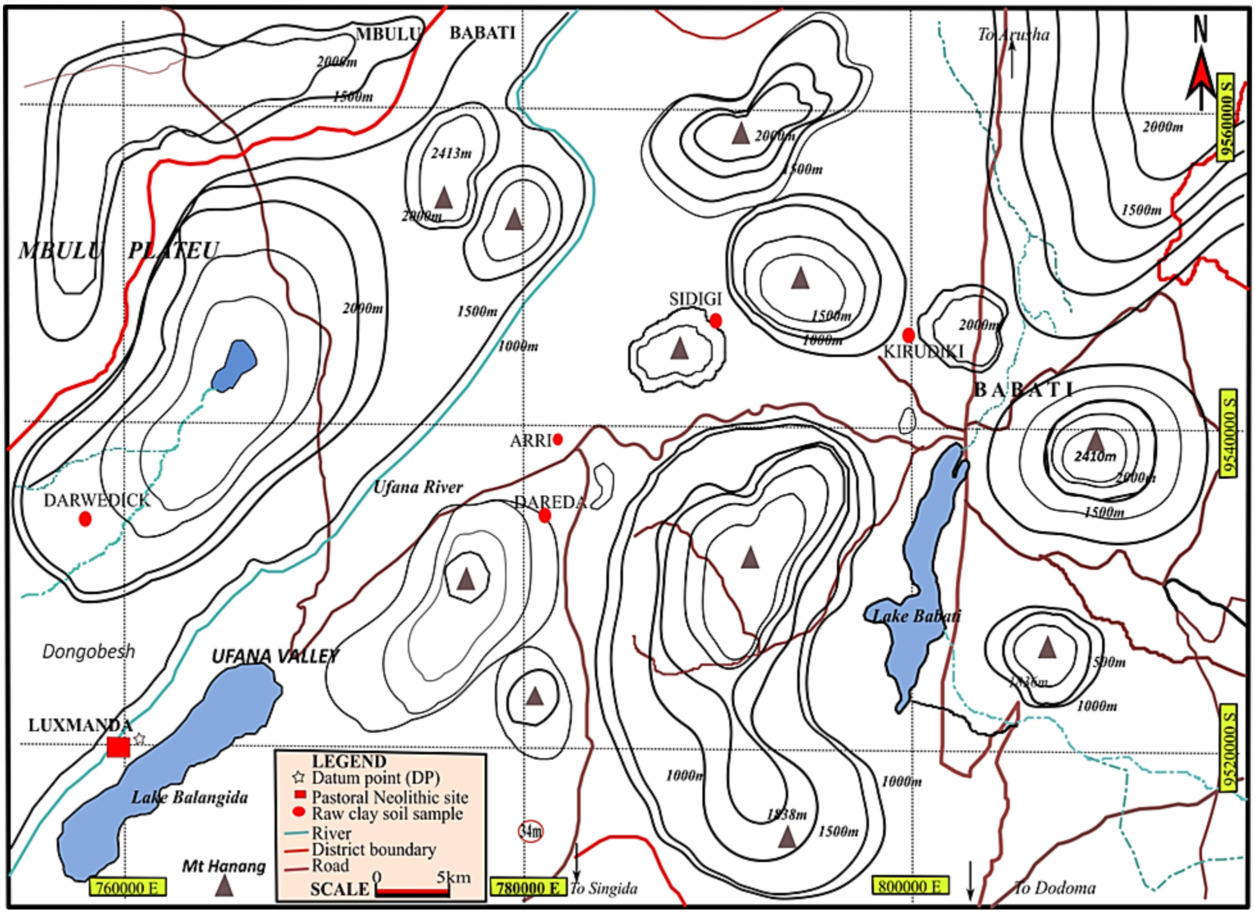


Figure 9.1: Map of Mbulu Plateau showing Luxmanda Archaeological site and the localities in which the raw clay samples were collected (Source: field data, 2018).

Table 9.1: Description of the Raw Clay Samples analysed.

S/N	Sample ID	Colour Description
1	DWKA/RCS1/18	Yellowish brown clay
2	DWKC/RCS4/18	Grey clay with yellowish to milky fine particles
3	SDGA/RCS5/18	Yellowish brown clay
4	SDGB/RCS6-10/18	Grey clay
5	DRDA/RCS1/18	Yellowish brown clay
6	KRDKB/RCS3/18	Dark grey clay
7	ARRI PHI/RCS1/18	Dark grey to black clay
8	ARRI PHI/RCS2/18	Red clay

Table 9.2: Raw Clay Samples collected from sixteen localities in five villages.

Area Name	Sample Code	UTM	Latitude	Longitude	Munsell Dry Colour	Munsell Wet Colour
SIDIGI	SDG B4/RCS 9/18	36 M	758681	9535983	5YR/7/1	2.5 YR4/2 Dark grayish brown
SIDIGI	SDG A/RCS 5/18	36 M	757768	9535914	2.5YR/6/4 Light yellowish brown	10YR/5/4 Yellowish brown
SIDIGI	SDG B1/RCS 6/18	36 M	758681	9535983	5YR Light gray	10YR/4/2 Dark grayish brown
SIDIGI	SDG B2/RCS 7/18	36 M	758681	9535983	10YR/6/4 Light yellowush brown	10YR/5/2 Grayish brown
SIDIGI	SDG B3/RCS 8/18	36 M	758681	9535983	5YR/6/3 Pale Olive	2.5YR/5/3 Light Olive brown
SIDIGI	SDG B5/RCS 10/18	36 M	758681	9535983	2.5 YR/6/3 Light yellowish brown	2.5 YR/7/4 Light gray
DARWEDICK	DWK A/RCS 1/18	36 M	757917	9532249	10YR/7/4 Light gray	10YR/5/8 Yellowish brown
DARWEDICK	DWK B/RCS 2/18	36 M	757917	9532249	5YR/6/3 Pale Olive	2.5YR/4/2 Dark grayish brown
DARWEDICK	DWK C/RCS 4/18	36 M	757768	9531878	10YR/6/2 Light yellowish brown	10YR/5/2 Grayish brown
DARWEDICK	DWK C/RCS 3/18	36 M	757768	9531878	10YR/6/6 Brownish yellow	Dark yellow brown
KIRUDIKI	KRDK A1/RCS 1/18	36 M	794277	9538580	2.5YR/5/6 Light Olive brown	2.5YR/6/4 light yellowish brown
KIRUDIKI	KRDK A1/RCS 2/18	36 M	794277	9538580	2.5 YR/4/2 Dark grayish brown	2.5 YR/4/4 Olive brown
KIRUDIKI	KRDK B/RCS 3/18	36 M	794627	9538158	5YR/4/1 Dark gray	2.5 YR/3/3 Dark Olive brown
ARRI	ARRI PH1/RCS 1/18	36 M	788824	9530732	2.5 YR/5/8 Red	2.5/4/6 Red
ARRI	ARRI PH1/RCS 2/18	36 M	788773	9530803	2.5YR/4/2 Drak grayish brown	2.5YR/3/2 Very dark grayish brown
DAREDA	DRD A/RCS 1/18	36 M	775800	9529812	10YR 6/4 light yellowish brown	10YR/4/4 Dark yellowish brown

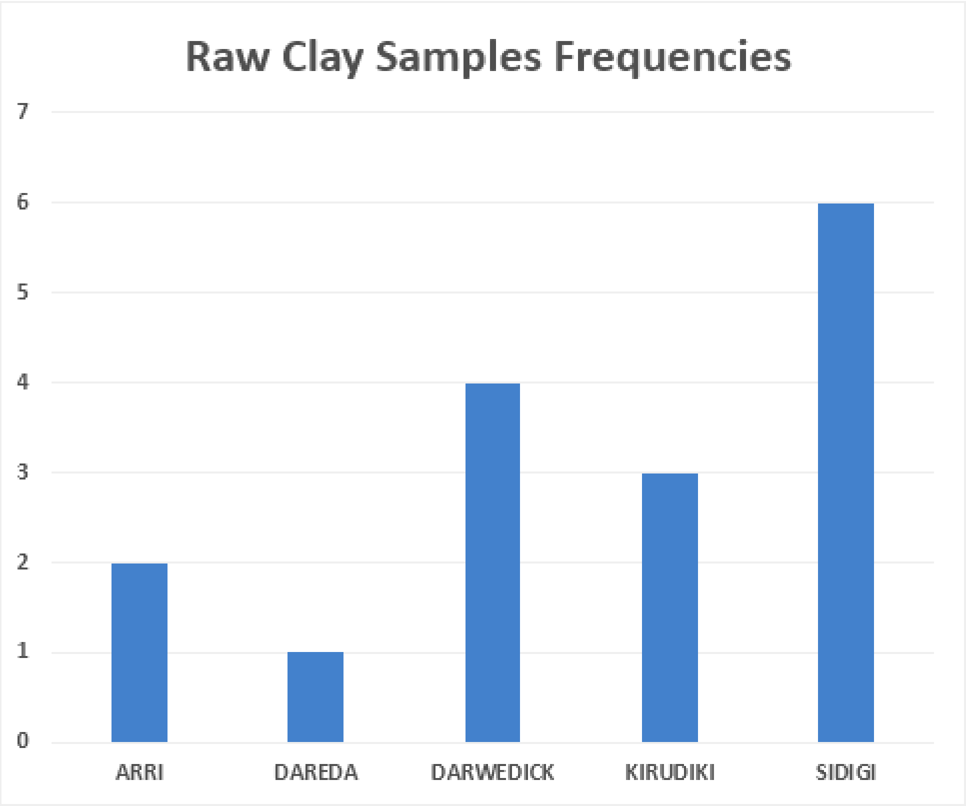


Figure 9.2: Raw clay samples frequency distribution from five villages.

