A study on the Ceramics (Pottery) of Myrkhan Neolithic Site of East Khasi Hills District, Meghalaya Plateau, India

A Thesis Submitted in partial Fulfilment of the
Requirements for the Degree of

Doctor of Philosophy

by

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DECLARATION

I solemnly declare that the work presented in this Ph.D. thesis, entitled **"A study on the Ceramics of Myrkhan Neolithic Site (East Khasi Hills District), Meghalaya Plateau, India"** is the result of research carried out by me in the Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, India under the supervision of Dr. Sukanya Sharma, Professor (Archaeology). This thesis has not been submitted in whole or in part for any other degree or qualification at any other university or institution. Any data, results, or conclusions presented within this thesis are the outcome of my original research, analysis, and interpretation.

In keeping with the general practice of reporting scientific observations, due acknowledgement has been made wherever work described is based on findings of other investigations.

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CERTIFICATE

This is to certify that the work contained in the thesis entitled **"A study on the Ceramics of Myrkhan Neolithic Site (East Khasi Hills District), Meghalaya Plateau, India"** by Momi Das (Roll No. 146141016), student in the Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, India for the award of the degree of Doctor of Philosophy was carried out under my supervision. The collection of materials from secondary and primary sources has also been done by herself. The results embodied in the thesis have not been submitted to any other University or Institute to award any degree or diploma.

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Abstract

The thesis entitled "**A study on the Ceramics (Pottery) of Myrkhan Neolithic Site (East Khasi Hills District), Meghalaya Plateau, India"** deals with the detailed study of the ceramic (pottery) assemblages recovered from the excavated site of "Myrkhan". The study incorporates quantitative analysis of the morphological variations of the pottery fragments and the physiochemical and elemental analysis of the pottery fragments of Myrkhan. It is a site specific study that will try to understand the site formation process and the different cultural forms which developed there. Archaeological sites are windows into the past, preserving the material remains of ancient way of life. By studying these sites, we can unravel the rich tapestry of human heritage, safeguarding it for future generations. For the present study ceramic (pottery) assemblages have been chosen from the excavated area for its most important criteria of long durability and being one of the most informative artifact found in the archaeological sites to understand the site formation process and other related information on that region and the people living there. Another reason of selecting the site is the study area was excavated most recently and no prior work has been done on the ceramics found in the site to reveal any site information.

The site Myrkhan has been understood as a tool manufacturing site or factory site. Stone tools in different stages of development, hammer stones, anvils have been recovered from the site. There is a high concentration of debitage or stone flakes, which was a major criterion for calling it a factory site. Along with tools pottery and other artefacts like iron slags, ring stone, small beads have been found.

One of the important fact about the site is the C14 dates of the lower layer Cal BP 3500 ± 30 BP2 which gives the earliest Neolithic date in the Neolithic culture of the entire Northeast region. Less occurrences of evidences like pottery in comparison to the high density of unfinished stone tools indicates that this place was a temporary seasonal camp of small groups of people possibly and not used for permanent settlement.

A circular stone structure found in the excavated area make it more complex to understand the sites context.

The current investigation is broadly divided into two sections is aimed at studying the pottery found in the site. The first section will focus on morphological analysis, encompassing classification based on several criteria, including pottery type, design, color, thickness, and the reconstruction of pottery shapes. This morphological classification will aid in comprehending

the similarities and differences among pottery samples from four distinct layers identified during excavation.

The second section will delve into physiochemical and elemental analysis of the pottery samples to discern pottery provenance, the source of raw materials, the manufacturing process, and firing temperature. Various scientific methods, such as Powder X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Energy-Dispersive X-ray Spectroscopy (EDX), Mohs' Scale Hardness Test, Porosity Test, and Thin Section Petrography, have been used in this phase.

A comparative evaluation of these two phases of analysis aids in comprehending the temporal progression of the culture, the developmental phases of the craft, and the identification of local or non-local products by tracing the sources of raw materials and the movements of the people who practiced the craft during the Neolithic period.

Chapter Outline-

The content of this thesis entitled "" **"A study on the Ceramics (Pottery) of Myrkhan Neolithic Site (East Khasi Hills District), Meghalaya Plateau, India"** "" have been divided into six chapters based on results of experimental work carried out during research period as follows –

Chapter 1: Introduction

First chapter is introductory chapter. This chapter will discuss importance of site study in archaeology followed by the description of the site Myrkhan. This part will also discuss the aim and objectives of present study and methodological framework and a review of literature on impressed pottery.

Chapter 2: Geography and Geology of the Study Area

Second chapter presents the geomorphological and geological setup of the study area, which also includes topography, drainage pattern and the available clay sources in the entire Meghalaya state.

Chapter 3: A Comparative Analysis of Morphological Variations of the Ceramics

A total number of potsherds excavated from the site Myrkhan are selected for Morphological analysis. The basic attributes consider for classification are type, colour, pattern of impression, thickness. This chapter also presents the reconstruction of pottery fragments of 27 selected samples.

Chapter 4: Scientific Analytical Study of the Pottery

This chapter will investigate mineralogical and elemental properties of 35 selected pottery samples and 2 soil samples from four different layers and from different depths. This analysis is carried out with the aim to unveil the provenance and the manufacturing process of the selected pottery samples.

Chapter 5: A Comparative Study on the Morphological and Scientific Investigation of Ceramics (Pottery) of Myrkhan

This chapter deals with the comparative analysis of Morphological data and the mineralogical and elemental data of the samples based on different layers and pottery types.

Chapter 6: Conclusion

Concluding chapter will be summing up basic findings of present study.

Chapter-1

Introduction

"Archaeology is partly the discovery of the treasures of the past, Partly the meticulous work of the scientific analyst, partly the exercise of the creative imagination. It is toiling in the sun on an excavation in the deserts of Central Asia, it is working with living Inuit in the snows of Alaska. It is diving down to Spanish wrecks of Roman York. But it is also the painstaking task of interpretation so that we come to understand what these things mean for the human story. And it is the conservation of the world's cultural heritage against looting and against careless destruction." – by (Renfrew & Bahn, 2012)

1.1 General Introduction of Myrkhan Neolithic Site

1.1.1 Importance of Archaeological Site Study

In archaeological research, site study plays an important role. Site study is important to know the process by which the specific context was made or derived. Archaeological sites may be thought of as places where artifacts, features, structures, and organic and environmental remains are found together (Renfrew & Bahn, 2012). To describe it in a simple way an archaeological site is any place where human beings have left evidence of their presence or activities. These sites can range from prehistoric settlements and burial grounds to ancient cities, temples, and industrial complexes and also it could be a small piece of pottery or could be a site with huge architectural remains. These are the links to bygone eras that provides valuable insights into the livelihood, social beliefs, practices and cultures of our ancestors.

Artifacts and features are the two main primary evidences that indicates presence of archaeological sites. Artifacts are transferable human made objects or probably used by humans that are left behind in the site. Features are the non-transferable objects or evidence of the human behaviour, activities and technologies that was practiced once in those sites by the then living population. Evidences also include macro and microscopic flora and fauna, as well as molecular evidence such as lipids, DNA, and stable isotopes[1].

[1] Stable isotopes are non-radioactive forms of atoms. It can be used by measuring their amounts and proportions in samples, for example in water samples. Naturally-occurring stable isotopes of water and other

Archaeological sites are very important to study as they preserve the material culture of bygone civilizations, contributing to the collective cultural heritage of humanity and allows us to connect with our roots. The excavation and study of archaeological sites enable historians and archaeologists to refine their understanding of historical timelines, cultural development, and social evolution. Archaeological research employs various scientific techniques, including carbon dating, DNA analysis, and remote sensing, advancing our understanding of the past through interdisciplinary collaboration.

The archaeological evidence is found in a context which consists of its immediate matrix (the material surrounding it, usually some sort of sediment such as gravel, sand, or clay), its provenance (horizontal and vertical position within the matrix), and its association with other finds (occurrence together with other archaeological remains, usually in the same matrix) (Renfrew & Bahn, 2012). If any artifacts found in any archaeological site is misplaced from its context, all the contextual information will be lost. For example, a looted vase may be an attractive object for a collector, but far more could have been learnt about the society that produced it, had the archaeologists recorded it from where it was found (in a tomb, ditch, or house?) and in association with what other artifacts or organic remains (weapons, tools, or animal bones?) (Renfrew & Bahn, 2012)

Any artifacts collected from the context of an excavated or explored site give us vital information about many unknown facts of our past societies and about the people and their cultures. Ceramics or pottery plays an important role here, as it has been proved as the most durable human made material. Ceramics around the globe demonstrate an infinite diversity of material, form and decoration, resulting in the multiplication of literally thousands of individual ceramic traditions (Gaimster & Freestone, 1997). It is essential to have the idea about how to define and interpret these products culturally and scientifically and also understand the stages of development over time of individual technologies and craft traditions. It is also important to know, how to measure the impact of one tradition on another.

For the present study ceramic (pottery) assemblages have been chosen from the excavated area for its most important criteria of long durability and being one of the most informative artifact found in the archaeological sites to understand the site formation process and other related information on that region and the people living there. Another reason of

substances are used to trace the origin, history, sources, sinks and interactions in water, carbon and nitrogen cycles.

selecting the site is the study area was excavated most recently and no prior work has been done on the ceramics found in the site to reveal any site information.

When potters produce a vessel, they make different technological choices that are embodied in recipes, which involve using specific raw materials in relatively constant proportions (Lemonnier, 1993). The study of paste recipe is very essential in the study of archaeological ceramics. As observed ethnographically in India recipes used to produce ceramics go beyond environmental, technical, functional as well as economic and also have social and cultural values. Thus recipes are strongly related to social norms that regulate the manufacturing process and are consequences of the knowledge acquired by individuals as a result of technological and social behaviour. Using specific materials and procedures can work, whether consciously or unconsciously, as an agent capable of strengthening the bonds of identity and social cohesion among members of the same community in a process of materializing the cultural tradition (Santacreu, 2014). Recently several anthropological and sociological studies have interpreted technologies as cultural choices that are determined as much by local perceptions and then social context as any material constraints or purely functional criteria. Using the example of ceramic technology, archaeologists consider how material science studies can contribute to and benefit from the understanding of technology as a social construct. Apart from the potential difficulties, there is the contention that both material scientists and archaeologists have gained much and have much to gain by cooperating together to study ancient technologies and that the concept of "technological choices" can facilitate a wider consideration of the factors shaping technological developments (Sillar & Tite, 2000). In archaeological research work, study of material science become important to investigate its provenance, production, technology and cultural framework and the changes that occur over time. It helps in a culturally meaningful way to incorporate the scientifically procured results in an archaeological interpretation.

1.1.2 About The Site Myrkhan

The different parts of the Khasi Hills of Meghalaya plateau have great potential for an in-depth study about Neolithic culture. Many archaeological sites have been explored and few have been excavated in this archaeologically potential region. The site Myrkhan was explored and excavated very recently. In the year 2016 this site has been excavated by Dr. Marco Mitri. This site is situated in the East Khasi Hills District, Meghalaya and it is a Neolithic site. The site is named by the of the nearby village Myrkhan, which is almost 1/2 km away from the site.

These hills are inhabited by the Khasi-Pnar community who speaks Austro-Asiatic language and are known to be one of the earliest ethnic groups belonging to Monkhmer group of proto Australoid race in Indian sub-continent and they also share similar genetic makeup with the Munda group and other Austro-Asiatic speaking population of South-East (Mitri & Neog, 2016; Sarma, 2003).

Myrkhan village is located in Mylliem subdivision of East Khasi Hills district in Meghalaya, India. It is situated 5km away from sub-district headquarter Mylliem (tehsildar office) and 14km away from district headquarter Shillong. According to census 2011 total population of Myrkhan is 276, out of which male population is 143 and female population is 133. There are about 47 houses in Myrkhan village. Mylliem is the nearest town to Myrkhan village for all major economic activities.[2]

The site has been declared as a tool manufacturing site or factory site used by the then population. A numerous numbers of stone tools had been recovered from the area along with a huge numbers of stone flakes, which was considered as one of the major criteria of calling it a factory site. Another reason for consider it as a factory site is the types of tool and the number of waste flakes and debris found there. Along with tools pottery and other artefacts like iron slags, ring stone, small metal beads have been found.

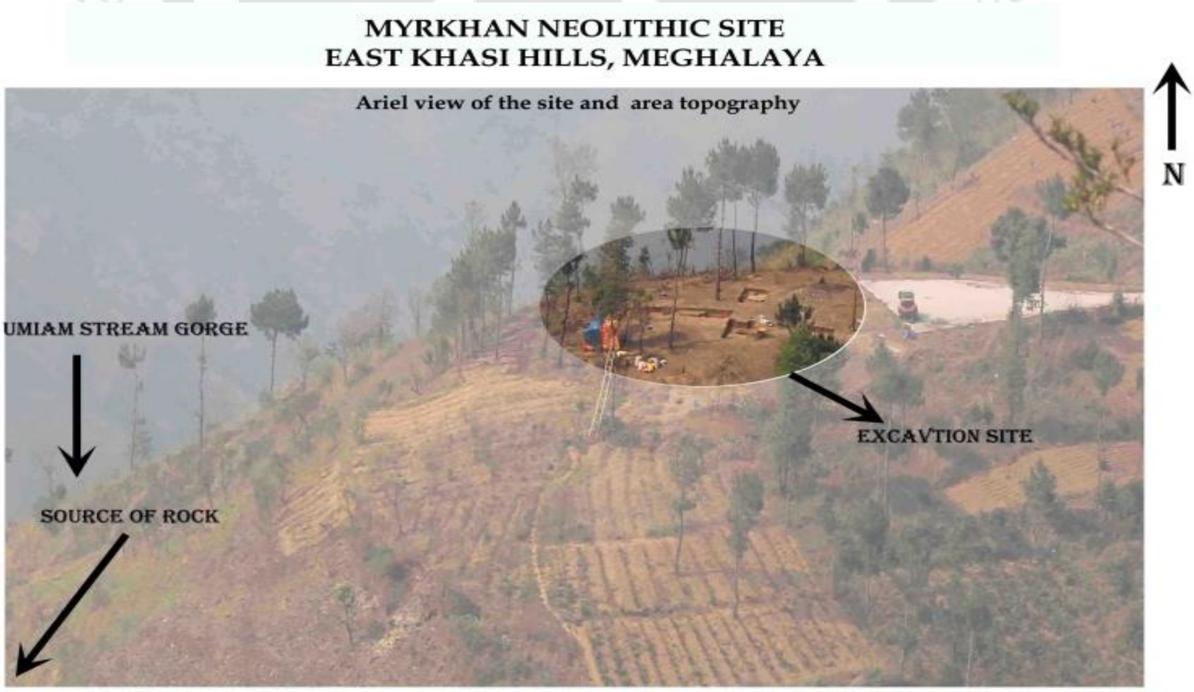
One of the important fact about the site is the C14 dates of the lower layer which gives the earliest Neolithic date in the Neolithic culture of the entire Northeast region. An extensive study of the site can provide us information about the earliest people who lived there during that period.

Less occurrences of usable products such as pottery along with the type of stone tools indicates that this place was possibly not used for permanent settlement by the then population. One more important thing is presence of a circular stone structure found in the sites excavated area make it more complex to understand the sites context. It is very difficult to understand for how long this place had been used by the people who inhabited that area once or whether it is only one group of people or more than one group of people who had been using this site for tool making. It is important to understand the chronology of a site in order to get idea about the unknown facts of the past of that region and to do comparative analysis with other such archaeological sites.

[2] Source: https://villageinfo.in/meghalaya/east-khasi-hills/mylliem/myrkhan.html, (Indian Village Dictionary)

Map 1.1 Google Earth Satellite Image of Myrkhan showing the excavated area (Source: retrieved 4/5/2021)

Map 1.2 Arial view of the excavated site of Myrkhan, Source: (Mitri & Neog, 2016)



1.1.3 Archaeology of Meghalaya

Meghalaya plateau located in Northeast India is known for its rich archaeological heritage[3], which have been proved through archaeological exploration and excavation conducted by various research individuals in different parts of this plateau from past decades. The archaeological researches that conducted in the region primarily focuses on the exploration and study of prehistoric sites, megalithic structures, rock arts and many more that provide insights into the regions ancient history and the lives of its early inhabitants. Archaeology of Meghalaya mainly focuses on the megalithic culture, prehistoric sites, rock arts, cave and shelter sites from where many information has been collected so far. The megalithic tradition of Meghalaya involves the erection of large stone structures. These structures include menhirs, dolmens, cist burials etc. which reflects the cultural practices and beliefs of the people who lived in the region in ancient times. Many excavated prehistoric sites in Meghalaya provide insights into the regions ancient history. These sites consist of artifacts, tools, pottery and other remnants that help archaeologists to understand the lifestyle, technology and cultural practices of the early inhabitants. Such artifacts were also recovered from the many of the caves in this region, that shows evidence of early human habitation there.

The three main tribes Khasi, Jaintia and Garo occupying this land. The history of the Khasis and Jaintia can be traced from the early part of 16^{th} century, but there is no clear cut record prior to this period. Unfortunately, there is little historic material available on Garos (Rao R. R., 1981). Many Neolithic and Early Neolithic sites has been discovered in Khasi, Jaintia and Garo hills of Meghalaya. The exploration of the archaeological heritage in this region commenced through numerous endeavors initiated by the faculty and students of the Department of Anthropology at Guwahati University after the year 1956. These efforts led to the uncovering of Stone Age sites in Garo Hills and the unearthing of various antiquities from this region. Few important Neolithic sites has been discovered by them which has been published in Indian Archaeology- A Review (1967-68) (Subba, 2012).

The Garo and Khasi Hills region witnessed early human habitation, as evidenced by the discovery of numerous early Neolithic and Neolithic sites. Notable sites in Garo Hills, including Rongram, Bibragre, Selbalgre, and Misimagre, along with significant sites in Khasi Hills like Barapani, Sawmer, Sohpetbneng, and Myrkhan, underscore a pronounced Hoabinhian and Neolithic influence (Marak, Chaudhuri, & Eds., 2020). The remnants of

[3] Archaeological Heritage is the movable and immovable signs of the recent and distant past in a region.

prehistoric stone tools persist in collective memory, taking the form of myths such as the tale of "goers gitchi" among the Garos and the celestial descent at Sohpetbneng among the Khasis. Additionally, these tools exhibit technological affinities with their modern counterparts. Another prehistoric tradition, which transcends into historical phases and endures to the present, is the widespread prevalence of megalithic structures. Extensive clusters of these structures are found in Nartiang and Shangpung in Jaintia Hills and Cherapunji (Sohra) and Mawphlang in Khasi Hills, among others. These megalithic structures continue to play a pivotal role in the socio-cultural fabric of the region (Marak, Chaudhuri, & Eds., 2020).

Within the context of prehistoric exploration in Meghalaya, T.C. Sharma, in his article titled "Assam in Prehistoric Times," published in Kamrupa, draws attention to two artifacts exhibiting potential Palaeolithic characteristics. The primary focus of Stone Age site identifications post-1966 is predominantly centered around the valleys of Rongram, Ganol, and Simsang rivers. To date, a total of 19 sites have been unearthed, with one in East Garo Hills, seven in West Garo Hills, and one in Khasi Hills in Meghalaya. The initial report on the discovery of Palaeolithic stone tools in the Garo Hills was jointly presented by Sharma and Sharma in the Journal of Assam Science Society in 1971 (Subba, 2012). Eminent Indian and foreign scholars/archaeologists, including K.B. Cordrington of London University and H.D. Sankalia, V.N. Misra, R.V. Joshi, R.S. Pappu, and S.N. Rajaguru of Deccan College, Pune, have visited most of these sites and conducted geomorphological and archaeological investigations in collaboration with the Department of Anthropology at Gauhati University.

T.B. Subba examined stone tools collected from the Garo Hills spanning the Palaeolithic and Mesolithic periods, integrating his findings into his thesis titled "Prehistoric Archaeology: Stone Age Cultures of Garo Hills, Meghalaya." He notably shed light on various quaternary formations found in different river valleys of the Garo Hills, providing solid stratigraphic evidence for Palaeolithic cultures (Sharma, Goswami, & Das, 1972). A survey of Quaternary formations in the Garo Hills was conducted in collaboration with the Department of Anthropology at Guwahati University, aiming to enhance the understanding of the geological background for Stone Age cultures previously reported (Rajaguru, 1981). They actively engaged with the research team, offering their expertise to establish chronological sequences of prehistoric cultures in Northeast India. Reports on two Pleistocene mammalian fauna species further contributed to establishing these chronologies (Badam, 1974).

Stone age sites in Meghalaya have revealed cultural materials spanning various phases of this age. Initially, the Neolithic phase was thought to be the sole culture of the prehistoric era. Sankalia, during his visit to the Garo Hills in 1969-70, identified palaeoliths among the previously discovered sites (Sankalia, 1974). The discovery of the Chopper tradition at Nangalbibra in the Simsang-Nangal Valley of East Garo Hills District expanded our understanding. Concurrently, another lithic tradition emerged, featuring flake tools and a few microliths, indicating the presence of Levallosian and Microlithic traditions. Sonowal conducted a study on sites in the river valleys of Rongram, Ganol, and Didami in the West Garo Hills (Sonowal & Sharma, 1983). Additionally, Sharma reported a microlithic industry at Selbalggre-II in West Garo Hills District. Excavations at the site revealed a clear microlithic horizon below the Neolithic level, featuring predominantly non-geometric microliths alongside plain handmade pottery (Sharma T. C., 1979). Furthermore, Hoabinhian tools were discovered in the Rongram valley and at sites in Bibragre, Matchakholgre, and Ganolgre of West Garo Hills District, indicating a diverse array of traditions spanning Palaeolithic, Mesolithic, and Neolithic contexts (Sharma & Mahanta, 1993).

The Department of Anthropology at Gauhati University has been conducting archaeological explorations in Meghalaya since 1968, leading to the discovery of several Neolithic sites, including Selbalggre, Rongram-Alagre, Chitra-Abri, Ganolgre, and Rengchengre in the West Garo Hills. Selbalggre and Rongram-Alagre underwent trial digging, revealing two cultural layers at Selbalggre: a Neolithic layer with chipped and ground stone axes, a scraper, and plain handmade grey pottery, and a microlithic layer with a significant quantity of microliths, fluted core, hammer stones, and micro flakes. Rongram showcased a stratification of Neolithic above and Hoabinhian below. Chitra-Abri yielded numerous shouldered celts, indicative of the Asiatic Neolithic complex. Additionally, the Barapani site, discovered by T.B. Subba, revealed cultural relics such as typical axes, flakes, and blade tools made from phylite, found on the surface. The suggestion for a broad-based ethno-archaeological study based on present-day material, cultural patterns, settlement-subsistence practices, and lifestyle of the Garo people was put forward. Roy's contribution focused on correlating cultural material elements of the past and present by studying the shifting cultivation practices of the Garo Hills and tracing Neolithic agricultural patterns (Subba, 2012).

1.2 Objective of Research

1.2.1 Statement of Problem

The site Myrkhan is a newly excavated site which has yielded cord marked pottery. Along with the stone tools and waste flakes a sizable number of pot sherds have been found in the excavated site. The number of diagnostic sherds found in the site is less and not a single base part of pottery is found there. So it is very difficult to reconstruct the shape of the sherds for which functional aspects cannot be traced out easily. Therefore, one important question rises here is, for what purpose this particular type of pottery has served in the site? Another question is whether the sherds are locally available there or it has been imported from other sites. Through compositional analysis of the paste recipe compared with morphological analysis, an attempt will make to understand such facts about the potsherds collected from Myrkhan Neolithic site.

1.2.2 Research Questions

1. What purpose did the pottery serve in the site? / How was these potteries used in the site?
2. All the collected potsherds from the site Myrkhan were locally manufactured or traded from somewhere else?
3. If the craft was practiced locally what are the sources of raw materials?
4. Is the composition of raw material homogenous or heterogeneous in nature?

1.2.3 Main Research Objectives

1. The study aims to understand the intra site and inter site variations and similarities found in the paste recipes of the potsherds and to get idea about the regional and cultural interactions.
2. The study aims to reconstruct the manufacturing processes of the potsherds collected from the excavated site of Myrkhan.
3. Application of scientific methods for determining the provenance of the cord marked pottery and it sources of raw materials.
4. The mineralogical and elemental analysis of the pottery will try to find out if the potteries with different impressed designs also show variations in its composition as well.

1.3 Methodology Used

Over the last few decades, ceramics analysis has become more significant to collect archaeological information and to help to understand the way of life of the different cultural groups due to its abundance and variety. The depiction of past systems of production and exchange lies at the core of this research. The analysis of pottery and its description is treated under four heads: physical properties, composition of materials, technique, and style. These are obvious divisions but they do not represent independent or unrelated aspects of pottery. The physical properties are directly affected by materials and by the potter's techniques, also the nature of the material often limits the choice of technique, and both material and technique in turn influence style (Shepard, Ceramics for the Archaeologist, 1956). The basic aim of most scientific studies of artifacts is to determine two main types of information (Gibson & Woods, 1997):

- The composition of the material with a view to establishing its place of origin.
- The technology employed.

The identity of paste recipe and an adhesive is often unknown in the study of ancient pottery because of lack of records. Simple methods of identification that used by the researchers are generally visual observation, colours and shapes of the pottery along with correlation with other associated findings to reconstruct chronology and stratigraphic sequences. Since it is questionable whether visual methods allow for consistent accurate differentiation between paste recipes and adhesives, various scientific methods have been used in the field of pottery investigation to know its provenance, to trace out proper trade links or regional interactions and to differentiate between locally manufactured and imported products as well as to identify the regional variations in its raw materials, designs and manufacturing processes. Scientific characterization of pottery deals with the examination of the properties of ceramics and it involves in their mineralogical composition, microstructure, surface traits and provenance studies (Peacock, 1970).

The methodology that has been used in the research work for the analysis of the potsherds physical and chemical properties are discussed below.

1. Categorization
2. Classification
3. Characterization (Characterization is the division among the pots based on the variations of its raw materials)

Taking into consideration of these three aspects of pottery study the methodology broadly divided into two parts. These are

1. Morphological Attribute Analysis
2. Mineralogical and Physiochemical Analysis

1.3.1 Morphological Attribute Analysis

The study of morphological attributes has been of especial use in these areas of ceramic study – typological phase, contextual, ethnographical, and quantification. Mainly two methods are used here for the preliminary classification of the sherds for the understanding of the similarities and differences between the potsherds collected from all the layers of the excavated site Myrkhan.

I) Typological Analysis

Typological analysis refers to systematic classification of artifacts into different types based on similar form, style, methods of manufacture, raw materials, colour etc. This is the prime basis for dating material objects before the use of modern dating techniques. Typological analysis helps archaeologists to reconstruct the cultural and historical sequences. It was started in the 1880s, at the same time as Pitt-Rivers was developing his typological approach to other classes of artifacts (Pitt, Augustus, & Lane, 1906).

II) Reconstruction of pottery shape

The shape of a pottery is always related to its function. A pottery's overall shape gives an idea about what purposes it serves the people who used it in the ancient time. The shape of the potteries varies according to its function. For example, cooking pots and storing pots are different in shape. Pottery use to store liquid items are also different in shape, generally it possesses long neck. Understanding the pottery shape and size also helps to get idea about the people (nomadic, semi nomadic or permanent settler) and the type of site pattern (permanent or temporary).

1.3.2 Mineralogical and Physiochemical Analysis

I) X-Ray Diffraction (XRD)

X-ray diffraction (XRD) is an important tool in mineralogy for identifying, quantifying and characterising minerals in complex mineral assemblages. Its application to ancient ceramics, which are a mixture of clay minerals, additive minerals and their transformation products yields information on the mineral composition of objects. Details of production processes, like firing temperatures and kiln atmospheres as well as applications of slips or glazes may thus become transparent (Stanjek & Häusler, 2004). This method of ceramic characterization is based on identifying minerals by their crystalline structure (Zussman, 1977).

It is based on constructive interference of monochromatic X-rays and a crystalline sample. In addition, *X*-ray diffraction analysis is also used to determine firing conditions. Firing temperatures can be estimated based on the presence and absence of mineral phases.

A total number of thirty-seven samples have been chosen for XRD analysis. The potsherds selected from different trenches and depths have been characterized by XRD analysis to assess the mineralogical composition.

Method: Proper sample preparation is one of the most important requirements in the analysis of powder samples by X-ray diffraction. Reduction of powders to fine particles also ensures enough particle participation in the diffraction process. The shreds were carefully hand-ground with an agate mortar and pestle. The X-Ray Powder Diffraction Spectra were recorded on TTRA III Riguku X-Ray Diffractometer using Cu kα radiation at a wavelength of 1.5406 Å. The diffraction data were recorded over 2θ range between 5 and 75 °q with a scanning step of 0.22° 2q and at a scanning speed of 4° 15/minutes per samples. Mineralogical composition of the studied samples is determined with the standard interpretation procedures of XRD.

II) Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy or FTIR is an instrumental technique used to identify the functional groups present in organic and inorganic compounds by measuring their absorption of infrared radiation over a range of wavelengths. It is useful as it can tell us what molecules are present in a sample and at what concentrations. (Margaris, 2014; Smith, 2011). Infrared (IR) spectroscopy is one of the most used spectroscopic techniques in analytical laboratories for both qualitative and quantitative analysis. It measures the interaction of IR radiation with a sample, to provide chemical identification. An infrared spectrum represents a fingerprint of a sample with absorption peaks which parallel to the frequencies of vibrations between the bonds of the atoms making up the material. Because each different material is a unique combination of atoms, no two compounds produce the exact same infrared spectrum. Therefore, infrared spectroscopy can give a positive identification of material. Infrared spectroscopy is an alternative technique for qualifying the interactive effect of soil clay and soil organic materials, and is thus widely used in soil analysis (McCarty & Reeves, 2006). Infrared spectra of archaeological artifacts reveal the type of clay and temperature of firing

(Velraj g. , Janaki, Musthafa, & Palanivel, 2009). The main purpose of using this method is to identify unknown materials (organic and inorganic materials) in a sample and to determine the quality and consistency of a sample (In clay by studying the firing temperature). During FTIR analysis, an absorbance spectrum of the sample is created which provides information about the unique chemical bonds and molecular structure of the material.

Using the infrared spectra, unique information about the group of minerals to which the specimen belongs, the degree of crystalline and non-crystalline impurities and reactions of minerals with chemicals in their environment can also be inferred.

Method: FT-IR spectra of the pottery samples were recorded on a Bruker Alpha FT-IR spectrometer with 5 scan mode by using KBr pellets technique in the wave number range from 4000 $cm^{-1}$to 400 cm^{-1}. The KBr pressed pellet technique was used by mixing the powdered samples with KBr in weight proportion of 1:20. Each FTIR spectrum has run on average of 200 scans with the specific precision in the region of the spectrum.

The IR spectra of the pottery samples are analysed as in the received state at the laboratory in room temperature. By studying the IR spectra graph the frequency of the functional group can be trace out and by studying this functional group one can get the mineralogical composition of the component or the substances present in the studied sample. To get the idea of the substances present in the sample the first think to figure out is what functional group is present in the molecular level. The FTIR spectra of all samples are analysed and the minerals are assigned using available literatures.

III) Energy Dispersive X-Ray (EDX)

Energy dispersive X-ray spectroscopy (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. It shows the presence of elements in a sample along with its percentage. As a type of spectroscopy, it relies on the investigation of a sample through interactions between electromagnetic radiation and matter, analyzing x-rays emitted by the matter in response to being hit with charged particles. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing x-rays that are characteristic of an element's atomic structure to be identified uniquely from each other.

Method: For EDX data analysis, experiment is done in a Gemini Field Emission Scanning Electron Microscope (FESEM), which is equipped with a windowless EDS. The powder pottery sample is attached to a metallic holder (aluminum stub) with the help of a carbon tab (double side adhesive carbon conductive tab). The ceramic products need to be covered by a thin conducting surface layer, usually done with gold or carbon in an argon atmosphere. After coating a uniformly conducting cover is formed, which help in reduce heating by the electron beam, the prepared sample is placed in the sample holder of the FESEM machine. The energy of characteristic X-ray that is emitted when electrons strike a solid specimen enabled to identify the mail elements that were present in the pottery samples (Karapukaityte, Pakutinskiene, Tautkus, & Kareiva, "SEM and EDX characterization of ancient pottery. Lith.", 2006).

IV) Hardness Test

Hardness is the resistance of a mineral to scratching. It is a property by which minerals may be described relative to a standard scale of 10 minerals known as the Moh's Scale of Hardness. The Moh's scale of mineral hardness is a qualitative ordinal scale characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material. Created in 1812 by German Geologist and mineralogist Friedrich Moh's, it is one of several definitions of hardness in materials science. The minerals that make up the Moh's scale are listed in the table below. The degree of hardness is determined by observing the comparative ease or difficulty with which one mineral is scratched by another or by a steel tool.

Table 1.1: Mohs hardness scale (Minerals along with its hardness level)

Mineral	Moh's Hardness
Talc	1
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Orthoclase	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

V) Porosity Test

Pores in archaeological ceramics can form in a number of different ways and reflect both deliberate choices and uncontrollable factors. Porosity study can indicate whether the potsherds collected from a site are belonging to one source or from various sources of manufacture. As less diagnostic potsherd has been found in the site, it is difficult to reconstruct the shape of the wares. So the functional aspects of the wares are not identifiable easily. But with the help of the quantitative analysis of Apparent Porosity, a difference between the manufacturing process, functions of the wares and other attributes as well can be made. There are different methods of measuring apparent porosity depending upon the type of the samples. The method used in my research is as given below.

Method (The boiling water method): The boiling water method of the determination of apparent porosity is applicable to burnt clays only. The specimen is first weight in the room temperature in a desiccator. This weighing and all subsequent weighing shall be made to an accuracy of 0.1 g. Then place the specimen in distilled water and boil for two hours and then allow cooling to room temperature while still immersed in water. During boiling it should be taken care that the test specimen is not in contact with the heated bottom of the container. After boiling and cooling, blot lightly with a piece of filter paper and weight the soaked test specimen suspended in air. Then calculate the apparent porosity by subtracting the dry weight (D) from the saturated weight (W).

Calculation:

Obtain the apparent porosity (P) in percent from the following formula

$$P = \frac{W-D}{W-S} * 100$$

VI) Thin Section Petrography

Thin section petrography is a useful methodology for the study and classification of clay fabrics. It can be used to examine a wide variety of materials, including rocks, minerals, slags, concrete, mud brick and plaster as well as fired clays. The method can provide evidence for a number of important aspects of ceramic studies including the determination of provenance and the reconstruction of technology (Peterson & Betancourt, 2009). A ceramic thin section is a transparent polished piece, whose thickness varies from 20-30 µm, mounted on a glass slide, use for studying cultural and technical issues of archaeological significance of the craft, pottery. Study of thin section petrography gives us idea about the non-plastic inclusions in the pottery samples. Matrix is basically the clay defined by its size that is 20 µm and other minerals are more than 20 µ in size, which is the basic criterion to make a difference between matrix and minerals. Non-plastic minerals are may be of four types- rock, minerals, biomass and grog[4] (grind potsherds).

According to the Riederer, the study of ceramic thin sections give three types of information regarding their paste and raw materials, which is helpful to know the technology of pottery manufacturing (Riederer, 2004).

1. First, mineralogical composition of the coarse grained temper, which differs significantly from place to place, depending on the both regional geology and the potters' habits and experience.

2. Second, determination of the percentage of temper in the ceramics- grain size, grain size distribution and number, size, shape of pores and it is helpful to know the potters' technique of preparing and shaping the clay.

3. Third, sometimes helpful to determine and estimate the firing temperature, firing length and firing atmosphere by detecting changes of minerals during firing the ceramics.

Method: The petrographic microscope is provided with a polarizing prism below the stage that transmit the light vibrating in one direction only. A second polarizing prism, mounted to slide in and out of the microscope tube, is oriented to transmit only those light rays which are vibrating at right angles to the ones that enter the specimen. The microscope stage revolves and is laid off in degrees so that the specimen can be turned at any angle to the direction of vibration of the entering light, and the angle of rotation measured. There are wedges and plates of minerals that can be inserted in the tube to determine the relative velocity of light travelling in different directions in a mineral and to make other observations. The various optical properties that can be measured with the petrographic microscope afford precise criteria for the identification of transparent minerals (Shepard, Ceramics for the Archaeologist, 1956).

[4] Grog is made from a number of materials that have been fired and then ground up. It can be made from ground-up brick or other refractory rock or can be made from waste pottery that is broken by accident and recycled by making it into grog.

1.4 On Impressed Pottery Around the World with Special Reference to India and Northeast India

1.4.1 Existence of Impressed pottery in World Context

Pottery was considered to be made before the end of the Pleistocene, which also represents the early and middle Holocene culture of east and Southeast Asia. In general, an impressed pottery is those created through the method of pressing objects or materials into its walls preferably the outer surface, while the clay is in a pliable state. Among the impressed pottery the cord-marked potteries were found worldwide and it trace back to the Neolithic cultural phase. The cord-marked pottery tradition seems to have continued in the mainland cultural pool for at least 6,000 years and probably considerably longer. Radiocarbon dates for earliest Jomon pottery in Japan range back to 9,500 B.P. (Oba & Chard, 1963) and earlier, whereas cord-marked pottery of the Corded Ware Culture in Taiwan may be as old as 11,000 B.P. (Chang K. C., 1968). At the other extreme, at a Malayan site in Pahang, the upper boundary of a cord -marked pottery stratum that is directly succeeded by a "Late Neolithic" stratum has been dated by radiocarbon at 4,800-800 years B.P. and 6,400-3,200 years B.P. at two standard deviations (Dunn F. L., 1970). In Southeast Asia, except for Taiwan, where pottery seems to have appeared before or at the close of the Pleistocene, the cord-marked pottery tradition is largely confined to the mainland cultural pool. On the mainland, Cord-marked pottery is often found associated with Hoabinhian like implements and the absence of cord-marked pottery from the island isolates until rather late in the Holocene parallels the similar absence of Hoabinhian -like tools already noted (Dunn F. L., 1970). However, in Malayan stratified sites, as at Hoabinh and Bac Son in Indochina, cord-marked pottery appears considerably later than the earliest Hoabinhian-like tools (Dunn F. L., 1964; Peocock & Dunn, 1968). In the limestone hill of Kuala Bering, (Malaysia) several shelters and caves were found and among one of the cave two small sherds of crude cord-impressed pottery were found (Peocock & Dunn, 1968). This helps to explain the virtual absence of cord-marked pottery at localities where pebble tools have been found in Sumatra; the Hoabinhian-like industry of Sumatra appears to have been introduced long before the pottery-making idea arrived in the southernmost subarea of the mainland (that is, the Malay Peninsula). Although the evidence is still fragmentary, all indications point to a northerly origin for the pottery-making idea in eastern Asia.

The sites of Xianrendong in Jiangxi and Zengpiyan in Guangxi have yielded artifacts from the 10th to the 7th millennium BCE that include low-fired, cord-marked shards with some incised decoration and mostly chipped stone tools; the probable function of these pots has been considered for cooking and storage. The Jomon period, which covers a great expanse of time, constitutes Japan's Neolithic period. Its name is derived from the "twisted cord" or "cord markings" that characterize the ceramics made during this time and the earliest Jomon culture is dated to 10,500BC. This is supposed to be the oldest examples of cord-marked sherds found in the world. Incipient Jomon (10,500-8000 BEC) marks the transition between Palaeolithic and Neolithic. Archaeological findings indicate that people lived in simple surface dwellings and fed themselves through hunting and gathering. They produced deep pottery, cooking containers with pointed bottoms and rudimentary cord markings-which can be said as the oldest examples of pottery known in the world. The corded earthenware culture of the Neolithic Age (6000-4000 BP) was discovered at various places within the great basin where the Chindwin and Ayeyawady rivers flow from Kani down to Letpanchebaw and Thegone.

Quihendong cave is located in Zhangping City in Fujians, next to a stream at the foot of a limestone hill. It was discovered in 2008 and excavated over three seasons between 2009 and 2011. The excavated remains have been dated to 17000- 7000 BP. A small portion of sherds have cord marks and impressed dots. No shape could be reconstructed, but the rims seem to all belong to guan jars with a diameter ranging between 15 and 30 cm. (Wang & Sebillaud, 2019).

In the eastern Ontario, part of Canada, corded pottery is reported where cord mark has been found both internally and externally. Research has been done in this site focusing on the spread of the corded pottery in this region. According to Lee (1958:50) corded pottery are rare in Ontario. This pottery came from a level overlain by a middle woodland component.

Evans, H.N. worked in Malay Peninsula region where he found cord-marked pottery in the cave remains belonging to the upper layers. It is ascribed to an upper (later) Neolithic culture. It has been found with stone implements of the finely polished type.

In the Nan Basin and at Obluang in Chiang Mai Province of Thailand excavation had been carried out by the French Archaeological mission and the Fine Arts Department of Thailand. A number of surface collection including incised and cord marked sherds, pedestal vessel sherds along with stone tools such as choppers and polished axes and flakes and quartzite have been reported.

The prehistoric tradition of Myanmar (Burma) earthenware could be traced back as far as 13,400±200 years before the present (BP) with the collection of some simple cord-marked potsherds, an earliest Hoabinhian culture or earlier than the Spirit Cave (Thailand), from the excavation of Padah-Lin caves in the Ywa-ngan Township (Shan-State) in January 1969. The late Anyathian (12000-6000 BP) culture site in Myanmar belongs to the late Palaeolithic Age (75000-9500 BP). A late Neolithic culture in Central and Northern Europe from C. 2800 BC, named after a characteristic cord-marked decoration found on pottery. The commonest shapes are the beaker and the globular amphora. The ware is always associated with primitive agriculture (Barbara, 2000).

Cord marked pottery, according to some scholars were the earliest type in South-East Asia belonging to Hoabinhian period. But later on it has been proved that the proper cord marked pottery with two or three twisted cord impression appeared later only. In South-East Asia Viet Nam handmade pottery has been found from both the early and late phase of Hoabinhian culture, these are low temperature fired and course texture tempered with sand grains of various sizes. The shape of the pots are all round bottom and bowls with straight and slightly flaring rims without ring feet and decorated by basket-like impression made by a wrapped paddle, but cord marking was absent there.

Ann. S.Cordell has done a detailed study on the paste and technological variabiltity of sample of Denford (500 B.C.-A.D. 800) and Savannah (A.D. 800-1500) period pottery from the St. Marys region. Deptford and Savannah period pottery can be distinguished in terms of paste as well as surface treatment. Savannah period pottery represents both plain and cord marked pottery, which can further be distinguished by the prominence of grog tempering in the cord marked potteries and absence of grit tempering in the plain wares.

Borger cord marked pottery has been named after its place Borger in Hitchington city, Texas, United Kingdom. The villagers of this place developed this style of pottery at around 1100 A.D. They make thin cord marked pottery.

Tai of mainland Southeast Asia and shan, in Northeast Myanmar (Burma) are the people who practice pottery making. They make the paddle impressed or carved paddle potteries. Carved paddle impressed pottery were recovered from the Khun Yuan, near the Burma border, North western Thailand. The Earliest known example of this kind of pottery is from Southern China, where it was been called geometric pottery, named after the geometric impressed patterns on the body of the vessels (Chang K. C., 1987). The Bau-Malay pottery from Island Southeast Asia is another example of carved paddle pottery. The common decoration of Bau-Malay pottery is impressed on the body with a carved paddle, which is used in the paddle and anvil forming or finishing of the vessel (Solheim , 1990). Often two different carved paddles were used, giving a simple impressed decoration on the bottom and the body and a somewhat more complicated pattern on the shoulder and from the use of a carved paddle developed the use of simple or moderately complex stamps to impress repeated patterns around the vessel on the shoulder (Solheim , 1990). Solheim also mentioned that in some of the areas the later decoration of this kind of pottery included vertical ridges or channels, usually accompanied by the impressed stamp patterns. The earliest known sites for this geometric pottery are in Gwangtung and have C^{14} dates between 3000 and 2500 B.C. (Meacham, 1975).

This geometric pattern or carved paddle pottery has been found alongside Hong Kong area by 2000 B.C., in Southern China and in Viet Nam at around 800 B.C. Similarly, Carved paddle pottery were also found in archaeological sites of Taiwan, Southern Korea, Western Japan. It is still found to be practiced in Thailand, Laos and Burma. The Shan potters in the Northwestern Thailand, very close to Burma border make typical carved paddle impressed pottery (Solheim , 1990).

The carved paddle impressed pottery was said to be made by the Wa and Tai groups in Southwestern Yunnan who are Mon-Khmer language speaking group. Solheim after his extensive research on carved paddle pottery concluded that the carved paddle pottery of Malay people must have originated in South China, came to Malay by way of Yunnan and was then brought south by the Thai speaking people.

All the above evidences of prevalence of both the impressed potteries, cord-marked and carved paddle, gives us an idea about the widespread of this tradition around the globe. Though this type of pottery has been found in a broader geographical framework very less work has been done on its scientific analysis. Only the dating of the sites had been done in most of the places.

1.4.2 Existence of Impressed Pottery in Indian Context

Pottery has been a unique source for reconstructing cultural history of any place from the very beginning of archaeological investigation (Ha, 1984-1985). In India Impressed pottery has been reported in many parts besides Northeast. Northern Vindhyas and Gangetic valley yielded impressed pottery, among which cord marked pottery is typical in its physical feature. It is considered to be a unique characteristic of the ceramic traditions of Neolithic- Chalcolithic culture of Northeastern India looking into its wide occurrences in this region. The Eastern India comprises the areas Bihar, Jharkhand, Odissa, and West Bengal and Eastern part of Uttar Pradesh. It also covers the Northeastern part Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura which also reveals both cord-marked and carved paddle impressed pottery in Neolithic context as well as later periods.

Pottery featuring impressions made by cords has been uncovered in Neolithic-Chalcolithic contexts across various sites in Odisha, particularly associated with the pot burial tradition. One notable excavation took place at Golbai Sasan (Latitude 20º 01' N, Longitude 83º 33' E) in Odisha during 1991-92, revealing handmade pottery adorned with impressions from cords and reeds dating back to the Neolithic era. These pots predominantly consist of vases crafted from dull red and grey ware (Sinha, 1993). R. N. Dash describes a pottery style characterized by cord-marked tapering bodies, pointed bases, high necks, and colors ranging from grey to brown. Additionally, S. Kar documents cord-marked designs, including vertical, parallel, and irregular patterns, on red ware pottery discovered at the Gopalpur site. Cord-impressed pottery has also been found in smaller quantities at sites within the Middle Mahanadi valley, such as Khameswaripali, Khajeriapali, and Hikudi (Behera, Excavations at Khameswaripali-APrehistoric Settlement in the Middle Mahanadi Valley, Odisha: A Preliminary Report, 2000-01). Investigations conducted by the Department of Ancient Indian History, Culture, and Archaeology at Utkal University have led to the discovery of cord-impressed pottery at three distinct sites: Padanhuda, located in the Khurda district of Odisha (Behera, 2013). Additionally, excavations at the Chalcolithic sites of Banga Harirajpur in the Jatani block have also unearthed cord-impressed pottery (Basa, Sahoo, & Kar, 2014).

The sites located in Northern Vindhyan, namely Koldihawa, Mahagara, and Kunjum, have yielded a significant quantity of cord-impressed pottery, in addition to rusticated ware, burnished red ware, and burnished black ware. The corded pottery from this region is crafted from semi-levigated clay containing calcium granules and small iron nodules, and typically not subjected to high firing temperatures. Surface colors range from matte or dull red, while the core appears blackish, ashy, grey, or dull red. The fabric is coarse, and the core is porous, with most potsherds exhibiting thick to medium sections. Rice and millet husks serve as temper, mixed with chopped straw and leaves. These potteries are handmade, often inadequately fired, with visible palm and finger impressions. Cording patterns in this area vary in intensity and stroke, ranging from thick to thin, with vertical, horizontal, oblique, or slanting strokes, occasionally displaying multidirectional patterns. Pal noted resemblances in cord decorations on pottery from the Vindhyan region to those discovered at the Daojali Hading and Sarutaru sites in Assam (Pal, 1990). Identified distinctions here also includes color and decorative motifs.

From the previous studies it has been suggested that there were two phases of this culture, the earlier is going back to 5000 B.C. and the later could be given a date around Ca. 2000 B.C.

1.4.3 On Impressed Pottery of Northeast India: An Overview with Special Reference to Meghalaya

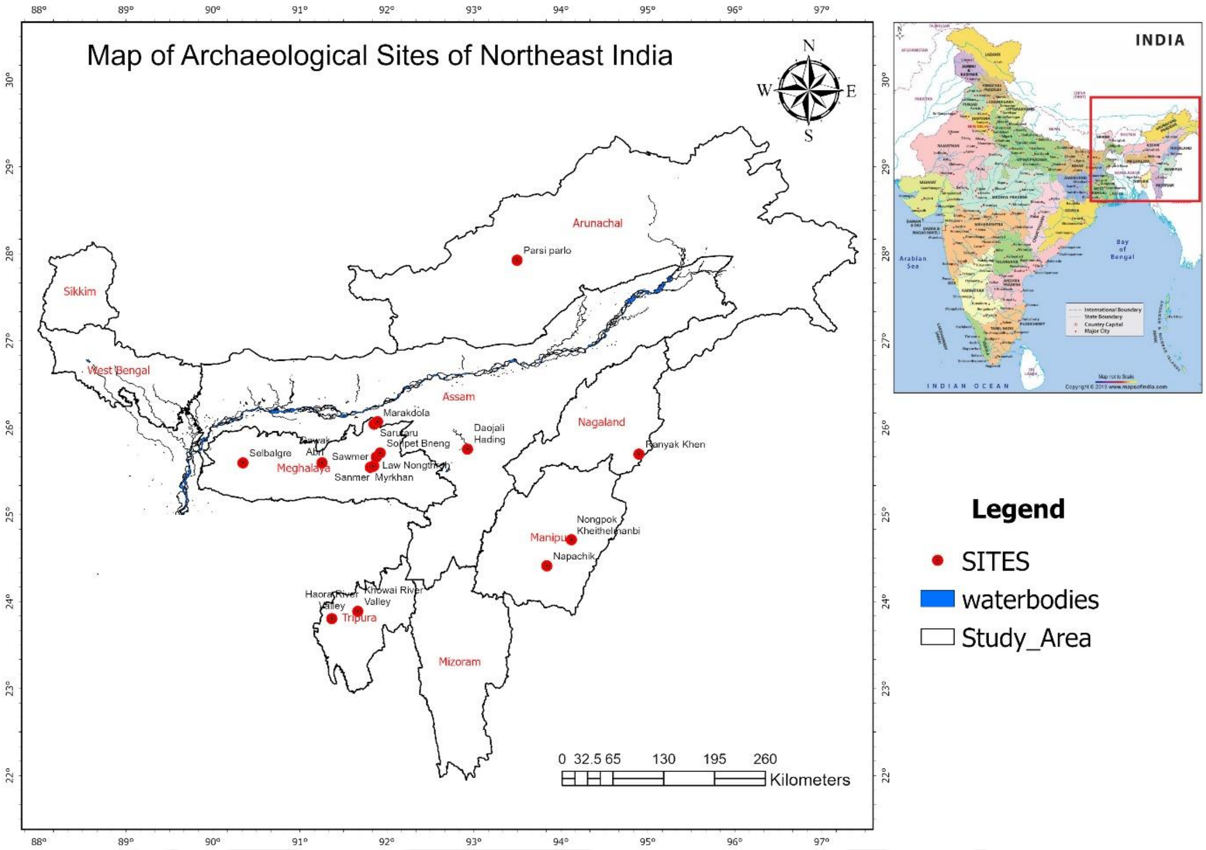
The Northeastern region has demonstrated its research potential in exploring prehistoric cultural evidence. While the distinctive burial customs of the Khasis, involving the construction of large sepulchral monuments known as megaliths, had captured the interest of British archaeologists in the past, and peculiar stone tools had been collected during the previous century, it is only within the last two decades that a concerted effort has been made to comprehensively understand and reconstruct the history of this region. This endeavor has been spearheaded by Prof. M.C. Goswami and his colleague Dr. T.C. Sharma, along with a group of young scholars from the Department of Anthropology at Gauhati University (Srivastava, 1987). The entire region has been delineated into various geographical divisions, as proposed by Singh (1999), including the Assam Valley encompassing the Brahmaputra plain, the Eastern Himalaya, Purvanchal, and the Meghalaya-Mikir region covering the hilly environs surrounding the valley. Neolithic sites in the Northeastern region that have undergone systematic investigation include DaojaliHading and Saru-Taru in Assam, Rongram Alagiri, Selbalgiri, and GawakAbri in the Garo Hills, Lowlongthroh in the Khasi Hills of Meghalaya, Ranyek Khan in Nagaland, Napachik and Nokpok Keithaleimbi in Manipur, and ParsiParlo in Arunachal Pradesh. Following the initial discovery of a jadeite Neolithic tool in 1867 from upper Assam by Sir John Lubbock, a considerable number of Neolithic tools from various sites across the Northeastern region have been documented. In the context of Northeast India, the pioneering investigation into cord-marked pottery was conducted by Prof. T.C. Sharma in 1967. This research focused on a stratified cultural deposit in Daojali Hading, situated in the Dima Hasao district. Four distinct pottery types were identified: cord-marked pottery, incised pottery, stamped pottery, and plain fine red ware. Among these, cord-marked pottery emerged as the predominant type, alongside other artifacts such as stone axes, shouldered celts, and quadrangular edges. Radiocarbon dating places the corded pottery at approximately 2.7 ± 0.3 ka (LD1728) (Sharma & Singh, 2017). Cord-impressed pottery was documented at the Neolithic sites of Sarutaru and Marakdola, a post-Neolithic site, by S.N. Rao in 1971. These sites are situated in the region bordering the Khasi Hills to the south and Kamrup District to the north. Nongpok Keithelmanbi, another Neolithic site in Manipur, was unearthed by O.K. Singh, revealing both cord-marked and curved paddle pottery. A charcoal sample from the corded ware stratum has been dated to 4460±120 years BP. Napachik, located in the Bishnupur District of Manipur, is another Neolithic site where cord-marked pottery was reported by Prof. Singh in 1981, dated to 1450 B.C. through TL dating. Additional findings at this site include plain ware, tripod leg ware, flake and pebble tools, and ground celts. Ranyak Khen in the Kiphire district of Nagaland, reported by Dr. Tia Toshi Jamir, has been dated to BP 6410 to 6290 (radiocarbon date). Beyond these Northeastern sites, Lownongthrough and Myrkhan in Meghalaya are significant Neolithic sites where both cord-marked and carved paddle pottery have been plentifully discovered, alongside other associated artifacts such as shouldered celts, shouldered and tanged axes, stone knives, and iron implements. The site Lownongthroh was excavated during the year 2013-14 and it lies in the Northern part of the central Meghalaya. The C14 dates from the site produces dates ranging from 2960±30 BP at the lowest layer and 1640±30 BP at the upper layer. The site Myrkhan is situated in the East-Khasi Hills of Meghalaya. Cord marked pottery is the dominant pottery type in this site and the site dated back to Cal BC 3500±30. Analysis of the cord marked potteries found in all these areas are done only on the basis of morphological features (Design, colour, quality of clay etc.), archaeometric investigation has been done only in few Neolithic sites.

