

ARCHAEOMETRIC INVESTIGATIONS OF POTTERY PRODUCTION AND
PROVENANCE AT THE NEOLITHIC AND CHALCOLITHIC
UĞURLU HÖYÜK-GÖKÇEADA

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UĞURLU HÖYÜK-GÖKÇEADA**

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ABSTRACT

ARCHAEOMETRIC INVESTIGATIONS OF POTTERY PRODUCTION AND PROVENANCE AT THE NEOLITHIC AND CHALCOLITHIC UĞURLU HÖYÜK-GÖKÇEADA

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This study aims to identify changes in raw material usage and production technologies through petrographic, mineralogical, and chemical analyses of 74 ceramic fragments from Uğurlu Höyük-Gökçeada, one of the earliest agricultural settlements in North Aegean, dating to the Neolithic and Chalcolithic periods (circa 6600-4900 BC).

The analysis reveals that the clay used in ceramic production across all archaeological phases is consistent with the island's geology, primarily originating from andesitic-rhyolitic and dioritic rocks. Within the main clay matrix, smaller amounts of schist, basalt, and sedimentary rocks from various regions of the island are also present. The andesitic-rhyolitic and dioritic rocks, which constitute the main raw material group, can be sourced from within a 1 km radius of the Uğurlu Höyük settlement. Schist has the potential to naturally mix with local materials from streams in the island's central or Marmaros region. Basaltic material, specific to the Eşelek area, is observed in two samples from the phase IV.

Statistical analysis of the chemical results indicates that, across all phases, two locations near the settlement were predominantly utilized, alongside various other sources from the area. It is noted that the use of different locations was more common in the earlier phases and became more restricted in later phases. A characteristic feature of this period is the consistent use of the coiling technique in ceramic production, with raw materials sourced from very close to the settlement, suggesting a local production process that persisted without significant alteration throughout the Neolithic and Chalcolithic periods.

Keywords: Petrography, Geochemistry, Pottery Characterization, Gökçeada-Uğurlu, Neolithic-Chalcolithic

ÖZ

NEOLİTİK VE KALKOLİTİK GÖKÇEADA-UĞURLU HÖYÜK'DE ÇANAK ÇÖMLEK ÜRETİMİ VE KAYNAK KULLANIMI ÜZERİNE ARKEOMETRİK ARAŞTIRMALAR

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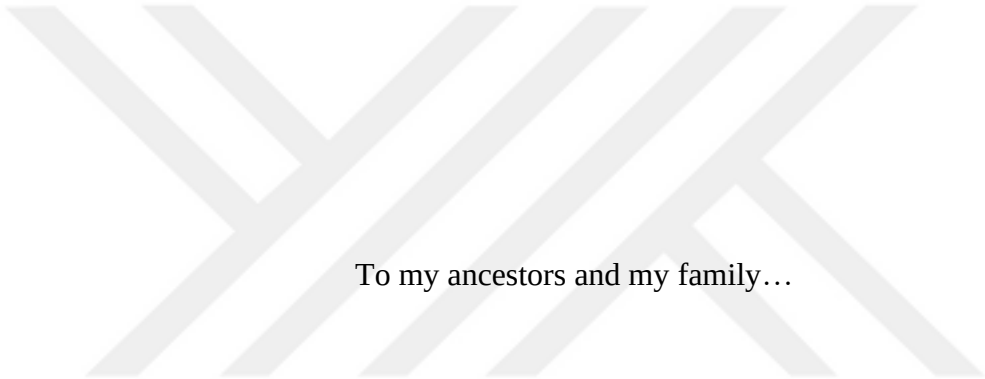
Bu çalışma, Kuzey Ege'nin en erken tarımcı yerleşimlerinden biri olan Uğurlu Höyük-Gökçeada'nın, Neolitik ve Kalkolitik dönemlerine ait (c.6600-4900 BC) 74 adet seramik parçası üzerinde, petrografik, mineralojik ve kimyasal analizler gerçekleştirerek, hammadde kullanımı ve üretim teknolojilerindeki değişimleri belirlemeyi amaçlamaktadır.

İncelenen tüm arkeolojik fazlarda, seramik üretiminde kullanılan hamurun ada jeolojisiyle uyumlu olduğu ve ağırlıklı olarak andezitik-riyolitik ve dioritik kayalardan köken aldığı anlaşılmaktadır. Bu ana hammaddenin oluşturduğu hamur içinde, az miktarlarda, adanın çeşitli bölgelerinde mevcut şist, bazalt ve sedimanter kayalar da görülebilmektedir. Ana hammadde grubunu oluşturan andezitik-riyolitik ve dioritik kayalar, Uğurlu Höyük yerleşimi ve çevresindeki 1km'lik alan içinden temin edilebilecek niteliktedir. Şist adanın merkezindeki veya Marmaros

bölgesindeki akıntılardan yerleşim çevresindeki hammaddelere doğal yollarla karışma potansiyelindedir. Bazaltik malzeme, Eşelek bölgesindeki kayalara özgü olup, Uğurlu'da IV. faza ait iki örnekte görölmektedir.

Kimyasal analiz sonuçlarının istatistiki incelemelerine dayanarak, tüm fazlarda, yerleşim çevresindeki iki lokasyonun ağırlıklı olarak kullanıldığı; bunun yanı sıra yine yerleşim çevresindeki çeşitli lokasyonlardan farklı kaynakların kullanıldığı anlaşılmaktadır. Bu tarz farklı lokasyon kullanımının ilk evrelerde daha yaygın, son evrelerde ise daha sınırlı olduğu da gözlemlenmektedir. Dönemin karakteristik özelliği olarak tüm fazlarda seramiklerin üretiminde ağırlıklı olarak fitil/sucuk tekniğinin kullanıldığı ve hammaddelerin yerleşimin çok yakınlarındaki kaynaklardan temin edildiği bir yerel üretim sürecinin Neolitik ve Kalkolitik dönemlerde bozulmadan devam ettiği anlaşılmaktadır.

Anahtar Kelimeler: Petrografi, Jeokimya, Çömlek Karakterizasyonu, Gökçeada-Uğurlu, Neolitik-Kalkolitik



To my ancestors and my family...

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LIST OF ABBREVIATIONS

ABBREVIATIONS

XRD: X-Ray Powder Diffraction

ICP-OES/MS: Inductively Coupled Plasma-Optical Emission Spectrometry / Mass Spectrometry

PPL: Plane Polarized Light

XPL: Crossed Polarized Light

ppm: parts per million

VRF: Volcanic rock fragments

SRF: Sedimentary rock fragments

MRF: Metamorphic rock fragments

BP: Before present

c: circa

Bt: Biotite

Q: Quartz

Pl: Plagioclase

AFs: Alkali Feldspar

Fs: Feldspar

Hb: Hornblende

Px: Pyroxene

Phy: Phyllosilicate (clay mineral/mica)

M: Mica

I: Illite

Mnt: Montmorillonite

K: Kaolin

Ch: Chlorite

G: Gypsum

C: Calcite

O: Oxidized

R: Reduced

r: Thinly reduced

o: Thinly oxidized

Clr: Color

SN: Sample number

ST: Surface treatment

Th: Thickness

Sm: Smoothing

Brn: Burnished

Vt: Very thin

Int: Interior

NS: Not slipped

CHAPTER 1

INTRODUCTION

Ceramics are one of the most common archeomaterials. Their original emergence dates back to the Eurasian hunter-gatherers of the Last Glacial Maximum (c. 30000 BC) who were making ceramic figurines. However, the earliest known pottery seems to have emerged in East Asia around c. 20,000 BC, (Craig et al., 2013). In the Near East, the emergence and wide spread of clay technologies and pottery is associated with the later stages of the Neolithic Process (c. 10000-6500 BC).

The emergence of sedentism and gradual dependence on domesticated plants and animals by formerly hunter gatherer communities, is called the Neolithic. The Neolithic Process first started in the Fertile Crescent and Anatolia (c. 10000-7000 BC) and then spread to Europe (c. 6800-4000 BC). During this time, major social changes in life also occurred; for example, the house-based family groups and social roles necessitated by agriculture, first emerged.

The emergence of pottery had a significant impact on prehistoric people's lifestyle and subsistence, increasing the usable food resources and leading to a sedentary life. Thus, archaeometrical investigations of pottery have been an important research area for understanding social, economic and technological advancement in prehistoric societies and is expected to help us to understand the technological change and continuity in production methods through time and to contextualize the results in wider social and economic terms.

In the archaeological literature, it is commonly assumed that pottery technology emerged as a response to the functional needs of food storage, food preparation and cooking. However, a number of recent studies would also suggest that first the pottery may have emerged as a symbolic display item (Craig et al., 2013).

Uğurlu Höyük which is located on the western part of the island of Gökçeada (Imbros) about 17 km away from the Gelibolu Peninsula is one of the earliest Neolithic sites in the North Aegean. It has been excavated since 2009 to shed light on the processes of Neolithization in this region, specifically to understand the effect of migrations from Anatolia on the local population (if any).

The aim of this study is to identify the shifts in raw material use and production technologies for ceramics through time and space in Neolithic and Chalcolithic site of Uğurlu Höyük in Gökçeada (Imbros Island, North Aegean) by investigating the mineralogical and chemical characteristics of a group of ceramics.

The purpose of this particular study is to investigate the material specifications and technological characteristics of a collection of Uğurlu Höyük by analytical methods. These investigations help us to understand mainly, the forming methods by the examination of macro-traces diagnostically, identification of firing atmosphere and forming and shaping techniques of pottery (such as coiling, slab building, pinching, moulding etc.) by stereomicroscope, the nature of the raw materials by using polarizing light microscope and chemical analytical methods. Hereby to get an idea about the pottery usage, processing, manufacture and technology of Uğurlu diagnostic and archaeometric methods are used. The outcomes are used to establish similarities and differences of the materials used in different cultural phases, by making the characterization of fabric groups. Hence to observe the change of the raw materials used through a time span of early Neolithic to early Chalcolithic through time.

- 1) Does the emergence of pottery at Uğurlu reflect a local development or an external influence?
- 2) Is there a change in pottery production techniques through the time and space at Uğurlu Höyük?
- 3) How does this change (if any) correlate with the other social and economic processes at the site?

In approaching the problem, 74 pottery sherds from Uğurlu Höyük levels V-IV-III (c. 6600 BC to 4900 BC) is studied.

The outline of the study is summarized as follows:

Chapter 1 is the introductory chapter, providing a brief information about the importance of pottery from emergence through Neolithic period and introduction to Uğurlu Höyük, outlining the research questions, and stating the aim of the research. Chapter 2 presents a literature review covering a brief overview on archaeometric studies of Neolithic pottery at Aegean Islands and Uğurlu-Gökçeada and gives information about the scientific methods for the identification and characterization of pottery. Chapter 3 describes about the sampling strategy and introduces the archaeometric methods applied to Uğurlu pottery samples. It describes the stereomicroscopic, petrographic, mineralogical (XRD) and chemical (ICP-OES/MS) methods used that are performed to answer the research questions. Chapter 4 presents and evaluates the results of the analyses. In Chapter 5 results of the analyses are explained and discussed. Finally, Chapter 6 offers conclusions and make suggestions for further research.



CHAPTER 2

LITERATURE REVIEW

2.1 A Brief Overview Archaeometric Studies of Neolithic Pottery at Aegean Islands and Uğurlu-Gökçeada.

The broad term “archaeometric studies” refers to, characterization and provenance of inorganic materials as mainly ceramics, metals and glasses, dating of archaeological materials, DNA studies on ancient genetic materials, identification of pigments, studies on preservation, restoration and reconstruction of cultural heritage monuments.

The Aegean Islands are in a critical location where Anatolia and Greece meet and according to many researchers played an important role part of a route spreading of a Neolithic way of life to Southeast Europe (Treuil et al., 1996). From prehistory to late antiquity the Aegean area played an important role and were important for the existence of sea routes which facilitated the movement of people, materials, technologies and trade throughout the continents (Stampolidis et al., 2015). A significant number of archaeometric studies concerning this area, covering a wide range of different time periods by multiple analysis techniques exist. Archaeometric studies in the area of Aegean Sea at prehistoric times can be divided into categories, as; dating studies, chemical analyses, DNA analyses, paleoenvironmental studies, geophysical studies, isotope analyses, restoration, and conservation studies. Basically, chemical analyses in inorganic materials are distinguished in four subcategories depending on the analyzed material as ceramics/potteries, glasses, metals and obsidian. The relevant studies are focused on the processing technology of the raw materials, chemical characterization and provenance studies. Potteries/ceramics are investigated with different techniques, including optical and

electronic microscopy, spectroscopic, X-ray related techniques, and nuclear methods.

Liritzis et al. (1991) studied Neolithic pottery from Aghios Petros (North Aegean) and the neighboring sites to explore the degree of contacts and influences among these sites based on Cluster Analysis of the trace elements obtained by Neutron Activation Analysis (INAA). Hein et al. (2004) sampled 17 clayey raw materials from seven different locations in Central and Eastern Crete, an area very popular for ceramics provenance studies. All samples were characterized by petrography and chemical and mineralogical analysis. By this method, deposits were distinguished, although some deposits showed compositional relations. Papageorgiou and Liritzis (2007) investigated and compared Neolithic ceramics from Aegean, Greece and Asia Minor (Ulucak) by using multivariate statistical techniques in evaluation of chemical data obtained by X-ray Fluorescence (XRF) spectroscopy. On the other hand, Hein et al. (2008) studied amphoras from Kos Island using NAA and XRF and petrographic analysis for chemical and mineralogical composition respectively. Furthermore, Quinn et al. (2010) studied Neolithic pottery from Youra island with a combination of petrographic analysis and INAA. Besides, Karatasios et al. (2013) studied ceramic microstructures, chemical and mineralogical composition of Hellenistic ceramic beehives from Agathonisi island by Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD) and petrographic methods. And, a data base of analytical results of analyses of diachronic pottery covering a wide range of areas in Aegean islands and Greece was published by Hein and Kilikoglou (2012).

The site of Uğurlu at the Island of Gökçeada is the earliest Neolithic settlement thus far known in the Eastern Aegean Islands, and it is likely to be in a critical importance for understanding the spread of a Neolithic way (Erdoğu, 2014). The latest archaeological findings on Gökçeada provide fresh insights into the early prehistory of the North Aegean Islands. The earliest discoveries consist of chipped stone tools dating back to the Middle Paleolithic period. The presence of Melian and Central Anatolian obsidian indicates long-distance exchange networks, implying that seafaring was necessary for at least part of the journeys (Erdoğu, 2016). The earliest

pottery found at the site appears around 6600 BCE (Phase VI–V), and its quantity is quite limited (only about 30 sherds) (Erdoğu et al., 2021).

Previously some pottery studies are done with 30 sherds (10 Phase V; 6600-5900 BC & 20 Phase IV; 5900-5500 BC) and three clay samples around. Thin-sections of Uğurlu were analyzed by Chris Doherty and Eleni Palamara using an optical microscope to provide information on characteristics of the pottery fabrics. Also, the Scanning Electron Microscope (SEM) was used and chemical composition of the fabric was also measured for each sample. Only one type of clay could be distinguished and it was non-calcareous of andesitic/dacitic composition. The minerals found were quartz, alkali and plagioclase feldspars, amphiboles and titaniferous minerals. However, most Phase IV samples appeared slightly coarser and contain higher amount of inclusions compared to those from Phase V. A comparison between the results of the thin section analysis and the chemical composition of the sherds and clay samples gave the impression that the Neolithic pottery of Uğurlu has been made of local clays (Erdoğu, 2014).

The other archaeometric analyses were conducted by Dirican (2018), on stone axes and chisels, obsidian, and marble artifact groups obtained from the IV-III (5900-4900 BC) and II (4900-4350 BC) phases of the mound. Petrography, XRD, P-XRF, and stable isotope methods were applied to determine the mineralogical and chemical properties of the raw materials used in the production of these artifact groups. The pottery's raw materials, illite and smectite clays, and andesite from the "Gökçeada Domes" was likely used as temper, with occasional use of volcanic rocks containing quartz monzonite, diorite, and diorite porphyry. Grinding stone artifacts likely originate from the "Çamlıca Metamorphics" northwest of Uğurlu Höyük. P-XRF analysis showed most obsidian came from Melos, with some Göllüdağ and Nenezi Dağ obsidian in Phase V, decreasing in later phases.

Also, Abuşaha (2024) studied 10 pottery sherds from the Early Chalcolithic Period of Uğurlu, Gökçeada. According to the results, the firing temperature is thought to

be 800-850°C and it was concluded that the samples examined were produced locally from clay resources in the region.

This thesis aims for a more detailed study by using petrographic, mineralogical and chemical analysis methods on pottery of Uğurlu, covering a time span of Early Neolithic to Early Chalcolithic (c.6600 BC to 4900 BC) and compare the results with soils obtained from different three locations on the island and the data obtained for volcanic rock samples by Şen et al. (2020), to support results and enlighten the change of raw materials in the pottery production through time. This study will also contribute to understand the effect of migrations from Anatolia through changes and transformations on traditional pottery production techniques.

2.2 An Introduction to Pottery

Ceramic is one of the most common archeomaterials found in the archaeological sites, since prehistoric times. Its diversity in materials used and the manufacturing technology makes the archaeological ceramic analysis avocatory.

Clay began to be processed tens of thousands of years ago to make prestige objects and representations such as figurines and ornaments. The origins of ceramic technology have long been identified with ceramic figurines from Dolni Vestonice that have been dated at 26,000 years before the present (B.P.) (Keally et al., 2004). When it first emerged in East Asia between 20,000 and 12,000 calibrated years before the present (cal BP), it was a hunter-gatherer innovation (Craig et al., 2013). Through time, fired clay, i.e pottery/ceramics, became widely used for cooking, storage, prestige technology for ritual, feasting, and display.

The term “pottery” refers to the, earthenware, tableware of terracotta, stoneware and porcelain as cooking and storage vessels. Pottery and ceramics are categorized based on their composition, surface treatments, and firing conditions. (Norton, 1970). Unvitrified, porous, and low-fired pottery includes terra-cottas and earthenware, while vitrified and high-fired, ceramics include stonewares and porcelains. Terra-

cottas are relatively coarse, porous wares fired at low temperatures, usually 900°C or less, the earliest fired pottery falls into this category (Rice, 1987).

Beginning from the Neolithic period, because pottery is indestructible and found in large quantity, its study in terms of style, has always been essential for the interpretation of archaeological sites, periods and regions. As a result, ceramics have got attention for archaeometric or archaeological science studies from their beginnings in the 1950s (Tite, 2008). The scientific study of archaeological ceramics examines the entire life cycle of surviving artifacts, from their production and distribution to their use and eventual disposal. (Tite, 1999, 2008). The reconstruction of the production technology of ceramics involves determining, first what raw materials were used and how they were prepared and, second, how the ceramics were formed, surface treated, decorated, and fired. Such information can be derived by analyzing the ceramics' macrostructure, microstructure, chemical and mineral/phase compositions. To identify the production center and/or the source of the raw materials used and their distribution, provenance studies are performed, on the basis of their thin-section petrography and/or chemical composition, whether pottery was locally produced or imported. (Tite, 2008).

The steps in the production of pottery may be summarized as;

Preparation of the clay, forming, drying, surface treatment and firing (Albero, 2014; Roux, 2019). The basic production steps of a pottery for Neolithic time, is shown schematically in Figure 2.1.

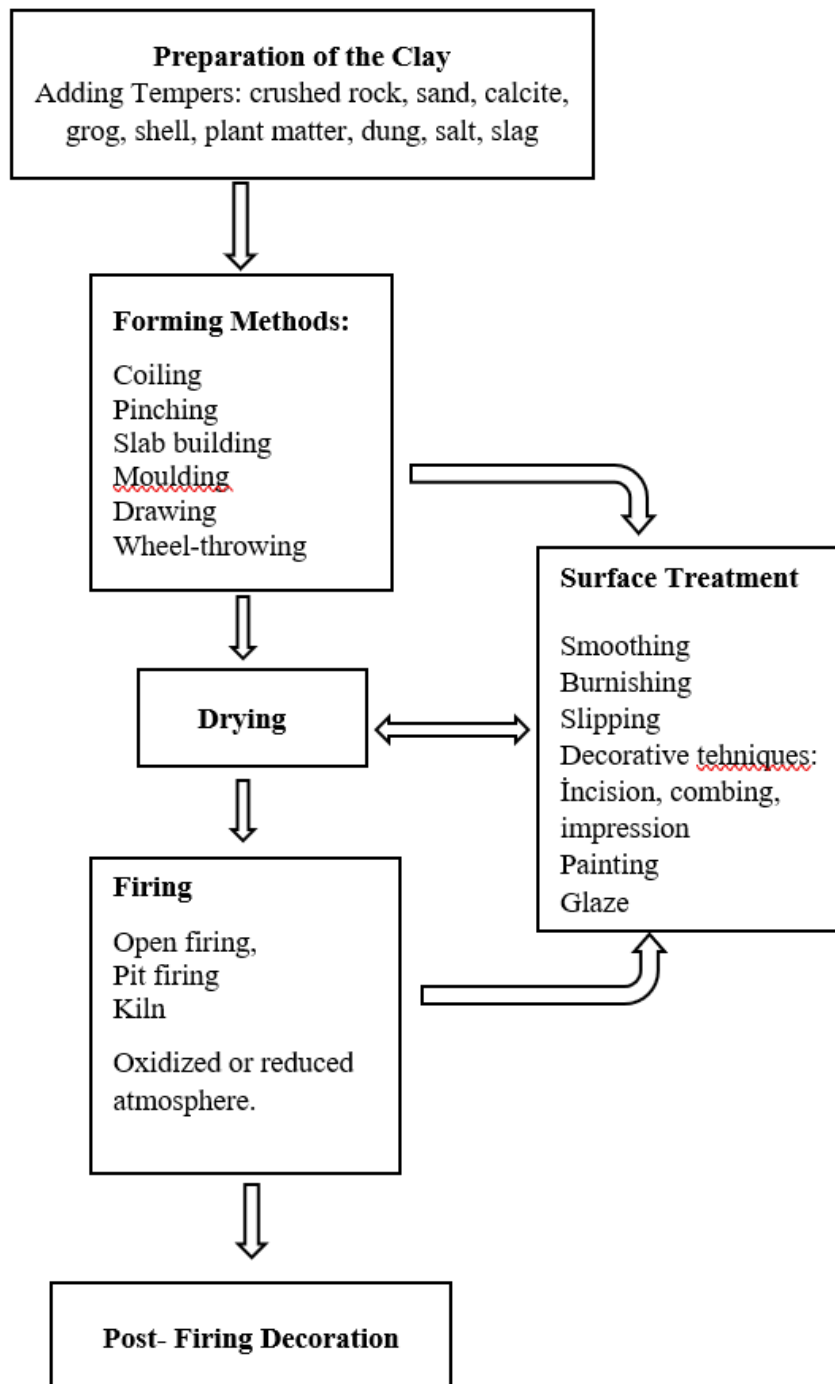


Figure 2.1. Flow chart of the basic method of pottery production (modified from Rye, 1981; Rice 1987)

2.2.1 Paste preparation

In this study, the term paste is defined as the plastic material with a particle size less than 0.1 mm. The preparation of the paste changes depending on the characteristics and properties of the clay material. The term clay usually describes a fine-grained earthy material that becomes plastic or malleable when moistened. The paste preparation includes the following processes: fragmentation, granulometric sorting, removal of the coarse materials, addition of tempers, mixing of the clay materials, homogenization and hydration. The main requirement in choosing clay for pottery production is to ensure that the clay is plastic enough for shaping but that its drying shrinkage is not so great as to cause cracking (Tite, 1999).

Some clays may be too plastic or sticky. The potters have added nonclay clastic materials to their clay mixtures to modify clay pastes. The intentional addition of aplastic materials to a clay paste is termed as ‘tempering’ and these additions, commonly called “temper” by archaeologists and this term is sometimes used as a synonym for aplastic inclusions (Quinn, 2013).

Besides helping to correct the paste’s stickiness, to control and adjust the malleability of the clay material, tempering also helps to increase porosity, reduce shrinkage, decrease drying time, reduce deformation in drying, and/or increase its thermal and/or mechanical resistance and improve firing characteristics. Raw materials such as sand, plant fiber, volcanic ash, crushed shell, rock, or pottery itself (grog) were added to solve these problems of workability. Tempers are generally added during homogenization (Rice, 1987).

Among the mineral tempers of ceramics, quartz is the primary and most dominant mineral since it is resistant to environmental conditions, chemical transformations and mechanical abrasion. Secondly important are a group of minerals with different compositions and varying crystallographic properties depending on their origin, are feldspars. Thus, they provide information on the rocks which they originate. Additionally, there is a big variety of different silicates, like micas, amphiboles and

pyroxenes, each representing a family of minerals from different varieties of rocks with a considerable diversity of properties (Riederer, 2004).

2.2.1.1 Addition of Temper

The term temper is defined as the aplastic material larger than the paste grain size. The addition of temper can affect some of the basic physical properties of pottery vessels related to their function. These are permeability, heating/cooling effect, thermal shock resistance and toughness. Specific types of temper can be added in order to control these properties.

Generally, the addition of temper does not exceed 20%, because a higher proportion may make the vessel brittle (Kilikoglou et al., 1998). During drying, the volume of the paste decreases in different degrees, depending on the properties of the clay material. On average, shrinkage varies from 2% to 10%. The primary role of temper addition is to arrange the degree of plasticity and shrinkage during drying. The addition of organic materials such as chopped grass, moss, or animal feces results in easier handling and improved plasticity (Roux, 2019).

Adding Material to Improve Resistance to Mechanical and Thermal Shocks:

Thermal shock resistance is the ability of a ceramic to withstand stress caused by sudden changes in temperature, such as heating and cooling. Resistance of a material to shock depends on its hardness and tenacity (Müller, 2016). Hardness describes a material's ability to resist surface penetration, while tenacity refers to the amount of work or energy needed to break the material through pressure, stress, or impact. Temper materials such as quartz, sand, grog, and graphite increase the refractoriness of the paste and provides cracks that reduce thermal conductivity of the vessel and increase its mechanical strength.

Tempered pastes exhibit greater tenacity compared to those without temper. For example, pastes containing more than 20% quartz and fired at 800°C are more tenacious than those with less than 10% quartz fired at 950°C. Although the latter

are harder, they show reduced deformation capacity and are more brittle. (Kilikoglou et al., 1998).

Toughness is defined as the ability of ceramics to endure physical shock without fracturing. The presence of non-plastic inclusions and pores helps to distribute and absorb the energy from a crack when physical stress is applied, thereby preventing its propagation. So, it is possible to increase the toughness of a vessel by adding tempers as shell or phyllite to the paste. (Tite et al., 2001; Quinn, 2022)

Adding Material to Improve Thermal Conduction and Heating Effectiveness:

Good thermal conduction helps considerably to resistance to thermal stress, which varies according to the difference in temperature between the outer and inner walls of the vase. In this case not too porous and permeable paste is required, which seems to be in contradiction with the production of pastes that are more resistant to thermal shock. Tempers such as calcite would be a good choice for cooking pots as they favor heat conduction and resistance to mechanical shocks (Quinn, 2013; 2022).

Heating effectiveness is the rate at which a ceramic vessel transfers heat from external source to its contents. The addition of specific types of temper such as granite can improve the heating effectiveness of a pottery vessel by increasing its thermal conductivity. Conversely, increasing the pore spaces by adding organic temper can reduce the thermal conductivity (Quinn, 2013).

Adding Material to Improve Conservation of Water Coolness:

To increase the coolness of the water inside the jars, ceramic pastes must allow continuous heat exchange on the outer wall. For this process, "hydroceramic" pastes are prepared that "sweat" due to condensation and evapotranspiration of water. In contrast, these pastes are not favorable for cooking pots. The preparation of hydroceramic pastes involves tempers that help porosity and permeability, which is the degree to which water passes through the vessel walls. The addition of organic tempers such as straw or dung, granite-type mineral temper additions or salted clay minerals can be used (Rice, 1987) for this purpose.

In this study, the term “aplastic inclusion/inclusion” is used rather than temper for avoiding any remark, because it is often difficult to ascertain whether the temper material has been deliberately added to enhance the workability of the paste or not.

2.2.2 Forming Methods

The primary techniques for making pottery vessels include modelling from a lump of clay by pinching, drawing, coiling, slab-building, moulding, and wheel throwing. (Berg, 2008). The coiling technique is a technique which includes the techniques by pinching, spreading, and drawing. The slab technique is a technique which involves the beating for the forming of the slabs. In this technique a vessel is constructed from one or more slabs of clay that are rolled or patted flat and then joined into the desired shape (Rice, 1987).

This work explores the potential of analysis based on the qualification of the orientation of aplastic components or pores of a ceramic body to distinguish between the two basic families of hand-building techniques as coiling and slab-building.

2.2.3 Surface Treatment / Finishing

The finishing techniques are achieved after the preforming stage (container with its final geometrical features but hasn't been subjected to finishing techniques) on wet or on leather hard clay surface (Hunt, 2016).

Surface treatments are usually carried out at the end of the drying phase, once the pottery vessels reach leather-hard stage. Surface treatments convert the vessel either by rubbing the vessel by hand or with a tool (smoothing, burnishing, polishing) and coating (slips, glazes, mineral pigments, organic materials, graphite, silica, carbon) to the desired finish. These tools include mostly cloth, leather, stones, bone, wood, corn, shell and water-worn pebbles etc.

The most common surface treatment techniques applied in Neolithic time, are slips and polishing. These operations have also effects on the behavior of the paste during the firing process. The direct application of a thin layer clay-rich layer to the outside of a ceramic object is called 'slipping'. A slip is applied by dipping the dried object into a mixture of fine clay and water or pouring this over it. The water is absorbed into the body, leaving the clay behind on the surface. For decorative reasons, slip is often made from different colored, usually finer clay from that of the body of the object. Colorants such as iron or manganese may be added to affect the fired color (Quinn, 2013).

Surface treatment techniques, that is smoothing and burnishing, help to define cultural, traditional, and economical state of an ancient society. A smoothed surface has large irregularities and a matte or dull appearance due to the diffuse reflection of light. A burnished surface has only small-sized irregularities and is lustrous/glossy due to specular reflection of light. Smoothing slightly aligns the platy minerals only at the very surface, whereas, burnishing may create two separate individual levels: A burnish peel and a subsurface layer (Ionescu and Hoeck, 2020). The differences can be shown by applied analytical methods, such as macroscopy, optical microscopy, electron microprobe, scanning electron microscopy, and vertical scanning interferometry.

2.2.4 Firing Procedures

The estimation of the firing temperature used in the production of pottery, together with the relationship between firing atmosphere and color, have been very important themes in technological pottery studies.

Firing causes mineralogical and microstructural modification of clay pastes, which results in changes in characteristics such as porosity, resistance to physical and thermal stress, color and hardness (Rice 1987). The type of raw material used, the kind of firing structure, temperature, atmosphere and duration of firing all influence

such microstructural and mineralogical changes. According to the Gosselain (1992), rather than firing temperature, the differences in the duration and temperature rate are important variables that allow firing structures to differentiate.

The two basic system for firing earthenware are an open firing, such as a bonfire, and firing in a closed structure, such as a kiln (Gosselain, 1992). Open firings typically reach their maximum temperatures in 20–30 min, and this temperature is reached for a few minutes. In contrast, kiln firings, take an hour or more to reach maximum temperature, and in the firing of pottery, this temperature is maintained for about 30 min. Because of the very fast heating rates achieved, only coarse textured pottery can be open fired. Otherwise, a fine textured vessel may crack because of the steam loss of absorbed and chemically combined water, which cannot escape. In contrast, because of the much slower heating rates, both fine and coarse-textured pottery can be fired in a kiln.

The firing atmosphere employed is normally apparent from the color of the pottery. Iron and organic matter occur in most natural clay sources and the abundance of these substances has an effect on the color of clay in its raw and fired state. Iron that is present in small quantities (usually <5%) has a strong effect on color depending on its abundance and oxidation state. Iron is oxidized to ferric minerals such as hematite (Fe_2O_3) during firing in an oxidizing atmosphere, giving the ceramic body an orange, red or brown color. This process takes place above c. 600°C, once all organic matter has been removed. Under reducing conditions iron exists as dark ‘ferrous’ minerals such as magnetite (Fe_3O_4), which contributes to the grey or black color of reduced ceramics caused by the presence of carbonized organic matter. Thus, red or buff pottery indicates an oxidizing atmosphere, whereas black to grey pottery indicates either a definite reducing atmosphere, or insufficient firing time for the organic material within the clay to have been burnt out (Quinn, 2013).

Much prehistoric pottery was fired at relatively low temperatures (<800°C) in open bonfire or pit firings (Middleton, 1997), and is rarely fully oxidized as a result of

direct contact with the fuel. Besides, mostly the time for complete oxidation is insufficient (Hunt, 2016).

2.3 Analysis Methods

The primary aim of the application of the physical sciences to the study of ancient ceramics is to reveal the reconstruction of their life cycle from production through distribution and use (Tite, 2008).

In this thesis, the identification methods are used for two different issues; one for the pottery forming techniques which includes, diagnostic examination, stereomicroscopic and polarized light microscopic techniques. Secondly, for the manufacturing and provenance studies of Uğurlu pottery samples, the raw materials used are identified by petrographical, mineralogical and chemical methods as microscopic, XRD (X-ray diffraction) and ICP-OES/MS (Inductively Coupled Plasma-Optical Emission Spectrometry/Mass Spectrometry).

2.3.1 Diagnostic Examination

Various diagnostic properties have been used for the identification of pottery-forming techniques, the most common of which are surface morphology, variability in wall thickness, and orientation of components of ceramic materials. (e.g., Balfet et al., 1983, 57–67; Courty and Roux, 1995; Ther et al., 2019).

The application of physical force on the plastic clay during forming is the main factor affecting the alignment of the components. Two basic types of hand-building techniques — slab building and coiling — can be clearly distinguished based on the effects of the forming process (Berg, 2008; Carr, 1990; Rye, 1981; Whitbread, 1996). The action of the potters' hands or the tools that were used can leave characteristic traces on the exterior of the object that are indicative of the construction methods that were employed.

2.3.2 Petrographical Examination

Petrographical studies by stereomicroscope and polarizing microscope can be successfully used for the observation of the surface treatments applied and for the manufacture techniques of ceramics. Stereomicroscope and polarizing microscope are the most common choices to investigate at (10–100×) and (100–1000×) scales.

2.3.2.1 Stereomicroscopy

The application of pressure to clay paste causes mineral particles, voids and organic fragments to apply a favorable orientation which will affect the whole clay paste (Rye, 1977, 1981). The direction of pressure and degree of compression applied to the clay, during the forming stage, causes the inclusions and voids to take up a preferred orientation. The resulting distribution and arrangement of inclusions and orientation and shape of the voids characterize the forming methods (Rye, 1977; Rye, 1981, Berg, 2008)

The slabs from which the vessel is built are usually formed by pinching, causing alignment of the inclusions and voids parallel to the margins of the vessel wall in the perpendicular section and the randomly oriented structure in the tangential section (Ther et al., 2019).

In coiling, rolling combined with compression is used to form the individual segments (coils) from which the vessel is built. (Middleton, 2005; Pierret, 1995; Rye, 1981; Whitbread, 1996). The concentric orientation of inclusions and pores in the section may be evidence for the use of the coiling method. Due to the rolling action, inclusions are aligned in the same direction as the movement of the tool and this can be viewed through the cross section. (Rye, 1977; Berg, 2008)

Besides studies based on thin sections and the diagnostic approach, there are other methods. Shaping techniques can be identified on pottery by imaging grain and void

orientation patterns, which are usually done using radiographs at the macroscopic scale (Berg, 2009; Glanzman, 1983; Rye, 1977, 1981).

The experimental approaches obtained by uCT techniques (Neumannová et al., 2017) and the imaged grain and void orientation patterns at the microscopic scale using high resolution scans of freshly cut pottery cross sections (Ross et al., 2018) are combined to examine the appearance and the characteristic features of the orientations of inclusions and voids produced by different forming techniques.

2.3.2.2 Polarized Light Microscopy

Polarized light microscope is used to study petrographically the thin sections of rocks, potteries and similar materials with light transparent minerals. It provides a detailed information about investigating effects of main forming techniques (coiling, slab building, pinching etc.), microstructure of ceramics, texture and nature of various mineralogical components. Thin section petrography is especially effective when a large group of non-plastic inclusions are present in the ceramics, so the Neolithic ceramics are very suitable for this purpose.

We can derive information about:

1. Non-plastic inclusions or temper: minerals and rock fragments, organics.
2. Pottery-making techniques on the basis of the nature of the tempers, the roundness, or angularity, of the inclusions, and the grain-size and distribution within the pottery groundmass, firing temperature, firing atmosphere (Echallier, 1984; Quinn, 2009).
3. Matrix/microstructure of paste; possible clay source, intentional tempering i.e., composition of fabrics as types, amounts, size ranges, roundness and sorting of non-plastic inclusions and types of accessory minerals (Blanco-Gonzalez, 2014).
4. Surface decoration or treatment such as slips, glazes and paint.

Through petrography, very important two main information about firing technology can be accessed: atmospheric conditions and temperature. During firing process, the volatiles as H₂O, organics and carbonaceous material are removed and fabric color is generally controlled by the oxidation of ferric oxides. Iron-rich clay is generally darker colored than clay with relatively lower amounts of iron. Oxidizing conditions produce a reddish-orange or brown fabric color, due to the oxidation of iron and iron-rich minerals (Fe₂O₃). This process takes place above 600°C, once all organic matter has been removed.

Black and gray fabrics, on the other hand, often indicate a reducing atmosphere (O₂ poor/CO rich). That is, a reducing atmosphere is responsible for both the reduction of iron oxides and deposition of carbonaceous material and thus yields dark and black colors and zonation. Most prehistoric firings are not completely oxidized nor reduced because the atmosphere can fluctuate extensively in time and temperature. (Hunt, 2019). Nevertheless, even in an oxidizing environment, if the firing is done quickly and vessels are not allowed a sufficient “soak time”, a dark core may be produced by the incomplete oxidation of iron in the fabric and/or the incomplete burning of organic material.

Firing features are easily visible macroscopically, but can be described more systematically on thin sections, incorporating void texture and groundmass features.

Equivalent firing temperatures for open firings generally range between 550-750°C and 750-950°C for kiln firings. Firing temperatures up to 1000°C are relatively easy to achieve in a kiln environment, although achieving temperatures between 1100-1150°C requires significantly more technological sophistication (e.g., thermal insulation of the kiln and throughput of hot gasses) (Tite, 1995). Specific minerals and rock inclusions also undergo color changes or may be destroyed during firing and can therefore be used for archaeothermometry. Amphiboles such as hornblende exhibit a change in body color in thin section from green to brown at c. 750°C. This is likely to be due to the oxidation of iron within the mineral and does not therefore take place at the same temperature in reduction-fired ceramics (Quinn, 2022).

The birefringence or isotropism of the groundmass is a function of the degree of vitrification, and thus can act as an estimate of firing temperature and soak time. For example, presence of fine-grained high-order phases embedded in the groundmass exhibiting anisotropic optical properties indicate either the use of a calcareous clay and/or a firing temperature below the decomposition of calcite at 750-800°C (Quinn, 2013, 2022). Isotropism in the groundmass, on the other hand, indicate either the use of non-calcerous resources or firing temperatures of 800-1000°C (Magetti, 1994).

2.3.3 Mineralogical Interpretation

Polarizing microscope is a way of mineral description. However, it cannot be sufficient if the sample is fine-grained. In the context of phase analysis for an archeological site, the well-established method is mineralogical identification by X-ray Powder Diffraction (XRD). Both mineral phases surviving from the raw materials and those formed during firing body are possible to interpret that provide information about raw materials and firing temperatures employed in ceramic production.

2.3.4 Chemical Interpretations

Chemical analysis for major, minor, and trace elements provides a compositional ‘fingerprint’ for grouping pottery samples made from the same raw materials and for distinguishing between groups of pottery made from different raw materials (Tite, 2008). The geology of the area where an archeological site exists and pottery samples are collected could be assessed together with the geological map of the area and clay samples collected.

Inductively coupled plasma–mass spectrometry (ICP/MS) is a multielement analytical technique used for the determination of trace elements, and is becoming increasingly popular for determining the provenance of materials found in archaeological contexts (Kennett et al. 2002; Neff, 2003).

This technique also helps to observe how far from a particular location people are likely to travel to obtain their raw materials. The potential advantages of ICP–MS compared to other techniques include: (1) the ability to analyze small samples, (2) more target analytes (~70); (3) lower detection limits (parts per billion) on more elements relative to other techniques; (4) the possibility of measuring the isotopic ratios of some elements (Kennett et al., 2004).

2.4 An Overview of Pottery Production in Uğurlu-Zeytinlik

2.4.1 Location and Geological Background

Gökçeada, which is the largest island of Turkey, is located at 20 km west of the Biga Peninsula. The Uğurlu-Zeytinlik Höyük is the earliest Neolithic settlement (6800 BC) thus far known in the eastern Aegean Islands, mainland Greece, the Balkans and Anatolia in the Neolithic and the Chalcolithic periods.

Starting at the time of the Last Glacial Maximum (around 21,000 years ago), the sea level was about 120 m lower than today (Lamback and Purcell, 2005). The island of Gökçeada, along with all the North Aegean Islands, was connected to the mainland. Sea level was 55-60 m lower during the Younger Dryas between 10800 and 9600 cal. BC. Gökçeada, together with Lemnos, became an island probably just after the Younger Dryas (Perissoratis and Conispoliatis, 2003; Efstratiou, 2014). Subsequently the rise in the level of the Aegean Sea continued, reaching a height approximately 20 m lower than today during the Neolithic period, around 7000-6500 cal. BC (Erdoğan, 2014), and the island of Gökçeada lay close to the Gelibolu Peninsula, ca. 10 km. Today, the seashore is about 2 km from the site of Uğurlu, but the site was located far from the shoreline during the Neolithic period. Archaeobotanical research shows that the first settlement was located where small swamps and lakes occur, and the Neolithic inhabitants of Uğurlu lived near a spring in this watery and fertile area (Erdoğan, 2016).

Gökçeada is a mountainous island and Mount Doruk (Elias), with an altitude of 673 m, is the highest point (Fig.2.2.).



Figure 2.2. Location of Uğurlu in the Northeastern Aegean (Erdoğan, 2016)

In the island, metamorphic, magmatic and sedimentary rocks are present. The oldest rocks of the island are Çamlıca metamorphic rocks consisting of sericitic schist, chloritic-schist, slate and marble (Okay et al., 1990; Tunç et al., 2002). Metamorphic rocks are present as blocks and pebbles and as enclaves in the acidic lavas in the northern parts of the Gökçeada Island (Elmas et al., 2017). Sedimentary rocks are claystone, sandstone, shale, siltstone, marl and conglomerate (İlgar et al., 2008). Magmatic rocks, mainly of volcanic type, cover extensive areas. Volcanic rocks outcropping in the NW of Gökçeada consist of rhyolitic lava and tuff-tuffites. These rhyolites and granitic plutons exposing in the NW of the island are named as Marmaros Magmatic Assemblage (Elmas et al., 2017). Lavas (basaltic andesite and andesite) and pyroclastic rocks, which spread over large areas to the east of Gökçeada, is named as the Eşelek volcanic rocks (Sarı et al., 2015) (Figure 2.3). Dark brown colored iron oxide nodules are present in tuffs

Andesite and diorite porphyric rocks occupying large areas of the island were named as Gökçeada domes by Sarı et al. (2015) and Şen et al. (2020) (Figure 2.3). Gökçeada andesitic lava/domes have hypocrySTALLine to holocrystalline porphyritic texture, and their phenocryst contents vary between 40-75%. The groundmass of the rocks is generally microcrystalline, and the degree of crystallinity with coarser crystals is relatively higher compared to samples flowing at the surface. Mineral content of the groundmass is basically formed by plagioclase microlites, clinopyroxene crystals, and opaque phases. Subhedral or euhedral phenocrysts and microphenocrysts are andesine variety of plagioclase, hornblende type of amphibole in essential amounts, augitic clinopyroxene, quartz and biotite are observed in minor amounts. Accessory minerals are titanomagnetite, ilmenite and magnetite as oxides, and apatite (Kurtuluş et al., 2010). Secondary minerals such as chlorite due to hydrothermal alteration are present. The groundmass is under the effect of silicification and carbonatization as quartz filling fractures and calcite are observed. There are three types of mineral assemblages in Gökçeada andesitic lava/domes; (1) plagioclase, hornblende, clinopyroxene $\pm$ quartz (crystal amount; 40-55%); (2) plagioclase, hornblende, clinopyroxene, biotite, quartz (crystal amount; 50-65%) and (3) plagioclase, hornblende, biotite $\pm$ quartz (crystal amount; 60-75%) (Şen et al. 2020).

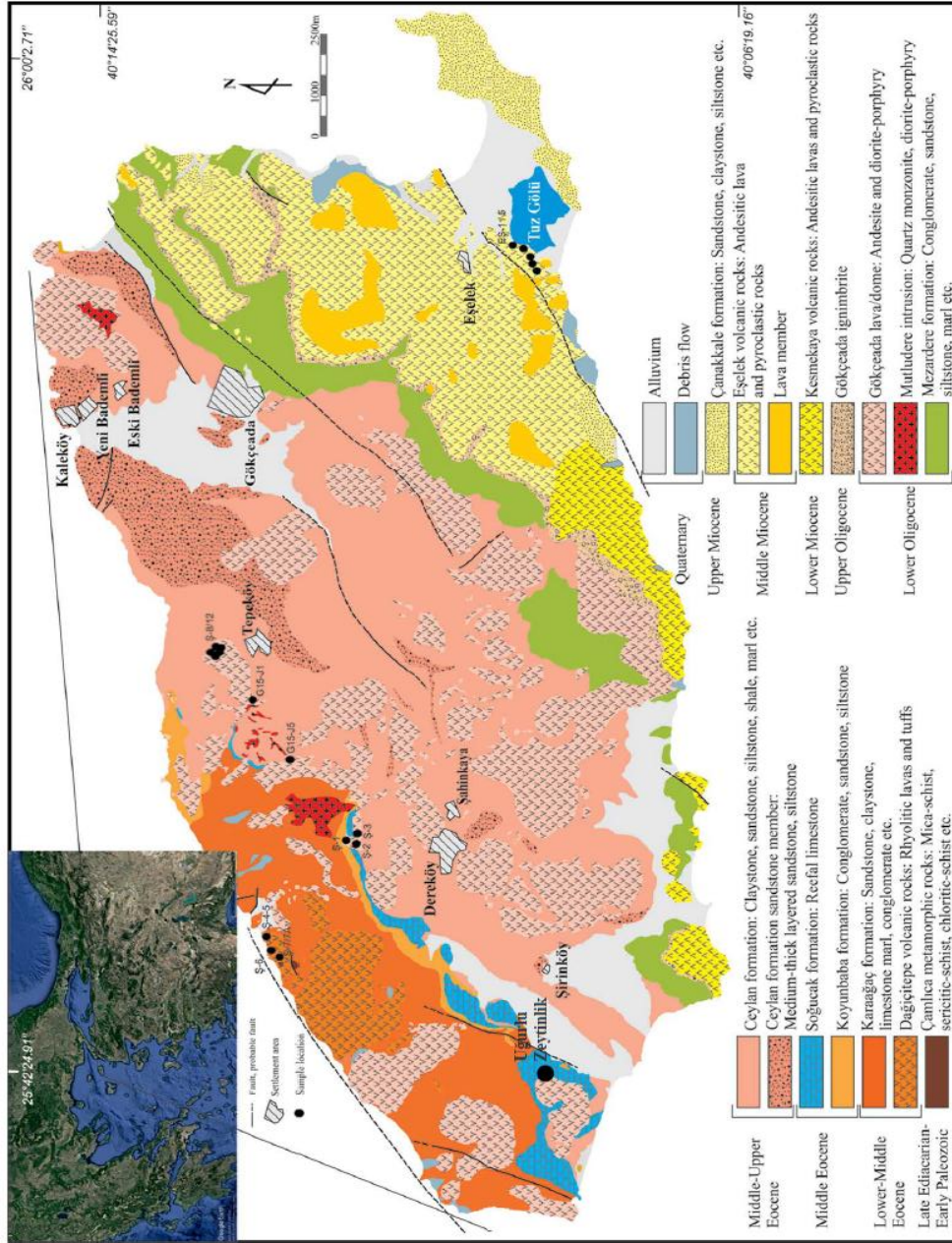


Figure 2.3. Geological map of Gökçeada (from Şen et al., 2020 modified from Sarı et al., 2015)

2.4.2 The Historical Background and General Characteristics of Neolithic Pottery Production

As seen in the plan of Uğurlu Site (Figure 2.4.) six main cultural phases with twelve layers of occupation have been revealed as a result of the excavations so far as following:

VI. Culture Phase for West Anatolia Proto Neolithic period (6760-6600 BC)

V. Culture Phase for West Anatolia Early Neolithic period (6600-5900 BC)

IV. Culture Phase for West Anatolia Late Neolithic period (5900-5500 BC)

III. Culture Phase for West Anatolia Early Chalcolithic period (5500-4900 BC)

II. Culture Phase for West Anatolia Middle Chalcolithic period (4900-4350 BC)

I. Culture Phase surface finds, Early Bronze Age and Medieval times materials.

The earliest three phases (VI, V & IV) date to the Neolithic period. Phase VI is represented in sounding trenches only. No architectural structures, were found in this Phase.

Phase III dates to the Neolithic-Chalcolithic transition. The pottery of Phase III, shows some similarities to the pottery of the Balkan Karanovo III and Early Vinca cultures, and so should be considered as a local development. The Phase II is the Middle Chalcolithic period and its equivalent to Western Anatolian Kumtepe Ia - Beşik Sivritepe Culture. The Phase I shows Early Bronze Age and Medieval times in the surface.

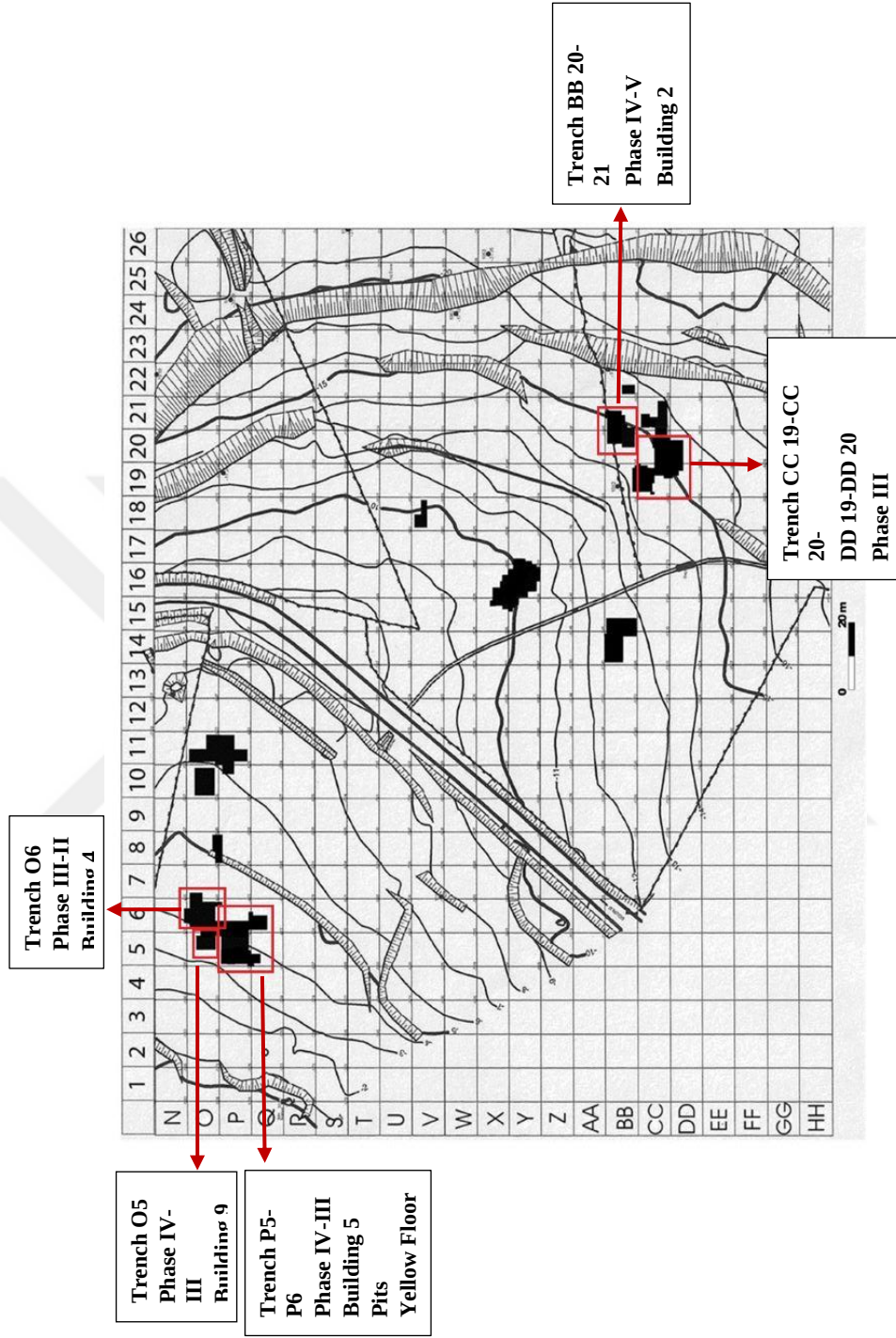


Figure 2.4. Uğurlu Site Plan (Modified by the author, Karamurat et al, 2021)

Pottery is the most common artefact found in Phase V. The vast majority of the pottery is red-slipped and burnished. Black burnished sherds were found in small quantities. All pottery is handmade and thin-walled. Deep bowls with an “S” profile, hole-mouth vessels and straight-sided shallow dishes are common shapes. Strong parallels to Uğurlu V pottery were found in Western Anatolian Neolithic sites as well as at the Marmara region sites and at Hoca Çeşme IV-III in Turkish Thrace (Bertram and Karul, 2005; Erdoğan, 2016).