9.2. Results of the Raw Clay Wet Analysis

The wet sieve analysis carried out on the eight samples indicates that the fine material shown as less than 125 microns is mostly composed of clay, of which between 58% and 93% was raw clay material and the rest are non-clay mineral inclusions (Table 9.3). The non-clay inclusions observed mostly consisted of the rock fragments of the rock forming minerals such as quartz, feldspar, mica and iron oxide. The most common non-clay minerals were quartz and feldspar, although other minerals like goethite and hematite were also observed. The majority of non-clay minerals inclusions grains were mainly composed of angular to sub angular, with a few round to sub round grains shape (Table 9.4; Table 9.5).

Table 9.3: Distribution and frequency of wet sieve nominal fractions.

Sample ID: DWKA/RCS1/18				
Nominal	**Weight Retained**	**%**	**Cumulative % Retained**	**Cumulative % Passing**
4000	1.40	1.27	1.27	98.73
2000	5.20	4.71	5.97	94.03
1000	9.30	8.42	14.39	85.61
500	6.20	5.61	20.01	79.99
250	4.60	4.16	24.17	75.83
125	1.60	1.45	25.62	74.38
Less than 125	82.17	74.38	100.00	0.00
Total	**110.47**	**100.00**		
Sample ID: DWKC/RCS 4/18				
Nominal	**Weight Retained**	**%**	**Cumulative % Retained**	**Cumulative % Passing**
4000	0.80	0.60	0.60	99.40
2000	2.20	1.64	2.23	97.77
1000	10.40	7.74	9.97	90.03
500	13.30	9.89	19.86	80.14
250	9.30	6.92	26.78	73.22
125	5.20	3.87	30.65	69.35
Less than 125	93.24	69.35	100.00	0.00
Total	**134.44**	**100.00**		
Sample ID: SDGA/RCS 5/18				
Nominal	**Weight Retained**	**%**	**Cumulative % Retained**	**Cumulative % Passing**

4000	2.20	2.07	2.07	97.93
2000	3.80	3.58	5.65	94.35
1000	6.80	6.40	12.06	87.94
500	7.20	6.78	18.84	81.16
250	3.40	3.20	22.04	77.96
125	0.60	0.57	22.60	77.40
Less than 125	82.18	77.40	100.00	0.00
Total	**106.18**	**100.00**		

Sample ID: SDGB/RCS 6-10/18

Nominal	Weight Retained	%	Cumulative % Retained	Cumulative % Passing
4000	1.30	1.03	1.03	98.97
2000	6.00	4.74	5.77	94.23
1000	14.90	11.77	17.53	82.47
500	16.80	13.27	30.80	69.20
250	10.60	8.37	39.18	60.82
125	2.70	2.13	41.31	58.69
Less than 125	74.31	58.69	100.00	0.00
Total	**126.61**	**100.00**		

Sample ID: DRDA/RCS 1/18

Nominal	Weight Retained	%	Cumulative % Retained	Cumulative % Passing
4000	3.40	3.76	3.76	96.24
2000	1.70	1.88	5.64	94.36
1000	3.00	3.31	8.95	91.05
500	4.80	5.30	14.25	85.75
250	5.00	5.52	19.78	80.22
125	1.80	1.99	21.77	78.23
Less than 125	70.80	78.23	100.00	0.00
Total	**90.50**	**100.00**		

Sample ID: KRDKB/RCS3/18

Nominal	Weight Retained	%	Cumulative % Retained	Cumulative % Passing
4000	0.00	0.00	0.00	100.00
2000	0.30	0.39	0.39	99.61
1000	2.80	3.63	4.02	95.98
500	5.90	7.64	11.66	88.34
250	4.70	6.09	17.75	82.25
125	1.00	1.30	19.05	80.95
Less than 125	62.48	80.95	100.00	0.00
Total	**77.18**	**100.00**		

Sample ID: ARRI PH1/RCS1/18

Nominal	Weight Retained	%	Cumulative % Retained	Cumulative % Passing
4000	0.60	0.94	0.94	99.06

2000	0.90	1.41	2.35	97.65
1000	1.30	2.04	4.38	95.62
500	3.30	5.17	9.55	90.45
250	3.80	5.95	15.50	84.50
125	1.40	2.19	17.69	82.31
Less than 125	52.56	82.31	100.00	0.00
Total	**63.86**	**100.00**		
Sample ID: ARRI PH1/RCS2/18				
Nominal	**Weight Retained**	**%**	**Cumulative % Retained**	**Cumulative % Passing**
4000	0.00	0.00	0.00	100.00
2000	1.10	2.15	2.15	97.85
1000	1.50	2.94	5.09	94.91
500	2.30	4.50	9.59	90.41
250	3.00	5.87	15.47	84.53
125	1.30	2.55	18.01	81.99
Less than 125	41.88	81.99	100.00	0.00
Total	**51.08**	**100.00**		

Table 9.4: Distribution of clay and non-clay minerals.

Nominal	Weight %	Mineral Content & Volume % by Visual Estimation	Grain Shape
Sample ID: DWKA/RCS1/18			
4000	1.27	Clear Quartz (40%), Ferruginous Quartz (20%), Weathered Feldspar (30%), Rock fragment composed of black mineral stained with iron oxide (5%), Rock fragments composed of quartz, feldspar and green coloured grains (5%)	Angular grains
2000	4.71	Clear Quartz (40%), Ferruginous Quartz (30%), and Weathered Feldspar (20%), Rock fragments composed of black mineral stained with iron oxide (10%)	Angular and sub-round grains
1000	8.42	Quartz grains: some are clear, milky and some are ferruginous (70%), Highly weathered Feldspar (25%), Black mineral stained with Goethite(5%)	Angular to sub-angular grains
500	5.61	Quartz grains: some are clear, milky and some are ferruginous (80%), Highly weathered Feldspar (20%)	Angular grains
250	4.16	Quartz grains: some are clear, milky and some are ferruginous (80%), Highly weathered Feldspar (15%), Black mineral (5%)	Angular to sub-angular grains
125	1.45	Quartz grains: some are clear, milky and some are ferruginous (95%), Black mineral (5%)	Angular to sub-angular grains
Less than 125	74.38	Very fine grained clay material	
Sample ID: DWKC/RCS 4/18			
4000	0.60	Quartz (50%), Feldspar (40%), Rock fragments (10%)	Angular grains
2000	1.64	Clear and ferruginous Quartz (50%), Feldspar (40%), Rock fragments (10%)	Angular grains
1000	7.74	Clear and ferruginous Quartz (80%), Feldspar (15%), Black mineral stained with Goethite (5%)	Angular grains
500	9.89	Clear and ferruginous Quartz (90%), Partially weathered Feldspar (10%)	Angular grains
250	6.92	Clear, milky and ferruginous Quartz (85%), Highly weathered Feldspar (5%), Rock fragments and Black mineral (10%)	Angular to sub-angular grains
125	3.87	Clear and ferruginous Quartz (80%), Green mineral (5%), Goethite balls (10%), Black mineral (5%)	Angular to sub-angular grains