The Khasi-Jaintia Hills of Meghalaya plateau inhabited by the Khasi-Pnar community having unique linguistic affiliation to the Austro-Asiatic language speakers and sharing a very close genetic makeup with the Munda group and other Austro-Asiatic speaking population of South-East Asia offers another unique space in the field of Archaeological research. With discoveries of stone-age artifacts surfacing in great numbers over the last one decade, the archaeological potential of the region is slowly finding an important place in the archaeological map of the country.

The Meghalaya plateau in the Northeast region holds significant evidence of Neolithic culture, including cord-impressed pottery. Sarutaru, a Neolithic site on the Assam-Meghalaya border, yielded numerous potsherds during excavations conducted by Rao in 1977, often found alongside stone axes (Rao S. N., 1977). These potsherds, classified into three ceramic types based on color (brown, buff, and grey), exhibited cord or basket-impressed decorations on their outer surfaces, arranged in parallel or criss-cross patterns. Despite their decoration, the pots were inadequately fired. They have been categorized into two groups based on the color of their outer surface: brown and grey. The exterior decoration styles observed at Sarutaru include simple cord impressions, twisted cord impressions, herringbone patterns, and zigzag patterns.

Marakdola, another site excavated by Rao, also revealed cord-marked pottery from the Neolithic period, situated just 1 kilometer away from Sarutaru. This site, showing a single cultural stratum. These findings from different parts of the region underscores the potential for further excavation in Meghalaya.

Map 1.3: Archaeological Map of Northeast India showing the Neolithic sites



1.5 Ceramics of Myrkhan Neolithic Site

The site Myrkhan is dated to Cal BC 1885 to 1765 B.C (approximately 3900 BP) which is obtained from a lower layer of trench 5 (Mitri & Neog, 2016). In any archaeological research ceramics are considered to be the most reliable source of data. Pottery has been a unique source for reconstructing cultural history of any place from the very beginning of archaeological investigation (Ha, 1984-1985). During the first phase of excavation conducted in Myrkhan 1402 potsherd were recovered. has Pottery fragments varying from medium to very small have been recorded. These sherds are divided into two categories taking into consideration the type of impression: 1. Cord marked and 2. Carved paddle.

Cord marked pattern is made with paddle coiled with cord(s). One of the most predominant pottery traditions of Neolithic cultural period found in North-East India is the cord marked pottery. Cord marked pottery is a specific type of pottery of the Neolithic of Southeast Asia, China, Pacific Islands etc. It has also been reported from Northeast India. From ethnographic parallels it is now understood that the design is made with twisted cord or cord impressions. In Myrkhan in cord marked pottery the dominant pattern is parallel (horizontal and vertical). Cord appears not as a tool, but as a substantial motif of decoration and seem to be most significant in the relief design of pottery (Zhushchikhovskaya, 2007).

The carved paddle types have distinctive groove patterns and are purely design impression (Mitri & Neog, 2016). The impression patterns are horizontal, vertical, zig zag and criss-cross.

In this work both these two types of pottery are attributed to the impressed pattern category of pottery as they show regular rows of impressions. In both the cases it has long been believed that objects such as strings, mats, knitted and woven materials, along with basketry and cages were pressed against the clay (Kobayashi, Simon , & Nakamura , 2003).

Apart from these two types of sherds few potsherds with plain surface and diamond shaped design (Fig. 3.5- D) have also been found in the second and fourth layer.

Due to the weathering of the surface of the pottery even in the buried condition the designs and patterns in the pottery of Myrkhan is sometimes not distinct. This can be recorded as a constraint in understanding the assemblage.

Presence of less diagnostic sherds in the excavated areas, make it difficult to reconstruct the shape and size of the potteries. For this reason, it is difficult to understand the probable utility of the pots.

Figure 1.1 Images of all the three types of potsherds found in Myrkhan excavation- A. Cord-marked Pottery, B. Plain Pottery, C. Carved paddle Pottery

Chapter-2

Geography and Geology of the Study Area

Meghalaya, translated as "the abode of clouds," is a northeastern state in India, renowned for its picturesque landscapes, diverse cultural heritage, and unique matrilineal society. The region has a rich historical tapestry that weaves together the traditions of its indigenous tribes and the impact of colonial influences. The history of Meghalaya is deeply rooted in the customs and traditions of its indigenous tribes, primarily the Khasi, Garo, and Jaintia people. These tribes have a distinctive social structure and governance system that predates colonial rule. The matrilineal society, where descent and inheritance are traced through the female line, is a remarkable aspect of these communities. The history of Meghalaya is deeply rooted in the customs and traditions of its indigenous tribes, primarily the Khasi, Garo, and Jaintia people. These tribes have a distinctive social structure and governance system that predates colonial rule. The matrilineal society, where descent and inheritance are traced through the female line, is a remarkable aspect of these communities.

Meghalaya holds significant archaeological importance owing to its diverse terrain and rich cultural heritage. Meghalaya boasts numerous prehistoric sites that provide glimpses into ancient human habitation. Excavations have unearthed tools, pottery, and remnants of ancient settlements, indicating the presence of early humans in the region. Notable among these sites are the Khasi and Jaintia Hills, where discoveries have been made dating back to the Stone Age and the Neolithic period.

The state is renowned for its intricate cave systems, some of which hold archaeological significance. Caves like the Krem Mawmluh, Krem Umshyrpi, and Siju Cave have revealed prehistoric paintings, engravings, and artifacts, shedding light on the cultural practices, artistry, and lifestyles of ancient inhabitants. These findings contribute significantly to understanding the socio-cultural evolution of early human societies in the region.

Meghalaya is adorned with megalithic structures, including dolmens, menhirs, and stone circles, scattered across various locations. These ancient monuments serve as enduring markers of the past, indicating burial sites, territorial boundaries, or ceremonial spaces. They stand as silent testaments to the traditions, beliefs, and social organization of ancient communities in Meghalaya.

Contemporary archaeological research in Meghalaya continues to unveil new insights into its past. Ongoing excavations, surveys, and interdisciplinary studies employ advanced scientific methods to unravel the complexities of ancient civilizations, trade networks, and societal structures that once thrived in the region.

The archaeology of Meghalaya serves as a testament to the diverse and vibrant history of the land, offering a glimpse into the lives, cultures, and achievements of its early inhabitants. Efforts toward systematic documentation, conservation, and scholarly research remain vital in safeguarding and comprehending this invaluable heritage for future generations.

2.1 Geomorphology of the Study Area

The state of Meghalaya is physiographically a highland region and one of the eight states of Northeastern region of India. It is located between 25º 02' north to 26º 06' north latitudes and 89º 48' east to 92º 50' east longitudes. In the year 1972 it has come into existence as a full-fledged state, under the Northeastern Re-Organization Areas Act 1971. The name ‘Meghalaya’ got relevance in the 1965 gazette of India for the first time which means “The Abode of Clouds”. Total geographical area of the state is 22,489 sq. km and it is surrounded by Dhubri and Kamrup District of Assam in the Northwest and North part of Meghalaya. Karbi Anglong, North Cachar Hills and Cachar Districts of Assam are surrounding the Northeast, east and Southeast part of Meghalaya. Sylhet plains of Bangladesh cover the entire South and Southeast part of Meghalaya. The whole hilly region of Meghalaya is divided into three physiographic domains by the following hill sections.

a) The Western Meghalaya (Garo Hills),
b) The Central Meghalaya (Khasi Hills),
c) The Eastern Meghalaya (Jaintia Hills)

Apart from this physiographic division the state has been divided into twelve administrative Districts. These are 1. East Khasi Hills District, 2. West Khasi Hills District, 3. South West Khasi Hills District, 4. Eastern West Khasi Hills District, 5. East Garo Hills District, 6. West Garo Hills District, 7. South Garo Hills District, 8. North Garo Hills District, 9. East West Garo Hills District, 10. East Jaintia Hills District and, 11. West Jaintia Hills District, 12. Ri-Bhoi District.

When the state of Meghalaya was separated from Assam on 21 January 1972, there were only two Meghalaya districts: United Khasi Hills & Jaintia Hills district and the Garo

Hills district. However, over time, the total number of districts of Meghalaya has increased to 12 (Allen, 1906).

2.1.1 Drainage System of Meghalaya

The drainage pattern of a hilly region plays an important role in its overall ecological setup and man and environment relationship as it is one of the basic source of the fundamental needs of human. It can provide us many useful information about the ancient settlement pattern or movement of the people. The drainage system of Meghalaya is controlled by its geological structure and physiographic features. It has divided the area into two parts namely Brahmaputra system in the North and Meghna/Surma system in the South. In Northern parts of Khasi and Jaintia Hills the rivers are the Khri, Digaru, Umtrew, Umiam and Umkhen, among these the Umtrew or the Digaru river originates from the west of the Sohpetbneng range in East Khasi Hills District, near Lum Raitong and flows towards west till it meets the waters from the Umiam river which is being diverted by the Umiam Hydel project. Umiew, Umngot, Umngi are the tributaries of Surma river, which fall in the southern part of the state. These originate from the Southern stopes of Khasi Hills and flow South wards into Bangladesh. The Tura range in Garo hills and the central uplands in Khasi and Jaintia Hillls form watersheds. Nearly all water sources/ drainage systems in the state originate from watersheds. The important rivers in the Garo hills of the northern group from the west to east direction are the kalu, Ringgi, Dadrik, Didram, Krishnai and Dadhaai. The southern group from west to east is the Sanda, Bandra, Bhogai, Dareng, Nitai and Simsang. Among the rivers of the Garo Hills the simsang is the longest and is the most navigable for a distance of about 30 kilometers. The magnificent gorges scooped out by the rivers in the Southern Khasi hills are the result of massive head ward erosion of antecedent streams, along joints of the sedimentary rocks over the blocks, experiencing relatively greater uplift. The northern part of the plateau, devoid of any sedimentary cover, is marked by long, incisive valleys formed by erosion along joints in the gneissic rocks and granites (Simon, 1991).

2.1.2 Topography of Meghalaya

Among the Districts of Meghalaya, the East Khasi Hills District is represented by plateau structure, famously known as the Shillong plateau with maximum elevation of 1984 m at Shillong peak. The plateau region is dissected by numerous rivers and nalas and thus form various geomorphologic units viz. highly dissected structural upper plateau, moderately dissected structural upper plateau, law dissected structural upper plateau. High to law dissected structural hills and valleys can also be seen in the districts along with small linear patches of piedmont alluvial plains in the southern most part. The Khasi Hills may roughly have divided into three lateral geographical zones, viz the narrow War country stretching across the southern margin of the district and consisting of low hills alternating with flat land. The climate of this area is generally humid and hot during the greater part of the year. Immediately north of this belt lies the extensive Khasi Highland, with an average height of 1,000 meters which starts from the very edge of the high escarpment overlooking the War country and slopes gradually northwards to the Central Range which at its highest points reaches altitudes of 1700 meters and over. This range is known as rain barrier, because of which the southern part of the belt receives markedly heavy rainfall and consists largely of sterile grassland and sparse growths of trees. The East Jaintia Hills District of Meghalaya is rugged where hills are generally flat topped, rising up to a height of 1200 m above mean sea level. This region of the state is characterized by high, moderate and low dissected hills, valleys and upper plateaus. Deep gorges and narrow valleys curved out by Myntdu, Lubha, Dikshim, Kapili, Hari rivers and numbers of other turbulent streams shaped the general topography. The Ri-Bhoi District area approximately mid-way between the northern borders, the land dips suddenly and then falls of perceptibility, though gradually, till it merges with the plains of the Brahmaputra valley into the North.

2.2 Geology of the Study Area

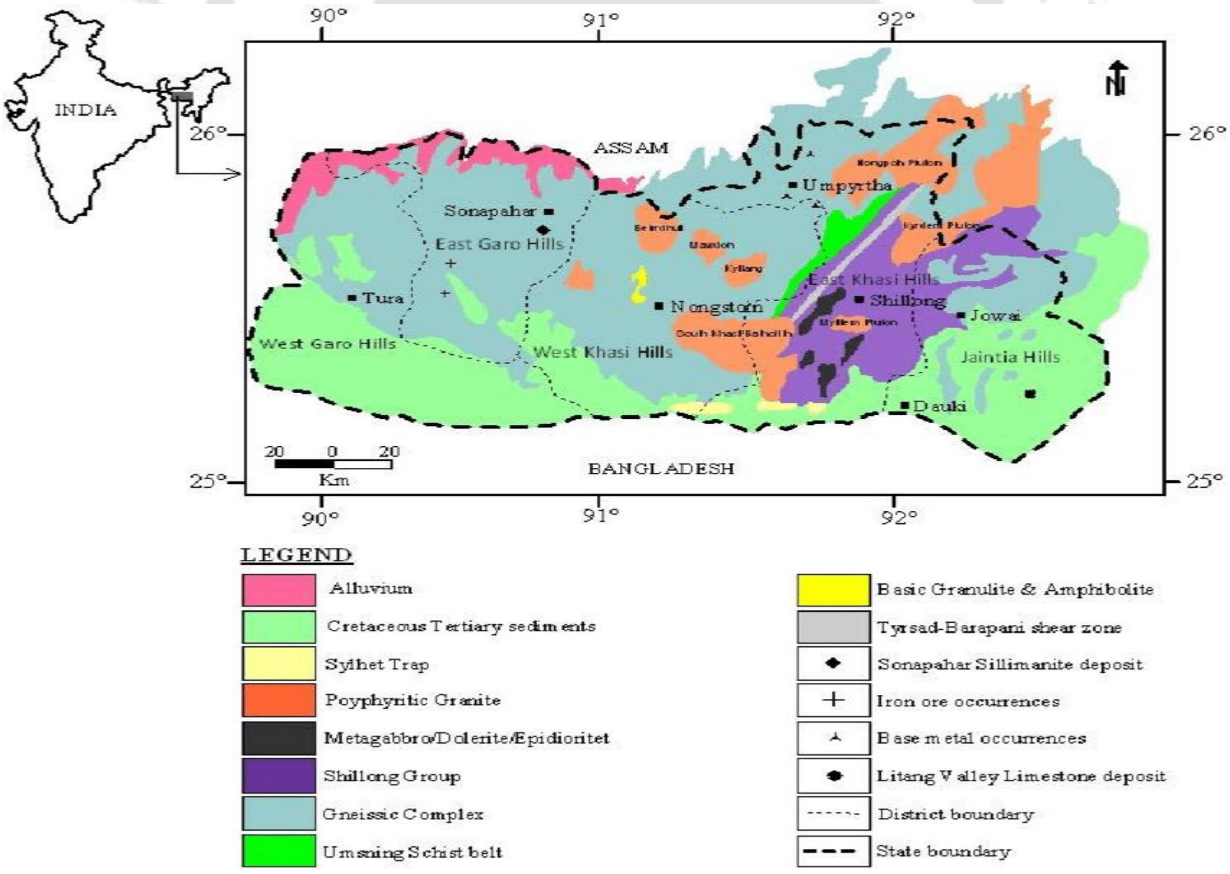
The geological formation of the Meghalaya Plateau is similar to the rock formations of the peninsular plateau and regarded as a part of the Peninsula that has been cut off by the intervening spread of the Gangas and Brahmaputra alluvium (Sarma, Meghalaya The Land and Forest A Remote Sensing Based Study, 2010). The plateau composed of Archaean and Precambrian sediments and above which the younger sediments of tertiaries and quaternaries are deposited (Subba, 2012). It comprises of rocks from the oldest Precambrian gneissic complex to the recent alluvium formations. The stratigraphic sequence of the five geological formations of Meghalaya are as follows:

1. The Cretaceous Tertiary sediments: These sediments are found in the southern parts of the state which comprises of the Khasi group, the Jaintia group and the youngest formation of Garo group and are very thick and extensive and the main rocks found in

this formation are shale, limestone, sandstone. These three groups are represented as Simsang, Bagmara and Sengapara formations.

2. The Sylhet traps: Occur in a narrow belt and run in the east west direction in the southern part of the Khasi hills and they include mainly basalt, rhyolites, acid tuffs and few others.
3. The lower Gondowana rocks: are found in the western parts of the Garo hills and they include pebble- beds, sandstone and shale.
4. The Shillong Groups of rocks: including the quartzite, granite, schist, conglomerate and other rocks occur in the central and eastern parts of the state and are marked by the presence of sills and dykes.
5. The Precambrian Gneissic complex: occupies the central and northern parts of Meghalaya and the rocks found in this formation are generally quartzite, gneiss and schist.

Map 2.1: Geological Map of Meghalaya (after Mazumdar, 1976) (Source: GSI)



The state Meghalaya is a treasure of many valuable minerals. There are large deposits of valuable minerals found in different parts of Meghalaya. These are coal, limestone, kaolin, clay, sillimanite, phospherite, quartz, iron-ores, gypsum, feldspar, base metal, glass-sand. The minerals include collection of granite also and a huge collection of valuable metals like gold and uranium. The sources of mineral resources are-

1. Limestone- Meghalaya yielded a huge amount of limestone. The areas where this minereal is available are cherrapunjee, Mawlong, Ishamati, Shella, Komorrah, Borsora, Bagli in Khasi Hills District. Lakadong Lumshonang, Nongkhlieh in Jaintia Hills District, Darrang Era- Aning, Siju and Chokpot in Garo Hills District.
2. Coal- Langrin and East Darrangiri in Khasi Hills District, Bapung in Jaintia hills District and West Darrangiri in Garo Hills District.
3. Clay (Lithomargic)- (White ware, earthen ware, furnance lining, curing soap etc.) Cherrapunjee and Mahadek in Khasi Hills District. Tangseng in Jaintia Hills Districts, Nangwalbibra and Rongrenggiri in Garo Hills District.
4. Granite- Nongpoh in Ri- Bhoi, Mylliem and Mawkyrwat in Khasi Hills District, Rongjeng in East Garo Hills District.
5. Kaolin- (White Ware) Mawphlang, Smit

Meghalaya is well known for a depositor of world's best sillimanite which is mainly found in the West Kahsi Hills. These natural sillimanite factories were form in the collaboration with corundum.

The lower Gondwana rocks of permo-carboniferous age are recognized at the western part of the Garo hills and consist of pebble bed, sandstone and carboniferous shale. The sylhet trap of middle Jurassic age comprising mainly of basalt, rhyolites, acid stuffs are exposed in a narrow E-W strip along the southern border of Khasi Hills.

The cretaceous tertiary sediments occupying southern part of the Meghalaya plateau comprises of the Khasi group (arenaceous facies), the Jaintia group (calcareous facies) and the youngest formation of the Garo group which is represented as simang, bagmara and chengapara formation ns. Besides these the Dupi Tilla group of mid- Pliocene age occurs in the western part of the Garo hills and towards south of Khasi Hills. Isolated patches of older Alluvium overlie the tertiary rocks along the southern and western borders of the state. The recent alluvium formation is mostly found in the river valleys of Garo and Khasi Hills District.

Among the three groups khasi, jaintia and garo mentioned above, the Khasi group is further divided in Jadukata, bottom conglomerate and the mahadek formations. The precambrian gneissic complex comprising para and orthogneisses, migmatites and the shilling group of rocks comprising mainly quartzites are exposed in the central, eastern and Northern parts of the Meghalaya plateau. They are intruded by basic and ultrabasic intrusive and late tectonic granite plutons.

As found in the GSI report the East Garo Hills District is characterized by dissected and rugged hilly terrain that slopes towards the north direction. The district is covered by dense tropical mixed vegetation in most of its areas. The geology of the East Garo Hills District is comprised with various rock types that originated at various epochs of earth evolution. The oldest known rocks comprising amphibolite, schist, banded magnetite quartzite (BMQ), calc granulite of Archaean age occur as small patches in eastern part of the District.

The study done by the GSI in the parts of Ri-Bhoi District of Meghalaya reveals that majority of the granitoid samples fall in the granite-monzo granite fields. Sillmanite gneiss contains eye shaped nodular aggregates of sillimanite and quartz. The mineral assemblage of garnetiferous sillimanite gneiss, cordierite gneiss and biotite gneiss with ± garnet indicates upper amphibolite facies of metamorphism. The area in Nongpoh Pluton, Ri-Bhoi District, Meghalaya is intrusive within the Meghalaya gneiss complex and Umsning schist belt. The litho- units observed in the area include sillimanite- biotite gneiss, granite gneiss, and diorite gneiss of Precambrian gneissic complex, mafic rock/lamprophyre (?), diorite- granodiorite, porphyritic granite and non- porphyritic granite of Nongpoh pluton. Disseminated grains of pyrite and chalcopyrite are observed in gneisses, diorite/grano-diorite, mafic intrusive rock, porphyritic granite, quartz and pegmatite veins. The Umtru area of the Ri-Bhoi District of Meghalaya shows presence of riverine soil and debris, coarse grained, pink to light gray granite gneiss. The parts of Ri-Bhoi District, Meghalaya represents variants of gneisses of Precambrian basement and granites of Nongpoh Pluton. The gneissic members comprise of granite gneiss, granite biotite gneiss and dioritic gneiss, sillimanite gneiss with enclaves of amphibolite. Nongpoh -pluton (Neoproterozoic- Cambrain) is intrusive within the precambrain gneissic Complex and has two variants porphyritic granite and grey non- porphyritic granite.

The West Khasi Hills District of Meghalaya shows basement gneiss-granulite, Shillong group of rocks, porphyritic granite (granitoids) and sedimentary sequences of Mahadek Langpar and Shella formations. Gneiss mainly consists of two types a) Biotite gneiss and b) Granite gneiss. Basalt (Shylhet trap) is exposed in the southern part of the area around Lumdiengngang – Mawdngen areas. The basalts are mainly amygdaloidal filled with secondary silica/ calcite. Basement gneiss, Shillong quartzite- phylite, granitoids and basalt are unconformably overlain by the Mahadek formation with its characteristic conglomerate-sandstone sequence. Tertiary sequence is represented by Shella formation with its alternate sandstone-limestone, alternate sandstone- shale coaly shale units with pyrites. The limestone of shella formation is profusely fossiliferous. The area East Garo Hills and West Khasi Hills Districs of Mehalaya, consists of crystalline rocks belonging to Assam- Meghalaya gneiss complex (Archaean to Palaeo-proterozoic) represented by K-feldspar rich granite gneiss, biotite gneiss, porphyritic pink granite, along with basic intrusive that are intruded by pegmatite veins and quartz veins of different dimensions.

The South of Sonapur, West Khasi Hills District, Meghalaya yield rock types mainly biotite gneiss, granite gneiss, quartzo- feldspathic gneiss, cordierite gneiss, basic granulite, amphibolite, granites of both porphyritic and non- porphyritic varieties, few mafic dykes and a number of quartz and pegmatite veins. Biotite gneiss is the predominant lithology and constitutes the main part of basement in the area. The quartz-feldspathic gneiss is at places sillimanite leading to sillimanite deposits. The Rambari in West Khasi Hills District of Meghalaya shows granite gneiss, banded gneiss, granite, charnochite and meta- norite as the main lithounits of the area. An analysis reveals presence of $Fe2O3$, $TiO2$, vanadium, Cu and Zirconium.

Parts of West Khasi Hills District of Meghalaya are mostly covered by gneissic complex intruded by granite. Tertiary clays occur on certain hill top overlaying the gneisses. The Southern parts of the area covered by older metamorphics represented amphibolite and gneissic complex. These rocks are intruded by khasi green stone, South Khasi batholith and Sylhet trap. The main lithounits observed in the area of Mawlong- Ishamati block of Shella Bholaganj belt, East Khasi Hills District, Meghalaya are upper Sylhet limestone of Shella formation and splintery shade of kopili formation.

The East-Khasi Hills District of Meghalaya is situated in the south Central part of the state of Meghalaya and covers an area of 2748 sq. km. It is bounded by the Ri-Bhoi District on the north, West Jaintia Hills District on the east, Eastern west Khasi Hills District and South West Khasi Hills District in the west. In the southern part, the District shares international boundary with Bangladesh. The lithologies exposed in the area of East Khasi Hills and Jaintia hills Districts of Meghalaya include basement gneiss, meta volcano- sedimentary sequence of Shillong group intruded by kyrden granite pluton and basic rocks. The imprints of contact metamorphism in the meta-sediments of Shillong group are preserved along the intrusive contact, both at the contact of Granite pluton where alumina silicates are developed metapelites.

The South-Eastern part of Meghalaya plateau situated in Jaintia Hills District, Meghalaya. The area is Geomorphologically occupied by high rising hills and steep gorges. East Jaintia Hills District is located in the eastern most part of Meghalaya and carved out from the former Jaintia Hills District on the 31st July of 2012 with an area of 2040 sq. km. It shares its international boundary with Bangladesh in the south and state boundary with Assam in the east and District boundary with West Jaintia Hills District in the North and West. The general geological setup of this area is characterized by the presence of different types of rocks belong to the different ages from Precambrian to Tertiary. This part of Meghalaya is well known for its large deposits of high grade limestone that belongs to the Upper Sylhet limestone member of the Shella formation of the Jaintia group of Eocene age. The Jaintia group in an around the area is calcareous facies (Shelf facies), divided into two formations viz. Shella Formation and Kopili Formation. The drainage pattern is dendritic to sub parallel dominantly controlled by fractures, joints bedding planes and faults. Myntdu Nadi, kailaipai nala and Moblai nala flows towards South while Kaduma nadi, Um lurem River flows towards east. The Litang Valley, Jaintia Hills District, Meghalaya exposes mainly the middle Tertiary sedimentary sequence comprising Shella and Kopili formations of middle to upper Eocene age. The limestone in the study area contains mega foraminifera in abundance as observed in the hand specimen. Identification of microfossils is done through study of thin section. A part of North of Larket block, Litang valley, Jaintia Hills District, Meghalaya was geologically exposes mainly the middle tertiary sedimentary sequence comprising kopili and shella formation of middle to upper Eocene age and recent to sub recent alluvium. The shella formation is represented by nummulitic limestone and the Kopili formation is represented by shale and ferruginous nummulitic argillaceous limestone/marl.

Mawyput is located approximately 10 km SW of Jowai towards Dawky. It is represented by gabbro-anorthosite, pyroxenite, serpentinite without the carbonatite phase. Towards North, this area is surrounded by Granitegneiss. Main lithotypes found in this area are quartzite, coarse to very coarse porphyritic granite, medium grained/medium to coarse grained, gabbro, pyroxenite, dolerite, and mica-schist. Enclaves of Amphibolite (?) and Quartzites are found within the granites of Mawpyut.

2.2.1 Soil type of Meghalaya

Soil is one of the most important components of land through which an interaction of all natural factors is possible. The soil type of an area is based on the factors like geology, relief, climate and vegetation. The soil of an area is formed by breaking down rocks, decayed organic materials, other living organisms and moisture contain in the thin surface on the earth comprising mineral particles to form nutrients for vegetation. The red loamy soil is found exposed in the central part of the East Khasi Hills District of Meghalaya state. It is a product of weathering of rocks like granites, gneisses etc. which are relatively rich in clay forming minerals. This type of soil is rich in organic matter, nitrogen and acidic in nature. In the Northern area of East Khasi Hill district Laterite soil is found. These are the weathering products of rocks like quartzite, schist, conglomerate etc. These soils are rich in iron and aluminium. Alluvial soils are one of the soil types found exposed in the southern part of the district that are rich in potash but poor in phosphate content. They are acidic in nature.

The district area falls mainly within the shilling or Meghalaya Plateau which is constituted mainly of Precambrian rocks of gneissic composition in which granites, schists, amphibolite, cal silicate rocks occur as inclusions of various dimensions. The gneisses form the basement complex for the overlying Shillong Group of rocks. The presence of primary structures like current bedding, ripple marks etc. indicated the quartzites of the Shillong group are of sedimentary derivative later metamorphosed to quartzites.

These hills of Meghalaya Plateau are inhabited by the Khasi- Pnar community who spoke the Astro-Asiatic language and also sharing similar genetic makeup with the Munda group and other Austro- Asiatc speaking population of South-East. The study area Myrkhan falls under East Khasi Hills District of Meghalaya. It is situated at a distance of 1.1 k.m. uphill east of the Umiam River and 22 k.m to the south of another Neolithic site Lawnongthroh of Meghalaya. The evidences collected from the site seem to indicate the function of the site as a factory site. The site is located close to the source of amphibolites outcrop which was the dominant type of raw material used for making stone tools by the pre-historic settlers of these hills.

2.2.2 Sources of Clay in Meghalaya:

In the study of ceramics to identify the raw materials that were used to make the pots is the one of the basic concern of the researchers. The main ingredients that consists the raw material of a pottery is the clay. To know the probable provenance of the raw material the sources of the clay that are exists in the entire Meghalaya region are studied using the help of GSI map and GSI report. The spatial distribution of the clay in the state is as follows-

In the East Garo Hills District in few areas clay is available. From the report of Geological Survey, it is found that The Rongengiri- Khera clay deposit occurs at some places in Rongengriri reserve forest and lies over the granite gneiss. This clay deposit is of residual origin and suitable for ceramic industries. Bands of clay also occur interbedded with shella/Tura sandstone formation. The clay bands occur from Rongrengiri in the south to

Samanda Megapgiri in the north. The Nengra clay deposits occur mainly on the Williamnagar-Nengra road section. The type of soil in the region where clay is found is red sandy soil mostly.

The South Garo hills falls under the southern slopes of the topographical division of Meghalaya. The District is represented by a wide variety of rock type starting from the older metamorphic of Archean age to the Alluvial deposits of recent age. The oldest known rock comprises amphibolite, quartz sillimanite schist of Archean age occurs as small patches in this area. One clay source occurs in between Sodugiri and Nongwalbibra region of the District. Apart from that clay also exists along in six different lithologies that represent few areas of this district in patches.

The West Garo Hills District falls under the Western slope of the topographical division of the Meghalaya state. The geology is represented by the presence of wide variety of rock types that originated in various epochs of earth evolution. Mapable units of quartz sillimanite schist, banded magnetite quartzite and amphibolite are delineated and belonged to Archean and Proterozoic age. There are almost 10 clay sources are present in different areas of the District within the mapped area. Deposition of lithomargic clay occurs on the Northern part of the Tura town and also along the Tura-Rongram road and South bank of Ganol river. White clay occurs over the partly kaolinised gneissic platform. Bauxite clay occurs near Chandmari and Domeselgiri.

In the East Khasi Hills District the area with the existence of clay is sandstone covered. Dolerite is found nearby one clay source and arkose/gritty sandstone, coal, fireclay and shale and Fossiliferous limestone / calcareous shale, sandstone are available near another clay source. These are the two clay sources near Mylliem and Laitlyngkot.

In West Jaintia Hills District, near Jowai there is clay source that falls under the lithology arkose/gritty sandstone, clay and shale. Another clay source is existing near Nartiang within the lithology arkose/gritty sandstone, coal, fireclay and shale. In between Laskein and Kopili River, there is another clay source which falls under arkose/gritty sandstone, coal, fireclay and shale lithology.

The general geological setup of East Jaintia Hills District is characterised by the presence of different types of rocks belonging to different age from Precambrian to Tertiary. The migmatites of Assam Meghalaya Gneissic Complex are the oldest rock units of the district mostly exposed along the rivers and nala and are highly deformed with general structural fabric of NW-SE. This unit is unconformably overlain by cretaceous-tertiary sediments that cover maximum area of the District. Among the three sub groups of this cretaceous tertiary sediments the Khasi Group represented by cretaceous mahadek formation which comprises of feldspathic sandstone, conglomerate and clay. No other clay sources are available in the entire region of East Jaintia Hills District. Limestone and coal are t wo major minerals associated with the rock formations of the area.

Ri-Bhoi district is situated in the Northern part of the Meghalaya State. The area of Ri-Bhoi District forms a part of the Meghalaya plateau comprising Archean basement complex and younger sediments. Gneisses and schistose rocks of the Archean age are the oldest rocks of the area forming the basement complex. The older Alluvium comprising of dark brown to brown oxidized sand, silt clay of Chapar and Sarbhog formation is found towards Northern part of the District. Clay sources are found near Um siang river, Bymihat and Umpirtha region that falls under three different lithology that comes under Newer and older Alluvium group.

2.3 The Regional and Geomorphic Background of the Study Area- Myrkhan, Meghalaya Plateau:

2.3.1 The People

The time earlier to the arrival of British there are no written records on the History of Meghalaya. Therefore, to uncover the origin of the people of this land is a difficult task for the researchers. Meghalaya is inhabited by three major groups of people- The Garos covering the East and West Garo Hills District and the Khasi-Pnar people covering the east and west Khasi hills and the Jaintia Hills District. The Khasi-Pnar group indicated two prominent sub-groups of the Khasi and the Pnar. They follow primarily a matrilineal system. The groups living in the northern and southern part of the main central highland, section were known by the terms of 'The Bhoi and War'. They are divided into number of clans and are basically differentiated from each other by their location and function they perform. The Khasi group belongs to the Mon-Khemar sub-family of the Austro-Asiatic language speaking group of people. They are linguistically distinct from the other communities inhabiting Northeast India, who belongs to the Sino- Tibetan and Tibeto-Burman speaking group of people. The Garo group is a part of the greater Bodo Kacheri family both by ethnic group and language. Austro-Asiatic is a very diverse phylum of 168 languages whose original geographical unity has been lost, due to migration and intrusion of other languages in its midst. It is mainly spoken in Southeast Asia where the most representative languages are Khmer, Mon and Vietnamese, and also in northern India (Khasi, Munda). Austro-Asiatic is often regarded as comprised of two branches, a western branch (Munda) and an eastern one (the remainder, including Khasi).

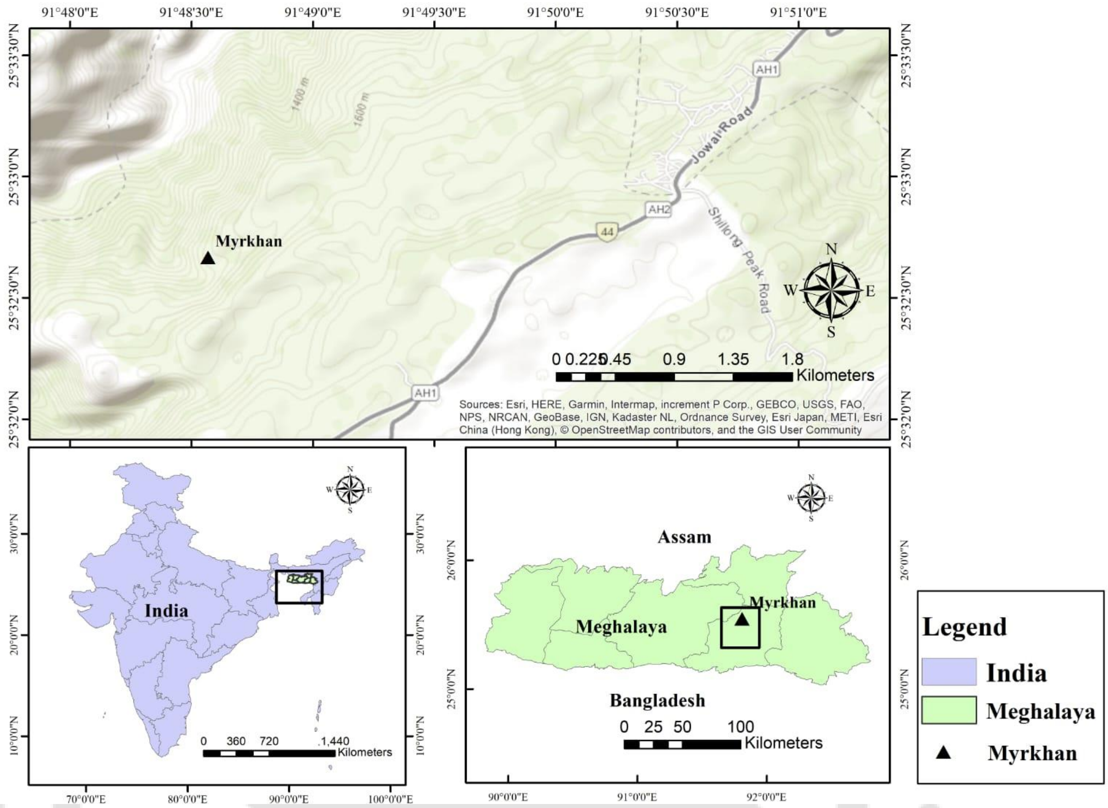
The linguistic and genetic data of the people from these hills adds to the importance of understanding the prehistoric archaeological evidences from these hills as the present community could be one of the remnants of the earliest wave of humanity into North East India. The Neolithic period probably marked the most visible phase in prehistoric period when early farmers migration into the region was more rapid and widespread (Mitri & Neog, Preliminary Report on The Excavations of Neolithic sites from Khasi Hills Meghalaya, 2016).

2.3.2 The Area

East Khasi Hills represent the southwestern part of the shillong plateau, Meghalaya, Northeast India. It is one of the seven districts of Meghalaya covering an area of 2748 sq km. Shillong the head quarter of East Khasi Hill and capital of Meghalaya is well connected with the other districts of Meghalaya and also with the adjoining state Assam and other North-eastern states. Two major highways pass through East Khasi Hills District- National Highway 40 connects Shillong to Jorabat, Assam in the North and extends South wards to Dauki, at Bangladesh border and National highway 44 connects Shillong to states of Tripura and Mizoram of North-eastern states.

Geomorphologically, the East Khasi hills are an undulatory one. The districts represent a remnant of ancient plateau of Indian Peninsular Shield which is deeply dissected suggesting several geo tectonic and structural deformities that the plateau has undergone. It comprises of denuding high and low hills with deep gorges. The site Myrkhan is located in a hill top. The site of Myrkhan the excavation of which is still in the preliminary stage is situated at a distance of 1.1 k.m uphill east of the Umiam River and 22 K.M. South of the site of Lawnongthroh. The evidences collected from the site seem to indicate the function of the site as a factory site. The site is located close to the source of amphibolite out crop which was the dominant type of raw material used for making stone tools by the pre-historic settlers of these hills. The paper will try to bring some insights about the relationship between technology and natural resources from the site of Myrkhan and make a comparative study of the above mentioned sites. The paper is also expected to provide closer understanding of the Neolithic cultures with the ethnographic population on the given geographical space.

Map 2.2: Map of India showing the location of the site Myrkhan



2.4 Conclusion

Studying the geography and geology of an area is essential when conducting provenance studies for several reasons:

1. **Understanding Geological Processes**: Geology provides insights into the formation processes of different types of rocks, minerals, and sediments in a particular region. This understanding helps in identifying potential sources of raw materials used in artifacts or materials under study. For example, specific geological formations may be associated with certain types of minerals or rocks, aiding in the identification of their origin.
2. **Identifying Geological Signatures**: Geological features such as mineral composition, isotopic ratios, and sedimentary structures leave distinct signatures that can be traced back to their source regions. By analysing these signatures, researchers can narrow down potential geographic origins of artifacts or materials.

3. **Spatial Analysis**: Geography plays a crucial role in determining the distribution of natural resources and environmental conditions across different regions. Geographic information systems (GIS) and spatial analysis techniques allow researchers to map and analyze the distribution of artifacts or materials in relation to geological features, landforms, and environmental factors. This spatial perspective provides valuable insights into patterns of resource utilization, trade routes, and cultural interactions.
4. **Environmental Context**: Geographical and geological factors influence the environmental conditions and landscapes of a region, which in turn affect human activities, settlement patterns, and resource exploitation strategies. By studying the environmental context, researchers can better interpret the socio-economic and cultural aspects associated with the provenance of artifacts or materials.

In summary, integrating geographical and geological perspectives into provenance studies enhances our understanding of the origins, distribution, and cultural significance of artifacts or materials, contributing to broader interpretations of human history, trade networks, and environmental interactions that is the interaction of the inhabitants of the site with their surroundings.

Therefore, a detailed study on the geology and the geography of the state Meghalaya is done here. The soil and rock type found in all the districts of the area is studied to understand the formation of the site location and this will also help in understanding whether the raw material used for making the stone tools and the pottery was locally available. The red loomy soil is found exposed in the central part of the district. It is a product of weathering of rocks like granites, gneisses etc. which are relatively rich in clay forming minerals. This type of soil is rich in organic matter, nitrogen and acidic in nature. In the Northern area of East Khasi Hill district Laterite soil is found which are the weathering products of rocks like quartzite, schist, conglomerate etc. These soils are rich in iron and aluminium. Alluvial soils are one of the soil types found exposed in the southern part of the district that are rich in potash but poor in phosphate content. They are acidic in nature.

The district area predominantly lies within the Shillong or Meghalaya Plateau, characterized by Precambrian rocks primarily composed of gneiss. These gneisses contain various inclusions such as granites, schists, amphibolites, and cal silicate rocks of varying sizes. Serving as the basement complex, the gneisses underlie the overlying Shillong Group of rocks. Within this geological context, the quartzites of the Shillong group exhibit primary structures like current bedding and ripple marks, indicating their sedimentary origin before undergoing metamorphism into quartzite. The site Myrkhan is identified as a manufacturing site for stone tools, utilizing raw materials sourced from amphibolite and slate rock outcrops located in close proximity to the site itself.

The clay sources across all districts of Meghalaya were analyzed using Meghalaya's GIS report. In the East Khasi Hills District, two clay sources were identified, both situated between the Mylliem subdivision and Cherrapunji along the main connecting road. The study area, known as "Myrkhan," is located within the Mylliem subdivision, approximately 14 kilometers from the district headquarters in Shillong. However, these clay sources are not in close proximity to the Myrkhan site. In the East Garo Hills District, the clay deposits found there are of residual origin and suitable for ceramic industries. Considering the distance from Myrkhan to the clay source in East Garo Hills District and other clay sources across Meghalaya, it becomes apparent that they are quite distant. Logically, artisans of that period, engaged in crafting clay pottery, would likely prefer to collect clay from the nearest available source rather than traveling long distances.

The study clearly indicates that the raw material sources utilized for crafting stone tools and pottery at Myrkhan are distinct. This suggests that Myrkhan was likely not a permanent habitation site for Neolithic craftsmen, but rather a seasonal stopover primarily dedicated to the production of stone tools.

Chapter-3

A Comparative Analysis of Morphological Variations of the Pottery

3.1 A General Overview

The Neolithic cultural phase and the advent of agriculture are regarded as pivotal factors influencing global population distribution and the dissemination of cultures to various regions through human migration. Pottery serves as a crucial tool for assessing these phenomena, allowing for comparisons of morphological similarities and differences across different geographical areas. Since its inception, pottery has played a significant role in archaeological research, owing to its exceptional durability as a human creation from ancient times. This chapter will focus on the physical characteristics of impressed pottery unearthed at the Myrkhan site in the Meghalaya plateau, providing a comparative analysis based on its physical attributes.

Northeast India boasts a wealth of archaeological significance, with numerous sites spread across all states in the region, both protected and unprotected. The verified sites provide valuable insights into the archaeological importance of this region within India. Since the inception of archaeological investigations by scholars in the Northeast, many explored sites have been excavated using rigorous archaeological methods. These investigations yield valuable information about past cultures and the inhabitants of the region during different periods of time. The historical, geographical, and socio-cultural context of Northeast India contributes to its uniqueness. Moreover, the area has proven to be archaeologically rich, attracting researchers to conduct studies aimed at uncovering prehistoric cultural evidence.

During the last three years, two Neolithic sites were tested through small scale excavations to ascertain a chronological and cultural context of the surface finds from Khasi and Jaintia hills (Mitri, 2009). Myrkhan is one of the excavated sites among these two. The site Myrkhan has been explored and excavated during the year 2016 and it is still in its initial phase of work. It is located between 25º32’40.01” Latitude in the North and 91º48’34.06” longitude in the East at 5094 feet AMSL. The site is in a hill top and is situated at a distance of 5 km to east of the Umiam stream of Meghalaya Plateau, which flows almost the entire Northern Khasi hills till it joins the Brahmaputra River in Assam. The excavated site is also named by the name of the nearby village Myrkhan. The site Myrkhan is located 45 kilometers south of another Neolithic Site Lawnongthroh in the East Khasi Hills District of Meghalaya. The flora of the site Myrkhan and the surrounding areas falls under the temperate type due to the high altitude of the Khasi Hills highland area. The site is covered with an enormous amount of waste fIakes and stone artifact which is clearly visible on the surface level. The flakes and other artifacts are found scattered within a 3 square kilometers radius of the site. A number of unfinished stone tools has been recovered along with the waste flake debris. The area at the extreme south-west end of the modern villages is observed with a huge concentration of archaeological remains such as waste flakes, stone artifacts and other cultural materials as well which might had been heaped there by the former cultivators inhabited in that area. This area measures 6 meters to the East west direction and 20 meters to the north south direction. The excavated area of the site Myrkhan unearthed unfinished stone tools in abundance along with a number of finished tools, potsherds, ring stone, very small metal beads after the 1st phase of excavation is done. These cultural assemblages collected from the excavated area give indication of Neolithic settlement pattern.

The surface evidence from the flat area clearly suggests that it was used for mainly stone tool manufacture since it is found close to an amphibolite and slate rock outcrop. The rock outcrop is definitely a source for stone tools at the site and it is located close to a small stream which flows westward to join the umiam stream at the gorge.

The flat area of the site was mapped for excavation and topographic setting presents a very minimal erosional flow for artifacts. However, along the sites of this flat area and except the Northeast direction where the slope runs uphill, the area is identified with steep slope.

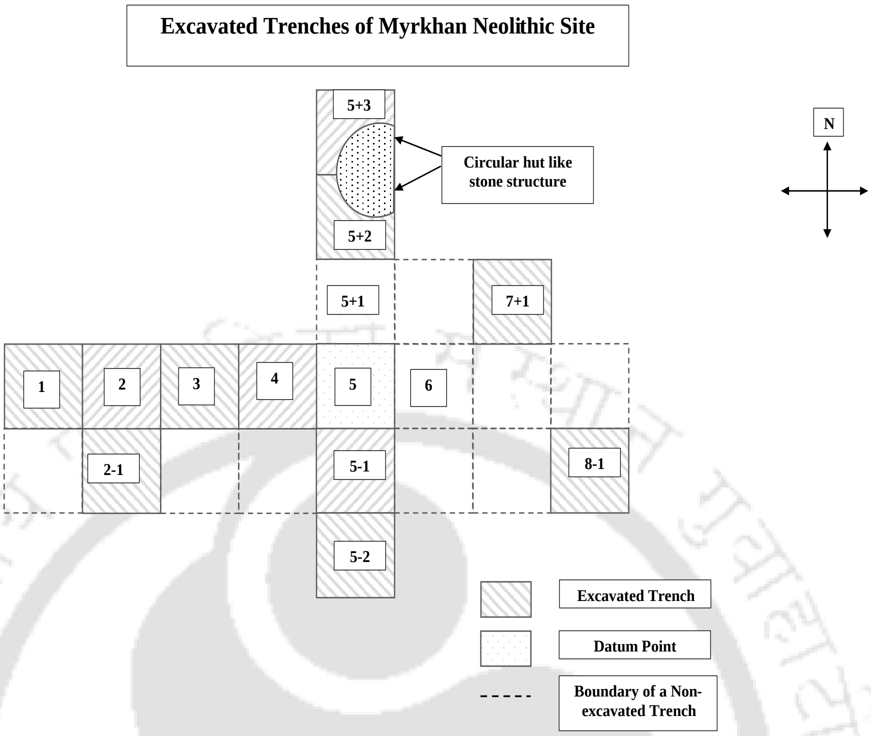
3.1.1 On Excavation of the site

After a detail exploration of the site the area in the mid of the hill top was selected for excavation. The surrounding slope areas are also observed carefully to understand the site in a better way. It has been observed that due to human activities the waste flakes and other artifacts rolled down the hillsides and got detached from its context. The flat area at the hill top was selected for excavation as probability of erosional flow is minimum in this area.

Figure 3.1: The aerial view of the excavated trenches after the 1st phase excavation

The excavation was preceding by digging a trial trench first, to understand the possibilities of the site. After the mapping of the site, a 20×20 meters' layout was designed for excavation. To conduct the excavation, the grid method of horizontal excavation was used. A total number of 11 trenches has been excavated during the first phase of excavation of the site Myrkhan. Before the excavation carried out in the trenches two trial trenches were dug up to the depth of 80 centimeters to understand the stratigraphic profile of the site and to get an idea about the possibility of getting cultural assemblages in the site. The measurement of the trenches are 2×2 meters square. Trenches are named as T1, T2 and so on. Trench T5 is considered as datum point as the area of this trench is in the highest peak of the region. and from the datum point the trenches towards the North direction are named as T+1, T+2…. And the trenches towards the south direction are named as T-1, T-2….and so on.