It is observed that the settlement enlarged considerably in Phase IV which is dated between 6000 BC and 5650 BC. There is apparent progress in pottery production in the Phase IV. Neolithic pottery from Phase IV is of an extremely high technological standard, demonstrating a degree of ingenuity and creativity. Pottery is handmade, lustrously burnished and thin-walled. It has been sorted into seven ware groups. Red-slipped black ware is dominant, 60% of the total assemblage. A jet-black surface color is common. Different tones of red and pink slip are applied on the exterior surfaces and below the rim of the interior surfaces. The thickness of the slip application varies greatly, and generally shows a mottled appearance on the surface. Other wares include the red slipped buff ware (12%), the black/ gray burnished ware (9%) and the brown burnished ware (7%). Red and black burnished coarse wares also occur (Erdoğan, 2014).

The Phase III is marked by the Neolithic-Chalcolithic transition at the site. Phase III pottery is homogenous and completely different from previous phases. Sherds are coated with a black, grayish black slip-on reddish-brown surfaces, and generally show a mottled appearance on the surface. Fresh breaks in sherds show incomplete oxidation firing. Four-footed bowls with ear-like or strap handles, large lids, boxes, and button-like or horned handles are characteristic.

Various decorative techniques have been employed, such as impression, incision and channeling. No exact similarities exist between Uğurlu Phase III pottery and Anatolian pottery traditions. (Erdoğan, 2014). The pottery of Phase III, shows some similarities to the pottery of the Balkan Karanovo III and Early Vinca cultures, and

so should be considered as a local development. Phase II is Middle Chalcolithic period and its equivalent to Western Anatolian Kumtepe Ia - Beşik Sivritepe Culture. Phase I shows Early Bronze Age and Medieval times in the surface.

2.4.3 Diagnostic Features of Gökçeada-Uğurlu Pottery

The ceramics are in red, brown and black tones. Depending on the context, it is understood that 50-70% of the black material is present and that all of them are handmade

Phase V Pottery:

Phase V Pottery repertoire consists of well-polished, thin-thick and well-crafted ceramics. It is a ceramic group in which bright red, brown and purple-black tones predominate (Figure 2.5)

The decoration consists of anthropomorphic decorations in the form of relief decorations and horn-shaped decorations (Figure 2.6). Short and long strap handles with rope holes are placed symmetrically on both sides of the body. There are no cups with legs.

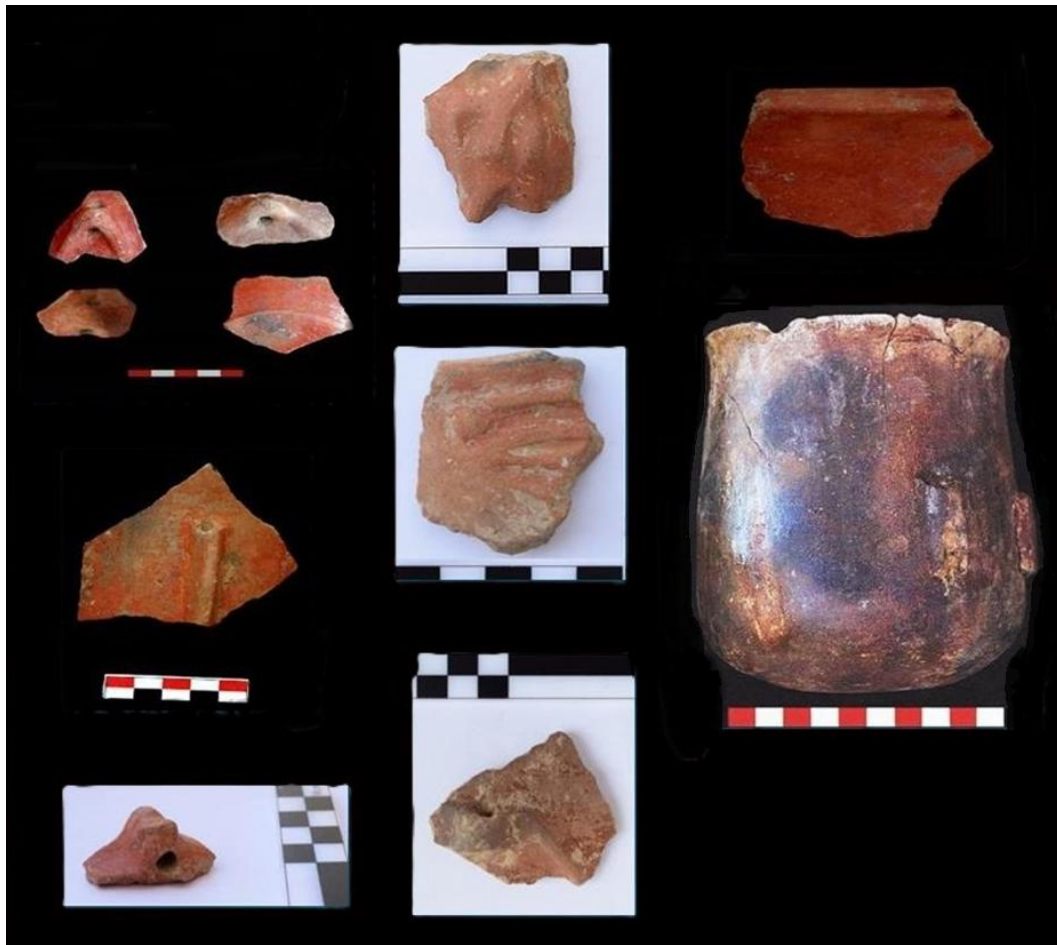


Figure 2.5. Photos from selected pottery of Phase V

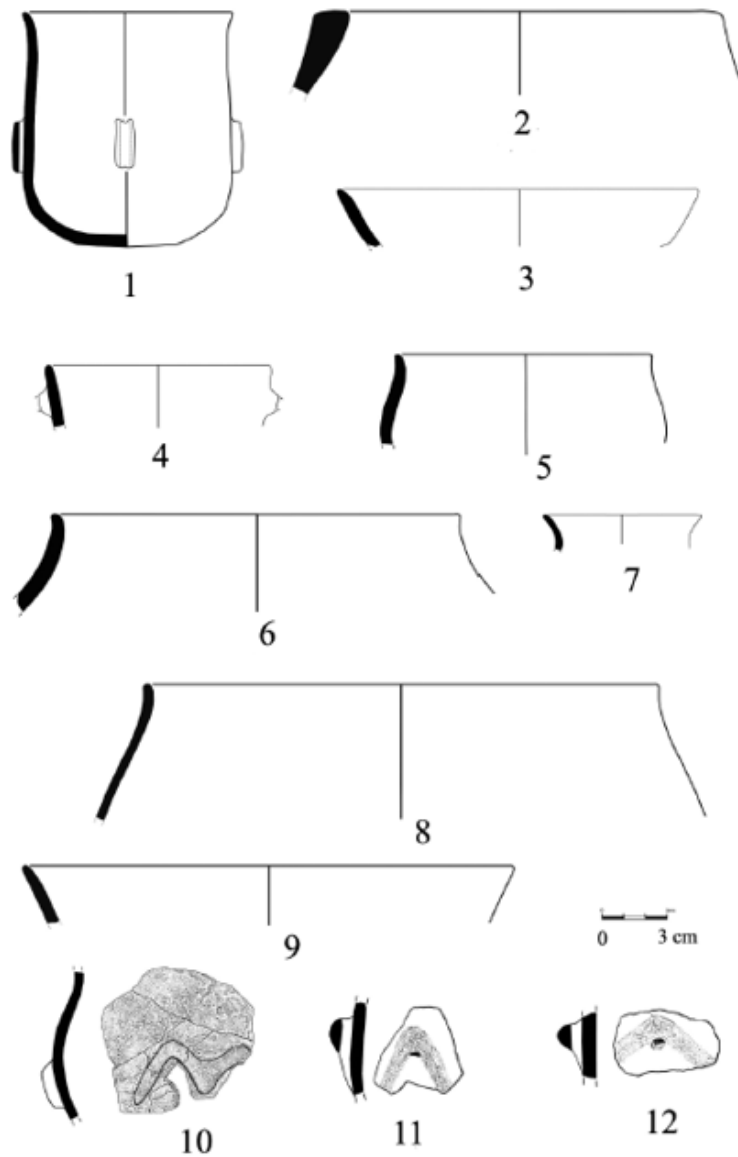


Figure 2.6. Selected pottery forms of Phase V (Erdoğu, 2014)

Phase IV Pottery:

The ceramics of this level have similar characteristics to Phase V and show continuity. However, the variation in color tones increases in red-brown-black-purple intermediate tones (Figure 2.7). Along with the "impresso" (printed) decorated ceramics seen in the Aegean and the Mediterranean, Karanovo (Balkans)

influential white painted decorated ceramics, as well as incised/incised decorations, although in small quantities, are also seen on this floor. In addition, "ear-like" and "box" vessels, which are special forms of footed vessel forms, appear for the first time, albeit in small quantities, probably in the last period of this level (Figure 2.8).





Figure 2.7. Photos from selected pottery of Phase IV

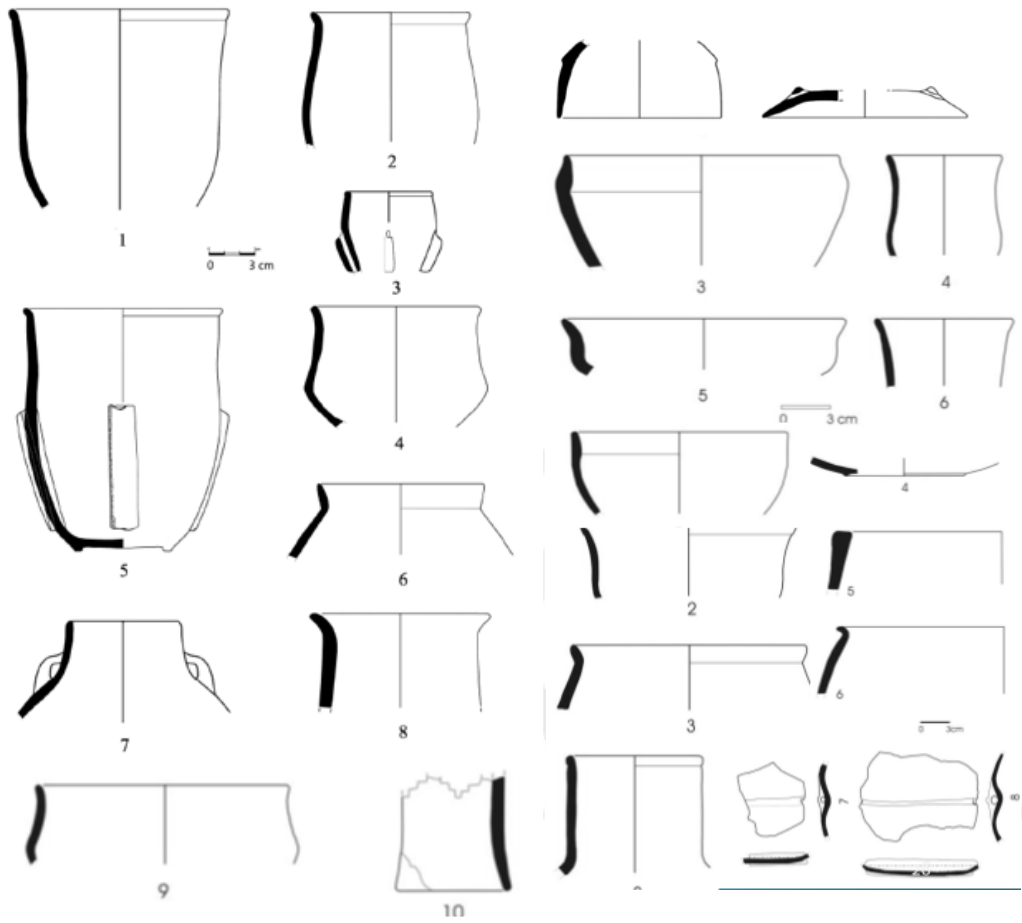


Figure 2.8. Selected pottery forms of Phase IV (Erdoğu, 2014)

Phase III Pottery:

Although there is diversity in ceramic forms, especially in carinated S-profile vessels, lugged and box vessels, they are generally rough in terms of workmanship. (Figures 2.9 and 2.10). The intermediate tones in the colors have disappeared and there are mostly red-black and small amounts of brown tones. Drawing/scraping and encrustation (scratching with white filling) are frequently seen decoration items.

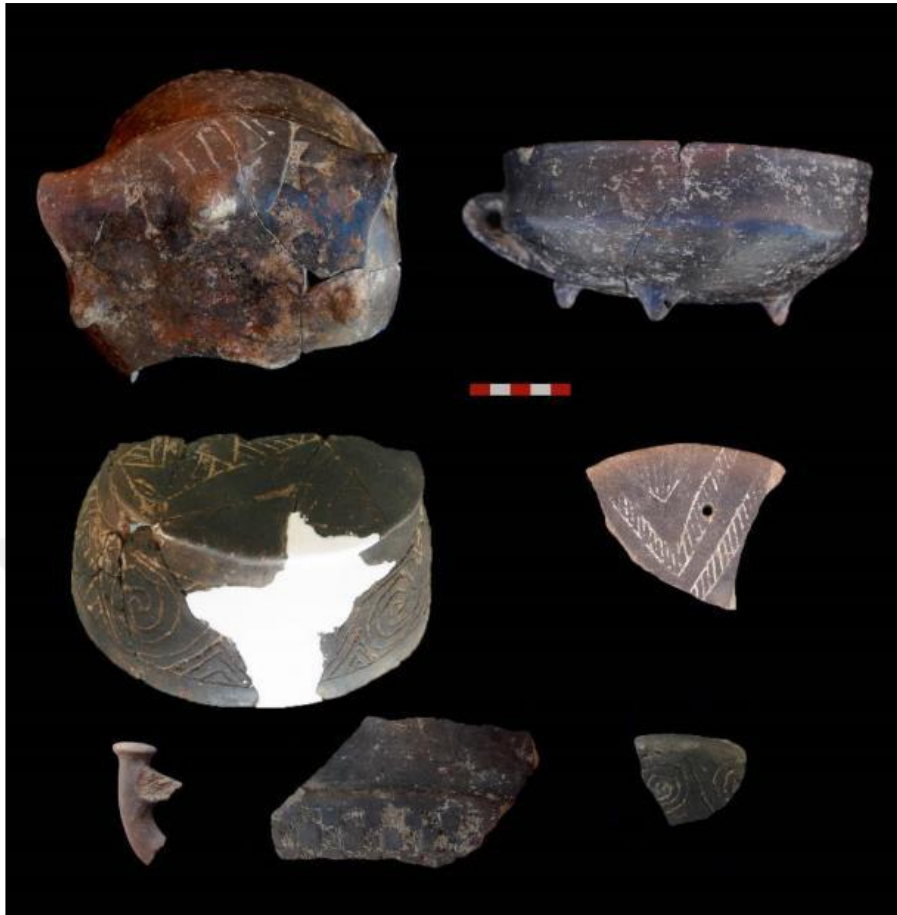


Figure 2.9. Selected pottery photos from Phase III



Figure 2.10. Selected pottery forms of Phase III (Erdoğan, 2014)

The sampling strategy and applied scientific methods of the study for the characterization of Uğurlu pottery are mentioned in the next chapter.

CHAPTER 3

METHODS OF STUDY

In this chapter, the methods applied for the characterization and identification of Uğurlu pottery samples are explained in detail. Starting from sampling, classification and grouping of the samples are done with the naked eye according to their diagnostic features. Cross-sections are prepared to diagnose both the visual features of the samples and to evaluate the forming methods of the pottery. Then thin sections are prepared for each sherd used to obtain petrographical information about samples. Afterwards XRD analysis is performed to support thin section results and chemical analysis methods for provenance and to get information about the paste content of the pottery samples are mentioned in detail.

3.1 Sampling

The sherds are gathered from Gökçeada, Uğurlu-Zeytinlik site. Sampling was determined by the following criteria: shape, color, construction zone, potsherd size, wall thickness, fabric, chronological time interval in order to establish protocols for a correlation between features of a ceramic fabric and specific forming operations.

3.1.1 Classification and Grouping of Samples According to the Analysis

The samples from the site are studied according to culture phase time scales. In this study only the archaeological phases V, IV and III are handled. The samples are chosen to represent the characteristics of each Phase. The distribution of the location of the analyzed samples through the phases is listed in Table 3.1. In this study, 74 samples are chosen for three phases and documented by photograph.

Firstly, diagnostic features of the pottery that provide information on forming and surface treatment techniques, are examined. Diagnostic (macroscopic) observation of each sherd is carried with naked eye for traces about production techniques. Then, stereomicroscope is used. For this, thick slice of cross section is prepared for each sample and 74 samples are photographed. Total of 24 samples from three phases are distinguished to study and determine the forming techniques.

Thin section analysis is performed on 73 samples. After that, XRD (73 samples), ICP-OES/MS (61 samples) analyses are applied. IGPET software is used to plot diagrams concerning the data by ICP-OES/MS analysis. Table 3.2. shows distribution and purpose of the analysis according to the phases.

Table 3.1 Distribution of the analyzed samples according to the phases and locations

Phase III	Building 3	Pit					
		Ö25	Ö29	Ö102	Ö191	Ö148	Ö116
Sample	87, 88, 89, 299, 300, 301, 302	91, 92, 94, 99,101,102, 104, 105, 106	113, 116	119, 128	138,139 140	303, 304	133
Phase IV	Filling	Building 5	Building 8			Yellow floor	
Sample	234	305, 306, 307, 308, 309, 310, 311	162, 168 172, 178 185, 312, 313, 314, 315, 316, 317, 318			221, 222, 223, 227	
Phase V	Building 2					?	
Sample	245, 250, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335,					264, 259, 262, 265, 267	

Table 3.2 Type and number of analyses applied to the pottery samples of Uğurlu

Process/ Analysis	Purpose	Number of Analysis			
		Phase V	Phase IV	Phase III	Soil
Photograph	To identify the samples	24	24	26	-
Thick Slice of Cross-Section	To get information about inclusion characteristics, firing atmosphere, and forming techniques	24	24	25	-
Thin Section	To get information about raw material content, firing temperature, and surface treatments techniques.	24	24	25	-
XRD	To support thin section results, firing temperature and identify clay types.	23	24	26	8
ICP-OES/MS	Provenance	20	21	20	3
IGPET software	To show correlation of elements	20	21	20	3
Statistical Analysis	To group samples, to see the compositional kinship	20	21	20	3

3.2 Methods

3.2.1 Visual / Diagnostic Examination

The interpretation of pottery samples in terms of production techniques is related on diagnostic features that provide information on the techniques, methods, procedures and tools used. Macroscopic observation precedes the microscopic scale and the first examination of a sherd is carried with naked eye for traces about production techniques.

3.2.1.1 Forming processes and surface treatments

Each sample is examined by naked eye for diagnostic features, surface treatment techniques and the traces of forming methods as coiling and slab building for the sherd samples. Visual examination is done for both inner and outer surfaces. A fresh cut section is chipped by saw, from the sherd and examined for the firing atmosphere identification and define dimension and distribution feature of the grits.

3.2.2 Petrographic methods

Cross sections are cut perpendicular to the surface of the sherds, to enable investigation of possible surface alterations. Cross sections of the sherds are prepared at the Department of Geology Engineering, Middle East Technical University (METU).

To evaluate and characterize the samples using thick slice of cross-section Stereo microscope Nikon SMZ25 with a camera DS Fi3 is used. The imaging software of the instrument is NIS-Elements D 5.10.

Generally, x0.63 magnification is used to take the microphotographs.

It is aimed to investigate the most used forming techniques in Near Eastern archaeology, by using simple and low-cost approaches for pottery samples. For this purpose, diagnostically presumed or pre-examined samples that carried some marks for defined coil-built or slab techniques are explored to find evidence.

The direction of pressure and degree of compression applied to the clay, during the forming stage, causes the inclusions and voids to take up a preferred orientation, Figure 3.1. Different shaping techniques result in different deformations of clay (Ross et al., 2018). Therefore, grain and void orientation patterns in the fabric by using microscopy can be useful to distinguish between shaping techniques. The complexity of the shaping process requires, a combination of both, macroscopic and microscopic studies.

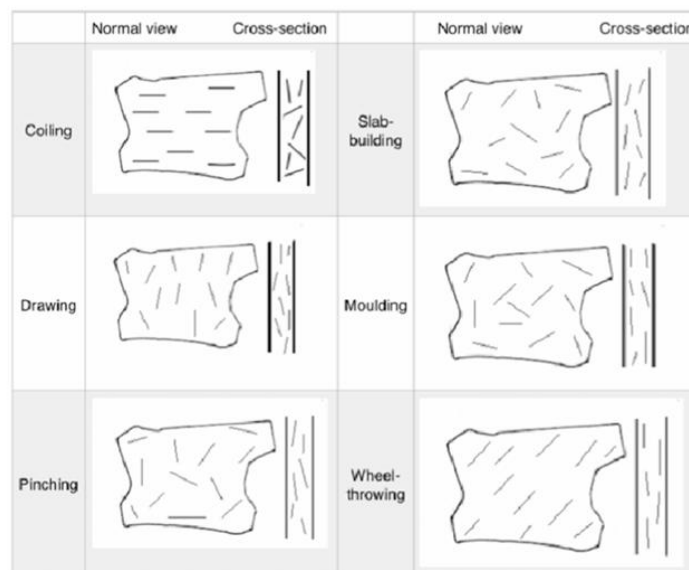


Figure 3.1. Schematic diagram of the characteristic features of the main pottery forming techniques (Carr, 1990; Rye, 1981; Ross et al., 2018).

Micro-tomography (uCT) is also performed (Neumannová et al., 2017), for the visualization and analysis of inner structures already defined by Appoloni et al. (2004). In the Figure 3.2. a. Experimentally replicated variants of coiling and slab building (Ther et al., 2019) are shown. In the Figure 3.2. b. Visualization of voids in vertical and horizontal view are shown. White lines illustrate the dominant orientation of voids in different types of coiling techniques (Neumannová et al., 2017). These experimental approaches obtained by uCT techniques and the imaged grain and void orientation patterns using high-resolution scans of cross sections (Ross et al., 2018) are combined to examine and characterize the different forming techniques by evaluating the orientations of inclusions and voids produced.

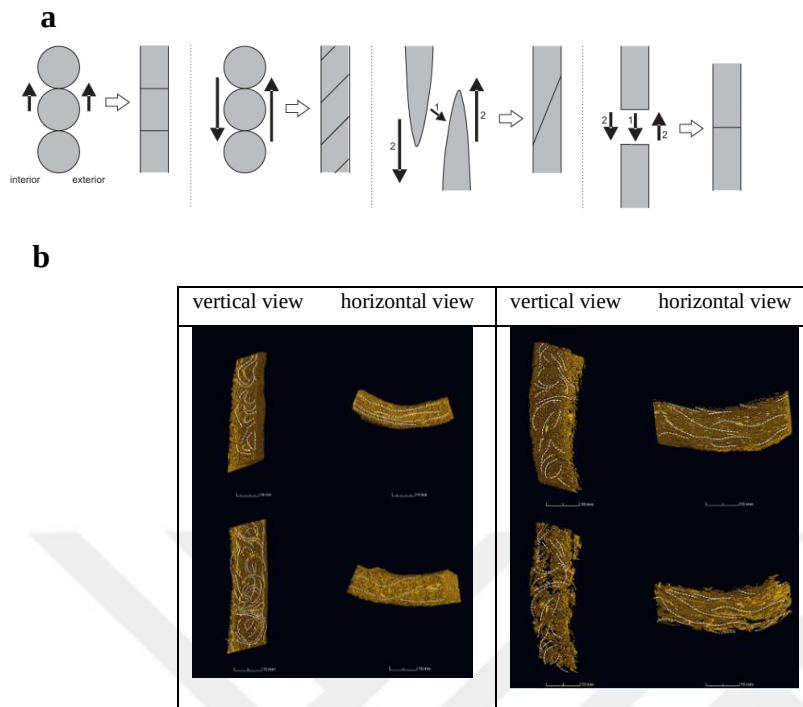


Figure 3.2. a. Experimentally reproduced variants of coiling and slab building (Ther et al., 2019), b. Visualization of voids in vertical and horizontal view (Neumannová et al., 2017).

This combination of the information obtained from the literature is blended to get information about the forming techniques using the stereomicroscope and polarized light microscope. In this way it may be a cheapest way to have an idea about the forming techniques of the pottery at a first instance.

3.2.3 Thin Section Analysis

Thin-section petrography is used for the analysis of rocks, pottery and other materials because it provides a detailed understanding of the texture and the nature of the various mineralogical components and constitutive phases of the materials.

The process of preparing thin sections for archaeological pottery sherds is similar to that applied to rock samples. The first step in this process is to cut the sherd in the chosen direction (vertical or horizontal) and get a small chip. Once cut the surface of the chip is grounded to provide a smooth surface and bonded to a microscope slide.

Carborundum is commonly used as an abrasive. Powder with a diameter of 600-800n grit is used for polishing. The polished chip is washed thoroughly under water to remove abrasive. Once bonded, the majority of the ceramic chip needs to be cut off. The section is ground to c. 50-100 μm at which point quartz inclusions exhibit high first to second order interference colors. Then ground thin sections are brought to the desired thickness of 30 μm by hand polishing. At this thickness quartz exhibits first-order grey and white interference colors. Then its washed thoroughly to remove abrasive powder and then covered with a thin cover glass with the help of epoxy resin (Canada Balsam).

Standard thin sections were prepared from each pottery sample at the Mineralogy and Petrography Researches Laboratory of MTA (Mineral Research & Exploration General Directorate-Ankara) and at the Department of Geology Engineering, Middle East Technical University (METU), which are used to acquire petrographical information about the samples.

The petrographic analysis is done, and microphotographs of the thin sections under plane-polarized (PPL) and cross-polarized light (XPL) are taken at the Mineralogy-Petrography Laboratory of the Department of Geology Engineering, METU. The prepared thin sections are studied with the polarizing light microscope (Leitz Orthoplan-POL, with a Leica DFC 295 camera attached to it). The software used is LAS (Leica Application Suite) V4.2. The individual thin sections are grouped and separated into fabric classes based upon the nature of dominant non-plastic inclusions, fabric and textural characteristics. Groupings are described using a modified version of the methodology proposed by Whitbread (1989, 1995).

At first instance surface treatment techniques are evaluated and supported by the information obtained by diagnostic examination and thick slices of cross-section

studies by stereomicroscope. Treatment techniques as burnishing/polishing and smoothing which are frequent during all the Neolithic is evaluated according to Figure 3.3. In this figure burnished surface is straight as the smoothed surface is wavy. Elongated and round forms inclusions composing the ceramic paste and their orientation due to the process, are shown exaggerated vertical scale for the ceramic piece (Ionescu and Hoeck, 2020).

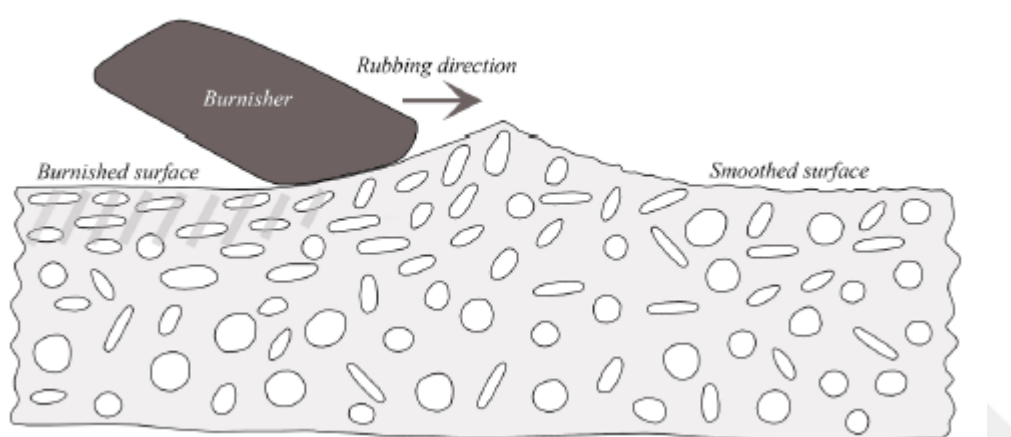


Figure 3.3. Formation of subsurface layer by the burnisher (Lepere, 2014)

As seen from the Figure 3.3, burnishing compacts and reorients clay particles, resulting in parallel linear facets and a glossy surface.

Clay matrix of the ceramics were evaluated according to the birefringence of the paste. Birefringence is a change in intensity in the clay matrix in XPL, which is caused by the minute clay minerals going in and out of extinction and is affected by vitrification and sintering of the clay minerals. It is therefore important in giving idea about the atmosphere and degree of firing (Quinn, 2022).

The characterization of pottery materials using a polarized light microscope is based on sedimentary petrology and soil micromorphology. It is developed

methodologically to describe and interpret a series of compositional / textural (i.e., fractioning, tempering, clay mixing), mechanical (i.e., homogenization, shaping), and thermal (i.e., firing, use) transformations of the clay (e.g., Peacock, 1970; Maggetti 1982; Echallier, 1984; Rice, 1987; Quinn, 2013; Thér 2016; Heimann and Maggetti, 2019; Roux 2019; Eramo, 2020). A detailed system for the thorough description of archaeological ceramics in thin section was first developed by Ian Whitbread. In the description process of the fabric groups, Whitbread system is used, as microstructure, groundmass, textural concentration and void shape features from soil morphology. The aplastic components are evaluated based upon grain size, shape, frequency, and homogeneity of distribution (Figures 3.4, 3.5, 3.6). The shape and size of voids, are useful characteristics for describing ceramic fabrics and inferring technological information from them. The shape of the voids is evaluated according to the diagram shown in Fig. 3.7.

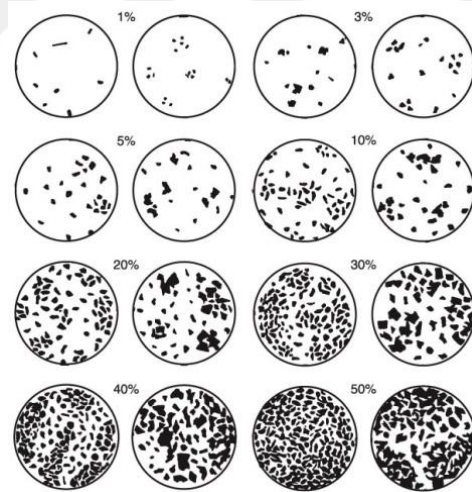


Figure 3.4. Comparison chart for the visual estimation of percentage area (after Terry and Chilingarian, 1955).

	1	2	3	4	5	6
Class	Very Angular	Angular	Sub-Angular	Sub-Rounded	Rounded	Well Rounded
High Sphericity 2						
Low Sphericity 1						

Figure 3.5. Grain shape diagram (Ownby, 2009)

Sorting refers to the distribution of inclusions in the deposit, and it is a measure of the frequency with which particles of the same size occur (Figure.3.6).

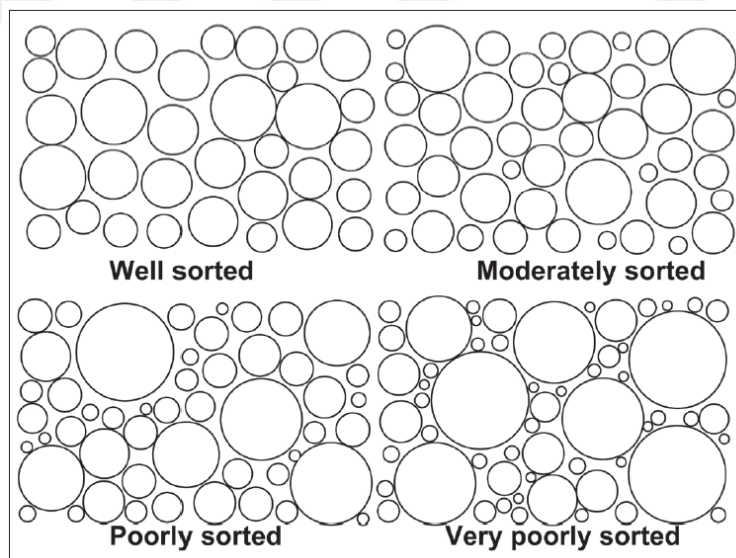


Figure 3.6. Chart for estimating the degree of sorting (Quinn, 2022).

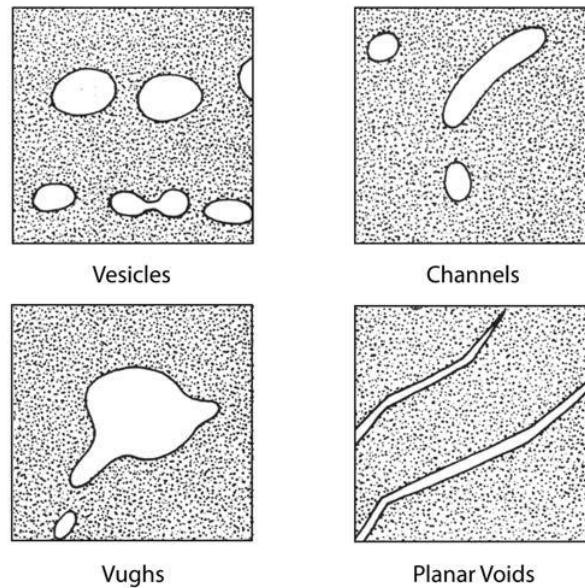


Figure 3.7. Void shape diagram in archaeological ceramic thin sections. Modified from Stoops (2003).

The description of each inclusion type begins with an indication of its relative abundance within the fraction that it forms a part of. A commonly used set of frequency label is: Predominant (>70%), dominant (50-70%), Frequent (30-50%), Common (15-30%), Few (5-15%), Very Few (2-5%), Rare (0.5-2%), Very Rare (<0.5%), Absent (0%). (Quinn, 2013).

The inclusions in a ceramic paste are divided into three main categories; one is mineral grains, second is rock fragments and other (Smith, 2008). Rock fragments can be categorized as; derived from volcanic/igneous, sedimentary or metamorphic rocks. The other constituents are (1) grog (reused pottery fragments), (2) organic residues as, carbonized/charred plant materials, etc.

Two main features give information about firing temperature; one is amphibole that undergoes a change in body color in thin section from green to brown at c. 750°C.

The other is the birefringence or isotropism of the groundmass which is observed under 750-800°C. So, these two points are especially stated for all samples.

The pottery samples are grouped according to groundmass characteristics (fine or silty base), aplastic inclusions, based upon grain size, shape and frequency. These inclusions are composed of mainly, the rock fragments (volcanic, sedimentary and metamorphic rock) and organic residues. Grouping and characterization is done separately for each phase and a fabric type is described for each phase.

3.3 Mineralogical Analysis X- Ray Powder Diffraction Analysis (XRD)

X-Ray Diffraction analysis of the pottery samples is carried out by the XRD Laboratory at the Central Laboratory, R&D Training and Measurement Center, METU.

Pottery samples are grounded in an agate mortar for random powder XRD analysis. The XRD analysis is done on Rigaku MiniFlex 600 (Goniyometer radius: 150 mm), D/teX Ultra 1D silicon strip detector. The wavelength used is Cu-K alpha radiation at 40kV and 15 mA. Diffraction patterns are recorded from 2-60° 2 θ , scan mode 1D, step width 0.02°, scan speed/ duration time 5.00 °/min. Mineral identification is done using the Rigaku PDXL Search Match software program. The results of the XRD analysis are used to confirm mineral identifications by petrographic study and to improve and verify the fabric types defined and grouped as a result of the petrographic analysis.

For determination of the dominant soil mineral species in the alluvial deposits at the close vicinity of Uğurlu settlement, field soil samples are collected from three different locations. Beside random powder XRD analysis, oriented slices of clay fractions of the samples (grain size < 2 micrometer) are also examined. In order to prepare oriented specimens, 10 g of samples are mixed with 1 L of distilled water and waited for 8 hours. The clay size material that remained in suspension is taken and centrifuged. A centrifuged clay-water mixture is put on to four glass slides for

each sample and left to dry at room temperature. For better adhesion of the sample, slides with a slightly ground surface are used. Afterwards, one slide of the four slides is left as air-dry, the second one is saturated with ethylene glycol in an oven at 60 °C and third and fourth ones are heated for 1 h at 300 °C and 550 °C, respectively. From each clay sample, one air-dried specimen, one ethylene glycolated and two heated specimens are measured, in order to distinguish particular phyllosilicate minerals (Brindley and Brown, 1980).

X-Ray Diffraction analysis of the soil samples was carried out at the XRD Laboratory of the Geological Engineering Department, METU. The XRD analysis is done on Rigaku MiniFlex 600 (Goniyometer radius: 150 mm), D/teX Ultra 1D silicon strip detector. The wavelength used is Cu-K alpha radiation at 40kV and 15 mA. While diffraction patterns of random samples are recorded between 2-70°2 θ , those of oriented slides are recorded from 2-40°2 θ with a step width 0.02°.

3.3.1 Chemical Analysis by Inductively Coupled Plasma–Optical Emission Spectrometry / Mass Spectrometry (ICP-OES/MS)

Inductively Coupled Plasma Optical Emission Spectrometry / Mass Spectrometry (ICP-OES/MS) analysis is performed by the Chemical Analysis Laboratory at the Central Laboratory, R&D Training and Measurement Center, METU. For ICP-OES analysis Perkin Elmer Optima 4300DV, and for ICP-MS analysis, Perkin Elmer SCIEX ELAN DRC II, with a mass of range 5-270 amu ng/L is used. After drying the samples at 105°C for two hours, the extraction process is performed by using Anton Paar Multiwave 3000 Microwave Digestion System (Rotor type 8SXF100). For the extraction process 0.3 g of the sample is extracted by using HNO₃ (Distilled), 2 ml HCl and 3 ml HF. Parameters: Power 200 W, ramp 5 min, hold 5 min (step 1) and power 1000 W, ramp 5 min, hold 15 min (step 2). For the third step quenching is performed with 18 ml 5% H₃BO₃, instrument parameters: Power 800 W, ramp 5 min, hold 15 min. At the last step samples and the blank samples are completed to 50 mL by deionized water.

Instrument Parameters are as follows:

ICP-OES: Perkin Elmer Optima 4300 DV, RF power: 1300 W, Plasma gas flow rate: 15 L/min, Auxiliary gas flow rate: 0.2 L/min, Nebulizer gas flow rate: 0.8 L/min, Sample uptake rate: 1.50 ml/min, Number of replicates: 3, Spray chamber: Ryton Double Pass (Scott type), Nebulizer: GemTip Cross-Flow.

ICP-MS: Perkin Elmer NexION 350D), RF power: 1300 W, Plasma gas flow rate: 18 L/min, Auxiliary gas flow rate: 1.2 L/min, Nebulizer gas flow rate: 0.92 L/min, Sample uptake rate: 1 ml/min, Number of replicates: 3, Spray chamber: Cyclonic, Nebulizer: Glass Meinhard concentric.

Statistical Classification:

A more advanced approach to analyzing compositional and/or textural variability in quantitative data is the application of multivariate statistical methods, such as hierarchical cluster analysis (HCA) and principal components analysis (PCA). Both approaches typically concentrate on quantitative data without distinguishing between dependent and independent variables. Their objective is to pinpoint interconnections among variables and individuals and to evaluate the importance of these relationships (Albero, 2014).

These mathematical approaches can permit the detection of more subtle patterning not visible by eye, as well as providing a means of graphically displaying in two dimensions the information contained within multiple variables. Modal and textural data is well suited to multivariate statistics and both types can be combined in the same PCA or HCA routine. With PCA, the multivariate data is reduced to a smaller number of key variables or ‘principal components’, which best express the variability in the dataset. These can be plotted against one another to visualize and further analyze compositional patterns within the samples, including the existence of groups and ‘outliers’ (Quinn, 2022)

Cluster analysis allows the investigation of the relationships among the variables of a dataset to recognize the existence of groups and is the most common multivariate

statistical method used in the chemical study of pottery (e.g., Everitt et al., 2011; Kettenring 2006; Barone et al. 2005; Papageorgiou et al. 2001). It explores the hierarchical relationships among individual samples and organizes them into a dendrogram, where samples and clusters are linked or separated based on their degree of similarity. The dendrogram can be divided at different similarity thresholds to establish various levels of classification (Quinn, 2022).

After evaluation of the ICP-MS analysis results, in order to achieve correct and meaningful results, some elements must be excluded for statistical analysis. After an extended period of burial, taphonomic processes can induce significant changes in the chemical and mineralogical composition of ceramics. This is especially true for elements such as Ca^{++} , Mg^{++} , K^+ , and Na^+ , which have a higher ability to exchange cations. (De La Fuente, 2008; Maritan and Mazzoli, 2004; Pollard et al., 2007; Tschegg, 2009). In this sense, not all chemical elements have the same range of variation in a group of pottery. It is often possible to observe wider variations in the concentrations of elements such as CaO , P_2O_5 , K_2O , Na_2O , Ba, Sr, Rb, As, etc., even if they are measured with high accuracy and low analytical error. For example, As - is volatile with firing and Cs, Rb, and K is mobile depending on the firing (Buxeda et al., 2001). Also, U, Pb and Li because of their low stability in soils are excluded (Tschegg et al., 2008). Consequently, chemical compositional studies often group samples without incorporating many of these elements into the analysis. In most instances, including them is viewed as a risk factor that can significantly skew the established chemical groups and complicate their interpretation (Arnold, 2000; Buxeda et al., 2001; Cau et al., 2002; Tite, 2008; Albero, 2014).

For PCA analysis; R which is a programming language widely used for statistical computing and data analysis is used. PCA reduces multivariate data to a smaller set of key variables, known as 'principal components,' that most effectively express the variability within the dataset.

R program is used for cluster analysis. Cluster analysis is performed on the sub composition Fe_2O_3 , Na_2O , TiO_2 , MnO , V, Zn, Cr, Sc, Ni, Ta, Zr, Nb, Mo, W, Co,

Ga, Pr, Nd, Sm, Eu, Gd, Tb, Ho, Dy, Er, Tm, Yb, Lu, Y, La, Th, Ce, Hf and Sn, as log ratios over the concentration of Lu as common divisor, because Lu was the least varied element. The average Euclidean distance was used as an inter-sample distance and the centroid clustering algorithm was employed on the distance matrix. Some elements affected by weathering and firing conditions and for the reasons mentioned above are excluded from the statistical evaluation.



CHAPTER 4

RESULTS

4.1 Visual/ Diagnostic Examination and Stereomicroscopy

The result of the visual diagnostic examination included color, surface treatment and identification of forming techniques if any relating marks existed. Also, for all sherds, fresh thick cuts are prepared, and used for the evaluation of firing atmosphere and grain size. Some other features concerning external evaluation, such as firing atmosphere, inclusion density, and grain size at first glance, are examined and evaluated by stereomicroscopy. The detailed diagnostic description of the pottery samples is given in Appendix A, Table A.1.

Phase V ceramics are orange, red, brown, brown black, red-black and red brown, slipped, burnished and smoothed. Generally, topography is regular, microtopography is smooth and compact, and grains are totally covered. Generally thin-walled wares are observed. Black/grey cores in fresh cut sherds demonstrate the incomplete oxidized firing. Traces of coiling techniques are felt by hand in some samples and also tool marks are observed in some samples. This period's pottery generally contains fine grains and dense inclusions.

Phase IV ceramics show a progress on surface treatment techniques and forms; as lustrously burnished thin-walled, multicolored sherds and foot and string forms are observed. Red-slipped black wares, different tones of red and reddish-brown slip and black and brown multi colored slips are observed. Thick (~1.7 cm) but rough or just smoothed orange wares are observed; there are also very thin-walled (~0.4 cm) wares, as well. Nearly all thin-walled wares are slipped and burnished. Brownish black, black/brown multi-color slipped and blackish red slipped wares are the characteristic of this phase. Also, it is observed that with the progressing forms of the wares, slip color varieties increase, and the color range of the pottery expands.

Some construction marks as bumps representing coiling techniques can be seen and felt by hand. Topography is partially regular in some samples and very thin cracks exist on the surface of the sherds in this Phase. Sample 234 is unique, due to its light grey color, smoothed, matte surface treatment and fine grains.

The Phase III ceramics are red, brown, black, red-brown and brown-black. It is seen that the color range is narrower. Some construction marks are seen, and the felt topography is partially regular. Also, very tiny cracks are observed for some samples. Red-slipped black wares or black slip-on reddish wares are also observed. In fresh cut sherds, a sandwich-like appearance, i.e., a grey/black core and orange margins are seen from the thick slice of cross-section. As with most Neolithic pottery firing, the oxidizing is incomplete or the firing atmosphere is mostly reducing. The aplastic inclusions are dense and medium to coarse-grained. It has been observed that pottery production has become more uniform and the craftsmanship has become rougher compared to Phases IV and V as also mentioned by Erdoğan, et al (2021).

4.2 Cross Section Studies

Fresh cut slices of cross-sections are used to provide an insight for firing atmosphere and inclusion size and density at a first glance by the naked eye. Then microphotographs of cross-sections taken under a stereomicroscope are used to evaluate the forming techniques.

Cross-sections used in the diagnostic evaluation of the sherd for grain size density evaluation and firing regime interpretations are also used for the determination of forming techniques. The representative samples are chosen for each phase. These cross-sections are evaluated according to the inclusion and void orientations each representing the basic forming techniques as coiling and slab building. For the interpretation of the forming techniques Figure 4.1 and 4.2 are used.

For firing regime and the grain size interpretations examples are illustrated in Figure 4.3. Sample 250 shows fined-grained and well sorted pottery fired in a reduced

atmosphere. Sample 320 is an example of a coarse-grained ceramic with a dark core, due to insufficient penetration of oxygen during firing. Sample 264 has a low density of inclusions, as sample 322 is an example of a pottery fired in an oxidized atmosphere. In Figure 4.4, Sample 324 is an example to sandwich typed firing, indicates insufficient amount of oxygen in the medium. Illustrated in Figure 4.9, Sample 116 is an example for another different situation of core margin firing effects. This sherd contains a light-colored (orange) core area and darker margins, indicating the organic-poor clay, probably rapidly fired under reduced atmosphere.

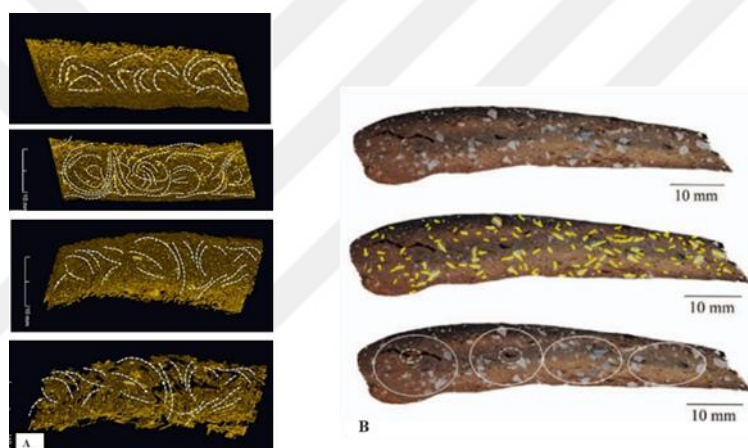


Figure 4.1. A. Void orientation in coiling technique (Neumannová, 2017), B. Inclusion orientation in coiling techniques (Ross, 2018).

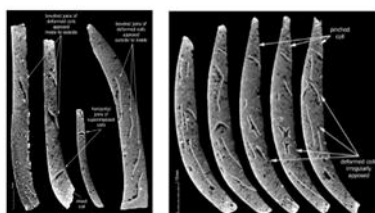


Figure 4.2. Examples of deformed coils (Kozatsas et al., 2018)

Phase V sample microphotographs of cross sections and discussion on forming techniques: The orientations of inclusions and voids affected by the forming techniques from Phase V are shown in Figures 4.3, 4.4 and 4.5.

In sample 250, a relatively coarse grain is seen in the middle of the void from the horizontal cross section (Figure 4.3). This can be explained by Ross (2018); force is needed to align such large particles, relative to smaller non-plastics. As such, they are seldom oriented the same way as smaller particles and they are consistently situated in the middle of vessel walls. In vertically cut cross-sections of samples 264 and 322, voids seen marked by circles, suggest the coiling forming technique.

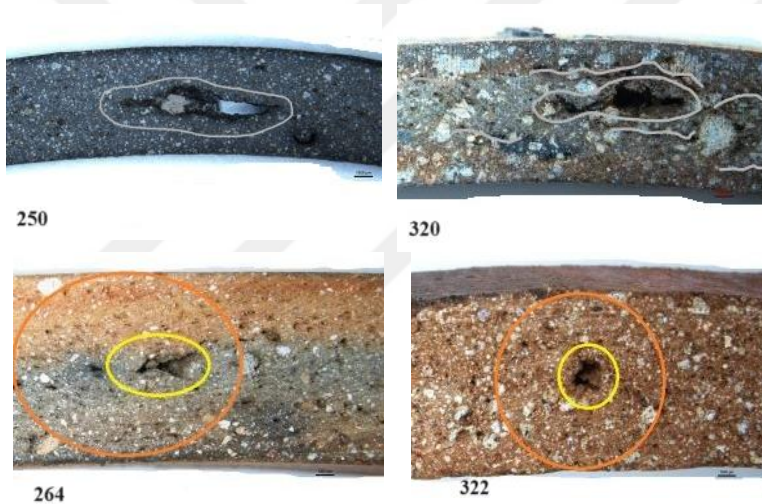


Figure 4.3. Void orientations of the samples in horizontal (samples 250 and 320) and vertical (samples 264 and 322) cross-sections.

At the left of Figure 4.4, inclusion orientations are seen for three different samples (327, 324 and 333). At the right of the figure, sample 327 shows an apparent vision of suspected coils that the spiraling inclusions surrounding them spaced approximately equidistant from each other, and voids are positioned in the middle of the inclusions. Sample 324 at the right of the figure, shows an example of deformed

coils processed during the forming action. Both examples to inclusion and void orientations in the samples, suggest coiling techniques.

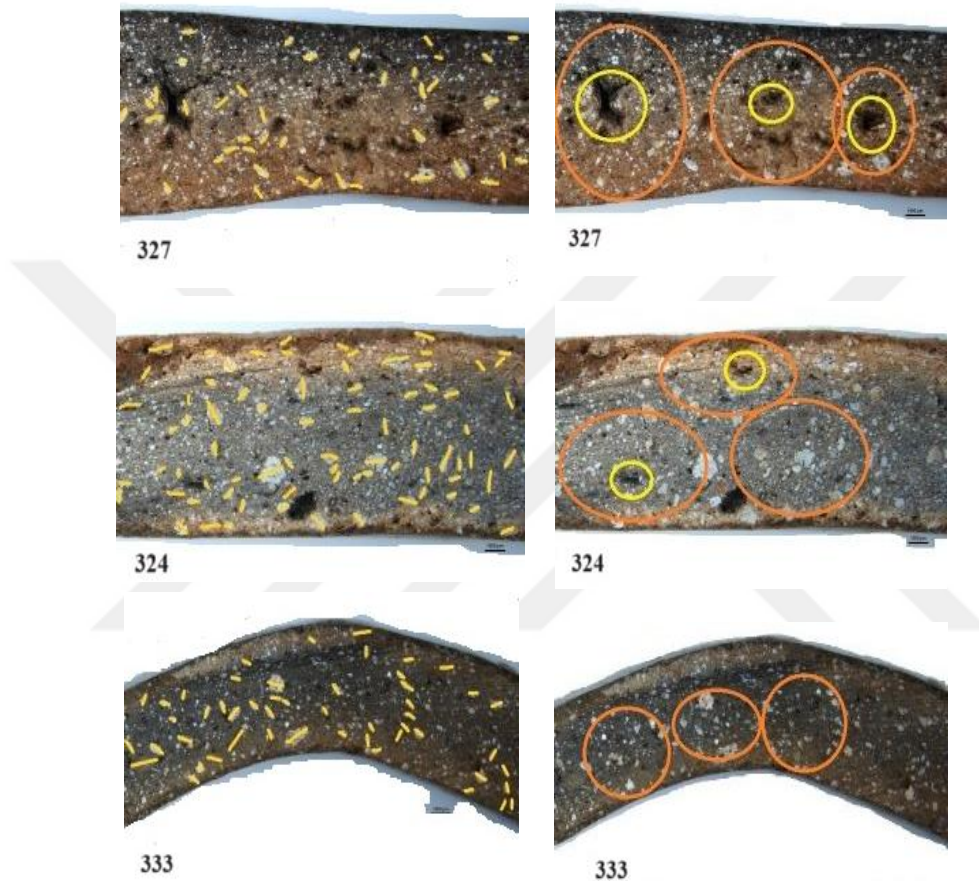


Figure 4.4. Inclusion and void orientations in cross samples in Phase V

In Figure 4.5, the orange ellipses show the outline of the preferred orientation of individual inclusions and yellow ellipses show the voids. In sample 326 the yellow lines show the orientation of voids in a deformed way from a limited image.

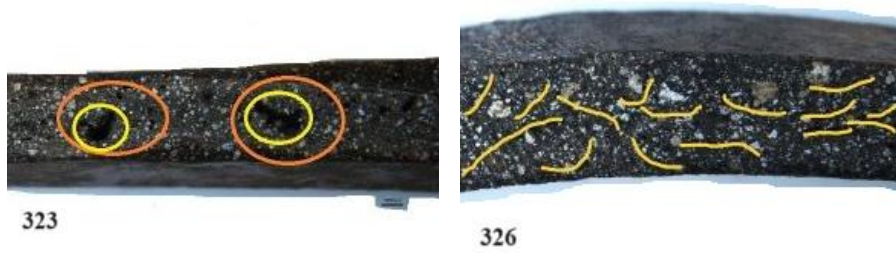


Figure 4.5. Sample 323 is an example to deformed coils, sample 326 shows the void orientations.

Phase IV sample microphotographs of cross sections and discussion on forming techniques: In Figures 4.6, 4.7 and 4.8 the orientations of inclusions and voids due to the forming techniques are shown for Phase IV.