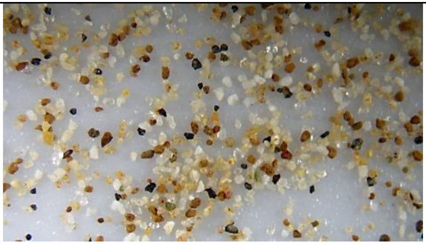
Nominal	Weight %	Mineral Content & Volume % by Visual Estimation	Grain Shape
Less than 125	69.35	Very fine grained clay material	
Nominal	**Weight %**	**Mineral Content & Volume % by Visual Estimation**	**Grain Shape**
Sample ID: SDGA/RCS 5/18			
4000	2.07	Milky Quartz (50%), Rock Fragments (50%)	Angular grains
2000	3.58	Milky and ferruginous Quartz (60%), Feldspar (10%), Rock fragments (30%)	Angular grains
1000	6.40	Clear, milky and ferruginous Quartz (75%), Round shaped Quartz coated with Goethite (20%), Quartz with greenish stains (5%)	Angular to sub angular grains; Round to sub-round grains
500	6.78	Clear, milky and ferruginous Quartz (80%), Round to sub-round grains of Quartz coated with Goethite (20%)	Angular to sub-angular grains; Round to sub-round grains
250	3.20	Clear, milky and ferruginous Quartz (60%), Round to sub-round grains of Quartz coated with Goethite (25%), Iron Oxide [Hematite mixed with Goethite] (10%), Green mineral (5 %)	Angular to sub-angular grains; Round to sub-round grains
125	0.57	Clear and milky (50%), Round to sub-round grains of Quartz coated with Goethite (30%), Black shiny mineral (10%), Green mineral (5%), Iron oxide (Hematite) – 5%	Angular to sub-angular grains; Round to sub-round grains
Less than 125	77.40	Very fine grained clay material	
Sample ID: SDGB/RCS 6-10/18			
4000	1.03	Rock Fragments (70%), Feldspar (30%)	Angular grains
2000	4.74	Clear and ferruginous Quartz (50%), Rock fragments composed of Feldspar and quartz (50%)	Angular grains
1000	11.77	Milky, clear and ferruginous Quartz (80%), Weathered Feldspar and Rock fragments composed of Feldspar and Quartz (20%)	Angular grains
500	13.27	Clear, milky and ferruginous Quartz (80%), Feldspar (20%)	Angular to sub-angular grains; Round to sub-round grains
250	8.37	Clear, ferruginous and milky Quartz (85%), Feldspar (10%), Black mineral (5%)	Angular to sub-angular grains; Round to sub-round grains
125	2.13	Clear and ferruginous (90%), Green mineral (7%), Black shiny mineral (3%)	Angular to sub-angular grains; Round to sub-round grains
Less than 125	58.69	Very fine grained clay material	
Nominal	**Weight %**	**Mineral Content & Volume % by Visual Estimation**	**Grain Shape**
Sample ID: DRDA/RCS 1/18			
4000	3.76	Grained Quartz – Quartz grains composed of very fine quartz crystals (60%), Multiple Quartz grains cemented together to form a single grain (40%)	Angular grains
2000	1.88	Grained Quartz – Quartz grains composed of very fine quartz crystals (70%), Multiple Quartz grains cemented together to form a single grain (20%), Rock fragment stained with Goethite (10%)	Angular grains
1000	3.31	Milky, clear and slightly ferruginous Quartz (95%), Feldspar (10%), Rock fragments (5%)	Angular grains
500	5.30	Clear, milky and slightly ferruginous Quartz and grained Quartz (98%), Black mineral (2%)	Angular grains, Sub-round grains
250	5.52	Clear, milky and slightly ferruginous Quartz (95%), Black mineral (5%)	Angular grains, Sub-round grains
125	1.99	Clear and slightly ferruginous Quartz (85%), Black mineral (15%)	Angular grains, Sub-round grains
Less than 125	78.23	Very fine-grained clay material	
Sample ID: KRDKB/RCS3/18			
4000	0.00	-	-
2000	0.39	Clear and ferruginous Quartz (90%), Rock fragments (10%)	Angular grains
1000	3.63	Clear and ferruginous Quartz (85%), Multiple Quartz grains cemented together to form a single grain (10%), Rock fragments (5%)	Angular grains

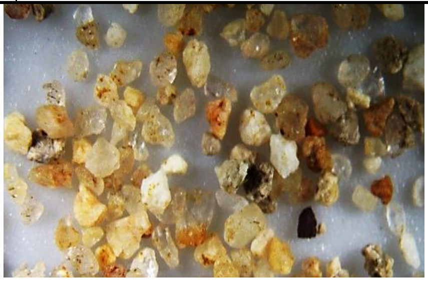
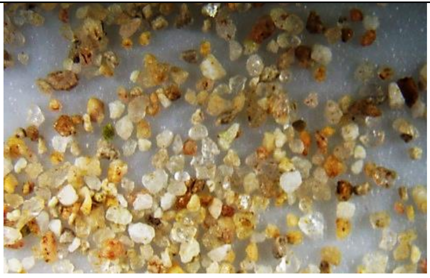
Nominal	Weight %	Mineral Content & Volume % by Visual Estimation	Grain Shape
500	7.64	Clear and ferruginous Quartz (90%), Multiple Quartz grains cemented together to form a single grain (5%), Black mineral (5%)	Angular to sub-angular grains; Round to sub-round grains
250	6.09	Clear and ferruginous Quartz (100%)	Angular to sub-angular grains; Round to sub-round grains
125	1.30	Clear Quartz (70%), ferruginous Quartz (25%), Black shiny mineral (5%)	Angular grains
Less than 125	80.95	Very fine grained clay material	
Nominal	**Weight %**	**Mineral Content & Volume % by Visual Estimation**	**Grain Shape**
Sample ID: ARRI PH1/RCS1/18			
4000	0.94	Rock fragments stained with Goethite (90%), Goethite balls enclosing fine quartz grains (5%), Slightly ferruginous milky Quartz with black inclusions (5%)	Round to sub-round grains
2000	1.41	Goethite balls enclosing fine grains (90%), Milky and clear Quartz (10%)	Angular, Round to sub-round grains
1000	2.04	Rock fragments, some of them stained with Goethite (10%), Clear, milky and slightly ferruginous Quartz (85%), Goethite balls (5%)	Angular grains, Sub-round grains
500	5.17	Clear and milky Quartz (95%), Goethite, Rock fragments some stained with Goethite (5%)	Angular grains, Sub-round grains
250	5.95	Clear and slightly ferruginous Quartz (97%), Black mineral (3%)	Angular grains, Sub-round grains
125	2.19	Clear and slightly ferruginous Quartz (90%), Black shiny mineral (10%)	Angular grains, Sub-round grains
Less than 125	82.31	Very fine grained clay material	
Sample ID: ARRI PH1/RCS2/18			
4000	0.00	-	-
2000	2.15	Ferruginous Quartz (90%), Rock fragments (10%)	Angular grains
1000	2.94	Ferruginous Quartz (90%), Rock fragments (10%)	Angular grains
500	4.50	Ferruginous Quartz (85%), Rock fragments (15%)	Angular to sub-angular grains; Round to sub-round grains
250	5.87	Clear and ferruginous Quartz (75%), Iron oxide (Hematite) balls, some of them enclosing fine grains of Quartz (20%), Black mineral (5%)	Angular to sub-angular grains; Round to sub-round grains
125	2.55	Clear and ferruginous Quartz (55%), Iron oxide (Hematite) balls, some of them enclosing very fine grains of Quartz (35%), Black shiny mineral (10%)	Angular grains; Round to sub-round grains
Less than 125	81.99	Very fine grained clay material	

Table 9.5: Non-clay minerals inclusion rock fragments.