Figure 3.2: Diagram of the excavated area showing the excavated and non-excavated trenches



The depths of the excavated trenches vary trench wise. The maximum depth of the trenches is 90 cm. Only the trench 5-1 was dup up to 90 cm. From this trench a charcoal sample was collected at the depth of 50 cm associated with cultural material and send for C14 date. The C14 method has given a date Cal BP 3500±30 BP for the site. Cultural materials were found only up to the depth of 50 cm. below 50 cm no cultural materials were found from any of the trenches. The layer below fifty is non cultural layer or sterile layer. In the flat surface of the hill the stone tools are lying abundantly. The trench 5+2 and 5+3 uncovered a circular stone like structure. The details of the trenches along with its depth is given below in the Table 3.1.

Table 3.1: Name of trenches along with Depths (in cm)

Sl No.	Name of the Trench	Depth of the Trench (in cm)
1	T1	40 cm
2	T2	50 cm
3	T2-1	40 cm
4	T3	50 cm
5	T4	70 cm
6	T5-1	90 cm
7	T5+2	50 cm
8	T5-2	40 cm
9	T5+3	40 cm

10	T7+1	40 cm
11	T8-1	40 cm

3.2 Diagnostic Features of the Pottery of Myrkhan

A total number of 1402 potsherds have been excavated from the site "Myrkhan" during its first phase of excavation. Among these 1402 potsherds 26 sherds were exclusively used for reconstruction of the shape of the body of the pottery and rest were used for quantification. Total number of the sherds used for measurement and morphological variation analysis is 1376. Below are the total counts of pottery fragments recovered, categorized by layers.

1st Layer- 655 potsherds

2nd Layer- 340 potsherds

3rd Layer- 333 potsherds

4th Layer- 48 potsherds

The first classification of the potsherds is done on the basis of its physical features, by Dr. Marco Mitri who has excavated the site. He has classified the sherds into two types- 1. Cord marked pottery and 2. Curved paddle pottery. The number of cord marked potteries are more than the number of carved paddle potteries. Apart from these impressed pottery fragments few plain pottery fragments were also found, which are very less in number in comparison to the other two types found in the site. Cord marked potteries in northeast region are said to be the type fossil of the Neolithic cultural period, though a clear distinction of these impressed potteries are not done yet in this highly archaeologically potential area. A more scientific approach to make a proper classification of these impressed potteries of northeast region is very much necessary to uncover many doubts of our past cultures. These potteries collected from Myrkhan has a large inclusions of crushed quartz. The exterior design found were created with cord that might be wrapped around a wooden paddle to create the surface. With a single piece of sherd, it is difficult to say about the pottery and the man behind it and the site where the people live in the past. But if a huge number of potsherds or potteries have been recovered from an archaeological site these potsherds can provide many information about the past cultures, human movements and relations within and between communities. The visible attributes of pottery and the probable use of the potteries as storage and cooking provides ideas to interpret pottery with its creator the human and their past societies.

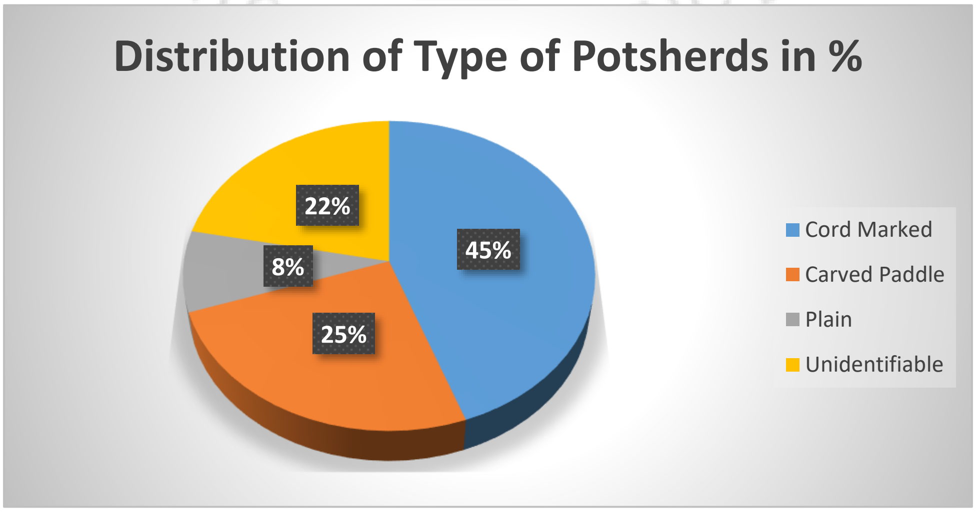
3.2.1 Typological Analysis

In the morphological analysis of the potsherds categorization is done before the classification of the sherds are carried out. In this research work all the excavated potsherds are classified on the basis of four categories, for a better understanding of its typology, function and other important aspects. These four categories are 1. Pottery type, 2. Impressed pattern, 3. Colour and 4. Thickness

I) Classification on the basis of pottery type

The surface treatment of a pottery succeeding to the manufacturing process is varied region or population wise and it is very important to study for the understanding of the craft pottery. It imparts the most characteristic visual aspect to the pottery. Surface treatment is either functional or stylistic (decorative), or sometimes it aids both ways. The first step to make groupings of the potsherds were based on its type of surface design. The main criteria taken here are cord marked, carved paddle, plain and last one is classified as unidentified. Many of the potsherds are very small in size and the pattern present in the sherds are not clearly visible to understand the pottery type, probably due to weathering effect. This type of sherds is classified as unidentified. After the shorting of the potsherds it has been found that the number of cord marked potsherds are highest in number. Carved paddle is 2nd highest in number and the number of plain faded ware are very less compare to the cord marked and the carved paddle sherds. Unidentifiable sherds are also more in number. According to its type the number of the potsherds found are as follows- 1. Cord Marked- 612, 2. Carved Paddle- 348, 3. Plain- 116, 4. Unidentifiable- 300.

Figure 3.3: Percentage of all the types of potsherds from Myrkhan

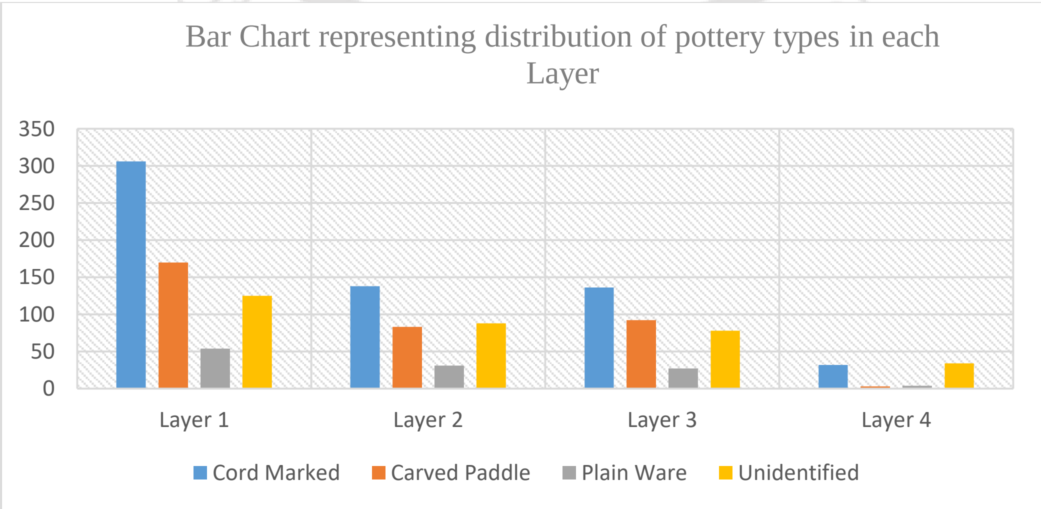


As the potteries are found above 50 cm, four layers in the section of the trenches are made according to the depth. The 1st layer is marked from the surface to the depth of 20 c.m. The second layer is from 20 cm to 30 cm. The third layer is from 30c. to 40 cm. and the last or the fourth layer is marked from 40 cm. to 50 cm. The number of potsherds found in the top most layer is highest. From the second and the third layer almost same number of potsherds are recovered. Only the fourth layer shows a very minimum number of potsherds in the trenches. T2, T4, T5+2 and T5-1 shows presence of potsherds on the lower most level. In the trench T2-1, potsherds are found only above 30 cm, in the 3rd and 4th layer potsherds do not exist.

Table 3.2 The details classification of the potsherds on the basis of the surface design

Sl. No.	**Layer** (Depth in cm)	**Types of potteries**				**Total no. of sherds (** in each Layer**)**
		Cord marked	Carved paddle	Plain ware	Unidentifiable	
1	**Layer-1** (0-20 cm)	306	170	54	125	655
2	**Layer-2** (20 -30 cm)	138	83	31	88	340
3	**Layer-3** (30-40 cm)	136	92	27	78	333
4	**Layer-4** (40-50 cm)	32	3	4	9	48
5	**Total no. of sherds (in each type)**	612	348	116	300	**1376**

Figure 3.4: Layer wise distribution of all the types of potsherds



II) Classification on the basis of Pattern of Impression

The 2nd step of classification is based on the pattern of impression on the surfaces of the potsherds. Total 5 types of pattern are visible in the upper surfaces of the potsherds. These patterns are Zig-zag, criss-cross, horizontal or vertical, diamond shape and plain. Rather than the impressions found on the outer surface of the potsherds no other decoration such as burnishing or coloring were applied. Pattern which are not clear are grouped as unidentified.

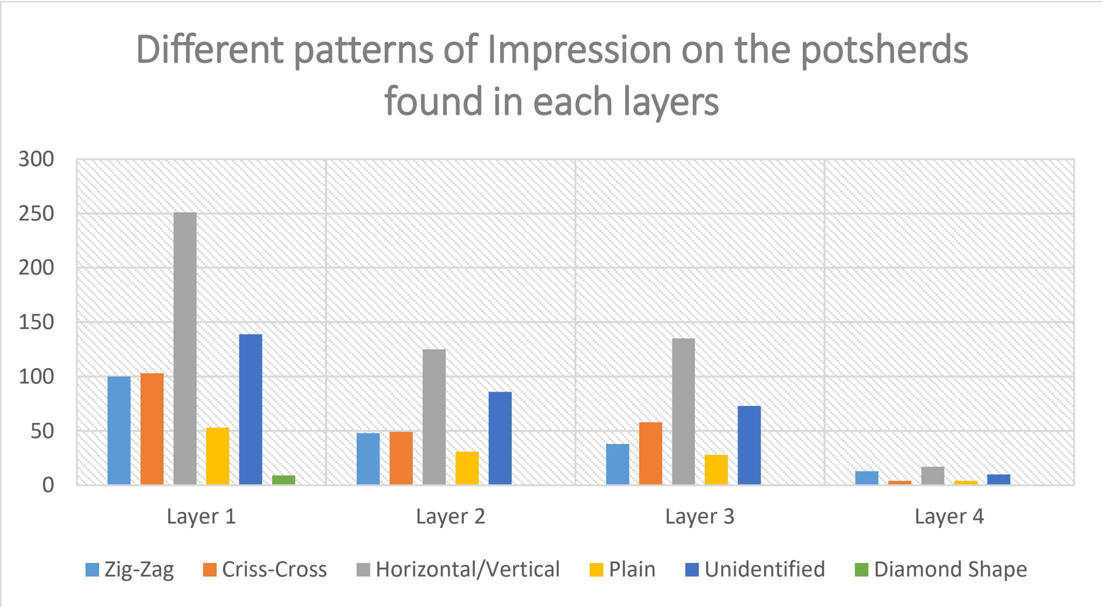
Figure 3.5: Photographs of all the five impressions found in the potsherds; A- Zig-zag, B- criss-cross, C- horizontal or vertical, D- diamond shape and E- plain.

After the classification is done it has been found that horizontal or vertical pattern is found mostly in the potsherds and it is more in numbers in all the four layers. Potsherds with diamond shaped pattern are very less in number. It is absent in the lowest layer and in both the 2nd and 3rd layer only 1 potsherd in each layer with this impression has been found.

Table 3.3: The details classification of the potsherds on the basis of pattern of design

Sl. No.	Layer (Depth in cm)	Pattern of Impressions						Total No. of sherds (in each Layer)
		Zig-Zag	Criss-Cross	Horizontal/ Vertical	Plain	Unidentified	Diamond Shape	
1	**Layer-1** (0-20 cm)	100	103	251	53	139	9	655
2	**Layer-2** (20 - 30 cm)	48	49	125	31	86	1	340
3	**Layer-3** (30-40 cm)	38	58	135	28	73	1	333
4	**Layer-4** (40-50 cm)	13	4	17	4	10	0	48
5	**Total no. of sherds (in each pattern)**	199	214	528	116	308	11	**1376**

Figure 3.6: Layer wise distribution of the potsherds with different patterns of impression



III) Classification on the Basis of Colour

The third criteria of classification are based on the colour of the potsherds. The colour of the potsherds are recorded from the cross section of the fragments. After a minimum thickness of weathered part is removed the original colour can be visible. Munsell colour chart has been used to identify and make a classification of the potsherds on the basis of its colour.

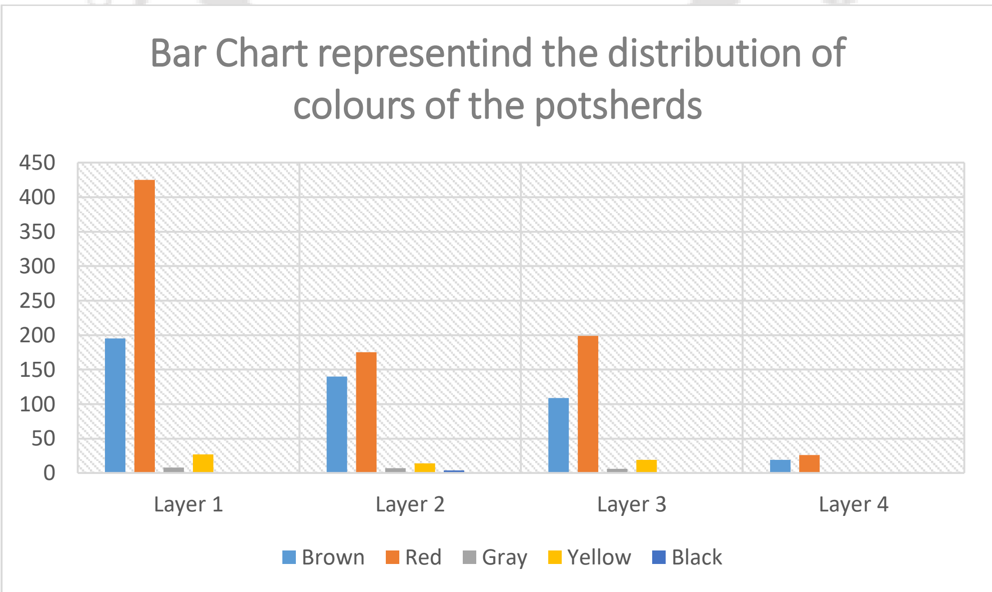
Soil colors are most conventionally measured by comparison with the munsell colour chart. The seven charts in the soil collection display 199 different standard colour chips systematically arranged according to their Munsell system as Hue, Value and Chroma. HUE indicates its relation to Red, Yellow, Green, Blue and Purple: VALUE indicates its lightness: and CHROMA indicates its strength (or departure from a neutral of the same lightness). The nomenclature for soil colour consists of two complementary systems: 1. Colour names, and 2. The Munsell notation of colour. Neither of these alone is adequate for all purposes. The Munsell notation is used to supplement the colour names wherever greater precision is needed, as a convenient abbreviation in field descriptions, for expression of the specific relations between colours and for statistical treatment of colour data. The symbol for hue is the letter abbreviation of the colour of the rainbow (R for red, YR for yellow-red, Y for yellow) preceded by numbers from 0 to 10. The notation for value consists of numbers from 0, for absolute black, to10, for absolute white. Thus a colour of value 5/ is visually midway between absolute white and absolute black. The notation for Chroma consists of numbers beginning at 0 for neutral grays and increasing at equal intervals to a maximum of about 20, which is never really approached in soil. For example, Brown/ HUE 10YR- 4/3.

The major colours I have found in the potsherds, while doing the classifications are Brown, red, yellow, and grey. The colour black is found only in 5 samples among all the potsherds. The colour black might formed due to firing condition. Red colour is found in highest number among all the potsherds, though its shades vary in the samples. The second highest colour found in the samples is brown. It is also found in the samples in various shades of brown. The potsherds found with the colour yellow and grey are very less in number in compare to the other two colours red and brown.

Table 3.4: The detail classification of the potsherds on the basis of colour

Sl. No.	Layer (Depth in cm)	Colour of the sherds					Total No. of sherds (in each Layer)
		Brown	Red	Gray	Yellow	Black	
1	**Layer-1** (0-20 cm)	195	425	8	27	0	655
2	**Layer-2** (20 - 30 cm)	140	175	7	14	4	340
3	**Layer-3** (30-40 cm)	109	199	6	19	0	333
4	**Layer-4** (40-50 cm)	19	26	1	1	1	48
5	**Total no. of sherds (in each Layer)**	463	825	22	61	5	**1376**

Figure 3.7: Layer wise distribution of the potsherds with different patterns of impression



The above colors are major classification. These major groups are again classified into sub groups according to the different shades of each color.

Table 3.5: Sub Classification of the major color Brown according to its various shades

Sl. No.	Layer (Depth in cm)	Brown											Total No.
		B	SB	DB	YB	DYB	LYB	GB	DGB	VDGB	RB	DRB	
1	**Layer-1** (0-20 cm)	15	51	22	29	19	3	3	10	8	22	13	195
2	**Layer-2** (20 -30 cm)	7	34	24	14	8	4	1	15	6	16	11	140
3	**Layer-3** (30-40 cm)	3	30	15	10	5	1	3	6	13	18	5	109
4	**Layer-4** (40-50 cm)	0	4	6	2	2	0	0	1	0	2	2	19
Total No		25	119	67	55	34	8	7	32	27	58	31	**462**

Table 3.6: Sub Classification of the major color Red according to its various shades

Sl. No.	Layer (Depth in cm)	Red					Total No.
		R	DR	YR	DuR	LR	
1	**Layer-1** (0-20 cm)	295	25	91	9	5	425
2	**Layer-2** (20 -30 cm)	115	13	42	5	0	175
3	**Layer-3** (30-40 cm)	146	9	37	6	1	199
4	**Layer-4** (40-50 cm)	15	1	10	0	0	26
Total Number		571	48	180	20	6	**825**

Table 3.7: Sub Classification of the major color Grey according to its various shades

Sl. No.	Layer (Depth in cm)	Grey				Total No.
		DG	VDG	DRG	PG	
1	**Layer-1** (0-20 cm)	4	2	2	0	8
2	**Layer-2** (20 -30 cm)	2	2	1	2	7
3	**Layer-3** (30-40 cm)	3	3	0	0	6
4	**Layer-4** (40-50 cm)	0	1	0	0	1
Total Number		9	8	3	2	**22**

It has been found that the major colours are again found in the potsherds in many shades. The colour brown shows maximum shades in the potsherds. These are brown (B), strong brown (SB), dark brown (DB), yellowish brown (YB), dark yellowish brown (DYB), light yellowish brown (LYB), grayish brown (GB), dark grayish brown (DGB), very dark grayish brown (VDGB), reddish brown (RB), dark reddish brown (DRB). Among all the shades of the colour brown, strong brown is found mostly in the potsherds. The colour red presents in five different shades in the potsherds. These are red (R), dark red (DR), yellowish red (YR), dusky red (DuR), light red (LR). The colour red is found more in numbers in the potsherds among all the shades. The colour gray represents four different shades. These are dark gray (DG), very dark gray (VDG), dark reddish gray (DRG), pinkish gray (PG). Yellow colour has only one shade i. e., Reddish yellow. All the potsherds in the colour group yellow presents reddish yellow. Black colour is also found in only 5 samples in the whole pottery collection of Myrkhan. It shows two shades, black and reddish black. The classification of the sherds based on colour helps us in sorting the sherds in different colour, which could be later examined with the physical and chemical analysis of the sherds and it will help us to understand the variations present is it.

IV) Classification on the Basis of Thickness

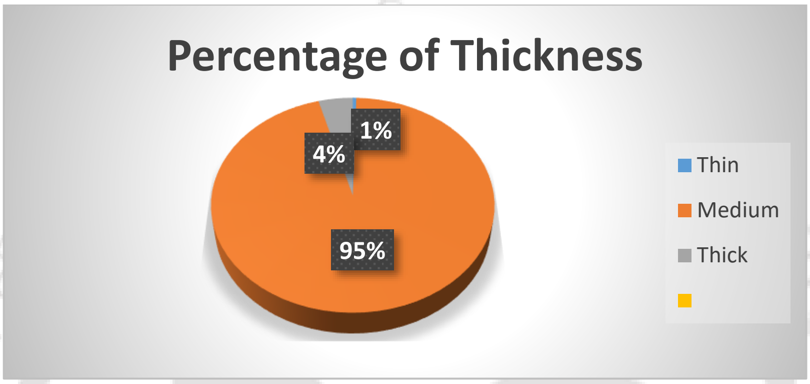
The forth classification is based on the thickness of the potsherds profile. Thickness of the profile of the pottery fragments can give us important information about its uses. While doing the classification three levels has been made on looking at the highest and lowest thickness of the profile of the potsherds.

Table 3.8: The detail classification of potsherds on the basis of thickness of the body

Depth	**Type of pottery**	**Thickness categories**			**Total No.**
		Thin (0-3 mm)	**Medium (4-7 mm)**	**Thick (8 mm and above)**	
0-20	Cord marked	2	291	14	307
	Carved paddle	0	168	2	170
	Plain ware	0	48	6	54
	Unidentifiable	0	120	4	124
20-30	Cord marked	1	133	4	138
	Carved paddle	0	83	0	83
	Plain ware	0	28	4	32
	Unidentifiable	1	84	3	88
30-40	Cord marked	1	132	3	136

	Carved paddle	0	89	3	92
	Plain ware	0	23	4	27
	Unidentifiable	1	69	8	78
40-50	Cord marked	0	29	3	32
	Carved paddle	0	3	0	3
	Plain ware	0	2	1	3
	Unidentifiable	0	9	0	9
Total		6	1311	59	**1376**

Figure 3.8 Total Percentage of thickness in all the three categories

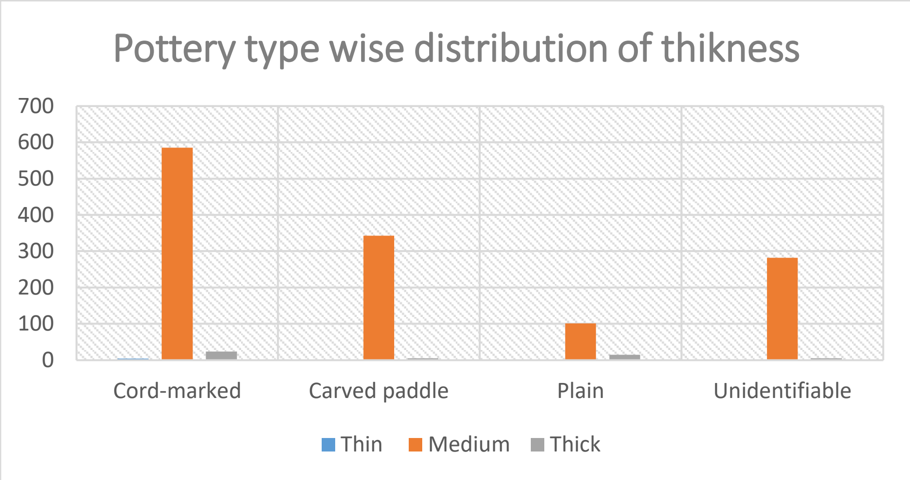


Looking at the distribution of the thickness of the body of the potsherds of Myrkhan potsherds has been classified into three categories. These are-

1. Thin- 0-3 mm
2. Medium- 4-7 mm
3. Thick- 8<

It has been found that only one percent of total potsherds is thin walled, 4 percent of the total potsherds are thick walled and the rest ninety-five percent of the potsherds are of medium thickness value. The lowest thickness value is 2.5 mm, found in a cord-marked potsherd and the highest thickness value is 9.5 mm, represents by a cord marked potsherd. The first category of thickness value is represented by the cord marked potsherds only. All the potsherds from the type carved paddle and plain pottery are above thickness value 3.

Figure 3.9: Distribution of the thickness of all the pottery types



In all the types of pottery medium thickness is found to be in large numbers. But if we compare the thickness value with the total number of the potsherds type wise, it is found that thick walled potsherds are more in plain pottery category in compare to the other two types of pottery that is cord-marked and carved paddle. It has been said that the thickness of the pottery wall is related to its function and also depends on the mobility of the people who manufacture it.

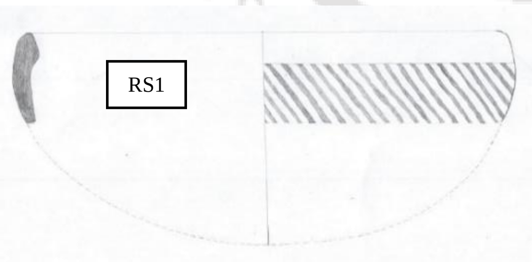
3.2.2 Reconstruction of Pottery Shape

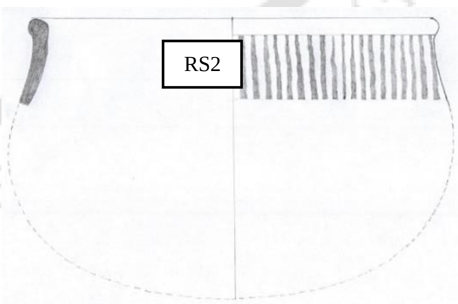
The reconstruction of archaeological pottery holds significant importance in uncovering insights about pottery production and its functional utility. A crucial initial step in this process involves identifying the diagnostic and non-diagnostic fragments of a pottery. Diagnostic sherds typically include the rim and base sections, while non-diagnostic sherds pertain to the body of the pottery. Successful pottery reconstruction relies on the discovery of both rim and base sections within an excavation site. It is widely acknowledged that the shape of a pottery vessel often correlates with its intended function. However, excavated artifacts are typically fragmented, with only a limited number of intact rim sherds available for analysis due to their size. Moreover, many fragments are too small to facilitate reconstruction. Consequently, only a select few rim sherds of adequate size (27 in total) are chosen from each layer for shape reconstruction. These rim sherds are assigned identification codes such as RS1, RS2, and so forth, with "RS" denoting "reconstructed sherd." A comprehensive layer-wise description of the reconstructed pottery is provided in the subsequent tables.

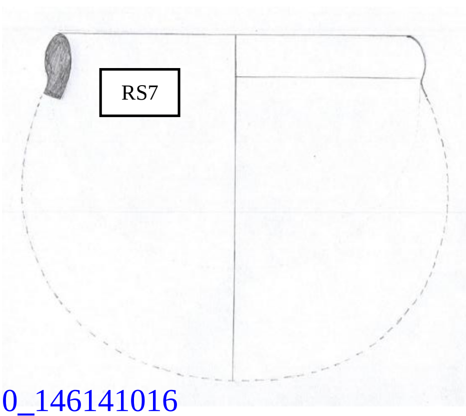
Table 3.9: Description of the reconstructed pottery from layer 1

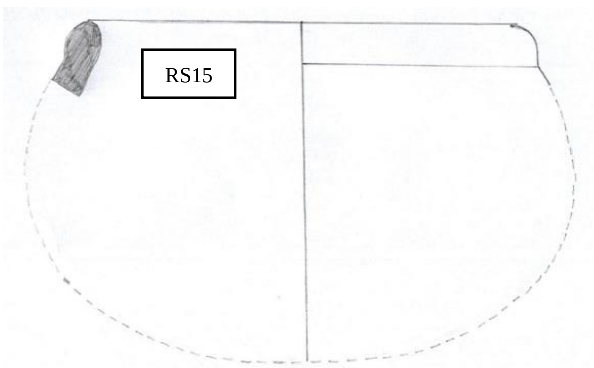
Sample Name	Layer 1								
	Trench	**Depth**	**Radius**	**Diameter**	**Height**	**Distance**	**Thickness**	**Type of Sherd**	**Colour**
RS1	2-1	0-20	9 cm	18 cm	4.1 cm	4 cm	R-9mm/B-5mm	Cord Marked	Reddish Brown 4/4 HUE 5YR
RS2	5-2	0-20	8 cm	16 cm	3 cm	3.5 cm	R-6mm/B-5mm	Cord Marked	Red/ HUE 2.5YR-5/8
RS7	5+2	0-20	10 cm (1:2)	20 cm	1.6 cm	2.6 cm	R-6mm/B-5mm	Unidentifiable	Red/ HUE 2.5 YR-5/8
RS15	5+3	0-20	8 cm	16 cm	1.4 cm	1.8 cm	R-6mm/B-5mm	Unidentifiable (Impressed)	Red/ HUE 2.5YR-4/8
RS16	5+2	0-20	7 cm	14 cm	1.3 cm	3.3 cm	R-6mm/B-7mm	Plain ware	Red/ HUE 2.5YR-4/6
RS20	1	0-20	8 cm	16 cm	1.3 cm	2.3 cm	R-6mm/B-6mm	Unidentifiable (Impressed)	Red/ HUE 2.5YR-4/8
RS24	3	0-20	11 cm (1:2)	22 cm	2.4 cm	2.5 cm	R-9mm/B-7mm	Carved paddle	Red/ HUE 2.5YR-5/8
RS26	4	0-20	12 cm (1:2)	24 cm	2.3 cm	2.3 cm	R-7mm/B-7.5mm	Carved paddle	Dark Red/ HUE 2.5YR-3/6

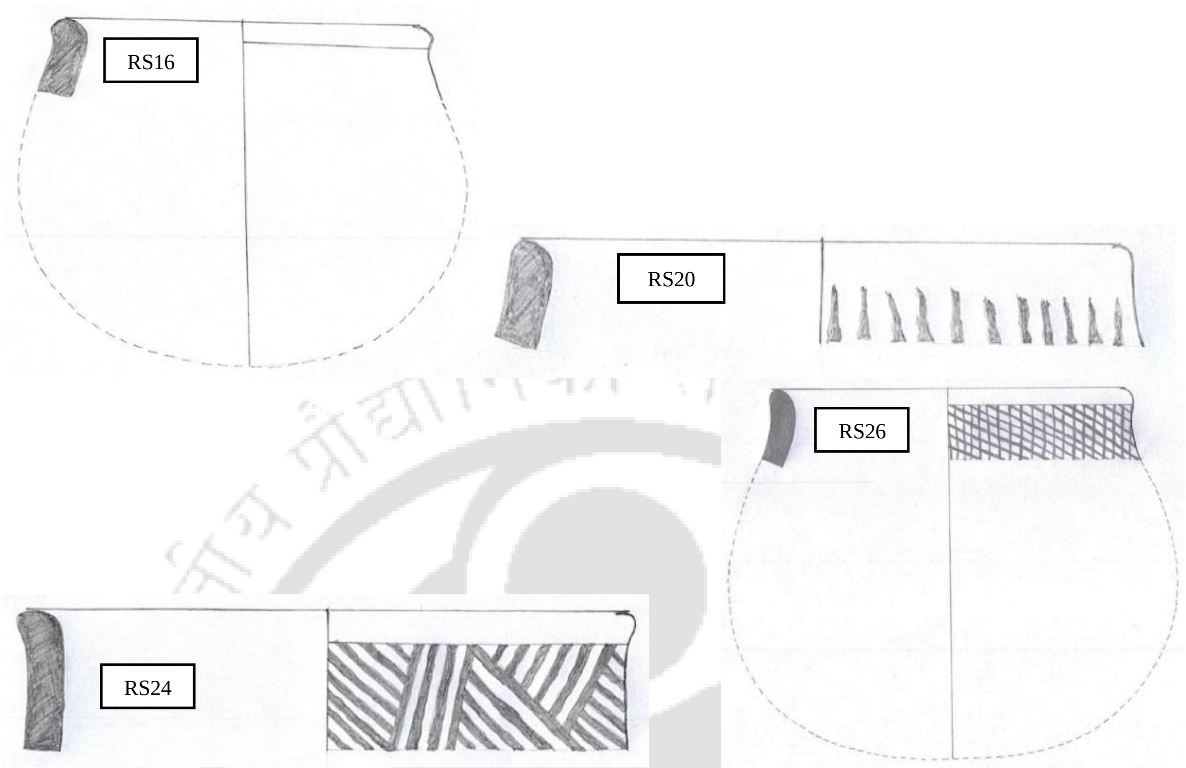
Plate 3.1: The drawings of the reconstructed pottery from layer 1 are shown below









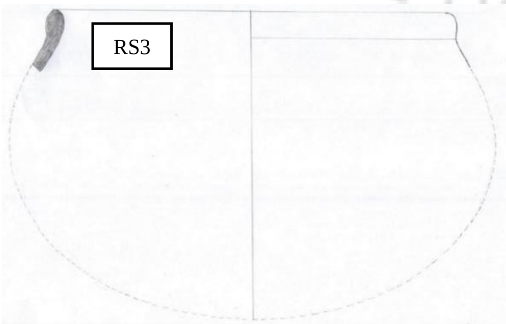


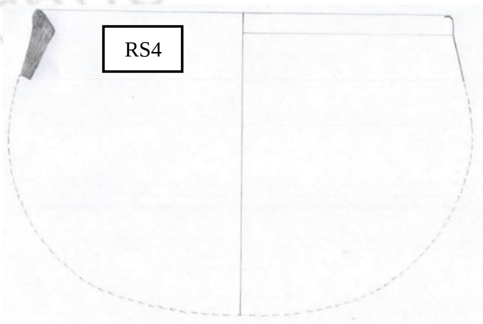
After analyzing the reconstructed pottery fragments from layer 1, it was observed that the cord-marked, carved paddle, and plain pottery varieties exhibit distinct rim shapes. The majority of these vessels are in the form of pots. Despite variations in design, almost all the pots are red in color, except for one which has a reddish-brown hue. The prevalent type of pot features a short neck with a gentle outward curve, while the rims of most pots are lightly thickened, with a few exceptions that lack this feature. Although the exact body shape is challenging to determine due to the fragmentary nature of many specimens, better-preserved examples often display an elliptical body with a lower center of gravity, while some specimens exhibit a more globular form. Another variant present in this assemblage is the bowl. Bowls can be categorized according to their rim-neck section and body shape. They may feature a hemispherical or shallow hemispherical body with a gently outward-turned neck, those with a squat globular body and an outward-turned neck, those with a hemispherical body and an open mouth, as well as those with an inward-turned neck. The bases of these vessels have not been definitively reconstructed; only a likely shape has been approximated based on the alignment of pottery fragments.

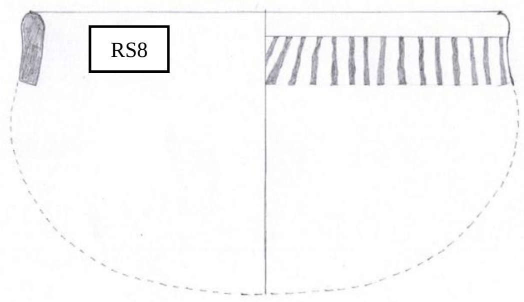
Table 3.10: Description of the reconstructed pottery from layer 2

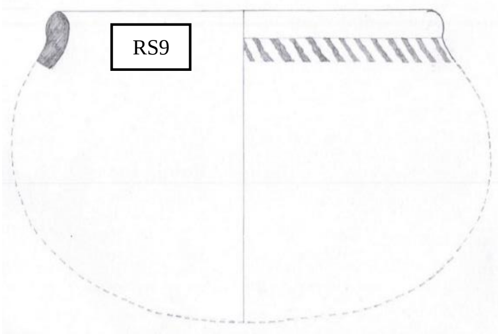
Sample Name	Layer 2								
	Trench	**Depth**	**Radius**	**Diameter**	**Height**	**Distance**	**Thickness**	**Type of Sherd**	**Colour**
RS3	2	20-30	7.5 cm	15 cm	2.1 cm	2.8 cm	R-6mm/B-6mm	Plain Ware	Yellowish Red/ HUE 5YR- 5/8
RS4	3	20-30	7.5 cm	15 cm	2.4 cm	2.5 cm	R-7mm/B-6mm	Plain Ware	Light brownish gray/ HUE 10YR- 6/2
RS8	2-1	20-30	11 cm (1:2)	22 cm	1.5 cm	2.1 cm	R-3.5mm/B-3.5mm	Cord Marked	Red/ HUE 2.5 YR-5/8
RS9	5+3	20-30	11.5 cm (1:2)	23 cm	1.5 cm	2.9 cm	R-6mm/B-4mm	Cord Marked	Yellowish Red/ HUE 5YR- 5/8
RS11	7+1	20-30	11 cm	22 cm	1.4 cm	1.8 cm	R-6mm/B-4mm	Unidentifiable	Red/ HUE 2.5YR-5/8
RS12	5+2	20-30	8.5 cm	17 cm	1.8 cm	2.1 cm	R-5mm/B-5mm	Plain ware	Red/ HUE 2.5YR-4/6
RS13	5-2	20-30	10.5 cm (1:2)	21 cm	1.5 cm	1.8 cm	R-5mm/B-5mm	Unidentifiable	Red/ HUE 2.5YR-5/8
RS14	2-1	20-30	10 cm (1:2)	20 cm	1.3 cm	2.8 cm	R-7mm/B-4.5mm	Unidentifiable	Red/ HUE 2.5YR-5/8
RS23	2	20-30	10.5 cm	21 cm	3.7 cm	3.7 cm	R-8mm/B-6.5mm	Plain ware	Red/ HUE 2.5YR-4/8

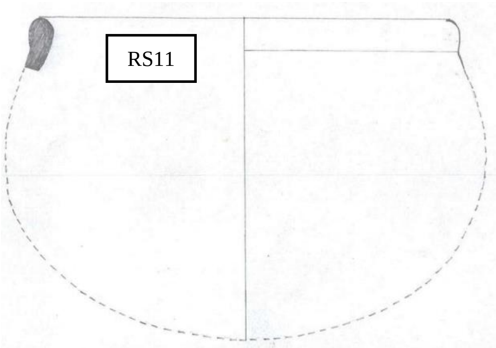
Plate 3.2: The drawings of the reconstructed pottery from layer 2 are shown below:

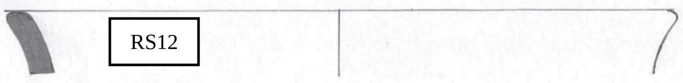


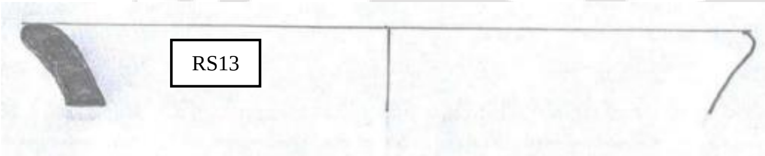


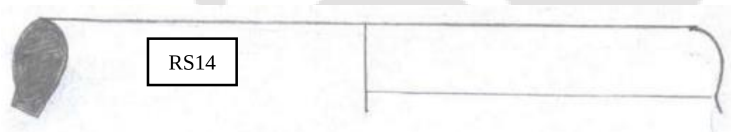


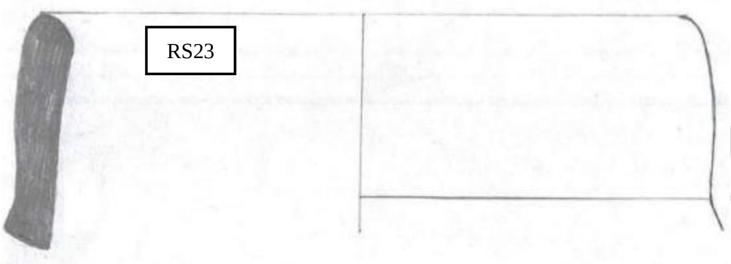










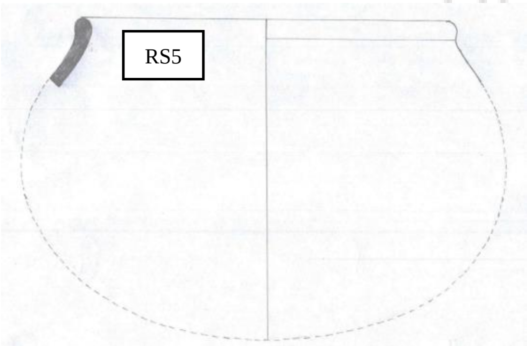


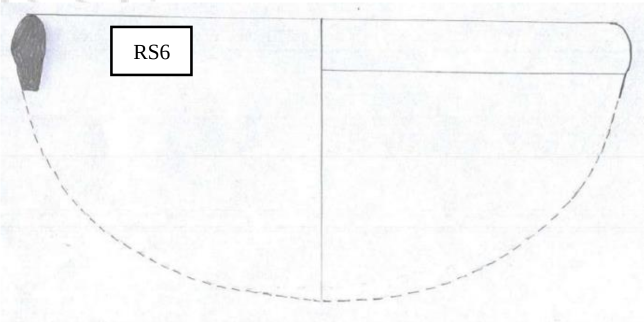
In the second layer as well, the reconstructed pottery reveals a mix of pots and bowls. Examining the rim shapes, some pottery fragments suggest vessels with long necks, although the body remains unreconstructed. Rim shapes vary between outward-turned, inward-turned, and open-mouth designs. The prevailing color across all the pottery is red, except for one piece found in a light brownish-gray shade. One particular rim shard stands out among the rest, featuring a comparatively longer neck.

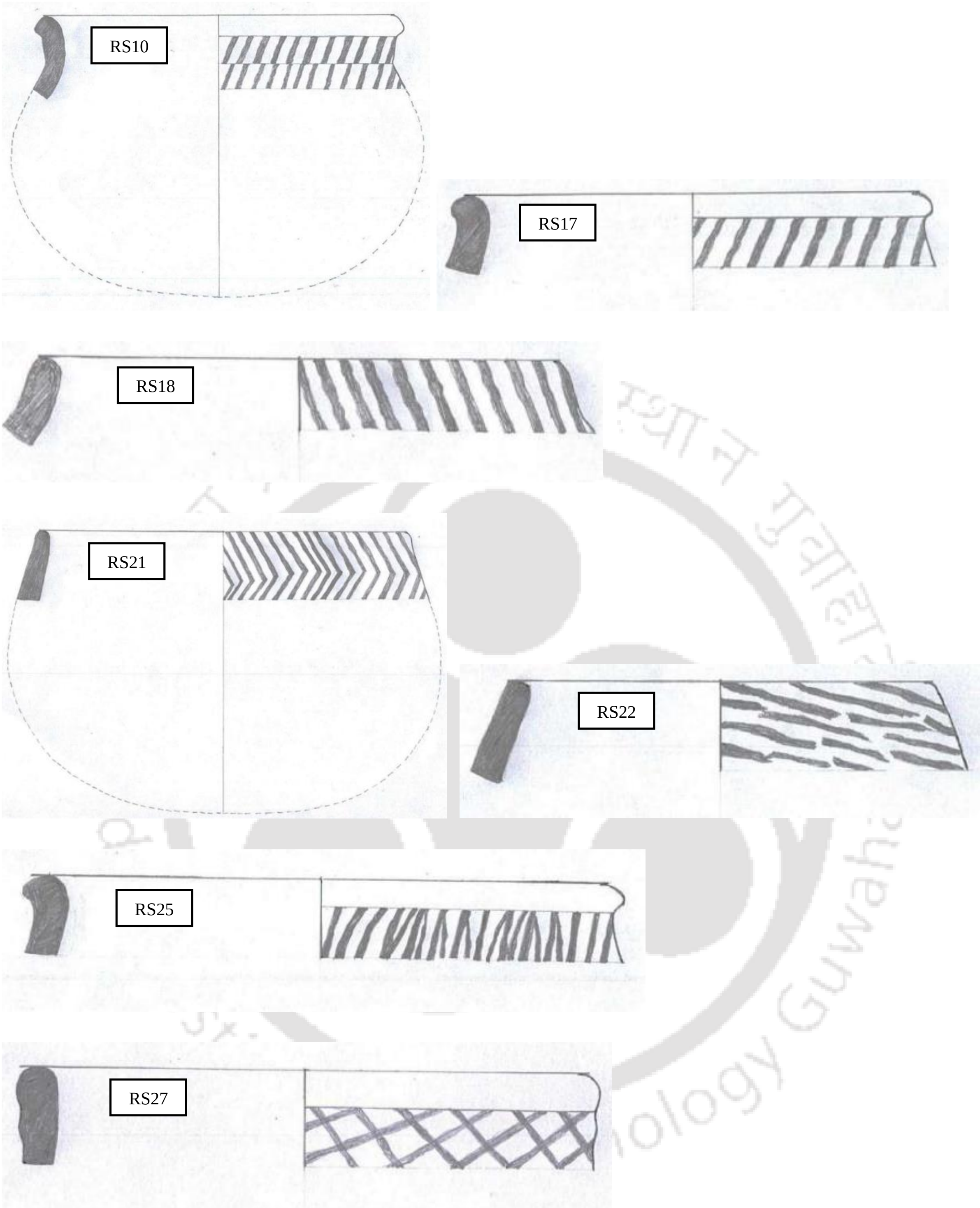
Table 3.11 Description of the reconstructed pottery from layer 3

Sample Name	Layer 3								
	Trench	**Depth**	**Radius**	**Diameter**	**Height**	**Distance**	**Thickness**	**Type of Sherd**	**Colour**
RS5	3	30-40	7 cm	14 cm	2.4 cm	3 cm	R-5.5mm/B-5mm	Plain Ware	Reddish yellow/ HUE 5 YR- 6/8
RS6	5-2	30-40	13.5 cm	27 cm	1.5 cm	3.9 cm	R-6.5mm/B-5.5mm	Unidentifiable (Impressed)	Yellowish Red/ HUE 5 YR- 5/8
RS10	8-1	30-40	11 cm (1:2)	22 cm	2.5 cm	1.7 cm	R-8mm/B-5.5mm	Unidentifiable (Impressed)	Yellowish Red/ HUE 5YR- 5/8
RS17	5-1	30-40	8 cm (1:2)	16 cm	1.3 cm	1.6 cm	R-7mm/B-6mm	Unidentifiable (Impressed)	Dark brown/ HUE 10R- 4/3
RS18	2	30-40	9 cm	18 cm	1.3 cm	1.9 cm	R-4mm/B-4mm	Cord Marked	Yellowish Red/ HUE 5YR- 4/6
RS21	3	30-40	14 cm	28 cm	2.4 cm	3 cm	R-5mm/B-8mm	Carved paddle	Yellowish Red/ HUE 5YR- 4/6
RS22	5+2	30-40	8 cm (1:2)	16 cm	1.7 cm	1.4 cm	R-4mm/B-4mm	Cord Marked	Dark brown/ HUE 7.5YR- 4/4
RS25	5-1	30-40	11.5 cm (1:2)	23 cm	1.3 cm	2.8 cm	R-7mm/B-6mm	Cord Marked	Dusky Red/ HUE 2.5YR- 3/2
RS27	4	30-40	11 cm	22 cm	1.8 cm	1.9 cm	R-7mm/B-5mm	Unidentifiable (Impressed)	Red/ HUE 2.5YR- 4/6

Plate 3.3: The drawings of the reconstructed pottery from layer 3 are shown below:





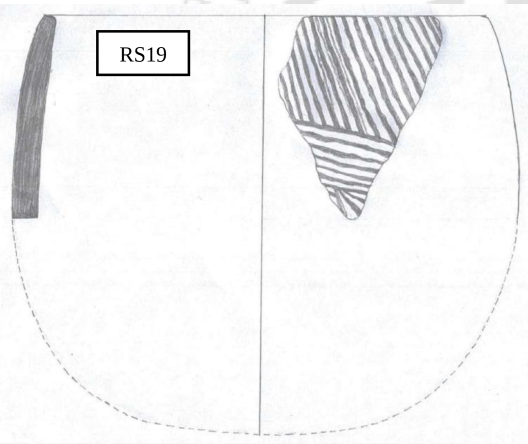


Within the third layer, out of 9 rim sherds, 4 have been successfully reconstructed to reveal their full body form. Similar to previous layers, both pots and bowls predominantly feature a globular body shape. Common rim variations include outward-turned rims, rims without thickening, and open mouths. The colors of the sherds span from red, yellow, to brown, with a predominance of yellowish-red hues in this layer. The majority of the pottery fragments from this layer bear cord markings.

Table 3.12 Description of the reconstructed pottery from layer 4

Sample Name	Layer 3								
	Trench	Depth	Radius	Diameter	Height	Distance	Thickness	Type of Sherd	Colour
RS19	3	40-50	13.5 cm	27 cm	6 cm	4.2 cm	R-5mm/B-8mm	Cord marked	Reddish brown/ HUE 5YR- 4/4

Plate 3.4: The drawing of the reconstructed pottery from layer 4 is shown below:



Only a single pot could be reconstructed from the lowest layer. Upon reconstructing the shape of the potsherd from layer four, it became evident that the vessel is bowl-shaped, featuring a hemispherical body and an open mouth, distinguishing it from others found. Although the rim design differs, lacking a distinct neck, the pot exhibits a reddish-brown hue.

3.3 Similarities and Differences found in the Potsherds

The ceramic assemblages excavated at the Myrkhan Neolithic site are characterized by distinctive morphological features, particularly the impressed designs adorning the outer surfaces of the potsherds. These designs consist of Cord Impressed markings, which served functional purposes, and Carved Paddle Impressed marks, used for decorative purposes. Cord impressed pottery is notably more abundant than carved paddle pottery at the site. Additionally, a small number of sherds with plain faded surfaces were unearthed during excavation. The cord impression technique represents a unique method of decoration within Neolithic cultures, not only in East Asia but also in Southeast Asia. Upon reconstructing the shape of the pottery, the sizes of the vessels can be categorized into three divisions. These are

1. Small (up to 15 cm diameter)
2. Medium (16 – 25 cm diameter)
3. Large (25 cm Diameter <)

Out of all the reconstructed sherds, the smallest pottery found measures 14 cm in diameter from Layer 1, while the largest pottery found measures 28 cm in diameter from Layer 3. Pottery from Layer 1 predominantly falls into small and medium size categories, with a ratio of 1:7, respectively. Similarly, Layer 2 also consists mainly of small and medium-sized pottery, with 2 out of 9 potteries classified as small and the rest categorized as medium. In Layer 3, among 9 potteries, 1 is classified as small, 6 as medium, and 2 as large. Pottery from Layer 4 falls into the large size category. Consequently, the large size category is primarily represented in the lower levels. Notably, two of the large-sized pottery pieces share a similar rim shape, both featuring cord impressed markings and bowl-shaped designs.

There isn't a significant variation in the colors of the potteries across all layers. Red remains the predominant color in each layer. Only one or two potteries in each layer exhibit different hues. For instance, in Layer 1, only sample RS 1 is brown in color, while the rest are red. Similarly, in Layer 2, only sample RS4 is gray, with the others being red. In Layer 3, RS17 and RS22 are brown, and RS5 is reddish-yellow; apart from these three, the rest are red. The lone pottery from Layer 4 is brown in color. Therefore, it is found that similarities are more than dissimilarities in between the layers of the excavated trenches. Another noteworthy characteristic discovered is pottery with elongated necks, exemplified by sample RS24 in Layer 1 and RS23 in Layer 2. RS24 features a carved paddle design, whereas RS23 is plain, lacking any decorative elements on its rim sherd.

3.4 Conclusion

Studying the physical characteristics of pottery is crucial for understanding its significance and establishing the chronological sequence of a site. Variations in these attributes provide insights into cultural evolution and the temporal span of specific cultural practices. Morphological analysis of pottery fragments from Myrkhan was conducted to identify similarities and differences, aiding in the interpretation of developmental stages and temporal sequences of the craft. The pottery fragments are primarily classified into three types based on their characteristics. These are-

1. cord marked pottery
2. carved paddle pottery
3. plain pottery.