Figure 4.6 shows three (in 312) and two (in 308) featured circular voids, located at the mid-points of suspected coils, surrounded by spiraling inclusions, indicative of coiling forming technique. Orange circles/ellipses mark the outline of coils, while the yellow circles are the hole formed during the coiling process.



Figure 4.6. Selected representative samples of Phase IV vertical cross sections.

In Figure 4.7 the yellow lines show the orientation of individual inclusions of Phase IV samples. In Sample 312 featured circular void, located at rim of the sherd is an indicative sign of the coiling forming technique.

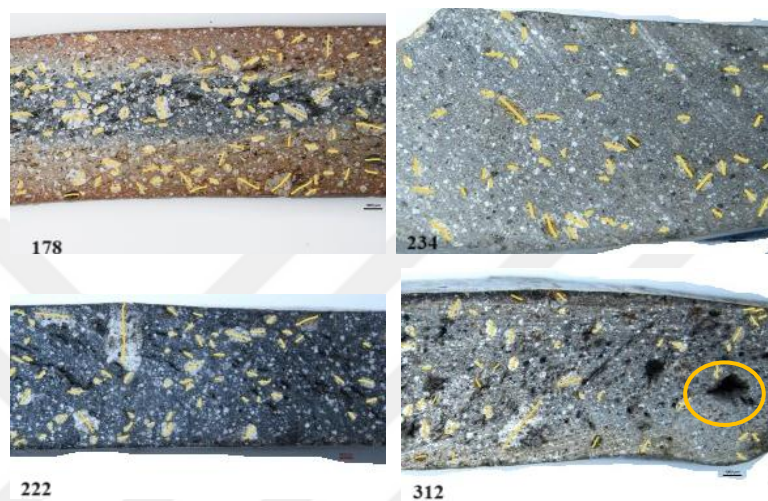


Figure 4.7. Examples to orientations of inclusions from phase IV.

Sample 318 is an example of the coiling technique. Three indicative signs of the coiling technique are shown in Figure 4.8 as an example.



Figure 4.8. Sample 318 is an example of the coiling technique.

Phase III sample microphotographs of cross-sections and discussion on forming techniques: In Figures 4.9, 4.10, and 4.11, the orientations of inclusion and voids of samples from Phase III are shown. Figure 4.9, shows featured circular voids, located at the mid-points of suspected coils, surrounded by spiraling inclusions, which may be an indication of the coiling forming technique. Orange circles mark the outline of coils, while the yellow circles are the voids formed.

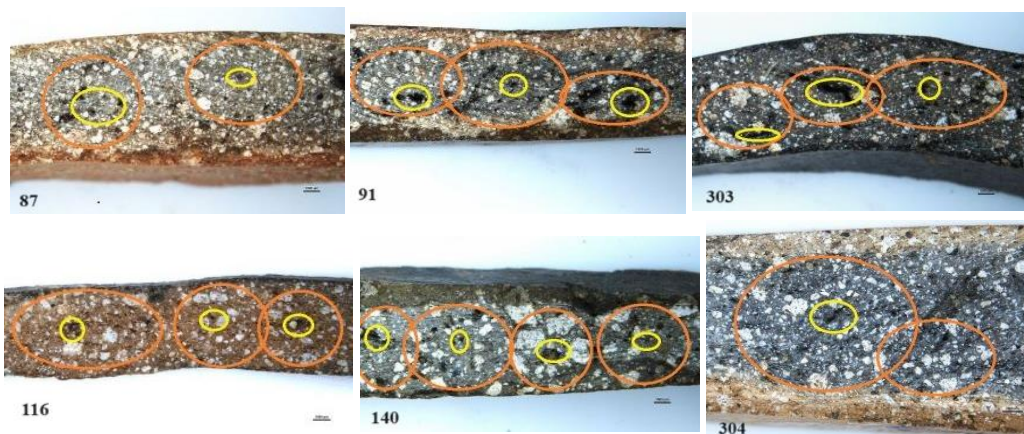


Figure 4.9. Selected representative samples of Phase III vertical cross sections.

Figure 4.10 shows the similarities with Figure 4.1 B (Ross et al., 2018) for orientations of inclusion through the cross-sections of Phase III samples. The yellow lines show the disordered orientation of individual inclusions of the samples resemble the behavior of the coiling techniques.

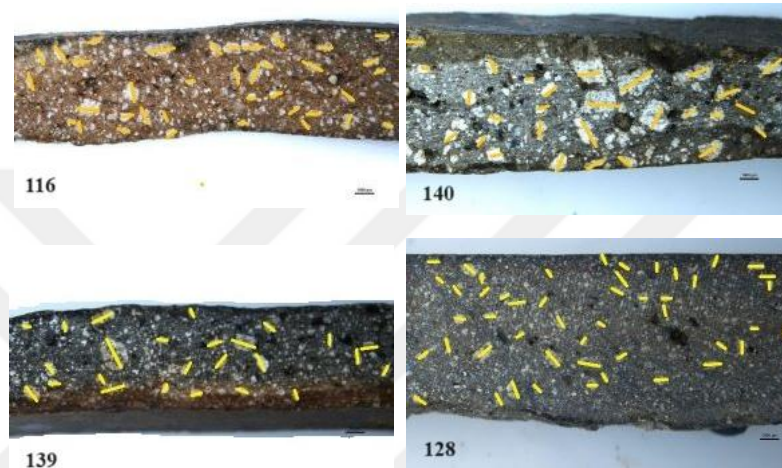


Figure 4.10. Orientations of inclusions in Phase III samples.

In Figure 4.11, vertical (sample 91) and horizontal (sample 304) cross sections of the samples show similar void orientations of coiling techniques in vertical and horizontal views given in Figure 4.1 A. The yellow lines show the different types of void orientations in coiling techniques.

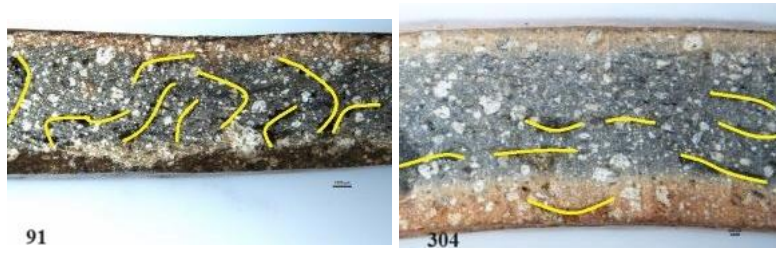


Figure 4.11. Examples of void orientations for Phase III

Evaluation of all cross sections:

- For generally all Neolithic sites and also for Uğurlu, the firing assumed to be done as open or pit firing. Taking this into consideration and observations in this study on clay matrix under microscope, three different colors existed on the cross section of the potteries. Generally, for firing atmosphere, a slow and oxidizing medium is a rare case. Due to this, the light color of the pottery (light/dark orange, red, dark yellow) indicates that the amount of oxygen is enough in the medium (oxidizing medium).
- Dark color (black, gray and dark brown) indicates that the amount of oxygen is insufficient in the medium (reductive medium).
- In the cross-section of pottery, if the color of pottery contains a black/grey zone and becomes lighter towards margins (from dark brown to orange), it means that pottery is fired in a short time.
- If there is a thin, light-colored margin just on the pottery surface, this suggests that the pottery was taken out from the reduced medium and cooled rapidly in the atmospheric medium.
- Lastly, a thin dark-color zone at the pottery surface, suggests that the pottery was covered with organic matter during the firing (it can be wrapped in straw maybe in contact with the fuel) (Quinn, 2013). All of these features are observed for all three phases, in potteries of the study, and sandwich typed (o-R-o), zoned firing is common, followed by reduced medium samples.

- Phase III samples differentiate from Phase IV and V with, different sorting degrees (poorly/very poorly). Phase V samples possess the finest and sparse aplastic inclusion amount among the three phases. Generally, sorting degree is regardless of the wall thickness of the vessels.
- Inclusion and void orientations, support the concentric marks or bumps on the surfaces of the vessels and point out the coiling technique. According to the results that has been analyzed with microscope, only coiling technique is clearly determined. Reaching conclusions about coiling method does not indicate that the other techniques, such as pinching, slab building or drawing are not used but these techniques may also have accompanied to the coiling technique.

4.3 Thin Section Analysis Results

Thin-section analysis allows the establishment of pottery-making techniques on the basis of the nature of the inclusions (aplastic components), grain shape, (roundness, or angularity), size and distribution within the pottery groundmass, firing temperature and firing atmosphere (Echallier, 1984; Quinn, 2009). The evaluation of the method and parameters are described below;

- Surface treatment is evaluated for smoothing, burnishing and slip.
- Appearance of the micromass, including color, birefringence, and the presence of organic matter (plant voids). The micromass is mentioned as showing birefringence when the microscope stage is rotated under crossed polars (XPL). In other words, fine-grained high-order phases embedded in the groundmass exhibiting anisotropic optical properties, reflects the extent of firing, estimated at less than about 700°C in oxidizing conditions from experimental studies (Whitbread, 1995).
- Size, shape, frequency and distribution of aplastic inclusions, and sorting degree.
- Volcanic rock fragments as rhyolite, andesite and basaltic andesite; plutonic rock fragments as granodioritic/dioritic rock fragments; sedimentary rock fragments as mudstone, clay-stone, siltstone, sandstone and marl; and metamorphic rock

fragments as schist; and for mineral fragments (quartz, feldspars, amphiboles, pyroxenes etc.)

- The other constituents as; grog (pottery fragments) and organic remnants as; carbonized plant, wood or coal.

Firstly, the surface treatment techniques are examined under microscope in PPL and XPL as shown in Figure 4.12. Figure 4.12 A (Sample 102) exhibits a thin layer of dark-brown colored slipped and burnished margin, B (Sample 324) and C (Sample 138) are examples for smoothed surface, and D (Sample 119) shows the characteristic image of a rough surface.

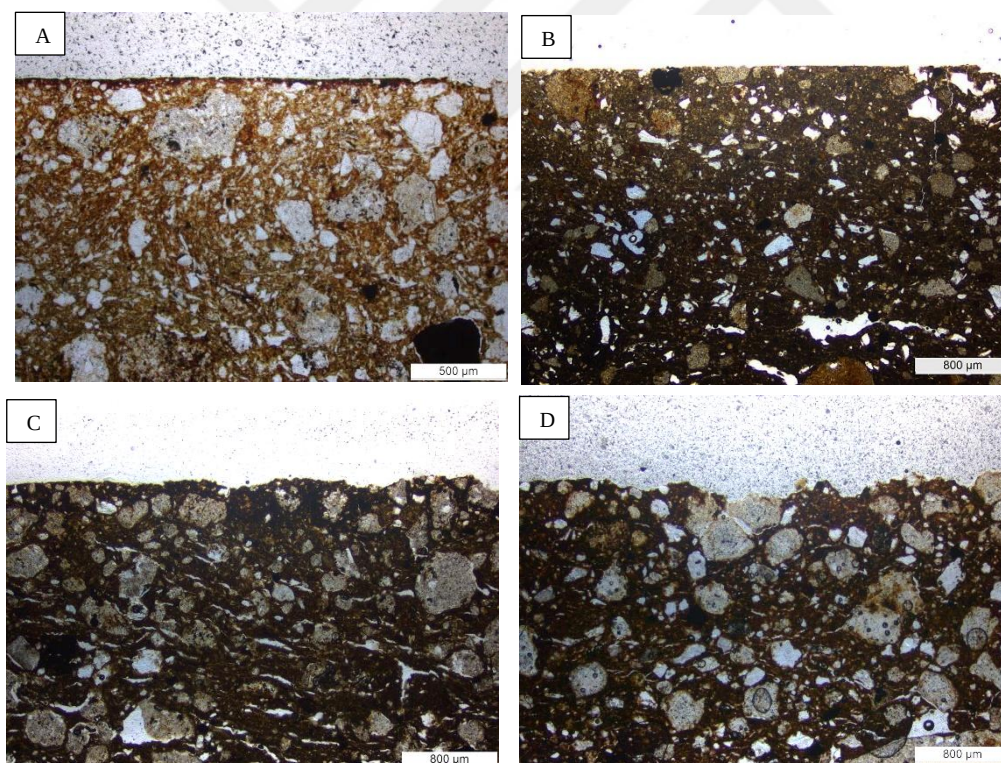


Figure 4.12. Polarized light microphotographs (PPL) of pottery showing surface treatment techniques

Firing effects on micromass is shown in Figure 4.13. In A (Sample 106) of the Figure an example for zoned firing (in PPL) is demonstrated. Dark core is due to insufficient diffusion of oxygen during firing. In B (Sample 91) of the figure (XPL), a sherd fired in an oxidized. In C (Sample 312) and D (Sample 94) of the figure, sherds fired in a reduced atmosphere in PPL and XPL respectively, is demonstrated. Also, for oxidized atmosphere the birefringence of the groundmass (that is changing color during rotation of the stage) in B, is noticeable. In D in XPL, the groundmass that does not give birefringence is shown.

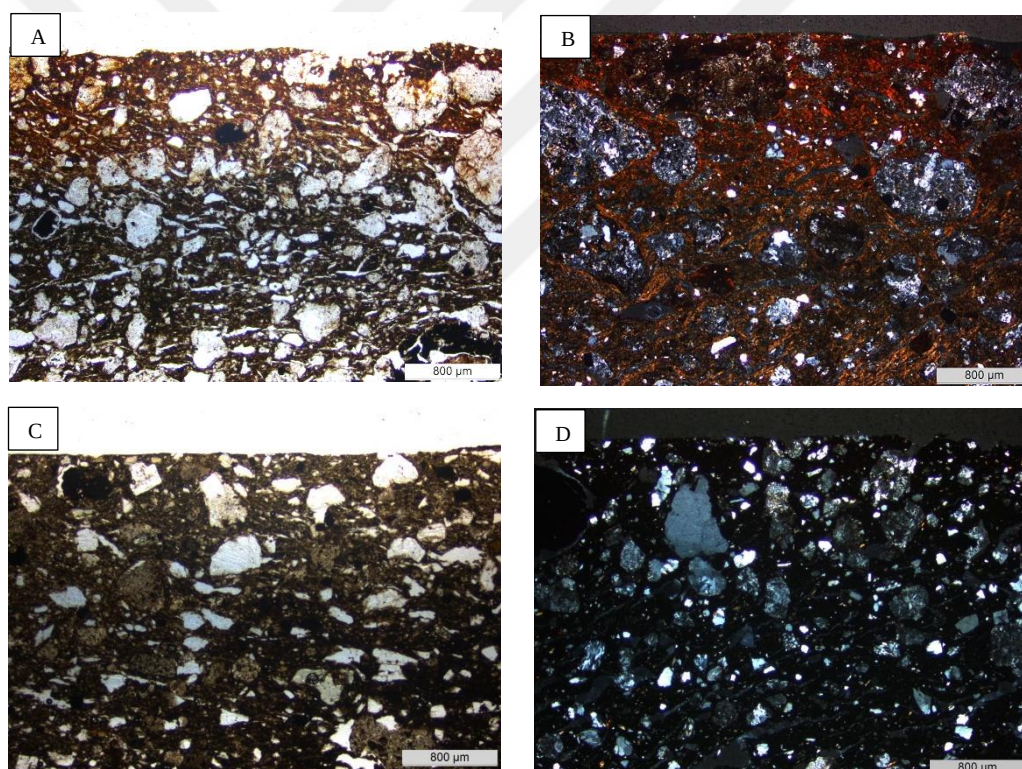


Figure 4.13. Examples of effect of firing atmospheres and soak time on micromass in PPL (a) and XPL (b, c) in 2.5x.

The firing is also important in achieving a good burnish. Many burnished objects are totally or partially black or brown; at least have darker colors. For a high-quality burnish, the object must be low-fired (700–760°C) (von Dassow, 2009, Ionescu and Hoeck, 2020).

Mineral fragments derived from granodioritic, porphyritic rhyolitic, andesitic or basaltic andesitic rocks are; quartz, feldspars (both plagioclase and alkali feldspars), amphiboles (hornblende), pyroxenes, micas (muscovite and biotite) and opaque minerals. Some of these mineral examples are shown in Figure 4.14. In Figure 4.14 A (Sample 302) and B (Sample 227) large mineral fragment in the middle belongs to plagioclase. In Figure 4.14 C and D green mineral fragments are hornblendes in PPL and XPL respectively (Sample 317). In Figure 4.14 E (Sample 227) brown mineral is a mica (biotite) and in F (Sample 102), quartz is demonstrated embedded in a volcanic rock fragment. In Figure 4.14 G and H (Sample 312) green mineral fragment is pyroxene in PPL and XPL respectively.

The rock fragments observed are igneous, sedimentary and metamorphic rocks. For the majority of the sherds, these rock fragments are of igneous rocks as rhyolitic, andesitic and basaltic andesitic rock fragments (in aphanitic to vitric texture) and granite to granodioritic rock fragments (as phaneritic texture). The characteristic examples of some rock fragments found in Uğurlu pottery is shown in figure 4.15. Dominantly found igneous rocks are porphyritic andesite, rhyolite and granodiorite. Figure 4.15 A and B (Sample 91) a porphyritic andesitic rock fragment with feldspar is shown in PPL and XPL respectively. In Figure 4.15 C and D (Sample 104) a porphyritic andesitic rock fragment with hornblende is shown in PPL and XPL respectively. In Figure 4.15 E (Sample 313) an example of basaltic andesitic rock fragment with clinopyroxene in PPL is shown. In Figure 4.15 F (Sample 299) a dioritic fragment in XPL is demonstrated. In figure 4.15 G (Sample 105) and F (Sample 94) volcanic rock fragments with devitrified groundmass (rhyolitic) are demonstrated.

In Figure 4.16, examples of fragments for sedimentary (sandstone, claystone, chert) and metamorphic rocks are seen. In Figure 4.16 A (Sample 322) and D (Sample 94), examples for calcedony and chert can be seen respectively. In Figure 4.16 B (Sample 140), an inclusion of siliceous sedimentary rock is seen. In Figure 4.16 C (Sample 334) and E (Sample 119) examples for sandstone are given. In Figure 4.16 F (Sample 94), the brown fragment is a claystone. In the metamorphic rock category usually shist/mica shist exists. Examples of metamorphic rocks are shown in Figure 4.16 G (Sample 119) and H (Sample 326).



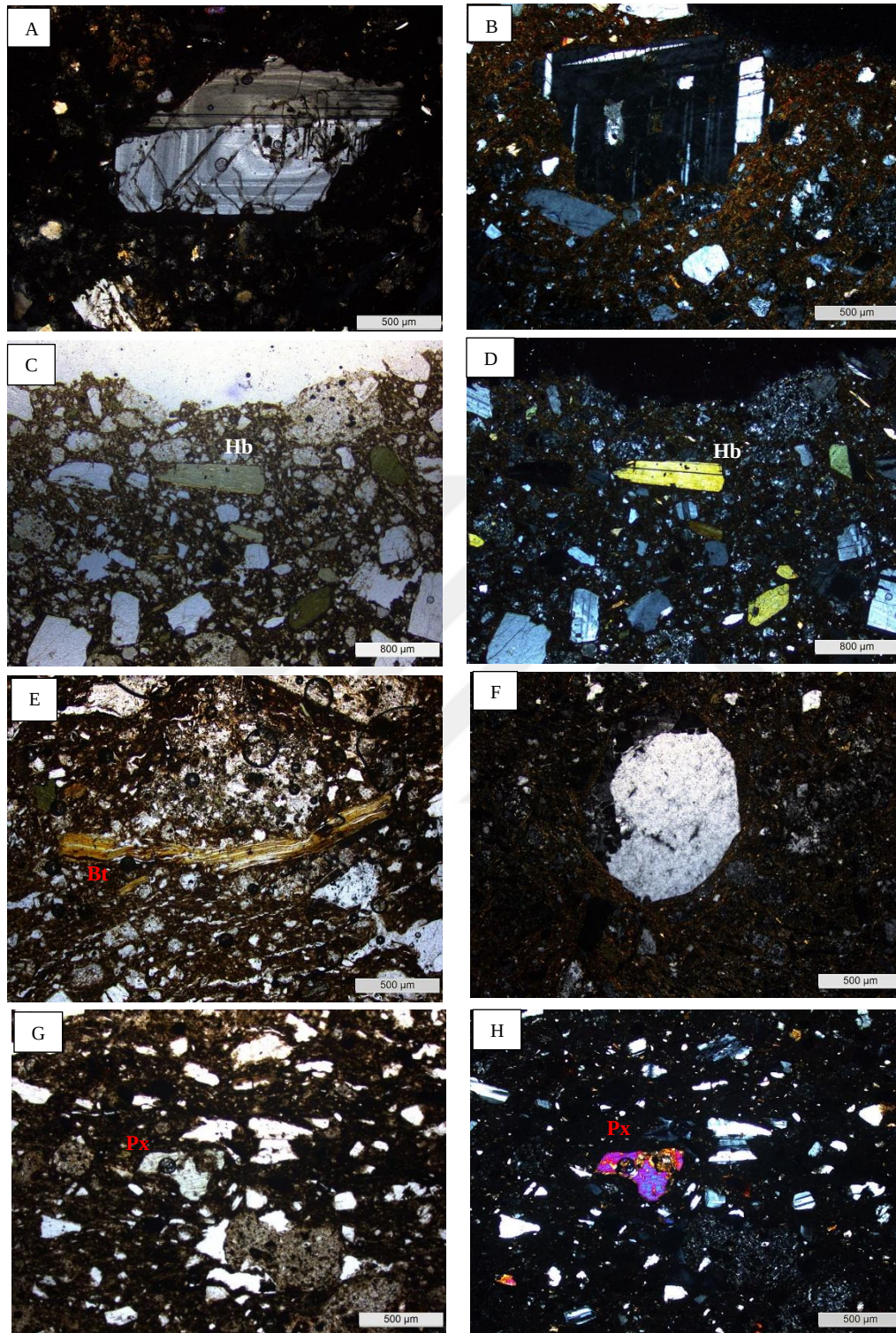


Figure 4.14. Characteristic mineral fragments from the samples. Bt: Biotite, Hb: Hornblende, Q: Quartz, Px: Pyroxene.

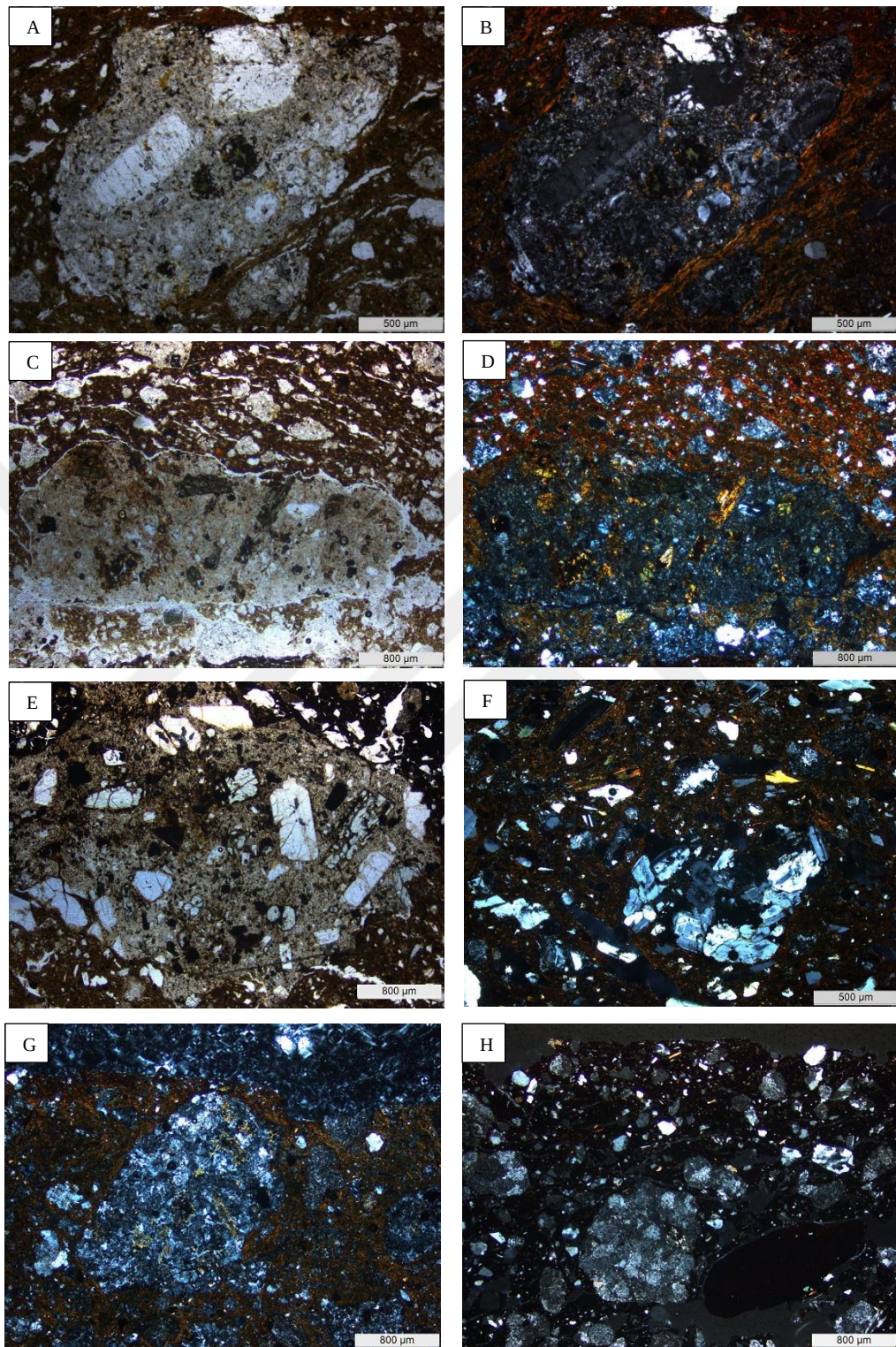


Figure 4.15. Characteristic igneous rock fragments from Uğurlu pottery samples.

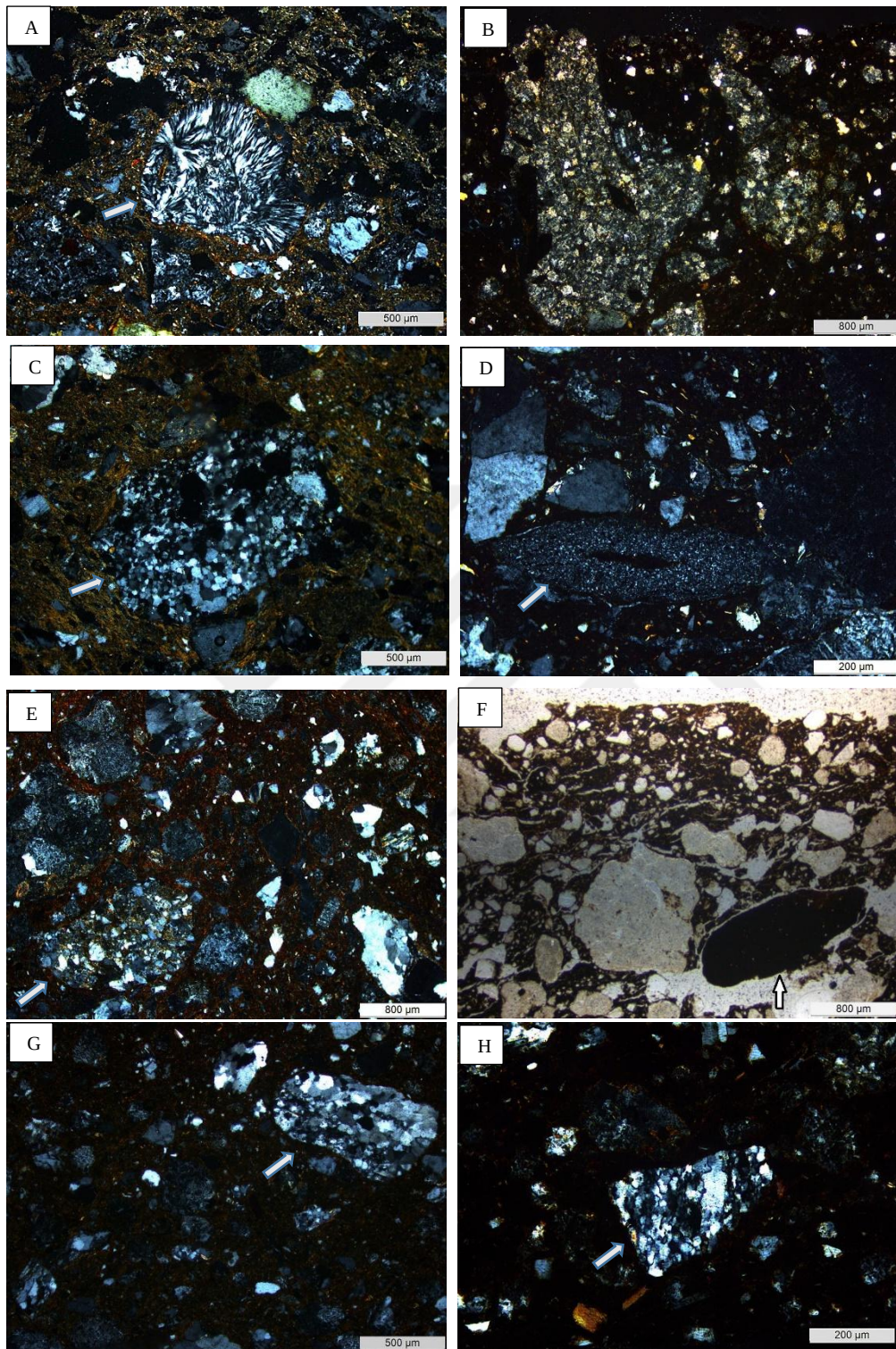


Figure 4.16. Characteristic sedimentary and metamorphic rock fragments from Uğurlu pottery samples

In some pottery samples, it is observed that mineral and rock fragments are crushed. The intense and closely spaced cross-cutting fractures and very angular shapes observed on the grains may suggest that these fragments are grounded in the clay preparation stage. An example of crushed fragments is shown in Figure 4.17 A (Sample 223) and B (Sample 113).

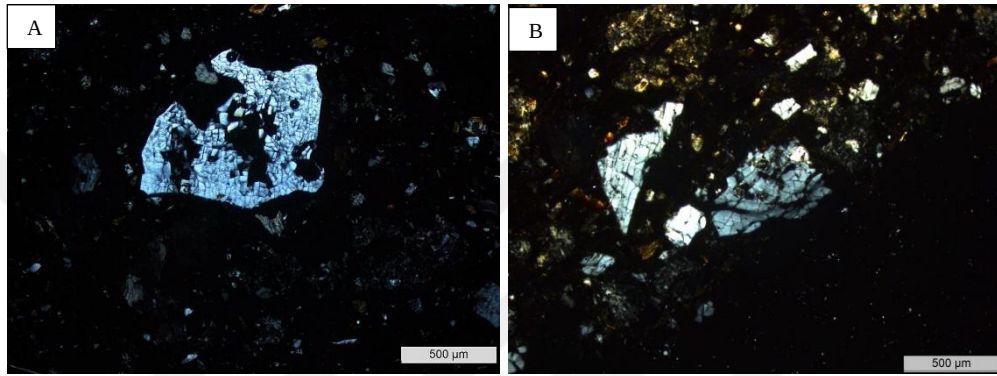


Figure 4.17. Examples of some crushed minerals in Uğurlu pottery samples

Thin section results of each sample is described in Appendix B, Table B.1.

4.3.1 Characterization of Fabric Groups

The samples are grouped based on thin section observations and separated into fabric classes by the nature of their dominant non-plastic inclusions, their clay matrix and textural characteristics. These groups are described in detail using a modified version of the methodology proposed by Whitbread (1989, 1995). The samples are identified and grouped qualitatively, utilizing standard visual charts for the visual estimation of percentage area and degree of sorting, grain shape diagram. The terms used are as follows; predominant :>70%, dominant: 50-70%, frequent: 30-50%, common: 15-30%, few: 5-15%, very few: 2-5%, rare: 0.5-2%, very rare:<0.5%, absent:0%. Grain

shapes: very angular, angular, sub-angular, sub-rounded and rounded. Sorting degree: well sorted, moderately sorted, poorly sorted, and very poorly sorted.

Grouping of each phase is done according mainly to inclusion frequency and content of the matrix. But also, groundmass texture (being fine or gritty) is taken into account during the evaluation of the groups.

The petrographic observations lead to distinguishing four main fabric classes for each phase within, depending on paste texture, quantity and types of rock and mineral fragments present.

4.3.1.1 Grouping Phase V

Fabric group V-A: Volcanic rock fragments (andesitic/ rhyolitic) are prevalent. This fabric class is divided into three sub-groups.

- V-A1: VRF (rhyolitic) are fine, infrequent and shapes are rounded to subrounded. Few mineral fragments probably defragmented from VRF is observed. Inclusion frequency is in the range of 25-45% and porosity varies between 3% and 15%. Sorting degree is mainly moderately sorted and the members of this fabric group are 262, 265, 323, 325.
- V-A2: Sericitized VRFs characterize this group. Individual angular/sub angular green hornblende and biotite exist in the groundmass. Inclusion frequency is in the range of 25-40% and porosity varies between 7 and 12%. Sorting degree is poor. Members of this fabric group are; 245, 326, 327, 328, and 330 (has a distinguishing fabric with fine groundmass compared to other samples). Sample 330 contains sericitized and hematitized VRFs.
- Loner V-A3: Sample 331 is coarse grained and inclusion density is high. Some VRF are stained and some contain a silicified groundmass. Also a few clay stones /clay pellets exist. Hematitization occurs in the groundmass.
- Loner V-A4: Sample 250 distinguishes from the other samples by its rounded to subrounded fine, well sorted inclusions of VRF (rhyolitic/andesitic)

predominant. It also includes large biotite fragments as 1.1 mm, and some charred plant remains.

Fabric group V-B: Mineral fragments derived from dioritic rocks are prevalent along with VRF. Samples include coarse grained inclusions. Mineral fragments mostly consist of alkali feldspars, plagioclases, hornblendes and mica. Inclusion frequency is in the range of 30%-40% and porosity varies between 10% and 15%. The sorting degree is moderately to poorly sorted. This group can be subdivided into two.

- V-B1: Members of this fabric group are; 267, 322, 335. Inclusion density is lower than group B2
- V-B2: This group contains andesites with opacified brown /black hornblende phenocrysts. Potteries are coarser grained and basaltic andesitic types of RFs exist. Members of this fabric group are; 319 and 320.

Fabric group V-C: Sedimentary rock fragments prevalent. In this fabric group generally, SRF (mudstone and limestone are prevalent) and hematitization is observed in the groundmass. Inclusion frequency is 30-40% and porosity varies between 5-15%. Sorting degree is well to poorly sorted. Members of this fabric group are; 259, 324, 329, and 332.

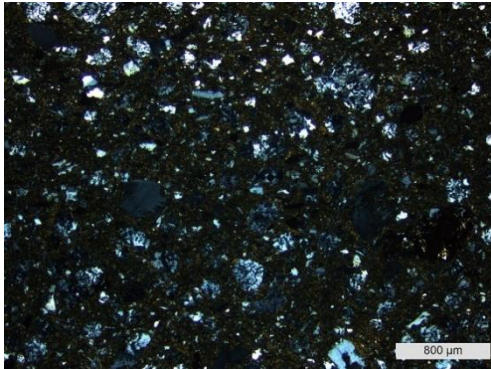
Fabric group V-D: Metamorphic rock fragments prevalent: In this fabric class, MRFs along with SRFs are prevalent. SRFs include sandstone, limestone, claystone and chert. VRFs (rhyolitic/andesitic) are infrequent. Inclusion frequency is 30-35%. Porosity varies between 7-12%. Sorting degree is well to poorly sorted. Members of this fabric group are 264, 321, 333, and 334.

Also, big biotite fragments are prevalent in pottery samples of Phase V. Samples 319 and 320 exhibit andesite fragments with partially or fully opacified hornblendes as in Eşelek volcanic rocks of Gökçeada (Şen et al., 2020).

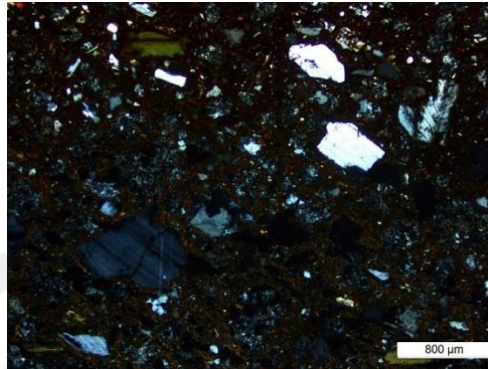
Representative microphotographs for Phase V fabric classes are shown in Figure 4.18. Fabric V-A (Sample 262), V-B (Sample 322), V-C (Sample 312) and V-D

(Sample 333) represents VRF, Dioritic rock fragments, SRF and MRF prevalent fabric types respectively.

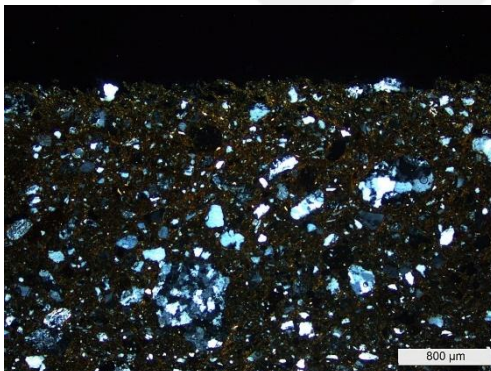
Fabric V-A



Fabric V-B



Fabric V-C



Fabric V-D

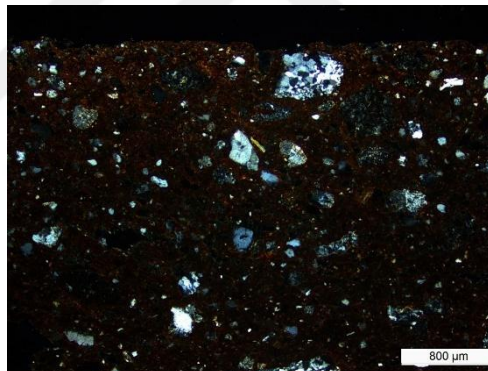


Figure 4.18. Microphotographs of Phase V samples representing each fabric group (XPL).

4.3.1.2 Grouping Phase IV

Fabric group IV-A: Volcanic rock fragments (andesitic/ rhyolitic) are prevalent. This group is divided into sub-groups.

- IV-A1: Volcanic rock fragments (VRF) (andesitic) predominant. In this fabric group generally, some volcanic rock fragments have silicified and some have devitrified groundmass. Clay paste is fine. Samples contain ferruginous pellets. Inclusion density is generally high. Sorting is poor. Inclusion frequency is in the range of 25%-45% and porosity varies from 7% to 15%. Sorting degree is poor and the members of this fabric group are 162, 178, 221, 307, 308, 314, and 318.
- IV-A2: Volcanic (rhyolitic) rock fragments are prevalent. It contains sedimentary rock fragments (SRF) (claystones) and few metamorphic rock fragments (MRF). Hematitization is seen in the clay paste. Inclusion frequency is in the range of 40%-45% and porosity varies between 10% to 12%. Sorting degree is poor and the members of this fabric group are 168, 172, 306, and 315.

Fabric group IV-B: In this fabric group basaltic andesite is prevalent and it contains zoned plagioclases and charred plant remains as well. Inclusion frequency is approximately 40% and porosity varies from 10% to 15%. The micromass of the samples does not give birefringence and the members of this fabric group are: 312, and 313.

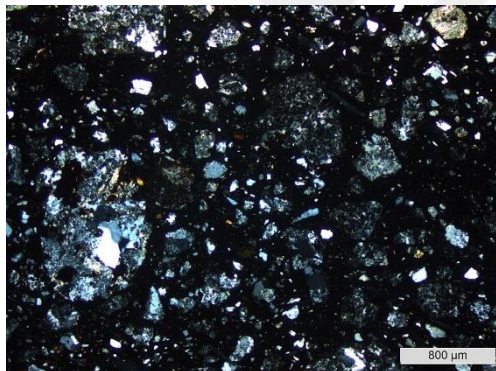
Fabric group IV-C: Mineral fragments derived from dioritic rock are prevalent along with VRF (andesitic). Mineral inclusions are coarse and inclusions are dense in the clay matrix. Inclusion frequency is in the range of 30%-50% and porosity varies between 5% and 15%. Sorting degree is poor. This group can be divided into two.

- IV-C1: Members of this fabric group are 222, 227, 305, 309, 311, 316, and 317.
- IV-C2: This subgroup contains MRFs. Members of this fabric group are; 223 (crushed mineral fragments) and 234.

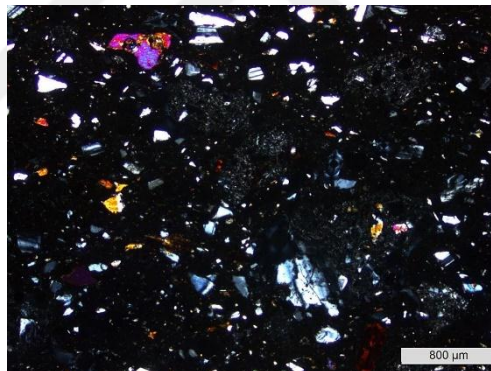
Fabric group IV-D: The characteristic feature of this phase is that MRF (schist) and SRF (claystone, micritic limestone) are prevalent. Inclusion density is low and sorting degree is poor. Members of this fabric group are 185, 310. As differentiating from the other samples, Sample 310 contains frequent (~ 30%) amounts of micritic limestone.

Fabric group IV-A1 generally consists of rough, thick and orange-colored ceramics with zoned firing. Some are slipped but not burnished well, except Sample 306. IV-A2 is generally light brown, slipped and burnished. Fabric group IV-C generally consists of dark red or brown ceramics without zoning except Sample 317 (red orange). A common feature of fabric class IV-D is that they are thin, slipped and burnished. It is observed that generally the stylistically attentive pieces are tempered with mineral fragments. Representative microphotographs for Phase IV fabric classes are shown in Figure 4.19. Fabric IV-A (Sample 308), IV-B (Sample 312), IV-C (Sample 227) and IV-D (Sample 185) represents VRF, Basaltic rock fragments, Dioritic rock fragments, and MRF prevalent fabric types respectively.

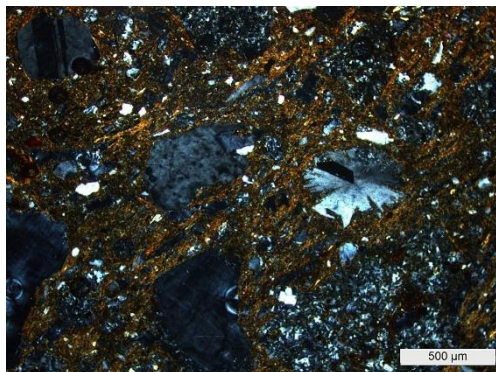
Fabric IV-A



Fabric IV-B



Fabric IV-C



Fabric IV-D

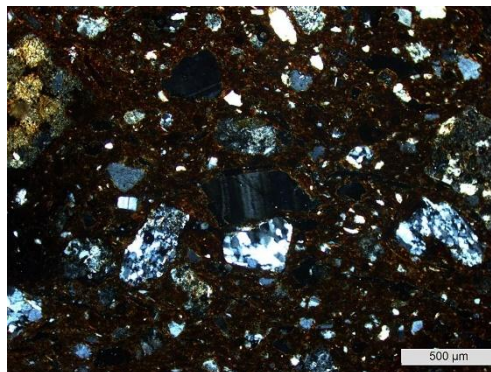


Figure 4.19. Microphotographs of Phase IV samples representing each group (XPL).

4.3.1.3 Grouping Phase III

Fabric group III-A: Volcanic rock fragments are predominant. This group is divided into four sub-groups.

- III-A1: Fine grained: In this fabric group generally, andesitic rock fragments are well rounded to subrounded and the sphericity of the inclusions is high. Organic (plant) remains exist. The member of this group is Sample 88.
- III-A2: This group is characterized by its medium-grained inclusions and fine groundmass. Opaque particles and hematitization in the ground mass are prevalent and the porosity is high. Inclusion frequency is between 30%-40% and porosity is approximately 10%. Sorting is very poor. The members of this fabric group are 87 and 89
- III-A3: The highlight of this group is that the samples have fine and relatively low inclusion content. Inclusion frequency is approximately 30% and porosity varies between 5% and 7%. The roundness and sphericity of the inclusions are subrounded (sr) to sub angular (sa). Sorting degree is moderate to poor, and inclusion size varies between <0.2 and 3mm. The members of this fabric group are; 102, 105 and 138.
- III-A4: In this group porphyritic volcanic (andesite) rock fragments are dominant. Mineral fragments as hornblende, feldspars and pyroxene from volcanic rocks exist. This group also contains iron-stained rock fragments, and a few sedimentary rock fragments. Inclusion frequency is between 25% and 40% and porosity vary between 7% and 15%. The roundness and sphericity of the inclusions are subrounded (sr) to very angular (va), sphere (sp) to low sphere (lsp) and sorting is generally poor. The hematitization (Samples 116 and 139) and some burnt organic remains are observed in some samples. The members of this fabric group are 91, 104, 116, 128, 139 and 301.

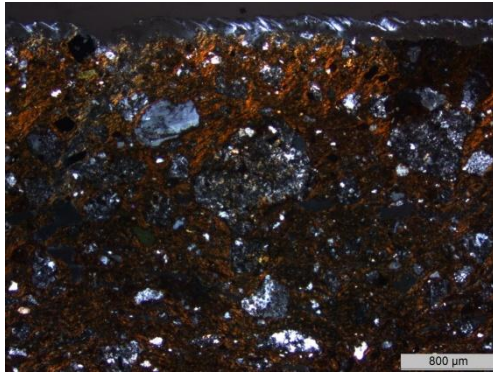
Fabric group III-B: Granodioritic rock fragments are dominant. Along with volcanic rock fragments, angular minerals fragments exist in the clay paste. Mineral fragments mostly consist of feldspars, quartz and hornblendes. Some VRFs have

glassy background and the paste is generally very fine. Inclusion frequency is approximately 40% and porosity varies between 7% to 15%. Sorting is generally poor and the members of this fabric group are, 99, 133, 299, 303, and 304. The samples 303 and 304 contain organic remains.

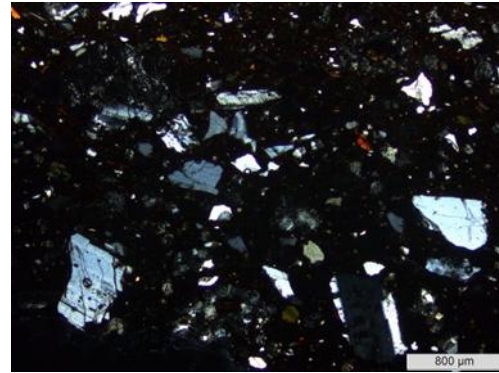
Fabric group III-C: Sedimentary rock fragments are prevalent. In this fabric group along with the volcanic rock fragments, the sedimentary rock fragments as, sandstones, mudstones, claystones, etc. and mineral fragments exist in the clay paste. Generally, the rock fragments are altered (rock fragments with silicified and glassy groundmass). Inclusion frequency is in the range of 30%-50% and porosity is mostly 10%. Sorting degree is poor. Members of this fabric group are 92, 106, 113, 140, 300, 302.

Fabric Group III-D: Metamorphic rock fragments are prevalent fabric group. In this group along with volcanic rock fragments and few sedimentary rock fragments, significant amount of metamorphic rock fragments (mica-schist) is observed. Inclusion frequency is approximately 40% and porosity varies between 7% and 12%. The sorting degree is poorly sorted and the members of this fabric group are 94, and 119. Representative microphotographs for Phase III fabric classes are shown in Figure 4.20. Fabric III-A (Sample 91), III-B (Sample 299), III-C (Sample 300) and III-D (Sample 119) represents VRF, dioritic rock fragments, SRF and MRF prevalent fabric types respectively.

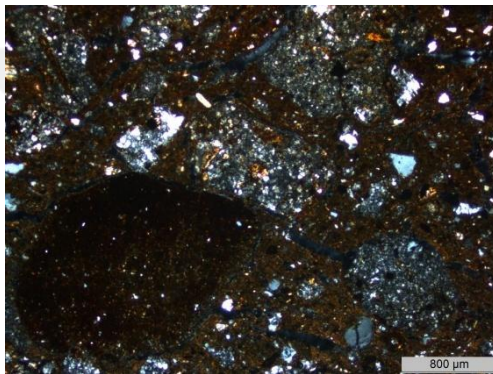
Fabric III-A



Fabric III-B



Fabric III-C



Fabric III-D

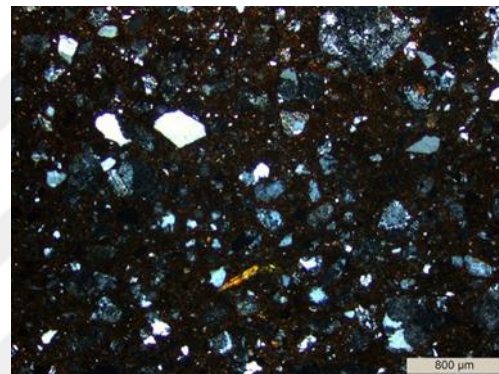


Figure 4.20. Microphotographs of Phase III samples representing each fabric group (XPL).

Paste texture, paste mineralogy, quantity, size, porosity, shape, sorting and mineralogy of inclusions are investigated. Petrographic observations generally suggest the existence of four different type of pottery fabrics (volcanic, dioritic, metamorphic and sedimentary prevalent fabrics). The main distinguishing petrographic features may indicate rounded rock fragments (mainly rhyolitic and andesitic) in the paste-matrix as well as in the large angular mineral fragments, which are quartz, alkali feldspar, plagioclase, green hornblende, micas (biotite and muscovite) and pyroxenes which are defragmented from dioritic rocks.

One of the remarkable differences between phases is that, while lime-stone tempered samples are seen in small amounts, it is not encountered at all, in Phase III. The other main difference among phases is that some samples in Phase V are fine-grained and scarce textured. In Phase V, inclusions are very fine grained, infrequent and rounded to sub-rounded, suggesting that during the paste preparation stage, temper addition is low or coarse grains are picked up, or maybe the inclusions coming from the clay are adequate.

In the geology of Gökçeada mainly volcanic rocks cover very large areas. Andesite and diorite porphyry rocks in the vicinity of Uğurlu site show differences in terms of textural and mineralogical contents. The main mineral constituents are plagioclase, alkali feldspar, hornblende, clinopyroxenes and opaque minerals (Sarı, et al., 2015). The petrographic analysis of the pottery samples show that they contain rock fragments and individual mineral fragments found in vicinity of Uğurlu site as; porphyritic andesite, quartz monzonite, diorite-diorite porphyry, basaltic andesite, andesitic pyroclastic, conglomerate, sandstone, siltstone, claystone, marl, shale, limestones, mica schist/schist.

For all phases, fossil remains are not observed in any sample, and grog is very rarely encountered. For each phase organic or plant remains are encountered infrequently in some samples suggesting that they may have come with the clay or rock fragments occasionally. Fabric classes within each phase, exhibit some differentiations in raw material selections, and preparation of the clay (mixing) or temper addition. Some clay pastes are inhomogeneous and in some samples plastic inclusion sizes cover a great range between 0.2-7 mm, i.e., very poorly sorted. It generally seems to be petrographically consistent with the island's geology but a few samples are evaluated with other supportive analyses.

It is observed that in all phases, especially more frequently in Phase III pottery samples have sharp-edged angular mineral fragments (sometimes cracked), while the rock fragments are subrounded to rounded. This may suggest that the extrusive (volcanic) rock fragments have undergone a sieving process, due to coming with the

clay, while the mineral temper is added by grinding or crushing the intrusive (plutonic) rock fragments deliberately. Besides one noticeable observation is that, while for phases IV and V the petrographic groups may be related with diagnostic features of the potteries from Phase III, do not have any correlation to others in thin section groups and the diagnostic features (thickness, surface treatment, color etc.).

4.4 XRD Results

XRD analysis is performed for the determination of the minerals and to support or control the thin section results.