Nominal	Images and Details
Sample ID: DWKA/RCS1/18	
4000	 Rock fragment composed of quartz, feldspar and green coloured grains
2000	 Rock fragment stained with Goethite and Hematite, Clear Quartz, Milky Quartz, Ferruginous Quartz
1000	 Rock fragments, Clear Quartz, Milky Quartz, Ferruginous Quartz, Feldspar
500	 Clear Quartz, Feldspar, Rock fragment, Slightly ferruginous Quartz
250	 Clear Quartz, Milky Quartz, Ferruginous Quartz, B**lack mineral**
125	

	Clear Quartz, Milky Quartz, Ferruginous Quartz, Black mineral
Nominal	**Images Details**
Sample ID: DWKC/RCS4/18	
4000	 Feldspar, Rock Fragment, Quartz
2000	 Clear Quartz, Ferruginous Quartz, Feldspar, Rock Fragment
1000	 Clear Quartz, Ferruginous Quartz, Feldspar, Black Mineral Stained with Goethite
500	 Clear Quartz, Ferruginous Quartz, Feldspar
250	 Clear Quartz, Ferruginous Quartz, Feldspar, Rock Fragment, Black Mineral
125	 Clear and ferruginous Quartz, Green mineral, Goethite balls, Black mineral
Nominal	**Images and Details**

Sample ID: SDGA/RCS5/18	
4000	 Rock fragment composed of Iron Oxide and Quartz
2000	 Rock Fragment, Milky Quartz, Ferruginous Quartz, Feldspar
1000	 Clear Quartz, Ferruginous Quartz, Feldspar, Quartz coated with Goethite
500	 Clear Quartz, Milky Quartz, Ferruginous Quartz, Quartz coated with Goethite
250	 Milky Quartz, Ferruginous Quartz, Clear Quartz, Quartz coated with Goethite
125	 Clear and milky, Round to sub-round grains of Quartz coated with Goethite, Black shiny mineral, Green mineral, Iron oxide (Hematite)
Nominal	**Images and Details**
Sample ID: SDGB/RCS6-10/18	

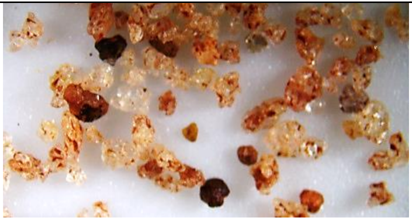
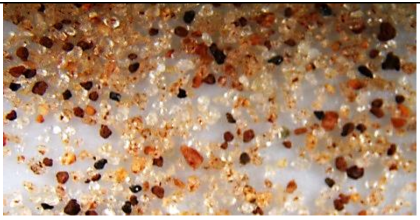
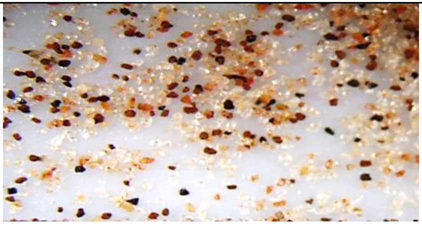
4000	 Rock fragment composed mainly of weathered feldspar, iron oxide and quartz
2000	 Ferruginous Quartz, Rock fragment composed of weathered feldspar and quartz
500	 Clear Quartz, Milky Quartz, Black mineral, Feldspar
250	 Clear Quartz, Ferruginous Quartz, Milky Quartz, Green mineral
125	 Clear Quartz, Green mineral, Ferruginous Quartz, Black mineral
Nominal	**Images and Details**
Sample ID: DRDA/RCS1/18	
4000	 Grained Quartz – Quartz grains composed of very fine quartz crystals

	 Multiple Quartz grains cemented together to form a single grain
2000	 Multiple Quartz grains cemented together to form a single grain; Grained Quartz – Quartz grains composed of very fine quartz crystals
1000	 Multiple Quartz grains cemented together to form a single grain, Milky Quartz, Clear Quartz, Rock fragments composed of black mineral and Quartz, Slightly Ferruginous Quartz
500	 Clear Quartz, Milky Quartz, Slightly Ferruginous Quartz, Multiple Quartz grains cemented together to form a single grain, Black mineral
250	 Clear Quartz, Milky Quartz, Slightly ferruginous Quartz, Black mineral
125	 Clear Quartz, Slightly ferruginous Quartz, Black mineral
Sample ID: KRDKB/RCS3/18	
4000	-

2000	 Rock fragment composed of Quartz and blackish to brown material Ferruginous Quartz, Clear Quartz
1000	 Clear Quartz, Milky Slightly Ferruginous Quartz, Rock fragment composed of Quartz and Iron Oxide, Multiple Quartz grains cemented together to form a single grain
500	 Clear Quartz, Ferruginous Quartz, Black flaky mineral
250	 Clear Quartz, Ferruginous Quartz, Black mineral
125	 Clear Quartz, Ferruginous Quartz, Black mineral

Nominal	**Images and Details**
Sample ID: ARRI PH1/RCS1/18	
4000	 Rock fragment stained with Goethite

	 Goethite ball enclosing fine quartz grains
	 Slightly ferruginous milky quartz with black inclusions
2000	 Rock fragment stained with Goethite, Milky Quartz, Clear Quartz
1000	 Rock fragment some stained with Goethite, Clear Quartz, Milky Quartz, Slightly ferruginous Quartz, Goethite balls
500	 Clear Quartz, Milky Quartz, Iron Oxide (Hematite), Rock fragment stained with Goethite
250	 Clear Quartz, Slightly ferruginous Quartz, Black shiny mineral, Goethite

125	 Clear Quartz, Slightly ferruginous Quartz, Black shiny mineral
Nominal	**Images and Details**
Sample ID: ARRI PH1/RCS2/18	
4000	-
2000	 Ferruginous Quartz, Rock Fragments
1000	 Ferruginous Quartz, Rock Fragments
500	 Ferruginous Quartz, Rock Fragments
250	 Clear Quartz, Ferruginous Quartz, Hematite, Black mineral
125	 Clear Quartz, Ferruginous Quartz, Hematite, Black mineral

9.3. Discussion

The non-clay mineral inclusions are usually fragments of rocks or mineral grains of common rock-forming minerals (Quinn, 2013). The non-clay minerals form a substantial component of the study of raw clay. The differences in the composition of the minerals association in the specific fractions are due to changes in sieve and the contribution of source materials. The mineralogical examination of the raw clay from Mbulu plateau reveals that the main content of non-clay mineral inclusions are clear quartz and ferruginous quartz grains subordinated by rock fragments, feldspars, and shiny black minerals, most probable mica. Iron oxide is also present in each sample in form of either yellow stains indicating the presence of Goethite [FeO(OH)] or red stains indicating the presence of Hematite [Fe_2O_3]. Occasionally, in samples DWKA/RCS1/18, DWKC/RCS4/18, SGDA/RCS 5/18 and SGDB/RCS 6-10/18 an unidentified green mineral was observed. Apart from that, some interesting features of non-clay minerals observed were rock fragments composed of black mineral stained with iron oxide (Figure 9.3), round to sub-round grains of quartz coated with goethite (Figure 9.4), grained quartz/quartz grains composed of very fine quartz crystals (Figure 9.5), multiple quartz grains cemented together to form a single grain (Figure 9.6), and iron oxide balls enclosing fine quartz grains (Figure 9.7). For more images taken from each sample and their detailed descriptions see Table 9.5 above. In general, a large amount of each sample is composed of angular to sub angular grains, indicating that the raw clay samples originated and were formed not far from their place of origin (primary origin), while a few grains of raw clay materials with a mixture of round to sub round non clay grains suggests that the raw clay material was formed from different geological settings and transported through time to the places where they were found (secondary origin).

The non-clay mineralogical composition of the raw clay material inclusion from Mbulu plateau are consistent with Narosura PN pottery sherds fabric inclusions from Luxmanda site discussed in chapter 6, 7, and 8 of this thesis. Particularly interesting is the close resemblance both in composition and texture between nearby clay sources in DWKA/RCS1/18, DWKC/RCS4/18, SGDA/RCS 5/18 and SGDB/RCS 6-10/18 with the pottery sample 1051 and 1524 (for critique, see chapter 8) from Luxmanda. The similarity therefore permits to ascertain that the provenance of archaeological Narosura PN pottery excavated at Luxmanda site was of local origin in the Mbulu plateau and the raw clay material used for making probably were obtained from the sources described above.

Figure 9.3: Sample DWKA/RCS1/18 (4000microns): Rock fragment composed of black mineral stained with iron oxide [Goethite + Hematite].

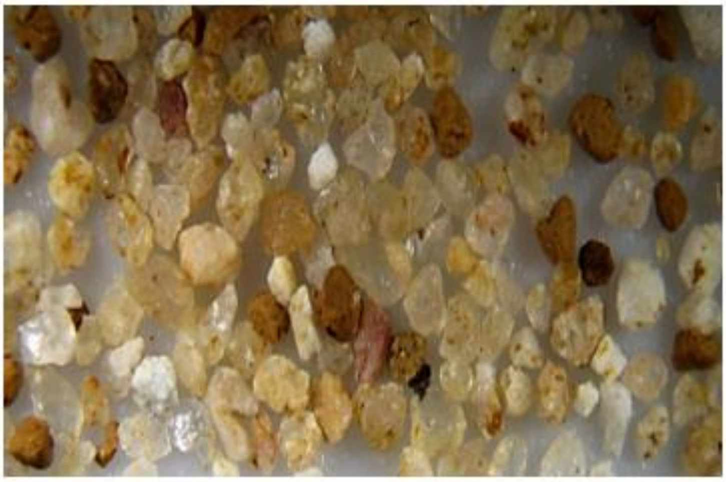


Figure 9.4: Sample SDGA/RCS5/18 (500microns): Round to sub-round grains of clear quartz and quartz coated with iron oxide [Goethite].