While evaluating the occurrence of the three pottery types across all four layers, it was observed that the presence of carved paddle pottery in the lowest layer is significantly lower compared to the upper three layers. The distribution of the percentage of all three types of potsherds is provided in the table below.

Table 3.10: Distribution of the percentage of all the three pottery types

Sl. No.	**Layer**	**Types of Pottery**			**Total %**
		Cord Marked Pottery	**Carved Paddle Pottery**	**Plain Pottery**	
1	Layer 1	58%	32%	10%	100%
2	Layer 2	55%	33%	12%	100%
3	Layer 3	52%	36%	12%	100%
4	Layer 4	82%	8%	10%	100%

In the first three layers, the number of carved paddle potsherds remains relatively consistent, and the ratio of cord-marked to carved paddle potsherds is also consistent across these layers. This represents a notable difference observed during the typological classification of the pottery fragments. Additionally, a charcoal sample retrieved from the lowest layer of Trench-5-1, recovered alongside cultural materials at a depth of 50 centimeters, was subjected to C14 dating by Dr. Marco Mitri, yielding a date of Cal BP 3500 ± 30 BP (Mitri & Neog, 2016). Therefore, the typological variation between the top three layers and the lowest layer, along with the similarity observed among the top three layers, suggests that the lowest layer may be older than the upper three layers. This indicates transitions in the developmental stages of the craft.

In ceramic analysis, the initial step involves categorizing the pottery. Categorization entails sorting the sherds based on their visible attributes. Following categorization, the classification of pots is carried out by grouping them based on differences in attributes within the same category. "Color" serves as the second attribute used for classifying pottery fragments, whereby potsherds are grouped into three categories based on color. These are-

1. Red Ware
2. Brown Ware and
3. Grey Ware

Red ware predominates throughout the entire pottery assemblage and across all layers. When considering all layers combined, the percentages of all three groups are as follows.

Table 3.11: Distribution of percentage of pottery type based on colour

Sl. No.	**Type of Pottery**			**Total %**
1	**Red Ware**	**Brown Ware**	**Grey Ware**	
	63%	35%	2%	100%

All four layers contain these three types of pottery, with no significant differences observed among the layers based on these groups. The thickness of the potsherds ranges from medium to high, with only 1% of the total potsherds classified as having thin walls. The majority of potsherds belong to the medium thickness group. Layer-wise uniformity in thickness is not evident. Reconstructing the shape of pottery fragments using rim sherds reveals two probable shapes: pots and bowls. Both types of pottery are represented in all layers. Based on the analysis above, it can be concluded that the production of carved paddle pottery increases over time. However, aside from this, no major differences are observed in terms of pottery shape and other morphological attributes.

Chapter-4

Scientific Analytical Study of the Pottery

4.1 Use of Scientific Analysis in the Study of Archaeological Remains

A pot is a material object and it itself carries some information about the material culture of the people that made it (Griffiths, 1999). Potteries are made out of clay and transformed into the most long-lasting material through heating process.

For a comprehensive understanding of past cultures, it's vital to comprehend the reasons behind the particular methods used in pottery making. The composition of the paste recipe and adhesive often remains unknown in the study of ancient pottery due to a lack of records. Simple methods aiding researchers in identification typically involve visual observation, noting the colors and shapes of pottery, and correlating these findings with other associated artifacts to reconstruct chronology and stratigraphic sequences. However, relying solely on visual methods may raise questions regarding consistent and accurate differentiation between paste recipes and adhesives. As a result, various scientific methods have been employed in pottery investigation to determine its origin, trace trade links or regional interactions, distinguish between locally made and imported products, and identify regional variations in raw materials, designs, and manufacturing processes.

. Thus methodology that use in the field of archaeology does involve an intrigue planning with a specific programme regulated by a set of rules. Over the last few decades, pottery analysis has become the central to drive archaeological information and to help to understand the way of life of the different cultural groups due to its abundance and variety. The physical characteristics of the potteries like the colour, texture, style and size of the clay particles composing them can reveal the civilization, technology of manufacture and method of firing adopted to bake them and the technical skill evolved by the ancient artisans lived at that time (Velraj G. , Janaki , Mohamed Musthafa, & Palanivel, Estimation of firing temperature of some archaeological pottery shreds excavated recently in Tamilnadu, India, 2009). For approaching critical issues such as social interactions, movements and identities of past people reconstruction of manufacturing process of pottery is important. Spectrographic analysis has been used in the study of pastes, with the aim of differentiating pottery from different sources (Shepard, 1956)

The evidences of this pottery making can be traced in the Northeast region from the Neolithic Era with the involvement of various types of traditional knowledge. Impressed potteries are commonly found in the Neolithic sites belonging to the Northeastern region. Among the impressed pottery the cord marked pottery is one unique type of the Neolithic period, which can also be term as the type fossil of this region.

The material under study consists of 37 samples, among which 35 are potsherds and 2 are soil samples collected from the excavated trenches during its 1st phase excavation. The potsherds selected from different trenches and depths have been characterized by XRD, FTIR, EDX, hardness test, porosity test and petrographic analysis to assess the mineralogical and physiochemical properties of the paste recipes of the sherds.

Table 4.1: Description of the experimented potsherds

Sl. No.	**Sample name**	**Layer Depth (cm.)**	**Trench**	**Colour**	**Pattern of Design**	**Thickness of the Sherds (mm)**	**Length and breadth (mm)**	**Space between lines (mm)**	**Type of pottery**	**Description**
1	**M1/2^{-1}/0-20**	0-20	2-1	Reddish brown/ HUE 5YR-4/4	Criss-Cross	6	L25/B19	3	Cord Marked	Body part, small in size, course ware
2	**M2/4/20-30**	20-30	4	Very dark grayish brown/ HUE 10YR- 3/2	Zig-zag	4	L23.5/B14	1.5	Carved paddle	Body part, medium in size, course ware
3	**M3/3/30-40**	30-40	3	Strong brown/ HUE 7.5YR- 5/8	Vertical/ Horizontal	5	L23/B20	1.5	Cord Marked	Body part, medium in size, course ware
4	**M4/5^{+2}/40-50**	40-50	5+2	Dark reddish brown/ HUE 5YR-¾	Criss-Cross	6	L24/B23.5	1	Cord Marked	Body part, medium in size, course ware
5	**M5/7^{+1}/0-20**	0-20	7+1	Red/ HUE 2.5 YR- 4/8	Vertical/ Horizontal	6	L38/B35	1.5	Cord Marked	Body part, big in size, course ware
6	**M6/7^{+1}/0-20**	0-20	7+1	Red/ HUE 2.5 YR- 4/8	Zig-zag	7	L41/B28	1	Carved paddle	Body part, medium in size, course ware
7	**M7/5^{-1}/40-50**	40-50	5-1	Reddish brown/ HUE 5YR-4/4	Vertical/ Horizontal	8	L60/B43	1	Cord Marked	**Rim sherd**, very big in size, course ware
8	**M8/1/30-40**	30-40	1	Strong brown/ HUE 7.5YR- 5/8	Vertical/ Horizontal	7.5	L37/B29	0.5	Unidentifiable	Body part, big in size, course ware
9	**M9/2/20-30**	20-30	2	Red/ HUE 2.5YR- 4/8	Plain surface	7	L37/B31.5	-	Plain ware	**Rim sherd**, medium in size, course ware

10	**M10/2^{-1}/0-20**	0-20	2-1	Yellowish brown/ HUE 10YR- 5/4	Plain surface	6	L43/B26	-	Plain ware	Body part, medium in size, semi course ware
11	**M11/2^{-1}/0-20**	0-20	2-1	Dark reddish gray/ HUE 5 YR- 4/2	Criss-Cross	9	L38/B27	1	Cord Marked	Body part, medium in size, semi course ware
12	**M12/7^{+1}/20-30**	20-30	7+1	Reddish brown/ HUE 5YR-4/4	Vertical/ Horizontal	4	L32/B24	0.5	Cord Marked	Neck part, outward bending medium in size, course ware
13	**M13/7^{+1}/20-30**	20-30	7+1	Strong brown/ HUE 7.5YR- 4/4	Vertical/ Horizontal	5	L32/B28	1	Cord Marked	Body part, medium in size, course ware
14	**M14/5^{-2}/30-40**	30-40	5-2	Red/ HUE 2.5YR- 4/8	Criss-Cross	6	L32/B24	2.5	Cord Marked	Body part, medium in size, semi course ware
15	**M15/8^{-1}/30-40**	30-40	8-1	Dark brown/ HUE 7.5YR- 4/4	Zig-zag	5	L30/B21	1	Carved paddle	Body part, medium in size, course ware
16	**M16/5^{+2}/20-30**	40-50	5+2	Reddish brown/ HUE 5YR-4/4	Not clear	5.5	L18/B11	-	Unidentifiable	Body part, small in size, course ware
17	**M17/5^{-1}/40-50**	40-50	5-1	Red/ HUE 2.5YR- 4/6	Vertical/ Horizontal	8	L39/B36	1	Cord Marked	Body part, big in size, course ware
18	**M18/5^{-1}/40-50**	40-50	5-1	Dark reddish brown/ HUE 5YR-3/3	Not clear	4	L11/B8	0.5	Unidentifiable	Body part, very small in size, course ware
19	**M19/5^{+2}/40-50**	40-50	5+2	Yellowish red/ HUE 5YR- 4/6	Not clear	6	L10/B9	-	Unidentifiable	Body part, very small in size, course ware
20	**M20/3/20-30**	20-30	3	Red/ HUE 2.5YR- 4/6	Vertical/ Horizontal	4.5	L10/B9	1.5	Carved paddle	Body part, very small in size, course ware
21	**M21/5^{+2}/20-30**	20-30	5+2	Dark yellowish brown/ HUE 10YR- 4/4	Plain surface	7.5	L20/B10	-	Plain ware	Body part, small in size, semi course ware
22	**M22/5^{-1}/20-30**	20-30	5-1	Yellowish red/ HUE 5YR- 4/6	Not clear	6	L23.5/B22	1	Unidentifiable	**Rim sherd**, inward bending, medium in size, course ware
23	**M23/2^{-1}/20-30**	20-30	2-1	Reddish brown/ HUE 5YR-4/4	Criss-Cross	6	L30/B22	0.5	Carved paddle	Body part, medium in size, course ware
24	**M24/2^{-1}/20-30**	20-30	2-1	Reddish yellow/ HUE 7.5YR- 6/6	Criss-Cross	6.5	L37/B25	0.5	Carved paddle	Body part, big in size, course ware

25	**M25/2^{-1}/20-30**	20-30	2-1	Yellowish brown/ HUE 10YR- 5/4	Vertical/ Horizontal	4	L29/B27	1	Carved paddle	Body part, medium in size, course ware
26	**M26/1/2 0-30**	20-30	1	Dark brown/ HUE 10YR- 3/3	Zig-zag	4.5	L31/B20	1	Carved paddle	Body part, medium in size, course ware
27	**M27/1/2 0-30**	20-30	1	Black/ HUE 10YR- 2/1	Vertical/ Horizontal	4	L25/B23	1	Cord marked	Body part, medium in size, course ware
28	**M28/1/2 0-30**	20-30	1	Dark brown/ HUE 7.5YR- 4/4	Vertical/ Horizontal	4.5	L34.5/B27	1	Cord marked	Body part, medium in size, course ware
29	**M29/1/2 0-30**	20-30	1	Black/ HUE 10YR- 2/1	Criss-Cross	4	L29/B27	1	Carved paddle	Body part, medium in size, course ware
30	**M30/4/2 0-30**	20-30	4	Reddish yellow/ HUE 5YR-6/8	Vertical/ Horizontal	8	L35/B24	1	Cord marked	Body part, medium in size, semi course ware
31	**M31/4/2 0-30**	20-30	4	Strong brown/ HUE 7.5YR- 5/8	Criss-Cross	7	L35/B33	0.5	Unidentifiable	Body part, big in size, course ware
32	**M32/2/3 0**	20-30	2	Red/ HUE 2.5YR- 4/8	Zig-zag	5	L30/B25	1	Carved paddle	Body part, medium in size, course ware
33	**M33/5^{-1}/30-40**	30-40	5-1	Reddish brown/ HUE 5YR-4/4	Vertical/ Horizontal	5.5	L47/B31	1.5	Cord Marked	Body part, big in size, course ware
34	**M34/3/3 0-40**	30-40	3	Strong brown/ HUE 7.5YR- 5/6	Vertical/ Horizontal	6.5	L35.5/B32	1	Cord Marked	Body part, big in size, course ware
35	**M35/7^{+1}/ 30-40**	30-40	7+1	Strong brown/ HUE 7.5YR- 5/6	Vertical/ Horizontal	5	L49/B40	1.5	Cord Marked	Body part, curves inward, big in size, course ware
36	**M-S01/3/20**	3	20 cm							Soil sample
37	**M-S02/4/60**	4	60 cm							Soil sample

Out of the examined pottery fragments, 16 exhibit cord marking, 10 display carved paddle patterns, 3 are plain ware, and 6 remain unidentified.

Table 4.2: Photographs of representative experimented samples

Sl. No.	Sample Code	Outer Surface	Inner Surface	Description: Physical Attributes
1	M5/7^{+1}/0-20			Impression- Parallel lines in outer surface, plain in inner surface. Colour- Red/ HUE-2.5YR-5/8 Thickness- 0.5 c.m. (without cord impression- 0.7 c.m) Cord breath- 0.2 c.m Core- Fine, Body part (Non- diagnostic)
2	M6/7^{+1}/0-20			Impression- Zig Zag lines in the outer surface, Plain in the inner surface Colour- Reddish Brown/HUE-2.5YR-4/4 Thickness- 0.6 c.m. (without cord impression- 0.7 c.m) Cord breath- varies between 0.1 c.m - 0.2 c.m Core- Fine ware Body part (Non-Diagnostic)
3	M10/2^{-1}/0-20			Impression- Both the outer and inner surface is plain; no impression is found. Colour- Weak Red/ HUE-2.5YR-5/2 Thickness- 0.5 c.m. Core- Very fine ware Body part (Non-Diagnostic)
4	M11/2^{-1}/0-20			Impression- Criss-cross lines in half part of the outer surface, one third of the dorsal surface is plain, Plain in the inner surface Colour- Light Reddish Brown/ HUE-2.5YR-6/4 Thickness- 0.8 c.m. (without cord impression- 0.9 c.m) Cord breath- 0.1 c.m Core- Fine ware Body part (Non-Diagnostic)
5	M14/5^{-2}/30-40			Impression-Deep criss-cross lines in the outer surface and comparatively big in size, Plain in the inner surface Colour- light Red/ HUE-2.5YR-6/6/ Thickness- 0.5 cm. (without cord impression- 0.8 cm) Cord breath- 0.3 cm Core- Medium fine ware Body part (Non-Diagnostic)
5	M33/3/30-40			Impression- parallel lines in the outer surface, Plain in the inner surface Colour- Yellowish Red, Black in the inner surface/HUE-5YR-5/6

				Thickness- 0.4 cm (without cord impression- 0.5 cm) Cord breath- 0.2 cm Core- Fine ware Body part (Non-Diagnostic)
7	**M34/3/30-40**			Impression- Parallel lines (difficult to identify the exact pattern) in the outer surface and comparatively small in size, Plain in the inner surface Colour-Reddish Yellow/ HUE-7.5YR-6/6 Thickness- 0.6 cm. (without cord impression- 0.7 cm) Cord breath- 0.1 cm Core- Medium coarse Body part (Non-Diagnostic)
8	**M35/7^{+1}/30-40**			Impression- Parallel lines in the outer surface and comparatively big in size, Plain in the inner surface Colour- Very Pale Brown// HUE-10YR-8/3 Thickness- 0.4 cm (without cord impression- 0.5 cm) Cord breath- varies between 0.2 cm - 0.3 cm Core- Coarse ware Body part (Non-Diagnostic)

4.1.1 X-Ray Diffraction Analysis (XRD)

X-ray Diffraction (XRD) analysis is a valuable technique in the study of Neolithic pottery, offering insights into the mineral composition and structural characteristics of ceramic materials. The identification of minerals present in pottery samples helps archaeologists understand the geological sources of raw materials used in pottery production. It can provide information about the firing temperature of pottery. Changes in the crystallographic structure of minerals due to heating can be detected, allowing estimation of the maximum temperature reached during firing. XRD is used to characterize clay minerals present in pottery, such as kaolinite, illite, and montmorillonite. This helps in identifying different types of clay used by ancient potters and understanding local ceramic traditions. Comparing the mineralogical composition of pottery samples with geological sources in the surrounding area can provide insights into trade networks, exchange systems, and the movement of raw materials during the Neolithic period.

I) Experimental and Sample Preparation

Powder diffraction is one of the few techniques which is truly phase sensitive and is a well-established tool for quantitative phase analysis (Kockelmann, Kirfel, & Hähnel, 2001). The mineral diffraction patterns are manifested by characteristic peaks position, intensity, shape and breath. Peaks in the high angle parts of the patterns are indicative of the non-clay constituents of the specimens whereas low angle side related to the clay minerals.

For the analysis, a small fragment of specimen of about 0.2 g of the ceramic material (pot shred) was ground manually by using an agate mortar and pestle. Twenty to Thirty milligrams of the powdered sample were uniformly dispersed on a cover glass which served as a sample holder in the X-ray diffractometer. Subsequently, the X-ray diffraction patterns were obtained at ambient temperature with a TTRA III Riguku X-Ray Diffractometer using Cu kα radiation at a wavelength of 1.5406 Å. Diffraction patterns were recorded over 2θ range between 5 and 75 °q with a scanning step of 0.22° 2q and at a scanning speed of 4° 15/minutes per samples. The same instrumental conditions were used in all cases.

A total number of thirty-five pottery fragments and two soil sample collected from the excavated trenches are used for XRD analysis. The potsherds were selected from different trenches and depths. The results of XRD data and the identified minerals found in all the experimented samples are given below in details in table 4.3.

Table 4.3: Minerals identified from XRD graphs of pottery and soil samples of Myrkhan

Serial No.	Mineral Groups	d = λ/2sinθ (in Å)	Mineral Identification
M1/2^{-1}/0-20 (Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	Kaolins	6.4663	Kaolinite
2	Kaolins	4.4756	Kaolinite
3	Feldspars	4.2383	Microcline
4	Oxides, Hydroxides	3.3295	Quartz
5	Oxides, Hydroxides	3.2156	Quartz
6	Feldspars	2.9935	Anorthite
7	Kaolins	2.6960	Kaolinite
8	Kaolins	2.5175	Kaolinite
9	Oxides, Hydroxides	2.1538	Quartz
10	Micas	2.0412	Biotite
11	Oxides, Hydroxides	1.8175	Quartz
12	Kaolins	1.7496	Kaolinite
13	Kaolins	1.6687	Kaolinite
14	Oxides, Hydroxides	1.5370	Quartz

M2/4/20-30 (Trench: 4, Depth: 20c.m.-30c.m.)			
1	Kaolins	4.4721	Kaolinite
2	Oxides, Hydroxides	4.2508	Quartz
3	Oxides, Hydroxides	3.3429	Quartz
4	Oxides, Hydroxides	3.1998	Quartz
5	Oxides, Hydroxides	2.4553	Goethite
6	Oxides, Hydroxides	2.2771	Quartz
7	Oxides, Hydroxides	2.1251	Quartz
8	Oxides, Hydroxides	1.9793	Quartz
9	Oxides, Hydroxides	1.8169	Quartz
10	Kaolins	1.6717	Kaolinite
11	Oxides, Hydroxides	1.5421	Quartz
12	Oxides, Hydroxides	1.3752	Quartz
M3/3/30-40 (Trench: 3, Depth: 30c.m.-40c.m.)			
1	Amphiboles	8.4392	Hornblende
2	Feldspars	4.2352	Microcline
3	Oxides, Hydroxides	3.7756	Orthoclase
4	Oxides, Hydroxides	3.3429	Quartz
5	Oxides, Hydroxides	2.4412	Goethite
6	Oxides, Hydroxides	2.2780	Quartz
7	Oxides, Hydroxides	2.1274	Quartz
8	Oxides, Hydroxides	1.9761	Quartz
9	Oxides, Hydroxides	1.8164	Quartz
10	Oxides, Hydroxides	1.5450	Quartz
11	Oxides, Hydroxides	1.3702	Quartz
M4/5^{+2}/0-50 (Trench: 5+2, Depth: 0c.m.-50c.m.)			
1	Kaolins	4.4721	Kaolinite
2	Feldspars	4.2290	Microcline
3	Oxides, Hydroxides	3.3564	Quartz
4	Oxides, Hydroxides	3.2388	Rutile
5	Feldspars	2.9965	Anorthite
6	Kaolins	2.6948	Kaolinite
7	Kaolins	2.5154	Kaolinite
8	Oxides, Hydroxides	2.4502	Goethite
9	Oxides, Hydroxides	2.2745	Quartz
10	Oxides, Hydroxides	2.1009	Quartz
11	Oxides, Hydroxides	1.8217	Quartz
12	Kaolins	1.7472	Kaolinite
13	Kaolins	1.6890	Kaolinite
14	Oxides, Hydroxides	1.5410	Quartz
15	Oxides, Hydroxides	1.3691	Quartz
M5/7^{+1}/0-20 (Trench: 7+1, Depth: 0c.m.-20c.m.)			
1	Amphiboles	8.4207	Hornblende
2	Kaolin	4.4987	Kaolinite
3	Oxides, Hydroxides	4.2588	Quartz
4	Serpentines	3.6807	Chrysotile
5	Oxides, Hydroxides	3.3289	Quartz
6	Kaolin	3.2693	Kaolinite

7	Oxides, Hydroxides	3.1304	Goethite
8	Feldspars	2.9411	Anorthite
9	Kaolin	2.6946	Kaolinite
10	Oxides, Hydroxides	2.5891	Hematite
11	Kaolin	2.5049	Kaolinite
12	Oxides, Hydroxides	2.4477	Goethite
13	Oxides, Hydroxides	2.2729	Quartz
14	Oxides, Hydroxides	2.1242	Quartz
15	Micas	2.0180	Biotite
16	Oxides, Hydroxides	1.8125	Quartz
17	Oxides, Hydroxides	1.7506	Hematite
18	Kaolin	1.6914	Kaolinite
19	Oxides, Hydroxides	1.5401	Quartz
20	Oxides, Hydroxides	1.4488	Hematite
21	Oxides, Hydroxides	1.3737	Quartz
22	Oxides, Hydroxides	1.2849	Hematite
M6/7^{+1}/0-20 (Trench: 7+1, Depth: 0c.m.-20c.m.)			
1	Amphiboles	8.4335	Hornblende
2	Feldspar	7.2412	Orthoclase
3	Phosphate	4.8046	Millisite
4	Serpentines	4.4628	Halloysite
5	Oxides, Hydroxides	4.2556	Quartz
6	Kaolin	3.5755	Kaolinite
7	Oxides, Hydroxides	3.3466	Quartz
8	Oxides, Hydroxides	3.2338	Rutile
9	Zeolite	3.0126	Amicite
10	Feldspars	2.9625	Anorthite
11	Oxides, Hydroxides	2.7594	Hematite
12	Oxides, Hydroxides	2.5626	Goethite
13	Oxides, Hydroxides	2.5268	Ilmenite
14	Oxides, Hydroxides	2.4717	Goethite
15	Oxides, Hydroxides	2.2800	Quartz
16	Micas	2.2020	Biotite
17	Oxides, Hydroxides	2.1296	Quartz
18	Oxides, Hydroxides	2.0352	Biotite
19	Oxides, Hydroxides	1.9739	Quartz
20	Oxides, Hydroxides	1.8936	Quartz
21	Kaolin	1.6723	Kaolinite
22	Kaolin	1.6171	Kaolinite
23	Oxides, Hydroxides	1.5412	Quartz
24	Oxides, Hydroxides	1.3737	Quartz
M7/5^{-1}/40-50 (Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	Kaolin	4.4878	Kaolinite
2	Oxides, Hydroxides	4.2816	Quartz
3	Kaolin	3.3645	Kaolinite
4	Oxides, Hydroxides	3.2010	Rutile
5	Feldspars	2.9275	Anorthite
6	Oxides, Hydroxides	2.5729	Ilmenite

7	Oxides, Hydroxides	2.4539	Goethite
8	Oxides, Hydroxides	2.2818	Quartz
9	Oxides, Hydroxides	2.1273	Quartz
10	Oxides, Hydroxides	1.9837	Quartz
11	Kaolin	1.6700	Kaolinite
12	Oxides,Hydroxides	1.5390	Quartz
13	Oxides,Hydroxides	1.3743	Quartz
14	Oxides,Hydroxides	1.2885	Hematite
M8/1/30-40 (Trench: 1, Depth: 30c.m.-40c.m.)			
1	Kaolin	4.4951	Kaolinite
2	Oxides, Hydroxides	4.2556	Quartz
3	Oxides, Hydroxides	3.3387	Quartz
4	Oxides, Hydroxides	2.4487	Goethite
5	Oxides, Hydroxides	2.2764	Quartz
6	Oxides, Hydroxides	2.1280	Quartz
7	Oxides, Hydroxides	1.9772	Quartz
8	Oxides, Hydroxides	1.8190	Quartz
9	Kaolin	1.6745	Kaolinite
10	Oxides, Hydroxides	1.5431	Quartz
11	Oxides, Hydroxides	1.4546	Hematite
12	Oxides, Hydroxides	1.3748	Quartz
13	Oxides, Hydroxides	1.2878	Hematite
M9/2/20-30 (Trench: 2, Depth: 20c.m.-30c.m.)			
1	Amphibole	8.4079	Hornblende
2	Oxides, Hydroxides	4.2556	Quartz
3	Micas	3.3368	Biotite
4	Oxides, Hydroxides	3.1373	Rutile
5	Feldspars	2.9873	Anorthite
6	Feldspars	2.8331	Anorthite
7	Oxides, Hydroxides	2.6946	Hematite
8	Kaolin	2.5695	Kaolinite
9	Oxides, Hydroxides	2.4560	Goethite
10	Oxides, Hydroxides	2.2809	Quartz
11	Oxides, Hydroxides	1.8190	Quartz
12	Kaolin	1.7511	Kaolinite
13	Kaolin	1.6709	Kaolinite
14	Oxides, Hydroxides	1.5476	Quartz
15	Oxides, Hydroxides	1.4232	Quartz
16	Oxides, Hydroxides	1.2818	Hematite
M10/2^{-1}/0-20 (Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	Oxides, Hydroxides	4.2653	Quartz
2	Feldspars	3.8129	Orthoclase
3	Oxides, Hydroxides	3.3309	Quartz
4	Oxides, Hydroxides	2.4550	Goethite
5	Oxides, Hydroxides	2.2747	Quartz
6	Oxides, Hydroxides	2.1242	Quartz
7	Oxides, Hydroxides	1.9791	Quartz
8	Oxides, Hydroxides	1.8201	Quartz

9	Kaolin	1.6727	Kaolinite
10	Oxides, Hydroxides	1.5412	Quartz
11	Oxides, Hydroxides	1.3743	Quartz
M11/2^{-1}/0-20 (Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	Kaolin	7.2223	Kaolinite
2	Feldspars	4.2915	Microcline
3	Oxides, Hydroxides	3.3666	Quartz
4	Feldspars	3.2599	Microcline
5	Oxides, Hydroxides	2.5604	Ilmenite
6	Oxides, Hydroxides	2.4560	Goethite
7	Feldspars	2.2934	Anorthite
8	Oxides, Hydroxides	1.8228	Quartz
9	Oxides, Hydroxides	1.5461	Quartz
10	Oxides, Hydroxides	1.3745	Quartz
11	Oxides, Hydroxides	1.2569	Hematite
12	Oxides, Hydroxides	1.2298	Quartz
M12/7^{+1}/20-30 (Trench: 7+1, Depth: 20c.m.-30c.m.)			
1	Phosphates	4.2981	Variscite
2	Oxides, Hydroxides	3.4914	Quartz
3	Oxides, Hydroxides	3.3526	Quartz
4	Oxides, Hydroxides	3.2487	Rutile
5	Oxides, Hydroxides	2.4591	Goethite
6	Oxides, Hydroxides	1.8201	Quartz
7	Oxides, Hydroxides	1.5416	Quartz
8	Oxides, Hydroxides	1.3762	Quartz
9	Oxides, Hydroxides	1.2549	Hematite
10	Oxides, Hydroxides	1.2291	Hematite
M13/7^{+1}/20-30 (Trench: 7+1, Depth: 20c.m.-30c.m.)			
1	Phosphates	4.2948	Variscite
2	Kaolin	3.3506	Kaolinite
3	Oxides, Hydroxides	2.4623	Goethite
4	Oxides, Hydroxides	2.2898	Quartz
5	Oxides, Hydroxides	2.1280	Quartz
6	Oxides, Hydroxides	1.9791	Quartz
7	Oxides, Hydroxides	1.8190	Quartz
8	Kaolin	1.6709	Kaolinite
9	Oxides, Hydroxides	1.5442	Quartz
10	Oxides, Hydroxides	1.3840	Quartz
11	Oxides, Hydroxides	1.2553	Hematite
M14/5^{-2}/30-40 (Trench: 5-2, Depth: 30c.m.-40c.m.)			
1	Oxides, Hydroxides	4.2884	Quartz
2	Oxides, Hydroxides	3.7881	Hematite
3	Oxides, Hydroxides	3.3530	Quartz
4	Oxides, Hydroxides	3.1635	Quartz
5	Oxides, Hydroxides	2.1319	Quartz
6	Kaolins	1.8221	Kaolinite
7	Oxides, Hydroxides	1.5452	Quartz
8	Oxides, Hydroxides	1.3761	Quartz

M15/8^{-1}/30-40 (Trench: 8-1, Depth: 30c.m.-40c.m.)			
1	Oxides, Hydroxides	4.2732	Quartz
2	Oxides, Hydroxides	3.7138	Hematite
3	Oxides, Hydroxides	3.3347	Quartz
4	Oxides, Hydroxides	3.2476	Rutile
5	Kaolins	2.6251	Kaolinite
6	Oxides, Hydroxides	2.5686	Hematite
7	Oxides, Hydroxides	2.4629	Goethite
8	Oxides, Hydroxides	2.2876	Quartz
9	Oxides, Hydroxides	2.1255	Quartz
10	Oxides, Hydroxides	1.9801	Quartz
11	Oxides, Hydroxides	1.8190	Quartz
12	Kaolins	1.6718	Kaolinite
13	Oxides, Hydroxides	1.5752	Quartz
14	Oxides, Hydroxides	1.5428	Quartz
15	Oxides, Hydroxides	1.4542	Hematite
16	Oxides, Hydroxides	1.3803	Quartz
M16/5^{+2}/20-30(Trench: 5+1, Depth: 20c.m.-50c.m.)			
1	Oxides, Hydroxides	4.2611	Quartz
2	Oxides, Hydroxides	3.3456	Quartz
3	Oxides, Hydroxides	3.2407	Rutile
4	Oxides, Hydroxides	2.4639	Goethite
5	Oxides, Hydroxides	2.2901	Quartz
6	Oxides, Hydroxides	2.2373	Quartz
7	Oxides, Hydroxides	2.1297	Quartz
8	Oxides, Hydroxides	1.9758	Quartz
9	Oxides, Hydroxides	1.8165	Quartz
10	Kaolins	1.7466	Kaolinite
11	Kaolins	1.6722	Kaolinite
12	Oxides, Hydroxides	1.5424	Quartz
13	Oxides, Hydroxides	1.3750	Quartz

M17/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	Kaolins	4.4763	Kaolinite
2	Oxides, Hydroxides	4.2549	Quartz
3	Oxides, Hydroxides	3.3363	Quartz
4	Oxides, Hydroxides	2.4506	Goethite
5	Oxides, Hydroxides	2.2762	Quartz
6	Oxides, Hydroxides	2.2202	Quartz
7	Oxides, Hydroxides	2.1263	Quartz
8	Oxides, Hydroxides	1.8156	Quartz
9	Oxides, Hydroxides	1.5408	Quartz
10	Oxides, Hydroxides	1.3699	Quartz
M18/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	Oxides, Hydroxides	4.2413	Quartz
2	Oxides, Hydroxides	3.3338	Quartz
3	Oxides, Hydroxides	3.2279	Rutile
4	Feldspars	2.9695	Anorthite

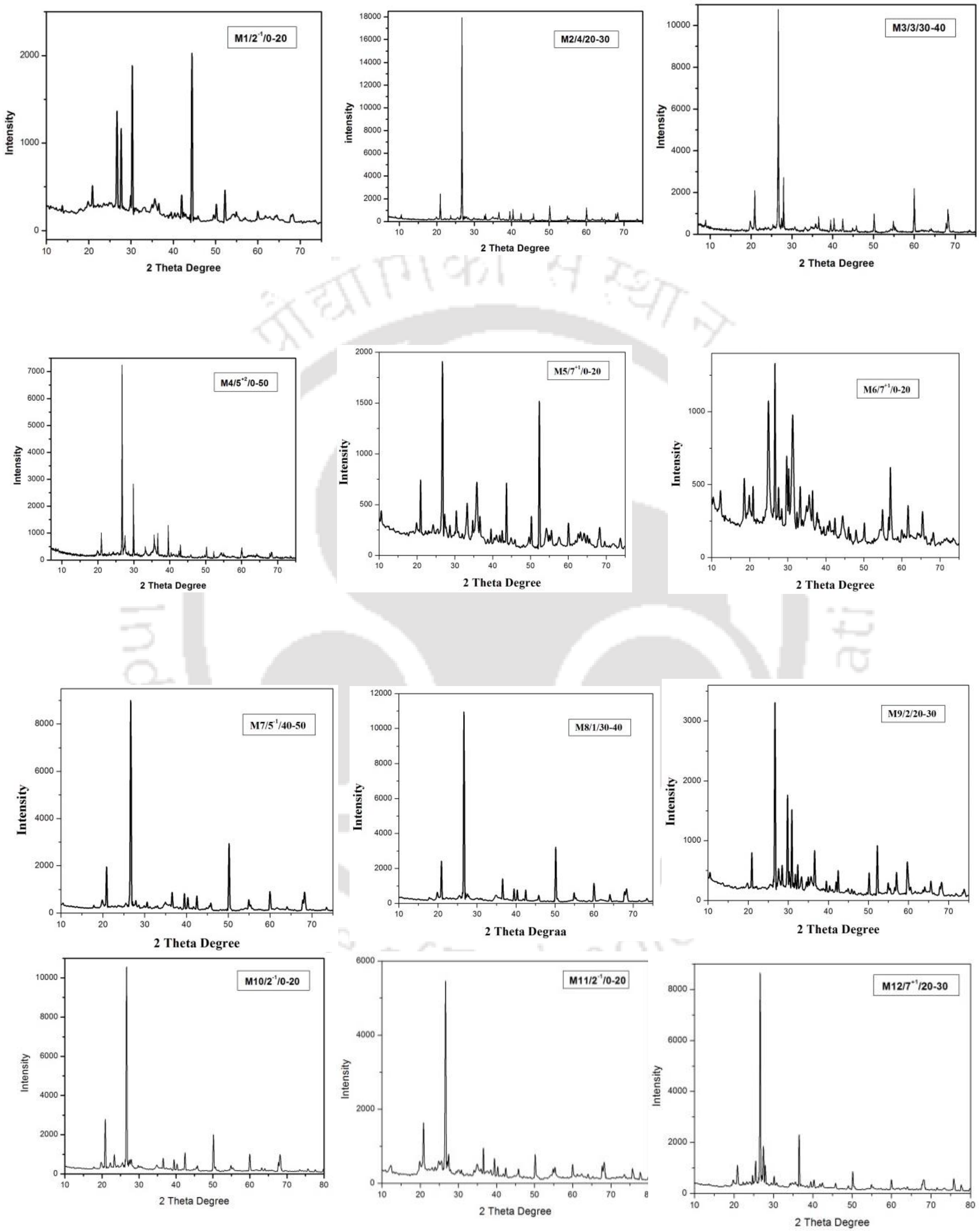
5	Kaolins	2.5507	Kaolinite
6	Oxides, Hydroxides	2.4456	Goethite
7	Oxides, Hydroxides	2.2728	Quartz
8	Oxides, Hydroxides	2.1249	Quartz
9	Oxides, Hydroxides	1.8116	Quartz
10	Kaolins	1.6677	Kaolinite
11	Oxides, Hydroxides	1.5370	Quartz
12	Oxides, Hydroxides	1.3820	Quartz
M19/5^{+2}/40-50(Trench: 5+2, Depth: 40c.m.-50c.m.)			
1	Oxides, Hydroxides	4.2482	Quartz
2	Oxides, Hydroxides	3.3444	Quartz
3	Oxides, Hydroxides	2.4623	Goethite
4	Oxides, Hydroxides	2.2766	Quartz
5	Oxides, Hydroxides	2.1208	Quartz
6	Oxides, Hydroxides	1.8139	Quartz
7	Oxides, Hydroxides	1.5398	Quartz
8	Oxides, Hydroxides	1.3740	Quartz
M20/3/20-30(Trench: 3, Depth: 20c.m.-30c.m.)			
1	Feldspars	4.2310	Microcline
2	Oxides, Hydroxides	3.3338	Quartz
3	Oxides, Hydroxides	3.2103	Rutile
4	Feldspars	2.9662	Anorthite
5	Kaolins	2.6885	Kaolinite
6	Oxides, Hydroxides	2.4401	Goethite
7	Oxides, Hydroxides	2.1422	Quartz
8	Oxides, Hydroxides	1.8110	Quartz
9	Oxides, Hydroxides	1.7461	Hematite
10	Kaolins	1.6131	Kaolinite
11	Oxides, Hydroxides	1.5418	Quartz
12	Oxides, Hydroxides	1.3676	Quartz
M21/5^{+2}/20-30(Trench: 5+2, Depth: 20c.m.-30c.m.)			
1	Feldspars	4.2276	Microcline
2	Oxides, Hydroxides	3.3486	Quartz
3	Oxides, Hydroxides	3.1794	Rutile
4	Oxides, Hydroxides	1.8139	Quartz
5	Oxides, Hydroxides	1.3697	Quartz
M22/5^{-1}/20-30(Trench: 5-1, Depth: 20c.m.-30c.m.)			
1	Feldspars	4.2448	Microcline
2	Micas	3.3191	Biotite
3	Oxides, Hydroxides	3.1987	Quartz
4	Oxides, Hydroxides	2.4434	Goethite
5	Oxides, Hydroxides	2.1192	Quartz
6	Oxides, Hydroxides	1.8087	Quartz
7	Kaolins	1.6682	Kaolinite
8	Oxides, Hydroxides	1.5346	Quartz
M23/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	Feldspars	4.2482	Microcline
2	Oxides, Hydroxides	3.3444	Quartz

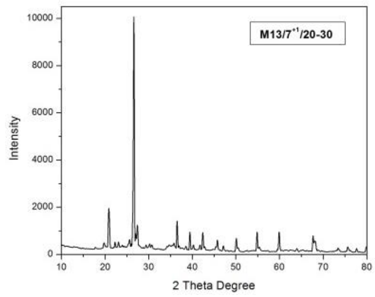
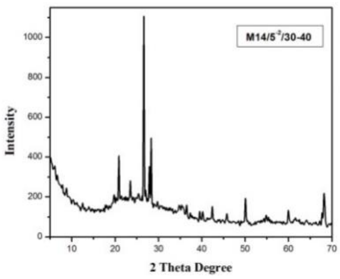
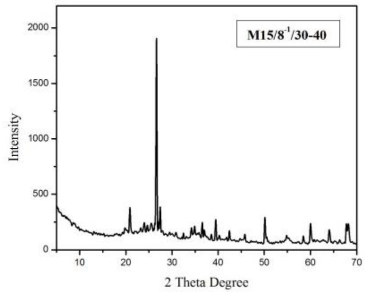
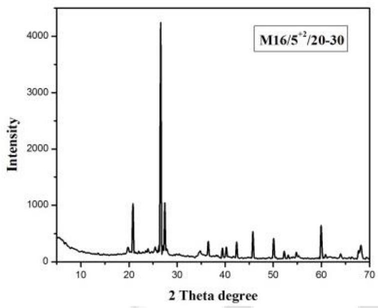
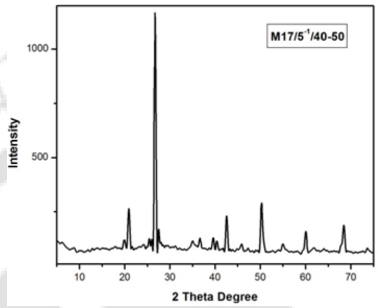
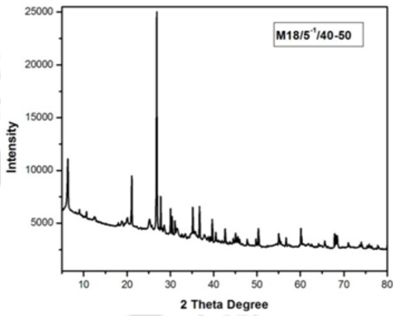
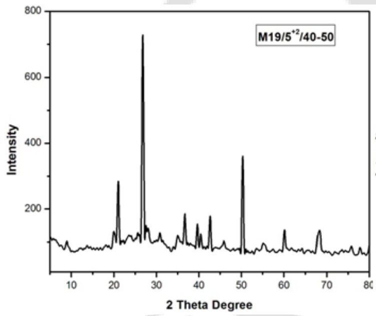
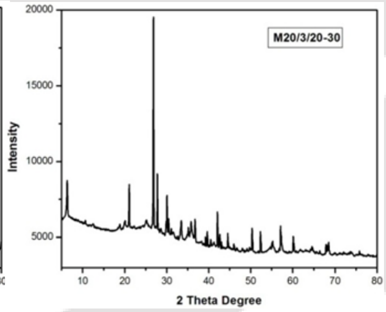
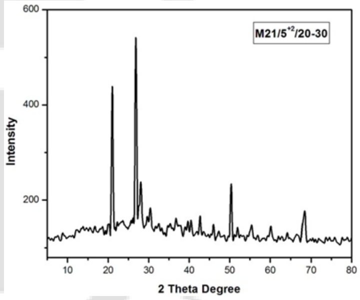
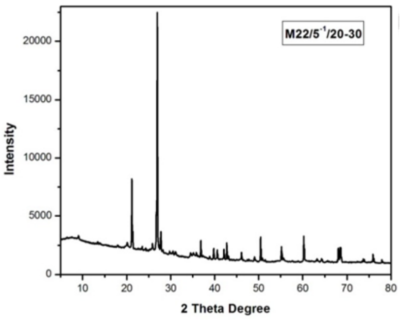
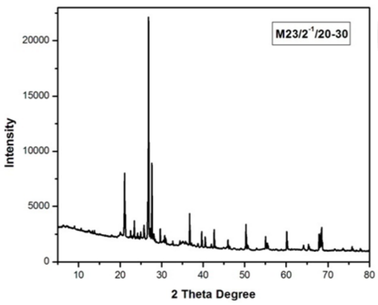
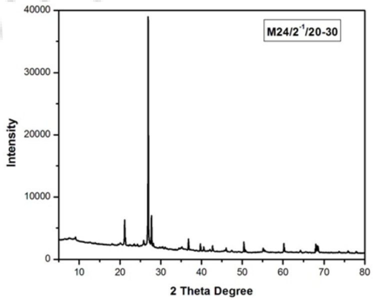
3	Oxides, Hydroxides	3.2319	Rutile
4	Oxides, Hydroxides	2.4533	Goethite
5	Oxides, Hydroxides	2.2747	Quartz
6	Oxides, Hydroxides	2.1224	Quartz
7	Oxides, Hydroxides	1.8145	Quartz
8	Oxides, Hydroxides	1.5398	Quartz
9	Oxides, Hydroxides	1.3713	Quartz
M24/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	Micas	3.3191	Biotite
2	Feldspars	3.2142	Anorthite
3	Oxides, Hydroxides	2.4556	Goethite
4	Oxides, Hydroxides	1.8156	Quartz
M25/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	Feldspars	4.2276	Microcline
2	Oxides, Hydroxides	3.3571	Quartz
3	Feldspars	3.2142	Anorthite
4	Oxides, Hydroxides	2.4423	Goethite
5	Oxides, Hydroxides	1.8127	Quartz
6	Oxides, Hydroxides	1.5362	Quartz
M26/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	Oxides, Hydroxides	4.2448	Quartz
2	Oxides, Hydroxides	3.3380	Quartz
3	Plagioclase Feldspar	3.2378	Albite
4	Feldspars	2.8874	Anorthite
5	Kaolins	2.6126	Kaolinite
6	Oxides, Hydroxides	2.4578	Goethite
7	Oxides, Hydroxides	2.2709	Quartz
8	Oxides, Hydroxides	2.2347	Quartz
9	Oxides, Hydroxides	2.1331	Quartz
10	Oxides, Hydroxides	1.9750	Quartz
11	Oxides, Hydroxides	1.8174	Quartz
12	Kaolins	1.6663	Kaolinite
13	Kaolins	1.6181	Kaolinite
14	Oxides, Hydroxides	1.5410	Quartz
15	Oxides, Hydroxides	1.3810	Quartz
M27/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	Oxides, Hydroxides	4.2517	Quartz
2	Oxides, Hydroxides	3.3678	Quartz
3	Oxides, Hydroxides	3.1833	Rutile
4	Oxides, Hydroxides	2.2823	Quartz
5	Oxides, Hydroxides	1.8168	Quartz
6	Kaolins	1.6720	Kaolinite
7	Oxides, Hydroxides	1.4266	Quartz
M28/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	Oxides, Hydroxides	4.2413	Quartz
2	Oxides, Hydroxides	3.3550	Quartz
3	Oxides, Hydroxides	3.2201	Rutile
4	Oxides, Hydroxides	2.5280	Ilmenite

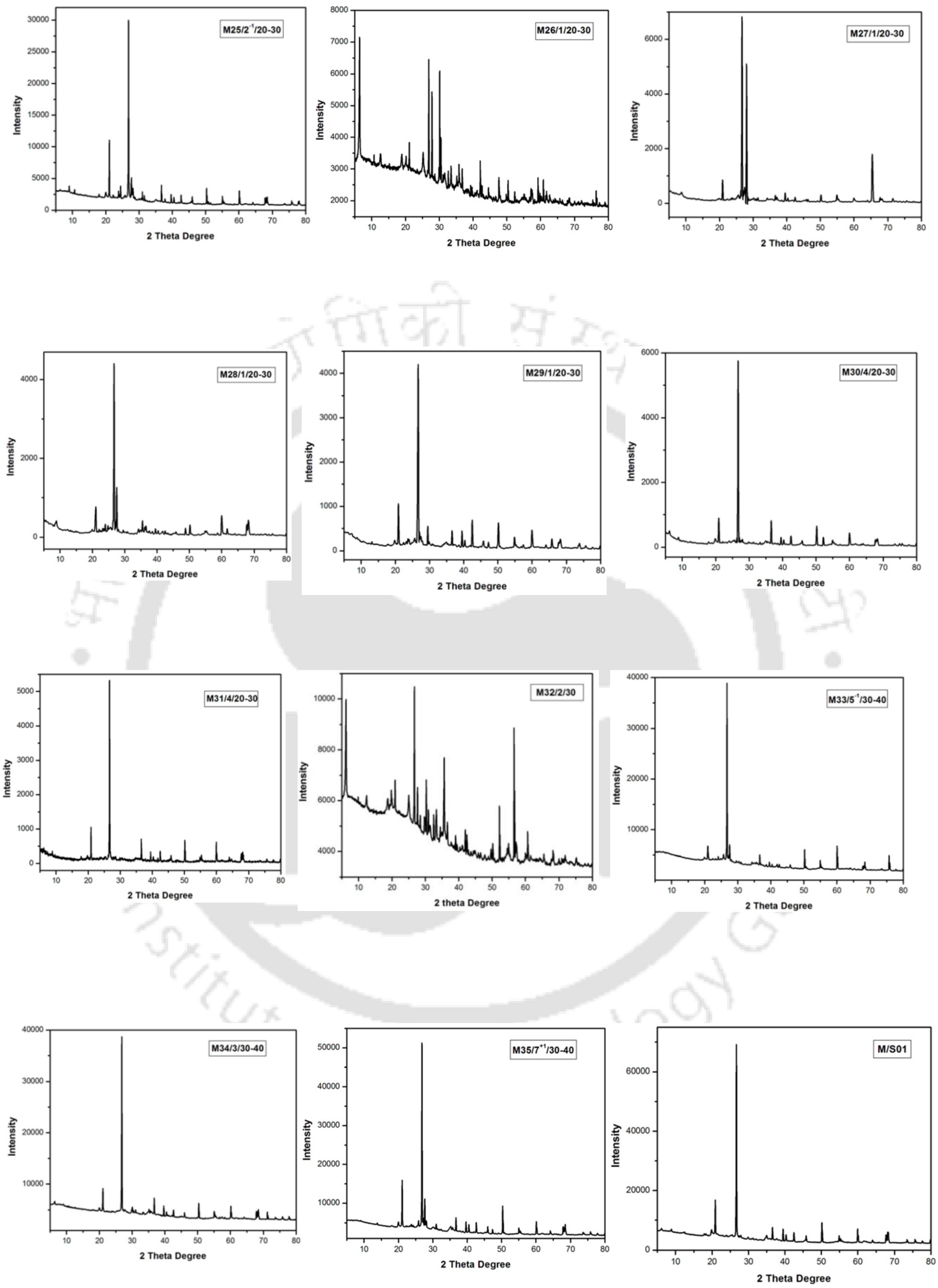
5	Oxides, Hydroxides	1.8221	Quartz
6	Oxides, Hydroxides	1.5394	Quartz
7	Oxides, Hydroxides	1.3758	Quartz
M29/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	Phosphates	4.2866	Variscite
2	Oxides, Hydroxides	3.3657	Quartz
3	Calcite Group	3.0461	Calcite
4	Oxides, Hydroxides	2.4713	Goethite
5	Oxides, Hydroxides	2.2823	Quartz
6	Oxides, Hydroxides	2.1323	Quartz
7	Oxides, Hydroxides	1.9834	Quartz
8	Oxides, Hydroxides	1.8168	Quartz
9	Kaolins	1.6749	Kaolinite
10	Oxides, Hydroxides	1.5426	Quartz
11	Oxides, Hydroxides	1.4176	Quartz
12	Oxides, Hydroxides	1.3764	Quartz
M30/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)			
1	Oxides, Hydroxides	4.2586	Quartz
2	Oxides, Hydroxides	3.3593	Quartz
3	Kaolins	2.4611	Kaolinite
4	Oxides, Hydroxides	2.2823	Quartz
5	Oxides, Hydroxides	2.1192	Quartz
6	Oxides, Hydroxides	1.8221	Quartz
7	Kaolins	1.7514	Kaolinite
8	Oxides, Hydroxides	1.5390	Quartz
M31/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)			
1	Phosphates	4.2971	Variscite
2	Oxides, Hydroxides	3.3571	Quartz
3	Oxides, Hydroxides	2.4668	Goethite
4	Oxides, Hydroxides	2.2804	Quartz
5	Oxides, Hydroxides	2.1290	Quartz
6	Oxides, Hydroxides	1.8203	Quartz
7	Oxides, Hydroxides	1.5430	Quartz
8	Oxides, Hydroxides	1.3761	Quartz
M32/2/30 (Trench: 2, Depth: 20c.m.-50c.m.)			
1	Kaolins	4.4778	Kaolinite
2	Oxides, Hydroxides	4.2413	Quartz
3	Kaolins	3.5661	Kaolinite
4	Oxides, Hydroxides	3.3212	Quartz
5	Oxides, Hydroxides	3.2220	Rutile
6	Feldspars	2.9596	Anorthite
7	Oxides, Hydroxides	2.6979	Hematite
8	Oxides, Hydroxides	2.5173	Ilmenite
9	Oxides, Hydroxides	2.1531	Quartz
10	Oxides, Hydroxides	1.6266	Hematite
11	Oxides, Hydroxides	1.5271	Quartz
12	Oxides, Hydroxides	1.3755	Quartz
M33/5^{-1}/30-40 (Trench: 5^{-1}, Depth: 30c.m.-40c.m.)			