During evaluation of the XRD results, a comparison among the samples from different fabric classes is made, and the similarities and differences among them are checked. The mineral contents of the samples are given in Table 4.1. Generally, the samples contain feldspars, hornblende, quartz, mica and pyroxene (e.g., Figure 4.14)

Table 4.1 XRD data and related fabric class of the Uğurlu pottery samples

Sample	Fabric class	XRD results
Phase V		Mineral phases
245	V-A2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Clay mineral
250	V-A4	Quartz, Plagioclase, Alkali Feldspar, Mica
259	V-C	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
262	V-A1	Quartz Plagioclase, Alkali Feldspar, Mica
264	V-D	Quartz, Plagioclase, Alkali Feldspar, Mica
265	V-A1	Quartz, Plagioclase, Alkali Feldspar
267	V-B1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica,
319	V-B2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Clay mineral
320	V-B2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Clay mineral
321	V-D	Quartz, Plagioclase, Alkali Feldspar, Mica
322	V-B1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Clay mineral
323	V-A1	Quartz, Plagioclase, Alkali Feldspar, Mica

Table 4.1 (continued)

324	V-C	Quartz, Plagioclase, Alkali Feldspar, Mica,
325	V-A1	Quartz, Plagioclase, Alkali Feldspar, Mica
326	V-A2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
327	V-A2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
328	V-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
329	V-C	Quartz, Plagioclase, Alkali Feldspar, Mica
330	V-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
331	V-A3	Quartz, Plagioclase, Alkali Feldspar, Mica
332	V-C	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
333	V-D	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Clay mineral
334	V-D	Quartz, Plagioclase, Alkali Feldspar, Mica,
335	V-B1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Clay Mineral
Phase IV		
162	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
168	IV-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
172	IV-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
178	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Mica
185	IV-D	Quartz, Plagioclase, Alkali Feldspar, Hornblende? Mica
221	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Mica
222	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende
223	IV-C2	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
227	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
234	IV-C2	Quartz, Plagioclase, Alkali Feldspar, Hornblende
305	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Mica
306	IV-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
307	IV-A1	Quartz, Plagioclase, Alkali Feldspar
308	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Mica
309	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Pyroxene, Mica
310	IV-D	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, Calcite,
311	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
312	IV-B	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
313	IV-B	Quartz, Plagioclase, Alkali Feldspar, Mica.
314	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
315	IV-A2	Quartz, Plagioclase, Alkali Feldspar, Mica, Clay mineral
316	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
317	IV-C1	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
318	IV-A1	Quartz, Plagioclase, Alkali Feldspar, Hornblende
Phase III		
87	III-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
88	III-A1	Quartz, Plagioclase, Alkali Feldspar, Mica

Table 4.1 (continued)

89	III-A2	Quartz, Plagioclase, Alkali Feldspar, Mica
91	III-A4	Quartz, Plagioclase, Alkali Feldspar
92	III-C	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica, clay mineral
94	III-D	Quartz, Plagioclase, Alkali Feldspar, Mica
99	III-B	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
101	-	Quartz, Plagioclase, Alkali Feldspar, Mica
102	III-A3	Quartz, Plagioclase, Alkali Feldspar, Plagioclase, Mica.
104	III-A4	Quartz, Plagioclase, Alkali Feldspar, Mica
105	III-A3	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
106	III-C	Quartz, Plagioclase, Alkali Feldspar, Mica
113	III-C	Quartz, Plagioclase, Alkali Feldspar, Hornblende
116	III-A4	Quartz, Plagioclase, Alkali Feldspar, Hornblende? Mica
119	III-D	Quartz, Plagioclase, Alkali Feldspar, Mica
128	III-A4	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica
133	III-B	Quartz, Plagioclase, Alkali Feldspar, Hornblende, Mica.
138	III-A3	Quartz, Plagioclase, Alkali Feldspar, Mica
139	III-A4	Quartz, Plagioclase, Alkali Feldspar, Mica
140	III-C	Quartz, Plagioclase, Alkali Feldspar, Mica
299	III-B	Quartz, Plagioclase, Alkali Feldspar, Pyroxene, Mica
300	III-C	Quartz, Plagioclase, Alkali Feldspar, Mica
301	III-A4	Quartz, Plagioclase, Alkali Feldspar, Mica
302	III-C	Quartz, Plagioclase, Alkali Feldspar, Mica
303	III-B	Quartz, Plagioclase, Alkali Feldspar, Mica
304	III-B	Quartz, Plagioclase, Alkali Feldspar, Pyroxene

Some representative examples for mineral identification for pottery samples are shown below. To compare the thin section and XRD results for each phase, the samples are re-evaluated and generally, the XRD data supports the thin section observations. Only low amounts of minerals as pyroxenes and hornblendes observed in thin sections sometimes could not be observed on XRD diagrams. One of the differences observed in Phase V compared to the other two Phases is that, clay minerals could be observed on the profiles more often. This may be due to low firing degrees (as 600-850°C) or the higher ratio of clay matrix to the lower amounts of inclusions in the paste. Some examples are shown in Figures 4.21, 4.22, 4.23 and

4.24 in the XRD profiles. The different types of phases identified in various samples are illustrated in the related XRD profiles.

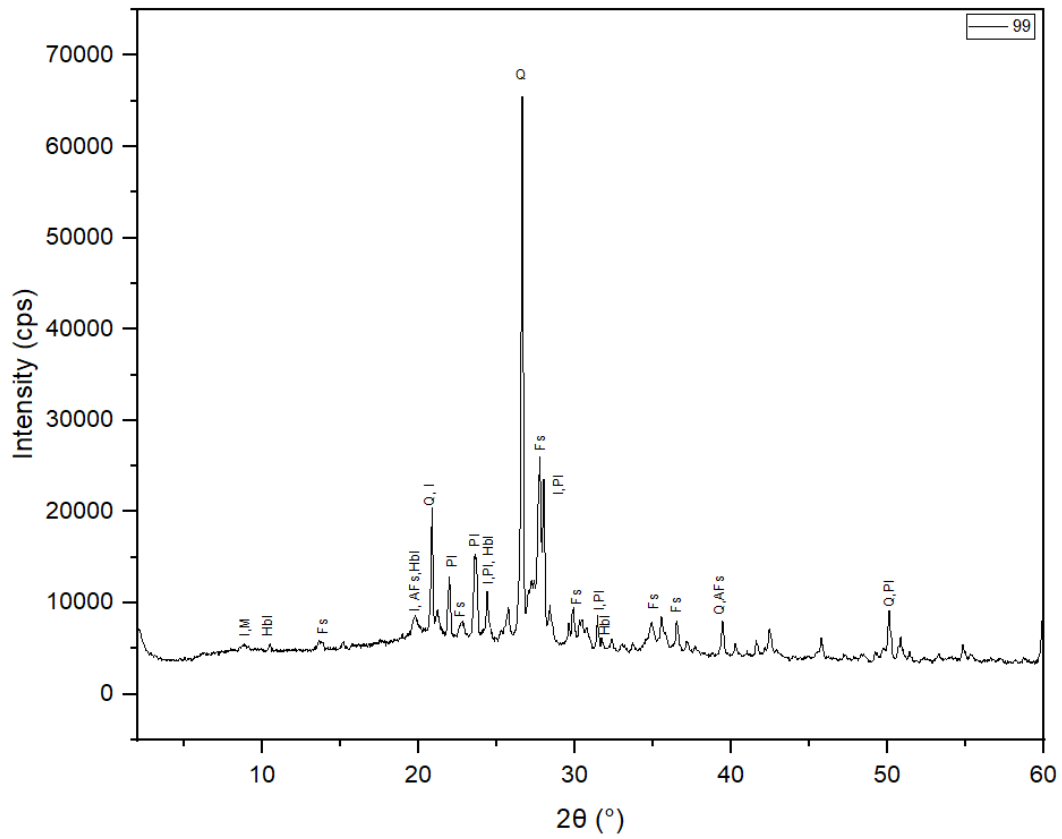


Figure 4.21. XRD chart of a representative sample from the Phase III. I: Illite, M: Mica, AF: Alkali Feldspar, Fs: Feldspar, Pl: Plagioclase, Hbl: Hornblende, Q: Quartz

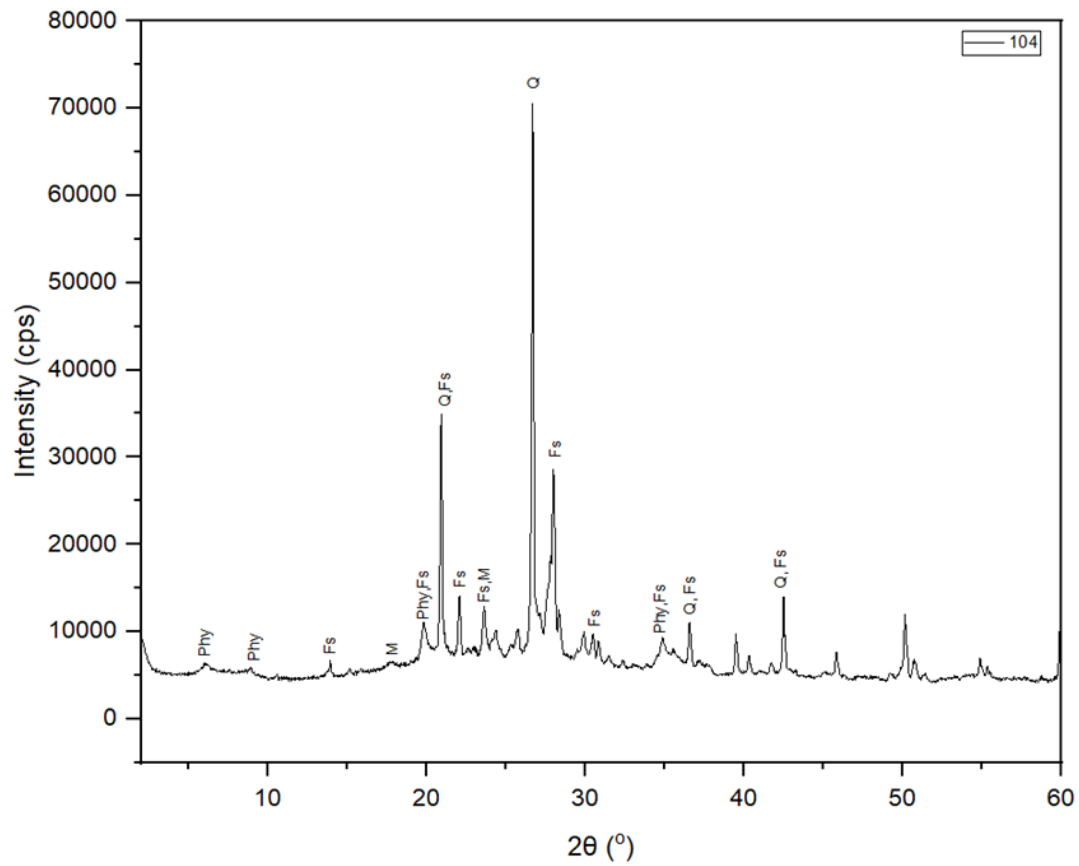


Figure 4.22. XRD chart of a representative sample from phase III. Phy: phyllosilicate (clay mineral/mica), M: Mica, Fs: Feldspar, Pl: Plagioclase, Q: Quartz

For Sample 304, according to thin section analysis results it is observed that it contains volcanic rock fragments as basaltic andesite with hornblendes, feldspars and pyroxenes. In Figure 4.23, the XRD chart supports this result.

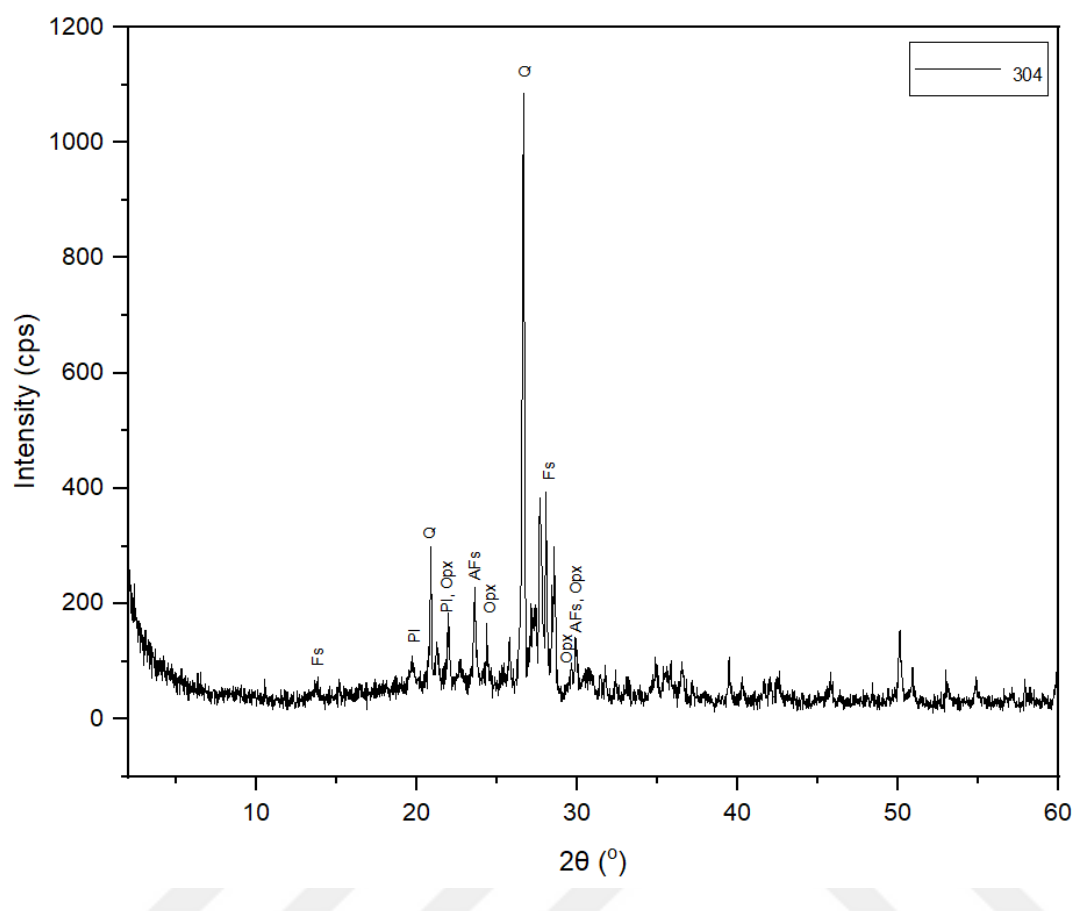


Figure 4.23. XRD chart of a representative sample from phase III. Q: Quartz, Fs: Feldspar, AFs: Alkali feldspar, Pl: Plagioclase, Opx: orthopyroxene.

Sample 324 is a significant sample differing from the other samples containing high amount of mica and feldspars. The XRD profile of this sample is illustrated in Figure 4.24.

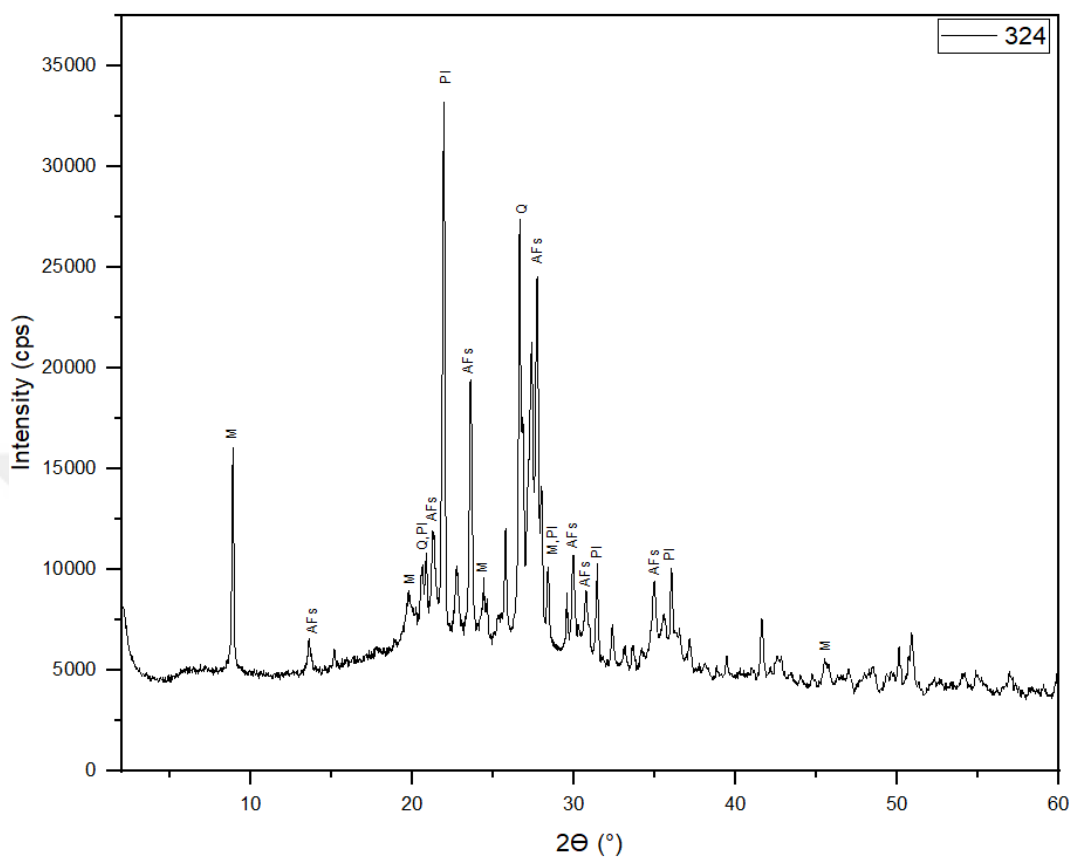


Figure 4.24. XRD profile of Sample 324 from phase V. Q: Quartz, M: Mica, Afs: Alkali feldspar, Pl: Plagioclase

The phases found in the samples are controlled over thin section observations and found to be supportive for thin section results. XRD profiles shown in Figure 4.25 illustrates the mineralogical key differences of the investigated minerals between two samples from different fabric groups of Phase V. The profiles show the variation between fabric groups and supports the group difference. Sample 265 belongs to VRF (rhyolitic) prevalent fabric group mostly containing quartz, plagioclase and alkali feldspar minerals. Sample 322 belonging to dioritic rock fragments prevalent group contains quartz, plagioclase, alkali feldspar, hornblende, mica and clay

minerals. Feldspar group minerals show higher abundance compared to Sample 265 due to the coarse grains of feldspars.

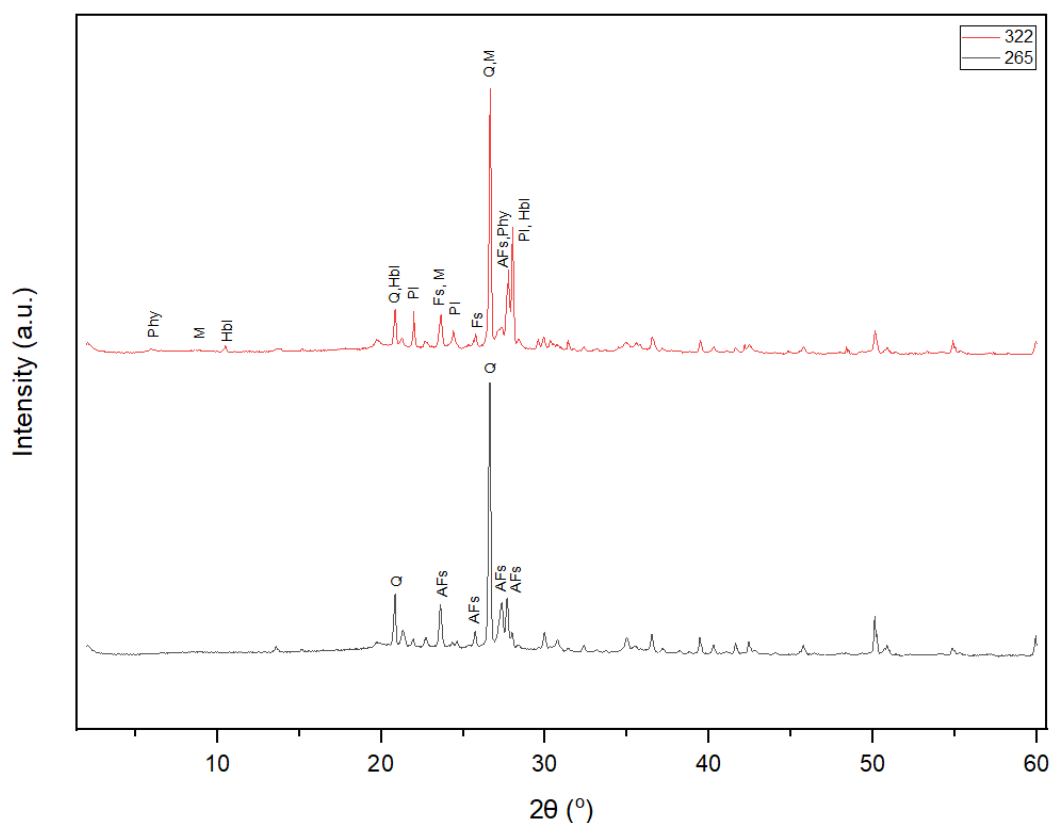


Figure 4.25. XRD profiles of two samples from different fabric groups of Phase V
Phy: phyllosilicate (clay mineral/mica), M: Mica, Fs: Feldspar, Pl: Plagioclase, Q: Quartz, AFs: Alkali feldspar, Hbl: Hornblende.

In Figure 4.26, representative samples for four fabric classes of Phase III are represented in an XRD profile. One significant difference that; the major quartz peak of Fabric D (Sample 119) which is highly tempered with metamorphic and VRFs, has nearly twice as much as those of the other samples which belongs to Fabric A (Sample 102, VRF prevalent), Fabric B (Sample 133, dioritic prevalent) and Fabric

C (Sample 106, SRF prevalent). Fabric B, in which dioritic rock fragments are prevalent contains a higher amount of plagioclase than the other samples belonging to the other fabric groups as VRF and MRF prevalent, which matches with the results of petrographic findings.

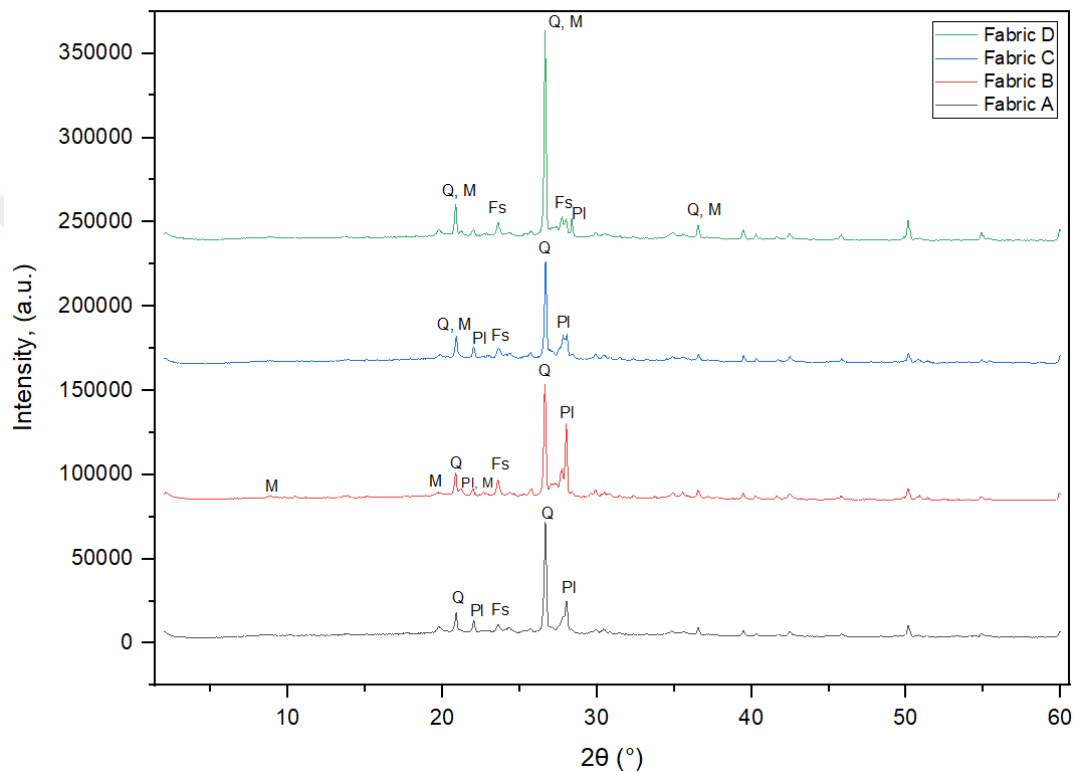


Figure 4.26. XRD profile illustrates the mineralogical key-differences of the investigated mineral phases of four fabric classes of Phase III.

One of the differences observed in the Phase V compared to the other two Phases is that, clay minerals are observed more apparently on the profiles. This may be due to low firing degrees (<850°C) or the higher ratio of clay matrix to the lower amounts of inclusions in the paste.

XRD results and evaluation of soil samples:

Soil samples are collected from three locations to study the characteristic features of the clays of the island. The purple solid circles in Figure 4.27 demonstrate the locations for the samples U-11, U-13 and U-14. Clay and non-clay minerals in the soil samples are identified by XRD analyses of bulk and clay fractions. XRD results are summarized in Table 4.2. Quartz, plagioclase, alkali feldspars, gypsum, mica, calcite are the non-clay minerals detected in the bulk soil samples as observed on Figure 4.28, clay minerals as well as non-clay minerals are present on the profiles of bulk soil XRD patterns. For clay minerals, XRD plots air dry, of ethylene glycol treatment and heated up to 300°C and 550°C, are given in Figure 4.29 as an example. The XRD patterns of the oriented slides of the soil samples display that montmorillonite, illite and kaolin are prevalent (e.g., Figure 4.29).

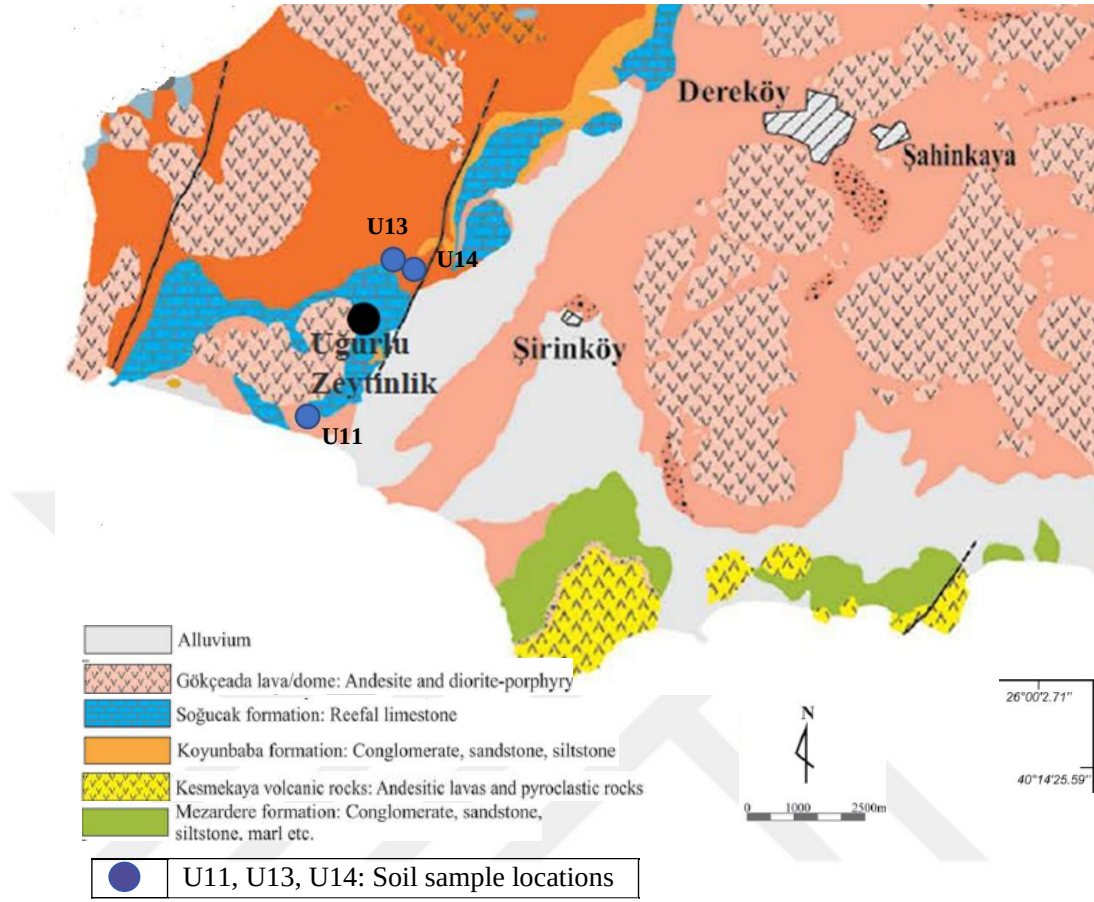


Figure 4.27. Soil sample locations in Gökçeada. Modified from Geological map of Gökçeada (from Şen et al., 2020; Sarı et al., 2015).

Some of the soil samples contain high amount of calcite, while the potter samples are generally lack of calcite according to the thin section studies and XRD analysis. Minerals found in the soil samples show similarities to those in the pottery samples containing high amounts of quartz.

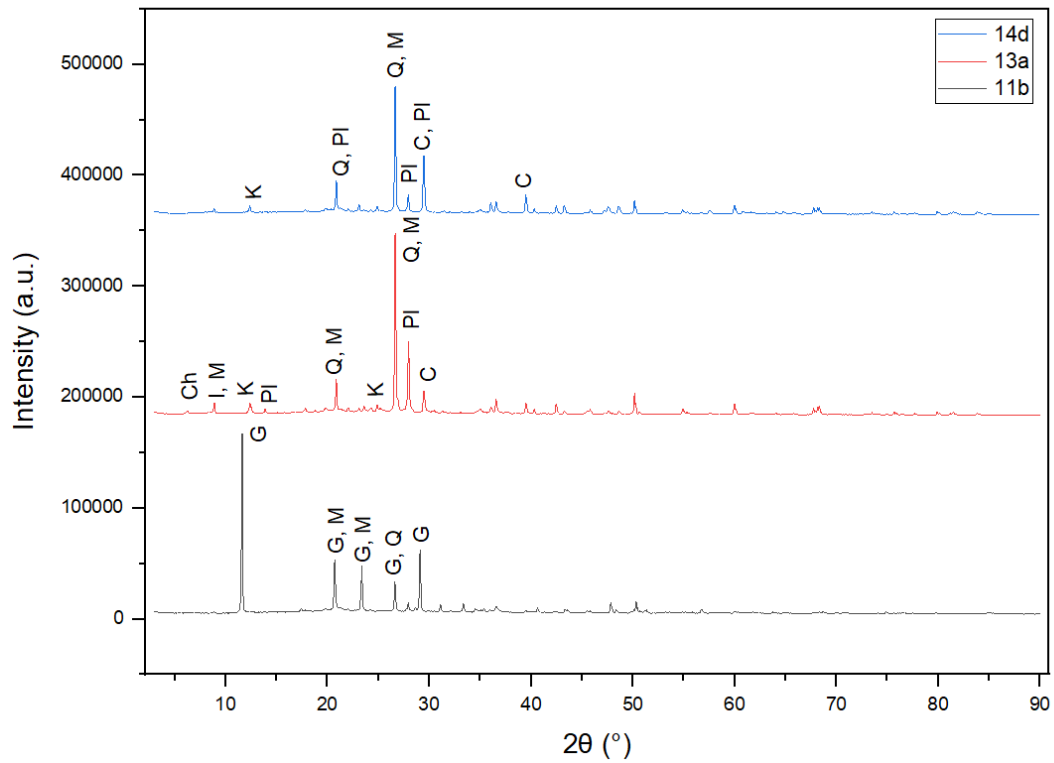


Figure 4.28. XRD chart of examples for the soil samples from each location. G: Gypsum, C: Calcite, K: Kaolin, M: Mica, I: Illite, Ch: Chlorite, Q: Quartz, PI: Plagioclase.

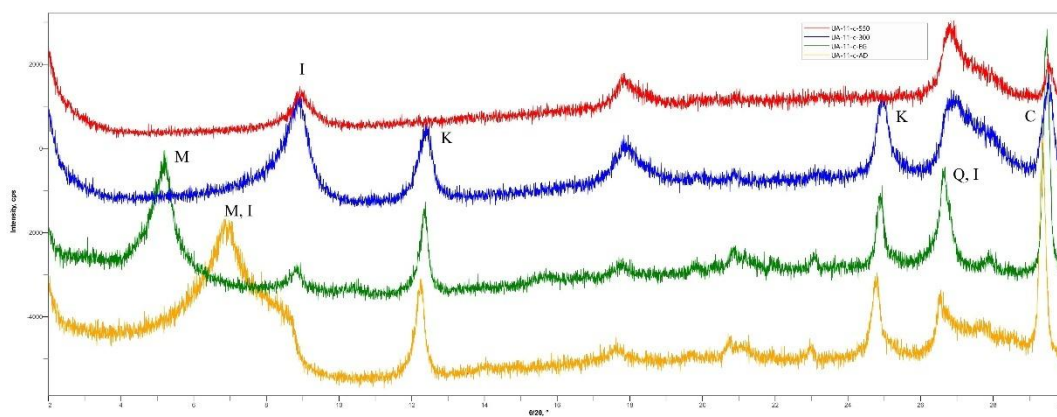


Figure 4.29. An example of the Sample U11-c; XRD charts overlaid to define clay types. Q: Quartz, I: Illite, Mnt: Montmorillonite, K: Kaolin, C: Calcite.

Table 4.2 Mineral content of the soil samples by XRD analysis.

Field Soil Samples	XRD Data: Minerals	XRD Data: Clay
U11-a	Quartz, Calcite	Montmorillonite, illite, Chlorite
U11-b	Quartz, Gypsum, Mica	Illite,
U11-c	Quartz, Plagioclase, Calcite, mica	Montmorillonite, Illite, Kaolin,
U13-a	Quartz, Calcite (low)	Montmorillonite (low)-Illite mixed layer, Kaolin
U13-b	Quartz, Plagioclase, Mica, Calcite	Montmorillonite, Illite, Kaolin,
U13-c	Quartz, Plagioclase, Mica, Calcite	Montmorillonite, Illite, Kaolin,
U14-b	Quartz, Plagioclase, Calcite	Vermiculite, Illite, Kaolin
U14-d	Quartz, Plagioclase, Calcite	Illite, Kaolin

4.5 ICP-OES/MS Results Statistical Analysis of Uğurlu Pottery Samples

61 pottery samples are analyzed at METU Central Laboratory, METU in Ankara with ICP-OES/MS method. The results of the chemical analysis for chosen pottery samples for the phases and three soil samples are given in the Appendix C, Table C.1.

Samples are selected from three different phases after thin section samples are examined under a polarized light microscope, representing different types of fabric in a way that is as different as possible. ICP-OES/MS analysis data, includes concentration of 50 elements in weight percent for major and minor oxides (Si, Al, Ca, Mg, Na, K, Ti, Fe, Mn, P) and in ppm for trace elements (As, Ba, Cd, Cr, Co, Cs, Cu, Ga, Hf, Li, Ni, Mo, Pb, Nb, Rb, Sn, Sr, Ta, V, W, Zn, Zr, Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Sc, Tb, Th, Tm, U, Yb, Y). IGPET (2008) software is

used to evaluate the data, even though it is generally used to interpret geochemical features of the rocks.

Major, minor and trace elements of the pottery are evaluated within themselves and also compared with the data of various volcanic rocks of Gökçeada obtained by Şen et al. (2020). The geochemical data used for comparison belongs Dağışitepe Rhyolitic, Gökçeada andesitic lava/domes (andesite and diorite porphyry) and Eşelek andesitic and pyroclastic rocks from Gökçeada, sample locations of which is marked on the geological map of Gökçeada as with black dots as Ş1-12, G15-J1/J5 and Eş-1-5 (Figure 2.3).

Major oxides Al_2O_3 and SiO_2 come quantitatively from clay and non-clay alumina-silicate minerals (Dias and Prudêncio, 2008). According to calculated parameters of pottery samples of the Phases III, IV and V, given in Appendix A, it is determined that mean concentration of SiO_2 varies between 58.7-66.8 wt% for the Phase III, 58.7-68.9 wt% for the Phase IV, and 58.7-69.1 wt% for the Phase V. Mean values of SiO_2 for Dağışitepe is 71.2 wt%, for Gökçeada andesitic lava/domes, 60.6 wt% and for Eşelek volcanic rocks it was 58.22 wt%. For three soil samples the SiO_2 values are significantly different from each other in the range of 28-59 wt%.

Al_2O_3 concentration is correlated with the clay content in the raw material. Al_2O_3 varied between 16.01-19.65 wt% for the Phase III, 13.4-18.5 wt% for the Phase IV and 14.6-17.9 wt% for the Phase V. For Gökçeada volcanic rocks, the values are close and varied between 15.8-17.2 wt%. Al_2O_3 contents of the soil samples are low in amount as in the range of 6-10.9 wt%.

Fe_2O_3 is the oxide which is the main constituent determining the color of paste of pottery (Maritian et al., 2006). Oxidation state of iron determines the paste color. Oxidizing atmosphere causes red color (Fe^{3+}) when it turns to darker colors (Fe^{2+}) in the lack of oxygen. $\text{Fe}_2\text{O}_3^{(t)}$ varies between 4.9-8 wt% for the Phase III, 6-10.2 wt% for the Phase IV and 5.2-7.9 wt% for the Phase V. For Gökçeada volcanic rocks, the values vary significantly as Dağışitepe is 1.1 wt%, for Gökçeada andesitic

lava/domes 5.1 wt% and for Eşelek volcanic rocks 7.1 wt%. The soil samples are between 6.6 and 18.4 wt%

Na₂O and K₂O concentrations are essentially controlled by feldspar group minerals. Feldspars are defined as rock forming minerals which are one of the most common minerals in soil. The sum of Na₂O and K₂O concentrations represents the amount of feldspar in pottery samples (Rollinson, 1993).

Na₂O varies generally between 1.3-2.4 wt% three for all phases, while it varies greatly between Gökçeada volcanic rocks as 0.2 to 4.8 wt%. For the soil samples it varies between 0.8-1.5 wt%. K₂O shows also close variations among three phases, and the average value is approximately 2.3 wt% as Gökçeada volcanic rocks varies between 2.9-5.5 wt%. K₂O average of the soil samples is 1.2 wt%

MgO concentration is controlled by pyroxene group minerals and biotite. MgO shows close variations among three phases, and the amount varies between 0.6-2 wt%. It varies between 0.2-3 wt% and 0.7-1.2 wt% in Gökçeada volcanic rocks and soil samples, respectively.

CaO is one of the most frequently selected parameters for classifying the raw material used in production as calcareous or noncalcareous. CaO amount of the Gökçeada pottery samples is very low i.e., <3.1 wt% for all samples except three samples having the values 4 and 5.6 wt% from the phases IV and V. CaO values are also low for Dağçıtepe and Gökçeada Andesitic lava/domes volcanic rocks but higher in Eşelek volcanic rocks as approximately 7 wt%. Albeit, the soil samples show significantly high values as 8.5- 19.6 wt%. The clays containing greater than 6 wt% CaO, are known as calcareous clays and less than 6 wt% CaO are known as non-calcareous clays (Tite and Maniatis, 1981; Ölçer and Akyol, 2022). According to the statement, CaO is less than 6 wt% in all the samples and the Uğurlu pottery samples are classified as non-calcareous.

A high P₂O₅ concentration usually serves as a measure of chemical changes induced after potsherds deposition because the pottery material is a chemically active matter,

which develops adsorption or precipitation of very fine-grained phosphate from the burial environment. (Freestone et al., 1985; Segvic et al., 2016). The chemistry of the analyzed pottery samples suggests a low-level of post-depositional alterations (e.g., $P_2O_5 \sim 0.6\text{wt}\%$).

The mean concentration of Zn is 77.8 ppm, and its range is between 44-108 ppm. This value in volcanic rocks (VR) of Gökçeada for Dağıcıtepe and Andesite Lava/Domes ranges between 35-86 ppm while it is approximately 230 ppm in Eşelek. For the soil samples it varies between 31-62 ppm.

The mean concentration of V, ranging between 65-194 ppm, is 143 ppm for the potteries. VR samples of Gökçeada greatly varies between 31-256 ppm.

Cr has a mean value of 85 ppm ranging between 38-218 ppm. Co is approximately 17 ppm and shows lower variation. Ni varies significantly between 44-174 ppm. Higher concentration values of Cr, Co and Ni in the potteries than average upper crust have been considered as a sign of mafic and ultramafic source of clay.

Sr contents of the potteries are in a broad range of 286-714 ppm, while VR samples of Gökçeada show a variation between 65-804 ppm. Also, the soil samples vary between 332-872 ppm for Sr. Sr concentration in pottery is controlled by carbonate rocks and plagioclase minerals in the raw material (Rollinson, 1993).

The concentration of Ba generally ranges between 740-1700 ppm for all pottery samples except two samples with very low values as 436 and 542 ppm from the Phase V. For volcanic rocks of Gökçeada this value varies between 1083-1775 ppm. And for the soil samples the value ranges between 150-330 ppm. For Ba, a detailed evaluation can be done among phases to make a comparison for VR content. So, the phases III and V has an approximate concentration of 1200 ppm whereas the Phase IV has a lower value of 970 ppm for Ba concentration. Concentration of Ba in soil is controlled by feldspar minerals (Rollinson, 1993).

The other element concentrations for all pottery samples are calculated as follows: 44-212 ppm for Zr, 1.79-5.22 ppm for U, 1.02-1.73 ppm for Eu, 0.31-0.85 ppm for

Tb, 0.35-0.94 ppm for Ho, 1.68-4.1 ppm for Dy, 1.01-2.76 ppm for Er, 0.18-0.41 ppm for Tm, 1.09-2.67 ppm for Yb, 0.19-0.38 ppm for Lu, 8.79-26.3 ppm for Y, 18.3-44.9 ppm for La, 8.37-25.1 ppm for Th, 43.6-89.7 ppm for Ce, 1.74-4.92 ppm for Hf, 6.08-17.5 ppm for Nb, 3.6-9.84 ppm for Pr, 13.4-36.8 ppm for Nd, and 2.6-6.58 ppm for Sm.

The mean concentrations of trace elements in the soil samples have different varying values. 31-62 ppm for Zr, approximately 1.58 ppm for U, 0.32-1 ppm for Eu, 0.17-0.63 ppm for Tb, 0.19-0.74 ppm for Ho, 1.04-3.95 ppm for Dy, 0.56-2.06 ppm for Er, 0.09-0.3 ppm for Tm, 0.61-1.95 ppm for Yb, 0.09-0.31 ppm for Lu, 5.47-18.96 ppm for Y, 9.05-19.9 ppm for La, 2.85-6.74 ppm for Th, 17.29-40.38 ppm for Ce, 1.11-2.27 ppm for Hf, 4.49-8.16 ppm for Nb, 1.98-4.92 ppm for Pr, 7.45-19.81 ppm for Nd, and 1.43-4.15 ppm for Sm.

Some major-oxide and trace element plots are obtained to compare the data within the phases, with the data belonging to the soil samples and/or with the data from volcanic rocks of Gökçeada from different locations of the island (Şen et al. 2020). Major-oxide variation diagrams for the pottery samples from all three phases and various volcanic rocks of Gökçeada, are given in Figures 4.30 to 4.34. The used legend of the symbols is given in Table 4.3.

Table 4.3 Legends used for the samples of three phases, the soil and rock samples of Gökçeada.

	Phase V ceramics
	Phase IV ceramics
	Phase III ceramics
	Gökçeada andesitic lavas /domes
	Dağıcitepe volcanic rocks
	Eselek volcanic rocks
	Soil samples

Fe_2O_3 vs Al_2O_3 variation diagram display that especially the Phase IV (green triangles) shows a widely distributed behavior compared to the Phase III (pink rhombus) (Figure 4.30)

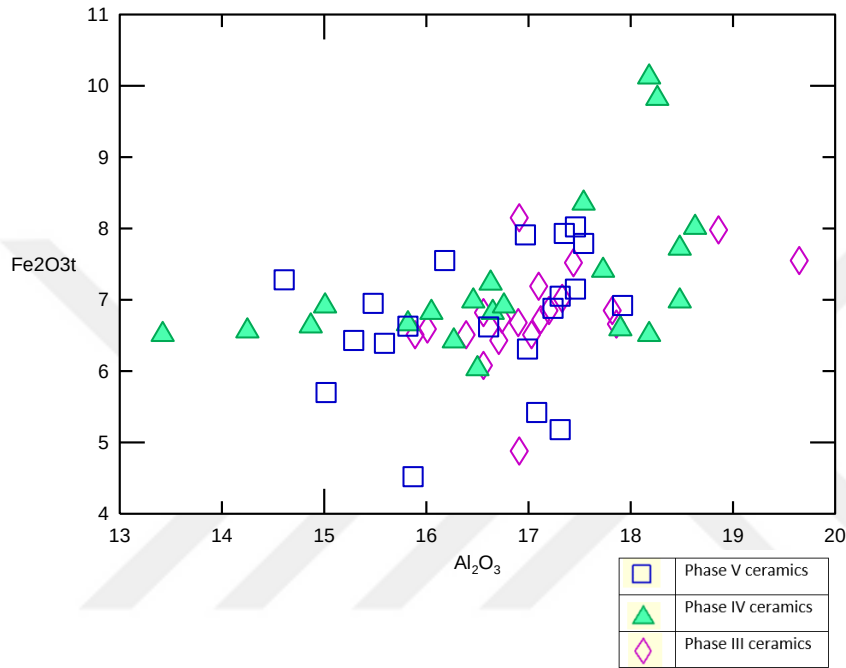


Figure 4.30. Fe_2O_3 vs Al_2O_3 variation diagram for all three phases.

K_2O content is thought to originate mainly from feldspars and illitic clays (Freestone et al., 2003; Semiz, 2021). The Phase III samples seem to contain more feldspar and/or illitic clays compared to the Phase V samples. Plot of K_2O versus SiO_2 for all three phases is illustrated in Figure 4.31.

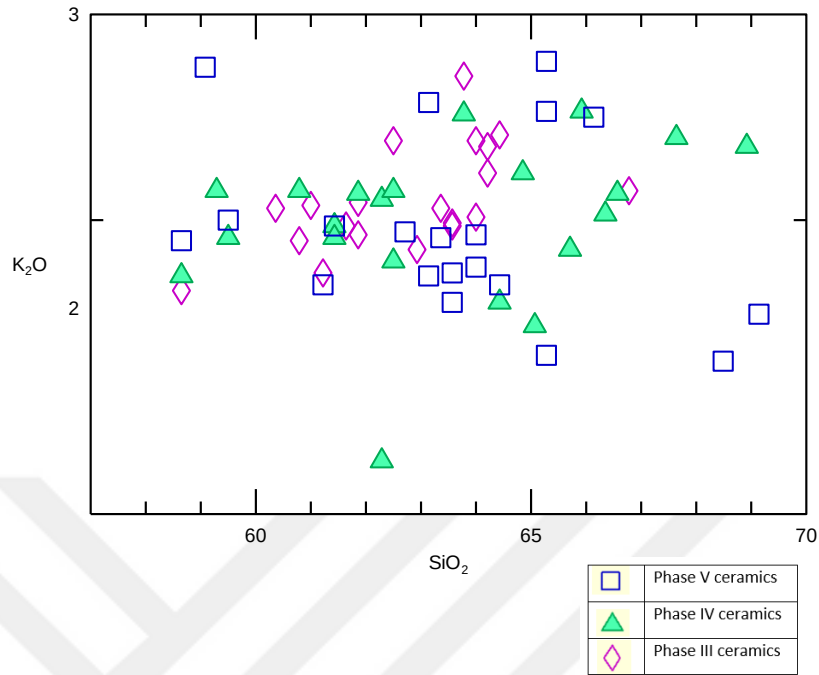


Figure 4.31. K₂O vs SiO₂ variation diagram for all three archaeological phases.

The sum of Na₂O and K₂O concentrations represents the amount of feldspar in pottery samples. This situation is illustrated in Figure 4.32. The Phase III samples seem to contain a higher amount of feldspar minerals compared to especially Phase V potteries, which is consistent with the thin section results as; Phase V samples are mentioned to contain less amount of inclusions.

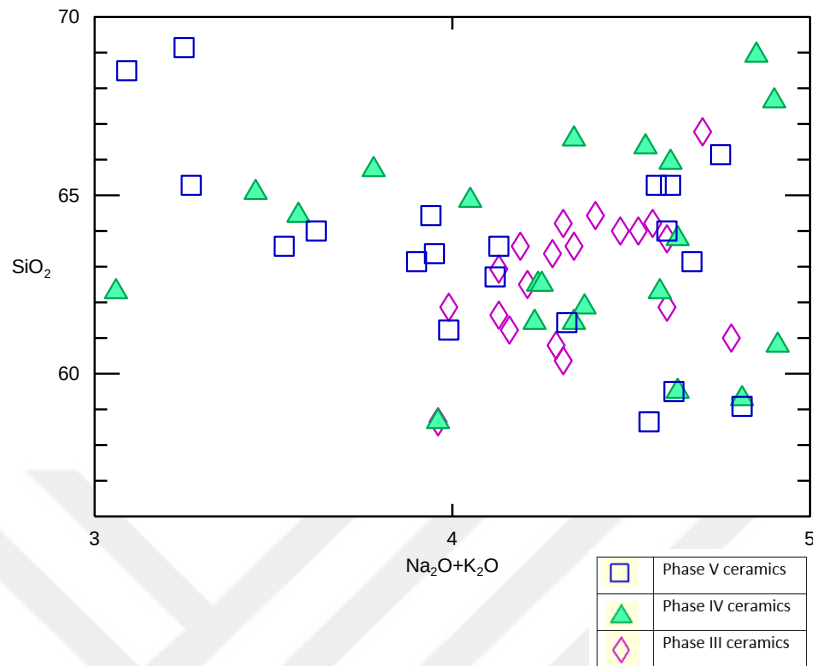


Figure 4.32. SiO_2 vs $\text{Na}_2\text{O}+\text{K}_2\text{O}$ variation diagram for all three phases.

Figure 4.33 illustrates the variation diagram MgO versus Fe_2O_3 . Concentration of MgO could be linked by chlorite, biotite microflakes, hornblendes (Vannoorenberghe et al., 2022) and pyroxene group minerals (Iordanidis et al., 2009). A remarkably high amount of biotite flakes observed in thin section samples of the Phase V confirms this situation. Phase IV shows more pyroxene and hornblende inclusions prevalent or may contain chlorite in the clay paste. A differentiation of raw material content is seen between Phase IV and Phase III.

In Figure 4.34, Fe_2O_3 versus SiO_2 variation diagram including the pottery samples all three phases, the soil samples and volcanic rocks of Gökçeada is illustrated. From the data of the soil samples, it can be inferred that Fe_2O_3 concentration may be directly related to the soil content of the paste. Because Fe_2O_3 concentration of the soil samples varies between 6.6 wt% and 18.34 wt% higher than the volcanic rocks

of Gökçeada. While a random distribution for the phases V and IV is apparent, the Phase III production appears to have originated from two different groups.

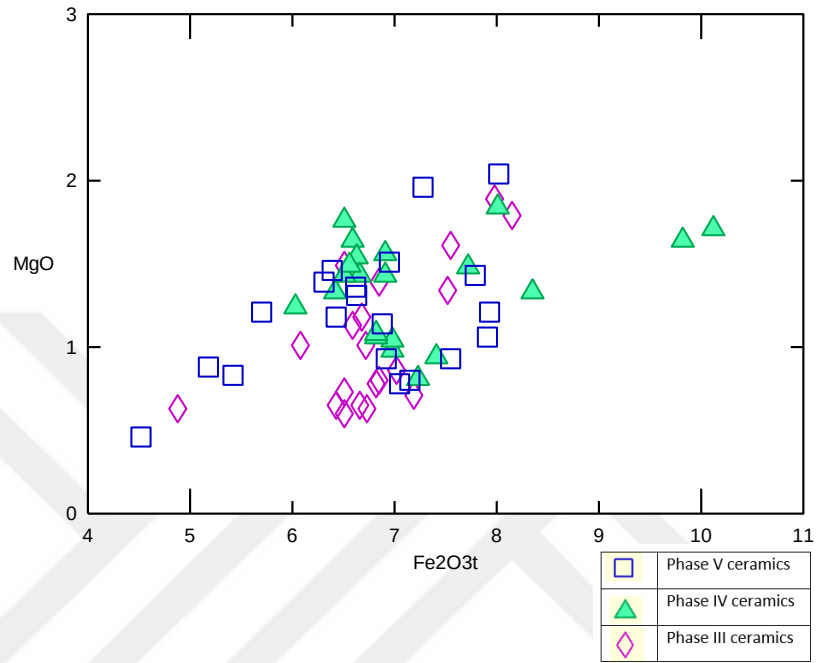


Figure 4.33. MgO vs Fe₂O₃ variation diagram for all three phases

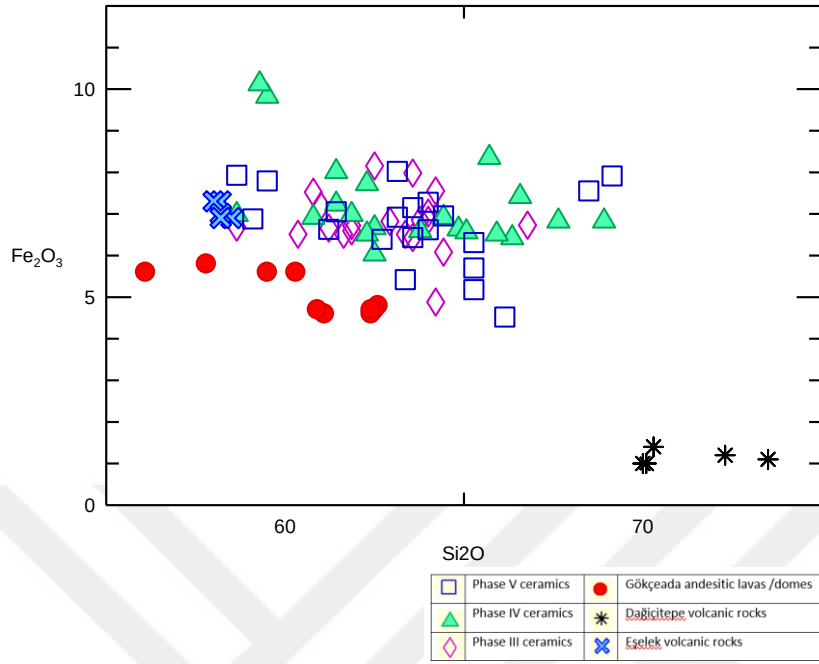


Figure 4.34. Fe_2O_3 vs SiO_2 variation diagram for all three phases and volcanic rocks of Gökçeada.

The plots given in Figures 4.32 to 4.34 show that the samples from the Phase III have a limited variation compared to the other two phases with a broader distribution among their samples.

Some diagrams are used to determine the rock classification as produced by Winchester & Floyd (1977) and reviewed by Pearce (1996). Figure 4.35 illustrates this diagram which is used to see the rock tempered potteries for three phases separately and all of the phases and the volcanic rocks of Gökçeada together. The characteristic behavior of Gökçeada volcanic rocks, as andesitic rocks and rhyolitic Dağçıtepe volcanic rocks are seen in the related regions as Eşelek volcanic rocks show more basaltic andesitic behavior.

According to this classification, it is seen that the Phase III samples show andesitic behavior probably related to the inclusion content of the clay paste. Besides the Phase

III samples show a more centralized behavior compared to more broadly distributed Phase IV and Phase V pottery samples.