Figure 9.3: Sample DWEKA/RCS1/18 (4000microns:

Figure 9.4: Sample SDGA/RCS5/18 (500MICRONS):

Figure 9.5: Sample DRDA/RCS1/18 (+4000microns): Grained Quartz – Quartz grains composed of very fine quartz crystals.

Figure 9.6: Sample DRDA/RCS1/18 (+4000microns): Multiple quartz grains cemented together to form a single grain.

Figure 9.5: Sample DRDA/RCS1/18 (+4000microns): Grined Quartz-Quartz grains composed of very fine qurtz crystals.

Figure 9.6: Sample DRDA/RCS1/18 (+4000microns): Multiple quarts grains cemented together toform a single grin.

Figure 9.7: Sample ARRI PHI/RCS1/18 (+4000microns):
Iron Oxide ball enclosing fine quartz grains

Figure 9.7: Smple ARRI PHI/RCS1/18(+4000micros):Iron Oxide ball enclosing fine quartz gains

9.4. Chapter Conclusion

This method has provided the percentage of both clay and non-clay minerals inclusions including quartz, feldspar, mica and other mineral rock fragments. It was also observed that the percentage of fine grained clay and non-clay mineral grains such as quartz, feldspar, iron oxide and mica was higher than the percentage of non-clay minerals grains fragments comprising of hematite and goethite with decreased percentage. The non-clay fraction quantification (Table 9.3) also assisted in providing a better characterisation of aplastic mineral inclusion discussed in chapter six (6) of this thesis. Using this method, a comparison of non-clay minerals inclusions from other chapters is made. Base on the results obtained from this analysis therefore, visually quantifying the mineral content and volume of non-clay minerals is suggested for the raw clay from Mbulu plateau (Table 9.4). From this study, the origin, development and distribution of clay and non-clay minerals have been identified from both primary and secondary formations. The results from this chapter have been useful to ascertain the possible raw clay provenance for Narosura PN pottery recovered from Luxmanda site on the Mbulu plateau region. Furthermore, the data from this chapter will also be a useful tool for understanding for comparing other Pastoral Neolithic sites in Tanzania and East Africa.

CHAPTER TEN: 10

TRADITIONAL AND CONTEMPORARY POTTERY PRACTICES: AN ETHNOGRAPHIC PERSPECTIVE ON POTTERY MAKING IN THE MBULU PLATEAU NORTH CENTRAL TANZANIA

10.0. Introduction

This chapter presents data on the materials and techniques used by the Mbulu people on the Mbulu plateau in northern Tanzania to make traditional and contemporary pottery. This ethnographic study describes the pottery manufacturing process in several villages and the sources of clay on the Mbulu plateau. It also describes and discusses inter-village and inter-potter variations in procuring raw clay, the methods of raw clay paste preparation/baking, the methods used to shape (manufacture) the vessels, and how (methods/techniques) and where (location) the pottery were fired. The few ethnographic differences observed and documented are not only significant in terms of how the pottery were manufactured on the Mbulu plateau, but also in gaining an understanding of the techniques and technology employed.

10.1. Materials Analysis Procedures and Methods

An ethnographic survey was conducted among the potters of the Mbulu plateau to find out and document the contemporary chain of work and the techno-novelty of pottery production in this area, and to discover how this activity evolved. The ethnographic data discussed here was collected in two summer seasons, in 2018 the raw clay sources were surveyed to document the procurement methods, and in 2019 by visiting the potter’s homes in Mbulu plateau. The fieldwork involved observing the many stages of pottery production, followed by interviewing the potters. The data were later supplemented by participating in the pottery-making process of five (5) communities of potters in Arri, Darwedick, Dareda, Kirudick and Sidigi villages (Figure 10.1). Although the ethnographic survey covered a large area (within a radius of 0-40 km from the archaeological site at Luxmanda) around the plateau, contemporary potters were only found in the above-mention villages. Currently, only a few pockets of potters’ communities continue with the art of making pottery on the plateau. The presence and spread of pottery paraphernalia in other places around the plateau were probably the result of trade conducted at the weekly *Gulio* markets.

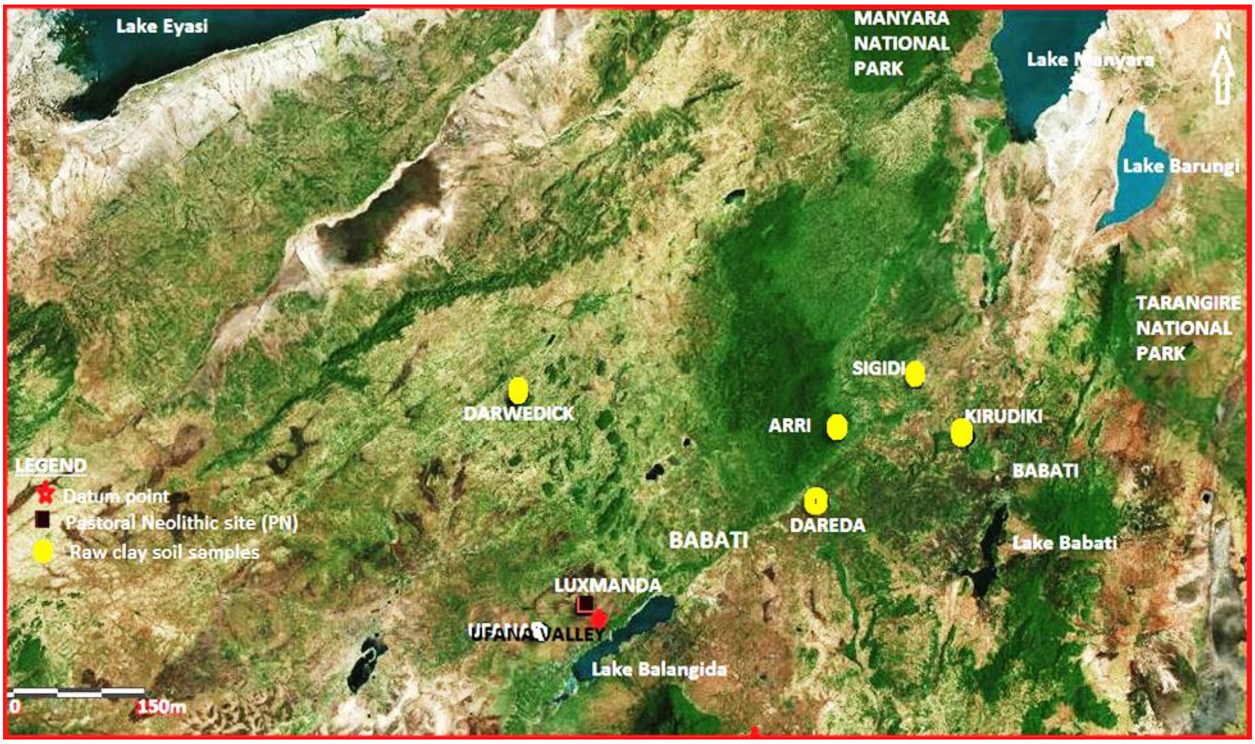


Figure 10.1: A geological map showing raw clay sources and the potters' villages in areas around the Luxmanda Pastoral Neolithic site.

10.2. Ethnographic Findings

10.2.1. Potters' sites and areas where raw clay was procured

Most of the raw clay material identified for manufacturing pottery came from villages at the top of the escarpment of Mbulu plateau, except for Arri and Kirudick, which were at the bottom/basement. The potters in the area procure clay based on its traditional plasticity quality and the type of pots to be made. Based on nature of the Mbulu terrain, most potters prefer to procure clay from nearby sources to avoid the inconvenience of transporting it, and so the sites where they make their pots are not far from the source of clay. Apart from pottery manufacturing, all the potters are engaged in small-scale agriculture as part of their subsistence activities, and their homes are surrounded by both food and cash crops.

10.2.2. Arri

Arri, one of the potters’ sites, is located UTM 36M 07888, 9530732; 1878 masl in the administrative ward in Babati Rural District in Manyara Region of Tanzania. According to the 2012 census, the ward has a population of about 14,146 (Census, 2012). The village has almost twenty (20) households engaged in pottery manufacturing, for which the raw clay is procured in Arri ward which is close to Sharmo village. The potters from this village manufacture different types of pot, such as cooking pots and frying pan/baking pots, as well as a few globular storage pots. According to the Arri potters, *they primarily specialize in making small pots that are easily transported to different areas for selling, unlike big storage pots that break easily when taken to the market. They do not often make large storage pots, because the nearby raw clay they procure from the source often breaks during firing when such pots are made.*

The potters of Arri mixed two types of raw clay when making pottery. Normal clay is used, and red clay is used as temper to colour the pots before being fired (Figure 10.2). The clay is mostly mined by the women, assisted by teenagers (children) in the potters’ family. In some cases, men are also involved in carrying large quantities of mined clay to their homes. After obtaining the clay, it is dried on top of sacks, animal skins or in buckets before being ground into fine powder that is finally mixed with water. The Arri potters do not add non-plastics to their clay because it is likely that it contains enough naturally occurring non-plastics.