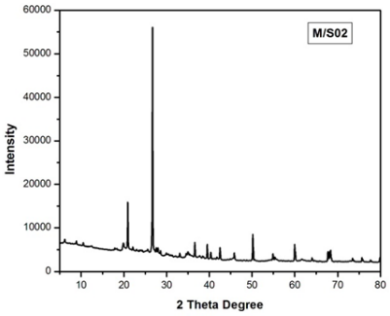
1	Oxides, Hydroxides	4.2830	Quartz
2	Oxides, Hydroxides	3.3444	Quartz
3	Oxides, Hydroxides	3.2260	Rutile
4	Oxides, Hydroxides	2.4511	Goethite
5	Oxides, Hydroxides	1.8151	Quartz
6	Kaolins	1.6706	Kaolinite
7	Oxides, Hydroxides	1.5394	Quartz
8	Oxides, Hydroxides	1.2572	Hematite
M34/3/30-40 (Trench: 3, Depth: 30c.m.-40c.m.)			
1	Feldspars	4.1903	Microcline
2	Micas	3.3275	Biotite
3	Oxides, Hydroxides	2.4456	Goethite
4	Oxides, Hydroxides	2.2728	Quartz
5	Oxides, Hydroxides	1.8110	Quartz
6	Oxides, Hydroxides	1.5366	Quartz
7	Oxides, Hydroxides	1.3697	Quartz
8	Oxides, Hydroxides	1.3246	Hematite
M35/7^{+1}/30-40 (Trench: 7+1, Depth: 30c.m.-40c.m.)			
1	Feldspars	4.2139	Microcline
2	Oxides, Hydroxides	3.3317	Quartz
3	Micas	3.2064	Muscovite
4	Oxides, Hydroxides	2.4434	Goethite
5	Oxides, Hydroxides	2.2747	Quartz
6	Oxides, Hydroxides	2.1276	Quartz
7	Oxides, Hydroxides	1.8122	Quartz
8	Oxides, Hydroxides	1.5386	Quartz
9	Oxides, Hydroxides	1.3673	Quartz
M-S01/3/20 (Trench: 3, Depth: 20c.m.)			
1	Oxides, Hydroxides	4.2517	Quartz
2	Oxides, Hydroxides	3.3550	Quartz
3	Oxides, Hydroxides	2.4611	Goethite
4	Oxides, Hydroxides	2.2861	Quartz
5	Oxides, Hydroxides	2.1249	Quartz
6	Oxides, Hydroxides	1.8191	Quartz
7	Oxides, Hydroxides	1.5422	Quartz
8	Oxides, Hydroxides	1.3740	Quartz
M-S02/4/60(Trench: 4, Depth: 60 c.m.)			
1	Feldspars	4.2448	Microcline
2	Oxides, Hydroxides	3.3275	Quartz
3	Oxides, Hydroxides	2.4533	Goethite
4	Oxides, Hydroxides	2.2794	Quartz
5	Oxides, Hydroxides	2.1298	Quartz
6	Oxides, Hydroxides	1.8226	Quartz
7	Oxides, Hydroxides	1.5394	Quartz
8	Oxides, Hydroxides	1.3719	Quartz

Figure 4.1: X-Ray Diffraction pattern of all the pottery sample and soil sample of Myrkhan




M13/7+1/20-30
Intensity
2 Theta Degree

M14/5+2/30-40
Intensity
2 Theta Degree

M15/8-1/30-40
Intensity
2 Theta Degree

M16/5+2/20-30
Intensity
2 Theta degree

M17/5-1/40-50
Intensity
2 Theta Degree

M18/5-1/40-50
Intensity
2 Theta Degree

M19/5+2/40-50
Intensity
2 Theta Degree

M20/3/20-30
Intensity
2 Theta Degree

M21/5+2/20-30
Intensity
2 Theta Degree

M22/5-1/20-30
Intensity
2 Theta Degree

M23/2-1/20-30
Intensity
2 Theta Degree

M24/2-1/20-30
Intensity
2 Theta Degree


M25/2^{-1}/20-30
M26/1/20-30
M27/1/20-30
M28/1/20-30
M29/1/20-30
M30/4/20-30
M31/4/20-30
M32/2/30
M33/5^{-1}/30-40
M34/3/30-40
M35/7^{+1}/30-40
M/S01
Intensity
2 Theta Degree
2 theta Degree



II) Result of XRD Analysis

The properties of a clay-based ceramic body formulation will be greatly affected by the mineralogical constitution of the clay. Apart from differences in properties upon firing, differences in mineralogical constitution also have a significant influence on the fabrication of ceramic products from such bodies.

This study has been carried out to assess the provenance of clay source of selected potteries excavated at the Neolithic Archaeological site of Myrkhan. The mineralogical assemblages found in all the samples are not similar. It was noticed that the analyzed potteries formed a heterogeneous mineralogical group.

The minerals found in all the samples include Quartz, Kaolinite, Microcline, Goethite, Anorthite, Hematite, Rutile, Biotite, Orthoclase, Chrysotile, Millisite, Halloysite, Amicite, Ilmenite, Variscite and Muscovite present in the samples in different proportions.

It is found that Quartz, Kaolinite, Goethite, Hematite and Anorthite are the major mineral substances found in most of the investigated sherds in varying quantity.

All the samples are characterized by a high content of quartz (SiO2) except sample M05. Quartz is completely absent in this sample. Quartz is often an indigenous inclusion found in clay deposits and thus its use as an intentionally added temper is not easy to determine. In either case, its abundance in the samples gives evidence for a different manufacturing processes (Papachristodoulou, Artemios, Kostas, & Konstantina, 2006). The presence of quartz and feldspars may indicate a temperature of at least 900 °C (Mirti & Davit, 2001). These two minerals persist on firing up to 1000 °C (Shimada, Häusler, Hutzelmann, & Wagner, 2003).

The percentage of Quartz in the samples is comparatively higher, including the soil samples collected from the excavated site. Quartz is a major mineral which makes the clay self-tempered. Abundance of quartz indicates that raw material might have been procured from piedmont area (Ravisankar, Chandrasekaran, Kiruba, Senthilkumar, & Maheswaran, 2010).

Kaolinite is the second major mineral present in the samples. The mineral Kaolinite is present in ten samples (M17, M18, M20, M22, M26, M27, M29, M30, M32, and M33) out of thirty-seven experimented samples. Kaolinite is not present in the soil samples.

The sample M06 shows difference in its mineralogical composition with the presence of Millisite, Halloysite, Amicite which are not present in the rest of the investigated samples.

Hematite is found in fourteen samples (1st phase- 10 samples, M20, M32, M33, and M34). The colour and also the firing atmosphere can be affected by hematite. Hematite is one of the most intense coloring materials and only 1- 1.5 % of hematite is sufficient to give the pottery a reddish colour (Palanivel & Kumar, 2011). Presence of hematite in the potsherds indicates that it has been fired in oxidizing atmosphere.

Hornblende is present in four samples, M09, M06, M05 and in M03**.** It is magnesium rich mineral which can be defined as an amphibole group of Calcium (Barnes, 1930).

Microcline (Feldspar mineral group) is found in eight samples (M20, M21, M22, M23, M25, M34, M35 and MS2). Microcline indicates firing temperature of the potsherds as below 800º C. It is also present in one of the soil sample i.e. MS2.

Goethite is present in all the samples except the samples M21, M27, M28, M30 and M32. It is present in both the soil samples.

Anorthite (Feldspar mineral group) is present in six samples (M18, M20, M24, M25, M26, M32,). New feldspars can be formed after firing and having the necessary minerals. This is the case of Anorthite, which can be observed at 900 ◦ C (Olivares, et al., 2010).

Rutile is present in thirteen samples (M06, M09, M12, M07, M04, M15 and M16, M18, M20, M21, M23, M27, M28, M32, and M33)

Biotite is present in three samples (M34, M22 and M24). Due to presence of Biotite in the samples, it can be assumed that those presenting brown / red colour or a combination of brown and black colours on the cross section were fired below 1000º C (Ntah, Sobott, Fabbri, & Bente, 2017)

Ilmenite is present in five of the sherds, these are M11, M07, M06, M28 and M32. Ilmenite confirms that the raw material of these samples is rich in iron and titanium (Olivares, et al., 2010).

Variscite is present only in four samples M12, M13, M29 and M31.

Albite is present only in one sample, M26.

Calcite is present in one sample, M29. The mineral calcite gets decomposed in between firing temperature 700º -900º C. Therefore, its presence indicates the sample has been fired in between 700º -900º C.

Muscovite is present in the sample M35. Presence of muscovite indicates the sample has been fired around 850 º to 1000º C (Olivares, et al., 2010).

Presence of a group of non- clay minerals such as Feldspars, Biotite, Hornblende etc. are representative of igneous material, which may indicate occurrence of volcanic ash (Grim, 1953).

4.1.2 Fourier Transform Infrared Spectroscopy Analysis (FTIR)

Fourier transform infrared (FTIR) spectroscopy emerges as a powerful analytical tool in the study of Neolithic pottery, offering detailed information about the composition, structure, and manufacturing techniques employed by ancient artisans. Of the various well-known methods of analysis, infrared absorption spectroscopy is a rapid, economical, and non-destructive physical method universally applicable for structural analysis of clay minerals (Manoharan, Veeramuthu, Venkatachalapathy, Radhakrishna, & Ilango, 2008). FTIR spectroscopy involves the measurement of infrared light absorbed by a material, which provides a unique fingerprint corresponding to its molecular structure.

FTIR spectroscopy allows for the identification of minerals, organic materials, and other compounds present in Neolithic pottery by analysing characteristic absorption bands, researchers can discern the types of clays, tempering agents, and organic residues used in pottery fabrication. Infrared spectra of archaeological artifacts reveal the type of clay and temperature of firing (Velraj G. , Janaki , Mohamed Musthafa, & Palanivel, 2009). The firing process significantly influences the chemical and structural properties of pottery. FTIR spectroscopy can differentiate between various firing techniques (e.g., oxidation, reduction) based on the alteration of mineral phases and organic residues within the pottery matrix. Surface treatments such as coatings, paints, or decorative pigments leave distinct chemical signatures on pottery surfaces. FTIR analysis facilitates the identification of these materials, aiding in the reconstruction of Neolithic pottery decoration and artistic practices.

The main purpose of using this method in the present study is to identify unknown materials (organic and inorganic materials) in a sample and to determine the quality and consistency of a sample (In clay by studying the firing temperature.

I) Experimental and sample preparation

To undergo FTIR analysis of the samples, KBr pellets/disks is used in the experiment by preparing the sample using powdered sample and KBr. The concentration of the sample in

KBr should be in the range of 0.2% to 1%. In this method a lower concentration in the sample is required as too high a concentration usually causes difficulties obtaining clear pellets. The sample is first ground using a mortar and the adding KBr in it grind it again till a fine mixture is prepared. A homogeneous mixture will give the best results. For very hard samples, add the sample first, grind, add KBr and then grind again. Using this mixture, the film is prepared, which should be homogenous and transparent in appearance. The film is then inserted in the IR sample holder and run the spectrum. FTIR spectra on the pottery samples were recorded on a Bruker Alpha FT-IR spectrometer with 5 scan mode by using KBr pellets technique in the wave number range from 4000 cm^{-1} to 400 cm^{-1}. The KBr pressed pellet technique was used by mixing the powdered samples with KBr in weight proportion of 1:20.

The IR spectra of the pottery samples are analysed as in the received state at the laboratory in room temperature. By studying the IR spectra graph the frequency of the functional group can be trace out and by studying this functional group one can get the mineralogical composition of the component or the substances present in the studied sample. To get the idea of the substances present in the sample the first think to figure out is what functional group is present in the molecular level. The FTIR spectra of all samples are analysed and the minerals are assigned using available literatures.

Each FTIR spectrum has run on average of 200 scans with the specific precision in the region of the spectrum. The peak positions of various bands of varied intensity observed in these spectra along with their tentative assignments are given below in the Table with Graphs.

Table 4.4: FTIR spectra of Pottery and Soil Samples of Myrkhan with tentative Vibrational Assignments

Serial No.	Frequencycm^{-1}	As received State	Tentative Vibrational Assignments
M1/2^{-1}/0-20(Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	3411	Strong, Broad	O-H stretching, Alcohol/ Water molecule
2	1629	Weak to Medium	C=C ,Alkene
3	1393	Very Weak	Carbonate overtone/combination
4	1036	Very Strong	Si-O – Si (Kaolinite)
5	796	Weak	Si-O of quartz
6	694	Weak	Si-O of quartz
7	541	Weak	Fe-O of Hematite
8	476	Weak	Si-O-Si bending (microcline)
M2/4/20-30 (Trench: 4, Depth: 20c.m.-30c.m.)			

1	3435	Strong, Broad	O-H stretching of absorbed water molecule
2	1633	Weak to Medium	Quinolines, N-H bending vibration)
3	1025	Very Strong	Si-O – Si (Kaolinite)
4	785	Weak	Si-O of quartz
5	687	Weak	Si-O of quartz
6	549	Weak	Fe-O of Hematite
7	480	Strong	Si-O-Si bending (microcline)
M3/3/30-40 (Trench: 3, Depth: 30c.m.-40c.m.)			
1	3431	Strong, Broad	O-H stretching of absorbed water molecule
2	1639	Weak to Medium	Quinolines, N-H bending vibration)
3	1040	Very Strong	Kaolinite
4	800	Weak	Si-O of quartz
5	698	Weak	Si-O of quartz
6	541	Very Weak	Fe2O3
7	484	Very Weak	Si- O-Si bending (Microcline)
M4/5^{+2}/0-50 (Trench: 5+2, Depth: 0c.m.-50c.m.)			
1	3436	Strong	O-H stretching of absorbed water molecule
2	1634	Very weak	H-O-H bending of water
3	1037	Very Strong	Kaolinite
4	797	Weak	Si-O of quartz
5	694	Weak	Si-O of quartz
6	543	Weak	Si-O –Al or Fe2O3
7	480	Weak	Si-O-Si bending (microcline)
M5/7^{+1}/0-20 (Trench: 7+1, Depth: 0c.m.-20c.m.)			
1	3407	Strong, Broad	O-H stretching,Alcohol
2	1632	Very weak	H-O-H bending of water
3	1390	Very Weak	Carbonate overtone/combination
4	1096	Very Strong	Si-O-Si (Kaolinite)
5	551	Weak	Si-O –Al or Fe2O3
6	462	Strong	Si-O-Si bending (microcline)
M6/7^{+1}/0-20 (Trench: 7+1, Depth: 0c.m.-20c.m.)			
1	3366	Medium	Amines (N-H)
2	2062	weak	Aromatics
3	1641	Weak to Medium	Alkene (C=C)
4	1384	Very Weak	Carbonate overtone/combination
5	1035	Very Strong	Kaolinite
6	668	Very Weak	Si-O of Quartz
7	544	Very Weak	Fe-O of Hematite
M7/5^{-1}/40-50 (Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	3405	Strong, Broad	O-H stretching,Alcohol
2	1632	Very weak	H-O-H bending of water
3	1392	Very Weak	Carbonate overtone/combination
4	1029	Very Strong	Si-O-Si (Kaolinite)
5	795	Weak	Si-O of quartz
6	693	Strong	Si-O of quartz

7	536	Very Weak	Fe-O of Hematite
M8/1/30-40 (Trench: 1, Depth: 30c.m.-40c.m.)			
1	3340	Medium	Amines (N-H)
2	1641	Weak to medium	Alkene (C=C)
3	1029	Very Strong	Si-O-Si (Kaolinite)
4	800	Weak	Si-O of quartz
5	693	Weak	Si-O of quartz
M9/2/20-30 (Trench: 2, Depth: 20c.m.-30c.m.)			
1	3445	Strong	O-H stretching of absorbed water molecule
2	2924	Medium to Strong	Alkane (C-H)
3	2858	Medium to Strong	Alkane (C-H)
4	1646	Weak to Medium	Alkane (C=C)
5	1464		Carbonyl group (C-O)
6	1390	Very Weak	Carbonate overtone/combination
7	1084	Very Strong	Kaolinite
8	803	Weak	Si-O of quartz
M10/2^{-1}/0-20 (Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	3449	Strong	O-H stretching of absorbed water molecule
2	1630	Very Weak	H-O-H bending of water
3	1384	Very Weak	Carbonate overtone/combinations
4	1034	Very Strong	Si-O-Si (Kaolinite)
5	797	Weak	Si-O of Quartz
6	778	Weak	Si-O of Quartz
7	694	Very Weak	Si-O of Quartz
8	514	Very weak	Fe2O3
9	475	Very weak	Fe2O3
M11/2^{-1}/0-20 (Trench: 2-1, Depth: 0c.m.-20c.m.)			
1	3697	Medium	O-H stretching of inner layer water
2	3620	Medium	Inner O-H group of absorbed water
3	3448	Medium	O-H stretching of absorbed water molecule
4	1630	Very Weak	H-O-H bending of water
5	1384	Very Weak	Carbonate overtone/combinations
6	1031	Very Strong	Si-O-Si (Kaolinite)
7	1009	Very Strong	Si-O-Si (Kaolinite)
8	913	Very Strong	Al-OH
9	777	Very weak	Si-O of Quartz
10	694	Very weak	Si-O of Quartz
11	536	Very Weak	Si-O-M (iv)
12	469	Very Weak	Si-O-Si bending (Microcline)
M12/7^{+1}/20-30 (Trench: 7+1, Depth: 20c.m.-30c.m.)			
1	3448	Medium	O-H stretching of absorbed water molecule
2	1629	Weak	H-O-H bending of water

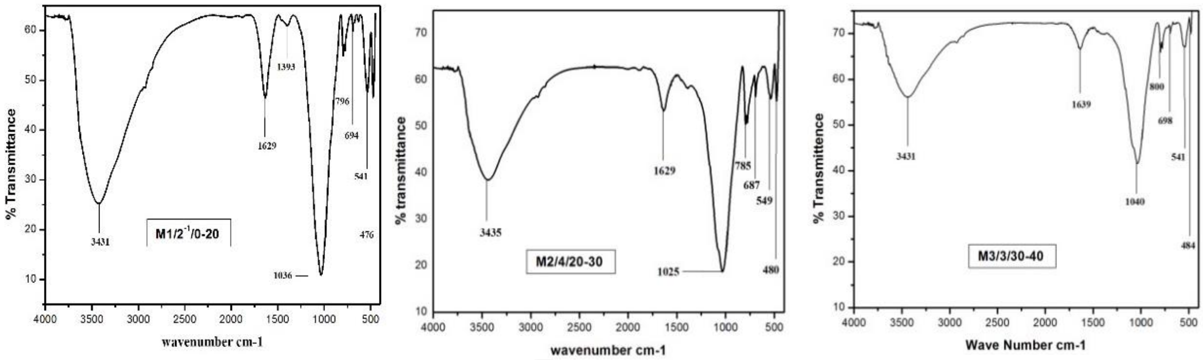
3	1384	Very Weak	Carbonate overtone/combinations
4	1029	Very Strong	Si-O-Si (Kaolinite)
5	535	Very Weak	Fe2O3
6	473	Very Weak	Si-O-Si bending (Microcline)
M13/7^{+1}/20-30 (Trench: 7+1, Depth: 20c.m.-30c.m.)			
1	3453	Medium	O-H stretching of absorbed water molecule
2	1631	Medium	H-O-H bending of water
3	1384	Very Weak	Carbonate overtone/combinations
4	1029	Very Strong	Si-O-Si (Kaolinite)
5	777	Weak	Si-O of Quartz
6	693	Very Weak	Fe2O3
7	535	Very Weak	Fe2O3
8	475	Very Weak	Si-O-Si bending (Microcline)
M14/5^{-2}/30-40 (Trench: 5-2, Depth: 30c.m.-40c.m.)			
1	3448	Medium	O-H stretching of absorbed water molecule
2	1633	Very Weak	H-O-H bending of water
3	1384	Very Weak	Carbonate overtone/combinations
4	1031	Very Strong	Si-O-Si (Kaolinite)
5	778	Medium	Si-O of Quartz
6	693	Very Weak	Si-O of Quartz
7	530	Very Weak	Fe2O3
8	471	Very Weak	Fe2O3
M15/8^{-1}/30-40 (Trench: 8-1, Depth: 30c.m.-40c.m.)			
1	3467	Very Strong	O-H stretching of absorbed water molecule
2	1629	Weak	H-O-H bending of water
3	1384	Very Weak	Carbonate overtone/combinations
4	1027	Very Strong	Si-O-Si (Kaolinite)
5	693	Very Weak	Si-O of Quartz
6	534	Very Weak	Fe_2O_3
7	473	Very Weak	Fe_2O_3
M16/5^{+2}/20-30(Trench: 5+2, Depth: 20c.m.-30c.m.)			
1	1645	Variable (Very Weak)	H-O-H bending of water
2	1011	Strong	C-O stretching(Ether)
3	777	Very Strong	Si-O bend of Quartz
4	689	Very Weak	Fe-O of Hematite
M17/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	1008	Strong, Broad	C-H bending (Organic Compound)
2	777	Very Strong	Si-O bend of Quartz
3	694	Very Weak	Si-O of quartz
M18/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)			
1	3368	Strong, Broad	N-H stretching, (Amine)
2	1648	Very Weak	H-O-H bending of water

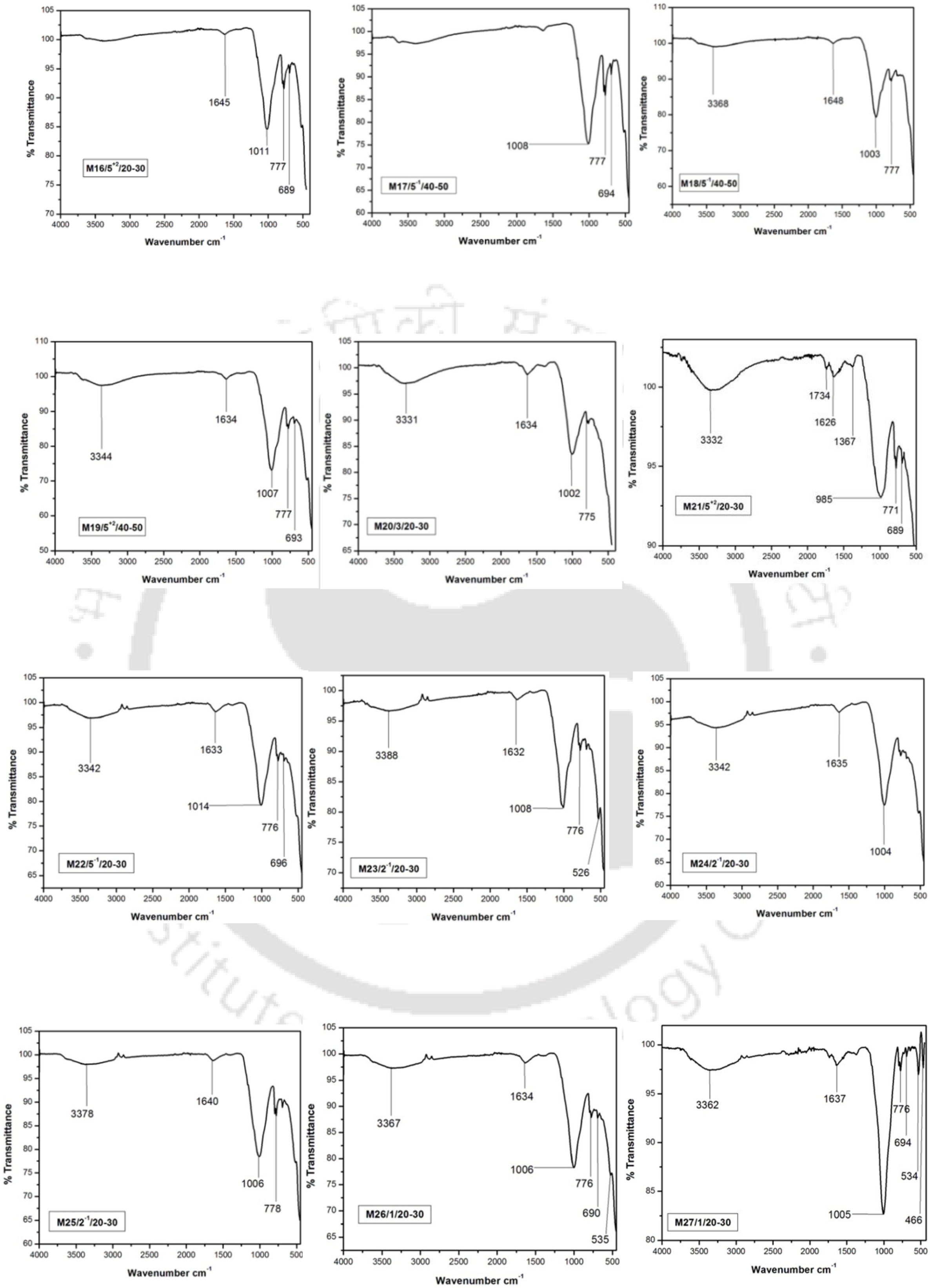
3	1003	Very Strong	Si-O Stretching
4	777	Very Strong	Si-O bend of Quartz
M19/5^{+2}/40-50(Trench: 5+2, Depth: 40c.m.-50c.m.)			
1	3344	Strong	N-H stretching, (Amine)
2	1634	Very weak	H-O-H bending of water
3	1007	Strong, Broad	C-H bending (Organic Compound)
4	777	Very Strong	Si-O bend of Quartz
5	694	Weak	Si-O of quartz
M20/3/20-30(Trench: 3, Depth: 20c.m.-30c.m.)			
1	3331	Strong	O-H stretching of absorbed water molecule
2	1634	Very weak	H-O-H bending of water
3	1002	Very Strong	Si-O Stretching
4	775	Very Weak	Si-O of Quartz
M21/5^{+2}/20-30(Trench: 5+2, Depth: 20c.m.-30c.m.)			
1	3332	Strong	O-H stretching of absorbed water molecule
2	1734	Strong	C=O stretching(saturated Aldehyde)
3	1626	Very Weak	H-O-H bending of water
4	1367	Variable	C-H bending (Alkane)
5	985	Very Strong	Al-Oh
6	771	Very Strong	Si-OofQuartz
7	689	Very Weak	Fe-O of Hematite
M22/5^{-1}/20-30(Trench: 5-1, Depth: 20c.m.-30c.m.)			
1	3342	Very Weak	N-H stretching, (Amine)
2	1633	Very weak	H-O-H bending of water
3	1014	Very Weak	Carbonate overtone/combination (Feldspar)
4	776	Medium	Si-O of quartz
5	696	Very Weak	Si-O of quartz
M23/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	3388	Medium	Amines (N-H)
2	1632	Very Weak	H-O-H bending of water
3	1008	Strong, Broad	C-H bending (Organic Compound)
4	776	Medium	Si-O of quartz
5	526	Very Weak	Fe-O of Hematite
M24/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	3342	Very Weak	N-H stretching, (Amine)
2	1635	Very Weak	H-O-H bending of water
3	1004	Very Strong	Si-O Stretching
M25/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)			
1	3378	Very Weak	N-H stretching, (Amine)
2	1640	Very Weak	H-O-H bending of water
3	1006	Very Strong	Si-O Stretching
4	778	Weak	Si-O of Quartz
M26/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	3367	Very Weak	N-H stretching, (Amine)

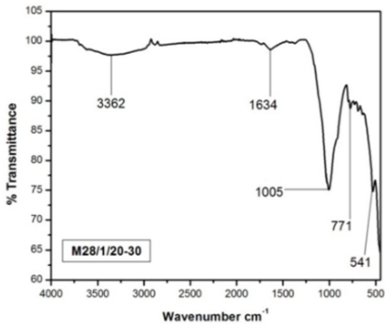
2	1634	Very Weak	H-O-H bending of water
3	1006	Very Strong	Si-O Stretching
4	776	Very Weak	Si-O of Quartz
5	690	Very Weak	Si-O of Quartz
6	535	Very Weak	$Fe_2O_3$of Hematite
M27/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	3362	Very Weak	N-H stretching, (Amine)
2	1637	Weak	H-O-H bending of water
3	1005	Very Strong	Si-O Stretching
4	776	Very Weak	Si-O of Quartz
5	694	Very Weak	Si-O of Quartz
6	534	Very Weak	Fe_2O_3
7	466	Very strong	Microcline
M28/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	3362	Very Weak	N-H stretching, (Amine)
2	1634	Very Weak	H-O-H bending of water
3	1005	Very Strong	Si-O Stretching
4	771	Very Strong	Si-O of Quartz
5	541	Very Weak	Fe_2O_3
M29/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)			
1	3358	Medium	Amines (N-H)
2	1635	Very Weak	H-O-H bending of water
3	1006	Very Strong	Si-O Stretching
4	778	Very Weak	Si-O of Quartz
5	543	Medium	Fe-O of Hematite
M30/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)			
1	3360	Medium	Amines (N-H)
2	1633	Weak	O-H bending of water
3	1004	Very Strong	Si-O Stretching
4	777	Very Strong	Si-O bend of Quartz
5	692	Very Weak	Si-O bend of Quartz
M31/4/20-30 (Trench: 4, Depth: 20c.m.-30c.m.)			
1	1008	Strong, Broad	C-H bending (Organic Compound)
2	781	Very Weak	Si-O of Quartz
M32/2/30 (Trench: 2, Depth: 30c.m.)			
1	1641	Very Weak	H-O-H bending of water
2	1008	Strong, Broad	C-H bending (Organic Compound)
M33/5^{-1}/30-40 (Trench: 5-1, Depth: 30c.m.-40c.m.)			
1	3361	Very Weak	N-H stretching, (Amine)
2	1635	Very Weak	H-O-H bending of water
3	1006	Very Strong	Si-O Stretching
4	776	Strong	Si-O of Quartz
5	527	Medium	Fe-O of Hematite
M34/3/30-40 (Trench: 3, Depth: 30c.m.-40c.m.)			

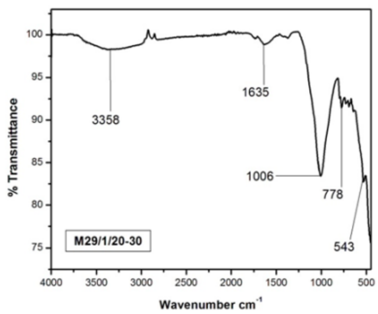
1	3371	Very Weak	N-H stretching, (Amine)
2	1738	Strong	C=O (saturated aldehyde)
3	1365	Strong, two bands	N-O stretching (Nitro)
4	1217	Medium-Strong	O-C (acids) Carboxylic Acids & Derivatives
5	1008	Strong, Broad	C-H bending (Organic Compound)
6	777	Very Strong	Si-O bend of Quartz
7	697	Very Weak	Si-O of Quartz
M35/7^{+1}/30-40 (Trench: 7+1, Depth: 30c.m.-40c.m.)			
1	2970	strong, very broad	C-H stretching (Alkanes)
2	1737	Strong	C=O stretching (Ester)
3	1365	Strong, two bands	N-O stretching (Nitro)
4	1217	Medium-Strong	O-C (acids) Carboxylic Acids & Derivatives
5	996	Very Strong	Al-Oh
6	776	Strong	Si-O of Quartz
7	646	Very Weak	Al-O co-ordination vibration
8	628	Strong	C-Cl stretching (Alkyl Halide)
M-S01/3/20 (Trench: 3, Depth: 20c.m.)			
1	3440	Medium	O-H stretching of absorbed water molecule
2	1634	Medium	H-O-H bending of water
3	1002	Very Weak	Carbonate overtone/combination
4	911	Very Weak	Al-OH
5	777	Very Strong	Si-O bend of Quartz
6	693	Very Weak	Si-O of Quartz
7	529	Very Weak	Fe-O of Hematite
8	466	Very Weak	Microcline
M-S02/4/60(Trench: 4, Depth: 60c.m.)			
1	3439	Medium	O-H stretching of absorbed water molecule
2	1633	Medium	H-O-H bending of water
3	1004	Very Strong	Si-O Stretching
4	777	Very Strong	Si-O bend of Quartz
5	693	Very Weak	Si-O of Quartz
6	530	Very Weak	Fe_2O_3
7	467	Very Weak	Microcline

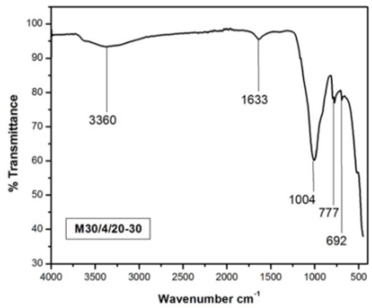
Figure 4.2: FTIR spectrographs of all the pottery samples and soil samples of My

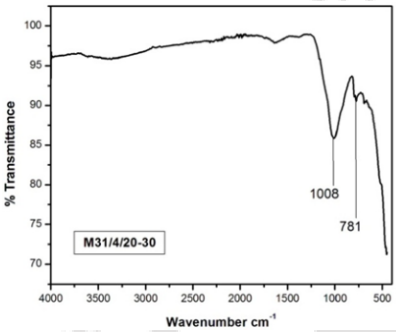


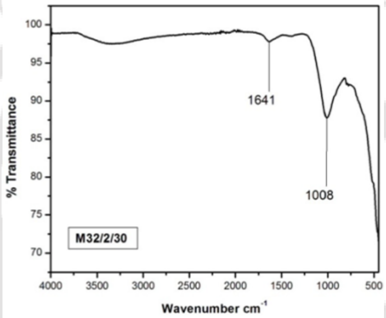

M16/5+2/20-30
1645
1011
777
689
M17/5-1/40-50
1008
777
694
M18/5-1/40-50
3368
1648
1003
777
M19/5+2/40-50
3344
1634
1007
777
693
M20/3/20-30
3331
1634
1002
775
M21/5+2/20-30
3332
1734
1626
1367
985
771
689
M22/5-1/20-30
3342
1633
1014
776
696
M23/2-1/20-30
3388
1632
1008
776
526
M24/2-1/20-30
3342
1635
1004
M25/2-1/20-30
3378
1640
1006
778
M26/1/20-30
3367
1634
1006
776
690
535
M27/1/20-30
3362
1637
776
694
534
1005
466
% Transmittance
Wavenumber cm-1

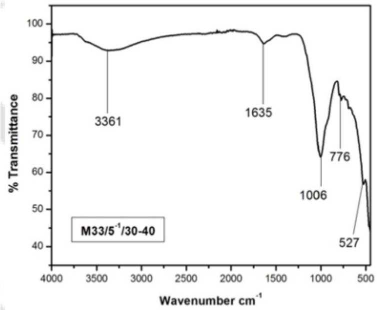

M28/1/20-30
3362
1634
1005
771
541
% Transmittance
Wavenumber cm⁻¹

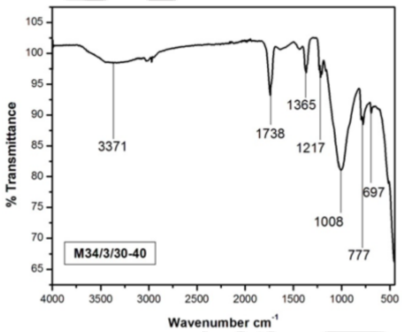

M29/1/20-30
3358
1635
1006
778
543
% Transmittance
Wavenumber cm⁻¹

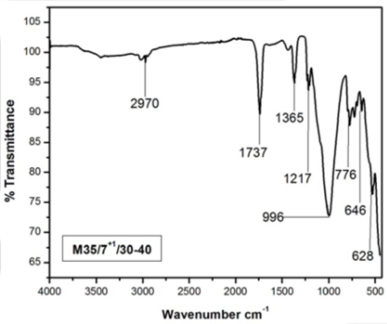

M30/4/20-30
3360
1633
1004
777
692
% Transmittance
Wavenumber cm⁻¹

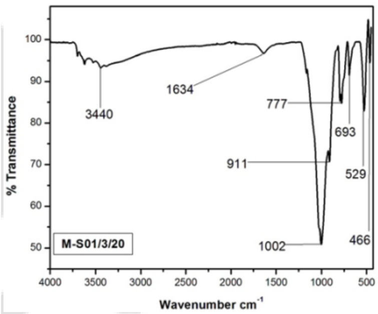

M31/4/20-30
1008
781
% Transmittance
Wavenumber cm⁻¹

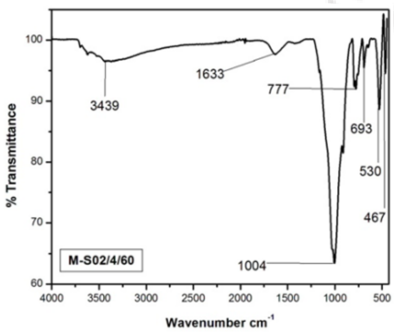

M32/2/30
1641
1008
% Transmittance
Wavenumber cm⁻¹


M33/5⁻¹/30-40
3361
1635
1006
776
527
% Transmittance
Wavenumber cm⁻¹


M34/3/30-40
3371
1738
1365
1217
1008
777
697
% Transmittance
Wavenumber cm⁻¹


M35/7⁺¹/30-40
2970
1737
1365
1217
996
776
646
628
% Transmittance
Wavenumber cm⁻¹


M-S01/3/20
3440
1634
777
693
911
529
1002
466
% Transmittance
Wavenumber cm⁻¹


M-S02/4/60
3439
1633
777
693
530
467
1004
% Transmittance
Wavenumber cm⁻¹

II) Result of FTIR Analysis

The FTIR spectra of all the experimented samples are shown in the above graphs. FTIR spectra show presence of minerals quartz, feldspars (Microcline, Orthoclase), clay mineral (Kaolinite and Montormorlinite), iron oxides (Hematite) and organic compounds. This identification has been made on the basis of the characteristic IR wave numbers of the minerals.

The clay minerals as well as associated minerals including iron oxides undergo characteristic chemical and physical changes during firing which can be followed by FTIR technique as well as other techniques like X-ray diffraction, scanning electron microscopy, differential thermal analysis, optical microscopy etc. The firing temperature of the pottery fragments can be determined with the help of the study of thermal transformation of the clay minerals present in them.

In the IR studies of clay, the Si–O stretching vibrations were observed at 790 cm^{-1}, 693 cm^{-1}, 538 cm^{-1} and 468 cm^{-1} showing the presence of quartz (Marel, Willem, & Beutelspacher, 1976), which is the most common and presented by almost all the studied samples in different amounts. The appearance of Si-O-Si and Si-O bands also support the presence of quartz (Marel, Willem, & Beutelspacher, 1976). The Si-O bonds are the strongest bonds in the silicate structure and can be readily recognized in the infrared spectra of such minerals by very strong bands in the region 900 cm^{-1} – 1100 cm^{-1}, which is due to stretching and as well as less intense bands in the region 400 cm^{-1} – 800 cm^{-1} regions due to bending (Kumar & Rajkumar, 2014). The SiO deformation band of the clays appears at 467 cm^{-1} (Annamalai, Ravisankar, Naseerutheen, Chandrasekaran, & Rajan, 2014). The quartz mineral in the samples were detected with bands at 467 cm^{-1},693 cm^{-1}, 777 cm^{-1} (in eight samples) and these IR absorption peaks were also previously reported by many authors and again the appearance of absorption bends at 466 cm^{-1}, 694 cm^{-1}, 696 cm^{-1} and 697 cm^{-1} also indicates the presence of quartz. In the samples M01**,** M02**,** M03**,** M04, and M09 the quartz mineral has been found with the bands at 780 cm^{-1}, 700 cm^{-1} and 460 cm^{-1}.

Clay minerals present (kaolinite and montmorillonite) at 1030 cm^{-1}, 1635 cm^{-1} and 3440 cm^{-1} (Annamalai, Ravisankar, Naseerutheen, Chandrasekaran, & Rajan, 2014) and a weak band at 2926 cm^{-1} and 2853 cm^{-1} (C-H bond) indicate presence of organic compounds. Clay deposits generally contain variable amounts of organic matter, but organic additives can also be used by potters during preparation of the ceramic paste, in order to achieve more plasticity (Ravisankar, et al., 2013). In the sample M6 the presence of band at 1035 cm^{-1} of kaolinite is assigned to Si–O stretching mode of silicates, which indicates that the samples have been fired above 750º C and made up of disordered clay. It also indicates that the pottery was made up of red clay (Ravisankar, et al., 2011). In the received state, the presence of the band at 535 cm^{-1} indicates the presence of iron oxides. At 250º C water evaporates and the intensity of the both bands remains the same up to 750º C. It indicates that they were fired above 750º C under open atmosphere and it is well established from the red color of the pottery (Ravisankar, et al., 2013).

The intensity and sharpness of absorption IR bands in the studied samples are the characteristic of the Alkane groups with the frequency 2924 cm^{-1} and 2858 cm^{-1} in the sample M09 and it confirm presence of long Hydrocarbon chains such as fatty acids.

The presence of the bands such as 3696 cm^{-1}, 3620cm^{-1}, 3453 cm^{-1}, 1033 cm^{-1}, 693 cm^{-1}, 537 cm^{-1}, 469cm^{-1} shows the presence of kaolinite. These strong bands at 3696 cm^{-1}, 3622 cm^{-1} and 3450 cm^{-1} indicate the possibility of the hydroxyl linkage, which is found in M10, M11, M13 and M14. However, a broad band at 3450 cm^{-1} and a band at 1633 cm^{-1} in the spectrum of clay suggests the possibility of water of hydration in the adsorbent. It is possible to analyze the lipid extract from archaeological samples by FTIR and determine the organic part of archaeological ceramic samples.

The peak 1034 cm^{-1} found in the sample M10 indicate red clay origin of kaolinite and the peak at 1040 cm^{-1} with the strong intensity found in the sample M3 also indicate the red clay origin of kaolinite used in the making the potteries (Palanivel & Velraj, 2007).

IR spectrum of M09 shows a strong band at 3445 cm^{-1} is due to O-H stretching of water molecule.

The vibrations observed at 913 cm^{-1} in the sample M11 indicate the possibility of the presence of hematite (Gadsden, 1975).

A weak IR spectrum around 3622 cm^{-1}, 1633 cm^{-1} is indicative of gypsum found in the sample M11 and M02. A strong band 693 cm^{-1} in the sample M07 shows the possibility of the presence of calcite (Gadsden, 1975).

A weak band 1638 cm^{-1}, 1632 cm^{-1} is due to H-O-H bending vibration of absorbed water molecule found in M04, M05, M13 and M14.

The samples M13, M12, M03 and M05 are composed of kaolin with high quantity of aluminum hydro oxide and iron oxide indicated by a weak band at 535 cm^{-1} and 537 cm^{-1} and 551 cm^{-1}. The presence of iron oxide makes it red in colour.

The O-H stretching modes from alcohols and phenols are mostly broad and very strong (3200-3650 cm^{-1}). The O-H peaks due to carboxylic acids show a very broad and less intense peak between 2500 and 3500 cm^{-1}. The change in peak shape is a result of the different degree of hydrogen bonds in alcohol and carboxylic acids.

Peaks that are due to N-H stretching modes (M08 and M06) are sharper than O-H-peaks (3300-3500 cm^{-1}). This is the most important range in the entire IR spectrum for organic chemists (Dr. A. Bacher, 2002).

If there is a very strong peak between 1640 and 1850 cm^{-1}, there is most likely a carbonyl function in the molecule. Analysis of the exact peak position will reveal further what type of carbonyl function is present (Dr. A. Bacher, 2002).

According to Ross et al. (1931), the FT-IR absorption band around 3630 cm^{-1} is due to hydroxyl groups which persist up to 800° C. The experimented Myrkhan pottery samples did not show an absorption band at 3630 $cm^{-1}$and this result indicates that these potteries were fired up to temperature 800°C.

The minimum firing temperature can be confirmed by the bands present at 915 cm^{-1} and 875 cm^{-1}. The band at 915 cm^{-1} Al (OH) vibrations due to octahedral sheet structure, begins to disappear with increasing temperature. At 500° C, the band is completely absent (Elsass & Olivier , 1978). None of the samples of the present study showed the band at 915 cm^{-1} implying that all samples were fired above 500° C.

The decomposition of kaolinite and formation of metakaolinite occurs in the temperature range 450-650°C (Ravisankar, et al., 2013). The presence of kaolinite in the samples signifies that the temperature was not that high to complete the decomposition of the mineral which again indicate that the firing did not exceed 650° C. Therefore, this can be confirmed that the samples which show presence of kaolinite were fired below 650° C. Metakaolinite has broad vibrational bands around 1098 cm^{-1} (Si–O stretching), 826 cm^{-1} (Al–O stretching) and 469 cm^{-1} (Si–O in plane bending) (Ravisankar, et al., 2013). The sample M5 shows a band at 1096 cm^{-1} (Si–O stretching) of kaolinite, which indicates the firing temperature range within 450-650° C.

Organic carbon is the amount of carbon bound in an organic compound. Its forms are derived from the decomposition of plants and animals. The molecules of organic compound contain carbon, oxygen, nitrogen and hydrogen (Pluske, Murphy, & Sheppard, 2009). The intensity and sharpness of absorption IR bands in the studied samples are the characteristic of the Alkane groups with the frequency 2970 cm^{-1} and it confirms presence of long Hydrocarbon chains such as fatty acids (organic compound) and also reveals by the frequency around 1008 cm^{-1} in few experimented samples.

The infrared spectrum of the samples M21, M34 and M35 are characterized by a carbonyl stretch at the frequency 1734 cm^{-1}, 1738 $cm^{-1}$and 1737 cm^{-1} (Silverstein, R. M., 1998).

It has stated earlier on the IR analysis of archeological artifacts that the absorption band at frequency 1626 cm^{-1} to 1645 cm^{-1} is due to the H-O-H bending of water molecule which have been found in 18 samples out of the all experimented sample showing to the absorption of moisture present in the samples (Palanivel & Kumar, 2011).

The band at 1648 cm^{-1} in the sample M18 corresponds to strongly hydrogen bonded water, whereas the band at 1626 cm^{-1}in the sample M21 is attributed to less strongly hydrogen bonded water and corresponds to the position of the water bending mode of liquid water (Shoval , et al., 1999).

Most of the samples give very strong band in the region 1100 cm^{-1}- 1000 cm^{-1} which is characteristic of silicate mineral. The 1003 cm^{-1} - 1006 cm^{-1} is attributed to the Si-O stretching vibration present in all proportions of rock processing residue mixed ceramic samples (Vijayaragavan , et al., 2013).

The band in 1011cm^{-1} and 1014 cm^{-1} is assigned to feldspar which can be identified as microcline (Bayazit, Isik, & Issi, 2015).

Some iron oxides that do not normally occur in natural clays may form during firing of pottery, such as Hematite may form during oxidizing condition. The absorptions bends observed at 535 cm^{-1} in M26 and 534 cm^{-1} in M27 are attributed to the hematite present in the samples respectively. Therefore, the absence of these bends in rest of the samples indicates absence of hematite in its composition. The formations of hematite depend on the firing atmosphere prevalent at the time of manufacture. The hematite peak at 535 cm^{-1} and 534 cm^{-1} in the samples M26 and M27 implies that the potteries were fired in an oxidizing condition (Ravisankar, et al., 2011). The samples which show absence of hematite band indicates that the firing condition achieved may be in a reduced atmosphere for the samples. So it is inferred that the artisans of Neolithic period of this region were well aware of technique of firing the potteries in both oxidizing and reducing atmosphere.

The IR spectra of the samples M27, M-S01 and M-S02 show a medium band around 466 $cm^{-1}$and 467 cm^{-1}which indicates the presence of microcline (Kieffer S W, 1979 and Ciancio 1994).

When air has been allowed at a higher temperature during cooling which enabled the oxidation of iron components formed during reduced atmosphere, the reason for the red colour of the pottery. Allowing air during cooling is a common practice for coloration of the pottery clays.

4.1.3 Energy Dispersive X-Ray Analysis (EDX)

Energy dispersive X-ray spectroscopy (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. It can help establish the geological sources of raw materials used in Neolithic pottery production. By comparing the elemental signatures of pottery samples with those of potential clay deposits, researchers can infer procurement patterns, trade routes, and social interactions among Neolithic communities.

EDX analysis involves bombarding a sample with high-energy X-rays. The energy of characteristic X-ray that is emitted when electrons strike a solid specimen enabled to identify the mail elements that were present in the pottery samples (Krapukaityte, 2006). By measuring the energy and intensity of these emitted X-rays, EDX can identify and quantify the elements present in the sample, providing valuable information about its chemical composition.

By examining elemental distributions and variations within pottery samples, researchers can discern firing conditions, kiln types, and post-firing treatments, contributing to the reconstruction of ancient pottery-making processes. As a type of spectroscopy, it relies on the investigation of a sample through interactions between electromagnetic radiation and matter, analyzing x-rays emitted by the matter in response to being hit with charged particles. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing x-rays that are characteristic of an element's atomic structure to be identified uniquely from each other. EDX analysis of the pottery samples shows the presence of elements in it along with its percentage.

I) Experimental and sample preparation

For EDX data analysis, experiment is done in a Gemini Field Emission Scanning Electron Microscope (FESEM), which is equipped with a windowless EDS. The powdered pottery sample is attached to a metallic holder (aluminum stub) with the help of a carbon tab (double side adhesive carbon conductive tab). the sample is securely fixed to the holder to prevent any movement during analysis. Carbon conductive tab is used here, because carbon has a low atomic number and the peak of the X-ray graph of carbon doesn’t interfere with other peaks of other elements. The ceramic products need to be covered by a thin conducting surface layer, usually done with gold or carbon in an argon atmosphere. Gold is the material most commonly used for the preparation of electron microscope specimens because of its high electrical conductivity and fine grain size resulting in high-resolution images. After coating, a uniformly conducting cover is formed, which help in reduce heating by the electron beam, the prepared sample is placed in the sample holder of the FESEM machine. EDX spectra are acquired from multiple areas of the pottery sample to ensure representative elemental composition data.