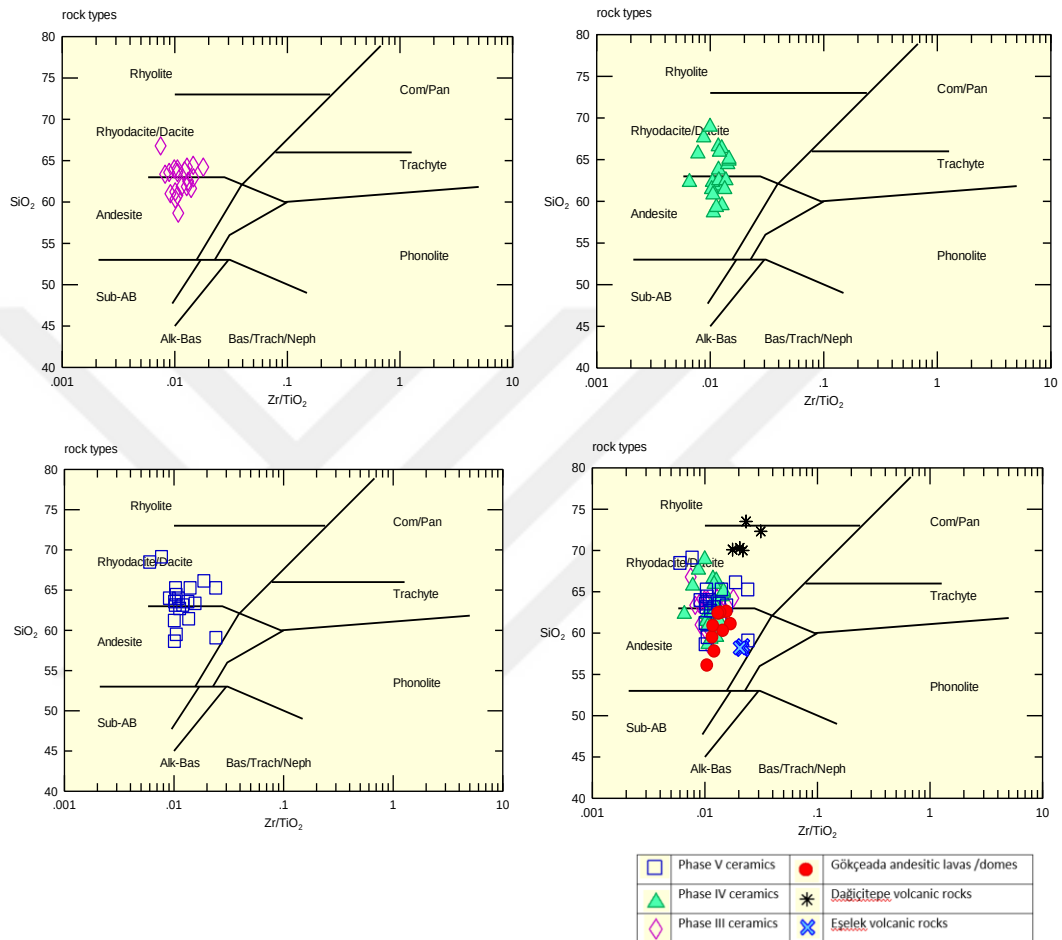


Figure 4.35. Zr/TiO_2 vs SiO_2 diagram of the pottery samples and Gökçeada volcanic rocks (Winchester and Floyd, 1977).

The lower amount of Ba and higher amount of SiO_2 of two samples of the Phase V, in Figure 4.36 may suggest a lower amount of rhyolitic inclusions but a higher amount of quartz inclusions or clay content with a lower amount of Ba. Another observation related to the diagram was that pottery samples show a broader

distribution. Besides, the discrimination of raw material and/or inclusion type use among the phases could be observed.

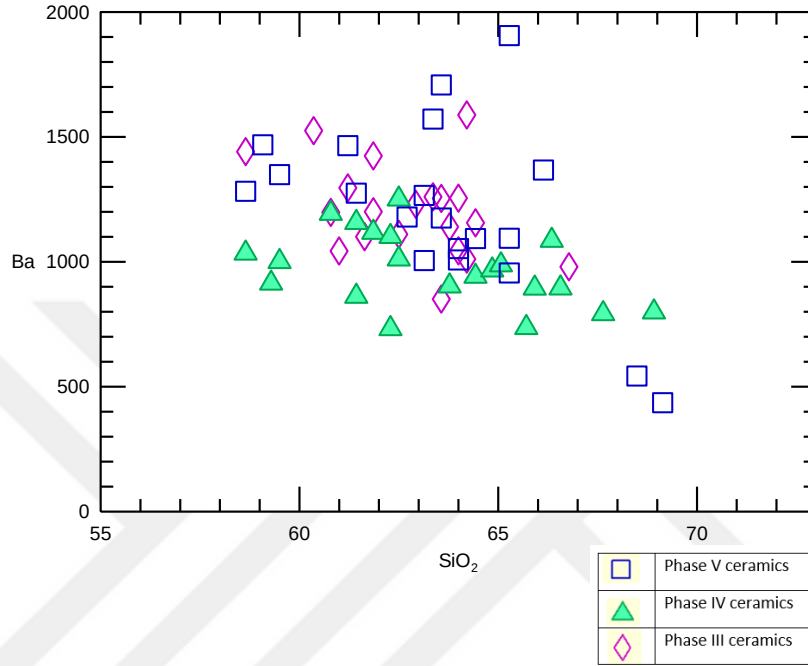


Figure 4.36. Ba vs SiO₂ diagram of the pottery samples from three phases.

The elements Zr and Cr can be linked to the heavy minerals, zircon and chromite. High concentration of these minerals is usually correlated to higher amounts of and/or coarser quartz inclusions (Vannoorenberghe et al., 2022). In Figure 4.37, Zr versus Cr variation diagram for all three phases and volcanic rocks of Gökçeada is shown. Eşelek volcanic rocks exhibiting basaltic andesitic character contains higher Zr and lower Cr while, andesitic lava/domes contain lower Zr and a wide range of Cr. The zirconium content may also be linked with the igneous phases, coming from the granodiorite, diorite (Iordanidis et al., 2009), local rocks of the island.

In conclusion most of the samples are in accordance with andesitic (red circles) and rhyolitic (black stars) rocks of Gökçeada, suggesting that the pottery samples contain andesitic/rhyolitic volcanic rock inclusions prevalently.

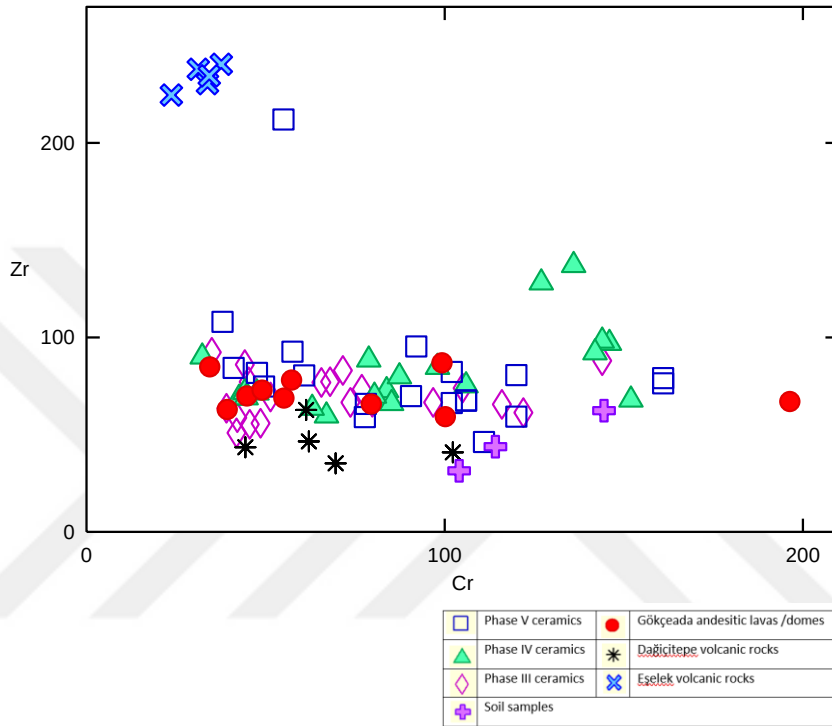


Figure 4.37. Zr versus Cr variation diagram for all three phases, volcanic rocks and soil samples of Gökçeada.

Zr vs Ba variation diagram including the potteries of the phases together with the volcanic rocks and the soil samples of Gökçeada is shown in Figure 4.38. As a homogenous broader distribution can be observed for Phase V, Phase IV displays a more loosely varied behavior. Phase III shows a more localized character as two relatively distinct groups.

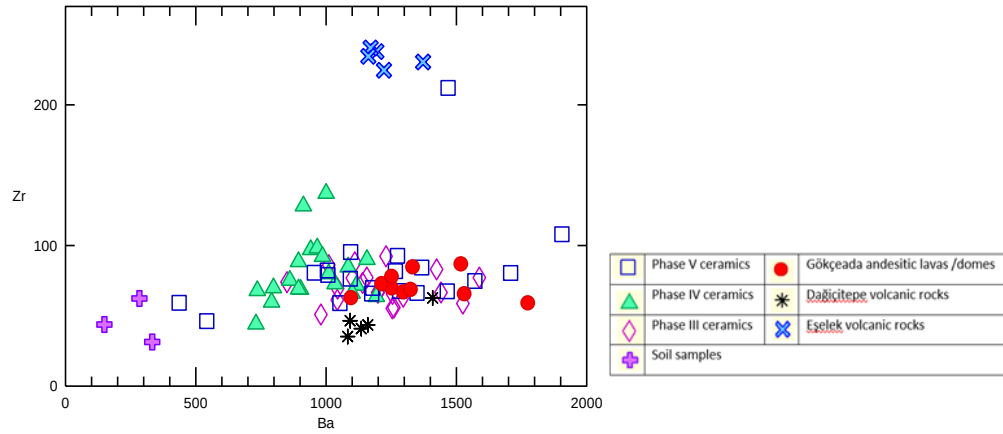


Figure 4.38. Zr vs Ba variation diagram, phases together with volcanic rocks and soil samples of Gökçeada.

Figure 4.39 illustrates the Sr versus Zr variation of the phases together with volcanic rocks and soil samples of Gökçeada. As seen from the diagram, samples fall in the region between soil samples and volcanic rocks of Gökçeada, implying a mixture of both raw materials (VRFs and soil) of the island.

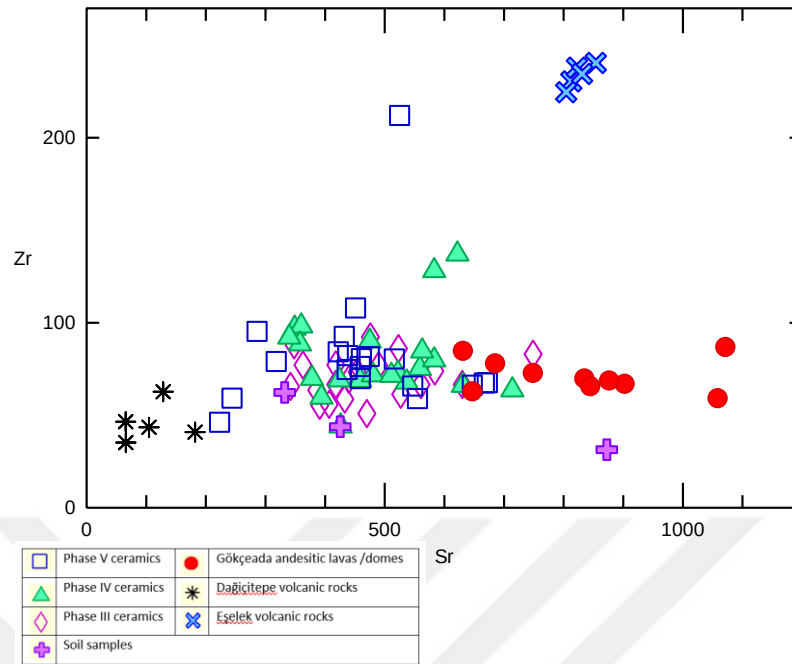


Figure 4.39. Zr vs Sr diagram for all three phases, volcanic rocks and soil samples of Gökçeada.

Lastly a diagram of Zr versus Ga is illustrated in Figure 4.40, showing the variation and distribution of samples through all three phases.

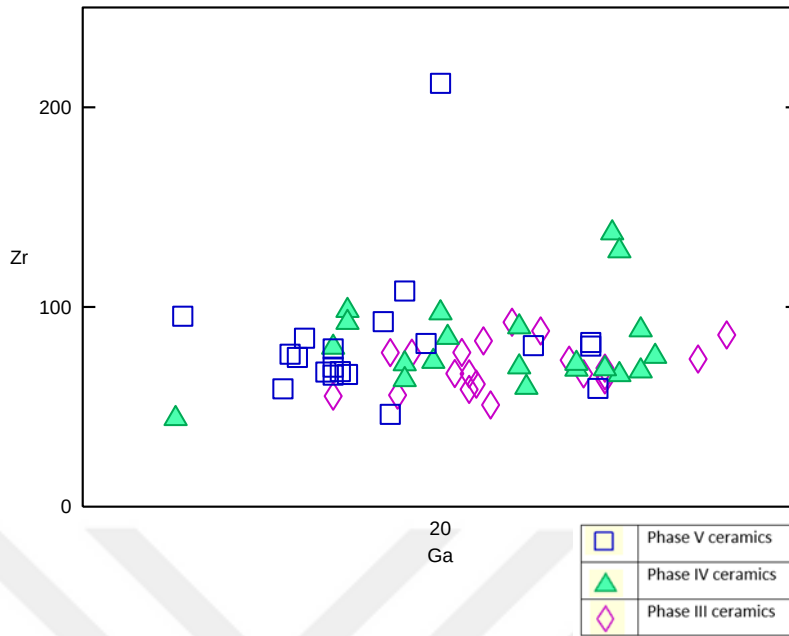


Figure 4.40. Plot of Zr vs Ga for all three phases of Gökçeada.

In Figure 4.40, while potteries belonging to the phases III and Phase V exhibits a grouping behavior, in Phase IV a random distribution is observed.

Due to their minimal natural variability and consistent geochemical behavior, REEs are highly valuable for distinguishing and classifying both natural rocks and pottery/ceramic samples. A Chondrite-normalized rare earth abundance patterns for all of the pottery samples are shown in Figure 4.41. Samples 88, 185, 312, 313 and 325 indicate a different production location compared to the other samples.

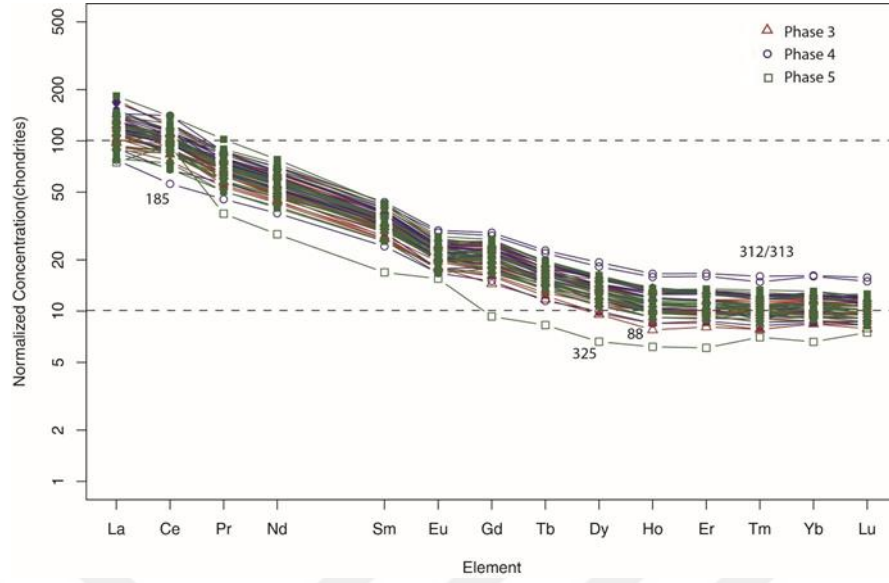


Figure 4.41. Chondrite-normalized (Sun and McDonough, 1989) rare earth abundance patterns for Uğurlu samples.

For element analysis considering the high values of Gökçeada Dağıçitepe, Andesite Lava/Domes and Eşelek volcanic rocks (Şen et al., 2020) and low values of the soil samples, it is meaningful that Uğurlu pottery samples have approximate values between two types of the sample sets as soil and VRs. Accordingly, VR fragments are supposed to be used as temper.

Hierarchical Cluster Analysis:

The hierarchical cluster analysis is performed on chemical data of all samples from all three phases, in accordance with the principles outlined in Chapter 3.3.1 and related dendrogram is given in Figure 4.42 and evaluated with the petrographic fabric groups. In general, the consistency between cluster analysis and thin section grouping is not supposed to be fully matching because it is related to different variables. The factors contributing to the thin section grouping changes as prevalent rock type contents, inclusion frequency, size, shape, features of groundmass texture as being fine, gritty or giving birefringence or not, and so on.

In the figure, 2 main groups are observed marked as “2” and “3”. The group marked with “1” stands for more apart and loner groups. Even so, evaluated with petrographic fabric groups, a consistency is observed with the chemical data groups that the samples of Group 2, marked with red generally belongs to dioritic fabric group as samples 320, 322, 335, 234, 222, 223, 317, 305, 309, 303, 304. On the other hand, Group 3 marked with green is generally composed of the VRF containing fabric group as samples 312, 313, 162, 318, 178, 250, 138, 105, 102, 314, 307, 308, 139, 301, 328, 330. The Group 1 marked as purple line, contains a reasonable amount of MRF prevalent fabric group as samples 310, 333, 334, 185, 264, 321. Also, outliers or loners can be given as 88, 310, 324, 325, 334.

These chemical data groups demonstrated in the dendrogram match with petrography-based groups to an acceptable extent.

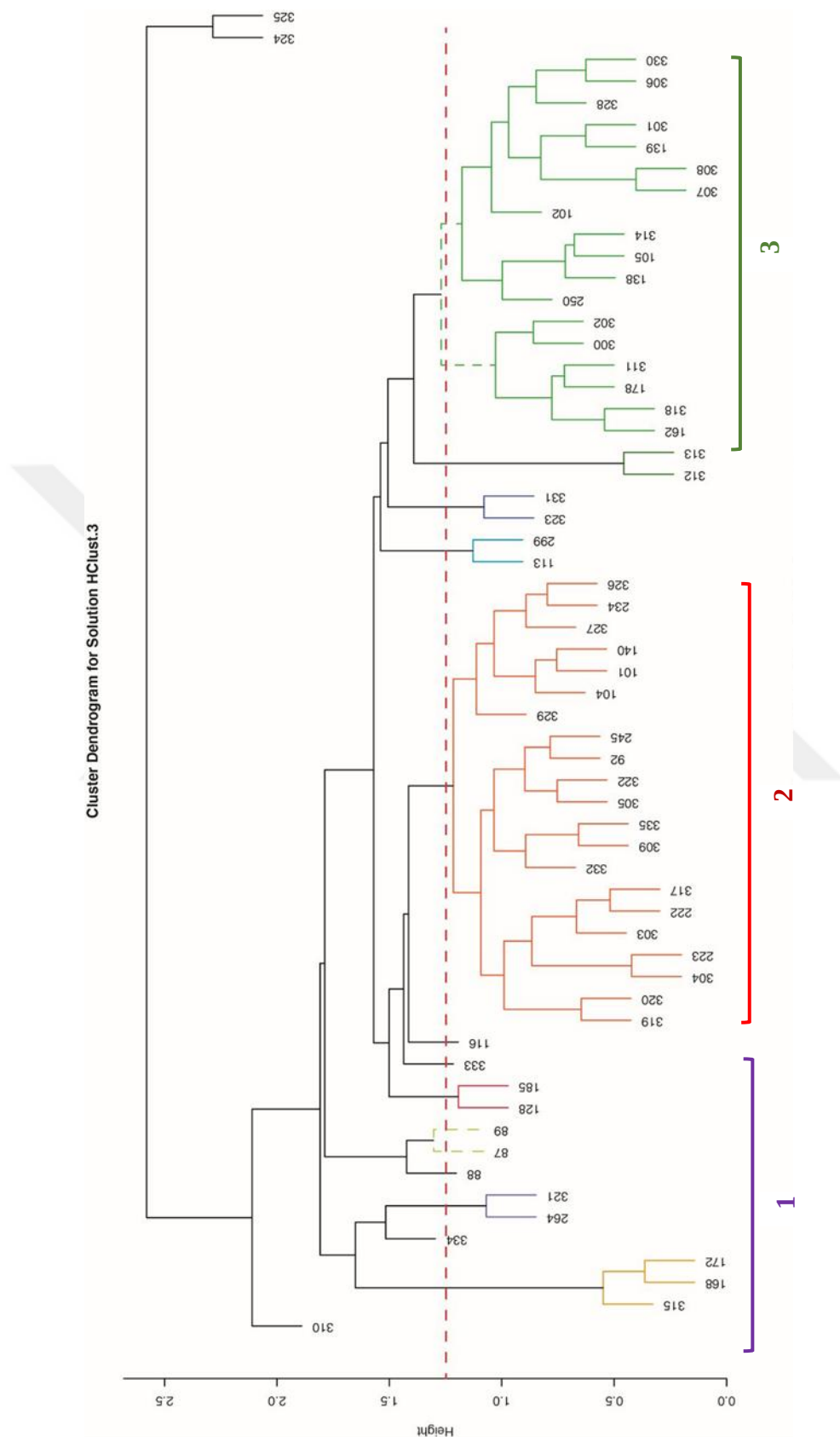


Figure 4.42. Cluster Dendrogram including all samples together with all phases

Principal component analysis (PCA) of the ICP-MS data was conducted on an auto scaled matrix containing 34 elements of 61 samples. This technique enables exploratory analysis to reveal general relationships within the data and provides a comprehensive visualization of all dataset information. Additionally, to evaluate similarities and differences among sherd samples from various locations, a PCA variable score plot was generated using the same R program.

In Figure 4.43, PCA analyses shows the compositional similarity among Uğurlu samples for all phases. Inset plots show the element loadings for two set of PCA analysis. Green shapes represent Phase V, purple shapes show Phase IV and red shapes are used to define Phase III. Rectangles illustrate VRF prevalent fabric group, while circles, rectangles and rhombus shapes are used for the fabric groups of dioritic, SRF and MRF prevalent, respectively for Phases V and III. For Phase IV, different from the other phases, circle shapes represent the basaltic andesite prevalent group and triangles represent dioritic rock fragments prevalent group, the other two shapes represent the same fabric groups as the other phases.

According to Figure 4.43, it is observed that the samples are generally clustered closer to each other showing a compositional similarity. Examined detailly, a slight distinction between groups can be seen. Several smaller groups and outlier samples (i.e., 264, 321, 324, 325, 334) can also be viewed on the plot, similar to cluster dendrogram (Figure 4.42). Since the chemical values are very close to each other, a grouping cannot be outlined among PCA analysis and the petrographic fabric groups.



CHAPTER 5

DISCUSSION

In this study an overall evaluation to assess the Uğurlu Site pottery production through a period of approximately 1700 years, macro and micro scale scientific techniques are used. Within this study, 74 samples were selected, comprising 24 samples each from Phases V and IV, and 26 samples from Phase III. The studied samples were taken from the site for analysis according to the criteria; the color, thickness and surface treatment in equal amounts as possible. In this chapter, the results for each phase in relation to the visual diagnostic evaluation, shaping and forming techniques, firing environment and raw material selection that were observed through petrographical, mineralogical and chemical analyses are discussed.

First, a detailed visual description of each sample was documented Secondly, the stereomicroscope was used for the evaluation of forming techniques. For this purpose, the inclusion and void orientations of cross-sections of each sample was examined under stereomicroscope and the photos obtained from X-ray micro computed tomography (micro-CT/uCT) analysis were used for evaluation.

Then petrographic, mineralogical and chemical analysis were performed. Petrographic analysis provides information on production methods, firing temperature and technology. For this purpose, thin-section analysis was done for the characterization of pottery, i.e., to get information about raw material content, firing temperature and surface treatments techniques. Also, for the characterization of fabrics, groupings were made for each phase, and then searched for if there was any correlation between raw material use and visual characteristics of the potteries.

To determine the phase composition of pottery, support petrographic observations and enlighten firing characteristics, XRD analysis was used. Lastly to question the idea of local or foreign production of the pottery, and to get an idea about the change

of the raw material use though time, ICP-OES/MS analysis was performed on 61 pottery and three soil samples. The analyses are summarized in Table 5.1.

Table 5.1 Summary of the analysis applied to Uğurlu pottery and soil samples

Analysis	Number of Analysis			
	Phase V	Phase IV	Phase III	Soil
Thick Slice of Cross- Section	24	24	26	-
Thin Section	24	24	25	-
XRD	23	24	26	8
ICP-OES/MS	20	21	20	3

General Observations:

Generally, pottery samples from all three archaeological phases consists of orange to red orange, brown/black brown and black or multicolored (brown-black prevalently). All of the pottery samples are handmade and majority is thin walled. Observations suggests that mostly coiling technique is used. For all phases, surface treatment techniques included slipping, smoothing and burnishing. Firing was usually in a reduced or incomplete oxidizing medium. Evaluation of the results of the petrographic and chemical analysis of the sherds and soil samples suggests that the Neolithic pottery of Uğurlu has been made of local raw materials.

1) Phase V

24 Phase V pottery samples are grouped in two main color scale. The characteristic visual features of Phase V samples are summarized in Table 5.2 according to their color, surface treatment and thicknesses. Meanings of the abbreviations used in Table 5.2. are; SN: sample number, ST: surface treatment, Th: Thickness, Sm: smoothing, Brn: Burnished, Vt: very thin

Table 5.2 Summary of the Phase V samples according to their diagnostic features.

Color	Brown/Black brown				Orange/Red orange			
SN	250, 319, 320, 326, 330, 333, 334				245, 259, 262, 264, 265, 267, 321, 322, 323, 324, 325, 327, 328, 329, 331, 335			
ST	Slip	Sm	Brn	Rough	Slip	Sm	Brn	Rough
	330, 333, 334	250, 326 330, 334	333	319, 320, 326	259,262 264,322 329,335	321, 323, 324, 328 329, 331	259,262 264,265 267,322 335	245 325 332
Th.	Vt≤0.6cm			Thin≤1cm			Thick>1cm	
	326,330,333, 262,265,323 324, 335			319, 320, 334, 259, 267 322, 327, 331, 332			245, 264 321, 325 328, 329	

Orange colored, slipped and slightly burnished or smoothed, low fired, thin potteries dominates this archaeological phase. According to cross section analysis; it is observed that Phase V pottery generally contain dense, fine lower amount of inclusions, compared to the other two Phases, while the shaping method appears to be “coiling” due to the marks left in cross sections (e.g., Figure 4.4).

Sherds generally demonstrate an incomplete oxidized firing. Only four of them are fired in an oxidizing medium (samples 259, 262, 265, 322: Table 4.1). The remaining 20 samples show firing in reduced atmosphere as dark colored or dark zoned cross sections as r-O-r (e.g., for reduced medium, sample 326 and showing zone due to incomplete oxidizing medium, sample 321, Table A.1). Also, thinly oxidized (o-R-o), areas at the very surface of the vessels suggests as if rapidly taken out to the atmospheric medium from reduced firing medium. This kind of pottery is mostly encountered in Phase V.

According to the petrographical and mineralogical results Phase V as in the other phases contains inclusions of mineral and rock fragments derived from andesitic, metamorphic and sedimentary rocks of Gökçeada. The distinguishing features of Phase V is the higher amount of coarse biotite fragments and metamorphic rock fragments (mica-schist) compared to the other two phases. In fabric group V-A1 all

the samples except 325 are thin-walled (~ 0.5 cm). On the other hand, one group that shares a common feature is fabric group V-C. They are all orange to red-orange.

Groundmass giving birefringence and green hornblendes already suggest a firing <750°C. Supported with also XRD data observed phyllosilicate minerals in low amounts in some samples may suggest lower firing temperatures (Iordanidis et al., 2009).

According to the chemical analysis results, contents of the samples slightly differ from the other two phases in raw material use. From the various element diagrams it is generally observed that, use of raw material is grouped in two or three different forming recipes.

Evaluation of petrographic fabric groups and hierarchical sample groups suggests the utilization of two locations predominantly near the settlement. These two groups were mainly composed of the two fabric types composed of andesitic/rhyolitic and dioritic rock fragments prevalent groups. It is observed that in Phase V, the local source composing the Hierarchical Cluster Group 2 (Figure 4.42) is more prevalently used than the Hierarchical Cluster Group 3 in pottery production.

2) Phase IV

24 pottery samples from Phase IV are grouped in three main color scales. The characteristic visual features of Phase IV samples are summarized in Table 5.3 according to their color, surface treatment and thicknesses. Some of the samples contain a two-colored slip with a well burnished appearance but, just only one sample stands out from the others due to its gray color. Mostly the samples are fired in a reduced atmosphere. Because the color scale is enlarged significantly, a detailed table is prepared. Meanings of the abbreviations used in Table 5.3 are; Clr: Color, SN: Sample number, ST: Surface treatment, NS: Not slipped, Th: Thickness, Sm: Smoothing, Brn: Burnished, Vt: Very thin, Int.: Interior, $Vt \leq 0.6\text{cm}$, $\text{Thin} \leq 1\text{cm}$, $\text{Thick} > 1\text{cm}$.

Table 5.3 Summary of the Phase IV samples according to their diagnostic features.

Clr	Red Brown/Black brown			Orange/Red orange			Yellow grey/grey	
Slip	Int. Slip	Black int. slip		Int. Slip	Black int. slip		Slip	NS
SN	185, 305	172, 168, 222, 306, 309, 310, 311, 315, 316		178, 221, 307, 314	227, 308		312, N312	234
ST	Slip & Brn	Multi-colored	Sm	Slip & Brn	Sm		Slip & Brn	
SN	172, 185, 305, 309	168, 222, 306, 310, 311, 315, 316	223	162, 178, 221, 317, 314	318		312, 313 multi-colored	
Th.	VT	Thin	Thick	VT	Thin	Thick	Thin	Thick
SN	172, 222, 306, 309, 310, 315	168, 185, 305, 311, 316	223	227	178, 307, 314, 317	162, 221, 308, 318	312, 313	234

Phase IV ceramics shows a progress on surface treatment techniques and forms; as lustrously burnished thin-walled, multicolored sherds and foot and string forms were observed. Red-slipped black wares, different tones of red and reddish-brown slip and black and brown multi colored slips were also observed. Brown toned, very thin to thin-walled potteries with a black slip on the interior part of the vessel, are dominant and are characteristic features of this phase.

According to cross section analysis; it is observed that Phase IV pottery generally contain dense and coarse inclusions, while the shaping method appears to be “coiling” due to the marks left in cross sections (e.g., Figure 4.7).

Sherds generally demonstrated an incomplete oxidized firing. Only two of them were fired in an oxidizing medium (samples 310 and 314: Table A.1). The remaining 22 samples showed firing in reduced atmosphere as dark colored or dark-color zoned cross sections as r-O-r (e.g., for reduced medium, sample 222 and showing zone due to incomplete oxidizing medium, sample 221, Table A.1).

According to the petrographical and mineralogical results Phase IV as in the other phases contains inclusions of mineral and rock fragments derived from andesitic/rhyolitic, basaltic, dioritic and metamorphic rocks of Gökçeada. On the

other hand special to Phase IV, it is observed that samples 312 and 313 contain basaltic rock fragments, specific to the Eşelek area. Groundmass giving birefringence and green hornblendes as well as well burnished sherds support a firing $<750^{\circ}\text{C}$ for some samples. Samples giving birefringence in their groundmass, was lower in amount compared to the other two phases due to reduced atmosphere firing.

According to the chemical analysis, one of the distinguishing features of Phase IV is the slightly lower amount Ba concentration and higher amount of rhyolitic characted rock fragments compared to the other two phases. As, Ba is controlled by feldspar minerals, this may be due to a different raw material source or recipe use. On the other hand, as the element variation diagrams (Figures 4.34-4.38, 4.40) examined Phase IV mostly shows a random wide distribution.

According to the evaluation of petrographic fabric groups and hierarchical sample groups, it is mentioned that two locations near the settlement, mainly composed of the two fabric types composed of andesitic/rhyolitic and dioritic rock fragments prevalent groups were predominantly utilized. It is observed that in Phase IV, the local source composing the Hierarchical Cluster (Figure 4.42) Group 2 and Group 3 are nearly equally used in pottery production. Also Phase IV petrographic groupings showed a relation to a greater extent, suggested by hierarchical sample groups.

Another finding is, as hierarchical groupings and diagnostic features of the ceramic samples were evaluated; for Phase IV there are some relations between the diagnostic features of the samples also as for Phase V (thickness, color, surface treatment etc) and their chemistry (e.g., samples 168, 172 and 315 are hierarchically grouped, brown with interior part black slipped and thin to very thin-walled potteries).

3) Phase III

26 samples from Phase III are grouped in two main color scales. The characteristic visual features of Phase III samples are summarized in Table 5.4 according to their color, surface treatment and thicknesses. Mostly the samples are fired in a reduced atmosphere. Only one of them is fired in oxidizing medium (Table A.1, Sample 116).

Phase III ceramics are red, brown, black, red-brown and brown-black. It was observed that color range has narrowed. Black slipped and interior surface black slipped, red-slipped black wares or black slip-on reddish wares are observed. In fresh cut sherds sandwich-like appearance, observed as the other two phases. Another important impression was that, ceramic production has become more uniform and smoothed and rough production increased. This period pottery generally contains dense medium to coarse aplastic inclusions.

The meanings of the abbreviations used in Table 5.4 are; SN: Sample number, ST: Surface treatment, Th: Thickness, Sm: Smoothing, Brn: Burnished, Vt: Very thin, Int: Interior, very thin ≤ 0.6 cm, Thin ≤ 1 cm, Thick > 1 cm

Table 5.4 Summary of the Phase III samples according to their diagnostic features.

Color	Brown /Black			Red/Orange	
	Brown		Black	Light orange	Red orange
SN	89, 91, 113, 140, 299, 300, 301, 303 (mc)		88, 92, 104, 105, 106, 128	87, 94, 119, 133, 138, 302, 304	99, 101, 102, 116, 139
ST	Slip	Int. slip	Smoothed	Burnished	Rough
SN	91, 92, 99, 101, 102, 104, 105, 106, 113, 116, 303	88, 91, 92, 99, 101, 104, 105, 106, 113, 303	87, 89, 116, 128, 133, 138, 139, 140, 299, 300, 301	88, 91, 92, 99, 101, 102, 104, 105, 106, 113, 303, 304	94, 119, 302
Th.	Very thin ≤ 0.6 cm		Thin ≤ 1 cm		Thick > 1 cm
SN	88, 89, 92, 94, 99, 104, 106, 113, 116, 138, 139, 140, 299		87, 91, 101, 102, 105, 128, 133, 300, 302, 303, 304		119, 301

According to the cross section analysis; it is observed that Phase III pottery generally contain dense and coarse inclusions, while the shaping method appears to be “coiling” due to the marks left in cross sections (e.g., Figure 4.9).

According to the petrographical and mineralogical results, Phase III as in the other phases contains inclusions of mineral and rock fragments derived from andesitic/rhyolitic, dioritic, metamorphic and sedimentary rocks of Gökçeada.

Groundmass giving birefringence and green hornblendes suggests a lower firing temperature as $<750^{\circ}\text{C}$. According to thin section observations mineral fragments were cracked, suggesting grinding of rock fragments during paste preparation.

As element variation diagrams (Figures 4.34-4.37, 4.40) examined, Phase III generally displays a limited variation suggesting a production from one or two locations. It is observed that in Phase III, the local source composing the Hierarchical Cluster (Figure 4.42) Group 3 is more prevalently used than the Hierarchical Cluster Group 2 in pottery production. On the other hand, the chemistry did not fit with the visual characteristics. In other words, it was like; various types of potteries were formed from one or two sources of prepared paste.

A detailed evaluation of petrographical, mineralogical and chemical analyses results are as follows:

Summary of thin section results for all phases:

1. Inclusion dimension and the quantity is increased through time from Phase V to Phase III. Finer inclusions may be a sign of sieving the granules before the paste preparation, as an indication of more attentive work, or more clear clay coming from the source or no need to add temper. But maybe as they discovered that the temper also facilitates the workability, they started to add temper. According to Bebbler (2017), pottery without temper have higher strength against mechanical shocks compared to tempered ceramics. According to his study, pottery formation and production were so crucial in prehistoric times that fracture strength may be ignored by adding temper to produce a more workable clay paste. So, adding temper may be an indication of technological progress related with the control of time and labor.
2. Rock fragment inclusions are generally rounded to subrounded, as mineral fragments were angular to very angular. This may indicate that probably volcanic (extrusive) rock fragments came within the clay, but minerals derived from an intrusive rock fragment as granite or granodiorite or derived from porphyritic andesite/basaltic andesite, were crushed or grinded and then mixed into the clay

paste, deliberately as temper to reduce the stickiness of the paste. In some samples fractures are observed in mineral fragments supporting the idea of crushing the rock fragments to add as temper into the clay paste or to reduce the size of the rock fragment coming with the clay.

3. Rock fragment inclusions are generally rhyolite, andesite, basaltic andesite, and metamorphic rock fragments mostly schist/mica schist and as sedimentary rock fragments, sandstones, clay stones/mudstones. And mineral fragments inclusions are quartz, alkali feldspars, plagioclases, amphiboles, mica and sometimes pyroxene which are prevalent through the island.
4. Although some organic materials as plant remnants are observed in some samples it has been thought to come from the environment by chance and not deliberately added. So, the pottery can be characterized as large amount of rock fragment inclusions and absence of organic residues.
5. Another important contribution of thin section analysis is for the estimation of the firing temperature. Because most prehistoric firings are not completely oxidized nor reduced atmosphere fluctuates extensively in time and temperature (Hunt, 2016). Birefringence of the clay, is observed prevalently in all three phases, least in Phase IV due to higher ratio of reduced medium firing and in relation with the emergence of black potteries may be related with the diagnostic concerns. For all three phases green hornblende is encountered prevalently in the samples, especially in Phase III. Due to this feature, we may assume during all that time span (Neolithic and Neolithic-Chalcolithic), firing temperature mostly varied between <750-850°C degrees. Also, high-quality burnish especially more frequently observed in Phase IV suggests low fired (700-760°C) potteries. This situation is encountered in all three phases.
6. Thin section analysis also supports the findings on stereomicroscope and diagnostic evaluation about firing atmosphere. Equivalent firing temperatures for open firings generally range between 550-750°C and 750-950°C for kiln firings (Tite, 1995). Pottery sherds containing a black/grey zone and orange/red margins suggests a short period time of firing and insufficient oxygen in the medium.

Besides, thin light-colored margin just on the pottery surface, of a dark colored ceramic suggests that the pottery taken out from the reduced medium and cooled rapidly in atmospheric medium. Maybe due to stylistics concerns. Besides, thin dark-color zone at pottery surface, suggests that the pottery is covered with organic matter during the firing (it can be wrapped in straw maybe in contact with the fuel). All of these situations are encountered for each phase, may indicate that some traditions in pottery making, continued over a long-time period.

7. The fabric groupings are categorized generally in four groups or in case, subgroups. In Table 5.5, a summary of fabric group distribution according to the phases is given. According to this table andesitic/rhyolitic fabric constitutes the most prevalent type for all three phases. While dioritic prevalent fabric type is most common in Phase IV, SRF prevalent fabric type is most prevalent in Phase III. On the other hand, MRF prevalent fabric type is most common in Phase V. Phase IV contains a different fabric class of basalt prevalent type and doesn't contain SRF prevalent fabric class.
8. According to the geological map of Gökçeada (Figure 2.3), thin section studies suggest, the use of raw materials that is consistent with the geological units in the vicinity of approximately 1 km to Uğurlu in the island. These units are igneous rocks from Gökçeada lava/domes consisting of andesite and diorite-porphyry; rhyolitic rocks from Dağçıtepe volcanics; sedimentary rocks from Ceylan formation consisting of claystone, sandstone, siltstone marl etc. and schist which has the potential to naturally mix from streams in the island's central or Marmaros region. Explanation for metamorphic rock fragments (mica-schist) observed especially in Phase V maybe also, that geological maps only present an idealized picture of surface geology, and they can mask levels of lithological and mineralogical variability that may have been of interest and relevant for the search of the raw material sources (Quinn, 2022).

Table 5.5 Fabric group distribution of the pottery samples according to the phases.

Fabric type	Phase V	Phase IV	Phase III
Andesitic/Rhyolitic	245, 250, 262, 265, 323, 325, 326, 327, 328, 330, 331	162, 168, 172, 178, 221, 306, 307, 308, 314, 315, 318	87, 88, 89, 91, 102, 104, 105, 116, 128, 138, 139, 301
	Total: 11 samples	Total: 11 samples	Total: 12 samples
Dioritic	267, 319, 320, 322, 335	222, 223, 227, 234, 305, 309, 311, 316, 317	99, 133, 299, 303, 304
	Total: 5 samples	Total: 9 samples	Total: 5 samples
Sedimentary (Phases V & III)/ Basaltic (Phase IV)	259, 324, 329, 332	312, 313	92, 106, 113, 140, 300, 302
	Total: 4 samples	Total: 2 samples	Total: 6 samples
Metamorphic	264, 321, 333, 334	185, 310	94, 119
	Total: 4 samples	Total: 2 samples	Total: 2 samples

As petrography gives an outline on the mineral composition, size and distribution of the plastic inclusions in the pottery body and provides information on production methods, firing temperature and technology, has to be supported with another method as XRD which covers higher amount of sample to analyze in a more homogenous way to give results. The results of XRD and thin section data complement and support each other.

Observed phyllosilicate minerals in low amounts in some samples, especially from Phase V may be an indication of lower firing temperatures (Iordanidis et al., 2009).

XRD results are examined and evaluated according to petrographical groupings to check out the similarities and differences between them. In accordance with thin section results quartz, feldspar, hornblende and mica inclusions varied in intensity related with the groups' characteristic features. Also, soil samples taken from three

different locations were compared for mineral composition with those of the pottery samples. The soil samples also have a high amount of quartz, feldspars, and calcite. Besides, most soil samples possessed montmorillonite, smectite and kaolin contained clay types. Even though the soil samples have high calcite content, it is not encountered in the pottery samples. Therefore, it is supposed that maybe different soil locations were used for the preparation of the pottery.

To question the idea of local or foreign production of the pottery and to get an idea about the change of the raw material use through time, ICP-OES/MS analysis is performed on 61 pottery and three soil samples. As it is known, the overall composition of a pottery is related to the geology of the area and the type of materials used. So, some important elements that give information about production, are compared within each phase, the soil samples and the data for volcanic rocks of Gökçeada acquired from Şen et al. (2020).

First of all, to examine the relation of the samples within each phase, diagrams are prepared using the data obtained for major oxides and trace elements. To make a comment on production technology and raw material use whether a local production or not, the results were compared with each other, with the soil samples and the data obtained from igneous rocks of Gökçeada taken from different locations Şen et al., (2020). According to the evaluation of the data the results obtained are as follows;

1. In Fe_2O_3 vs Al_2O_3 variation diagram, the Phase IV pottery samples show a wider distribution compared to the other two phases.
2. Feldspar content ($\text{Na}_2\text{O} + \text{K}_2\text{O}$) variation diagram shows a narrow distribution i.e., a homogenous behavior of Phase III samples against randomly distributed content in phases IV and V.
3. MgO controlled by hornblende, pyroxene and biotite content in the paste is lower in Phase III and higher in Phase IV.
4. Phase IV shows more rhyolitic tempered behavior, and phase III displays more andesitic content in the clay paste.

5. Zr and Cr content behavior is consistent with andesitic tempered Phase III potteries while, Phase IV potteries seem to contain coarser inclusions of quartz which may related with the granodioritic content also.
6. Phase V pottery samples contained low amounts of fine inclusions. According to the diagrams the raw material use seemed to be divided into two or three groups. Sample 324 and 325 are different from all the other samples as a result of petrographical and chemical analysis results. Maybe the production was carried out by different sources or from another site or craftsmanship.
7. Phase IV, demonstrates a random and independent distribution from each other in raw material and inclusion content. The samples 312, 313 (contained higher amounts of pyroxene due to basaltic rock fragments) and 185 are distinct from the other samples within the phase according to the evaluation of the results of petrography and chemical data. In this phase, the product scale is more diverse and maybe related with this phenomenon, the craftsman ship variation is higher than the other two Phases.
8. As for Phase III the situation is different. The results obtained from variation diagrams of elements, suggests that production is carried out from one or two defined locations, may imply a more localized production as Phase III showed a narrow variation for raw material selection and inclusion use.

Then, hierarchical analysis is performed to see the relation of all samples in all phases together through the whole observed time period. Also, the results are compared with the fabric groups in thin section analysis.

As the phases are evaluated together to see the provenance and fabric type relations with the chemistry. Hierarchical cluster analysis points mainly two production locations, as there is a remarkable consistency with the petrographic fabric groups. According to Figure 4.42, Group 2 generally consists of dioritic fabric groups as Group 3 consists mostly of VRF prevalent samples. These results also suggest two main local production areas for the time span through Neolithic to early Chalcolithic period. Besides, PCA analysis are consistent with cluster analysis results mainly showing two main local production sites and suggests about smaller groups and

outlier (not belonging to a group) samples. Different samples demonstrated by these statistical analyses may also suggest different production locations on the island.

Archaeological evaluation of the results:

The transition from Phase V to Phase IV; characterized by a broader utilization of environmental resources and the adoption of more advanced, creative technological standards; marked a significant transformation in pottery preparation techniques. During this period, social differences may have become more pronounced (Güzel, 2024; Hodder, 2014). During Neolithization, farming households achieved social and economic independence, leading to pronounced intra-household and inter-group status differences (Atakuman, 2022; Kuijt et al., 2011). In Phase III transition from Neolithic to Chalcolithic, a change to less varied diagnostic features and limited raw material use in the production of pottery at Uğurlu, may reflect the changing concepts of place and society in the immediate aftermath of the Neolithic Process, when interactions with the Balkans as well as with the Aegean intensified in this region (Karamurat et al., 2021). The progress of Uğurlu pottery production through Neolithic to Chalcolithic is summarized in Table 5.6.

Table 5.6 Summary of the progress in Uğurlu pottery production through Neolithic to Chalcolithic

Variable	Phase V	Phase IV	Phase III
Color variation	Limited color variation	Color variation remarkably increases	Color variation narrowed
Surface treatment / Wall thickness	Generally smoothed and slipped pottery / Thin walled	Lustrously burnished multicolored sherds with slips on both sides of the pottery / Thin walled	Homogenous pottery. Slipped, burnished mostly smoothed / wall thickness is homogenous, thickness is increased
Firing Temperature	Lower firing temperature, generally shows reduced or incomplete oxidation firing	Firing temperature increased, generally shows reduced or incomplete oxidation firing	Firing temperature increased, generally shows a thin oxidized layer on reduced or incomplete oxidation firing. Probably due to rapid cooling after firing.
Inclusion frequency	Lower inclusion use, moderate to poor sorting	Addition of slightly coarser inclusions, frequency is increased, poor sorting	Addition of coarser inclusions, frequency is increased, poor to very poor sorting
Raw material selection	2- 3 raw material mixture	Higher variation	Lower variation of raw material

To summarize,

For all three phases during the forming of potteries coiling technique was used. During the preparation of the clay paste, raw materials used as inclusions slightly differentiated through time. Inclusions used generally consist of volcanic, plutonic, sedimentary and metamorphic rock fragments of Gökçeada. Potteries were fired at low temperatures <850°C even some fired below 750°C.

As transition from Phase V to IV broader use of environmental resources, along with various technological transformations demonstrating a degree of creativity with lustrously burnished, two-colored and thin-walled potteries occurs.

Phase III is marked by the Neolithic-Chalcolithic transition. Phase III pottery is homogenous and different from previous phases diagnostically. The results obtained from some variation diagrams of elements, show a narrow variation for raw material selection and inclusion use in production. According to acquired diagrams and the statistical analyses, it is assumed that the production was carried out in mainly two locations through all time period and especially for Phase III a mass production may have taken place.

Finally, though inclusion content of the phases slightly differed from each other, raw materials; andesites, occasionally granodiorite/diorite porphyry from volcanic rocks of "Gökçeada Lava/Domes", sedimentary rocks from Ceylan formation (composing of claystone, sandstone, siltstone, marl etc.) and regional clays were likely used locally in the production of potteries.

CHAPTER 6

CONCLUSION

This study has aimed to investigate the changes in raw material use and production technologies for ceramics from Uğurlu Höyük-Gökçeada, one of the earliest agricultural settlements in North Aegean, through time and space, dating to the Neolithic and Chalcolithic periods. In the scope of this study, analyses were applied by using scientific techniques for a total of 74 sherd samples from Neolithic Phase V (6600-5900 BC), Phase IV (5900-5600 BC), and Early Chalcolithic Phase III (5500-4900 BC).

Stereomicroscopic observations have suggested clues of coiling techniques for the forming stage of pottery production continued for all 3 phases. According to the results of petrographical and mineralogical analyses, basically 4 types of fabric groups are observed for all three phases which are similar to each other through all examined time periods. The analyses reveal that the clay used in ceramic production across all archaeological phases is consistent with the island's geology, primarily originating from andesitic-rhyolitic and dioritic rocks. Within the main clay matrix, smaller amounts of schist, basalt, and sedimentary rocks from various regions of the island are also present. The andesitic-rhyolitic and dioritic rocks, which constitute the main raw material group, can be sourced from within a 1 km radius of the Uğurlu Höyük settlement. Schist has the potential to naturally mix with local materials from streams in the island's central or Marmaros region. Basaltic material, specific to the Eşelek area, is observed in two samples from the phase IV.

Statistical analysis of the chemical results indicates that, across all phases, two locations near the settlement were predominantly utilized, alongside various other sources from the area. It is noted that the use of different locations was more common in the earlier phases and became more restricted in later phases. This indicates the use of raw materials sourced from very close to the settlement, suggesting a local

production process that persisted without significant alteration throughout the Neolithic and Chalcolithic periods.

The shift from Phase V to Phase IV may lead to a transformation in more advanced pottery preparation techniques by broader utilization of resources and technological standards. In Phase III transition from Neolithic to Chalcolithic, a change to less varied diagnostic features and limited raw material use in the production of pottery at Uğurlu, may reflect the changing concepts of place and society in the immediate aftermath of the Neolithic Process, when interactions intensified in this region (Karamurat et al., 2021).

The obtained results are limited with the selected pottery and soil samples subjected to the test analysis. Although the analyses of this pottery samples from three archeological phases provide valuable insights into the technology of production of pottery at Uğurlu, it alone might not be sufficient to draw definitive conclusions about the societal structure and organization. Further research, integrating the other transition Phases and a separate study on pottery surface treatment techniques and slips may give additional information for the transformation of cultural change through time and analyses, which is essential for a complete understanding of the societal dynamics and social culture at Uğurlu.

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APPENDICES

A. Diagnostic Examination Results

Visual properties of the pottery samples, evaluated by naked eye and cross sections are given in detail in Table A.1. Question mark (?) used for indecisive situations. Abbreviations used are; O: Oxidized, R: Reduced r: thinly reduced, o: thinly oxidized.



Table A.1 Diagnostic features of Uğurlu pottery samples

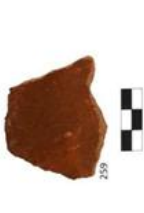
Sample ID	Phase/ Trench / Lot	Building/ Pit/ Floor	Photo	Cross Section	Explanation: Visual appearance and thickness of the pottery in cm
245	5 / BB20- 21 / B36	Building 2			Red, 1 cm. Outer surface red, smoothed and matt, inner surface is light orange, rough, decomposed and cracked as stratified layers. Item has smooth and compact microtopography. Grains are almost totally covered but some inserted grains exist. Wavy undulations exist due to the fashioning technique, probably due to the coiling technique. Firing: o-R-o (core is orange grey). Dense fine, sparse medium gritty, round and long platy voids exist, due to fashioning and plant remnants.
250	5 / BB20- 21 / B36	Building 2			Brown black, 0.5 cm. Both surfaces are brown black, smoothed and matt. Workmanship is very straight, thickness is equal along the sherd, topography is regular. Grains are totally covered. Smooth and compact, microtopography and micaceous glitz exist. Sooty appearance on the outer surface. Firing: R. Dense fine gritty, highly elongate voids exist parallel to the walls.
259	5 / BB20- 21 / ?	?			Maroon-red, 0.7 cm. Outer surface maroon-red, slipped and burnished inner surface brown and smoothed. Micaceous glitz exist can be seen on the inner surface. Item is smooth and compact, topography is regular. Grains are covered on the outer surface. Firing :O. Dense fine, sparse medium gritty.
262	5 / BB20- 21 / ?	?			Light yellow orange, 0.6 cm. Outer surface light yellow orange, inner surface is yellow, both surfaces are slipped and burnished. Item is smooth and compact grains are totally covered. Topography is regular. Firing: O. Dense fine gritty.

Table A.1 (continued)

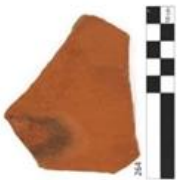
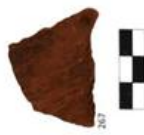
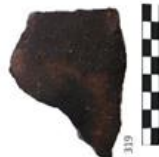
264	5 / BB20- 21 / ?	?			Orange, 0.9 cm. Both surfaces are orange, outer is burnished, inner is smoothed. Partly sooty appearance on the inner surface. Item is smooth and compact, grains are totally covered. Some treatment marks on the outer surface. Topography is regular. Firing: O-R-o. Dense fine, sparse medium gritty.
265	5 / BB20- 21 / ?	?			Red orange-black, 0.4 cm. Outer surface red black, slipped and burnished, inner surface is red orange, slipped and burnished. topography is regular, microtopography is smooth and compact, grains are totally covered. Firing: O. Dense fine gritty.
267	5 / BB20- 21 / ?	?			Red-black, 0.7 cm. Outer surface is two colored as red and black, slipped and burnished, treatment marks can be distinguished. Inner surface is orange red, slipped and burnished, fashioning marks can be felt probably due to the coiling. Topography is regular, microtopography is smooth and compact. Grains are totally covered. Firing :O-R. Dense fine, sparse medium gritty, some elongate voids exist, which are parallel to the Wall.
319	5 / BB20- 21 / B24	Building 2			Black brown, 0.8 cm. Outer surface is mottled black and brown, smoothed but matt and slightly rough. Inner surface is light brown and roughly smoothed, coarse grains can be easily seen. A rough workmanship can be observed. Some slightly wavy undulations exist. On the outer surface grains are not covered and some micaceous glitz exist. On the inner surface inserted grains and tiny crevices exist, and grains are partially covered, surface microtopography is irregular. Firing: R. Dense coarse gritty.