The clay is normally mixed with water by hand. After it has been properly mixed, half of the clay is used to make the pot as far as the rim, and the remaining clay finishes it on the following day. The pots are then left to dry indoors for 4 days before completely drying them in the sun for another 4 days. After the pots have dried, the potters of Arri collect firewood, dry leaves and grass for fuel to fire them, but they can use dry sisal and maize husks as a substitute for firewood. In preparation for firing, they first fill the bottom of a shallow pit that serves as a kiln with dry leaves and grass, then put the pots on top and cover them with firewood to burn them in a bonfire. This normally takes from three to four hours (3-4) hours depending on the weather and wind flow. Pots from Arri are in great demand in many places due to their reddish colour.

Figure 10.2: Drying the raw clay after mining it in Arri

10.2.3. Darwedick

The site of Darwedick is found at UTM 36M 0757917, 9532249; 1855 masl. This area has only two potters who habitually make pots for family use but not for selling. The low demand for clay pots is probably due to the invention of modern metal pots. The observation of one household revealed that, after the raw clay has been mined, the potters soak it directly in water for about an hour to remove the organic and non-plastic materials. The clay is then sieved and left to dry outside in patches of direct sunlight before grinding it to powder for future pottery making.

After the clay is ground, the potter mixes it with water and prepares the paste for making pottery. Later, the potter takes the prepared paste and shapes a small pancake-like slab of it into a circle and starts to make the pot. The pancake is then forced upwards from the centre with the palm of one hand inside the pot while the other hand uses a scraper on the outside to form the pot. After the pot has been formed, it is then partially dried in the shade for about a day before being exposed to direct sunlight for complete drying. The potters in Darwedick only make pots for serving food and for cooking. Soon after the pots are completely dry, firing is done on a bonfire, whereby the pots are covered with firewood, which is burnt until there is nothing but ashes. Finally, after the pots have cooled down the potter removes them from the firing area ready for use.

10.2.4. Dareda

This site is located at UTM 36M 07759800, 9529812; 1647 masl in Dareda township. The raw clay for making pottery is mined from a massive gorge on the south eastern side of the Akeut River valley located 1.5-2 km from the town. It is only mined the dry season to avoid accidents (dropping the clay) when the valley is flooded in the wet season. Although only two traditional potters were identified in this area, the raw clay from this site is mined and used by potters from the nearby villages of Gitting, Sabilo, Bariomo, Maganjwa, Dabil, Bashnet, and Dongobesh, to mention a few. The raw clay is mined by both women and children, after which they carry it to the respective potters' homes (Figure 10.3). Donkeys and a few oxen guided by men are also used to carry the massive amount of clay to places far from this site.

The observation made to one potter in Dareda revealed that, after the clay is mined and transported inside the weaved sacks to the potter's home. The raw clay is then left to dry for one to two weeks before pounding it into powder, which is then mixed with water until plasticity is obtained. The paste is then left to mix-up for one night before it is used to make pots. The pots made from this process are first dried inside the house for about 6 days before they are exposed to direct sunlight (for four days desiccation) for complete dehydration, after which they are fired (Figure 10.4).

Figure 10.3: Raw clay procurement in progress assisted by children

For firing, the potters put portions of firewood, dry leaves and grass in a shallow pit to form a kiln to burn the pots. The potters first put dry leaves at the bottom of the kiln, followed by the pots, which the potter then covers with grass before putting firewood on top it. Finally, the pots are fired until the colour turns to yellowish red that signifies the end of the firing process (Plate 8.3 A and B).

Figures 10.4 A and B: portion of the large storage area (with raw clay inside) and cooking pots at a potter's home in Dareda.

10.2.5. Sidigi

The site is located on the top of Mbulu escarpment a few kilometers from Luxmanda archaeological site. The area has two raw clay mining localities for manufacturing pottery located at UTM 36M 0758546, 9535914; 1887 masl and UTM 36M 0758681, 9535983; 1880 masl (massive pit). The first pit seems to have been used in the past but is no longer in use probably due to changes in the geomorphology, as reported by the potters. The second pit is massive, which is currently used for mining raw clay by several communities near to and far from this area.

The observation of potters near the huge pit indicated that the clay is mined by both women and men. Although men are involved, their main task is to assist in mining the raw clay during the dry season when the ground is too hard for women to mine, as well as transporting the raw clay from the mining area to other potters’ homes that are far from the site. After the clay has been brought to the potters’ homes, it is dried in the sun for a few days (3-6 days depending on the weather) before it is ground into powder, after which it is soaked in water for 24 hours. The following day the clay paste is kneaded to remove the stones. Pottery making begins only when the paste is as hard as leather. After the pots are made, they are left to dry inside the potter’s house for four (4) to seven (7) days before exposing them to direct sunlight (Figure 10.5 A and B). The pots are then fired in a shallow pit forming a kiln using firewood, dry grass and leaves as fuel. The pots made in this way are mostly cooking pots and are sold at various markets on the plateau.

Figure 10.5 A and B: Drying the pots inside the house and outside in the sun, respectively.

10.2.6. Kirudick

The site is located north east from Luxmanda archaeological site at UTM 36M 0794277, 9538580; 1286 masl low down on the Mbulu escarpment. The area is famously known as Gogo street (*mtaa wa wagogo*) because the potters speak both Gogo and Mbulu languages. The potters here claim to originate from the Gogo people in the Dodoma region of Tanzania, and through intermarriage and trading, they managed to settle with the Mbulu people many decades ago (Potters pers.com, 2018).

Several potters were identified in households visited in this area, where pots are made by both old and middle-aged women (Figures 10.5 A and 10.6 A and B). The middle-aged women assist in mining and carrying the raw clay to the elderly potters. Observation revealed that most potters' homes are near the raw clay sources. As a result, the raw clay is not mined in bulk, as in the sites described above. In making the clay paste the mined clay is left to dry on top of a flat rocky outcrop in the potter's yard (Figure 10.5 B), after which it is ground into powder and mixed with water, and later left for few a hours before the pots are made. This activity normally involved two to four potters at a time.

Figure 10.5 A and B: The old women making pots, and drying the raw clay on top of the rocky outcrop, respectively, in Kirudick.

The unique aspect of the pottery making style here is that they are a direct imitation of modern metal pots. The Kirudick potters make several clay vessels such as cooking pots, storage pots, cooking stoves and frying pans among others (Figure 10.6 A). After moulding the pots, they are either hidden inside their house or the rock shelter for primary drying before complete drying in direct sunlight. The firing process here involves firing the pots in a shallow pit

(Figure 10.6 B). The fuel used are maize and wheat husks which are put in the pit, followed by the pots that are covered by dry leaves and firewood.

Figure 10.6 A and B: Different pottery styles and firing remains (ashes) in a shallow pit.

10.3 Discussion

10.3.1. Traditional pottery-making process

The art of making traditional pottery involves various phases. These include procuring the raw material (raw clay and other aplastic material) from the source, preparing and kneading the clay paste, shaping the clay and making the pots, drying and putting slip or decorations on them, collecting fuel for making a fire in a pit, arranging the pots in the pit for firing, storing them for future use and selling them in the market (Figure 10.7).