II) Result of EDX analysis

Table 4.5: Elements identified through EDX analysis along with its percentage

Elemental Concentration Weight (%) (Samples)	**Elements**																					
	O	**C**	**Si**	**Al**	**Fe**	**K**	**Mg**	**Ti**	**Ca**	**F**	**Na**	**Cu**	**Mn**	**Zn**	**Br**	**P**	**Cl**	**S**	**Cr**	**Nb**	**Ba**	**Zr**
M1/2^{-1}/0-20	**56.1**	**3.5**	**21.5**	**7.7**	**5.4**	**2.2**	**1.2**	**0.3**	**0.2**	-	**0.3**	-	-	-	**0.9**	-	-	-	-	-	-	-
M2/4/20-30	**52.8**	-	**21.7**	**7.9**	**14.5**	**0.5**	**0.6**	**1.6**	**0.03**	-	-	-	-	-	-	-	-	-	-	-	-	-
M3/3/30-40	**53.2**	-	**20.7**	**10.4**	**8.1**	**1.5**	**0.3**	**0.5**	**0.2**	**4.8**	**0.1**	-	**0.2**	-	-	-	-	-	-	-	-	-
M4/5^{+2}/0-50	**50.0**	-	**16.7**	**9.7**	**17.8**	**1.5**	**1.0**	**1.6**	**0.8**	-	**0.5**	-	**0.1**	-	-	**0.3**	-	-	-	-	-	-
M5/7^{+1}/0-20	**48.2**	-	**13.3**	**9.3**	**18.4**	**0.6**	**1.7**	**2.8**	**1.0**	**3.6**	**0.5**	-	**0.2**	-	-	**0.4**	-	-	-	-	-	-
M6/7^{+1}/0-20	**54.1**	-	**14.8**	**9.0**	**12.2**	**0.3**	**3.8**	**0.9**	**3.4**	-	**0.4**	-	**0.3**	-	-	**0.2**	-	-	-	-	-	-
M7/5^{-1}/40-50	**42.8**	**34.8**	**10.6**	**4.2**	**4.9**	**0.7**	**0.5**	**0.6**	**0.4**	-	**0.5**	-	-	-	-	-	-	-	-	-	-	-
M8/1/30-40	**55.5**	-	**24.1**	**11.1**	**5.6**	**2.0**	**0.6**	**0.9**	-	-	-	-	-	-	-	-	-	-	-	-	-	-

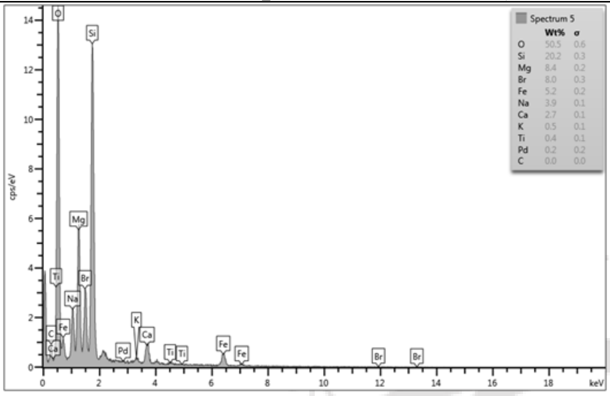
M9/2/20-30	**52.3**	-	**16.1**	**8.8**	**16.7**	**0.4**	**2.7**	**1.2**	**1.4**	-	-	-	-	-	-	-	-	-	-	-	-	-
M10/2^{-1}/0-20	**54.3**	**13.9**	**17.2**	**9.3**	**2.3**	**1.6**	**0.3**	**0.9**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M11/2-1/0-20	**49.6**	**19.9**	**15.3**	**8.3**	**3.7**	**1.6**	**1.0**	**0.2**	**0.2**	-	-	-	-	-	-	-	-	-	-	-	-	-
M12/7+1/20-30	**49.7**	**27.9**	**11.2**	**7.0**	**2.2**	**1.1**	**0.2**	**0.2**	-	**0.05**	-	-	-	-	-	-	-	-	-	-	-	-
M13/7^{+1}/20-30	**49.5**	**19.2**	**13.9**	**8.4**	**4.3**	**2.4**	**0.2**	**0.3**	**0.02**	**1.9**	-	-	-	-	-	-	-	-	-	-	-	-
M14/5^{-2}/30-40	**50.2**	**19.2**	**16.4**	**5.2**	**4.1**	**1.7**	**0.8**	**0.2**	**0.9**	**1.2**	**0.03**	-	-	-	-	-	-	-	-	-	-	-

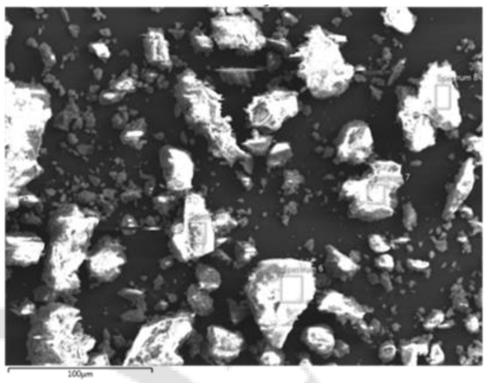
M15/8^{-1}/30-40	56.8		20.7	10.8	6.5	2.9	0.9	0.8	0.08	-	-	-	0.1	-	-	-	-	-	-	-	-	-
M16/5^{+2}/20-30	53.5	9.5	22.1	7.4	3.4	2.4	0.7	0.2	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
M17/5^{-1}/40-50	51.9	11	21.9	8.1	3.3	1.7	0.5	0.1	0.3	0.1	0.3	0.1	0.06	0.03	-	-	-	-	-	-	-	-
M18/5^{-1}/40-50	49.4	18.9	9	5.6	6.2	0.5	2.8	0.6	1.1	0.1	0.1	0.1	0.05	-	-	-	-	-	-	-	0.05	-
M19/5^{+2}/40-50	50.8	18.6	16.3	8.7	3	0.7	0.4	0.5	0.09	0.2	0.1	0.04	0.08	-	-	-	-	-	-	-	-	-
M20/3/20-30	48.2	19.5	8.6	6.7	12.1	0.1	1.4	0.8	1.4	-	0.1	0.01	0.3	-	-	0.2	0.02	o.o2	0.05	0.05	-	-
M21/5^{+2}/20-30	48.9	23.5	13.8	6.7	3.5	1	0.1	0.2	0.4	0.03	1.2	0.02	0.02	0.02		0.1	0.04	0.04	-	-	-	-
M22/5^{-1}/20-30	49.6	20.1	15.7	7.3	3.7	2.6	0.4	0.3	-	1.1	0.1	-	0.05	-	0.1	-	-	-	-	0.02	-	-
M23/2^{-1}/20-30	52.8	11.2	23.9	6.2	3	1.2	0.2	0.1	0.07	0.6	0.3	-	0.04	-	-	-	-	-	-	-	-	-
M24/2^{-1}/20-30	50.3	17	15.2	8.3	3.1	2.4	0.7	0.4	0.1	0.5	0.2	0.2	0.1	-	-	0.8	0.1	0.05	-	-	-	-
M25/2^{-1}/20-30	51.8	17.8	15.2	9.2	2.4	1.4	0.2	0.3	0.2	0.2	0.3	0.1	0.06	-	-	0.3	-	-	-	-	-	-
M26/1/20-30	48.2	19.2	17.4	5.9	3.8	0.9	0.9	0.3	0.2	0.6	0.5	0.1	0.2	-	0.7	0.3	0.1	0.06	-	-	-	-
M27/1/20-30	50.1	20.8	19.3	4.1	3.2	0.7	0.7	0.2	0.05	0.3	0.1	0.03	0.02	-	-	-	-	-	-	0.01	-	-
M28/1/20-30	48.9	16.4	14.1	6.8	7.7	1.8	0.9	2.3	0.1	0.3	0.1	0.1	0.03	-	-	-	-	-	-	-	-	-
M29/1/20-30	51.8	19.6	15.9	7.3	1.9	1.4	0.6	0.3	0.1	0.08	0.2	-	-	-	-	0.2	0.04	-	-	-	0.05	-
M30/4/20-30	46.7	20.6	17.8	6	5.7	0.7	0.7	0.6	0.1	0.1	0.1	0.3	-	-	-	0.08	-	-	-	-	-	-
M31/4/20-30	40.8	17.5	19.9	8.4	5.4	0.7	1.4	0.5	2.9	0.5	1.4	0.08	0.05	-	-	0.1	0.05	-	-	-	-	-

M32/2/30	46.4	17.5	9.2	5.7	12.4	0.3	2.7	1	3.8	-	0.1	0.06	0.05	-	-	0.3	0.03	-	-	-	-	-
M33/5^{-1}/30-40	49.5	15.1	17.8	8.5	4.2	1.6	0.6	0.4	0.07	0.2	0.1	0.2	-	-	-	0.05		-	-	-	-	-
M34/3/30-40	51.6	14.8	16.3	4.1	5.4	0.5	2.3	0.5	3.9	-	0.2	0.02	0.06	-	-	0.04	-	-	-	-	-	-
M35/7^{+1}/30-40	53.2	12.7	22.2	6.3	2.6	1.2	0.3	0.2	0.2	-	0.6	0.01	0.02	-	-	0.01	-	-	-	-	-	-
M-S01/3/20	53.7	7.3	20.4	8.4	4.4	1.6	0.8	1.4	0.08	0.1	0.5	0.05	0.05	0.1	-	0.07	0.03	0.08	-	-	-	0.2
M-S02/4/60	49.9	23.5	13	7	3.4	1	0.7	0.3	0.1	0.1	0.1	0.05	0.08	-	-	0.1	0.02	0.06	-	-	-	0.04

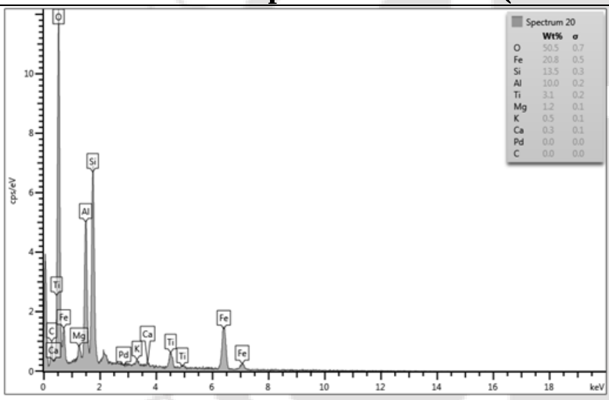
Figure 4.3: EDX graphs and photomicrographs of all the pottery and soil sample of Myrkhan pottery

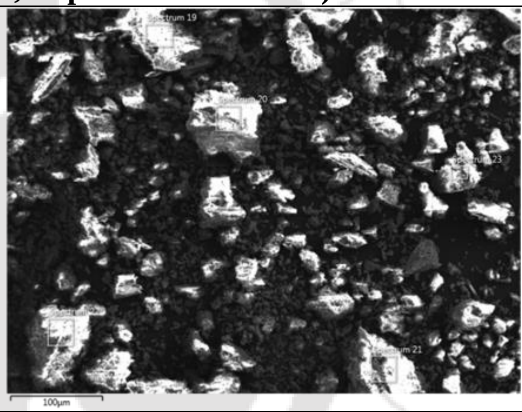
Graph 1: M1/2^{-1}/0-20(Trench: 2-1, Depth: 0c.m.-20c.m.)



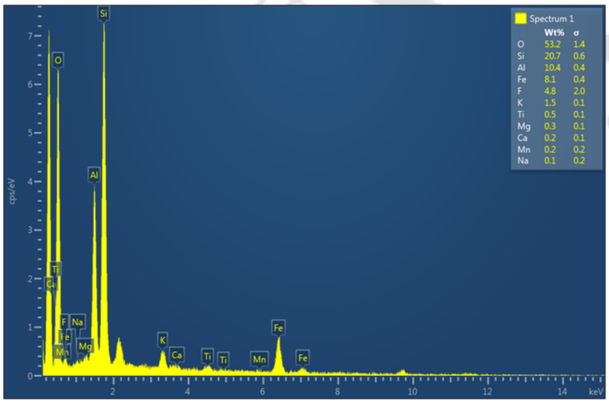


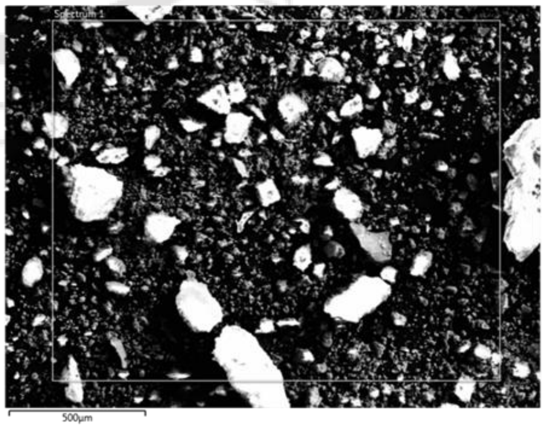
Graph 2: M2/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)



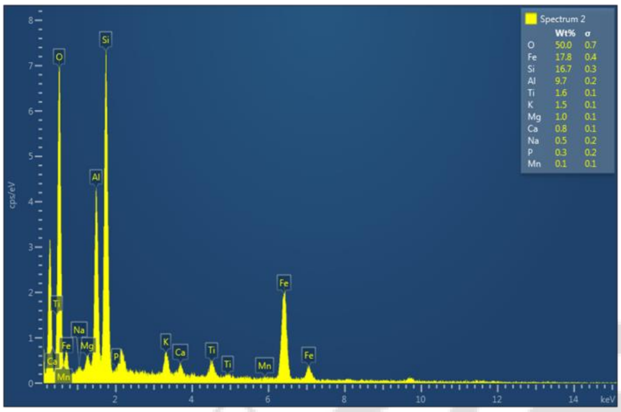


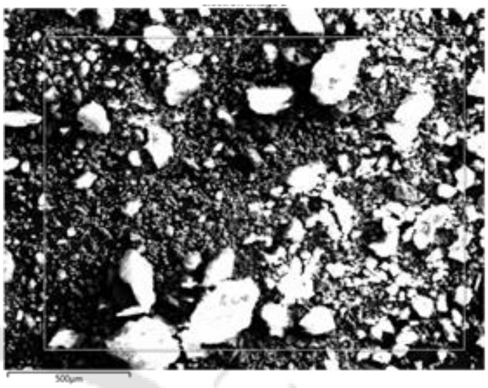
Graph 3: M3/3/30-40(Trench: 3, Depth: 30c.m.-40c.m.)



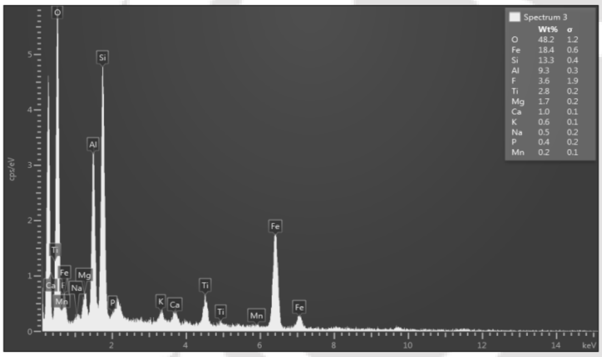


Graph 4: M4/5^{+2}/0-50(Trench: 5+2, Depth: 0c.m.-50c.m.)

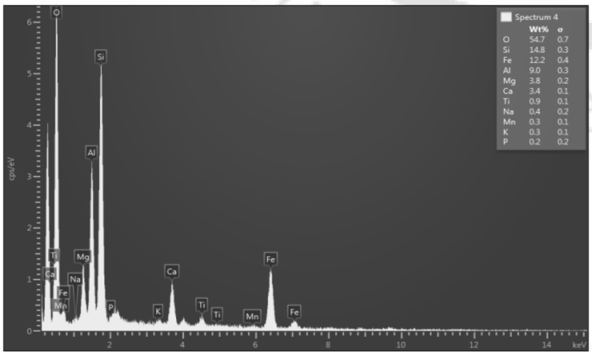




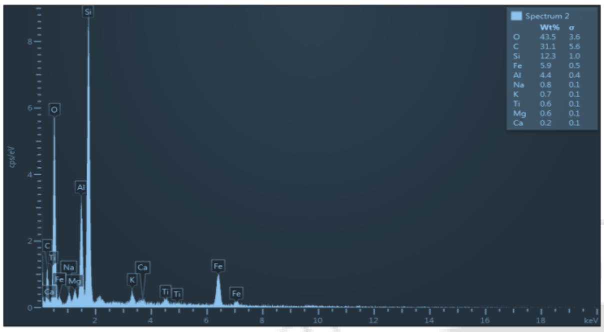
Graph5: M5/7^{+1}/0-20(Trench: 7+1, Depth: 0c.m.-20c.m.)

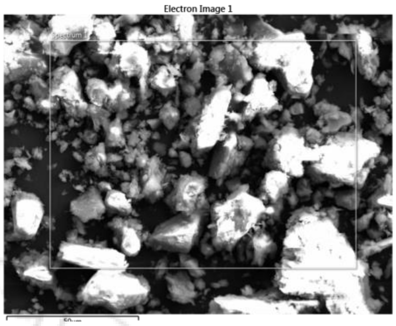


Graph6: M6/7^{+1}/0-20(Trench: 7+1, Depth: 0c.m.-20c.m.)

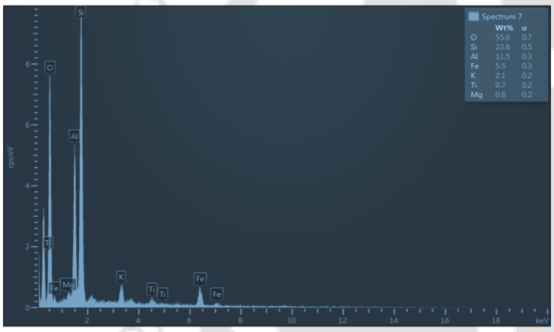


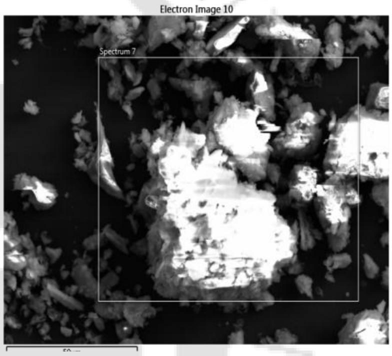
Graph 7: **M7/5-1/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)**



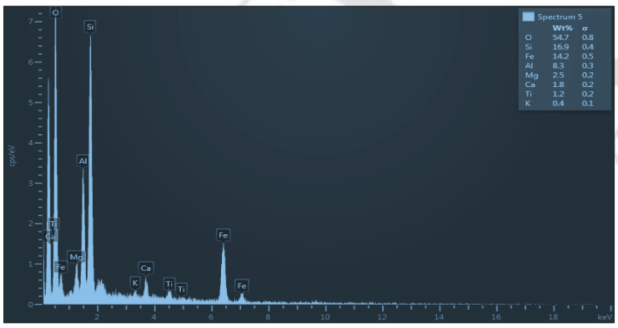


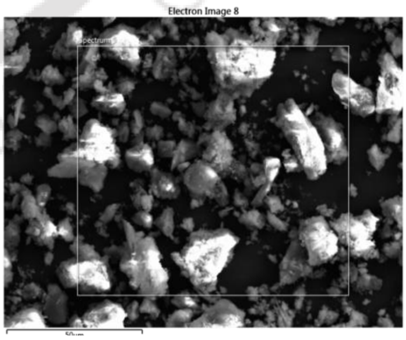
Graph 8: **M8/1/30-40(Trench: 1, Depth: 30c.m.-40c.m.)**



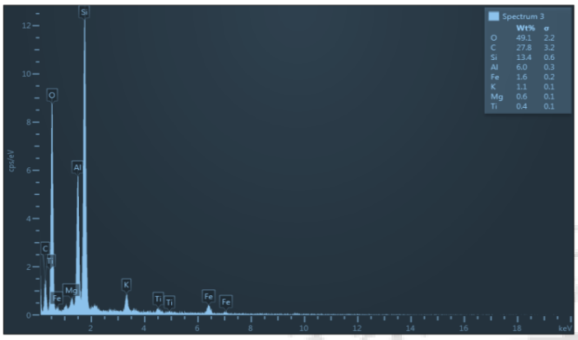


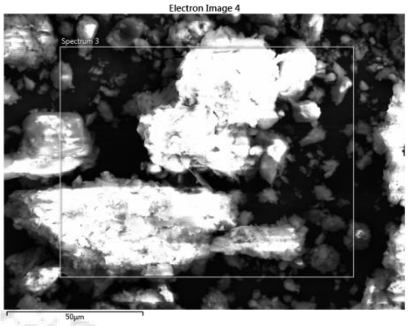
Graph 9: **M9/2/20-30(Trench: 2, Depth: 20c.m.-30c.m.)**



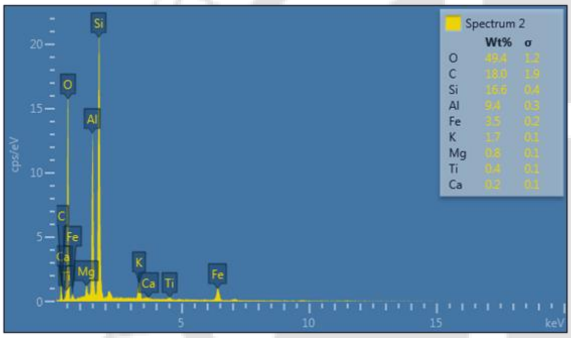


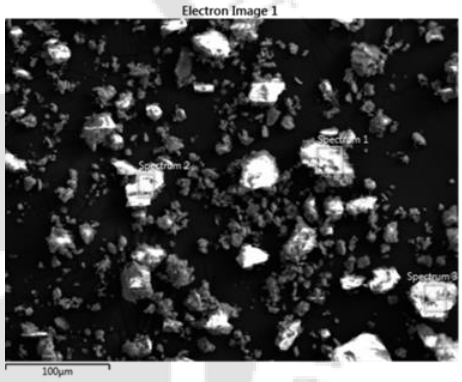
Graph 10: **M10/2^{-1}/0-20(Trench: 2-1, Depth: 0c.m.-20c.m.)**



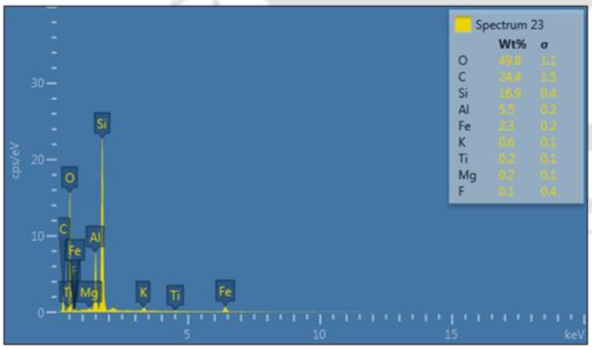


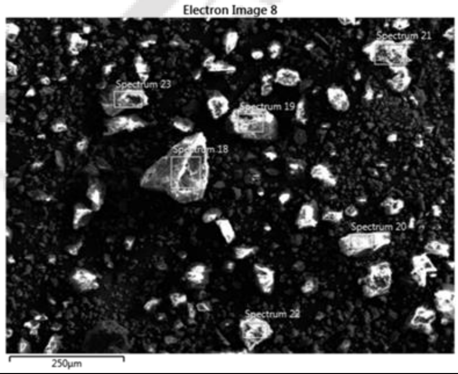
Graph 11: M11/2^{-1}/0-20(Trench:2-1, Depth: 0c.m.-20c.m.)



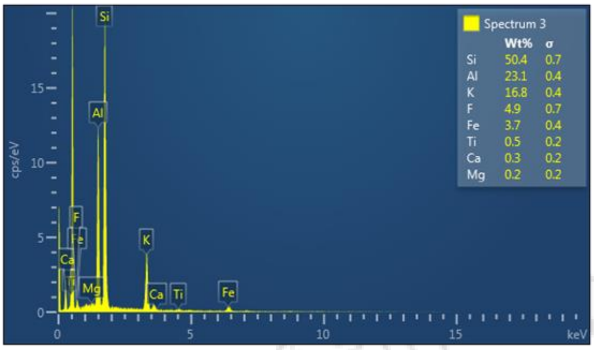


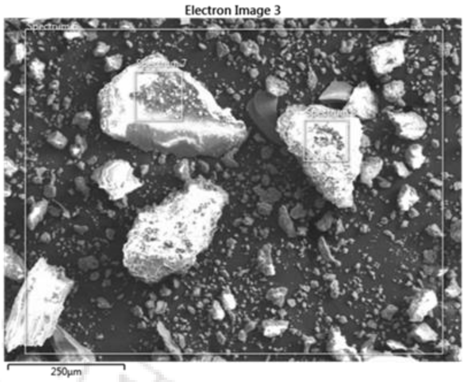
Graph 12: M12/2^{-1}/0-20(Trench: 2-1, Depth: 0c.m.-20c.m.)



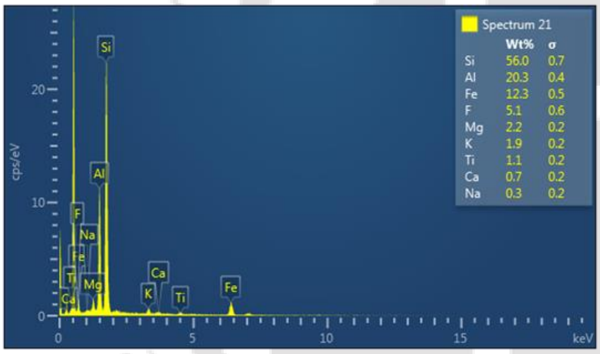


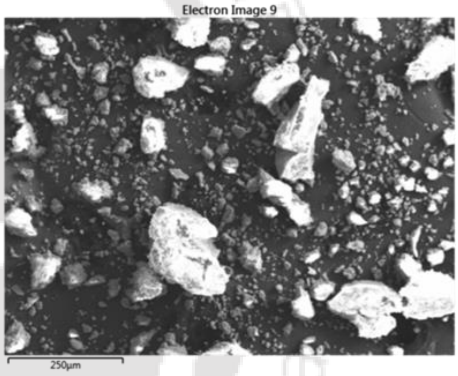
Graph 13: M13/7^{+1}/20-30(Trench: 7+1, Depth: 20c.m.-30c.m.)



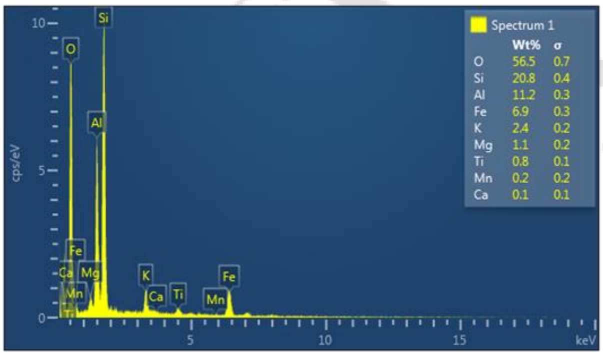


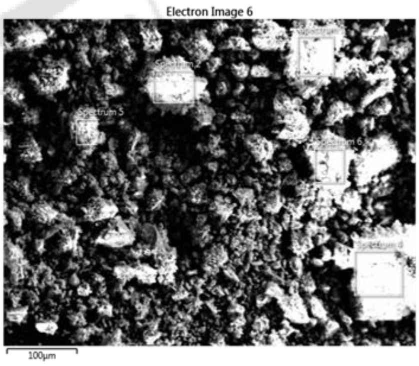
Graph 14: M14/5^{-2}/30-40(Trench: 5-2, Depth: 30c.m.-40c.m.)



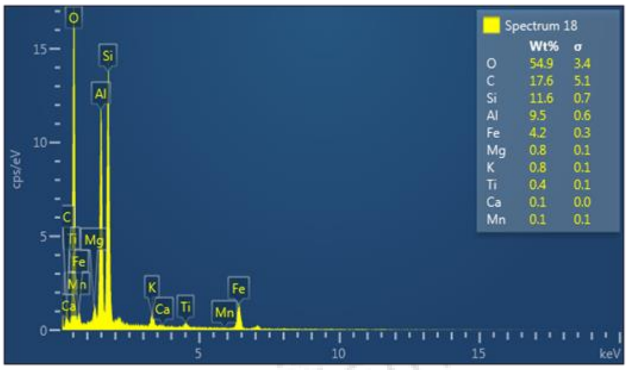


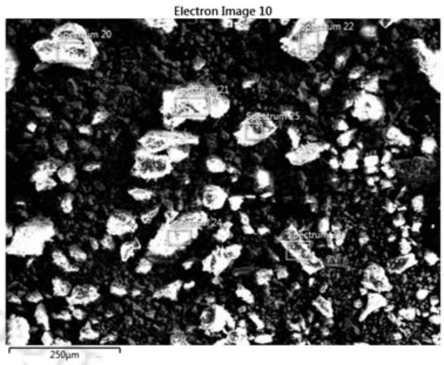
Graph 15: M15/8^{-1}/30-40(Trench: 8-1, Depth: 30c.m.-40c.m.)



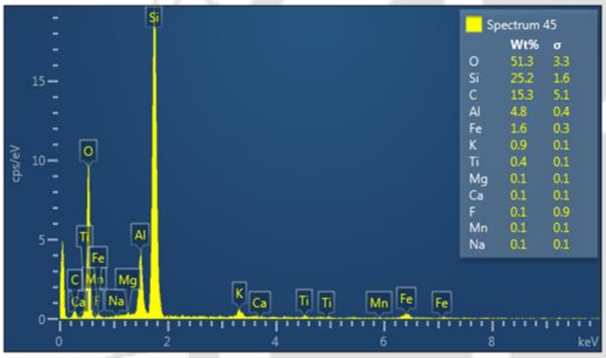


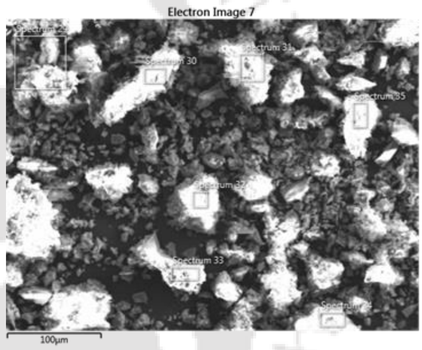
Graph 16: M16/5^{+2}/20-30(Trench: 5+2, Depth: 20c.m.-30c.m.)



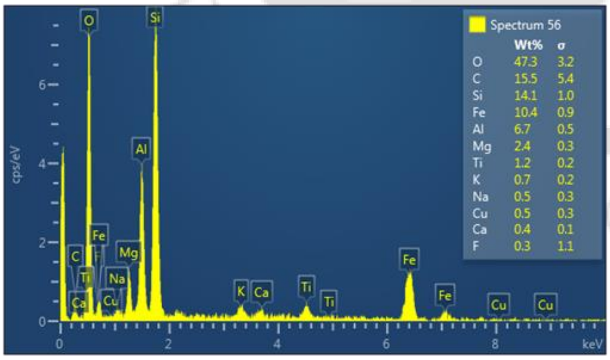


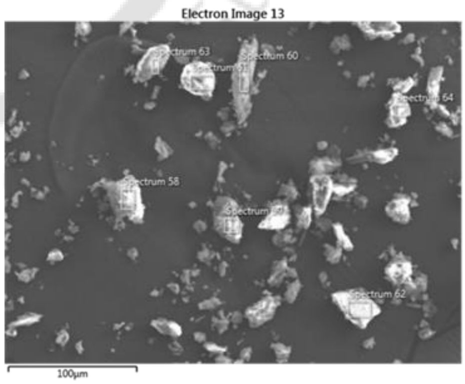
Graph 17: M17/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)



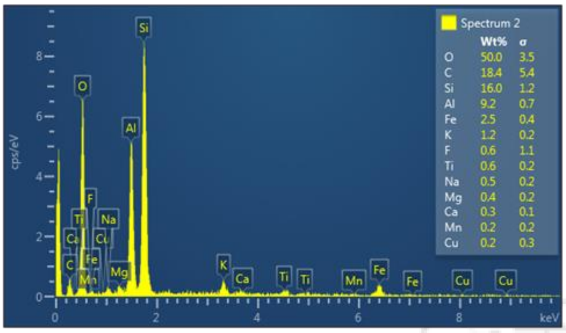


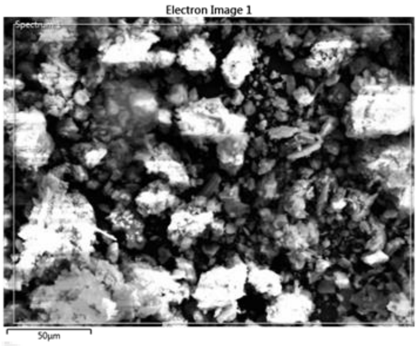
Graph 18: M18/5^{-1}/40-50(Trench: 5-1, Depth: 40c.m.-50c.m.)



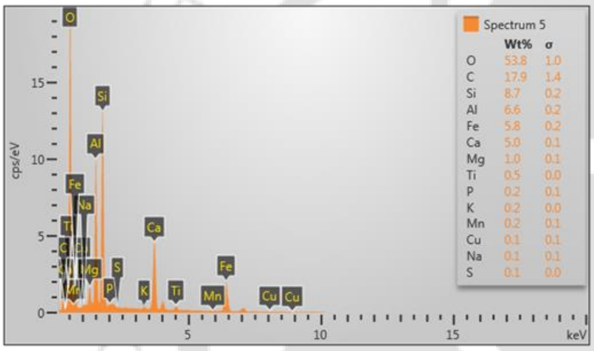


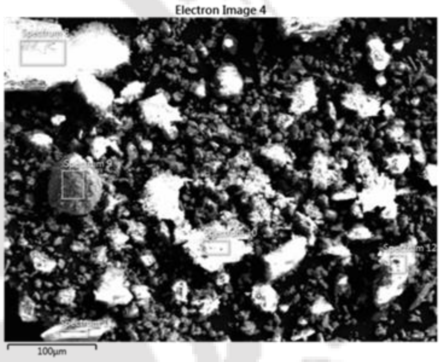
Graph 19: M19/5^{+2}/40-50(Trench: 5+2, Depth: 40c.m.-50c.m.)



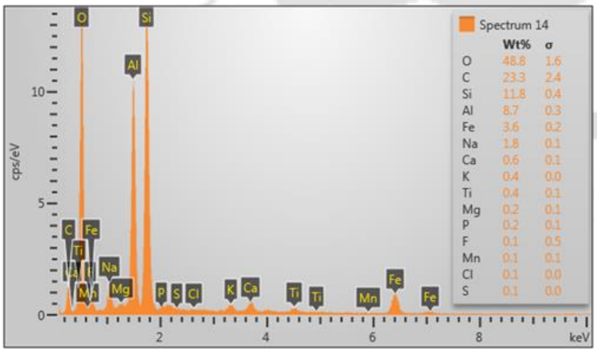


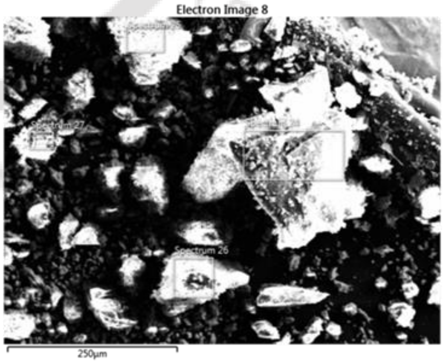
Graph 20: M20/3/20-30(Trench: 3, Depth: 20c.m.-30c.m.)



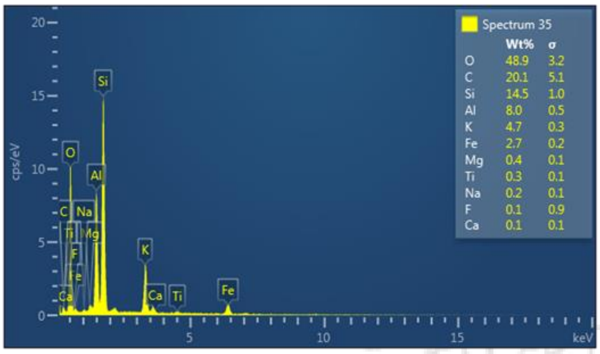


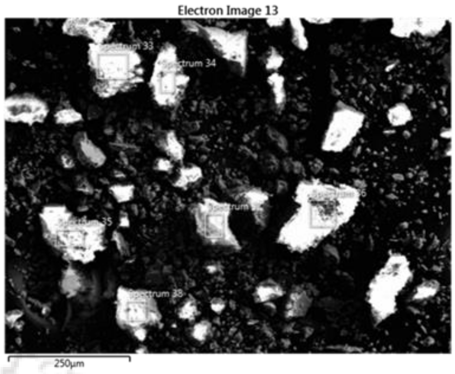
Graph 21: M21/5^{+2}/20-30(Trench: 5+2, Depth: 20c.m.-30c.m.)



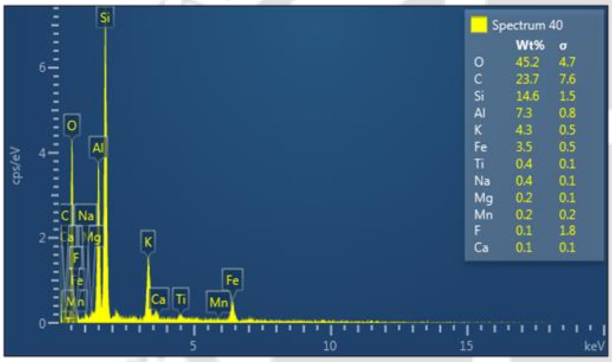


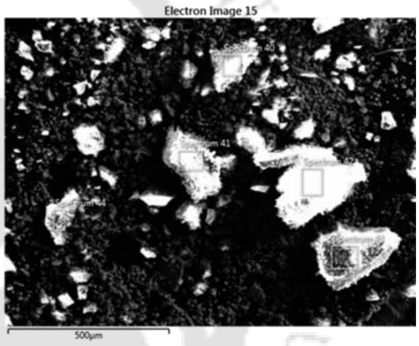
Graph 22: M22/5^{-1}/20-30(Trench: 5-1, Depth: 20c.m.-30c.m.)



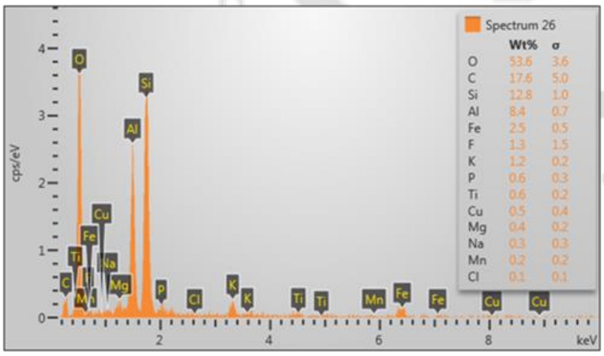


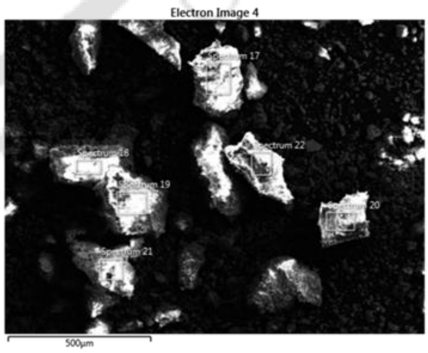
Graph 23: M23/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)



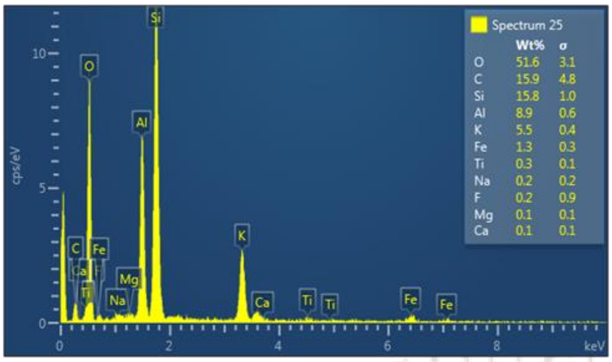


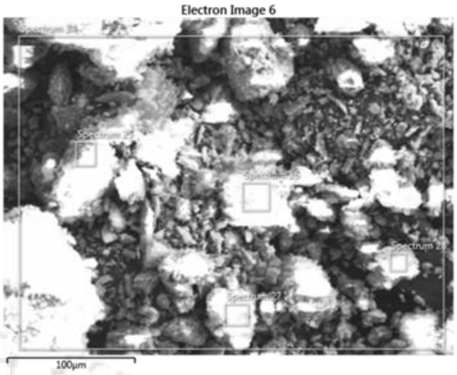
Graph 24: M24/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)



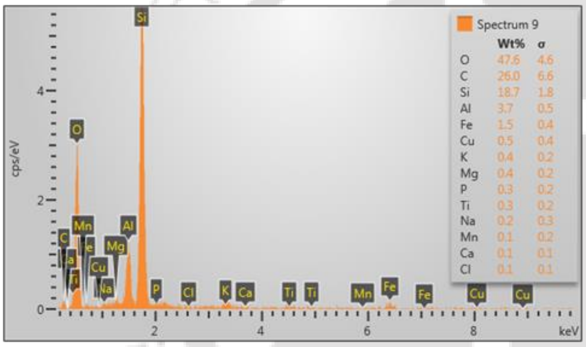


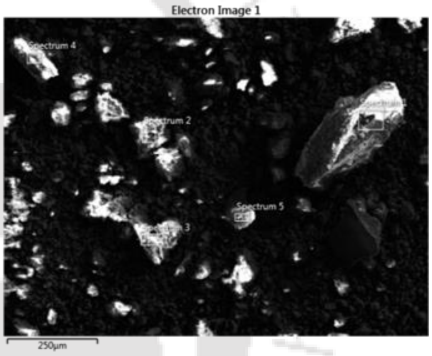
Graph 25: M25/2^{-1}/20-30(Trench: 2-1, Depth: 20c.m.-30c.m.)



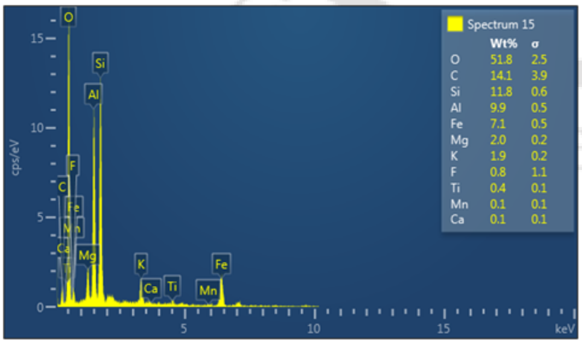


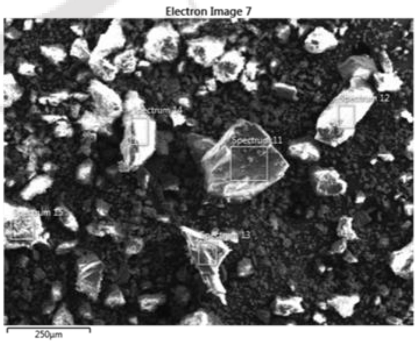
Graph 26: M26/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)

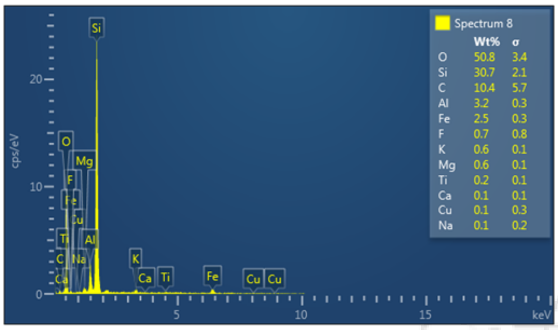
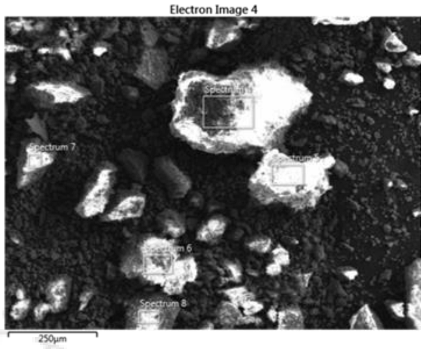


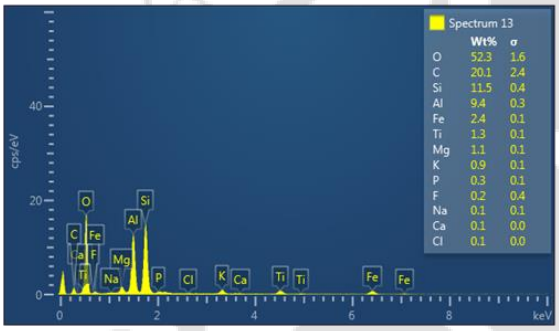
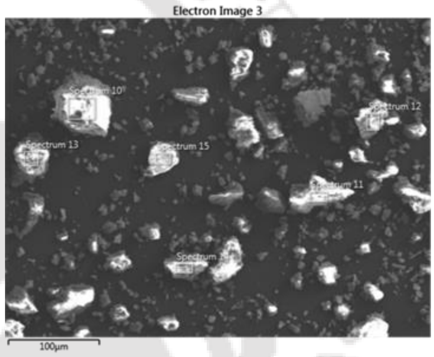


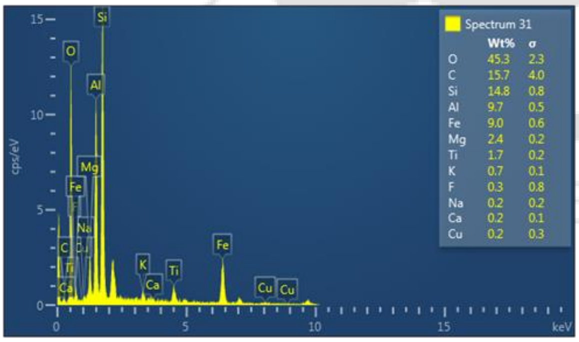
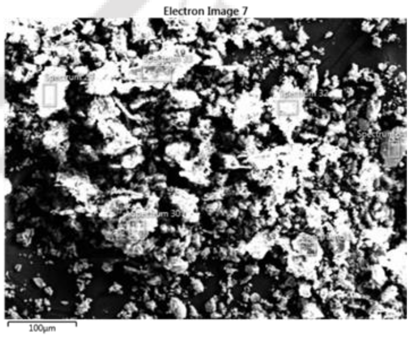
Graph 27: M27/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)



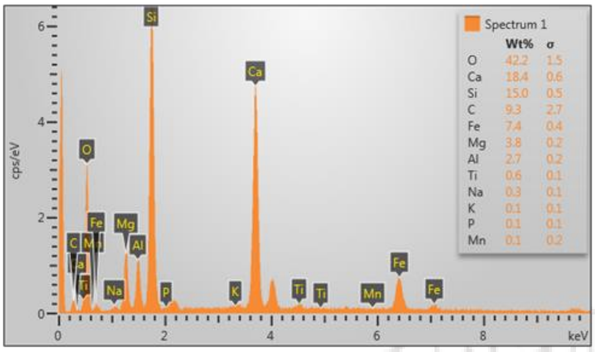


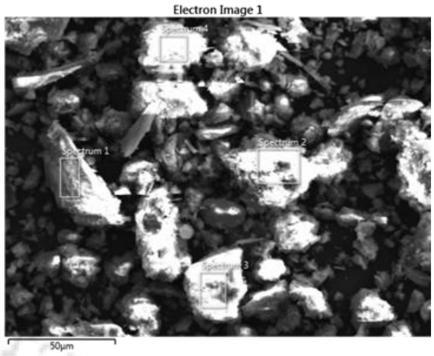
Graph 28: M28/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)	
	

Graph 29: M29/1/20-30(Trench: 1, Depth: 20c.m.-30c.m.)	
	

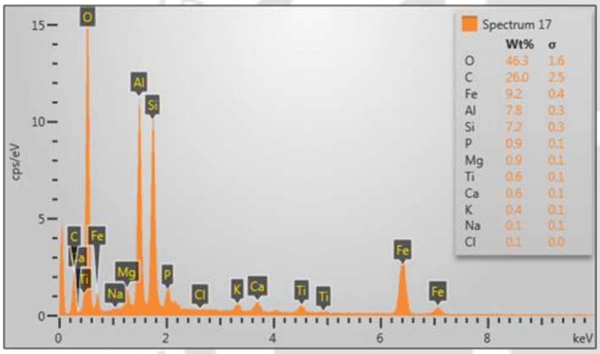
Graph 30: M30/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)	
	

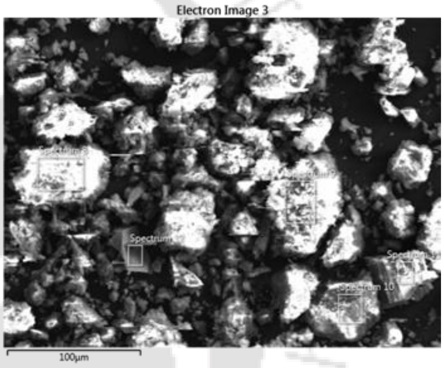
Graph 31: M31/4/20-30(Trench: 4, Depth: 20c.m.-30c.m.)



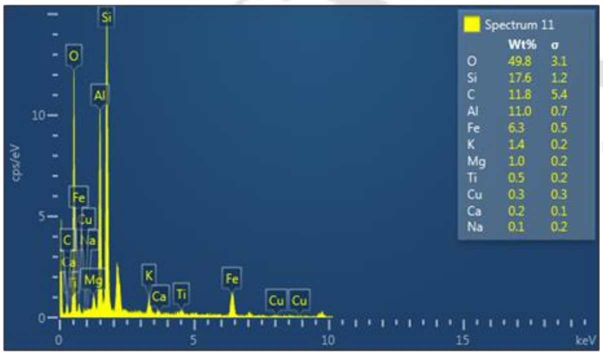


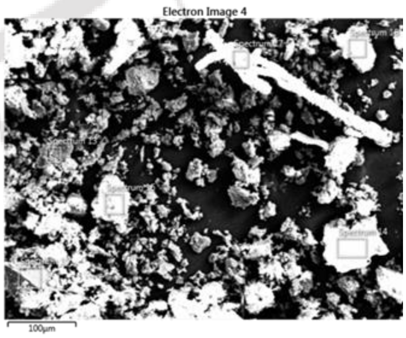
Graph 32: M32/2/30(Trench: 2, Depth: 30c.m.)



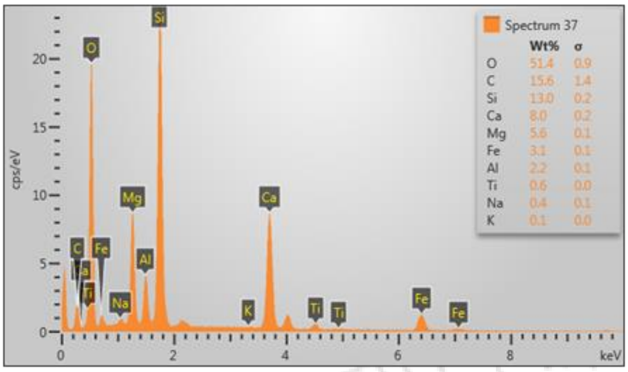


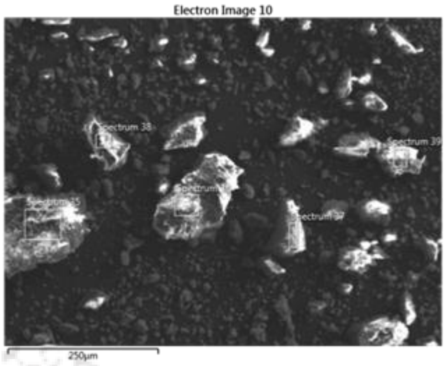
Graph 33: M33/5-1/30-40(Trench: 5-1, Depth: 30c.m.-40c.m.)



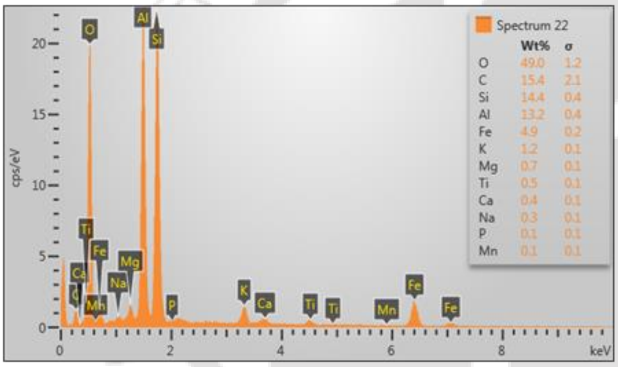


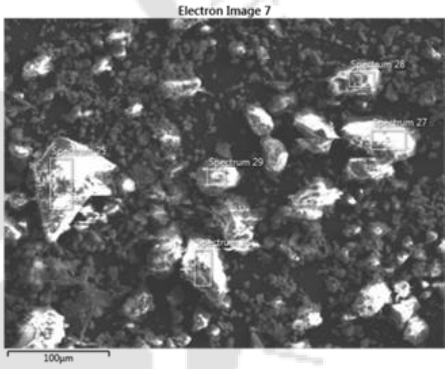
Graph 34: M34/3/30-40(Trench: 3, Depth: 30c.m.-40c.m.)