Table A.1 (continued)

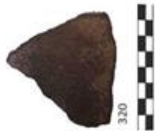
320	5 / BB20- 21 / B24	Building 2			Light-brown, 0.65 cm. Outer and inner surfaces are light brown, smoothed and matt. Some sooty appearance and micaceous glitz exist on the outer surface. On the inner surface inserted grains exist and tiny crevices exist, on the outer surface grains are partially covered. Surface microtopography is almost regular. Some concentric undulations can be felt on the inner surface, probably due to the coiling. The item is smooth and fluidified. Firing: R, dense fine-medium, sparse coarse gritty.
321	5 / BB20- 21 / B31	Building 2			Orange, 1.0 cm. Outer surface orange, smoothed, sparsely burnished, generally matt. Inner surface is orange, smoothed and matt. Some treatment marks exist on the outer surface and some undulations can be felt by hand on the inner surface. Item is smooth and compact, topography is regular, grains are almost covered. Surface microtopography is regular. Firing: o-R-o. Dense fine, sparse medium gritty.
322	5 / BB20- 21 / B31	Building 2			Red, 0.9 cm. Outer surface red and partly burnished, inner surface is orange and smoothed. Partly sooty appearance due to contact during firing. Some treatment marks during burnishing on the outer surface and slightly concentric undulations exist on the inner surface. Item is smooth and compact, grains are totally covered, micaceous glitz exist. Firing: O. Dense fine, sparse medium gritty.
323	5 / BB20- 21 / B31	Building 2			Red, 0.4-0.5 cm. Outer surface red/ orange, slipped, smoothed and partly burnished. Inner surface, maroon red, slipped and burnished. Both surfaces are smooth and compact. Topography is regular. Workmanship is painstaking and proper. Grains are totally covered. Firing: o-R-o, as if rapidly taken out to the atmospheric medium from reduced firing medium, dense fine gritty.

Table A.1 (continued)

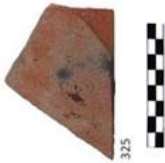
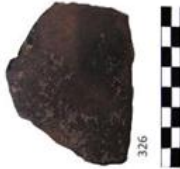
324	5 / BB20-21 / B31	Building 2			Orange, 0.6 cm, base. Outer surface is yellow orange, smoothed and matt. Inner surface is light orange, rough and matt. Inner surface has some concentric over thicknesses probably due to coiling, grains are not covered, though white grains some plant voids can be observed. Outer surface is more smooth, sooty appearance exist; surface is micaceous and grains are partly covered. Topography is irregular. Firing: o-R-o. Dense fine, sparse medium gritty, round and elongate voids can be observed from the cross section.
325	5 / BB20-21 / B36	Building 2			Light orange, 1.2 cm, base. Outer surface light orange, smoothed and matt. Inner surface is red brown, sooty appearance, rough and matt. On the inner surface some tiny crevices exist, grains are not totally covered. For the outer surface grains are almost totally covered. Topography is regular, partly some micro pull-outs exist on the surface. Firing: O-r-O. Dense very fine gritty, round and elongate voids.
326	5 / BB20-21 / B80	Building 2			Brown, 0.5 cm. Outer surface brown and sooty brown black, smoothed and matt. Inner surface black, smoothed and matt. Workmanship is neat. Item is smooth and compact, topography is regular. Almost all grains are covered. Firing: R. Dense fine, sparse coarse gritty. Elongate plant voids exist.
327	5 / BB20-21 / B80	Building 2			Red-brown, 0.6 -0.8 cm. Outer surface red brown and black, sooty appearance, slipped and burnished. Inner surface is orange and burnished. Irregular topography due to coiling technique. Concentric undulations can be observed and felt on the surface. Item is smooth and compact, grains are covered. Parallel scraping (probably by pebble or shell) and treatment marks can be observed on the outer surface, can be felt by hand on the inner surface. Micaceous glitz exists. Firing: r-O. Dense fine, sparse medium gritty.

Table A.1 (continued)

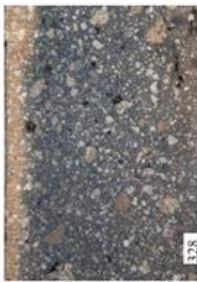
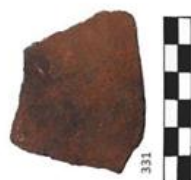
328	5 / BB20- 21 / B80	Building 2			Orange, 1.4 cm. Outer and inner surfaces are both orange, partly sooty. Grains are covered. Almost regular topography but some irregularities exist due to the coiling technique. Microtopography is smooth and fluidified. Micaceous glitz exists, it may contain grog temper as seen from the cross section. Firing: o-R-o. Dense fine, sparse medium gritty.
329	5 / BB20- 21 / B80	Building 2			Red, 0.9 cm. Outer surface red, smoothed, slightly burnished and soapy. Inner surface is orange and smoothed. Slight undulations related with the coiling technique. Item has smooth and compact microtopography. Topography is regular, grains are totally covered, micaceous glitz exist. Firing: O-R-o. Dense fine, sparse medium gritty.
330	5 / BB20- 21 / B80	Building 2			Brown, 0.5 cm, shoulder. Outer and inner surfaces are brown, slipped and slightly burnished (or shiny appearance may be faded through time). On the outer surface grains are totally covered, on the inner surface micro pull-outs can be seen. Microtopography is smooth and compact, topography is regular. Cross section; Firing: R. Dense fine gritty, voids may be related with the fashioning technique or plant remnants. Brown grains may be related with grog.
331	5 / BB20- 21 / B80	Building 2			Light orange, 0.6 cm. Inner and outer surface is light orange, slipped (?) and smoothed. A very thin layer of light orange be wet-smoothing applied and fired in a reduction medium, because the black body is visible just under. This may show, that it was fired in a reducing atmosphere and rapidly taken out to oxidizing medium. Treatment marks exist on the inner surface. Topography is regular. Microtopography is smooth and compact, grains are totally covered. Cross section; Firing: o-R-o. Dense fine-medium gritty.

Table A.1 (continued)

332	5 / BB20- 21 / B80	Building 2			Light orange, 0.7 cm. Inner surface is light orange, slipped (?), smoothed and matt. Outer surface is orange, rough and matt. Inner surface has partially covered grains, inserted grains and micaceous glitz. Outer surface has covered grains, wet-smoothing. Topography is regular, microtopography is smooth and fluidified. Firing: o-R-o, as it was fired in a reducing atmosphere and rapidly taken out to oxidizing medium. Dense fine and medium, sparse coarse gritty, also brown grains exist.
333	5 / BB20- 21 / B80	Building 2			Brown, 0.5 cm, shoulder (Carination?). Outer surface is two colored as brown slipped and burnished over black body, wavy treatment marks (wet-smoothing, or wash with clay slurry) can be distinguished. Inner surface is brown and smoothed and grains are covered. Topography is regular. Outer surface has smooth and compact microtopography, and grains are covered. Firing: O-r (wavy appearance). Dense fine gritty, sparse medium gritty.
334	5 / BB20- 21 / B80	Building 2			Brown, 0.6-0.7 cm. Outer surface brown, smoothed and matt, inner surface brown, deformed and rough. Outer surface has covered grains, smooth and fluidified, in addition, plant voids exist. Inner surface is irregular and protruding grains exist. Firing: O-R-o. Dense fine, sparse medium gritty.
335	5 / BB20- 21 / B80	Building 2			Red, 0.55 cm. Outer surface is red orange, slipped and burnished, inner surface is orange, slipped and burnished. Parallel treatment marks can be observed from color fluctuations, but can't be felt. Topography is regular. Microtopography is smooth and compact. Firing: O-R-o. Dense fine gritty.

Table A.1 (continued)

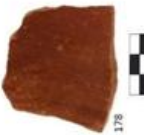
162	4 / P5 / B146	8			Red-orange, rim, 1.7 cm. Both surfaces are red-orange, smoothed maybe slightly burnished. Concentric over thickness in the inner surface and some construction marks exist (maybe pebble or leather) on the outer surface. Microtopography is irregular, grains are almost totally covered. Sherd is smooth and compact. Firing: O-R-o. Dense fine, sparse medium gritty.
168	4 / P5 / B146	8			Black-brown, shoulder, 0.8 cm. Both surfaces are black brown, slipped and burnished. Slip is two colored as brown and darker brown-black. Some marks for burnishing, exist (maybe pebble or leather) on the outer surface. Microtopography is regular. Grains are totally covered, smooth and compact sherd. Firing: R. Dense fine gritty
172	4 / P5 / B146	8			Brown- Black, 0.7 cm. Foot, both surfaces are brown black, slipped and burnished. Microtopography is regular, some tiny drying cracks exist. Grains are totally covered sherd is smooth and compact. Firing: R, dense fine, sparse medium gritty.
178	4 / P5 / B150	8			Red-orange, 0.9 cm. Outer surface red-orange, inner surface light orange. Both surfaces are burnished, outer surface is slipped and shiny, some construction marks as leather or brush, exist. The item is smooth and compact. Grains are covered, slip or maybe clay slurry applied. Some scraping striations and horizontal bumps exist due to construction technique so topography is almost regular. Firing: O-r-O, dense fine, sparse medium gritty.

Table A.1 (continued)

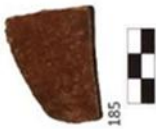
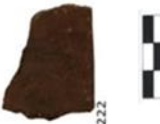
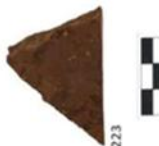
185	4 / P5 / B150	8	 185	 185	Red-black, 0.5 cm. Outer surface is red black, slipped and burnished, inner surface well smoothed, slightly burnished and black. Plant remnant voids appear on the inner surface. Shiny, smooth and compact surface. Grains are covered, maybe slip or clay slurry applied with a brush or fibrous plant or cloth. Firing: o-R, dense fine, sparse medium gritty
221	4 / P5 / B126	Yellow floor	 221	 221	Red, 1-1.2 cm. Both surfaces are red, but outer surface is darker red. Both surfaces are slipped and burnished. Shiny, smooth and compact surface. Inner surface has tiny cracks, some construction marks can be felt due to coiling. Grains are covered, clay slurry or slip may be applied with a brush, leather or fibrous plant. Topography is regular on the outer surface but bumps can be felt on the inner surface. Firing: O-r-o. Dense fine-medium, sparse coarse gritty
222	4 / P5 / B126	Yellow floor	 222	 222	Black- Brown, 0.55cm. Outer surface is two colored, light brown and black, inner surface is grey brown. Outer surface is slipped and burnished, inner surface is slipped and well smoothed. Grains are covered but also some floating (bumpy) grains exist. Surface is shiny, smooth and compact. Slip or clay slurry is applied as if with a brush or leather like material. Topography is regular but some tiny cracks exist. Firing: R. Dense fine-medium gritty.
223	4 / P5 / B126	Yellow floor	 223	 223	Black-brown, 1.2 cm. Outer surface is black brown and smoothed, inner surface is light orange, rough and decomposed and cracked as stratified layers. Outer layer may be wash. Grains are covered. Topography is regular, smooth and compact. Micaceous glitz on the surfaces and cross section. Voids seen from the cross section and inner surface may be traces of plant. Firing: o-R-o, medium gritty

Table A.1 (continued)

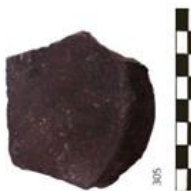
227	4 / P5 / B126	Yellow floor			Red-black, 1 cm. Outer surface red black slipped and slightly burnished, inner surface is light orange, slipped and slightly burnished. Microtopography is smooth and compact. Grains are almost totally covered. Topography is regular. Micaceous glitz on the surfaces and cross section. Firing: o-R-o. Dense fine-medium, sparse coarse gritty.
234	4 / P6 / B74	Filling			Grey, 1-1.4 cm. rim. Outer and inner surfaces are light grey and matt. Both surfaces are smoothed. Grains are covered, topography is regular, smooth and compact. Firing: R(?), dense fine, sparse medium gritty.
305	4 / P5 / B106	Building 5			Red-black, 0.7 cm. base. Outer surface red black (two colored), slipped and burnished, inner surface is orange and well smoothed, in addition some micaceous glitz can be observed. Cross section is brown. Item is smooth and compact. Grains are covered. Topography is regular, but slightly forming marks, protrusions exist, due to coiling. From the cross section, large and long planar voids can be observed, this can be due to plant remnants. Firing: R. Dense fine, sparse coarse gritty.
306	4 / P5 / B104	Building 5			Light-brown-black, 0.6-0.8 cm. foot. Outer surface two colored, light brown-black, slipped and burnished. Inner surface black Brown and smoothed, tiny cracks exist. Smooth and compact microtopography, shiny outer. Regular topography. Inserted and totally covered grains exist. Firing: o-R. Dense fine-medium, sparse coarse gritty.

Table A.1 (continued)

307	4 / P5 / B107	Building 5			Red-black, 1.1 cm, rim. Outer surface partly light and dark red-black and orange, smoothed and matt. Inner surface partly orange and light brown, slipped, burnished and shiny. On the outer surface some inserted grains exist, overall grains are almost totally covered. Topography is regular, smooth and compact. Firing: o-R-o. Dense fine, sparse medium gritty.
308	4 / P5 / B106	Building 5			Red, 1.2 cm. Outer surface is red, slipped and burnished. Inner surface is light brown and black, two colored, slipped and burnished. Item is smooth and compact; grains are almost totally covered. Topography is regular, but slightly construction marks, protrusions exist, due to coiling. Hardly seen tiny cracks on the outer surface. Firing: o-R, dense fine, sparse medium/coarse gritty.
309	4 / P5 / B107	Building 5			Brown, 0.4 cm, rim. Outer surface is brown, slipped and burnished. Inner surface is partly brown and black, slipped and burnished. Item is smooth and compact, grains are covered. Topography is regular, but slightly, protrusions exist, probably due to coiling. Firing: o-R. Dense fine, sparse medium gritty.
310	4 / P5 / B107	Building 5			Black-brown, 0.9 cm, foot. Outer surface is black-brown, slipped and burnished. Inner surface is brown-black and smoothed. The microtopography is smooth and compact, grains are covered. Almost regular topography, some undulations exist due to fashioning and construction. Cross section is orange-brown. Firing: O, dense fine, sparse coarse gritty.

Table A.1 (continued)

311	4 / P5 / B108	Building 5	 311	 311	Black-brown, 0.8 cm, rim. Outer surface two colored, brown and black, slipped and burnished. Inner surface is mostly black, slipped and burnished, also some construction marks exist. Microtopography is smooth and compact. Topography is almost regular; some undulations exist due to fashioning. Grains are covered. Firing: O-R, dense fine, sparse medium gritty.
312	4 / P5 / B150	Building 8	 312	 312	Light-orange, 1 cm, rim. Outer surface is light orange and partly black brown, two-colored, Slipped and burnished. Inner surface is also two-colored, light orange and largely darker brown, slipped and burnished. Grains are totally covered. Surface microtopography, smooth and fluidified. A slip or clay slurry could be applied. Surface is smooth but irregular, construction marks exist. From the cross section, many untidy, round and platy voids can be seen. Voids can be related with the fashioning technique and plant remnants. Firing: o-R-o, dense fine gritty, sparse medium-coarse gritty.
313	4 / P5 / B150	Building 8	 313	 313	Grey-light brown, 0.8-1 cm, rim. Outer and inner surfaces are two colored as grey, light brown slipped and well smoothed. Slip is wash or clay slurry, surface is smooth and fluidified. Micaceous glitz on the surfaces and cross section. Cracks exist on the outer surface. Grains are covered. Wall topography is irregular due to the slight protrusions. Construction marks or bumps shows coiling technique clues. Firing: o-R-o. Fine gritty, sparse medium /coarse gritty.

Table A.1 (continued)

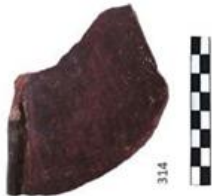
314	4 / P5 / B152	Building 8	 314	 314	Brownish-red, 0.8 cm, rim. Outer surface black-red, slipped and slightly burnished, inner surface is orange, well smoothed and matt. On the outer surface treatment marks (by pebble, corn or leather) and on the inner surface construction marks exist, probably due to coiling technique. Compact and smoothed, but tiny cracks exist. Topography is regular and grains are almost totally covered. Firing: O-r-O. Fine to medium gritty.
315	4 / P5 / B146	Building 8	 315	 315	Black-brown, 0.6-0.8 cm, base. Outer surface is black-brown, slipped and burnished, inner surface is black and smoothed. Inner surface has tiny cracks. Item is smooth and compact. Topography is regular, grains are totally covered. Firing: R. Dense fine, sparse medium gritty.
316	4 / P5 / B146	Building 8	 316	 316	Brown, 1 cm, pierced lug. Outer surface is brown, slipped and burnished, inner surface is black, slipped and burnished. Topography is regular, microtopography is smooth and compact. Grains are totally covered. Firing: R, dense fine gritty, sparse medium gritty.
317	4 / P5 / B49	Building 8	 317	 317	Red, 0.8 to 2 cm due to pierced lug. Outer surface is red, slipped and burnished, inner surface is light brown and rough. Topography is irregular due to the form of the sherd. Grains are almost totally covered. Microtopography is smooth and compact. Firing: o-R-o. Dense fine and medium gritty, sparse coarse gritty

Table A.1 Continued

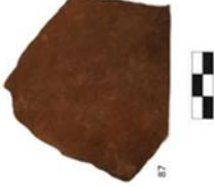
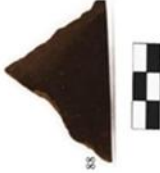
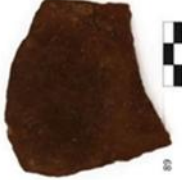
318	4 / P5 / B146	Building 8	 318	 318	Red, 1.8 cm, rim. Outer and inner surface both orange, smoothed and matt. Outer surface is smooth and compact, inner surface is smooth and fluidified, some tiny cracks exist. Topography is irregular, rough workmanship. Grains are totally covered. Coiling bumps can be felt by hand. Firing: o-R-o. Fine to medium gritty
87	3 / DD20 / B11	Building 3	 87	 87	Brown, 0.7cm. Carination, inner surface orange and matte, rough. Outer surface is matte but smoothed. Inner surface consists of partially covered grains. Inner wall is with irregular topography, outer wall is regular topography. Grits are partially covered. For to the construction technology, the bulges and construction marks can be felt by hand. Cross section; firing: o-R-o. Dense fine, sparse medium gritty.
88	3 / DD20 / B11	Building 3	 88	 88	Black, 0.5cm. Inner and outer surface is homogenous black, smoothed and slightly burnished. Cross section is completely black. Medium-fine grits, grits are perfectly obliterated on the surface. Bumps on the surface may be due to coiling technique. Scraping marks can be felt by hand on the inner surface. Firing atm.: R, dense fine, sparse medium gritty.
89	3 / DD20 / B11	Building 3	 89	 89	Red-brown, 0.6 cm. Shoulder, smoothed, slightly slippery surface. Cross section; medium-fine grit, inner surface light brown with partly slight darkness, sooty appearance, construction marks as strips on the inner surface, pointing to the coiling technique. Dark colored slip, underneath light brown, towards core, grey. Inner surface has a thin layer of clay coating or (wiping) and micaceous glitz. Firing: o-R-o, dense fine-medium gritty

Table A.1 Continued

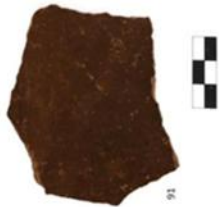
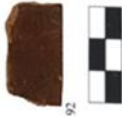
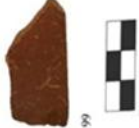
91	3 / P5 / B45	Ö25			Outer surface brown, inner surface red brown, 0.7cm, carination. The inner and outer surfaces are darker than the orange surface underneath due to burnishing. Both surfaces are slipped and burnished. Shiny surface, grains are covered, horizontal striations seen and felt by hand on the inner wall surface. Low irregularity due to the coiling technique. Surface smooth and compact, regular topography, slightly marked with hand processing. Dense fine-medium gritty. Firing: o-R-o
92	3 / P5 / B45	Ö25			Brown-black, 0.5 cm. Inner surface black. Both surfaces are slipped and burnished, outer surface is shiny, core is black. Outer brown surface may be clay coating or slip. Totally covered grains, regular topography, dense fine, sparse medium gritty. Firing: R
94	3 / P5 / B45	Ö25			Outer surface light-orange, inner surface light orange, slightly sooty appearance, 0.6 cm. Both surfaces are matte, self-slip and smoothed. Rough surface, partially covered grains, drying cracks may point out for self-slip technique. Slightly irregular topography felt by hand may be due to the coiling technique. Dense fine-medium gritty. Firing: o-R-o,
99	3 / P5 / B45	Ö25			Outer surface red-brown, inner surface black, 0.5 cm. Both surfaces are slipped, well burnished and shiny. Outer surface and inner surface have construction marks, may be wiping or scraping. Both surfaces are wash slipped or clay coated, while outer surface is red-brown bi colored, inner surface is black colored. Grains are totally covered and topography is partially smooth. Dense fine-medium gritty, Firing: O-r

Table A.1 (continued)

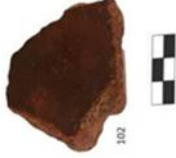
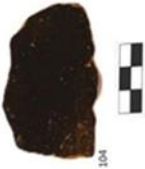
101	3 / P5 / B45	Ö25	 101	 101	Outer surface red-brown, inner surface black, 0.9 cm. Both surfaces are well burnished and shiny. Cross section black. Outer surface is wash slipped or clay coated, some construction marks on the outer surface. Totally covered grains, protruding grains, almost regular and compact topography. Firing: o-R, dense fine, sparse medium gritty, some elongate voids exist
102	3 / P5 / B45	Ö25	 102	 102	Outer surface red-brown, inner surface brown, 0.5-1 cm. Outer surface is slipped and well smoothed, inner surface is smoothed and matt. Cross section is dark grey, sandwich appearance. Outer surface is almost regular and compact topography. Totally covered grains. Construction marks on the inner surface. Outer surface is darker than the underneath due to the smoothing and firing. Firing: o-R-o, dense fine, sparse medium gritty, round and elongate voids
104	3 / P5 / B45	Ö25	 104	 104	Brownish black, 0.5 cm, shoulder, Slipped and burnished both surfaces, cross section Brown. On surface some striations exist due to construction marks. Almost regular topography, slightly concentric undulations can be felt by hand. Almost totally covered grains. Firing: r-O-r dense fine-medium, sparse coarse gritty
105	3 / P5 / B45	Ö25	 105	 105	Outer and inner surface is black, slipped and burnished, 0.6- 0.8 cm. Grains are covered, topography is regular. Microtopography is smooth and compact. Construction marks on the outer surface as lines. Firing: R, dense fine, sparse coarse gritty

Table A.1 (continued)

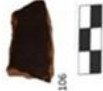
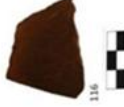
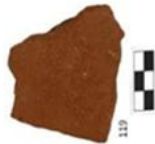
106	3 / P5 / B45	Ö25			Outer and inner surfaces black, 0.6 cm. Slipped and burnished. Cross section: core black grey, towards surfaces orange but surface is coated with a thin layer of black slip (Coated or wash slip). A unique sample. Smooth and compact topography, totally covered grains. Firing: r-o-R-o-r, dense fine gritty
113	3 / P5 / B52	Ö29			Black-brown outer surface, black inner surface, 0.5 cm. Both surfaces are slipped and burnished. Some construction marks and striations exist. Outer surface wash slip. Through cross section elongate voids can be seen which may be due to coiling technique. Outer surface smooth and compact. Totally covered grains, regular topography. Inner surface is also smooth and compact and holds regular topography but some tiny cracks also exist. Firing: R, dense fine, sparse medium gritty.
116	3 / P5 / B52	Ö29			Black-purple, 0.5 cm, sooty appearance on the outer surface, inner surface light orange. Outer surface smoothed, inner surface rough. Totally covered grains, slightly marked concentric undulations on the outer surface. Inner surface crusted and shed. Firing: r-O, dense fine, sparse medium-coarse gritty, but not homogenous distribution.
119	3 / O5 / B10	Ö102			Outer surface is light orange, 1-1.5 cm, inner surface black. Outer and inner surfaces matt and rough. On the outer surface protruding grains and partially covered grains. Microtopography is irregular. Dense fine, sparse medium gritty. Firing: O-r

Table A.1 (continued)

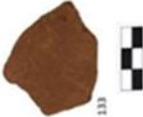
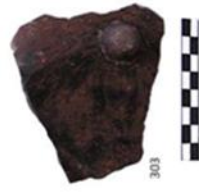
128	3 / O5 / B10	Ö102			Black both surfaces, 0.8 cm. Outer surface smoothed, matt and soapy, inner surface rough and shed. Cross section is black. Outer surface almost covered grains, micaceous glitz, regular topography. Firing: R, dense fine, sparse medium gritty.
133	3 / P6 / B4	Ö116			Brown outer surface, light brown inner surface, 1.1 cm. Both surfaces smoothed and matt. Both surfaces have micaceous glitz, outer surface have drying cracks and inserted grains. Probably, fluidified and smoothed. Partially covered grains, Firing: O-r, dense fine, sparse medium gritty.
138	3 / P5 / B161	Ö191			Both surfaces are orange, 0.6 cm. Rim, outer and inner surfaces smoothed, soapy feeling. Grains are smoothed but partially covered, probably not slipped. Some construction marks can be seen and topography is partially regular. Hardly seen, very thin cracks. Sandwich-like appearance from the cross section. Firing: o-R-o dense fine gritty.
139	3 / P5 / B161	Ö191			Brown-black, 0.5 cm. Rim, outer and inner surfaces smoothed, inner surface is darker than the outer surface. While outer surface is dark red-brown black, inner surface is greyish brown. Topography is regular, surface matt, some inserted grains exist. Surface smooth and compact. Slightly distinguishable construction marks. Firing: o-R, dense fine, sparse medium gritty, round voids exist.

Table A.1 (continued)

140	3 / P5 / B161	Ö191			Brown-black, 0.4-0.7 cm, rim. Both surfaces light brown to black due to firing atmosphere. Both surfaces smoothed. Sooty appearance on the outer surface due to contact during firing. Microtopography smooth. Partially covered grains, stands as if coated with a thin clay material or worked on wet paste. Drying cracks exist. Partially regular topography, striations of construction marks exist. Firing: R, dense medium to coarse, sparse fine gritty.
299	3 / CC19 / B31	Building 3			Light Brown, 0.55 cm, shoulder. Inner surface black brown. Both surfaces smoothed, soapy feeling. Partially covered grains, micaceous glitz. Regular smooth and compact topography. Firing: R. Dense, fine-coarse gritty.
300	3 / CC/DD19 / B9	Building 3			Brown, 1.1 cm, rim. Outer surface Brown to black Brown sooty appearance due to contact during firing. Inner surface light orange, both surfaces matt, slightly smoothed. Wavy topography due to construction technique. Tiny drying cracks. Totally covered grains, micaceous glitz on the surfaces. Surface microtopography, smooth and fluidified. Firing: R-o, dense medium-coarse gritty, round and elongate voids
301	3 / DD20 / B11	Building 3			Light Brown, 0.9-1.2 cm, base with foot, both surfaces light brown and matt. Fluidified surface, maybe smoothed by wet wiping, or a slurry clay. A thin layer of light brown may indicate that the item is taken to rapidly to the oxygenated medium just after reductive medium. Grains are partially covered. Sandwich appearance, firing: o-R-o. Dense fine, sparse medium gritty, dense round voids exist

Table A.1 (continued)

302	3 / DD20 / B11	Building 3			Red-brown, 0.7-0.9 cm (without foot), foot. Outer surface light orange to red Brown, inner surface grey. Brown due to sooty appearance. Smoothed, partly soapy, except foot. Smooth and compact microtopography, almost regular topography. Grains are totally covered. Firing: O-R, dense medium to coarse, sparse fine gritty.
303	3 / P6 / B45	Ö148			Brown-black, 0.8 cm. Foot. Outer surface is multicolored burnished, inner surface is soapy, smoothed and black. Plant residue voids can be seen on the inner surface. Elongate voids in horizontal view indicates the signs of coiling. Shiny, smooth and compact surface, floating grains exists. Shining may be carried out with a soft tool. Two different colors imply two different slip/clay slurry. Firing: R, dense fine, sparse medium gritty, round and highly elongate voids exist.
304	3 / P6 / B44	Ö148			Orange, rim 1cm. Slightly burnished, outer surface light orange, inner surface light orange/red-orange. Regular topography, slightly marked with hand processing. Both surfaces are smooth and compact, slightly shiny surface. Floating grains exist. On the inner surface tiny drying cracks exist. Firing o-R-o. Dense fine, sparse medium gritty.

B. Thin Section Results

Table B.1 Thin section results of the pottery samples of Uğurlu

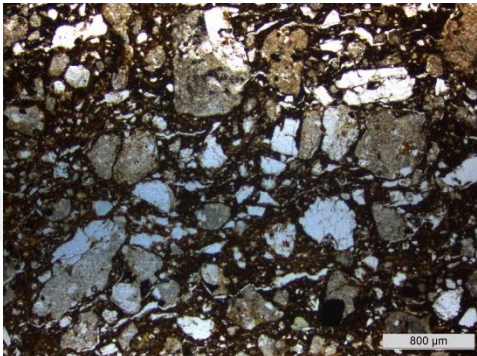
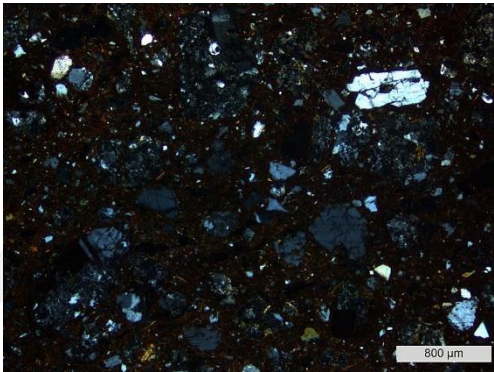
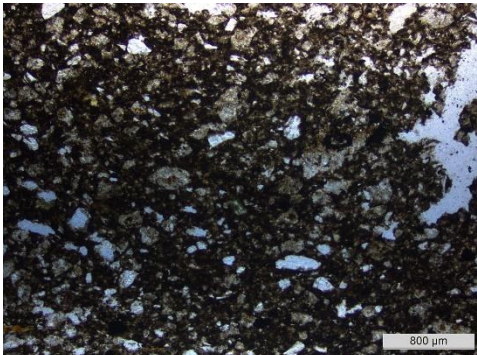
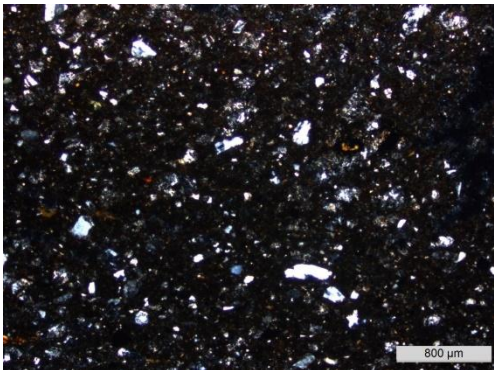
Thin Section results	
Phase V	
245	 
The outer surfaces were not well smoothed. Micromass: red brown in PPL, red-orange in XPL, gives birefringence. Inclusion frequency: %40, porosity: %7. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, 0.3 mm to 2 mm, sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende) derived from VRF (Rhyolitic / Andesitic): frequent, Mineral fragments (feldspars, mica, hornblende, quartz) derived from PRF (diorite): frequent, SRF (sandstone, mudstone, clay pellet): few. VRF (Schist): very few Notes: The clay matrix includes quite much mica (biotite and muscovite), some rock fragments are stained and altered (sericitized). Inhomogeneous clay mixing. Green hornblende.	
250	 

Table B.1 (continued)

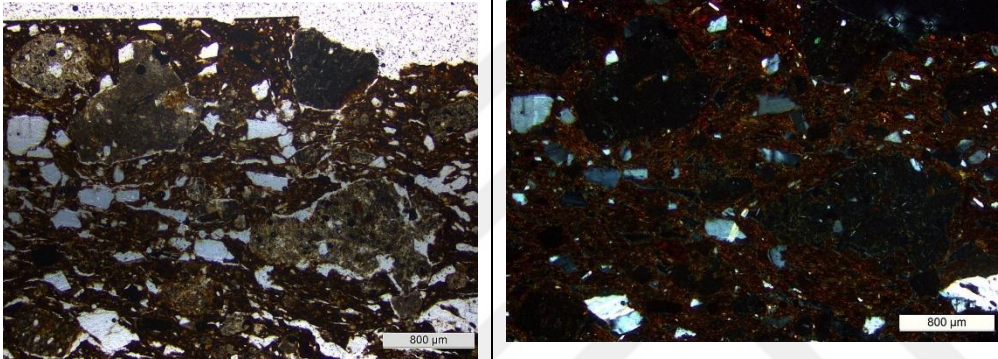
The outer surface was not well smoothed, and the inner surface is smoothed partly burnished. Micromass: blackish brown in PPL, partly grey brown-brown in XPL gives a slightly birefringence. Inclusion frequency: %40, porosity: %5. Pores mostly consist of vughs. Inclusions: very angular to sub rounded, 0.2 mm to 1.2 mm, sphere. Well sorted Rock fragments and individual mineral fragments (quartz, feldspar, mica) derived from VRF (rhyolitic / andesitic): predominant Notes: Elongate, vertical void due to charred plant remains exist. Biotite fragments as 1.1 mm exist.	
259 	
The outer surface was burnished and slipped; the inner surface was not well smoothed. Micromass: orange brown in PPL, orange to reddish orange in XPL. Inclusion frequency: %30, porosity: %7. Pores consist of vughs and planar voids. Inclusions: very angular to rounded, 0.3 mm to 2.5 mm, sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene) derived from VRF (glassy rhyolitic to basaltic andesite): Dominant, Granodioritic rock fragments and minerals (feldspars, hornblendes, mainly plagioclases): derived from PRF: frequent, SRF (Ferruginous clay pellets): very few, Notes: Rock fragments with feldspar and brown hornblende phenocrysts. Andesite fragments are dark colored, altered and the matrix is glassy. Fine clay matrix.	

Table B.1 (continued)

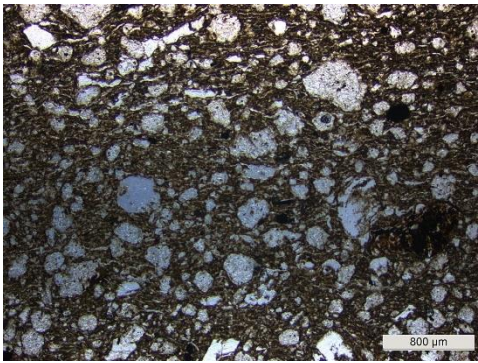
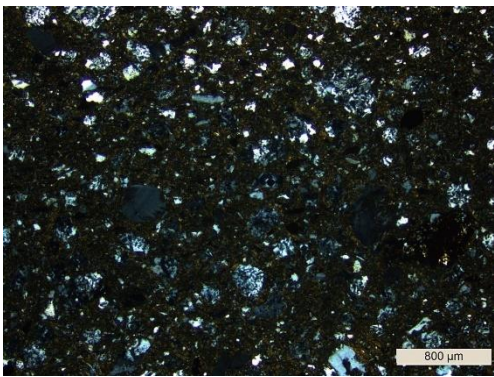
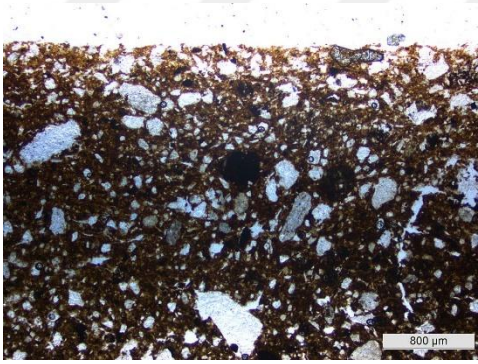
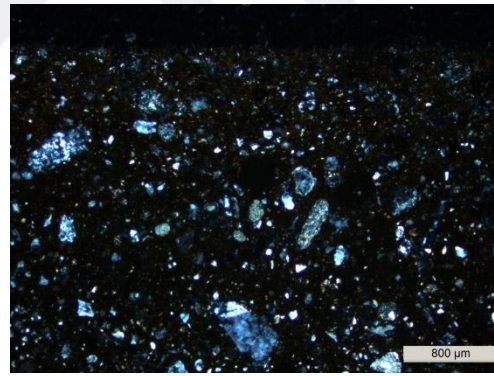
262 	
The outer surface was burnished and slipped; the inner surface was smoothed. Micromass: light brown in PPL, light orange-grey in XPL, gives birefringence. Inclusion frequency: %30, porosity: %3. Pores consist of vughs and thin planar voids. Inclusions: prevalently rounded to subrounded rock fragments, very angular to angular mineral fragments, 0.2 mm to 2.3 mm, sphere. Moderately sorted. Rock fragments and individual mineral fragments (plagioclase, hornblende, biotite) derived from VRF (andesitic): predominant, SRF (Ferruginous clay pellets): very few.	
264 	
Both surfaces were smoothed. Micromass: orange brown margins, light brown core in PPL, red brown margins, grey core in XPL, gives birefringence on margins. Inclusion frequency: % 30 porosity: %7. Pores consist of vughs and planar voids. Inclusions: very angular to rounded, < 0.2 mm to 2.2 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (feldspar, mica, quartz) derived from VRF (Rhyolitic /Andesitic): dominant, SRF (sandstone, ferruginous clay pellets, silt, chert): few, MRF (Schist): common.	

Table B.1 (continued)

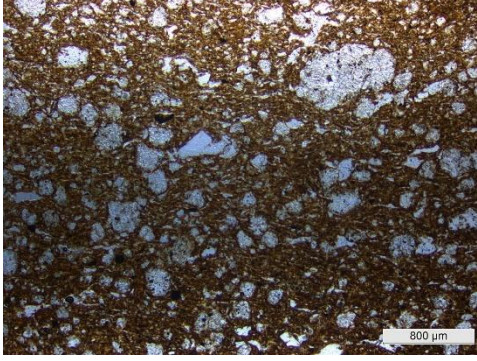
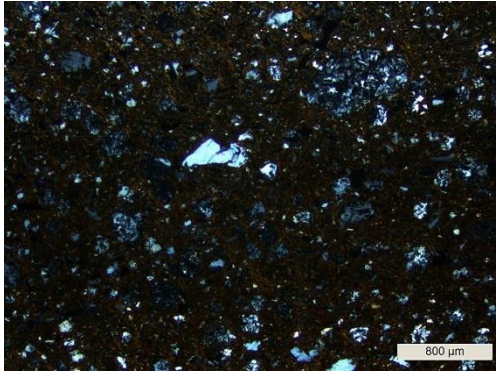
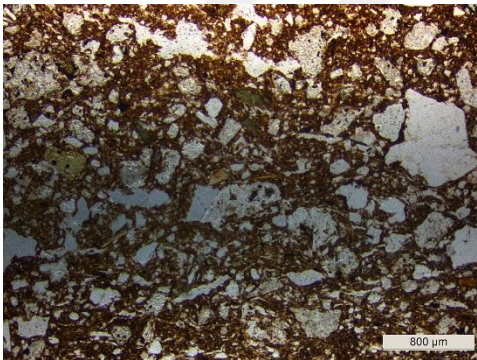
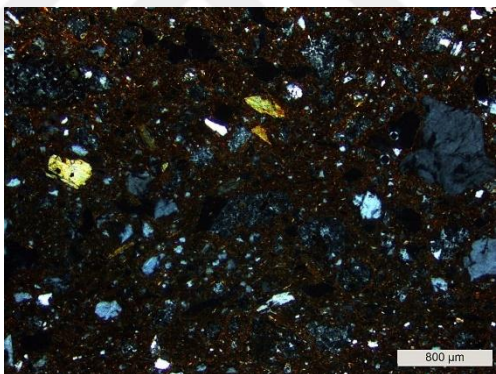
265 	
The outer surfaces were burnished. Micromass: light orange in PPL, orange in XPL, gives birefringence. Inclusion frequency: %25, Porosity: %3. Pores consist of vughs and thin planar voids. Inclusions: sub angular to rounded, < 0.2 mm to 1.2 mm, sp. Well sorted Rock fragments and individual mineral fragments (feldspar, quartz) derived from VRF (andesite): predominant, SRF (Ferruginous clay pellets): very few, Notes: Big pieces of biotite ~ 0.5mm.	
267 	
The outer surface was burnished and slipped; the inner surface was burnished. Micromass: light orange brown in PPL, light orange to red orange in XPL, gives birefringence. Inclusion frequency: % 30, porosity: %10. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, 0.2 mm to 3 mm, sphere to low sphere. Poorly sorted Rock fragments and individual mineral fragments (feldspar, hornblende, biotite) derived from VRF (rhyolitic/andesitic) rocks: frequent, Mineral fragments (feldspar, quartz, hornblende, mica) derived from PRF (diorite): frequent, SRF (Ferruginous clay pellets, sandstone): very few. MRF (Schist): few, Notes: Andesites with hornblende phenocryst. Free green hornblende minerals > 0.4 mm	

Table B.1 (continued)

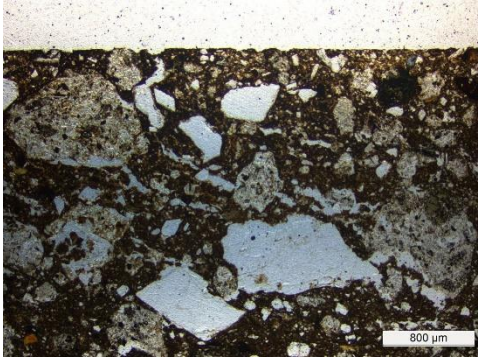
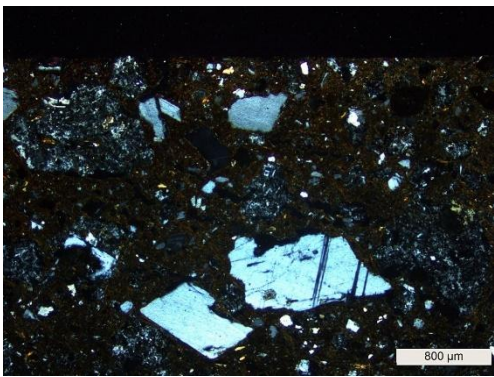
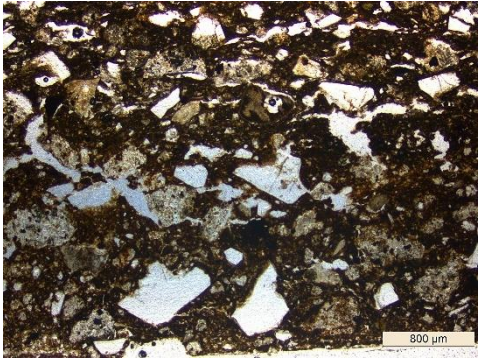
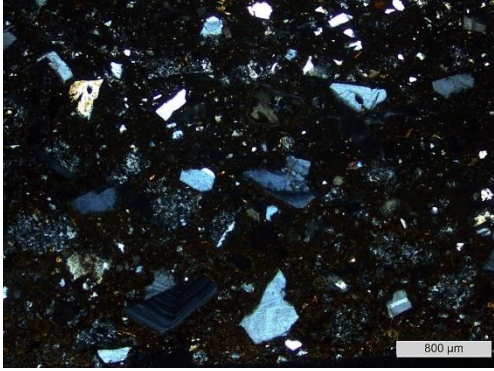
319 	
The inner surface was burnished and slipped, and the outer surface was smoothed. Micromass: light orange brown to brown in PPL, light orange to red orange in XPL, gives birefringence. Inclusion frequency: %30, porosity: %15. Pores mostly consists of vughs. Inclusions: very angular to sub rounded, < 0.2 mm to 3 mm, sphere to low sphere. Very poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, pyroxene, biotite) derived from VRF (andesite): dominant. Mineral fragments (Feldspar, quartz, hornblende, mica) derived from PRF (diorite): common, SRF (Ferruginous clay pellet): very few. Notes: Apatite on plagioclases and altered plagioclases exist.	
320 	

Table B.1 (continued)

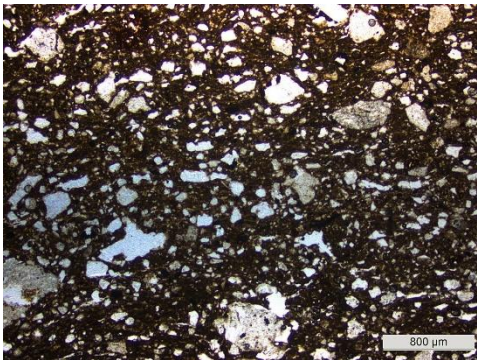
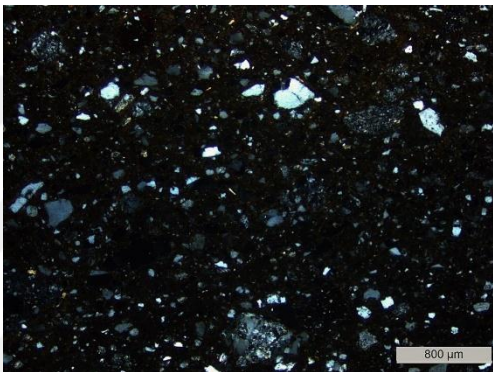
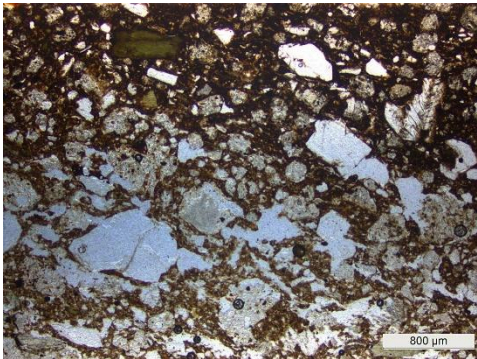
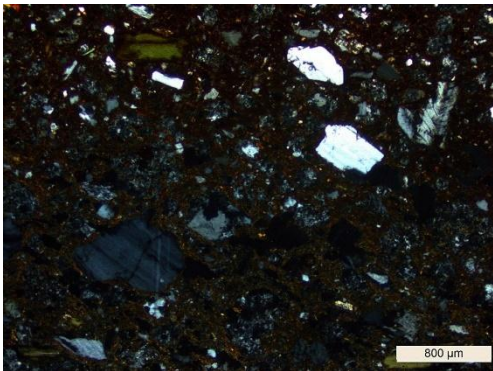
Slipped and burnished. Micromass: Margins are orange brown; core is brown in PPL. Margins are orange/brown, and the core is grey brown in XPL, gives a slight birefringence on the margins. Inclusion frequency: %30, porosity: %15. Pores mostly consist of vughs and planar voids. Inclusions: very angular to sub rounded, <0.2 mm to 4 mm, sphere to low sphere. Poor sorting. Rock fragments and individual mineral fragments (quartz, plagioclase, hornblende, pyroxene, biotite) derived from VRF (andesite): predominant, mineral fragments (Feldspar, quartz, hornblende, mica) derived from PRF (diorite): common, SRF (clay pellet, siltstone etc.): very few. Big elongate voids.	
321 	
Rough surface. Micromass: Margins orange brown, core dark brown in PPL. Margins orange /light brown, core grey brown in XPL, gives birefringence in the zones, a slight birefringence in the core. Inclusion frequency: %30, Porosity: %10. Pores mostly consist of vughs. Inclusions: angular to sub rounded, < 0.2 mm to 2.3 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica) derived from VRF (andesite): frequent, SRF (Ferruginous clay pellet, sandstone/siltstone, chert): common, MRF (schist): common,	
322 	

Table B.1 (continued)

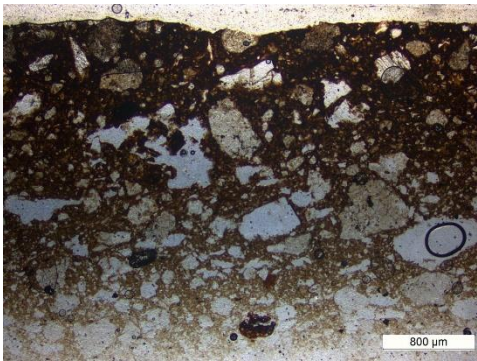
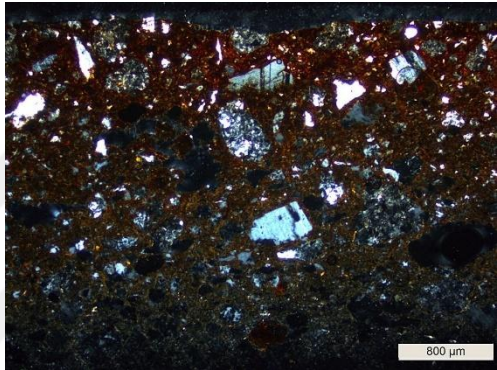
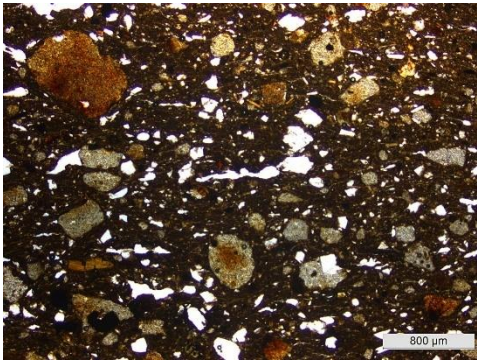
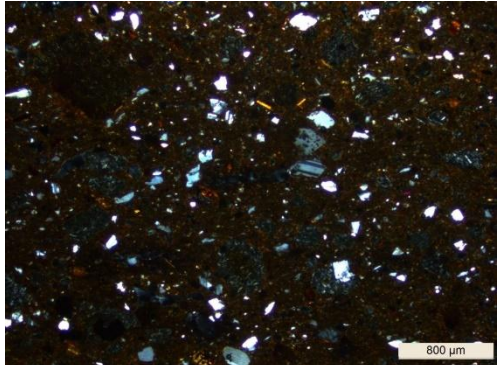
Rough surface, micromass: orange brown in PPL, red orange in XPL, gives birefringence. Inclusion frequency: %40, Porosity: %15, Pores mostly consist of vughs and planar voids. Inclusions: very angular to sub rounded, < 0.2 mm to 2.2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica) derived from VRF (andesite): dominant, Mineral fragments (feldspar, quartz, hornblende, mica) derived from PRF (diorite): frequent, SRF (Chert/chalcedony, sandstone): very few, MRF (Shist): few. Notes: Elongate pores are apparent.	
323 	
Slipped and burnished outer surface. Micromass: dark orange brown in PPL, red orange in XPL, gives birefringence. Inclusion frequency: %25, Porosity: %5. Pores consist of vughs and planar voids. Inclusions: very angular to rounded, < 0.2 mm to 1 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica) derived from rhyolitic to andesitic rock fragments: dominant. Mineral fragments (feldspar, mica, quartz) derived from PRF (diorite): common, SRF (Clay pellets): very few	
324 	

Table B.1 (continued)

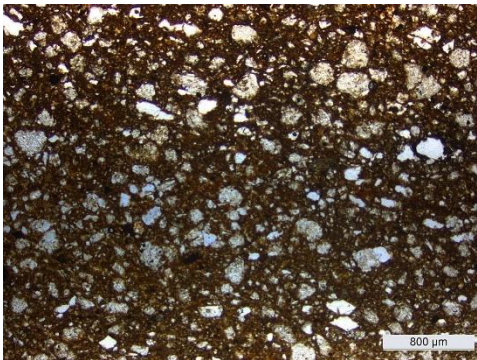
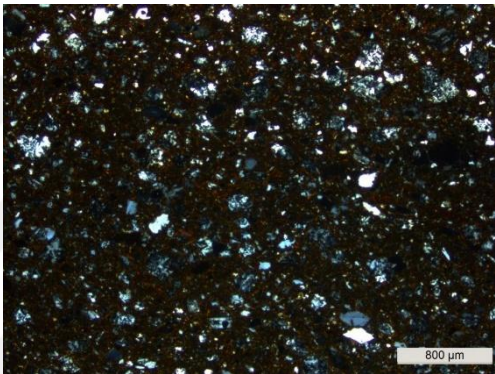
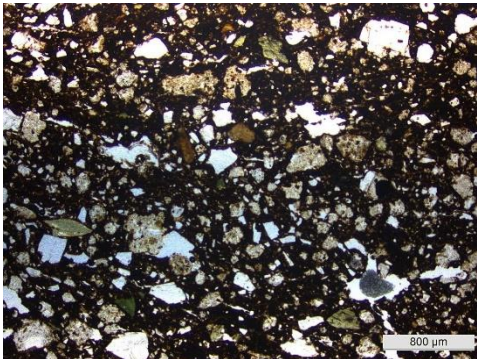
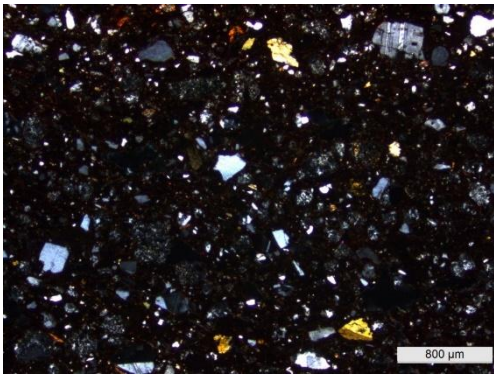
Burnished outer surface, smoothed inner surface, light to brown in PPL, light orange to red orange in XPL, gives a slight birefringence. Inclusion frequency: %25, Porosity: %12. Pores consist of vughs and thin planar voids. Inclusions: very angular to sub rounded, < 0.2 mm to 2.5 mm, sphere to low sphere. Poorly sorted, Rock fragments and individual mineral fragments (quartz, hornblende, feldspar, mica: biotite,) derived from VRF (rhyolitic / andesitic): predominant, SRF (Clay pellets, limestone): few, MRF Schist: very rare. Notes: Altered dark colored and glassy rock fragments exist. Voids indicating fiber remains.	
325 	
Smoothed outer surface, burnished and slipped? inner surface. Micromass: orange/orange brown in PPL, orange/reddish-orange in XPL, gives birefringence. Inclusion frequency: %40, porosity: %7. Pores consists of vughs. Inclusions: very angular to sub rounded, < 0.2 mm to 1 mm, sp. Well sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, mica) derived from VRF (andesite): predominant, SRF (Clay pellets): very rare, Organic residue: very few Notes: Elongate parallel voids may be due to a fiber residue.	
326 	

Table B.1 (continued)

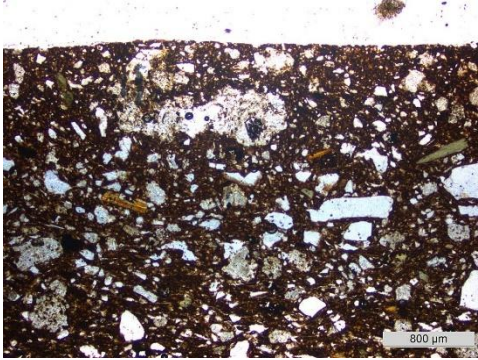
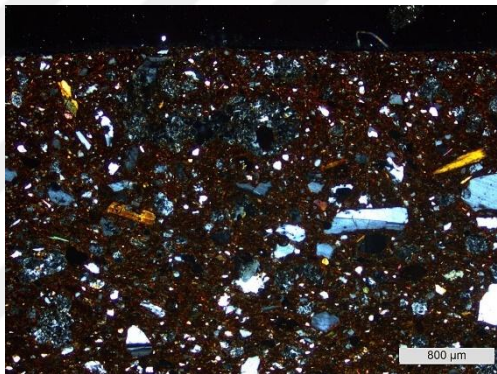
Slipped and smoothed outer surface, smoothed inner surface. Micromass: black brown in PPL, dark red brown in XPL. Inclusion frequency: %40, porosity: %10. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, < 0.2 mm to 2.5 mm, sphere. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, mica, pyroxene) derived from VRF (andesite): predominant. Mineral fragments (plagioclase, mica, hornblende, quartz) derived from PRF (diorite): common, SRF (claystone/Mudstone, sandstone): few, MRF (schist): rare. Notes: Andesites with hornblende and plagioclase phenocrysts. Free green hornblendes and biotite are prevalent in the paste.	
327 	
Burnished outer and inner surfaces. Micromass: rusty brown in PPL, orange brown in XPL, gives birefringence. Inclusion frequency: %25, porosity: %12. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, < 0.2 mm to 2.5 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, mica) derived from VRF (andesite): dominant. Mineral fragments (plagioclase, mica, hornblende, quartz, pyroxene) derived from PRF (diorite): frequent, SRF (Limestone): rare, MRF (Schist): very few, Organic residue: rare. Notes: Andesites with hornblende phenocrysts. Elongate void due to a fiber residue (plant remnant) and biotite near the surface. Green hornblendes exist.	