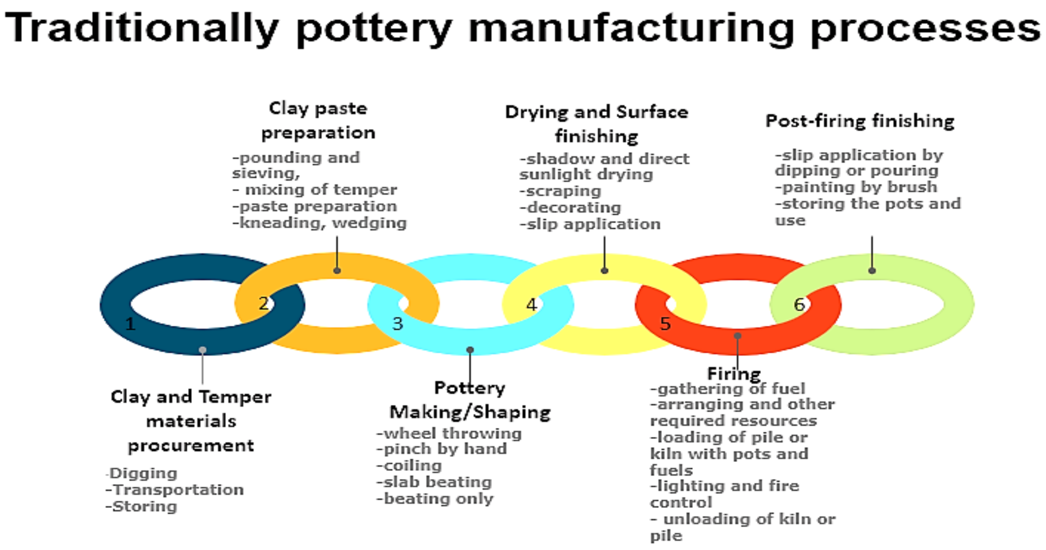


Figure 10.7: Phases and sub-stages of traditional pottery manufacturing process. Source: Author.

10.3.2. Procuring the Raw Clay

Clay is the fundamental raw material for any sort of pottery. The type of pottery to be made usually depends on the characteristics and properties of the clay being used. Potters usual pay special attention to the characteristics of raw clay sources, like plasticity, porosity and vitrification, before deciding to make pots (Rapp, 2009). This study observed that the potters on Mbulu plateau prefer to collect suitable clay from sources near their homes for easy transportation. This agrees with the threshold model of the 1–5km distance that potters are willing to go to procure clay (Arnold 2005; 2006). The huge amount of raw clay available in the valley where Dareda and Sidigi are situated was predominantly used and preferred by all potters on the plateau because, according to them, 'this clay has excellent properties', regardless of its distance from the potters' home. Quarrying, sorting and transporting the raw clay is mostly done by women, aided by children and a few men (for transporting the clay) at all the sites visited, except at Darwedick where these tasks were done by just two women, without the help of other members of the family or community. Generally, all the potters on the plateau collect raw clay during the dry season when the banks of the rivers, the valleys and lowlands are dry from May to August. Quarrying is mostly done in the banks of nearby valleys, rivers, and lowland stream beds. Apart from that, all the potters interviewed also reported a few taboos associated with the quarrying of clay. The one highlighted was that women who had sexual intercourse the night before quarrying were not allowed to quarry the clay or visit the quarrying site the next day.

10.3.3. Preparing the Clay Paste

The preparation of clay is one of the vital pottery-making processes. All naturally occurring clays contain both aplastic mineral and large pieces of other material (Rapp, 2009), which makes sorting or refining the clay a major challenge (Musharraf, Hossain, and Islam, 2012), because it is not formed from a single mineral but rather an aggregate of minerals and colloidal substances, except for some kaolinite clay deposits (Rapp, 2009). According to the researcher's observation, the Mbulu plateau potters are unlikely to use the clay as quarried. In most cases, they first prepare the clay by drying it, followed by kneading, crushing, and sieving it. Later on, they may occasionally combine the clay with an additional type of clay or temper materials, such as crushed rock, gravel, sand, plant material, animal dung, and crushed pottery. For example, the Arri potters mixed two types of raw clay for making pottery, and adding temper to clay may change its properties, resulting in both production-based and performance-based benefits (Woodward, 2002; Bebber, 2017). This is followed by adding water to the ground clay to prepare the clay paste, although in Darwedick and Sidigi they soak the clay in water to remove aplastic material. For instance, in Darwedick the potters soak the raw clay in water for one hour soon after it has been mined to remove the unwanted organic and non-plastic materials from it before drying it. On the other hand, the potters in Sidigi first allow the clay to dry and grind it before soaking it in water for one day, after which the paste is prepared. At all the sites it was observed that, after completing the preparation of paste, several lumps of paste are covered with plant leaves, sacks and cloths (kanga) to avoid drying while waiting until they are ready to start making pots.

10.3.4. Pottery Making

Pottery is a traditional hand-made craft that involves many diverse ways, such as coiling (laying clay coils on top of each other), slab building (joining slabs of clay together), pinching and pulling (pushing the clay either by hand or using a paddle and anvil) striping rings (strips of clay are scraped or pressed to join together) and wheel-throwing (a combination of hand building and throwing) (Gibson and Woods, 1997; McCarthy and Brooks, 1988).

The potters observed on Mbulu plateau use different methods to make pots. Amongst the methods observed during the visit are coiling, slabbing, pinching, scraping, pressing and beating. The potters’ choice of the method is mostly influenced by the type of vessel being made and the stages of forming it. Pots are made in two stages. The first stage involves making the upper half part of the pot by taking a large coil or slab from the lump of clay and placing it on a flat surface, either a wooden or old metal plate. The pot's upper half is then left to dry at room temperature until the next day, when it is firm enough to be handled (Figure 10.8). The second stage involves turning the pot's half upside down, so that the lower part of the pot is shaped to complete the base. All the pots observed had a rounded base. It was also noticed that there were mainly two types of pots (cooking and storage pots), which were traditionally shaped in this area, and their sizes varied according to the function of the pots. Other clay vessels like cooking stoves and frying pans among others were also observed (Figure 10.6 A).

Figure 10.8: Pottery partially dried inside the room and outside in the sun.

10.3.5. Pottery Drying and Surface Finishing

Based on Shepard (1956), finishing the surface depends on what the clay vessel is to be used for, and whether or not it is to be decorated. Finishing could be accomplished instantly when the clay is still plastic, or it might not be accomplished until the vessel is as hard as leather (Shepard, 1956). Although rarely seen on the Mbulu plateau pots, it was noticed that decorations and surface finishing are only applied once the pots have been shaped and are as hard as leather. Observation also revealed that after being shaped the pots or clay vessels were left to dry mostly inside the house or under a rock shelter before being exposed to direct sunlight. Drying pots inside the house normally takes one to four days, depending on the weather, where they are kept upside down. Once the pots are 60% dry, they are brought out to dry in the sun for two to four days until they are leather hard (Figure 10.9).

Figure 10.9: Pottery Drying

10.3.6. Pottery Firing Techniques

The Mbulu plateau potters generally fire their clay pots and other vessels in open places near their homes, either on a bonfire or in a shallow pit like a kiln. The potters from Arri, Darwedick and Kirudick use a bonfire to fire their clay products, while those from Dareda and Sidigi use a shallow pit to fire their products as in a bonfire. In both methods the pots are either placed on a flat piece of ground or in a shallow pit that has been dug, and fuel is placed below and above the pots. The techniques for firing only vary in terms of the fuel used for covering the pots, such as maize and wheat husks, dry leaves, dry grass and firewood, which have been passed down from their forefathers. Regarding how long it took to fire the pots, it was observed that it took between two and five hours, depending on the amount of pots to be fired and the type of fuel used, as well as the weather and time of year.

10.4. Chapter Conclusion

This chapter has presented ethnographic data on the pottery-manufacturing techniques and processes used by contemporary Mbulu plateau potters, and has shown that pottery making is a vanishing art. It is also the first extensive ethnographic study of how and where raw clay is procured on the Mbulu escarpment, and what methods are used to manufacture pottery in comparison with other contemporary pottery-making sites in Tanzania.

CHAPTER ELEVEN:11

GENERAL THESIS CONCLUSION

This thesis studied Narosura Pastoral Neolithic pottery from Luxmanda site (ca. 3000-2900 B.P), Mbulu Plateau of the North-Central Tanzania. It is the first study to present a combination (ceramic ecology-Matson, 1965a) of multiple analytical data (typology, petrography, geochemistry, wet sieve, and ethnography) to gain an understanding of technological and socio-economic aspects of Narosura PN pottery. The overall objective of this thesis was to characterisation of Narosura PN pottery fabric and to compare with the potential sources of raw clay in the Mbulu plateau region. This study applied multiple analytical techniques to delve into the technology of Narosura pottery PN pottery production to gain a better understanding of their provenance. One hundred and fifteen (n=115) pottery sherds and eight (n=8) lumps of raw clay were sampled and analysed, using macroscopic (typology, ethnography) and microscopic (wet sieve, petrography, SEM-EDS/EDAX and XRD) analysis. The results from these analyses were discussed and presented in individual chapters in this thesis.

The study provided an incredible amount of information on the possible sources of raw clay used for Narosura PN pottery ware manufacturing, its fabric inclusions, the techniques used for manufacturing (technology utilized to produce the samples) the pottery, the pottery firing conditions, the possible provenance of the pottery samples (whether made locally or imported to the site), and the current contemporary potters' capabilities. These are summarised below.