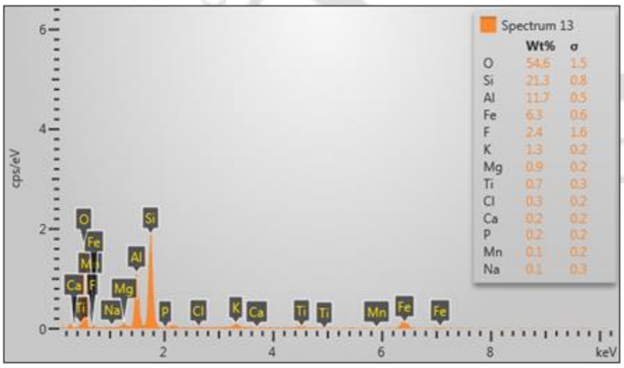


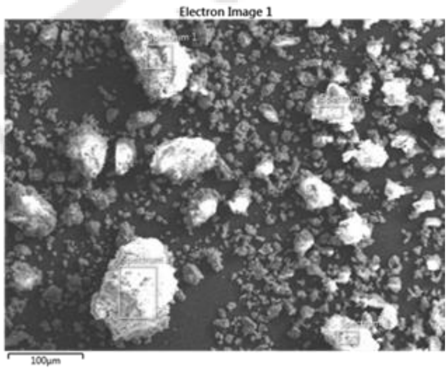
Graph 35: M35/7^{+1}/30-40(Trench: 7+1, Depth: 30c.m.-40c.m.)



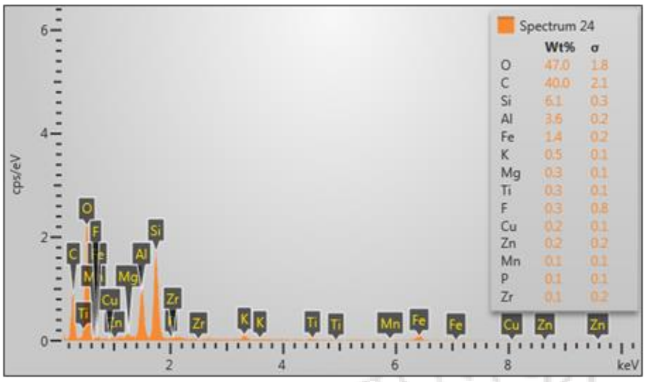


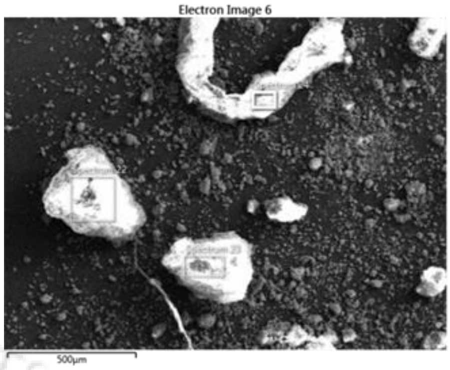
Graph 36: M-S1/3/20(Trench: 3, Depth: 20c.m.)





Graph 37: M-S2/4/60(Trench: 4, Depth: 60c.m.)





EDX analysis was conducted on a total of 37 samples, comprising both pottery and soil specimens, to discern their chemical composition. The potsherds revealed the presence of major and minor elements detectable through EDX. These elements include O (Oxygen), C (Carbon), Si (Silicon), Fe (Iron), K (Potassium), Mg (Magnesium), Ti (Titanium), Ca (Calcium), F (Fluorine), Na (Sodium), Cu (Copper), Mn (Manganese), Zn (Zinc), Br (Bromine), P (Phosphorus), Cl (Chlorine), S (Sulfur), Cr (Chromium), Nb (Niobium), Ba (Barium), and Zr (Zirconium).

The EDX spectra revealed that Si (Silicon), Al (Aluminum), Fe (Iron), and K (Potassium) are the predominant elements across all samples, with variations observed in their elemental composition. Following O (Oxygen) and C (Carbon), Si (Silicon) and Al (Aluminum) emerge as the major elements, characterized by relatively higher percentages. Additionally, minor elemental constituents detected in the analysis include Zn (Zinc), Br (Bromine), Cr (Chromium), Nb (Niobium), Ba (Barium), and Zr (Zirconium).

The sample M23 exhibits the highest percentage of Si (Silicon) at 23.9%, while the lowest Si content is observed in sample M20 at 8.6%. The consistent presence of Silicon across all samples suggests the utilization of raw materials rich in quartz for pottery production, a finding corroborated by XRD results.

Al (Aluminum) is also prevalent in relatively high percentages across all samples, except in sample M01. Aluminum content ranges from 4.1 wt. % to 11.5 wt. %, with the highest concentration found in sample M08 and the lowest in samples M34 and M27, at 11.5 wt % and 4.1 wt %, respectively.

Fe (Iron) content is notably elevated in several samples, with the highest percentage reaching 20.8% in sample M02. Conversely, the lowest Fe concentration is recorded at 1.6%

in sample M10. The prevalence of iron in the clay composition suggests the incorporation of iron-rich materials in the paste recipe. Exceptions to this trend include samples M29, M01, M08, and M09, where iron content is relatively lower at 1.9 wt. %, 5.2 wt. %, 5.5 wt. %, and 5.9 wt. %, respectively.

Calcium is detected in all samples, albeit at relatively low percentages, except for samples M12, M16, and M22. Most of the Neolithic potsherds show higher quantity of Si and lower content of Ca in their composition, which confirmed non-calcareous clay with simple mineral deposits (Damjanovic, et al., 2011). The presence of higher quantity of Si and Al2 reveal occurrence of Alumina- Silicate rich minerals such as clay minerals and Feldspars (Vecstaudza , Jakovlevs, Berzina-Cimdina , & Stikane , 2013).

Fluorine (F) is detected in samples M03 and M05, with concentrations of 4.8% and 3.6%, respectively.

The elemental analysis reveals a distinction in composition between the soil samples and the pottery samples, notably in the presence of Zr (Zirconium) in the former. However, the Zirconium content in both soil samples is not significantly high.

The occurrence of similar elements across the samples implies a shared history regarding the use of raw materials or manufacturing conditions. Additionally, the possibility of pottery transportation from one location to another could also be considered (Karapukaityte, Pakutinskiene, Tautkus, & Kareiva, 2006).

4.1.4 Hardness Test

Hardness testing involves measuring the resistance of a material to indentation or scratching, typically using standardized methods such as the Mohs scale, Vickers hardness test, or Brinell hardness test. In the context of Neolithic pottery, hardness tests provide insights into the mechanical properties of pottery samples, including its strength, durability, and resistance to wear and abrasion. By comparing the hardness of different pottery fragments, researchers can infer variations in clay composition, firing temperatures, and manufacturing techniques employed by ancient potters. In this study, method of Moh's Scale is used for hardness analysis. It is a property by which minerals may be described relative to a standard scale of 10 minerals.

The hardness of Neolithic pottery can provide insights into its intended use and functionality. For example, vessels designed for cooking or storage may exhibit higher hardness values to withstand thermal stress and mechanical strain, while ceremonial or decorative items may prioritize aesthetic qualities over mechanical strength. Hardness test analysis offers quantitative data on the mechanical properties of pottery, complementing qualitative observations from visual examination and chemical analysis. It provides a non-destructive means of characterizing pottery artifacts and can be performed using portable or laboratory-based equipment.

I) Experimental and Sample preparation

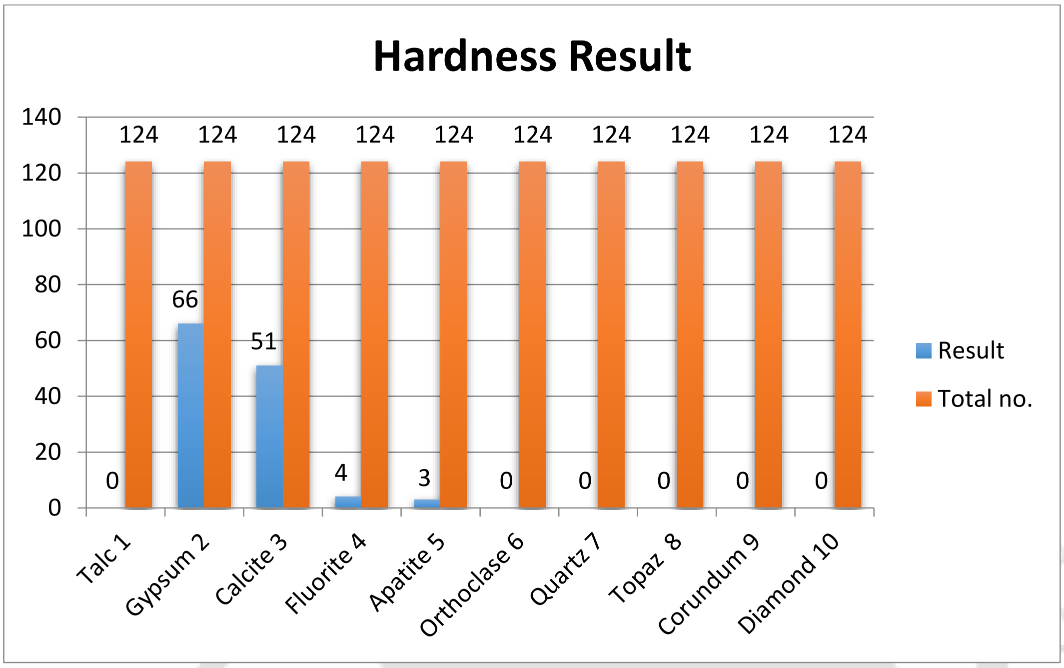
The Moh's scale of mineral hardness is a qualitative ordinal scale characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material. Created in 1812 by German Geologist and mineralogist Friedrich Moh's, it is one of several definitions of hardness in materials science. The minerals that make up the Moh's scale are listed in the table below. Pottery samples representing various types, forms, and cultural contexts are selected for analysis. These samples may include sherds, fragments, or complete vessels obtained from archaeological excavations or museum collections. In the present study samples from different Layers and trenches belonging to all the three types of pottery have been chosen for experiment. The degree of hardness is determined by observing the comparative ease or difficulty with which one mineral is scratched by another or by a steel tool.

Before conducting hardness tests, the surfaces of pottery specimens are cleaned and smoothed to remove any dirt, debris, or surface coatings that may interfere with the accuracy of the measurements. This is typically achieved through gentle brushing, wiping, or polishing using soft materials to avoid scratching the pottery surface. The Mohs hardness scale consists of a series of ten minerals, ranging from talc (rated 1) to diamond (rated 10), each representing a standard reference for comparative hardness assessment. To conduct the hardness test, a set of mineral picks or styluses corresponding to different hardness levels is used.Starting with the softest mineral (talc), each mineral pick is sequentially applied to the testing points on the pottery surface with a consistent pressure. The hardness of the pottery material is assessed based on the presence or absence of scratches produced by the mineral picks. The pick corresponding to the lowest hardness level capable of scratching the pottery surface indicates its Mohs hardness value.

The results of the hardness tests are recorded systematically, indicating the Mohs hardness value assigned to each testing point on the pottery specimen. Additionally, qualitative observations regarding the appearance, depth, and extent of scratches are documented to provide context for the hardness measurements.

II) Result of Hardness Test

Figure 4.4: The Moh's Scale measurement values have been summarized in the Pie Chart below:



For the hardness assessment of the sherds, a total of one hundred and twenty-four samples were subjected to testing using the Mohs scale. The findings reveal that the Neolithic sherds from Myrkhan exhibit predominantly low hardness values, with only a small proportion displaying medium hardness. Specifically, the hardness values range from 2 to 5, indicating a coarse nature of the potsherds. Among the tested samples, 66 sherds (53%) exhibit a hardness value of 2, while 51 sherds (41%) display a value of 3. Additionally, 4 sherds (3%) have a hardness value of 4, and the remaining 3 samples exhibit a hardness value of 5. These results collectively suggest that the majority of the potsherds possess relatively low hardness values.

4.1.5 Porosity Analysis

Porosity refers to the volume fraction of void space in a material. In the context of Neolithic pottery, porosity analysis involves measuring the volume of pores or voids within the ceramic matrix, which can be indicative of the firing temperature, clay composition, and post-firing treatments applied to the pottery. Pores in archaeological ceramics can form in a number of different ways and reflect both deliberate choices and uncontrollable factors. Porosity has long been recognized as an important feature to characterize in any study of ceramics (Rice, 2015). Porosity study can indicate whether the potsherds collected from a site are belonging to one source or from various sources of manufacture. There are several methods of estimating porosity of pottery. Boiling water method of apparent porosity test is used in the present study for evaluating levels of porosity of the excavated sherds of Myrkahn.

The formula used for the calculation of porosity has been repeated for all the representative sample collected from the site and then compared their porosity.

Throughout the clay processing and vessel fabrication stages, air bubbles may become entrapped within the material. Subsequent shrinkage during both drying and firing processes can expand these pores. Additionally, as carbonates dissociate and organic materials burn out during firing, further porosity may be generated. Conversely, if firing temperatures reach sufficiently high levels, porosity can decrease due to verification. The addition of temper additives such as sand or grog can maintain higher porosity levels, as the clay tends to contract away from these particles during drying and firing, thereby creating additional pore space (Reedy , Anderson , & Terry , 2017; Rice, 2015).

Certain ceramics are intentionally crafted to exhibit specific levels of porosity tailored to particular functions, whereas others are engineered to have minimal porosity. For instance, pottery vessels designated for cooking purposes necessitate a degree of porosity to accommodate thermal expansion and contraction over open flames, thus mitigating the risk of cracking. Conversely, storage ceramics designed to maintain contents at cooler temperatures require a pore structure conducive to evaporation; during usage, these pores may undergo further enhancement. The ability to quantify and comprehend pore characteristics holds significance as porosity serves as a direct reflection of the deliberate choices made by individuals in selecting and processing their raw materials, as well as in crafting and firing their ceramic wares.

I) Experimental and sample preparation

There is no particular way of to undergo sample preparation for this method. The only thing that has to be done before proceed with the experiment is to clean the surfaces of the collected pottery samples through brushing or wiping both the inner and outer surfaces of the samples. For porosity analysis boiling water method has been used. Dry weight of the potsherd is measured first and then boil it in a maximum temperature of 100^{o} C. After boiling, the excess water is soaked out using a tissue paper and measure the weight again. Using both the dry weight and wet weight the D value is calculated which gives us the porosity level of a potsherd.

II) Result of Porosity analysis

The result of Porosity has been showed in the table below-

Table 4.6: Porosity result of 73 pottery Sample

Sample No.	Wet Weight (g)	Dry Weight(g)	Volume (ml=g)	Porosity (w-d)/v)*100
1	3.85	3.58	2	13.5
2	11.34	9.96	5	27.6
3	7.19	6.75	3	14.66
4	4.76	4.42	2	17
5	6.3	5.9	2	20
6	9.67	8.68	3	33
7	5.84	5.52	2	16
8	5.75	5.32	2	21.5
9	3.94	3.73	2	10.5
10	4.8	4.38	2	21
11	4.16	3.93	2	11.5
12	16.84	15.76	8	13.5
13	6.7	6.21	4	12.25
14	5.61	5.2	3	13.66
15	3.25	3.01	2	12
16	4.74	4.43	2	15.5
17	6.23	5.8	3	14.33
18	3.03	2.85	1	18
19	6.04	5.66	3	12.66
20	4.63	4.35	2	14
21	25.33	23.61	10	17.2
22	4.27	3.81	2	23
23	18.06	16.82	9	13.77
24	6.07	5.6	3	15.66
25	9.36	8.66	2	35
26	3.19	2.98	2	10.5
27	4.6	4.27	2	16.5
28	7.31	6.81	3	16.66

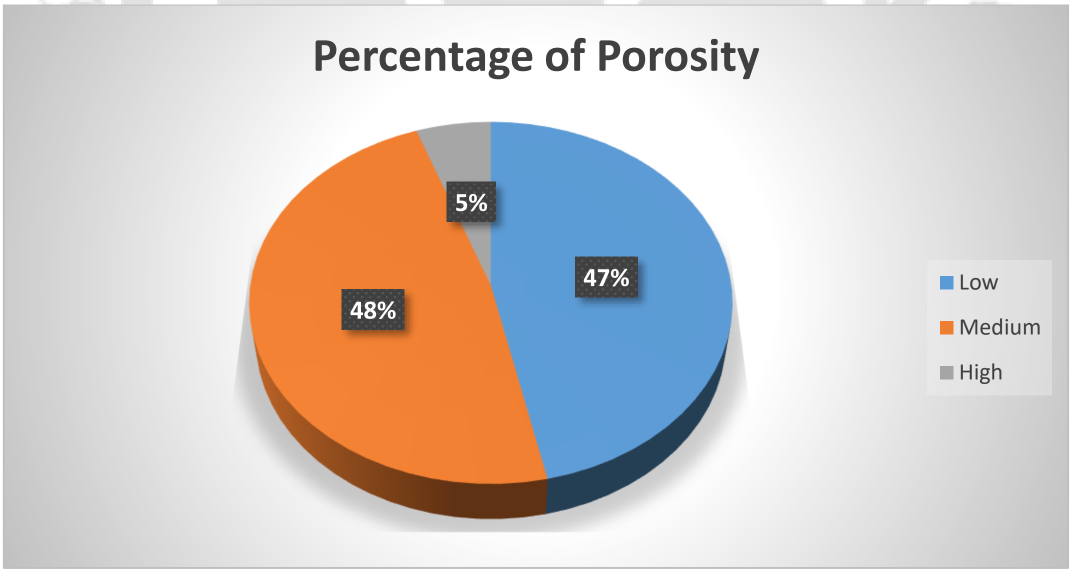
29	4.39	3.97	2	21
30	4.34	3.84	2	25
31	5.16	4.69	2.5	18.8
32	9.3	8.3	4	25
33	4.14	3.72	2	21
34	5.12	4.72	2	20
35	4.87	4.59	2	14
36	7.09	6.54	3	18.33
37	9.09	8.52	5	11.4
38	6.7	6.18	4	13
39	3.54	3.33	2	10.5
40	4.14	3.86	2	14
41	4.68	4.42	2	13
42	12.14	10.81	5.25	25.33
43	4.65	4.22	2	21.5
44	13.79	12.73	6	17.66
45	9.83	8.91	4	23
46	4.54	4.2	2	17
47	3.96	3.65	2	15.5
48	3.61	3.36	2	12.5
49	10.49	9.76	5	14.6
50	6.31	5.81	3	16.66
51	7.51	7.06	4	11.25
52	6.47	6.07	3	13.33
53	9.85	9.28	6.66	8.55
54	9.15	8.49	4	16.5
55	4.69	4.29	2	20
56	5.8	5.29	3	17
57	5.7	5.35	3	11.66
58	7.28	6.75	3.25	16.30
59	9.26	8.78	4	12
60	6.6	6.19	3	13.66
61	6.27	5.89	3	12.66
62	4.22	3.88	2	17
63	3.85	3.54	2	15.5
64	7.89	7.23	4	16.5
65	6.65	6.21	3.25	13.53

66	8.1	7.38	4	18
67	10.08	9.59	4	12.25
68	3.09	2.88	2	10.5
69	12.08	11.28	6	13.33
70	14.76	13.77	7	14.14
71	9.63	9.12	6	8.5
72	6.62	6.19	2	21.5
73	14.71	13.91	6.66	12.01

The porosity level found after calculation ranges from minimum 8.5 to maximum 35g. The results of porosity have been divided into three levels to figure out if there are any similarities of the pottery types along with its porosity level, which will give us a rough idea about its recipes and manufacturing processes. The three levels are considered as Low, Medium and High.

1. **Low**- Level of porosity ranges from 5-15
2. **Medium**- Level of porosity ranges from 15.1-25
3. **High**- Level of porosity ranges from 25.1-35

Figure 4.5: Pie chart representing the percentage of three porosity levels of the experimented samples



After the calculation of the porosity level of the sherds, it has been found that 34 sherds are under low porosity level, 35 sherds are showing medium porosity level and only 4 sherds are highly porous. Therefore, the percentage of low and medium porous level are almost same.

4.1.6 Petrographic Image Analysis

A ceramic thin section is a transparent polished piece, whose thickness varies from 20-30 µm, mounted on a glass slide, use for studying cultural and technical issues of archaeological significance of the craft, pottery. Study of thin section petrography gives us idea about the non-plastic inclusions in the pottery samples. Matrix is basically the clay defined by its size that is 20µ and other minerals are more than 20 µ in size, which is the basic criterion to make a difference between matrix and minerals. Non-plastic minerals are may be of four types- rock, minerals, biomass and grog (grind potsherds). Variations in mineralogy reflect differences in raw material sources, clay processing techniques, and firing conditions used by ancient potters. Examination of thin sections reveals the microstructural features of Neolithic pottery, including grain size, shape, orientation, and distribution. These characteristics provide clues about clay preparation methods, forming techniques, and firing regimes employed during pottery production.

I) Experimental and Sample Preparation

Creating thin section slides for petrographic analysis involves several steps. After selection of appropriate sample for analysis, thin sectioning is typically performed using a precision cutting instrument known as a thin section grinder or microtome. A trimmed pottery sample is then fixed on to a glass slide using an appropriate adhesive, such as epoxy resin or cyanoacrylate glue. The mounted sample is sliced into thin sections (usually around 30 micrometers thick) using a diamond-tipped blade or wire saw. These thin sections are then transferred to glass slides and affixed using a mounting medium, such as Canada balsam or synthetic resins.

II) Result of Petrographic Image Analysis

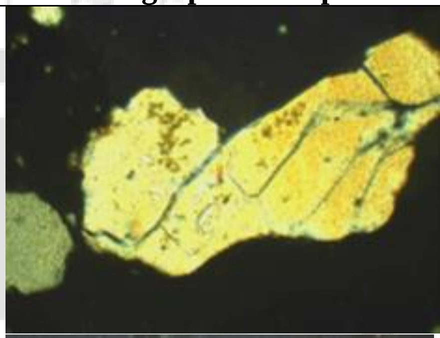
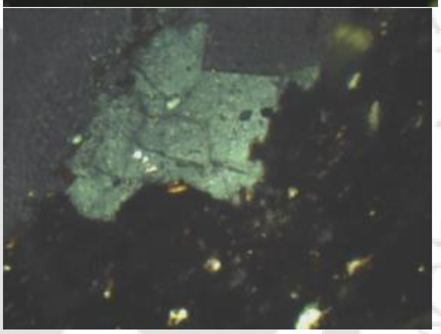
Thin section analysis is done to investigate the composition of the raw materials of the potsherds. It helps to understand the texture of the clay paste and the provenance of the clay sources. The petrographic image analysis makes it easier to differentiate or to establish whether the fabric of all the sherds from the sites are homogenous or heterogeneous in nature, taking into consideration all the observed organic matter, tempering materials and other materials in the thin section. Photomicrographs of thin slides of pottery samples along with description of its findings are discussed below.

Slide- S1:

Description:

The thin section of the sample shows dark brown matirx with the presence of large mineral particle. These particles are identified as quartz grains and mica which is sub angular in shape. Less voids found in the matrix.

Figure 4.6 Photograph and Photomicrograph of Sample 1

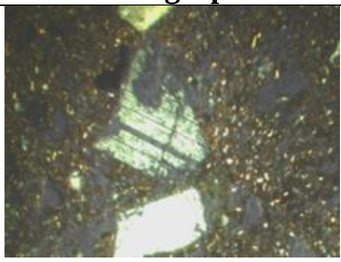
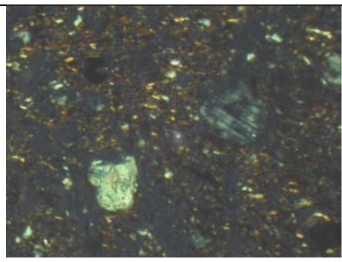
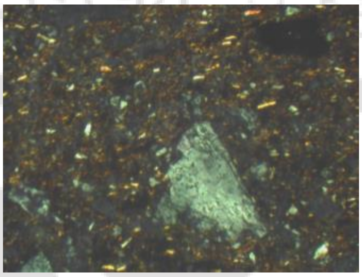
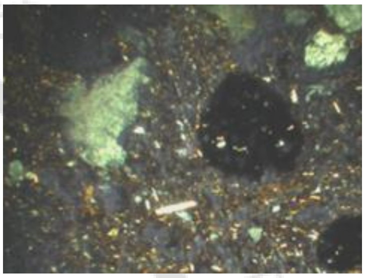
Photograph of sample S1	**Photomicrograph of sample- S1**
 	 

Slide- S2

Description:

Thin section of this sample shows composition of brownish micaceous materials. Voids observed in the matrix. Occurrence of microcline feldspar, plagioclase feldspar, quartz and biotite are observed in the section along with grogs. These are angular to sub angular in shape. Grogs are the crushed ceramic material added as temper to the raw clay during its making process as a raw material of a pottery or other clay item. In pottery its identification is often made in the cross section through microscope

Figure 4.7: Photograph and Photomicrograph of Sample 2

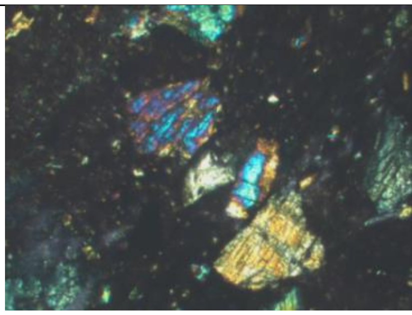
Photograph of sample S2	**Photomicrograph of sample- S2**
	 
	 

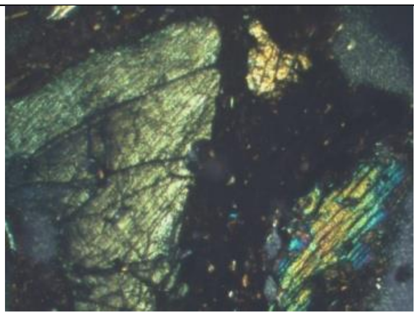
Slide- S3

Description:

The thin section of sample 3 shows dark brown matrix with presence of less voids in it. Matrix is dark brown. Grains are angular to sub angular in shape. The thin section shows presence of quartz, muscovite mica, and biotite mica grains. The layers of biotite mica crystals interlock with muscovite mica which is bright second and third order interference colours. Olivine shows bright up to second order interference colours and shows some opaque minerals along the crystal fractures.

Figure 4.8: Photograph and Photomicrograph of Sample 3

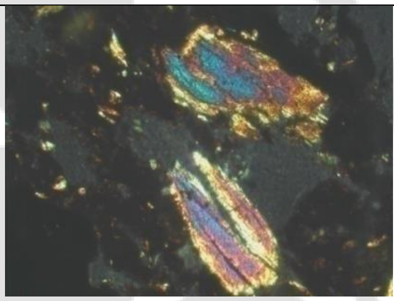
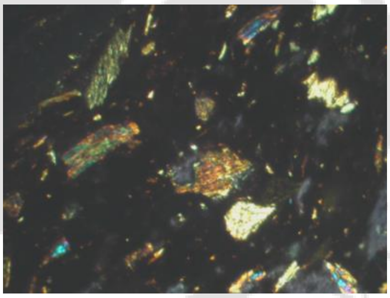
Photograph of sample S3	**Photomicrograph of sample- S3**
	

Slide- S4
Description:

The matrix presence more voids and is deep brown in colour. Particles found in the thin section are quartz, biotite, muscovite mica and the grains are angular to sub-angular in shape.

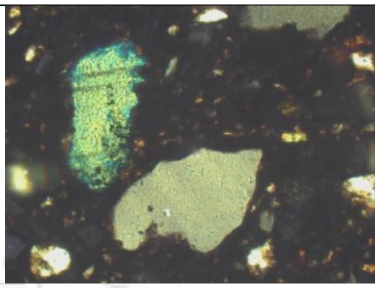
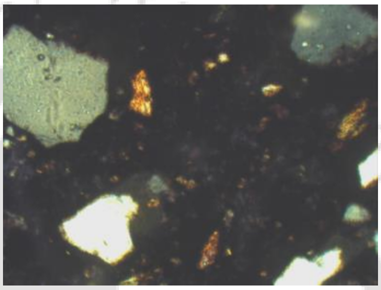
Figure 4.9: Photograph and Photomicrograph of Sample 4

Photograph of sample S4	**Photomicrograph of sample- S4**
	
	

Slide- S5
Description:

The matrix of this thin section is dark brown in colour with fewer voids. The grains are large and irregular in size and the size vary from angular to sub angular. Minerals found in the sample are quartz, biotite mica.

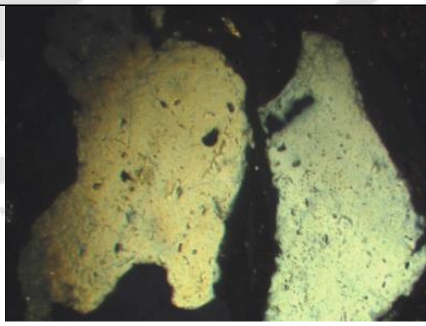
Figure 4.10: Photograph and Photomicrograph of Sample 5

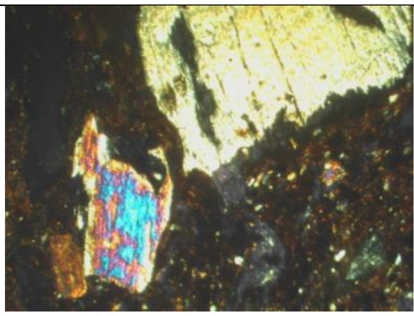
Photograph of sample S5	**Photomicrograph of sample- S5**
	
	

Slide- S6
Description:

Thin section of this sample shows dark brown matrix. Quartz found in this sample are large and sub angular in shape.

Figure 4.11: Photograph and Photomicrograph of Sample 6

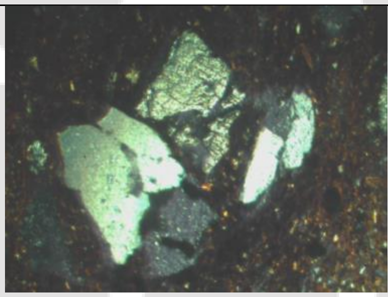
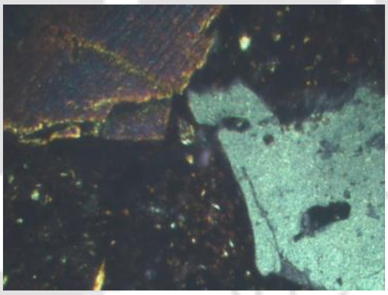
Photograph of sample S6	**Photomicrograph of sample- S6**
	

Slide- S7
Description:

The particle sizes seen in the thin section are big and sub angular in shape. Matrix is dark brown in colour. The sample shows presence of quartz and mica.

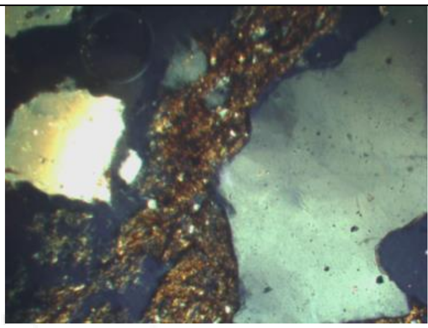
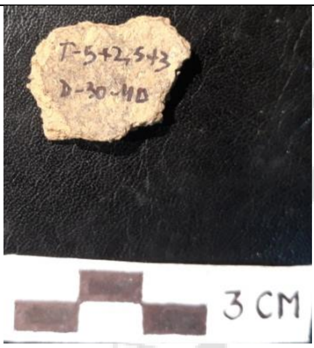
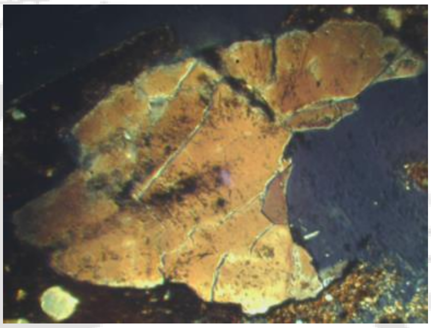
Figure 4.12: Photograph and Photomicrograph of Sample 7

Photograph of sample S7	Photomicrograph of sample- S7
	
	

Slide- S8
Description:

The matrix of this this section shows yellowish brown colour and more voids seen. Particle sizes are big. Quarts and mica are present.

Figure 4.13: Photograph and Photomicrograph of Sample 8

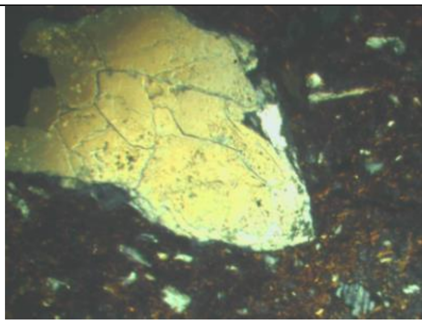
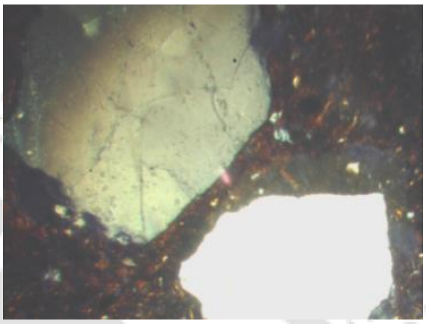
Photograph of sample S8	**Photomicrograph of sample- S8**
	
	

Slide- S9
Description:

The colour of the matrix is yellowish brown. Quartz, mica and microcline feldspars are seen in the thin slides. Grogs are also observed.

Figure 4.14: Photograph and Photomicrograph of Sample 9

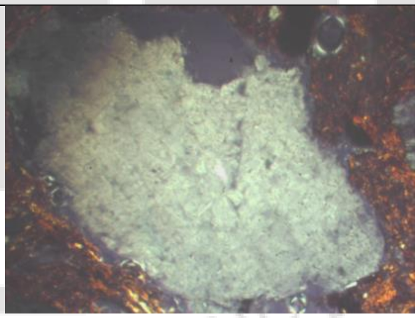
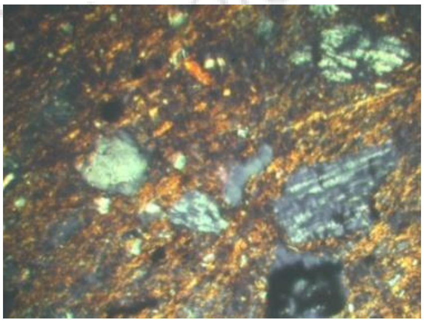
Photograph of sample S9	**Photomicrograph of sample- S9**
	

Slide- S10
Description:

Matrix is yellowish brown and less voids observed. Particle size are irregular in nature. Quartz and feldspar are found in the thin section. Grog found.

Figure 4.15: Photograph and Photomicrograph of Sample 10

Photograph of sample S10	**Photomicrograph of sample- S10**
 	 

Slide- S11
Description:

The minerals found in the thin slides are microcline feldspar, plagioclase feldspar, biotite mica. Grog can be seen in fewer amounts. Matrix is yellowish brown in colour. Fewer voids found.

Figure 4.16: Photograph and Photomicrograph of Sample 11

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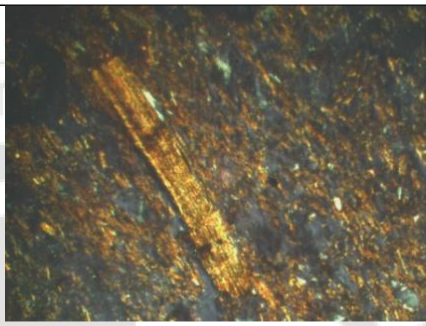
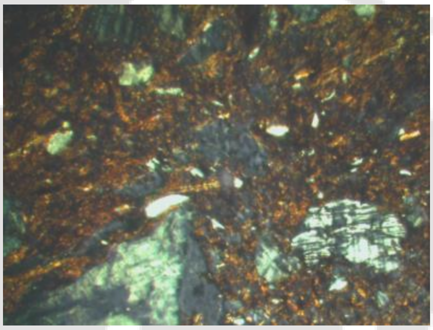
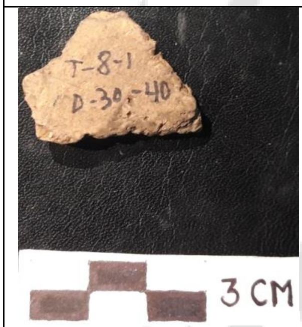
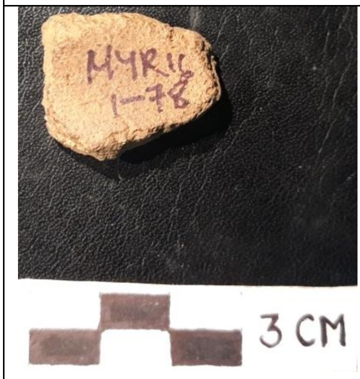
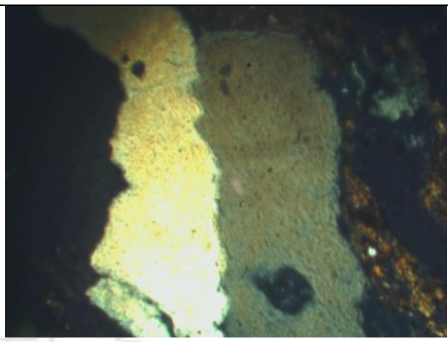
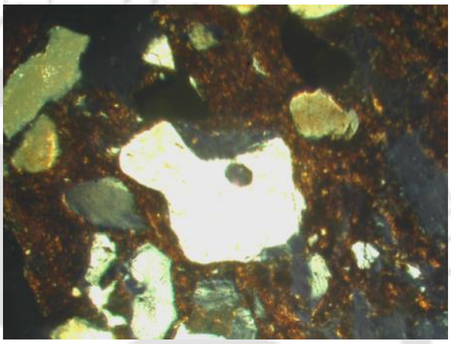
</td><td rowspan="2">
</td></tr>
<tr><td>
</td></tr>
</table>

Slide- S12
Description:

The minerals found in the thin slide are quartz, mica. The surface is coarse and the colour of the matrix is yellowish brown. Mica is big in size. Grog is also found in the thin slides.

Figure 4.17: Photograph and Photomicrograph of Sample 12

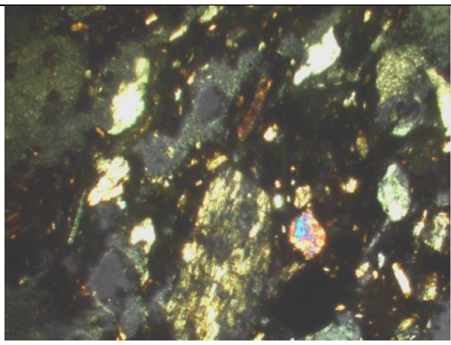
Photograph of sample S12	**Photomicrograph of sample- S12**
 	 

Slide- S13
Description:

The surface of the thin slide is loose and the colour of the matrix is dark brown. Mica, quartz and biotite are observed. The surface is coarse with more voids.

Figure 4.18: Photograph and Photomicrograph of Sample 13

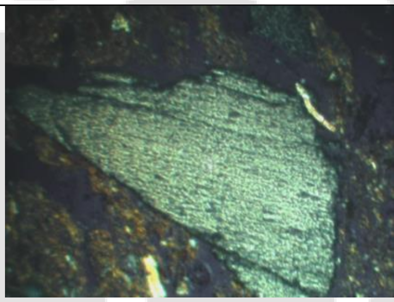
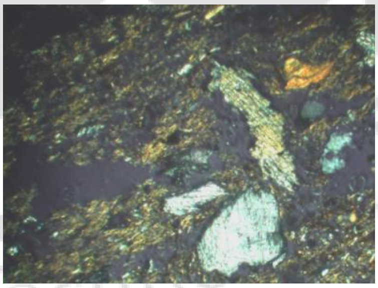
Photograph of sample S13	**Photomicrograph of sample- S13**
	

Slide- S14
Description:

The surface of the thin slide is loose and the colour of the matrix is yellowish brown. More voids found. Minerals observed here are quartz and muscovite.

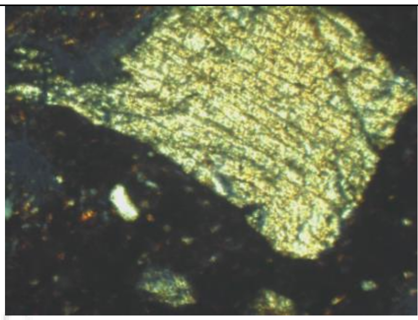
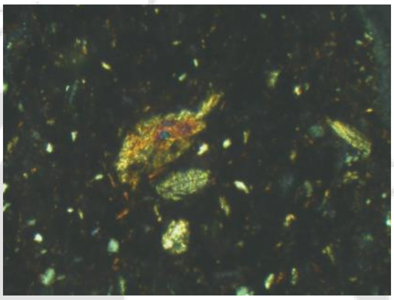
Figure 4.19: Photograph and Photomicrograph of Sample 14

Photograph of sample S14	**Photomicrograph of sample- S14**
 	 

Slide- S15
Description:

The surface is loose. Colour of the matrix is dark brown. The minerals seen in the thin slides are quartz, mica.

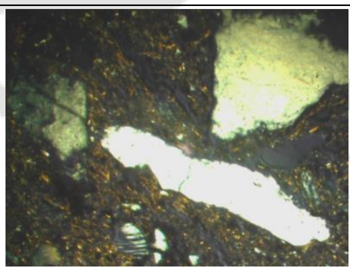
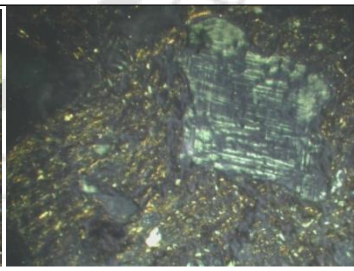
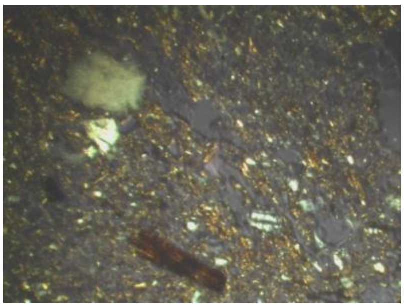
Figure 4.20: Photograph and Photomicrograph of Sample 15

Photograph of sample S15	**Photomicrograph of sample- S15**
	
	

Slide- S16
Description:

The colour of the matrix is yellowish brown. Surface is very loose. The minerals found in the thin slides are quarts, mica, microcline feldspar and plagioclase feldspar. Less voids found in the matrix.

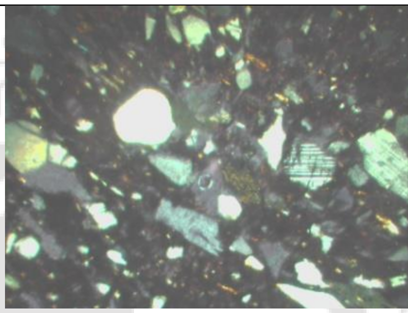
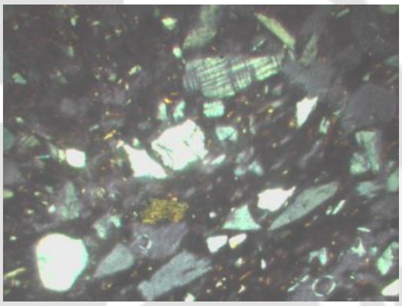
Figure 4.21: Photograph and Photomicrograph of Sample 16

Photograph of sample S16	**Photomicrograph of sample- S16**
	 
	

Slide- S17
Description:

The surface is very loose. The colour of the matrix is dark brown and voids seen. Microcline feldspar and plagioclase feldspars are observed along with quartz and mica. Few green particles are also observed, but unidentified.

Figure 4.22: Photograph and Photomicrograph of Sample 17

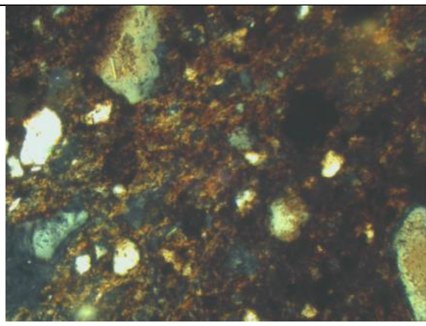
Photograph of sample S17	**Photomicrograph of sample- S17**
	 
	

Slide- S18
Description:

The colour of the matrix is yellowish brown. Fewer voids found in the matrix. Grogs are found more in numbers and surface is loose but comparatively less. Quartz and mica are observed.

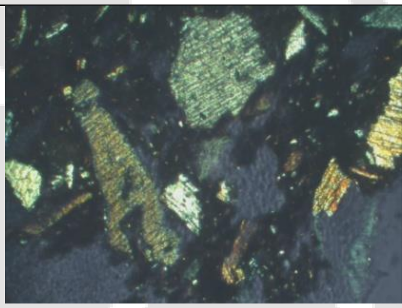
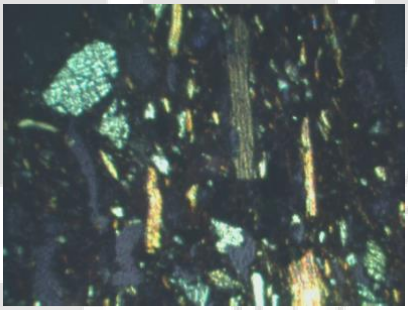
Figure 4.23: Photograph and Photomicrograph of Sample 18

Photograph of sample S18	**Photomicrograph of sample- S18**
	

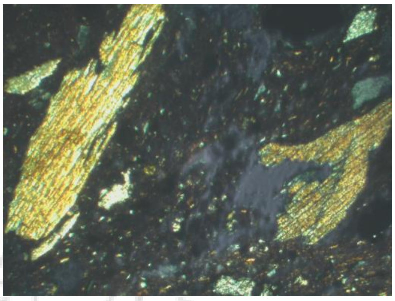
Slide- S19
Description:
The colour of the matrix is dark brown and the surface is very loose. Voids are seen in the matrix. The minerals observed in the biotite, quartz, mica and few coloured particles are observed, non-identified.

Figure 4.24: Photograph and Photomicrograph of Sample 19

Photograph of sample S19	Photomicrograph of sample- S19
	
	

Slide- S20
Description:
The surface is very loose and the colour of the matrix is dark brown, more voids found. Particle shapes are angular and large in size. Quarts and mica are observed.

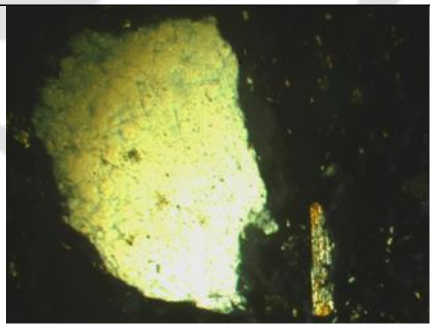
Figure 4.25: Photograph and Photomicrograph of Sample 20

Photograph of sample S20	Photomicrograph of sample- S20
	
	

Slide- S21
Description:

The matrix is very dark brown in colour and the surface is loose. The minerals observed in the thin slides are biotite and quartz.

Figure 4.26: Photograph and Photomicrograph of Sample 21

Photograph of sample S21	Photomicrograph of sample- S21
	

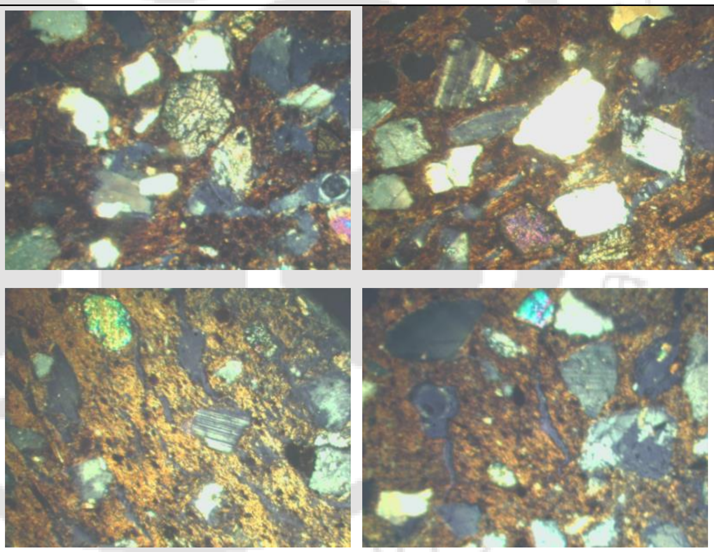
	

Slide- S22

Description:

The colour of the matrix is yellowish brown; surface is less loose and less voids seen. The minerals observed in the thin slides are plagioclase feldspar, biotite, quartz, mica, grog. Shapes of the minerals are angular and sub-angular.

Figure 4.27: Photograph and Photomicrograph of Sample 22

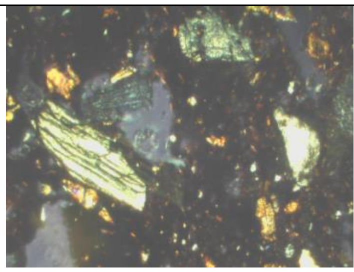
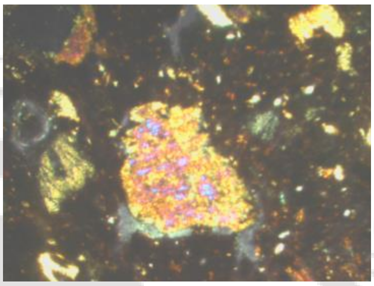
Photograph of sample S22	Photomicrograph of sample- S22
 	

Slide- S23

Description:

The colour of the matrix is dark brown and surface is less loose and voids are also very less. Minerals observed are quartz and unidentified colored particles.

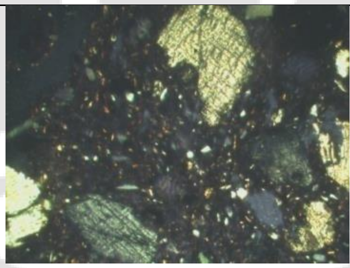
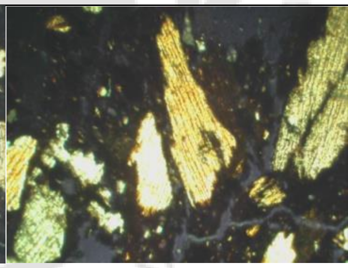
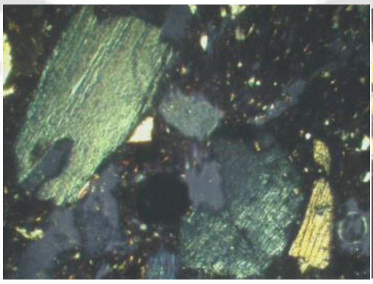
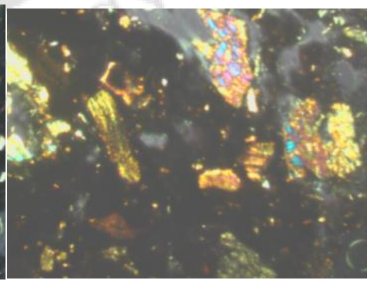
Figure 4.28: Photograph and Photomicrograph of Sample 23

Photograph of sample S23	**Photomicrograph of sample- S23**
	
	

Slide- S24
Description:

The colour of the matrix is dark brown in colour and surface is loose. Minerals found are quartz, mica and unidentified particles.

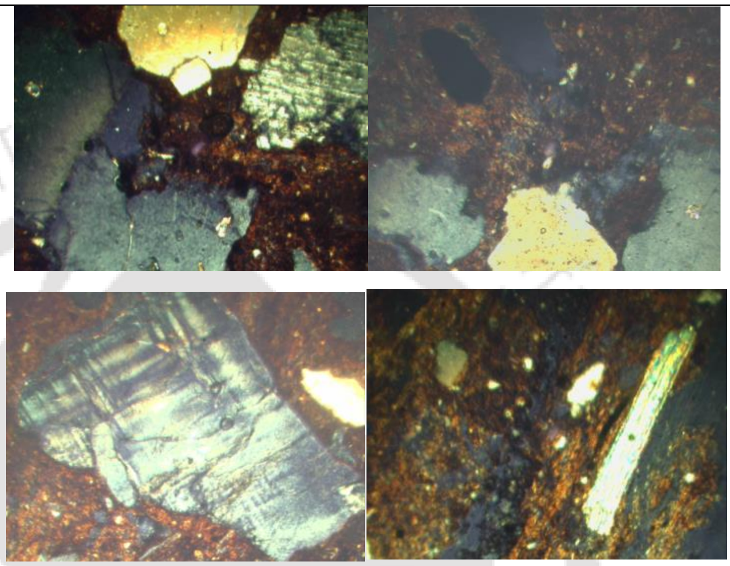
Figure 4.29: Photograph and Photomicrograph of Sample 24

Photograph of sample S24	**Photomicrograph of sample- S24**
	 
	 

Slide- S25
Description:

The colour of the matrix is brown. Surface is little loose and less voids found. The minerals observed in the thin section are microcline feldspar, plagioclase feldspar, mica, grog and quartz.