Table B.1 (continued)

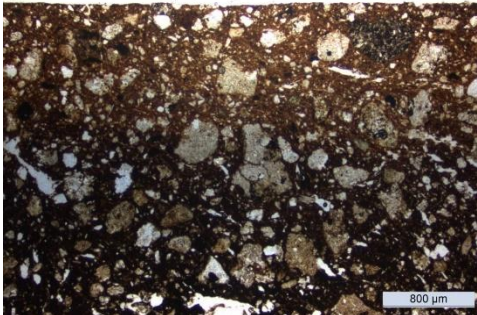
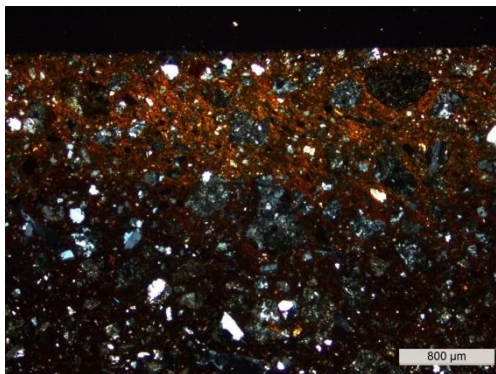
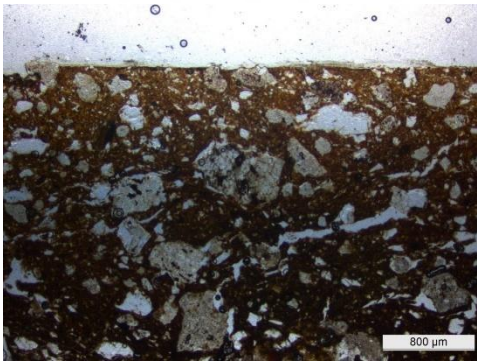
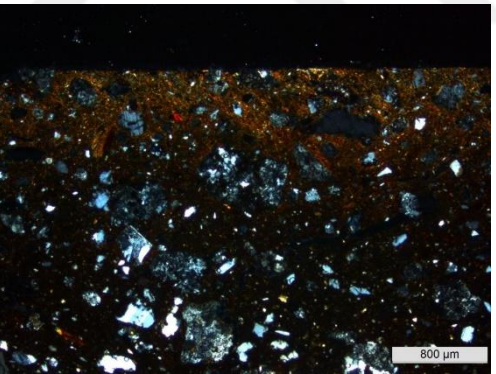
328 	
Smoothed outer surface and slipped and smoothed inner surface. Micromass: Margins orange, towards core brown in PPL. Margins reddish orange/light orange, core dark reddish brown in XPL. Partly gives birefringence especially margins. Inclusion frequency: %40, porosity: %7. Pores consist of vughs and planar voids. Inclusions: angular to sub rounded, < 0.2 mm to 3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, mica) derived from VRF (rhyolitic/andesitic): predominant, SRF (Clay pellet, sandstone, siltstone, etc.): few, Notes: Rhyolites with quartz phenocrysts (> 0.5mm). Sericite altered rock fragments exist.	
329 	

Table B.1 (continued)

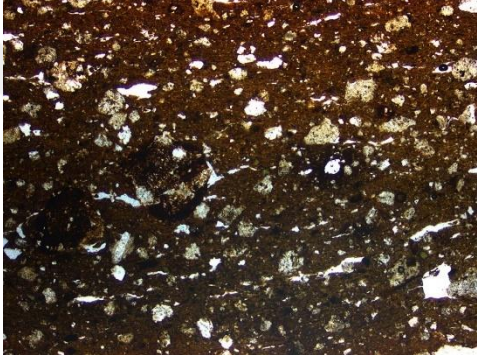
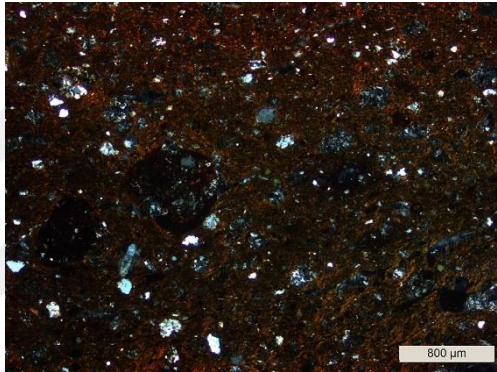
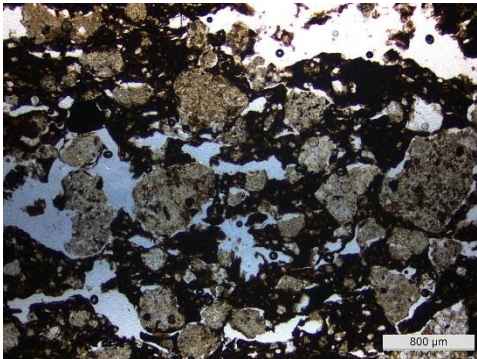
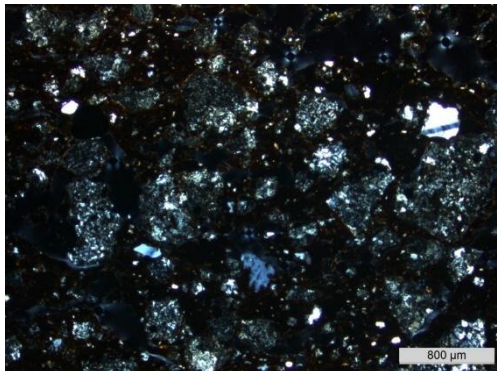
Outer surface is slipped? and both surfaces are smoothed. Micromass: Margins light orange, towards core brown/red brown in PPL, margins light orange, towards core dark reddish brown in XPL. gives a slight birefringence in core, gives birefringence on the margins. Inclusion frequency: %40, porosity: %5. Pores consist of vughs and thin planar voids. Inclusions: very angular to sub rounded, < 0.2 mm to 2.3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende) derived from VRF (andesitic): dominant. Mineral fragments (feldspar, mica, quartz, pyroxene) derived from PRF (Granodioritic): common, SRF (Phyllite, Mudstone, Chert etc.): few, Organic residue: very few.	
330 	
Both surfaces are smoothed. Micromass: margins light brown, towards core reddish brown in PPL. Margins light orange, core orange in XPL, gives birefringence. Inclusion frequency: %25, porosity: %10. Pores consists of vughs, planar voids and rare vesicles. Inclusions: sub angular to sub rounded, < 0.2 mm to 2.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende) derived from VRF (rhyolitic/andesitic): dominant, SRF (Clay pellet: few, Fiber (Organic) residue: very few. Fine clay matrix.	
331 	

Table B.1 (continued)

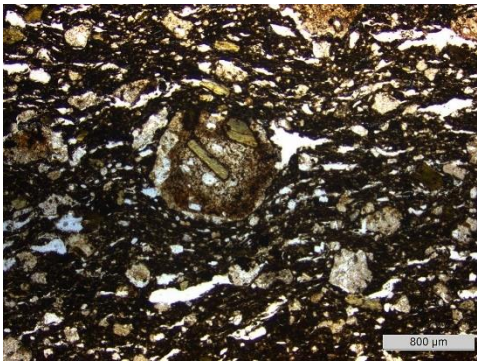
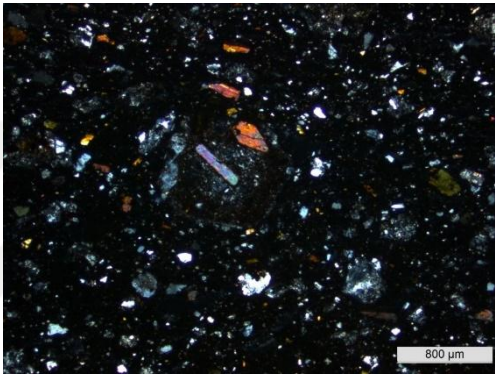
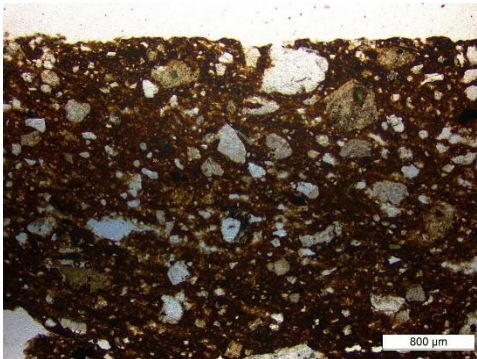
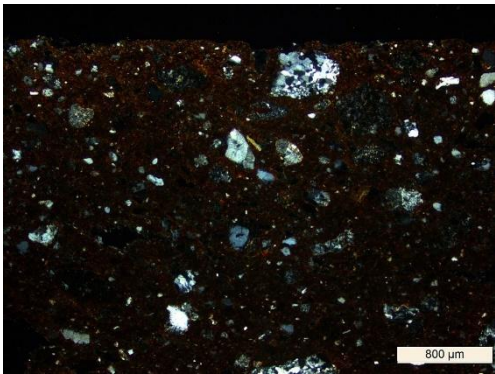
Slipped and smoothed outer surface, slipped? and smoothed inner surface. Micromass: dark brown in PPL, margins light orange, towards core dark reddish brown in XPL, gives a very slight birefringence. Inclusion frequency: %45, porosity: %15. Pores mostly consist of vughs. Inclusions: sub angular to sub rounded, < 0.2 mm to 2.7 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende) derived from VRF (rhyolitic/andesitic): predominant. Mineral fragments (feldspars, quartz) derived from PRF (diorite): few, SRF (Mudstone): very few	
332 	
Rough and slipped outer surface, slipped and smoothed inner inner surface. Micromass: margins light orange towards core greyish brown in PPL. Margins orange, towards core dark reddish brown in XPL. Margins gives birefringence. Inclusion frequency: %30, porosity: %15. Pores consist of vughs and planar voids. Inclusions: sub angular to sub rounded, 0.2 mm to 2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, derived from VRF (andesitic): dominant, SRF (Mudstone, limestone, ferruginous clay pellet, etc.): few, Grog: rare.	
333 	

Table B.1 (continued)

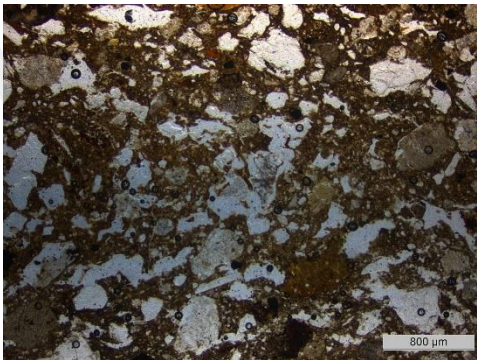
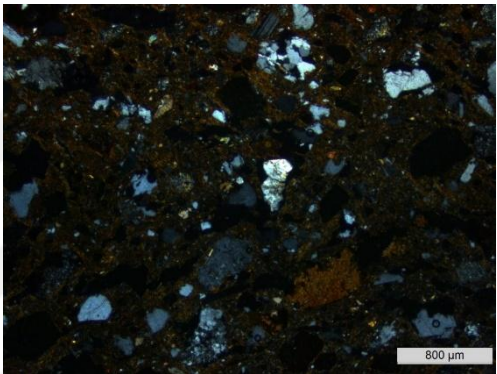
Rough outer surface and smoothed inner surface. Micromass: margins orange brown, towards core brown in PPL. Margins reddish orange, towards core brownish orange in XPL, gives birefringence on the margins. Inclusion frequency: %30, porosity: %12. Pores consist of vughs and planar voids. Inclusions: sub angular to rounded, < 0.2 mm to 2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende) derived from VRF (rhyolitic/andesitic): frequent, SRF (sandstone, mudstone, limestone, clay pellet): common, MRF (Schist): common	
334 	
Burnished and smoothed outer surface, rough inner surface. Micromass: reddish brown / brown in PPL, red orange / light orange in XPL, gives birefringence. Inclusion frequency: %35, porosity: %12. Pores consist of vughs and planar voids. Inclusions: very angular to rounded, 0.2 mm to 2.3 mm, sphere to low sphere. Poorly sorted Glassy volcanic rocks, rock fragments and individual mineral fragments (quartz, feldspar, mica, pyroxene) derived from (rhyolitic/andesitic): common. MRF (Granodiorite fragments undergone to faulting dynamo metamorphism; tiny gritty quartz and oriented micas): frequent, SRF (sandstone, Limestone, Mudstone, chert): frequent Notes: mylanitization due to dynamic metamorphism of granodiorite. Some rocks are very altered.	

Table B.1 (continued)

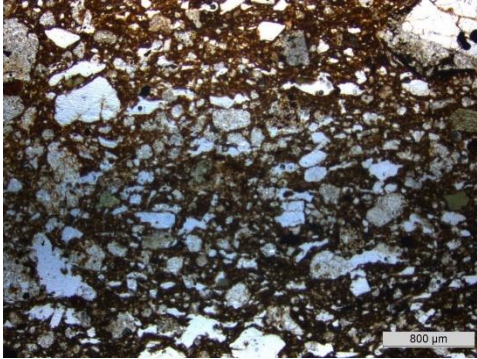
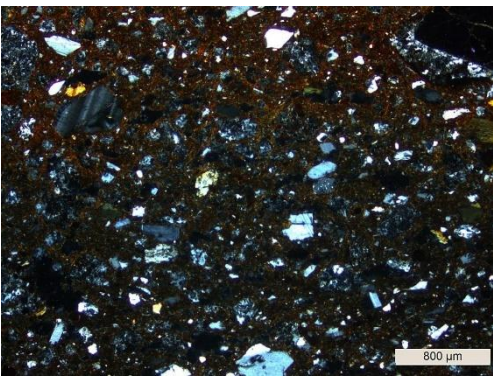
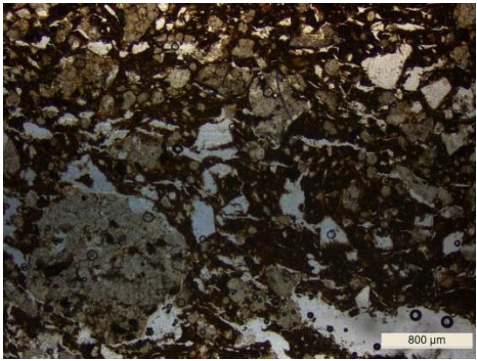
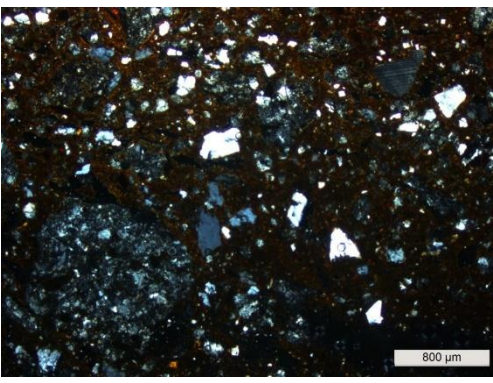
335 	
Both surfaces are rough. Micromass: margins brownish orange, towards core brown in PPL. Margins reddish orange, towards core greyish brown in XPL, gives birefringence. Inclusion frequency: %30, porosity: %10. Pores consist of vughs. Inclusions: very angular to rounded, 0.2 mm to 2.5 mm, sphere to low sphere. Poorly sorted, Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene, mica) derived from VRF (rhyolitic/andesitic): dominant. Mineral fragments (feldspar, hornblende, quartz) derived from PRF (Granodioritic): frequent, SRF (Clay pellet, Limestone, mudstone): very few, MRF (shist): very few. Fiber (organic) residue and green hornblendes exist.	
Phase IV	
162 	

Table B.1 (continued)

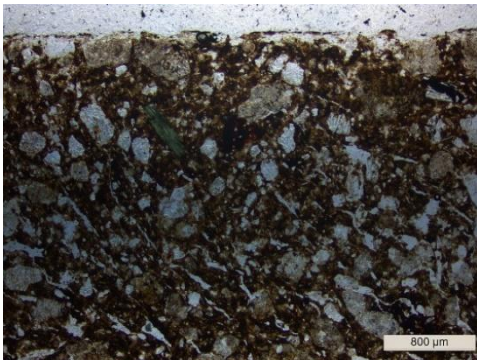
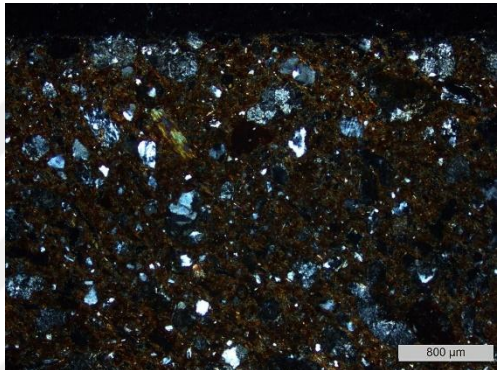
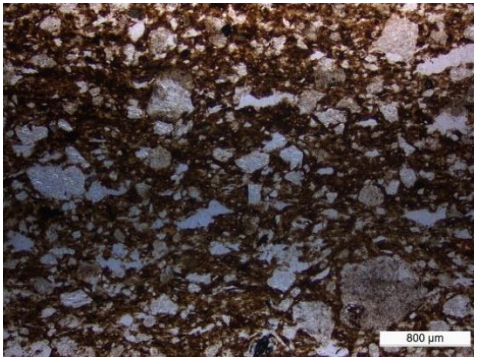
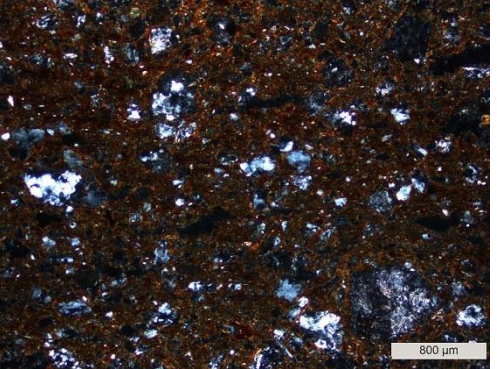
Both surfaces are smoothed. Micromass: surface brown, core dark grey in PPL, surface dark orange, towards core dark brown in XPL, gives birefringence towards margins. Inclusion frequency: %40, porosity: %10. Pores consist of vughs, planar voids. Inclusions: very angular to sub rounded, 0.2 mm to 3.2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (feldspar, hornblende, quartz, biotite) derived from VRF (Rhyolitic/Andesitic): predominant, SRF (Siltstone/mudstone, clay pellet): very few, limestone: very rare. Notes: Andesites with hornblende and feldspar phenocrysts exist	
168 	
Both surfaces are slipped and burnished, very thin layer of dark slip is observed. Micromass: red orange in PPL, brown XPL, gives birefringence. Inclusion frequency: %25, porosity: %7. Pores consist of vughs, planar voids. Inclusions: angular to sub rounded, 0.2 mm to 2.3 mm, sphere to low sphere. Poorly sorted, Rock fragments and individual mineral fragments (feldspar, quartz, hornblende, mica) derived from VRF (Rhyolitic to Andesitic): frequent, MRF (Schist): frequent, SRF (claystone, clay pellet): very few.	
172 	

Table B.1 (continued)

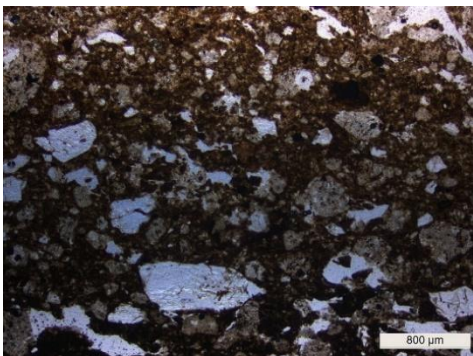
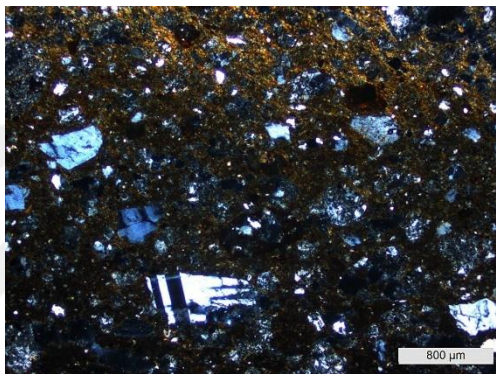
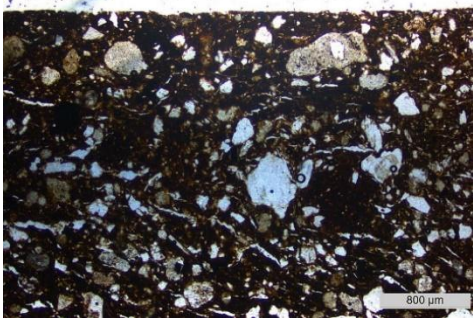
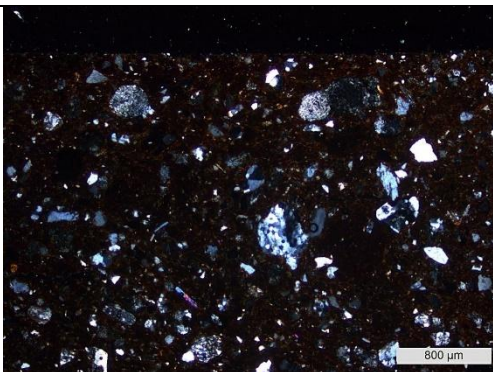
Smoothed and slipped surface. Micromass: light brown in PPL, orange red orange in XPL, gives birefringence. Inclusion frequency: %25, porosity: %10. Pores consist of vughs, planar voids and few vesicles. Inclusions: very angular to sub rounded, 0.2 mm to 4 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (feldspar, quartz, mica) derived from VRF (Rhyolitic to Andesitic; mostly): predominant, SRF (Claystone): few, Notes: Some mineral fragments are fractured.	
178 	
Burnished inner surface and partly smoothed, partly rough outer surface. Micromass: Margins light brown/red brown towards core dark brown in PPL. Margins light orange to red orange, towards core red brown in XPL. Margins gives birefringence. Inclusion frequency: %40, porosity: %10. Pores consist of vughs. Inclusions: very angular to sub rounded, <0.2 mm to 2 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (feldspar, quartz, hornblende, mica) derived from VRF (Rhyolitic to Andesite): dominant. Individual mineral fragments (feldspar, quartz, hornblende, mica) derived from PRF: few, SRF (ferruginous clay pellet, sandstone): very few, Notes: Some rock fragments are altered and stained. Andesites have opaque particle phenocrysts.	
185 	

Table B.1 (continued)

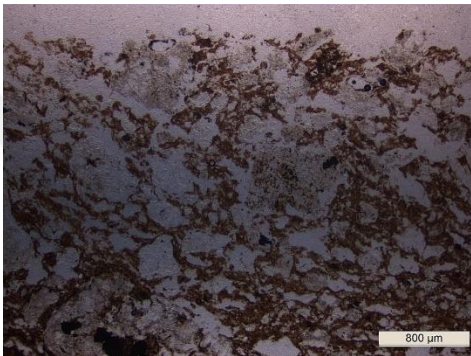
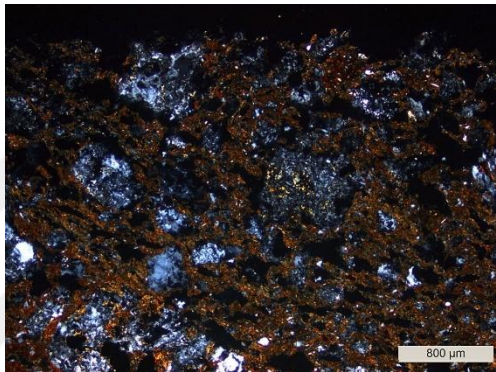
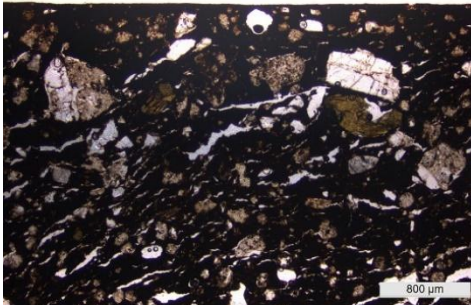
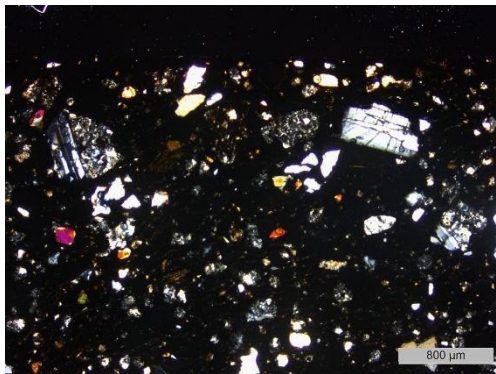
Burnished inner and outer surfaces. Micromass: orange brown in PPL, red orange in XPL, gives birefringence. Inclusion frequency: %35, Porosity: %10. Pores consist of vughs and mostly planar voids. Inclusions: very angular to sub rounded, <0.2 mm to 3.5 mm, sphere to low sphere. Poorly sorted Rock fragments and individual mineral fragments (feldspar, quartz, mica) derived from VRF (Rhyolitic/Andesitic): dominant, MRF (Schist): common, SRF (Claystone, mudstone, siltstone, clay pellet): very few	
221 	
Both surfaces are smoothed. Micromass: Surfaces orange brown, core grey brown in PPL. Surfaces orange to red orange, core orange brown in XPL, gives birefringence on the margins, core gives a very slight birefringence. Inclusion frequency: %45, Porosity: %12. Pores consist of vughs, planar voids and few vesicles. Inclusions: very angular to sub rounded, 0.3 mm to 3 mm, sphere to low sphere moderately sorted. Rock fragments and individual mineral fragments (Quartz, Feldspars) derived from VRF (Andesitic): predominant, MRF (Schist): few, SRF (chert): rare Notes: Some rock fragments are altered.	
222 	

Table B.1 (continued)

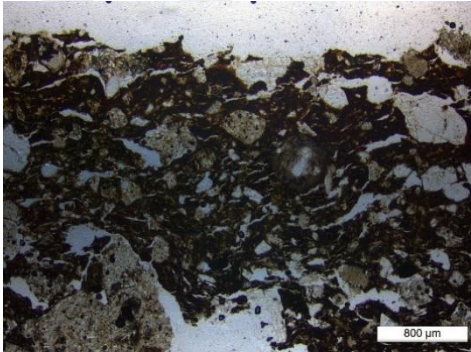
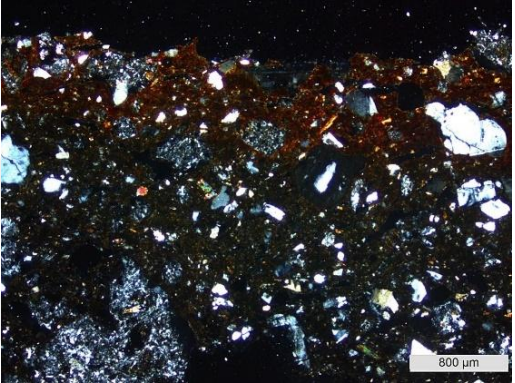
Burnished, probably slipped surfaces. Micromass: black-brown in PPL, dark brown in XPL, gives a slight birefringence. Inclusion frequency: %40, porosity: %10. Pores consist mostly planar voids. Inclusions: very angular to sub rounded, 0.2 mm to 3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspars, amphibole and mica) derived from VRF (Andesitic): predominant. Individual mineral fragments (Quartz, Plagioclase, amphibole and mica) derived from PRF (granodioritic): few Notes: Andesites with big plagioclase phenocrysts, some have amphibole phenocrysts. Some mineral fragments are fractured. Green hornblendes exist.	
223 	
Rough surface. Micromass: Margins are light brown/red brown, and the core is black-brown in PPL. Margins are dark brown/red brown, the core is black brown in XPL. Slightly OA near margins. Inclusion frequency: %35, porosity: %15. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, 0.3 mm to 2 mm, sphere to low sphere. Poorly sorted Rock fragments and individual mineral fragments (quartz, pyroxene, hornblende, biotite) derived from VRF (Rhyolitic to Basaltic andesitic): dominant. Individual mineral fragments (Quartz, Feldspar, amphibole and mica) derived from PRF (granodioritic): common, MRF: few Notes: Some andesites with amphibole and pyroxene phenocrysts exist. Mineral fragments are fractured. Green hornblendes.	

Table B.1 (continued)

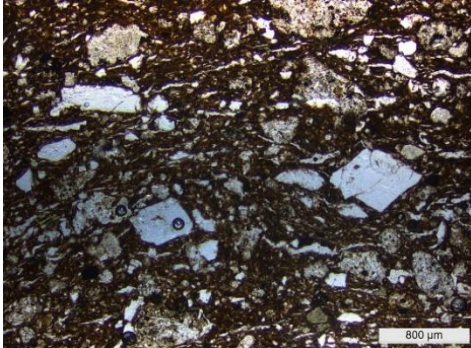
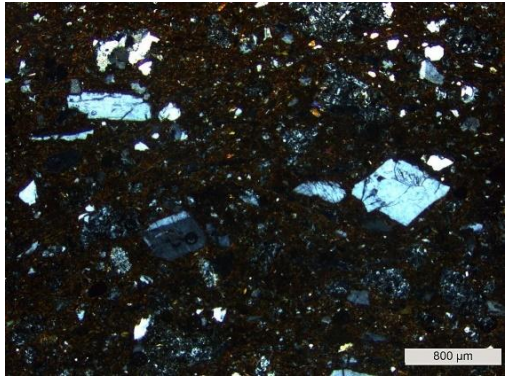
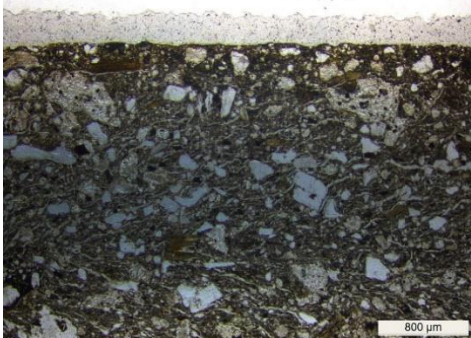
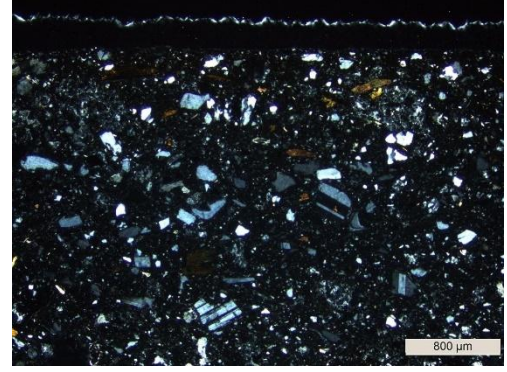
227 	
Burnished surfaces and slipped outer surface. Micromass: light brown to dark red brown from margins to the core in PPL. Light orange to dark red orange to from margins to the core in XPL, gives birefringence. Inclusion frequency: %40, Porosity: %5. Pores consist mostly of planar voids. Inclusions: sub angular to sub rounded, 0.4 mm to 3.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (hornblende, quartz, feldspar, pyroxene) derived from VRF (Andesitic/Basaltic andesitic): dominant. Individual mineral fragments (Quartz, Feldspar, hornblende and mica) derived from PRF (granodioritic): common, SRF (Clay pellet, marl, calcedony): very few Notes: Andesites with pyroxene, amphibole and big plagioclase (>1mm) phenocrysts. Organic remnants, green hornblendes and altered feldspars exist.	
234 	

Table B.1 (continued)

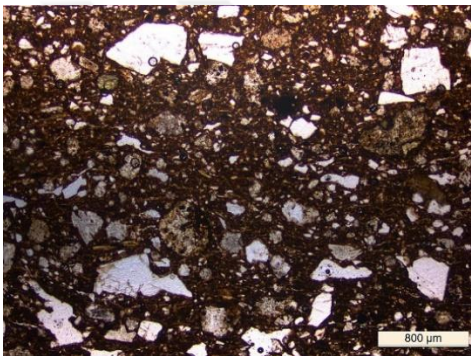
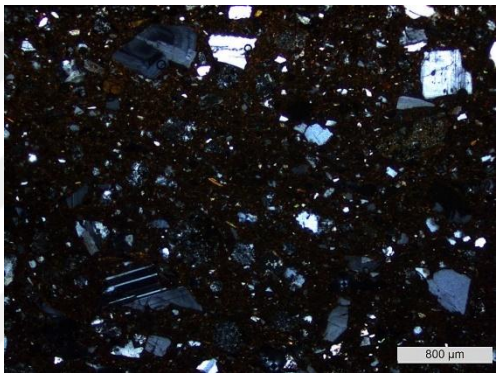
Partly burnished, smoothed and slipped surface. Micromass: light grey in PPL, dark grey in XPL. Inclusion frequency: %40, porosity: %7. Pores consist mostly planar voids and vughs. Inclusions: very angular to sub rounded, 0.3 mm to 2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (feldspar, plagioclase, hornblende, quartz and mica) derived from VRF (Andesitic): dominant. Mineral fragments (quartz, feldspars, quartz, hornblende and mica) derived from PRF (granodioritic): common, MRF (Schist): few, SRF (clay pellet): very few, grog: very few Notes: Andesites with hornblende and plagioclase phenocrysts. Andesitic rock fragments with glassy groundmass. Tiny fragments (<0.2mm) in clay matrix high in amount.	
305 	
Burnished outer surface and smoothed inner surface. Micromass: light brown to red brown in PPL. Orange to red orange in XPL, gives birefringence. Inclusion frequency: %30, porosity: % 5. Pores consist of mostly vughs. Inclusions: very angular to sub angular, 0.3 mm to 2.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (feldspar, hornblende, quartz) derived from VRF (Andesitic): dominant. Mineral fragments (quartz, feldspar, mainly plagioclase, hornblende, mica) derived from PRF (granodioritic): common, MRF (Schist): very few, SRF (Siltstone/mudstone, chert, clay pellet): very few. Notes: Andesites are stained and have Plagioclase and K-feldspar phenocrysts.	

Table B.1 (continued)

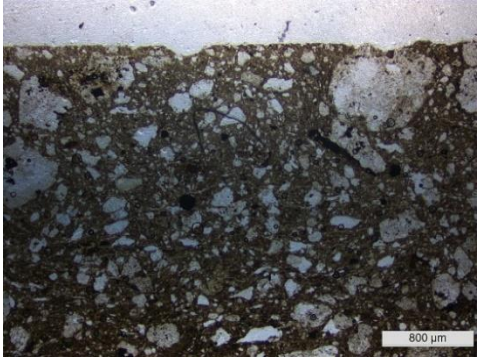
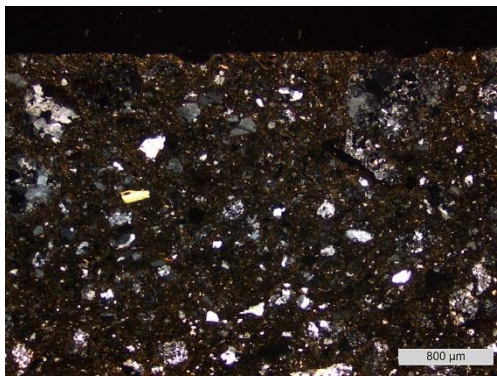
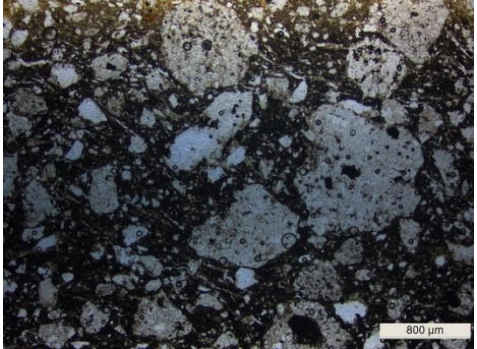
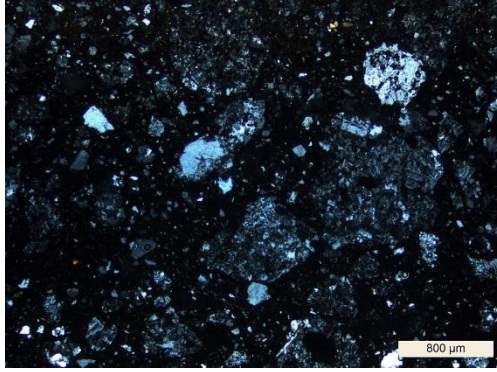
306 	
Burnished inner surface and smoothed outer surface. Micromass: margins light red orange, core light brown, in PPL. Margins orange-red, core orange-brown in XPL, gives birefringence. Pores consist of planar voids and vughs. Inclusion frequency: %40, porosity: %7, Inclusions: very angular to sub angular, 0.2 mm to 7 mm, sphere to low sphere. Very poorly sorted. Rock fragments and individual mineral fragments (quartz, hornblende, mica) derived from VRF (Rhyolitic prevalent/Andesitic): dominant, MRF (Schist): common, SRF (Sandstone/siltstone/marl/chert): few Notes: Hematite stained and altered rock fragments (sericitized claystone?) exist. Also, fiber (organic) remains exist.	
307 	

Table B.1 (continued)

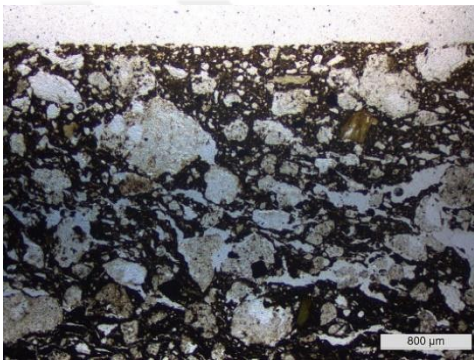
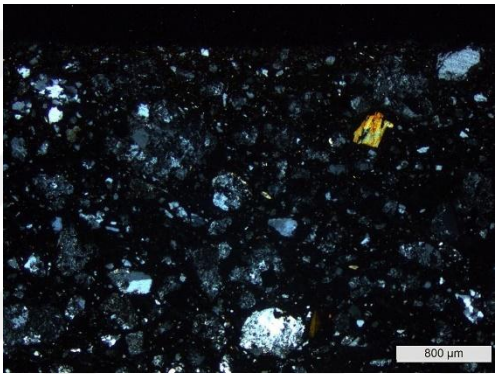
Rough outer surface, well smoothed/burnished inner surface. Micromass: red orange/light orange margins, towards core brown/dark grey orange in PPL. Margins light brown/red brown, towards core dark red black in XPL, only gives a slight birefringence on the margin. Inclusion frequency: %40, Porosity: %7. Pores consist of planar voids and vughs. Inclusions: very angular to sub angular, 0.3 mm to 3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (rhyolitic/andesitic): predominant, MRF (Schist): very few, SRF (sandstone): very few Notes: Rock and mineral fragments are generally altered and stained due to hematite. Amphibole: brown, probably altered. Andesites with brown hornblende phenocrysts exist.	
308 	
Burnished surfaces. Micromass: Margins light brown towards core dark brown in PPL, dark red brown in XPL. Inclusion frequency: %40, porosity: %15. Pores consist of planar voids and vughs. Inclusions: very angular to sub rounded, <0.2 mm to 2.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (rhyolitic to andesitic): dominant, MRF (Schist): very few, SRF (sandstone, clay pellet): few, Notes: Andesites with hornblende phenocrysts, and silicified, sericitized groundmass exist. Green hornblendes exist.	

Table B.1 (continued)

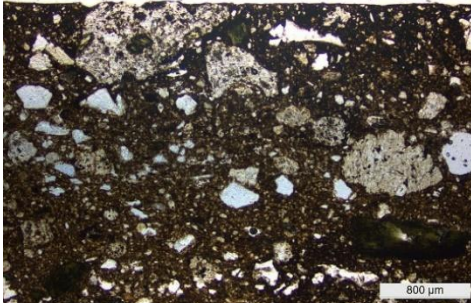
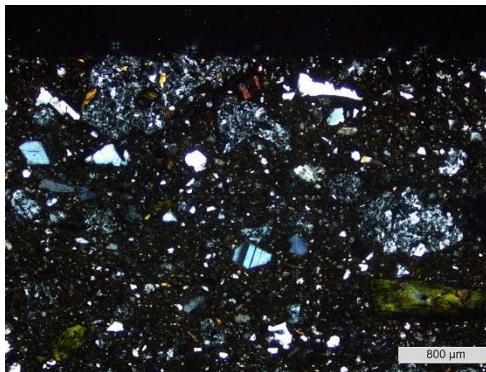
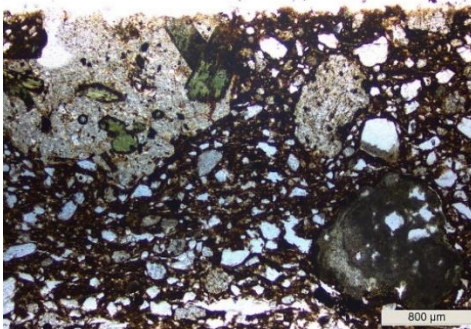
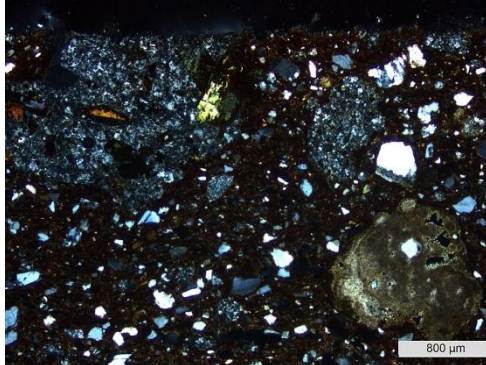
309 	
Burnished outer surface, burnished and slipped inner surface. Micromass: margins light brown, towards core darker brown in PPL, dark brown in XPL, gives a slight birefringence. Inclusion frequency: %35, porosity: %5. Pores consist of vughs. Inclusions: very angular to sub rounded, <0.2 mm to 2.3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene) derived from VRF (Andesitic / Basaltic): dominant. Mineral fragments (quartz, Feldspar, mainly Plagioclase, Quartz, Hornblende, Mica) derived from PRF (dioritic): few MRF (Schist): very few, SRF (Ferruginous clay pellet, marl): very few. Notes: Andesites with hornblende and pyroxene phenocryst and zoned plagioclase (>1mm) fragments and green hornblendes exist.	
310 	

Table B.1 (continued)

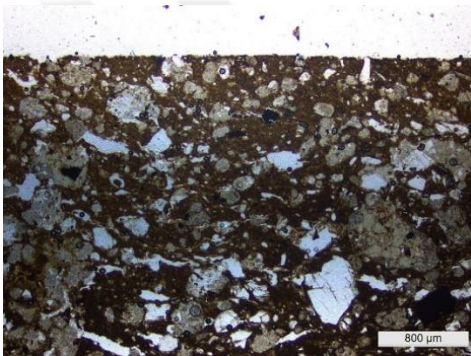
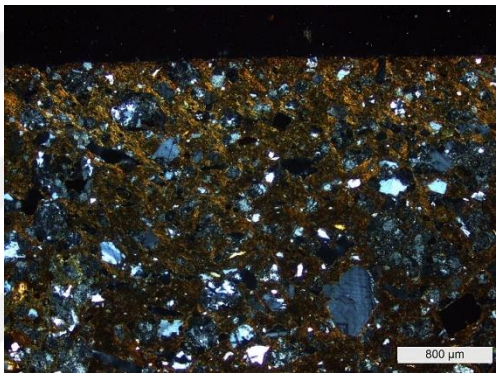
Well smoothed outer surface and rough inner surface. Micromass: red-brown in PPL, red-orange in XPL, outer margin is thinly black brown, gives birefringence. Inclusion frequency: %40, Porosity: %15. Pores consist of vughs. Inclusions: very angular to sub rounded, 0.2 mm to 3.5 mm, sphere to low sphere. Poorly sorted Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene) derived from VRF (Andesitic): frequent. Mineral fragments (quartz, feldspar, plagioclase, quartz, hornblende) derived from PRF (granodioritic): few, SRF (Micritic limestone, sandstone, mudstone, clay pellet, chert): frequent, MRF (Schist): few. Notes: Andesite with very big amphibole and pyroxene phenocrysts exist.	
311 	
Burnished inner surface and smoothed outer surface. Micromass: margins orange brown, core brown in PPL, red orange/orange in XPL, gives birefringence. Inclusion frequency: %35, porosity: %15. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, 0.2 mm to 1.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene) derived from VRF (rhyolitic/andesitic): predominant. Mineral fragments (quartz, feldspar, plagioclase, hornblende) derived from PRF (granodioritic): few, Notes: Rock and mineral fragments are generally altered, stained. Fine clay matrix. Green hornblendes exist	

Table B.1 (continued)

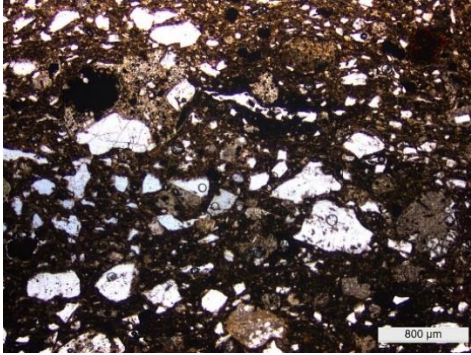
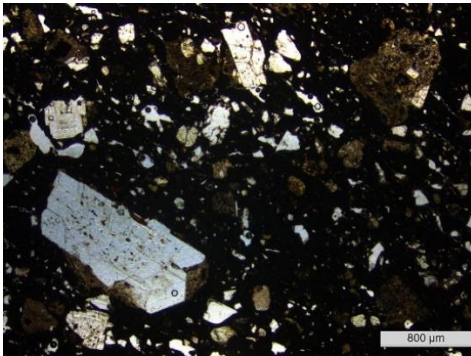
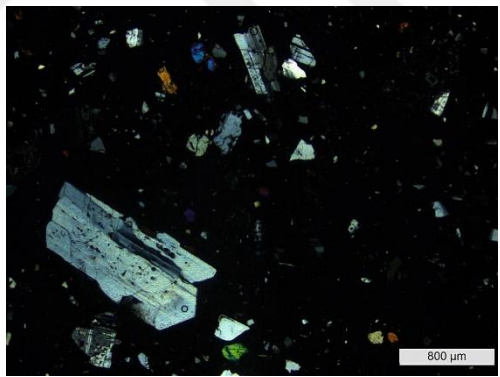
312 	
Burnished inner surface and smoothed outer surface. Micromass: Margins grey brown towards core brown in PPL. Dark grey margins, towards core black brown in XPL. Inclusion frequency: %40, porosity: %15. Pores consist of vughs. Inclusions: very angular to sub rounded, 0.3 mm to 4 mm, sphere to low sphere. Poor sorting. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende, pyroxene) derived from VRF (basaltic andesitic): predominant, SRF (Ferruginous clay pellets): very few, Notes: Altered rock fragments, zoned plagioclase (~ 2 mm) fragments and fiber (charred plant) remains exist.	
313 	
Slipped and burnished inner surface and rough/wavy outer surface. Micromass: light brown margins, black-brown core in PPL. Margins dark grey, core brownish black in XPL. Inclusion frequency: %40 Porosity: %10. Pores consist of vughs and planar voids. Inclusions: sub angular to rounded, 0.3 mm to 6 mm, sphere to low sphere. Poor sorting. Rock fragments and individual mineral fragments (hornblende, pyroxene, mica and prevalently plagioclase) derived from VRF (basaltic andesitic): predominant, SRF (Ferruginous clay pellets): very few, Notes: Andesite with pyroxene and plagioclase (~ 1-2 mm) phenocrysts.	