Regarding the clay that was used to manufacture the Narosura PN pottery paste, Peacock (1970) and Quinn (2013) noted that for provenance studies of ceramic vessels to be successful, they should use a combination of thin-section petrography and geochemistry, rather than just using ceramic typology (stylistic) to determine the provenance of a particular ceramic vessel. These studies usually analysed the texture of the ceramic paste inclusions (temper material) and their mineralogical composition and compared them with potential geological sources (raw clay) to find out if they relate to common sources of clay (Shepard, 1942; 1963; Quinn, 2013). In realisation of this argument, this study therefore prompted to extensively analyse and characterise the fabric of Narosura PN pottery with a stance of establishing their provenance on the basis of substance rather than form. To do this, thirteen (13) pottery samples were subject to petrographic analysis, and raw clay material from eight (8) localities were subject analysed by wet sieve soil (non-clay inclusion) analysis, supplemented by XRD compositional analysis of the eight raw clay samples and four pottery samples. By using multiple analysis techniques and by comparing the Narosura PN pottery fabric/paste with the Mbulu plateau raw clay, a closer similarity was observed. The inclusions in the raw clay observed through wet sieve analysis and the pottery pastes inclusions from thin-sections slides, as well as their rock type, mineralogical and geochemistry observed from SEM-EDS/EDAX and XRD analysis were also similar. Although this study focused on stratified pottery samples, the Narosura PN pottery sherds were relatively homogenous, suggesting that they had been produced from the same source of raw clay. Identifying the type of inclusions and tempering materials in the pottery samples paste and the raw clay enabled a comparison to be made with the geology of different localities in Mbulu region, which provided hints concerning the origin of Narosura PN pottery at Luxmanda site. This study therefore found out that the clay in the Mbulu plateau region was used for making Narosura PN pottery, as most of the sampled pottery reflects local geology.

The non-plastic inclusions present in Narosura PN pottery sample paste were used to attest how the pottery were tempered. Thin-section petrography and SEM-EDS/EDAX results revealed several tempering materials, which were divided into three categories according to the type of materials used as reflected in petrography and SEM-EDS/EDAX. The first category comprised vegetable temper material, the microscopic examination of some pottery samples pastes revealed several linear voids indicating the traces of vegetable inclusion (chapter six). The SEM micrograph image of sample 1327 (chapter seven) showed the fibrous like-structure of mineralised plant remains, which is an imprint of the vegetable inclusions. Although most of the pottery fabric inclusion were of a similar type, the presence of vegetable inclusions, linear and vesicle voids in a few samples implies that fragments were intentionally added by the potters. Since the majority of the pottery vessels observed consisted mainly of small bowls and cooking pots, it seems that the use of vegetable temper was to facilitate firing of the vessels rather than reinforcing the walls.

The second category of temper identified through microscopic petrographic analysis contained grog (grog are pre-existing pottery material added to clay paste) (chapter six). The mineralogical similarity between the different grog tempers and the other parts of pottery paste, especially for the most abundant minerals elements permit to conclude that the basic raw materials used to their preparation were nearly the same.

The third category was grits (crushed rock fragments added to the clay paste when manufacturing the pottery). Several grits of angular shape with coarse to fine grains were observed in the pottery samples in thin-section slides. Their presence and uneven size distribution in pottery samples were also used as indicator for deliberately added tempers. Therefore, it can be concluded that tempering materials were probably added to the raw clay pastes based on the intended function of the pottery.

Both macroscopic and microscopic analysis assisted in discovering the techniques used for manufacturing Narosura PN pottery. The one most occurring was the coiling method that was observed through initiating fresh vertical and horizontal breaking pottery samples and from random vesicles and circular voids. Another method used was slab building, although this was only seen in the vessels with thick wall identified as storage and cooking pots. Coils were mostly observed in bowls and thin wall vessels. The regular use of the coiling method in the majority of the samples is a further indication that the manufacturing technology had changed very little over time, and that the Narosura the potters inherited and maintained these skills through time. The nature of aplastic remains observed in pottery samples paste confirmed the standardisation of raw clay processing and pottery manufacturing. For instance, SEM micrographs images found no evidence some of inclusion in samples, suggesting a high level of clay processing skills, while some samples with irregular to regular inclusions of mixed sizes indicate a low of processing skills of the clay materials. The additional tempering materials such as organic materials (dung, straw etc.) while making pottery were also noticed, due to the presence of elongation voids, probably because organic material of different origin used to improve the workability, resistance to thermal shock and toughness, thereby preventing the propagation of cracks generated by the differential expansion of interior and exterior vessel walls upon heating or cooling (Chapter six).

The firing conditions of Narosura PN pottery was estimated based on typological, petrographical and geochemical analysis data. After the pottery samples were deliberately broken, the typological data showed that most of the pottery cores had dark to light colours, with multiple colours on the interior and exterior surface. The appearance of both dark to lights colours suggests that the pottery samples were fired under reducing condition with poor control of the oxygen in an open bonfire. This colouration of dark to light (reducing and oxidising) of the sample has also been referred to as ‘firing clouding’, which is mostly caused by the type of firing environment, distance of the vessels from the fuel, temperature variation and soaking time in fire (Quinn, 2013; Reedy, 2008). (Quinn, 2013; Reedy, 2008). The petrographic data also supported the reducing environment due to the existence of frequent patches of oxidised, carbonised black spots and irregular dark areas, with many voids on thin-section samples also proving that the firing conditions had been not nicely controlled. Furthermore, the presence of some minerals like calcite and the lack of vitrification in most samples revealed by SEM-EDS/EDAX and PXRD analysis also suggests that the pottery samples were fired at temperature not exceeding 1000° C, and the lack of calcite (CaCO3) decomposition. Furthermore, the PXRD diffractometric analyses indicates that for the production technologies used both low temperature forms and kilns that could not exceed the temperature of 900 degrees, these conditions are shown in the ceramics rich in gehlenite and free of illite, while the samples that have calcite were fired at a low temperature. The existence of mineralised plant substances observed in SEM-EDS/EDAX also support this hypothesis. The other distinguishing feature observation was that the surface of some pottery samples had been blackened, denoting that the pots had been used for cooking on a fire.

The similarity of the chemical and mineralogical properties of Narosura PN pottery from Luxmanda open air site (Grillo et al., 2018), those of a few Narosura PN pottery samples from bed two occupation at Eyasi-Mumba site some 80 km north west of Luxmanda (Mehlman, 1989; Prendergast, 2011; Grillo et al., 2018), and the properties of raw clay from Mbulu plateau area analysed in this study interestingly suggests that probably the clay sources from this area were used to make the Narosura PN pottery found in both sites. This might also indicate the clay used was formed from similar parent rocks, but perhaps obtained in a different location. The fact that the chemical and mineral compositions of Narosura PN pottery sherds from both sites are quite similar, and that Luxmanda had the largest deposit of single Narosura PN pottery ware (ca. 3000-2900 B.P) that similar with the Mbulu raw clay, would suggest that probably Narosura PN pottery were moving from Luxmanda site to Eyasi-Mumba site due to their vicinity. However, more studies are needed to compare the petrographic, geochemical composition, manufacturing and circulation among other Narosura PN pottery sites to confirm this hypothesis.

Both the ethnographic survey of the contemporary pottery-making process done by this study and analysis of the availability of raw clay to the Mbulu people have provided a deeper understanding of the level of technology used in contemporary ceramic production and their socio-economic implications. The ethnographic study revealed that, although the potters preferred to obtain raw clay from near their homes, they also regularly acquired it from further away in Darwedick, Sidigi and Dareda, through going there, exchanging it, or both. The ceramic vessels made were then transported to be sold at the weekly markets, known as *Gullio,* both within and outside the Mbulu plateau. The ethnographic survey revealed that, if contemporary potters from different areas within and outside the Mbulu plateau transport ceramic vessels to sell, it is likely that ancient pastoralists from Luxmanda would have transported Narosura PN pottery to the nearby Eyasi-Mumba site.

Finally, this study proposed that the future prospective studies should focus more on petrographic and geochemical research should to Narosura PN pottery and other Pastoral Neolithic sites in order to establish a database for future comparison. In addition, the remarkable amount of information and data provided by this study could be used in future as a first-hand ceramic ecology evidence for determining of the spread Narosura PN pottery across Tanzania and East Africa in general. Studies are also needed at different sites to assess and add the number on ceramic ecology studies to range of pastoral Neolithic sites and pottery samples, to discover the temporal variations, acquisition strategies and the lives of specialized herders.

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