Figure 4.30: Photograph and Photomicrograph of Sample 25

<table>
<tr><th>Photograph of sample S25</th><th>Photomicrograph of sample- S25</th></tr>
<tr><td>
</td><td rowspan="2"></td></tr>
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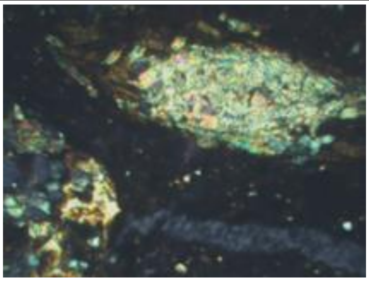
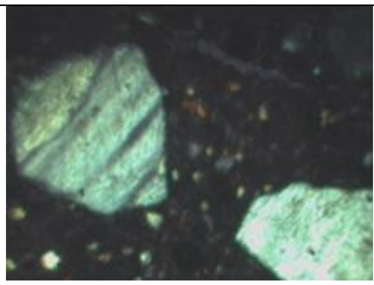
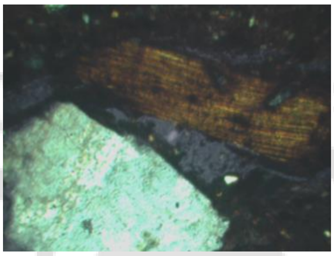
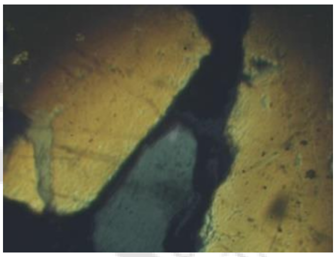
</td></tr>
</table>

Slide- S26
Description:

The colour of the matrix is very dark brown, Surface is loose and voids are also found. Minerals found are big in size and observed minerals in the thin section are quartz, micachist (gabro), mica, plagioclase feldspar.

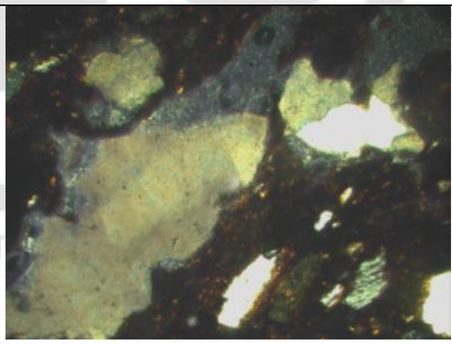
Figure 4.31: Photograph and Photomicrograph of Sample 26

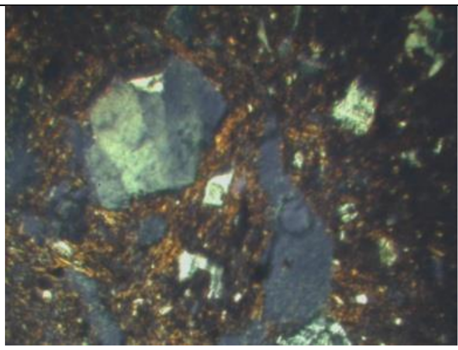
Photograph of sample S26	**Photomicrograph of sample- S26**
 	   

Slide- S27
Description:

The colour of the surface is yellowish brown. Surface is loose and less voids seemed. Sizes of the mineral are big. Quartz, mica, plagioclase feldspars are observed.

Figure 4.32: Photograph and Photomicrograph of Sample 27

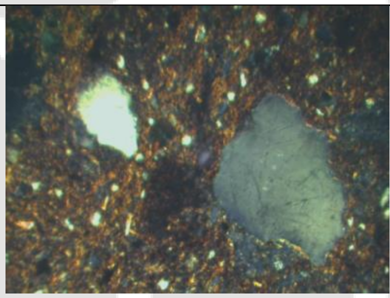
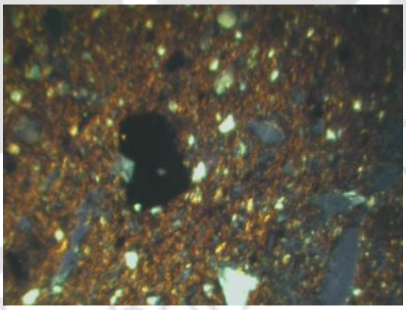
Photograph of sample S27	**Photomicrograph of sample- S27**
	

Slide- S28
Description:

The matrix is yellowish brown, loose surface. Mica, quartz and grog are present. Particle sizes are angular to sub angular.

Figure 4.33: Photograph and Photomicrograph of Sample 28

Photograph of sample S28	**Photomicrograph of sample- S28**
	
	

Slide- S29
Description:

Matrix is yellowish brown, voids observed. Minerals are microcline feldspars, calcite, quartz, mica and grog.

Figure 4.34: Photograph and Photomicrograph of Sample 29

<table>
<tr><th>Photograph of sample S29</th><th>Photomicrograph of sample- S29</th></tr>
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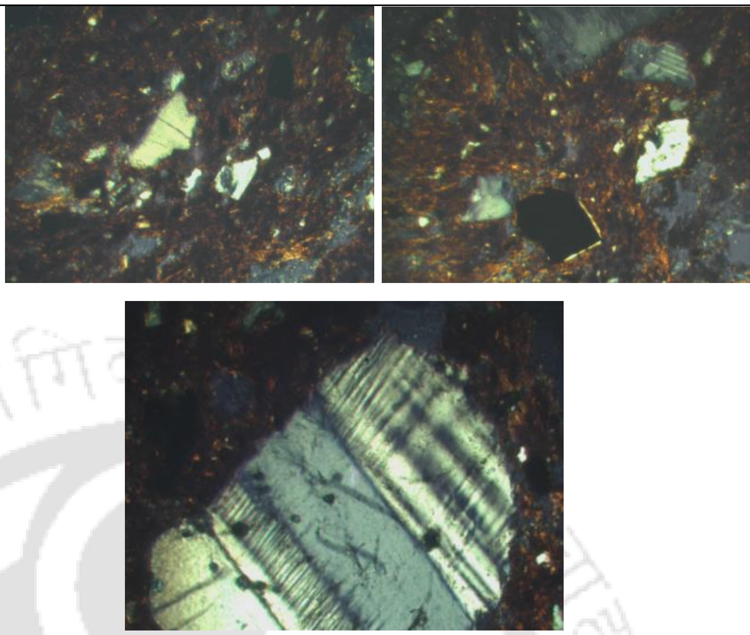
</td><td rowspan="2"></td></tr>
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</td></tr>
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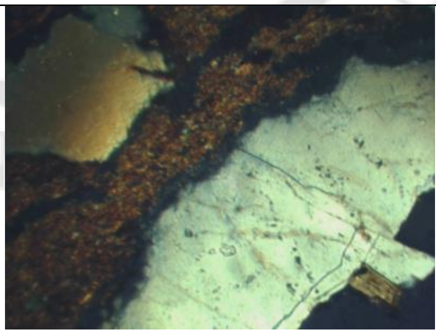
Slide- S30
Description:

Matrix is yellowish brown. Quartz and mica are found in thin section. Particle sizes are large and angular and sub angular in shape

Figure 4.35: Photograph and Photomicrograph of Sample 30

<table>
<tr><th>Photograph of sample S30</th><th>Photomicrograph of sample- S30</th></tr>
<tr><td>
</td><td></td></tr>
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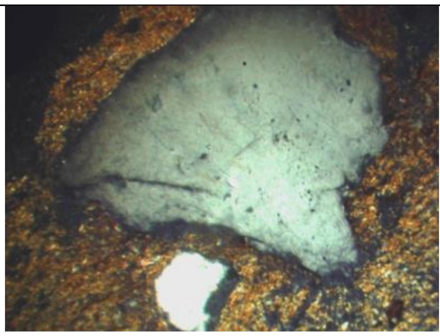
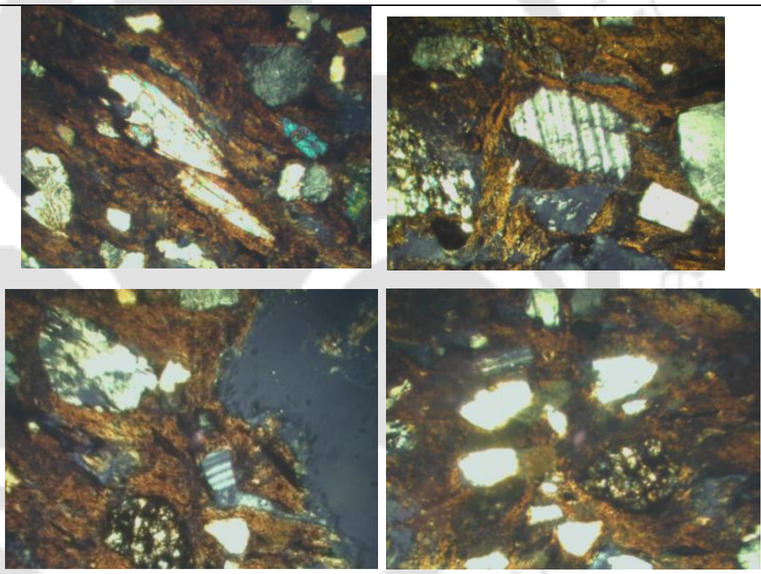
	

Slide- S31
Description:

The colour of matrix is yellowish brown. Surface is loose, but very less voids found in the thin section. Minerals observed are plagioclase feldspar, quartz, mica, grog and gabro.

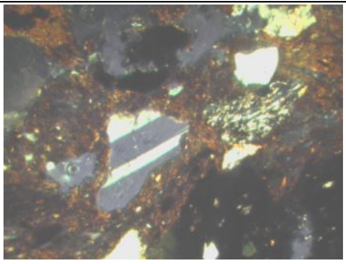
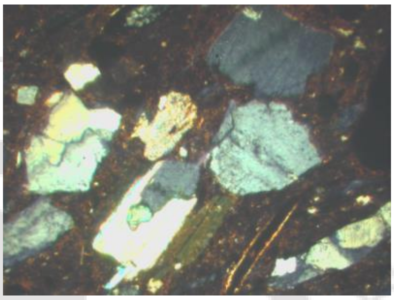
Figure 4.36: Photograph and Photomicrograph of Sample 31

Photograph of sample S31	Photomicrograph of sample- S31
 	

Slide- S32
Description:

The matrix is brown in colour. Very less voids found. Minerals found are plagioclase feldspar, mica, quartz, gabro and grog. Particles are angular to sub angular in shape. Biotite mica also found in the matrix (brown in colour and turns darker when it rotates under crossed polar light.

Figure 4.37: Photograph and Photomicrograph of Sample 32

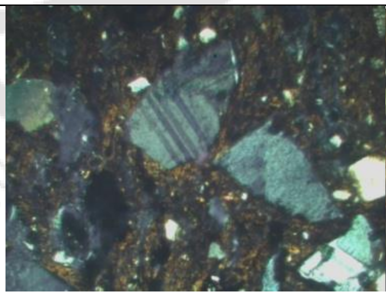
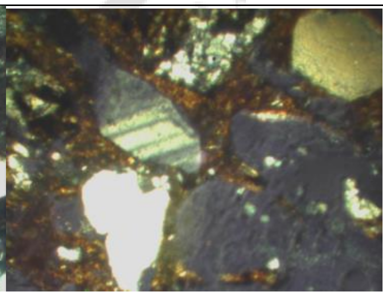
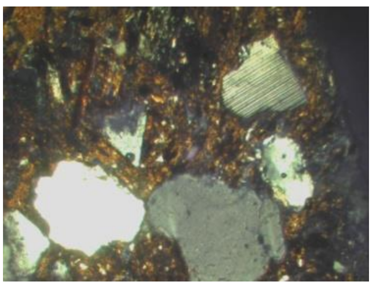
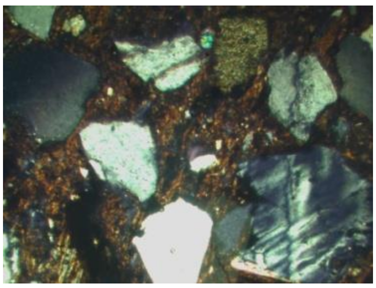
Photograph of sample S32	**Photomicrograph of sample- S32**
	  
	

Slide- S33

Description:

Matrix of this sample is brown in colour and less voids observed. Surface is loose. Minerals found are quartz, mica, grog, biotite and calcite. Gabro is also found

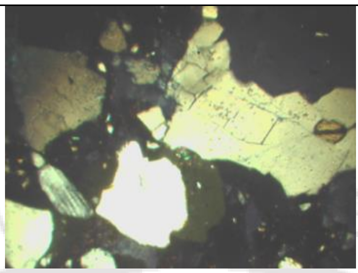
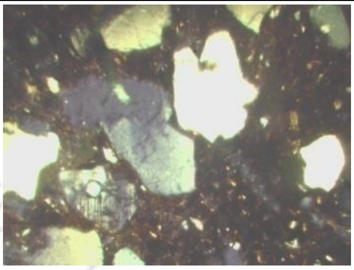
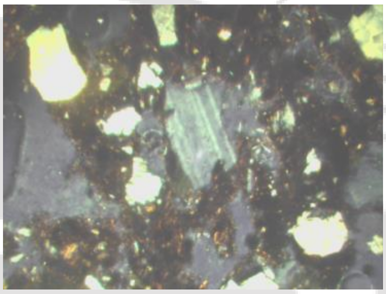
Figure 4.38: Photograph and Photomicrograph of Sample 33

Photograph of sample S33	**Photomicrograph of sample- S33**
	 
	 

Slide- S34
Description:

The matrix of this sample is dark brown in colour with fewer voids. Surface is loose. Minerals observed are mica, quartz, plagioclase feldspar.

Figure 4.39: Photograph and Photomicrograph of Sample 34

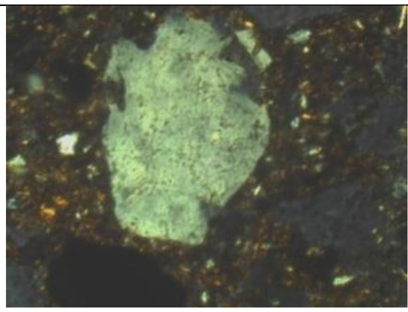
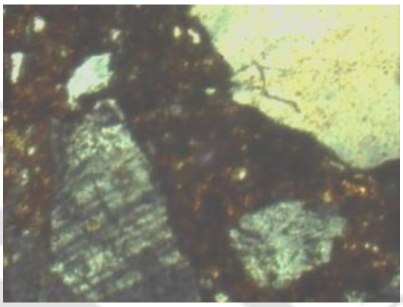
Photograph of sample S34	Photomicrograph of sample- S34
	  
	

Slide- S35
Description:

The matrix is yellowish brown in colour. Mineral particles are large in shape. Plagioclase feldspar, mica and quartz are observed.

Figure 4.40: Photograph and Photomicrograph of Sample 35

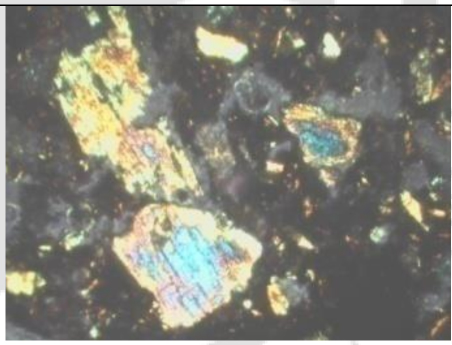
Photograph of sample S35	Photomicrograph of sample- S35
	

Slide- S36
Description:

The matrix is dark brown with more voids. Mica is observed here. Surface is loose.

Figure 4.41: Photograph and Photomicrograph of Sample 36

Photograph of sample S36	**Photomicrograph of sample- S36**
 	

The photomicrograph of the thin slides of potsherds shows the presents of inorganic materials, such as Quartz, Feldspar, Biotite mica, Orthoclase feldspar, Muscovite mica, Microcline feldspar, and Plagioclase Feldspar in its matrix. Grog has been found in some of the thin slides. It is difficult to identify why some pots were tempered, and not the others. More feldspar found in thin section refers to sandstone.

4.2. Conclusion

As discussed in the Chapter above, six methods have been applied in selected pottery samples and also in soil samples to understand the compositional analysis as well as quality of the samples to unveil few aspects of the present study such as provenance or locating the place of raw materials used in making the craft, understanding the manufacturing process that applied of the craft, site pattern etc.

The similarities of the materials found in an artifacts belong to one site, which is known as intra site similarities plays the role of a marker of social picture. Inter site differences of archaeological artifacts shows organizational aspects and give the idea of social structure. The variations in the composition of the potsherds may either imply pottery from different production sites or reflect the natural inhomogeneity of local clay deposits and the application of different manufacture processes in local workshops (Papachristodoulou, Artemios, Kostas, & Konstantina, 2006).

X-ray diffraction analysis that applied in this study is a powerful tool in the study of Neolithic pottery, offering valuable information about mineral composition, firing conditions, clay sources, provenance, and diagenetic processes. Integrating XRD data with other archaeological and geochemical analyses provides a comprehensive understanding of ancient ceramic technologies and socio-economic dynamics during the Neolithic period. The XRD analysis reveals Quartz, Kaolinite, Goethite, Hematite and Anorthite are the major mineral substances found in most of the investigated sherds in varying quantity. Quartz is found in all the samples only except one sample (M05). Another notable distinction is observed in the sample M06 representing Millisite, Halloysite, Amicite in its composition, which are not present in the rest of the sherds. Half of the samples show the presence of kaolinite in its composition. From the XRD data the firing temperature estimated is ranges from 600º C to 1000º C. From the presence of hematite in few of the pottery samples it can be ascertain that the sherds were fired in oxidizing atmosphere. Microcline and Anorthite are feldspar mineral group and are represented by few experimented samples indicating firing temperature between 800º -900º C. The maximum firing temperature is evident by the presence of muscovite (850 º to 1000º C) in one experimented sample. Presence of a group of non- clay minerals such as Feldspars, Biotite, Hornblende etc. are representative of igneous material.

Fourier transform infrared spectroscopy serves as a valuable tool in the comprehensive analysis of Neolithic pottery, providing crucial information about composition, manufacturing techniques, surface treatments, and alteration processes. It complements other analytical techniques such as X-ray diffraction and scanning electron microscopy, enhancing the overall understanding of Neolithic pottery. FTIR spectra shows presence of minerals quartz, feldspars (Microcline, Orthoclase), clay mineral (Kaolinite and Montormorlinite), iron oxides (Hematite) and organic compounds. Quartz is found almost in all the samples which is evident in the XRD result as well. From FTIR analysis it has been confirmed that red clay origin of kaolinite is used as a raw material for making potteries. The samples represent it also shows Aluminum hydroxide and iron oxide in its composition. Presence of iron oxide makes the material red in colour. Another notable observation is that the hematite peak at 535 cm^{-1} and 534 cm^{-1} found in few samples implies that the potteries were fired in an oxidizing condition. The samples which show absence of hematite band indicates that the firing condition achieved may be in a reduced atmosphere. Mineral phase analysis of ancient ceramics carried out by FTIR yields complementary information to XRD analysis as well.

Energy-dispersive X-ray spectroscopy analysis serves as a valuable tool in the multidisciplinary study of Neolithic pottery, providing crucial insights into its elemental composition, technological aspects, provenance, and preservation. Its application enhances our understanding of ancient ceramic traditions, trade networks, and socio-cultural dynamics, contributing to broader narratives of human history and material culture evolution. It complements other analytical techniques such as X-ray diffraction and microscopy, enhancing the comprehensive study of Neolithic pottery. The EDX spectra revealed that Si (Silicon), Al (Aluminum), Fe (Iron), and K (Potassium) are the predominant elements across all samples. Presence of high quantity of Silicon and low quantity of calcium in the samples reveals the clay type as non-calcareous clay.

The visible disparities in the mineral composition of the examined artifacts and structural clay products may stem from variations in clay sources and manufacturing methodologies. Consequently, the mineral characteristics observed through both FTIR, XRD and EDX analyses have contributed to understanding the uniformity in their composition and associations.

The application of the Moh's hardness scale to pottery analysis offers a valuable means of assessing the scratch resistance and durability of ceramic artifacts. By following a standardized sample preparation process and experimental procedure, researchers can obtain reliable hardness measurements that contribute to the comprehensive study of pottery materials, manufacturing techniques, and functional properties in archaeological contexts. The result of hardness analysis reveals that the potteries recovered from the site Myrkhan are belong to low hardness level. As it has already discussed that pottery used for cooking purposes are generally possesses high hardness value, therefore it can be assuming that most of the potteries are probably used for storing or other purposes.

Understanding the porosity of Neolithic pottery can provide insights into its intended use, whether for cooking, storage, or ceremonial purposes. Changes in porosity across different phases or regions can indicate technological advancements or changes in pottery production techniques over time. For example, improvements in kiln design or firing methods may result in lower porosity levels in pottery belonging to later period compared to earlier examples.

Based on the porosity analysis results, the pottery samples are categorized into three levels: High, Medium, and Low porosity. It is noted that 48% of the total samples fall within the low porosity category, while 47% belong to the medium porosity level, with only 5% falling into the high porosity range. One potential explanation for the prevalence of low porosity could be attributed to inadequate firing techniques.

Thin section petrographic analysis offers a detailed and systematic approach to studying Neolithic pottery, providing comprehensive insights into its mineralogical composition, microstructure, and firing history. It complements other analytical techniques such as X-ray diffraction, scanning electron microscopy, and chemical analysis, enhancing the multidisciplinary study of ancient ceramics. The photomicrograph of the thin slides of potsherds shows the presents of inorganic materials, such as Quartz, Feldspar, Biotite mica, Orthoclase feldspar, Muscovite mica, Microcline feldspar, and Plagioclase Feldspar in its matrix. Thin section analysis allows for the detection of tempering agents and inclusions incorporated. Common tempering materials include sand, grog, shell fragments, organic matter etc. In few samples grog is observed.

Based on the aforementioned analytical methods, it can be inferred that the results obtained from each experiment exhibit similarity or reinforce one another. The primary findings are as follows: firstly, the ubiquitous presence of quartz mineral across all samples; secondly, the utilization of kaolinite sourced from red clay for pottery production; thirdly, the identification of non-calcareous clay with elevated levels of aluminum hydroxide and iron oxide, as indicated by the findings from EDX, FTIR, and EDX analysis. While the outcomes of all experiments do not reveal uniformity in physical properties across layers, the samples yield heterogeneous results concerning their mineralogical and elemental compositions.

Chapter-5

A Comparative Study on the Morphological and Scientific Investigation of Pottery

5.1 Introduction

Archaeologists from the very beginning study the form and the physical attributes of the pottery, whenever a pottery or a potsherd is found in any excavated site or in the surface of an archaeological site. Pottery from two different locations may be similar for one of three different reasons, or combinations of these: they may be similar because of some form of historical connection between the two; they may be similar due to convergence and similar functional requirements; or the similarity may be completely coincidental. This reasoning applies equally to form, decoration, and method of manufacture of pottery. As time passed, it was felt that any kind of artifact interpretation is incomplete as long as we do not attempt to perceive 'the man behind the artifact' (Krishnan, 1997).

5.2 Interpretation of the results basis on ceramic types

It is relatively easy for the archaeologist to use a historical chronology when abundant artifacts are found that can be related closely to it. If a pottery typology has been worked out, the findings of known types of pottery in such historically dated contexts allows the pottery typology itself to be dated. The pottery from the site Myrkhan has been 1st dated as belong to the Neolithic period by comparing it with the associated findings (Stone tools, ring stone, beads etc.) and also with the pottery design. Impressed pottery from the Northeastern region are belong to the Neolithic cultural period. Later on carbon dating is done to date the site.

After quantification of all the sherds have been completed it is found that the cord impressed potsherds are dominant in nature. In all the Layers the number of cord marked sherds are higher. The lower layer presents very less number of potsherds along with unfinished tools. Inference can be made from here is people who were using that place for making stone tools were seasonal visitors. The percentage of pottery found in the upper layer continues to get higher and it reveals presence of finished stone tools along with other cultural materials. It is obvious that to make a complete tool is time consuming process and getting more finished tool indicates people might have stayed there for a long span of time. Apart from these evidences the presence of a burial in the excavated area make it more complex to understand whether it was only a factory site or it had been used as a habitational site by the Neolithic people.

The layer wise classification of the potsherds is done to understand the cultural sequence of the site. The variations in the sherds will indicate about the time span and help to understand the previously established Neolithic chronology of Northeast region in a better way.

The study on the pattern of impression present in the outer surface of the sherds reveals that the horizontal/ vertical pattern is most common. Almost 40% of the sherds represent this pattern, and it is mostly the found in the cord marked potsherds. Criss-cross and Zig-Zag patterns are characteristic features of the carved paddle wares. One typical pattern was found in only few of the potsherds, which is termed as diamond shape. It is not found in the lowest level. Though the number is very less but in the top most level potsherds with this pattern were found comparatively higher in number. This could be an indication of the human cognitive abilities.

In the potsherds the colour red is dominant among all. The second dominant colour is brown. Apart from these two yellow and grey colour is also found in different shades. Only four samples show shades of black colour.

On Thickness: David Braun suggested on the thickness of pottery wall that looking at the principles of material science studies, the thinner walled potteries are more thermally efficient and less prone to break from thermal shock than the thick walled potteries. From his view it can be understand that if a pottery assemblage shows thin wall mostly, it probably was used for cooking purposes. Thin wall potteries are more advantageous for a lengthy cooking period (Moore & Keene, 1983).

A piece of pot cannot give us the idea about its usability immediately after recovered from an archaeological site if a full pot is not available. From a recovered potsherd though its function, for example storing/cooking or other is not possible to determine clearly, but by examining the piece of sherd we can find out its suitable function, like for whether the pottery had been used for boiling food or storing purposes.

The scientific analytical method XRD, FTIR, EDX and Hardness Test, porosity analysis and thin section petrography have been used so far for the chemical and mineralogical characteristics of the sherds. The combination of all these scientific techniques of mineralogical and chemical analysis revealed the different constituents and its quantities in both the pottery samples and soil samples collected from the excavated site. A comparative assessment of the mineralogical and chemical data acquired from the experiments have been discussed in details below.

In the XRD result it has been observed that irrespective of all the pottery type and the layers the mineral quartz is present in all the potsherds in high quantity. It can be said that quartz is the most dominant type of mineral in the in the pottery assemblage of Myrkhan. The clay mineral kaolinite is another dominant type of mineral in the experimented sherds irrespective of sherds types and layers.

Clay type: On the basis of mineralogical content observed in the samples, the high quartz content and absence of calcite shows the samples are typical of non-calcareous clays (Ravisankar, et al., 2013). Presence of calcite is found only in one carved paddle potsherd (M29) from the layer 2.

Firing temperature: In the production of pottery, the firing and consequent cooling are the two important and most crucial stages. From the knowledge of firing temperature value achieved and method of firing one may be able to conclude how the process navigated and tempered the raw clay used to model a vessel. (Velraj G. , Janaki, Mohamed Musthafa, & Palanivel, Estimation of firing temperature of some archaeological pottery shreds excavated recently in Tamilnadu, India, 2009). The presence or absence of specific mineral assemblage is often used for the estimation of firing temperature of the pottery (Ravisankar, Chandrasekaran, Kiruba, Senthilkumar, & Maheswaran, 2010).

The presence of phyllosilicates indicates that the firing temperatures did not exceed 900º C (De Benedetto, Laviano, Sabbatini, & Zambonin, 2002). In a cord marked potsherd (M35) presence of phyllosilicate (muscovite) is observed. It is the only potsherd with this mineral among all the experimented sherds. The data recovered from the XRD analysis of the investigated sherds confirms the lower limit of firing temperature through the absence of the mineral illites in all the three types of samples. Samples do not contain illites suggesting that pottery has been burned at temperatures 560º C and above (Stuart, 2007) . Calcite get decomposed in between the firing temperature 700- 900º C. Therefore, from the presence and absence of the calcite in the mineralogical composition of the sherds also gives us the idea about the firing temperature. Calcite is observed only in one carved paddle potsherd (M29) from the layer 2, which indicate the maximum firing temperature of the sherd was 700º C. Presence of feldspar and quartz indicate the maximum firing temperature up to 1000º C (Shimada, et al., 2003). As the mineral quartz has been observed in all the experimented samples it can be said that The maximum firing temperature of the sherds were up to 1000º C.

Firing atmosphere: Hematite, identified as a crystalline phase in samples, indicates an oxidizing kiln atmosphere (Ravisankar, et al., 2013). Among the cord marked potsherds presence of hematite is observed in all the excavated layers though not in all the samples. In case of carved paddle potsherds few samples from layer 2 and 3 shows presence of hematite.

Potsherd with plain surface from the layer 2 shows hematite in its composition. Inferences can be made here that the sherds with presence of hematite were fired in oxidizing kiln atmosphere.

The experimental data of XRD reveals quartz to be the most important and abundant non clay mineral found in almost all the experimented samples. The study has shown that the people who practiced this craft used mixer of kaolinite and montmorillonite clays for making pottery and that in addition to the clay, quartz also formed raw materials. The presence of quartz gives information about the origin of the potteries; quartz was used in piedmont for covering of engobed pottery, while kaolin was used elsewhere for the same purpose. The presence of quartz in the largest part of the samples confirms thus the common origin of these samples (Ravisankar, Chandrasekaran, Kiruba, Senthilkumar, & Maheswaran, 2010).

The infrared spectroscopy in this analytical research seems to be useful for the compositional analysis of these Neolithic potsherds. Various bands and vibrational assignments prove the presence of both organic and inorganic matters and also give us an idea of the firing temperature. An IR spectrum can serve as a fingerprint for mineral identification, but it can also give unique information about the mineral structure, including the family of minerals to which the specimen belongs, the degree of regularity within the structure, the nature of isomorphic substituents, the distinction of molecular water from constitutional hydroxyl, and the presence of both crystalline and non-crystalline impurities (Jana & Komadel, 2001). From the FTIR studies, it is also concluded that all the samples have been fired above 600°C under different atmosphere.

5.3 Interpretation on the basis of different layers

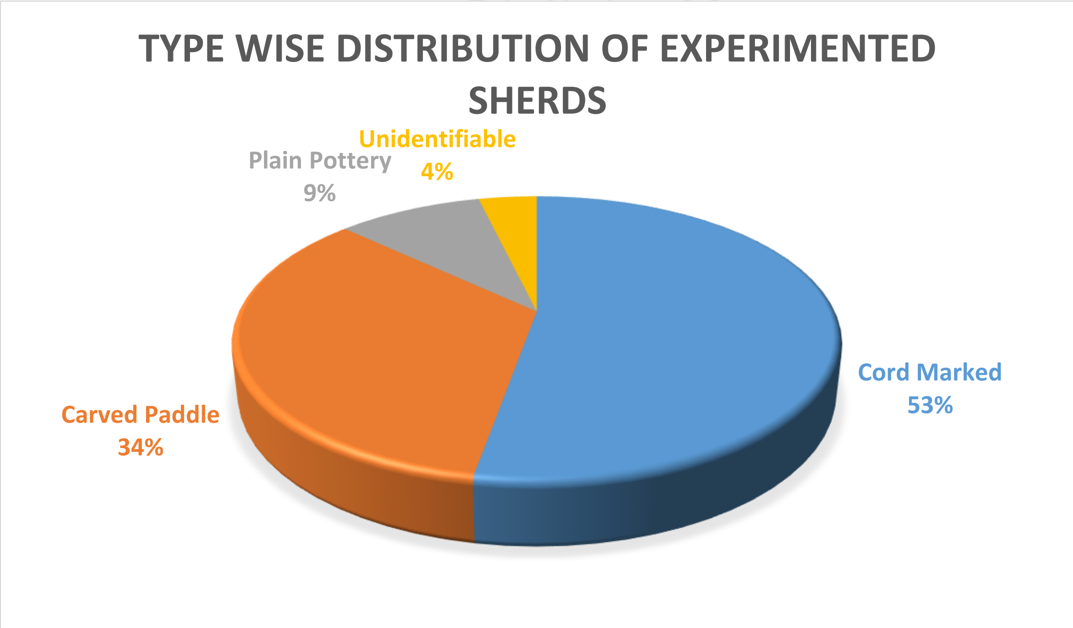
Since the section profile has been segmented into four distinct layers, a comparative evaluation of the pottery fragments has been undertaken to discern patterns of similarities and differences. This endeavor aims to categorize them accurately based on chronological and technological considerations. The total number of the experimented sherds in the four layers are as follows-

Table 5.1: Distribution of the experimented sherds according to its type and layer

Layer	Layer wise distribution of experimented pottery types				Total
	Cord Marked	Carved Paddle	Plain	Unidentifiable	
1	M1/2^{-1}/0-20	M6/7^{+1}/0-20	M10/2^{-1}/0-20		5
	M5/7^{+1}/0-20				
	M11/2^{-1}/0-20				
2	M12/7^{+1}/20-30	M2/4/20-30	M9/2/20-30	M16/5^{+2}/20-30	18
	M13/7^{+1}/20-30	M20/3/20-30	M21/5^{+2}/20-30	M22/5^{-1}/20-30	
	M27/1/20-30	M23/2^{-1}/20-30			
	M28/1/20-30	M24/2^{-1}/20-30			

	M30/4/20-30 M31/4/20-30	M25/2^{-1}/20-30 M26/1/20-30 M29/1/20-30 M32/2/30			
3	M3/3/30-40 M14/5^{-2}/30-40 M33/5^{-1}/30-40 M34/3/30-40 M35/7^{+1}/30-40	M15/8^{-1}/30-40		M8/1/30-40	7
4	M4/5^{+2}/40-50 M7/5^{-1}/40-50 M17/5^{-1}/40-50	M18/5^{-1}/40-50		M19/5^{+2}/40-50	5
Total	17	11	3	4	35

Figure 5.1: Percentage of the experimented sherds (based on its type)



As the major and minor minerals found in the pottery fragments are already discussed in Chapter 4, here sub-tables have been created based on the information provided in the preceding table, organized by layers, to enable a detailed discussion on the comparative assessment of the pottery. Further details regarding the pottery sherds are presented below the sub-tables. Results of compositional and elemental analysis collected through the used methods of XRD, FTIR and, EDX are compared here. In the tables below the symbol “+” denotes the presence of minerals in the composition of raw material of the sherds and “-” denotes the absence of minerals in the composition.

Table 5.2: Experimented pottery from Layer 1

Pottery type-	**Cord Marked**	**Carved Paddle**	**Plain**	**Unidentifiable**	**Total No.**
Sample Name-	M5/7^{+1}/0-20, M1/2^{-1}/0-20, M11/2^{-1}/0-20	M6/7^{+1}/0-20	M10/2^{-1}/0-20	-	
Total No.	**3**	**1**	**1**	**0**	**5**

Table 5.3: XRD result of the potsherds from Layer 1 presenting presence and absence of minerals

Mineral Identified	**Pottery Type**					
	Cord-marked			**Carved paddle**	**Plain**	**Unidentifiable**
	M1/2^{-1}/0-20	**M5/7^{+1}/0-20**	**M11/2^{-1}/0-20**	**M6/7^{+1}/0-20**	**M10/2^{-1}/0-20**	**0**
Kaolinite	++++++	+++++	+	+++	+	×
Quartz	+++++++	+++++++	+++++	++++++++	++++++++	×
Goethite	-	++	+	++	+	×
Microcline	+	-	++	-	-	×
Anorthite	+	+	+	+	-	×
Biotite	+	+	-	++	-	×
Hornblende	-	+	-	+	-	×
Orthoclase	-	-	-	+	+	×
Rutile	-	-	-	+	-	×
Hematite	-	++++	+	+	-	×
Chrysotile	-	+	-	-	-	×
Millisite	-	-	-	+	-	×
Halloysite	-	-	-	+	-	×
Amicite	-	-	-	+	-	×
Ilmenita	-	-	+	+	-	×

The experimented potsherds from layer 1 consist of cord marked, carved paddle and plain one. It is observed here that the mineral composition of the carved paddle impressed potsherd is different presenting more minerals from the other experimented sherds.

Table 5.4: Experimented pottery from Layer 2

Pottery Type-	Cord Marked	Carved Paddle	Plain	Unidentifiable	Total No.
Sample Name-	M12/7+1/20-30 M13/7+1/20-30 M27/1/20-30 M28/1/20-30 M30/4/20-30 M31/4/20-30	M2/4/20-30 M20/3/20-30 M23/2-1/20-30 M24/2-1/20-30 M25/2-1/20-30 M26/1/20-30 M29/1/20-30 M32/2/30	M9/2/20-30 M21/5+2/20-30	M16/5+2/20-30 M22/5-1/20-30	
Total No.	**6**	**8**	**2**	**2**	**18**

Table 5.5: XRD result of the potsherds from Layer 2 presenting presence and absence of minerals

Mineral Identified	Pottery Type																	
	Cord-marked						Carved paddle								Plain		Unidentifiable	
	M12/7+1/20-30	M13/7+1/20-30	M27/1/20-30	M28/1/20-30	M30/4/20-30	M31/4/20-30	M2/4/20-30	M20/3/20-30	M23/2-1/20-30	M24/2-1/20-30	M25/2-1/20-30	M26/1/20-30	M29/1/20-30	M32/2/30	M9/2/20-30	M21/5+2/20-30	M16/5+2/20-30	M22/5-1/20-30
Kaolinite	-	++	+	-	-	-	++	++	-	-	-	+++	+	+	+++	-	++	+
Quartz	+++++	++++++	++++++++	+++++++	+++++	+++	+++++++++	+++++	++++++	+	+++	+++++++++	+++++++	++++	+++++	+++	+++++++++	++++
Goethite	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+
Microcline	-	-	-	-	+	+	-	+	+	-	+	-	-	+	-	+	-	+
Anorthite	-	-	-	+	+	-	-	+	-	+	+	+	-	-	++	-	-	-
Biotite	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	+

Hornblende	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Rutile	+	-	-		+	+	-	+	+	-	-	-	-	-	+	+	+	-
Hematite	++	+	-	-	+	-	-	+	-	-	-	-	-	-	++	-	-	-
Albite	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Variscite	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The experimented potsherds from layer 2 consist of cord marked, carved paddle and plain plain potsherd and 2 unidentified pottery fragments. All the samples are heterogeneous in its composition. Few of the sherds shows absence of kaolinite and albite is present only in one sample of this layer. Similarly, hornblende is present only in one sample.

Table 5.6: Experimented pottery from Layer 3

	Cord Marked	Carved Paddle	Plain	Unidentifiable	Total No.
Sample Name-	M3/3/30-40 M14/5-2/30-40 M33/5-1/30-40 M34/3/30-40 M35/7+1/30-40	M15/8-1/30-40		M8/1/30-40	
Total No.	**5**	**1**	**0**	**1**	**7**

Table 5.7: XRD result of the potsherds from Layer 3 presenting presence and absence of minerals

Mineral Identified	**Pottery Type**							
	Cord-marked					**Carved paddle**	**Plain**	**Unidentifiable**
	M3/3/30-40	**M14/5-2/30-40**	**M33/5-1/30-40**	**M34/3/30-40**	**M35/7+1/30-40**	**M15/8-1/30-40**	**0**	**M8/1/30-40**
Kaolinite	-	+	-	-	-	++	×	++
Quartz	+++++++	++++++	++++++	+	+++	++++++++	×	++++++++
Goethite	+	-	+	+	+	+	×	+
Microcline	+	-	+	-	+	-	×	-
Anorthite	-	-	-	+	+	-	×	-

Biotite	-	-	-	+	-	-	×	-
Hornblende	+	-	-	-	-	-	×	-
Orthoclase	+	-	-	-	-	-	×	-
Rutile	-	-	+	-	-	+	×	-
Hematite	-	+	-	-	-	+++	×	++

The experimented potsherds from layer 3 consist of cord marked, carved paddle and 1 unidentified pottery fragment. More than 50% of the samples do not have kaolinite in its composition. Quartz is present in all the samples of the layer. Additionally, the mineral composition of the samples in this layer exhibits a heterogeneous nature.

Table 5.8: Experimented pottery from Layer 4

	Cord Marked	**Carved Paddle**	**Plain**	**Unidentifiable**	**Total No.**
Sample Name-	**M4/5+2/40-50** **M7/5-1/40-50** **M17/5-1/40-50**	**M18/5^{-1}/40-50**	-	**M19/5^{+2}/40-50**	
Total No.	**3**	**1**	**0**	**1**	**5**

Table 5.9: XRD result of the potsherds from Layer 4 presenting presence and absence of minerals

Mineral Identified	**Pottery Type**					
	Cord-marked			**Carved paddle**	**Plain**	**Unidentifiable**
	M4/5+2/40-50	**M7/5-1/40-50**	**M17/5-1/40-50**	**M18/5^{-1}/40-50**	**0**	**M19/5^{+2}/40-50**
Kaolinite	+++++	+++	+	++	×	-
Quartz	++++++	++++++	+++++++++	+++++++	×	+++++++
Goethite	+	+	+	+	×	+
Microcline	+	-	-	-	×	-
Anorthite	+	+	-	+	×	-
Rutile	+	+	-	+	×	-
Hematite	-	+	-	-	×	-
Ilmenita	-	+	-	-	×	-
Variscite	+	-	-	-	×	-

Pottery sherds from layer 4 exhibit characteristics of cord marking, carved paddling, and one unidentified fragment. This layer demonstrates minimal variation in its compositional analysis. The mineral composition and concentration appear to be largely uniform, with kaolinite present in all samples except one. Interestingly, the absence of kaolinite in a single sample results in a composition that diverges from the others.

5.4 Conclusion

This comparative analysis of the pottery fragments shades light on the provenance of the raw material of the products and its technological process. Apart from these high concentrations of some minerals may indicate geological profile of the study area. It may help us to differentiate among the local and the imported products.

Upon analysis, it has been determined that there is no consistent pattern of distinction or similarity among the pottery fragments across the various layers. This suggests that pottery from different layers exhibits notable similarities rather than differences. This finding remains consistent in both morphological and compositional analyses, indicating a complementary relationship between the two methodologies. However, it is noteworthy that in the layers, 2/3 pots display differences in composition, a phenomenon corroborated by morphological analysis. Furthermore, the layer 1 and layer 2 have more minerals in the composition of raw materials of the samples. During the reconstruction of the pottery fragments, it was observed that in each layer, 1 or 2 rim sherds exhibited peculiar shapes inconsistent with the rest. While a definitive conclusion cannot be drawn at this time, it is conceivable that the group of individuals practicing this craft may not be homogeneous, or alternatively, they may have employed varying technologies.

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Chapter-6

Conclusion

6.1 Summary of the Study

This study focuses on the comprehensive study of the ceramics excavated in the Neolithic site Myrkhan. Ceramics or the pottery has been taken for study to uncover the unknown culture and the people of that site once inhabited there. The study included a broad analytical approach which can be divided into scientific and nonscientific approach. The scientific analytical approach was used to understand the provenance of the potsherds found in the site. A brief study on the geology and geography of the study area is done in this regard. Knowledge of the geographical distribution of raw materials helps in identifying potential sources and understanding ancient trade networks or exchange systems.

It also tries to understand the manufacturing process of the potteries. A proper chronology of the site is build up with the help of the morphological analysis of the sherds. The nonscientific techniques also include the reconstruction of potteries. Diagnostic sherds are very less in the site. Only few rim sherds of very small size have been found in the site. Not a single piece of base part was found there. Therefore, to understand the functional aspect of the sherd collected from the site was a difficult task. Total 55 rim sherds were found in all the trenches in different depths. Out of 55 rim sherds 27 rim sherds have been reconstructed. The reconstruction of sherds helps to understand the shape and size of the sherds, which provide a lot of information about its usability by the then population of that area. The pots are mostly bowl and not big in size. The morphological analysis or a proper classification of the artifacts found in an excavated area is considered to be the basic task before moving for further analysis. Scientific analysis has been carried out to evaluate the provenance of pottery findings excavated at archaeological site Myrkhan. Tests showed that the majority of the examined sherds came from open fired kilns. A probable origin could not establish for the sherds. This study tried to make investigations into the provenance and distribution of the sherds recently excavated in that archaeological site Myrkhan, following two scientific approach- (i) chemical analysis of the samples and (ii) Physical analysis of the samples.

The availability and continuity of any craft is depend on its demands by the local people and its quality or other beneficiary aspects. Non continuity of this tradition of impressed pottery may be the result of other easily available product in this region. For instance, the growth of bamboo plants is very high in almost all the states of Northeast region including Meghalaya. From the ancient time to contemporary period it has been noticed that the people from these regions use a huge amount of bamboo products in their households for day to day work. These are long lasting and not easily breakable, which could be the reason for replacing the earthen wares.

The implications of this work, with regard to investigating both production and consumption sites, and for pottery provenance studies, are discussed. The findings suggest that these analytical techniques can be useful as an aid for chronological differentiations of Archaeological pottery. This work tried to build up ceramic chronologies for that particular site and tried to identify different phases in the Neolithic period and ascertain layers of the phases. It is done to evaluate whether pottery assemblage do give as much information on history and society of the people of Myrkhan. The study helps to construct a basic structure of the pottery tradition of the Neolithic people of the Khasi Hills District. The purpose of implementation of the above mentioned two impressions in the pottery are considered to be both functional and stylistic, though it marked a cultural phase in this region of India as well as in the world history of archaeology, because of its presence during the Neolithic cultural period all over the world.

Northeast India comprises of rich diverse cultural heritage. In all the Northeastern states the communities live there are having their own tradition, culture, different cultural practices, material culture according to the environment and ecological set up they are living in. In the contemporary world and even from the ancient time period with time these cultures of different communities are changing rapidly. Collection, preservation and conservation of these cultural heritage is significant to stay connected with our roots. Preservation of these material culture of the past as well as the present communities will provide a way for future research. The results of this study can be apply for chronological correlation for further research work by the future scholars.

EDX interpretation: silica- and alumina-rich raw materials, different firing temperatures for the body, one- or multi-step firing technologies. The obtained results have demonstrated that SEM and EDX analysis methods are indispensable tools of attaining information on some special technological features of ancient pottery (Karapukaityte, Pakutinskiene, Tautkus, & Kareiva, 2006).

Reason of Discontinuation of this typical Craft making tradition in this reason is not known clearly. There is no potters' community available in the entire Meghalaya region who practices this impressed design pots that was exists worldwide during the Neolithic cultural period. In the entire Meghalaya state potters' community is found only in the Lyrnai and

Tyrshang village in Jaintia Hills District, Meghalaya, who still practices pottery making tradition. But the process of manufacture is quite different and developed. The womenfolk are engaged in making potteries. One of the uniqueness found among them is, to preserve their traditional way of making they still do not use pottery wheel to make pots. These pots popularly known as the 'black pot' are handmade. The potters only use wooden tools to give shape to the pots. Two types of clay known as alluvial clay are used by these potters. They collect it from the alluvial region of the Sung Valley of West Jaintia Hills District. The two types of clays are slit pottery clay or Red clay and black clay. One of the probable reason of discontinuation of making impressed pottery that could mention here is the abundant use of bamboo items in day to day life of the people inhabited there. Bamboo grows naturally in a large amount and it is available in the entire area. Whether when study the Geological setup of the region it has been found that the raw material (i.e. clay) to prepare pots is found sparsely in few places in the different Districts of Meghalaya.

In this research work, the potsherds recovered from the archaeological site Myrkhan used as a supporting tool to find out the age old query about the origin of the people who inhabited this land in the Neolithic cultural period. Elman Service, an American Anthropologist made a fourfold classification of society depending on the settlement pattern. Mobile Hunter-Gatherer Groups (Sometimes Called "Bands"). These are small-scale societies of hunters and gatherers, generally of fewer than 100 people, who move seasonally to exploit wild (undomesticated) food resources. From the site information and the archaeological assemblages collected from the site a general information about the society can be drawn i.e. it must not be a large scale society. While dealing with the communities with mobile economy it is very difficult to study the society as the remains left by them in the used area is very scanty.

For the archaeological sites found worldwide, preservation is a significant concern. Archaeological research is an ongoing process and new discoveries and insights continue to emerge as researchers explore the region further. Meghalaya's archaeology contributes to a deeper understanding of the regions history and its place in the broader context of human civilization. The state government and archaeologists are working to protect and conserve Meghalaya's archaeological heritage, often collaborating with local communities to ensure that the sites are respected and maintained.

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Appendices

Appendix I
Images of potsherds from 4 Layers

Appendix II
Images of the excavated site and other the artifacts

Image 1: Photograph of excavated trench 5-1

Image 2: Photograph of a potsherd in a trench at the depth 50 cm.

Image 3: Photograph of Unfinished stone tools

Image 4: Photograph of the excavated site

Publications and Conferences

National Conferences:

1. Momi Das & Dr. Sukanya Sharma, *"Utilitarianism and Intangible Cultural Heritage: A Study in Assam"*, National Seminar on Cultural Heritage of Assam, Organised by Department of Anthropology, Guwahati University in Collaboration with Indira Gandhi Rastriya Manav Sangrahalaya, Bhopal. 23rd -25th April, 2015.
2. Momi Das, "*XRD Analysis and Morphological Study of the Pottery from Myrkhan, Meghalaya"*, National Seminar on Archaeology, History, Art, Museums and Folklores of the North-East India, Organised by Indian Archaeological Society, New Delhi in Collaboration with Rajiv Gandhi University (AP) and National Museum Institute (New Delhi). 20th- 22nd April, 2017.
3. Momi Das & Dr. Sukanya Sharma, "*Cord Marked Pottery: An Archaeometric Analysis"*, National Seminar on Contemporary Anthropology and North-East India and Forty- Eight Annual Conference of the Indian Anthropological Society, Kolkata, Organised by Department of Anthropology, Cotton University, Guwahati. 1st – 3rd November, 2018.

International Conferences:

4. Momi Das, Dr. Marco Mitri & Dhiraj Neog, *"Neolithic Cultural Materials from Khasi Hills of Central Meghalaya Plateau",* Himalayan Languages Symposium; An International Annual Conference for the Himalayan Language, Organised by Dept. of Humanities & Social Sciences, Centre for Linguistic Science & Technology, IITG. 8th-10th June, 2016.
5. Momi Das & Dr. Sukanya Sharma, *"Analysis of Pottery Attributes Using Scientific Methods"*, 6th International Congress, Society of South Asian Archaeology, Organised in Indian Museum, Kolkata. 16th – 18th March, 2018.
6. Momi Das & Dr. Sukanya Sharma, "*An Archaeometric Analysis of Cord- Marked Pottery of North-East India"*, International Joint Annual Conference (52nd Annual Conference of the Indian Archaeological Society, 47th Annual Conference of the Indian Society for Prehistoric and Quaternary Studies and 43rd Annual Conference of the History and Culture Society), Organised by the Department of Archaeology, University of Kerala, Kariavattom Campus, Thiruvananthapuram, Kerala. 7th – 10th November, 2019.

Attended Conferences:

7. Volunteered and participated in organising the National Level Graduate Research Meet, 2015, Organised by the Department of Humanities and Social Sciences, IIT Guwahati During 28th- 30th October, 2015.
8. Member of Organising Committee of the ICPR Sponsored Teachers Meet on Crisis of Multiple Identities in Contemporary World, Organised by the Department of Humanities and Social Sciences, IIT Guwahati. 15th – 17th February, 2016.

Workshop:

9. ICSSR- Sponsored Ten-Day Research Methodology Programme, Organised by Indian Institute of Technology, Guwahati. 14th- 23rd March, 2016.
10. Workshop on "Contributions of Earth Sciences to Archaeology", Organised by the Department of Archaeology, Cotton College State University, Guwahati. 4th January, 2017.