Table B.1 (continued)

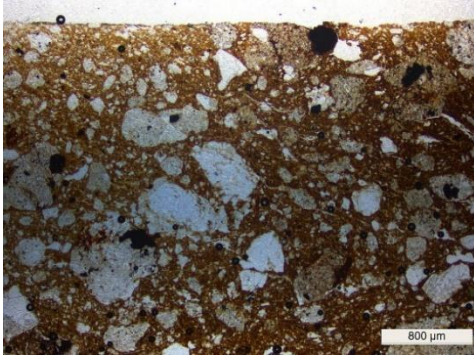
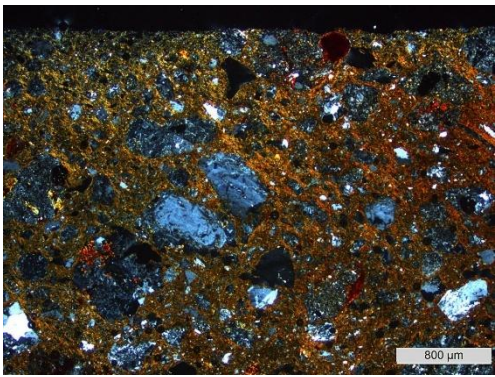
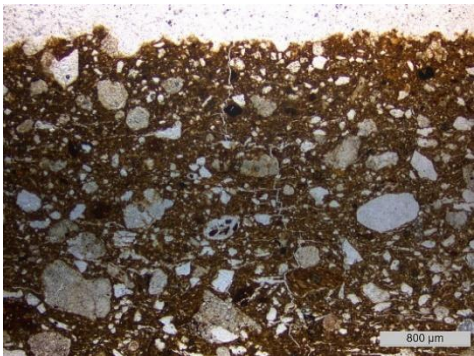
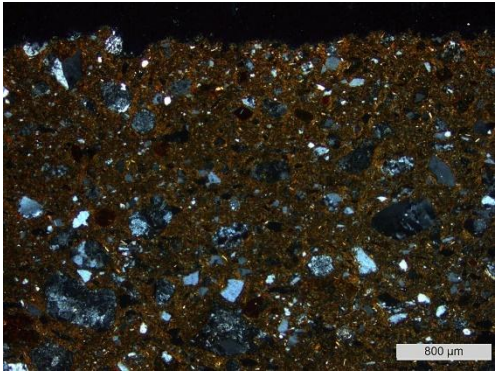
314 	
Both surfaces are well smoothed. Micromass: light orange margins, brown orange core in PPL. Margins orange, towards core reddish orange in XPL, gives birefringence. Pores consist of vughs and planar voids. Inclusion frequency: %40, porosity %10. Inclusions: very angular to sub rounded, 0.4 mm to 3.5 mm, sp. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (andesitic): predominant, SRF (VRF and sand grains enclaved by ferruginous pellet): common. Notes: fragment sphericity is high in general. The iron ratio is high, some rock fragments are sericitized. The elongated void due to fiber (charred plant) remains and VRF with green hornblende phenocryst exist.	
315 	

Table B.1 (continued)

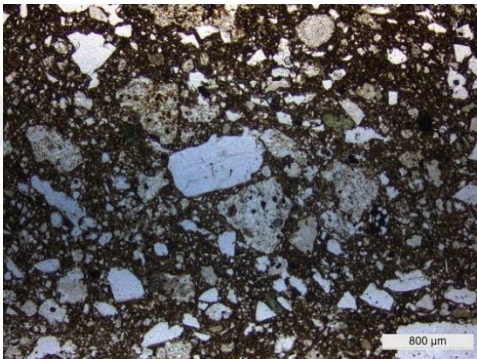
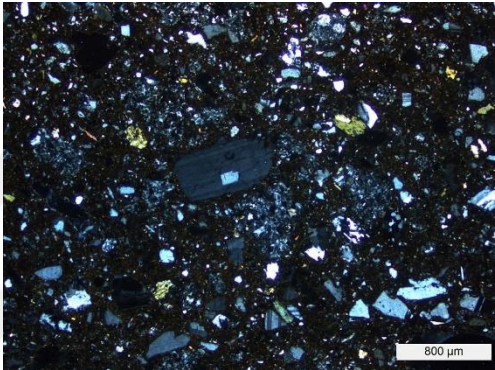
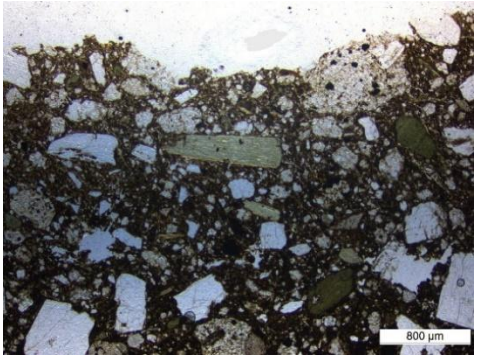
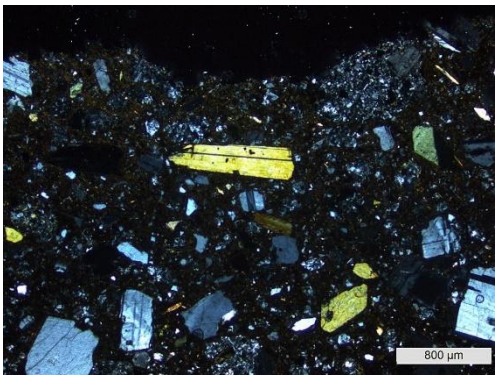
Smoothed outer surface and burnished inner surface. Micromass: light orange brown in PPL, orange in XPL, gives birefringence. Inclusion frequency: %40, porosity: %10. Pores consist of vughs and planar voids. Inclusions: very angular to sub angular, <0.2 mm to 2.3 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (Rhyolitic prevalently/Andesitic): dominant, SRF (Ferruginous clay pellet, mudstone and sandstone): common, MRF (Schist): common,	
316 	
Burnished outer surface and smoothed inner surface. Micromass: brown in PPL, orange brown in XPL, gives a slight birefringence. Inclusion frequency: %50 porosity: %7. Pores consist of vughs. Inclusions: very angular to sub rounded, 0.3 mm to 2.2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (Andesitic): dominant. Mineral fragments (quartz, feldspar, plagioclase, hornblende, mica) derived from PRF (granodioritic): common, MRF (schist): very few Notes: Andesites with hornblende phenocryst. Fiber remains and green hornblendes exist	
317 	

Table B.1 (continued)

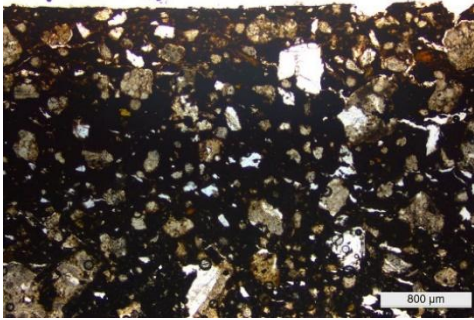
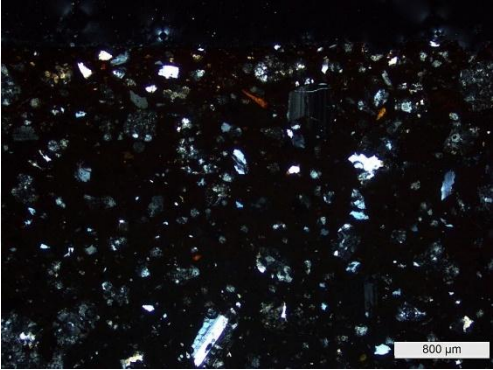
Rough surface. Micromass: margins light brown, core dark brown in PPL. Margins brown, towards core dark red brown in XPL, gives a slight birefringence on the margins. Inclusion frequency: %40 porosity: %5. Pores consist of vughs and planar voids. Inclusions: very angular to sub rounded, 0.2 mm to 4 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (Andesitic): dominant. Mineral fragments (quartz, feldspar, plagioclase, quartz, hornblende) derived from PRF (granodioritic): common, SRF (Marl, clay stone): rare, MRF (Schist): rare. Silty clay matrix, green hornblendes. Fiber remains exist. Notes: A thin void across the middle of the sample in the horizontal plane passes through the sample, maybe due to slab building. Andesites with quartz and hornblende phenocryst. Plant/shell temper remnants exist.	
318 	
Both surfaces are burnished and slipped. Micromass: Margins dark red, core dark grey black in PPL. Margins dark red brown, towards core reddish black in XPL. Inclusion frequency: %35, porosity: %7. Pores consist of vughs and thin planar voids. Inclusions: very angular to sub rounded, 0.4 mm to 3.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, mica, hornblende) derived from VRF (rhyolitic to andesite): predominant. Individual mineral fragments (quartz, feldspar, mica, hornblende) derived from PRF (dioritic): common, SRF (sandstone): very few, Notes: Mostly rock fragments and hornblendes are altered (some brown). Andesites with quartz, hornblende and feldspar phenocryst exist, and fragments are mostly clastic.	

Table B.1 (continued)

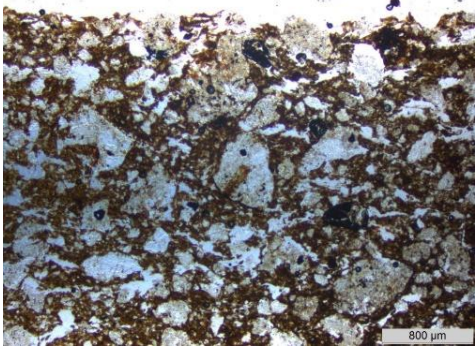
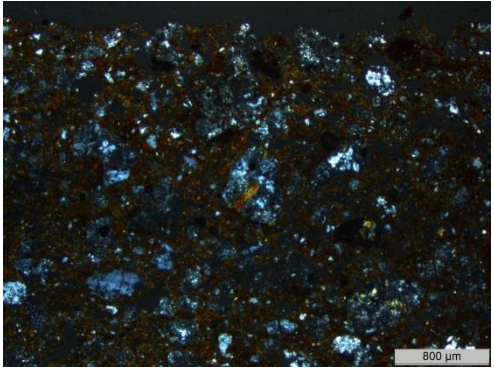
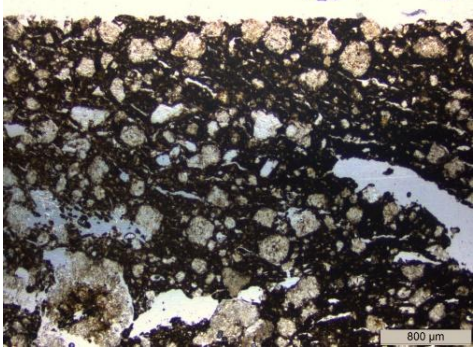
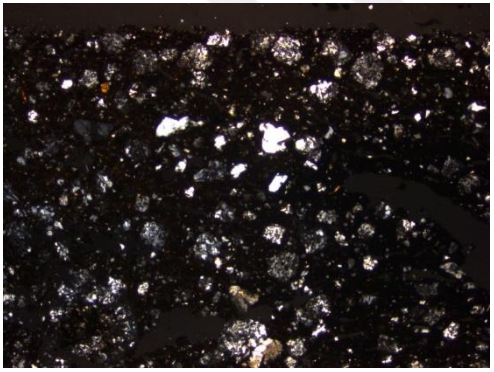
Phase III	
87 	
Smoothed outer surface, rough inner surface. Inclusion frequency: %30, porosity: %10. Pores consist of vughs and vesicles. Micromass: brown in PPL and orange to brown in XPL, gives birefringence. Inclusions: very angular to sub rounded, <0.2mm to 2mm, sphere to low sphere. Very poorly sorted. Rock fragments and individual minerals (quartz, feldspars, mica) derived from VRF (rhyolitic to andesitic): predominant, SRF (clay pellets): very few. Notes: Clay paste converted to biotite. Generally rock fragments and minerals are fractured. Clay matrix is silty.	
88 	
Both surfaces are smoothed. Micromass: brown black in PPL, dark brown to black in XPL. Inclusion frequency: 40%, Porosity: %10. Pores consist of vughs and planar voids. Inclusions: sub rounded, sub angular, <0.2 mm to 2.2 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual minerals (quartz, mostly feldspars, hornblende, mica) derived from volcanic rock andesitic fragments: predominant, SRF (Ferrous clay pellets): rare Notes: Homogenous clay mixing. The clay matrix partly dark around voids may be due to organic temper burnt out.	

Table B.1 (continued)

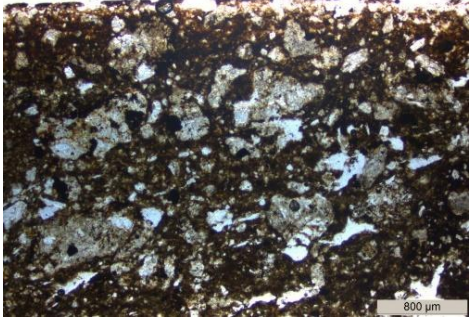
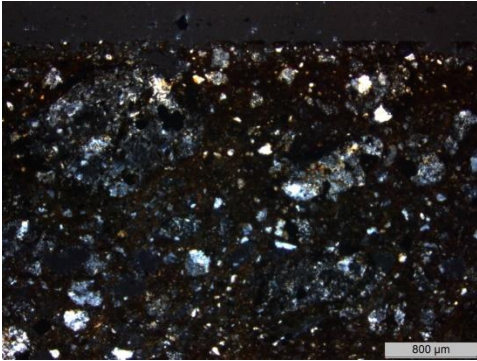
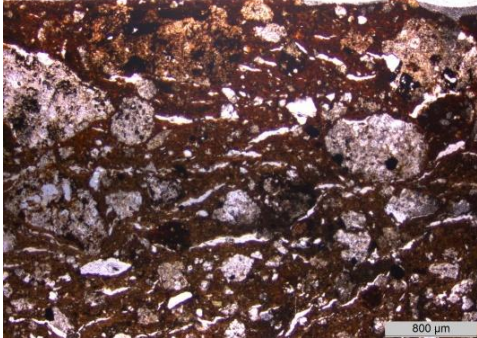
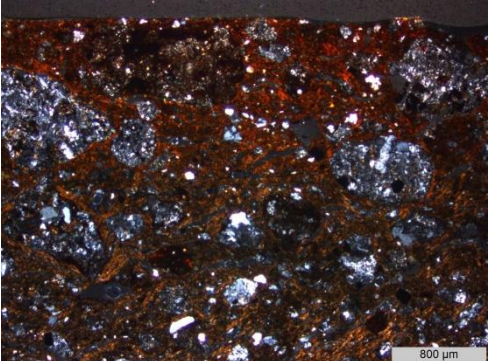
89 	
A thin dark slip layer is seen, smoothed/burnished surface. Micromass: brown in PPL, light brown to orange, grey core in XPL, gives a slight birefringence. Inclusion frequency: %40, Porosity: %10, Pores consist mostly of vughs. Inclusions: angular to sub rounded, <0.2 mm to 2 mm, high sphere to low sphere. Poorly sorted Rock fragments and individual minerals (quartz, feldspars, hornblende, muscovite) derived from VRF (andesitic rocks): predominant, SRF (Clay pellet): very few. Notes: Silty clay matrix, Inhomogeneous clay mixing, in paste biotite and muscovite formation is seen and the andesites are altered.	
91 	
Both surfaces are slipped and burnished. Micromass: light brown to red brown in PPL, light orange to red-orange in XPL, gives birefringence. Inclusion frequency: %30, porosity, %7. Pores consist mostly of planar voids and few vughs. Inclusions: angular to sub rounded <0.2 mm to 7 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual minerals (quartz, feldspars, hornblende, mica) derived from VRF (rhyolitic/andesitic): predominant, SRF (Ferruginous clay pellets): few Notes: Heterogenous clay mixing. Fine clay matrix. Significant transformation of clay paste to mica. Red burnt voids probably indicate organic/plant remains. Green hornblendes exist.	

Table B.1 (continued)

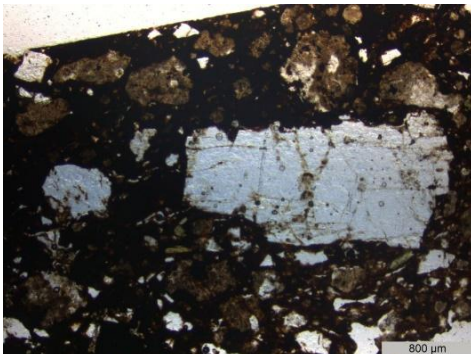
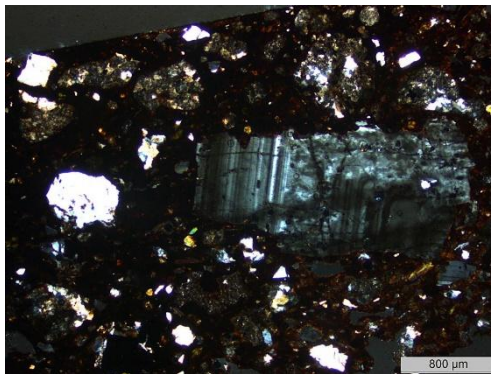
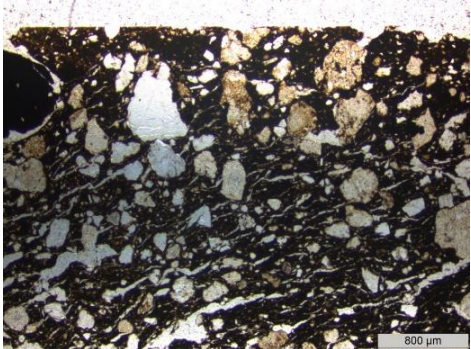
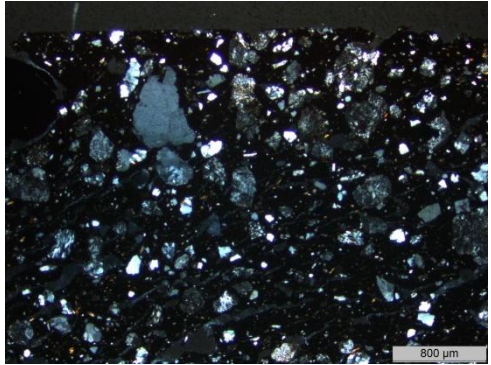
92 	
Both surfaces are slipped and burnished. Micromass: brown in PPL, dark reddish brown partly orange in XPL. gives birefringence moderately. Inclusion frequency: %50, porosity: %10. Pores consist mostly of vughs and channels. Inclusions: angular to sub rounded, <0.2 mm to 3 mm, sphere to low sphere. Poorly sorted Rock fragments and individual minerals (quartz, feldspars, hornblende, mica) derived from volcanic (rhyolitic to andesitic) rocks: frequent. Mineral fragments (mica, hornblende, mainly plagioclase) derived from PRF (granodioritic): common, SRF (Clay particle): very rare, chert: rare Notes: Mineral fragments are fractured. Granodioritic rock fragments and plagioclases are altered due to heat. Apatite exists on feldspars. Andesite containing hornblende and k-feldspar phenocrysts and green hornblendes exist	
94 	

Table B.1 (continued)

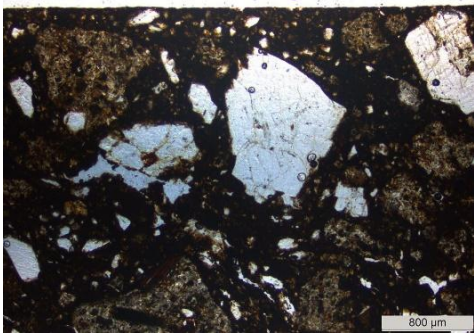
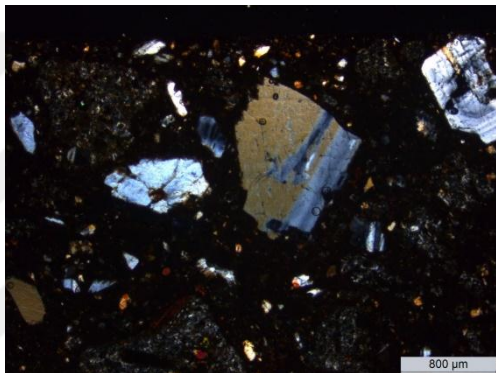
Smoothed outer surface. Micromass: brown orange toward walls, dark brown towards core in PPL, dark red brown, in XPL, gives a slight birefringence on the margins. Inclusion frequency: %40, porosity, %12. Pores consist mostly of vughs and planar voids. Inclusions: angular to sub rounded, <0.2 mm to 2.2 mm, sphere to low sphere. Poorly sorted Rock fragments and individual minerals (quartz, feldspars, hornblende, mica) derived from volcanic (rhyolitic prevalently to andesitic) rocks: frequent. Mineral fragments (plagioclase and quartz) derived from PRF (granodioritic): very few, MRF (derived from Schist): frequent, SRF (Chert, clay pellet, mudstone): very few, Notes: Granodioritic rocks fragments are altered. Clay pellets are oxidized by Fe.	
99 	
Both surfaces are burnished and slipped. Micromass: dark brown in PPL, red brown in XPL, gives a slight birefringence due to thick, thin section preparation. Inclusion frequency: 40%, porosity: %5. Inclusions: very angular to sub rounded, 0.2 mm to 3 mm, sphere to low sphere. Generally, equant. Sparse planar voids and vughs. Poorly sorted. Mineral fragments are angular to very angular. Rock fragments and individual minerals (quartz, feldspars, hornblende, mica, pyroxene) derived from VRF (Andesitic/basaltic andesitic): frequent. Minerals (quartz, alkali-feldspar and plagioclase, hornblende, biotite) derived from PRF (granodioritic): frequent, Notes: Apatite exist on Plagioclases. Green hornblendes exist.	

Table B.1 (continued)

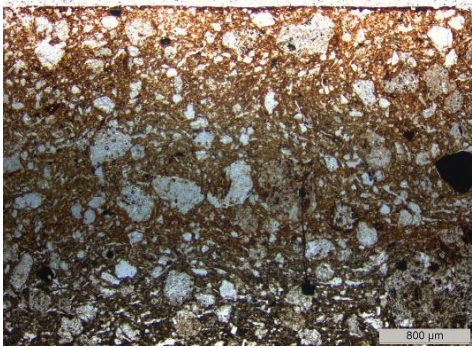
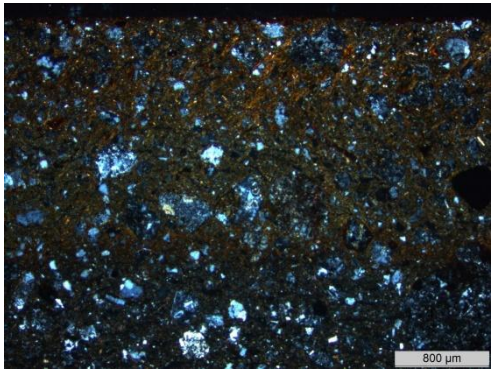
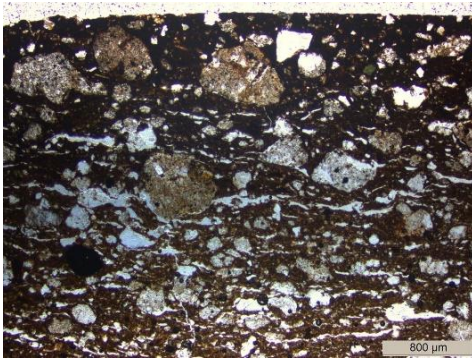
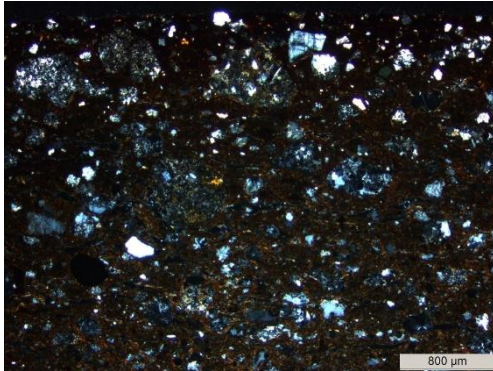
102 	
The outer surface is slipped (thin red-orange layer is seen) and inner surface is smoothed. Micromass: margins light orange, core brown in PPL, margins orange, core grey-orange in XPL, gives birefringence. Inclusion frequency: %30, porosity: %7. Pores consist mostly of vughs and planar voids. Inclusions: angular to sub rounded, 0.2 mm to 3 mm, sphere to low sphere. Poorly sorted Rock fragments and individual mineral fragments (quartz, feldspars, hornblende, opaque minerals and mica) derived from VRF (rhyolitic to andesitic): predominant, SRF (Claystone): very few, grog: rare Notes: Quartz with large fields (granoblastic) is seen in high amounts. Some rocks are biotized (stained). Andesite has a porphyritic texture with green hornblendes and feldspars.	
104 	

Table B.1 (continued)

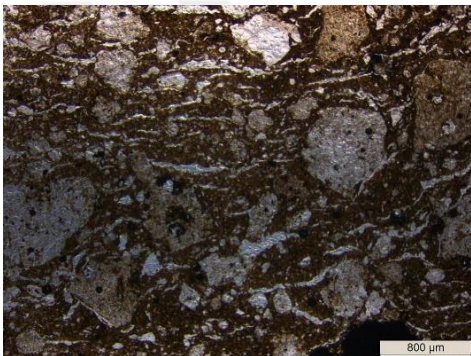
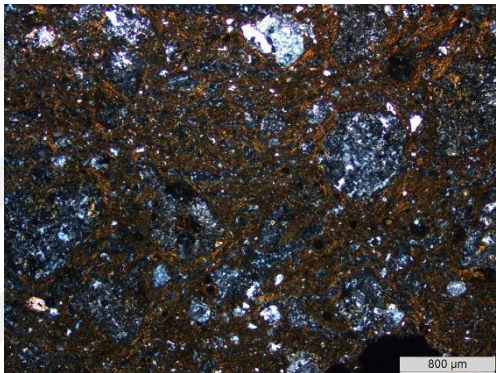
Partly burnished outer surface. A thin dark brown layer (in PPL) is observed on both surfaces. Micromass: margins red brown to brown towards inner zones in PPL, red-orange to orange from outer to inner margins in XPL, gives birefringence. Inclusion frequency: %30, porosity: %10. Pores consist mostly of planar voids and few vughs. Inclusions: very angular to sub rounded, <0.2 mm to 5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual minerals (quartz, feldspars, hornblende, mica) derived from VRF (rhyolitic to andesitic): predominant, SRF (clay particles, sandstones): very few, MRF: rare. Notes: Very large andesite fragments with hornblende and quartz phenocrysts. Generally parallel voids and coil like appearance of inclusions are observed. Fine clay matrix	
105 	
Burnished and slipped, a thin dark determinate margin on the outer surface and smoothed inner surface. Micromass: light red brown in PPL, light orange to red orange in XPL, gives birefringence. Inclusion frequency: %30, porosity: %5. Pores consist mostly of vughs and planar voids. Inclusions: very angular to sub rounded, <0.2 mm to 3 mm, sphere to low sphere. Purely sorted Rock fragments and individual mineral fragments (quartz, K-Feldspar, hornblende, pyroxene, mica and opaque minerals) derived from VRF (andesitic): predominant, SRF (clay stone, clay pellets): a few, MRF (schist): very few. Notes: Andesite biotized (stained), Grog: rare?, opaque inclusions exist. Fine clay matrix	

Table B.1 (continued)

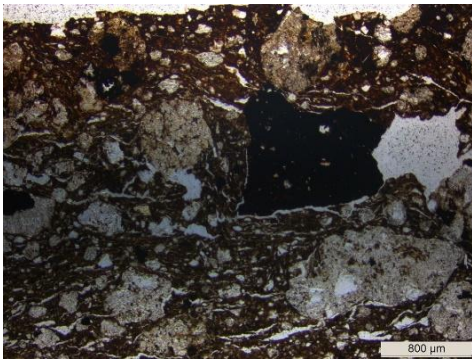
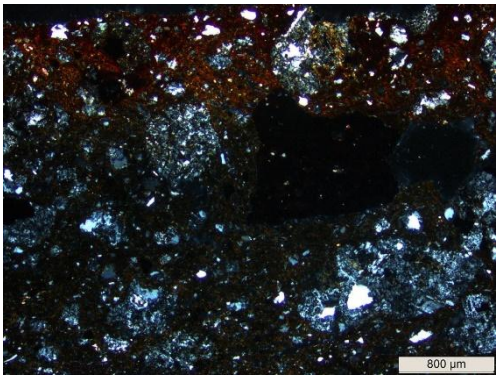
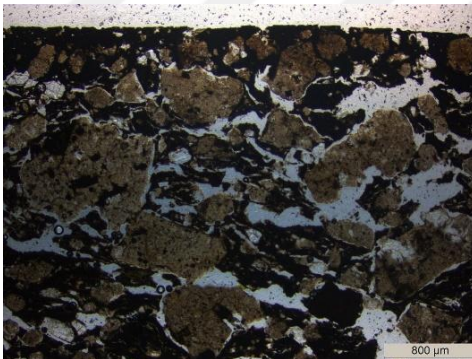
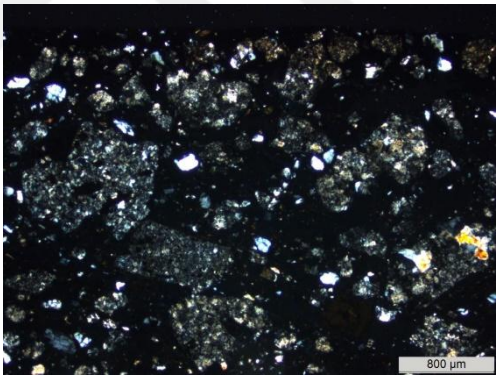
106 	
Surface is slipped, and burnished. Micromass: Brown orange margins, grey brown core in PPL, red orange-orange margins, dark brown core, in XPL, gives birefringence. Inclusion frequency: %40, porosity: %10. Pores consist mostly of planar voids and vughs. Inclusions: angular to rounded, <0.2 mm to 2 mm, sphere to low sphere. Very Poorly sorted. Rock fragments and individual mineral fragments (Quartz, Sanidine and plagioclase, mica, hornblende) derived from VRF (andesitic): predominant, SRF (Clay pellet, mudstone, chert): few, Notes: Some andesites with big hornblende and quartz phenocrysts. Silty clay matrix.	
113 	
Both surfaces are burnished. Micromass: black in PPL and XPL. Inclusion frequency: %50, porosity: %15. Pores consist mostly of vughs and few planar voids. Inclusions: very angular to rounded, <0.2 mm to 3 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (Quartz, Plagioclase and Alkali feldspar, Hornblende) derived from VRF (rhyolitic to andesitic): dominant, SRF (mudstone): rare Rock fragments and individual minerals (quartz, alkali-feldspar and plagioclase, hornblende) derived from PRF (granodioritic): common, Notes: Some mineral fragments are cracked. Andesites with big phenocryst of brown hornblende and feldspars exist. Fine grained clay paste.	

Table B.1 (continued)

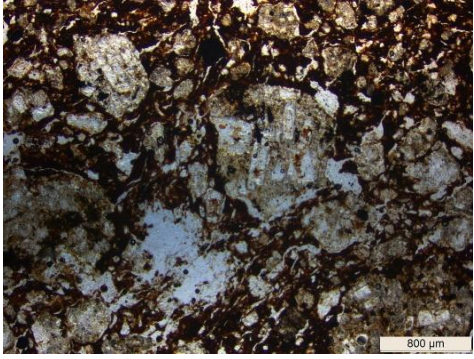
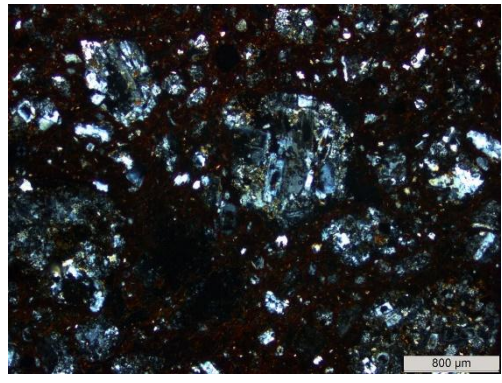
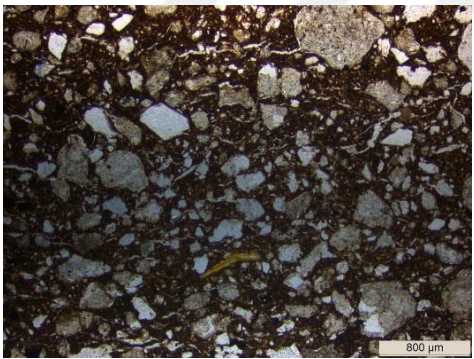
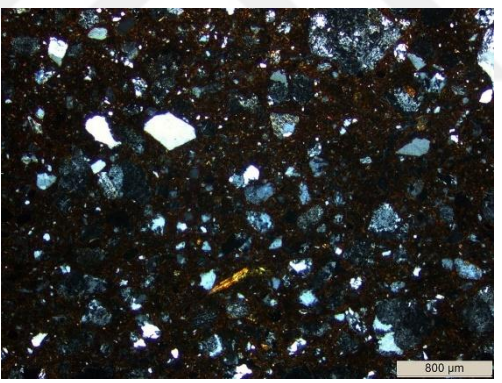
116 	
Burnished and slipped surface. Micromass: red brown in PPL, dark orange brown in XPL, gives birefringence moderately. Inclusion frequency: %40, porosity: %12. Pores consist of vughs and planar voids Inclusions: very angular to sub rounded, <0.2 mm to 4 mm, sphere. Very poorly sorted. Rock fragments and individual mineral fragments (plagioclase, hornblende, quartz, pyroxene, biotite) derived from VRF (andesitic): predominant, MRF (Schist): very few. Notes: Plagioclases are zoned. Volcanic rock fragments have feldspar (>0.5mm) and hornblende phenocrysts.	
119 	
Both surfaces are rough. Micromass: Margins to core lighter brown to darker brown in PPL, margins are light orange, towards core goes to red orange in XPL, gives a slight birefringence. Inclusion frequency: %40, porosity: %7. Pores consist mostly of vughs and less planar voids. Inclusions: very angular to sub rounded, 0,1 mm to 3.5 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (Quartz, Plagioclase and Alkali feldspar, Hornblende, Mica) derived from VRF (rhyolitic to andesitic): dominant, Mineral fragments (quartz, feldspars) derived from PRF (granodioritic): common, SRF (Sandstone, shale, clay stone etc.): common, MRF (schist): few, grog: very rare?	

Table B.1 (continued)

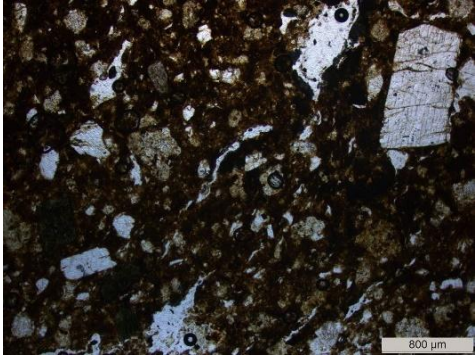
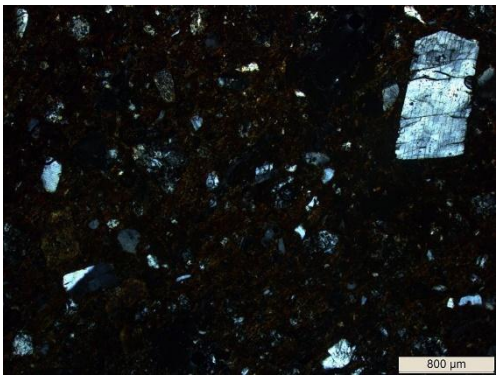
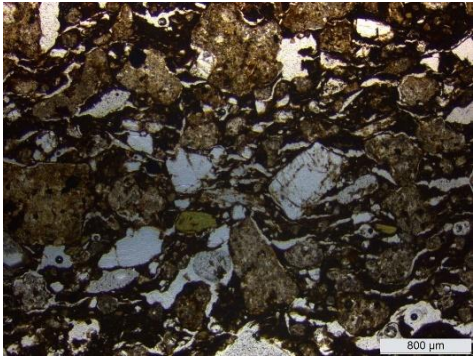
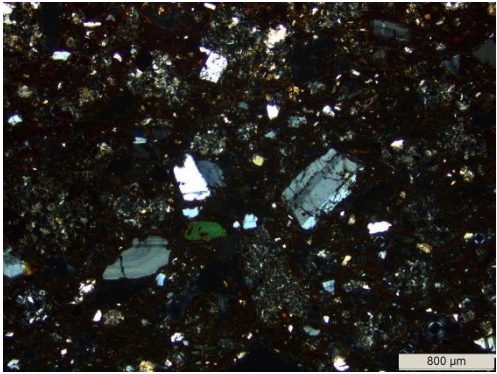
128 	
Smoothed surfaces. Micromass: brown in PPL, orange to red brown in XPL, gives birefringence. Inclusion frequency: %25, porosity: %7. Pores consist mostly of vughs and less planar voids. Inclusions: very angular to sub rounded, 0,2 mm to 2.8 mm, sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (Quartz, alkali feldspar, hornblende, mica and dominantly Plagioclase) derived from VRF (andesitic):_dominant. Rock fragments and individual minerals (quartz, alkali-feldspar and plagioclase, hornblende, mica) derived from PRF (granodioritic): frequent, SRF (Clay pellet): rare, Notes: Some mineral fragments are cracked. Biotitization exists in paste. Andesite with big Plagioclase phenocryst exist. Green hornblendes exist.	
133 	

Table B.1 (continued)

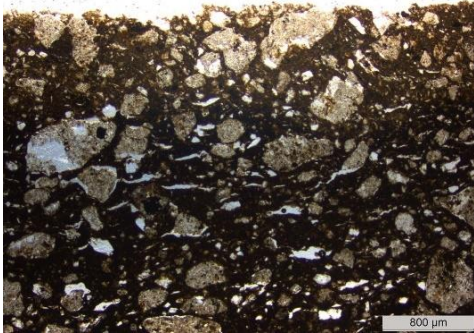
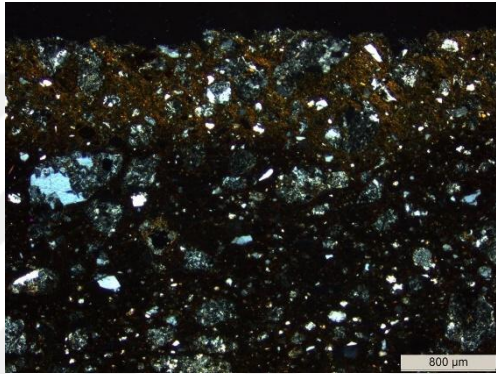
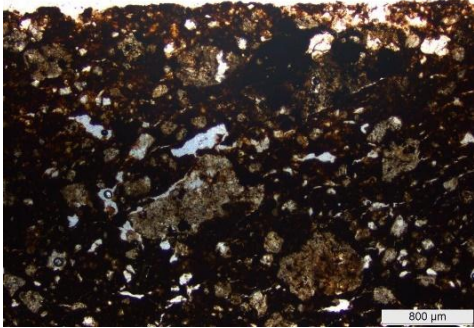
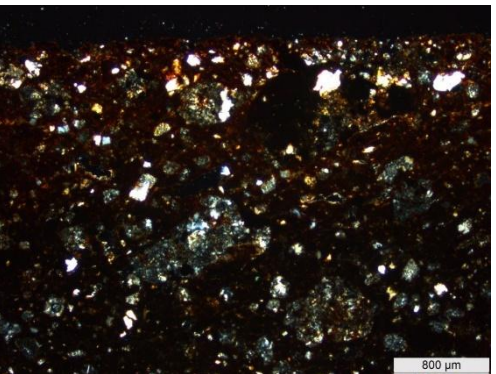
Rough and smoothed surfaces. Micromass: Dark brown to red-brown in PPL, dark red-brown to red orange in XPL, gives a slight birefringence. Inclusion frequency: %40. Porosity: %10. Pores consist mostly of vughs, planar and elongate voids. Inclusions: very angular to sub rounded, < 0,2 mm to 3 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (Quartz, feldspar, hornblende, mica) derived from VRF (andesitic): dominant. Rock fragments and individual minerals (quartz, feldspar, hornblende, mica) derived from PRF (granitic/granodioritic): frequent. Notes: Andesites with opaque particles phenocrysts and green Hornblendes are prevalent. Organic remnants exist.	
138 	
Burnished and partly slipped outer surface. Micromass: brown in PPL, outer surface slightly darker, inner surface slightly lighter compared to core body. Inner surface lighter orange, body red brown in XPL, gives birefringence moderately. Inclusion frequency: %30, porosity: 7%. Pores consist of vughs, planar and elongate voids. Inclusions: very angular to rounded, < 0,2 mm to 2 mm, high sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (Quartz, Feldspar, Hornblende, Mica) derived from VRF (rhyolitic/andesitic): predominant, SRF (Siltstone, clay stone): very few.	
139 	

Table B.1 (continued)

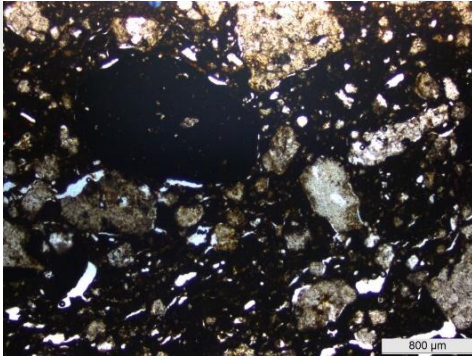
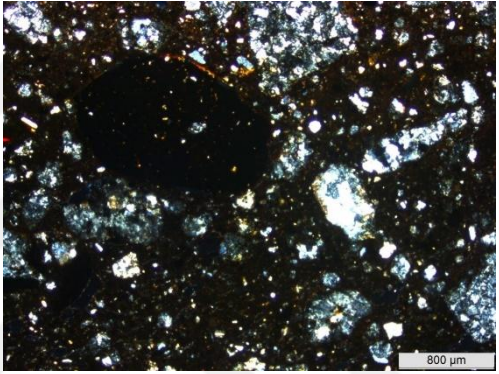
Smoothed surface. Micromass: inhomogeneous color due to firing atmosphere, surface red brown, core dark brown in PPL, red brown surface, darker red brown towards core in XPL, gives birefringence moderately to slightly. Inclusion frequency: %40, porosity %10. Pores consist prevalently of vughs and planar voids. Inclusions: very angular to rounded, 0.2 mm to 2.5 mm, high sphere to low sphere. Poorly sorted. Rock fragments and individual mineral fragments (quartz, feldspar, hornblende, mica, pyroxene) derived from VRF (andesitic): predominant, SRF (clay pellet): rare Notes: Andesites with opaque particle, feldspar and quartzite phenocrysts. Some free minerals seem cracked. Biotitization is apparent. Green hornblendes exist.	
140 	
Smoothed, partly burnished surfaces. Micromass: dark grey brown, lighter brown towards the inner surface, outer surface is dark grey brown in PPL, red brown in inner surface is lighter orange XPL, gives a slight birefringence towards inner margins. Inclusion frequency: %30 porosity %10. Pores consist of vughs and planar voids. Inclusions: very angular to rounded, 0.2 mm to 4.5 mm, sphere to low sphere. Very poorly sorted. Rock fragments and individual mineral fragments (Quartz, Feldspar, Mica,) derived from VRF (rhyolitic prevalently to andesitic): predominant, SRF (Mudstone, Clay pellet): very few, MRF (Schist): rare. Notes: Andesites are dark colored and clastic structure exist. This maybe degradation due to firing. Some free minerals seem cracked, biotitization is apparent.	

Table B.1 (continued)

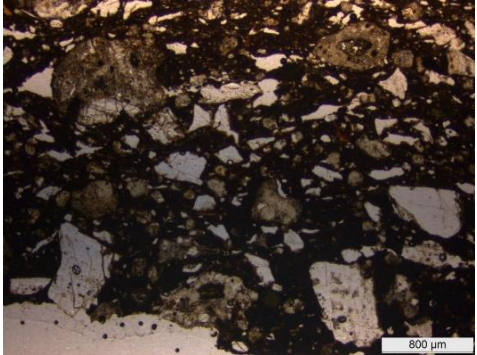
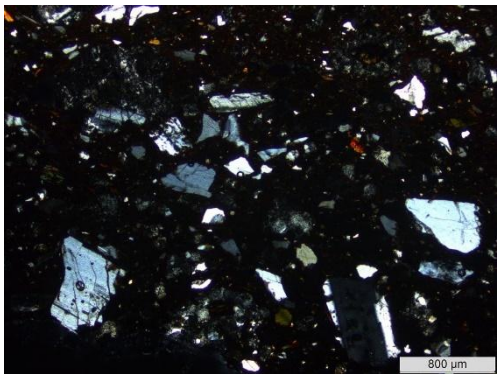
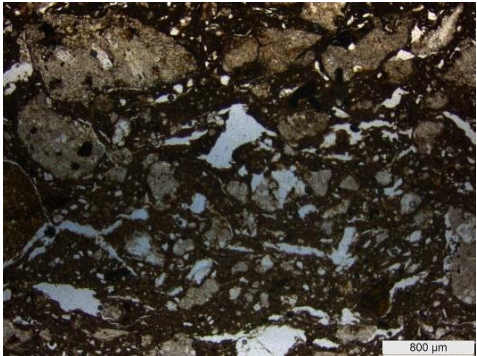
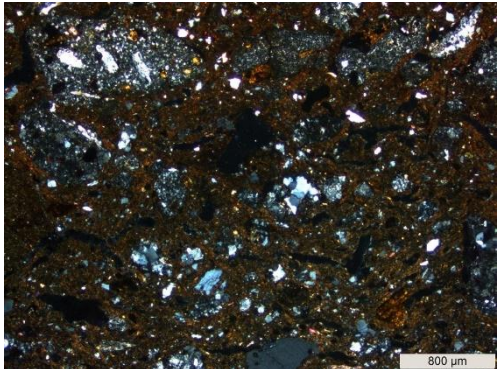
299 	
Smoothed and partly slipped outer and inner surfaces. A very thin layer of slip is seen partly on the outer surface. Micromass: Light brown to dark brown towards core in PPL. Light orange to dark red brown towards core in XPL, gives birefringence moderate to slight. Inclusion frequency: %40 Porosity: %7. Pores consist of vughs. Inclusions: very angular to sub rounded, 0.2 mm to 5.5 mm, sphere to low sphere. Poorly sorted. Mineral fragments derived from VRF (Rhyolitic to andesitic): common. Mineral fragments (Feldspar; mainly plagioclase, quartz, hornblende, pyroxene, mica) derived from PRF (Granodioritic): frequent. Notes: Andesites with large plagioclase and hornblende phenocrysts. Green hornblendes and biotite is prevalent.	
300 	

Table B.1 (continued)

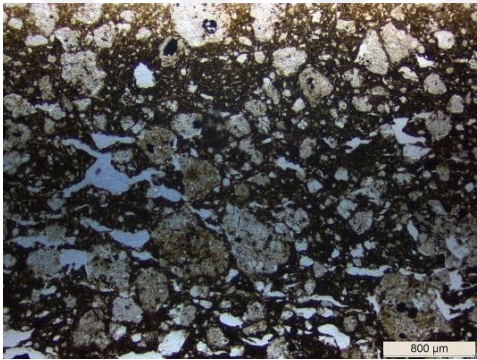
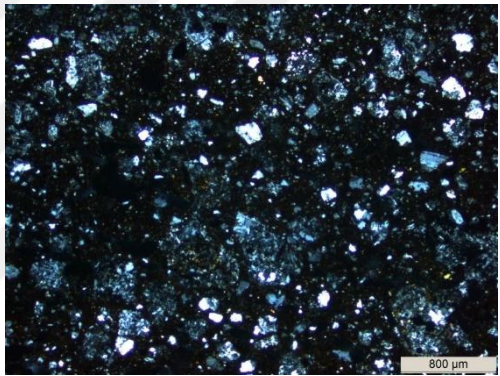
Both surfaces are smoothed. Micromass: orange to dark brown in PPL, light orange to red orange in XPL, gives birefringence. Inclusion frequency: %40, Porosity: %10. Pores consist of vughs and planar voids. Inclusions: angular to sub rounded, 0.2 mm to 7 mm, sphere to low sphere. Very poor sorting. Rock fragments and individual mineral fragments (quartz, hornblende, feldspar, mica) derived from VRF (andesitic): predominant. Rock fragments and individual minerals (quartz, alkali-feldspar, hornblende) derived from PRF (granodioritic): very few, SRF (Mudstone, clay pellets, etc.): few, MRF (Schist): very few Notes: Phenocrysts of andesites are biotized and some hornblendes changed into mica, the groundmass of VRF's are silicified. Fine-grained andesites with brown or carbonized black hornblende phenocryst. Organic remains are very few and clay is not homogenous.	
301 	
Smoothed surface. Micromass: thin layer of lighter brown to darker brown towards core in PPL, orange to dark orange brown towards core in XPL, gives birefringence. Inclusion frequency: %40, Porosity: %15. Pores consist of vughs, planar voids and a few vesicles. Inclusions: angular to sub angular, 0.3 mm to 3.5 mm, sphere to low sphere. Poor sorting. Rock fragments and individual mineral fragments (quartz, hornblende, feldspar, mica) derived from VRF (rhyolitic to andesitic prevalently): predominant, Notes: Some andesites are very phaneritic. Andesites contain quartz, plagioclase and hornblende phenocrysts. Some rocks are biotized or stained (ferruginous).	

Table B.1 (continued)

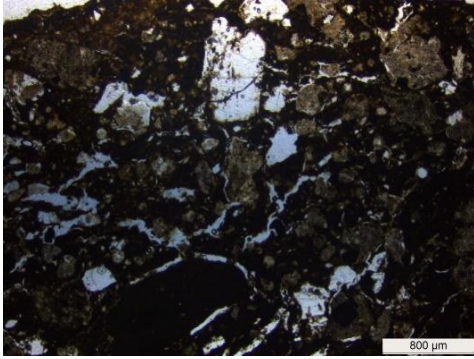
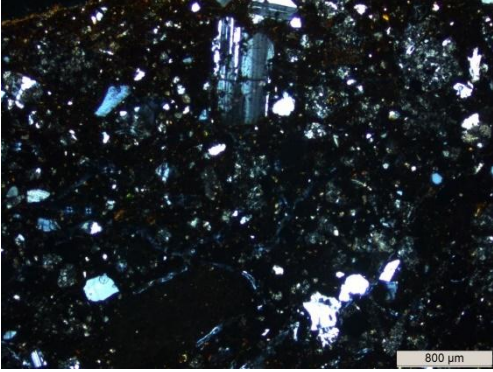
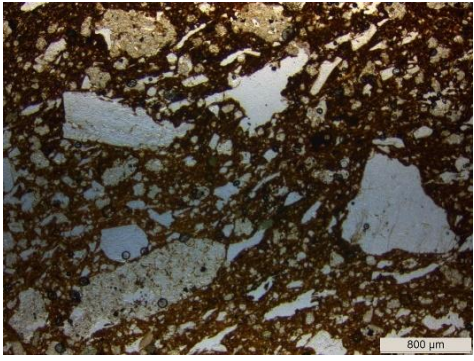
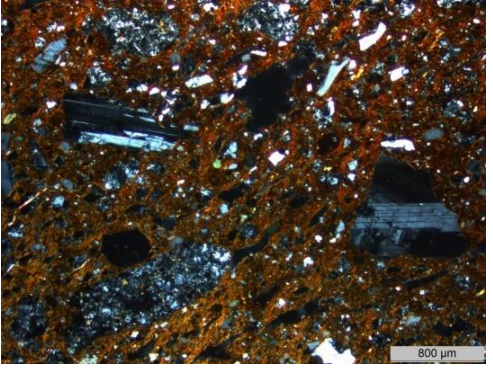
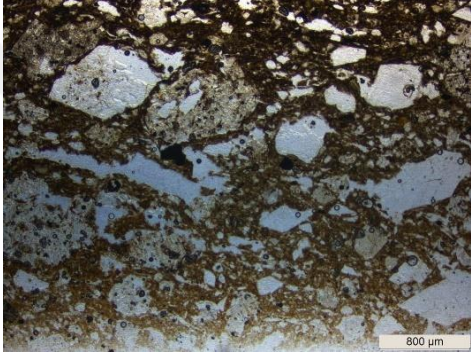
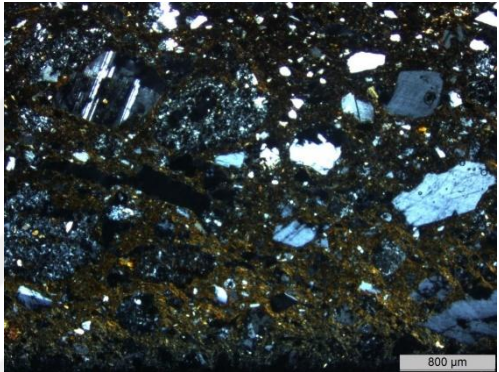
302 	
Smoothed surface, partly burnished inner surface. Micromass: margins red brown, core black brown in PPL, margins orange-brown to brown towards core dark red brown in XPL, gives birefringence very slightly close to the margins. Inclusion frequency: %40, porosity: %10. Pores consist of vughs, planar voids. Inclusions: sub angular to sub rounded, 0.3 mm to 4 mm, sphere to low sphere. Poorly sorted Rock fragments and mineral fragments (feldspar, quartz, mica) and derived from VRF (rhyolitic? andesitic): dominant. Mineral fragments (Feldspar, mainly Plagioclase, Quartz, Mica) derived from PRF (granodioritic): common, SRF (Siltstone/mudstone, sandstone, clay pellet): few. Notes: Andesites with feldspar and brown Hornblende phenocrysts with silicified groundmass. Some rocks are biotized or stained (ferruginous).	
303 	

Table B.1 (continued)

Burnished and slipped outer surface and well smoothed inner surface. Micromass: lighter orange to darker towards core in PPL. Lighter orange to red orange towards core in XPL, gives birefringence. Inclusion frequency: %30, porosity: %10. Pores consist of vughs, planar voids. Inclusions: angular to sub rounded, 0.2 mm to 2 mm, sphere to low sphere. Poor sorting Rock fragments and individual mineral fragments derived from VRF (andesitic): Frequent, Mineral fragments (Feldspar; mainly Plagioclase, Quartz, Hornblende, Mica) derived from PRF (granodioritic): frequent, SRF (Clay pellet): rare, Fiber tempers (Organic remains): few, Notes: Volcanic lithoclasts exist. Andesites with large feldspar and quartzite phenocrysts exist.	
304 	
Both surfaces slipped and slightly burnished. A thin layer of slip is observed. Micromass: Sandwich type coloring, dark grey brown core, margins light orange to red brown in PPL. Dark/red orange margins, dark reddish-brown core in XPL, gives birefringence towards margins. Inclusion frequency: %40, Porosity: %15. Pores consist of vughs, planar voids and few vesicles. Inclusions: very angular to sub rounded, 0.2 mm to 2 mm, sphere to low sphere. Moderately sorted. Rock fragments and individual mineral fragments (Hornblende, Feldspar, Pyroxene) derived from VRF (andesitic/ basaltic andesitic): dominant. Mineral fragments (quartz, feldspar, mainly Plagioclase, Quartz, Hornblende, Mica) derived from PRF (dioritic): common, SRF (Marl, Clay pellet): rare. Notes: Andesites with pyroxene, brown hornblende and feldspar phenocrysts exist. Clay paste is not well mixed, heterogeneity is observed. Green hornblendes exist.	

C. ICP-OES/MS Results

Table C.1 ICP-OES/MS Results of Uğurlu pottery and soil samples

Sample	wt %										
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Ca O	K ₂ O	Na ₂ O	MgO	TiO ₂	MnO	P ₂ O ₅	Loi
245	62.71	15.59	6.39	2.52	2.26	1.86	1.46	0.62	0.12	0.41	1.11
250	63.14	17.92	6.92	2.35	2.11	1.79	0.93	0.68	0.05	0.27	1.18
264	69.14	16.97	7.91	0.59	1.98	1.27	1.06	0.77	0.09	0.09	0.41
319	59.50	17.54	7.79	4.06	2.30	2.32	1.43	0.63	0.09	0.30	1.25
320	58.65	17.35	7.93	4.03	2.23	2.32	1.21	0.67	0.09	0.23	1.4
321	68.49	16.18	7.55	1.36	1.82	1.27	0.93	0.77	0.08	0.16	1.04
322	64.00	16.61	6.62	3.19	2.25	2.35	1.36	0.65	0.10	0.21	1.05
323	63.36	17.08	5.42	2.46	2.24	1.71	0.83	0.48	0.04	0.27	1.35
324	59.10	17.20	6.88	3.19	2.82	1.99	1.14	0.88	0.05	0.41	1.16
325	66.14	15.87	4.52	2.28	2.65	2.10	0.46	0.45	0.04	0.18	0.98
326	61.22	15.82	6.63	3.39	2.08	1.91	1.31	0.67	0.10	0.50	1.61
327	64.43	15.48	6.95	2.71	2.08	1.86	1.51	0.73	0.10	0.34	1.41
328	61.43	17.31	7.05	2.73	2.28	2.04	0.78	0.68	0.08	0.34	1.29
329	65.28	16.99	6.31	2.10	2.67	1.94	1.39	0.78	0.06	0.18	0.56
330	63.57	17.46	7.15	2.74	2.02	1.51	0.80	0.60	0.06	0.76	1.72
331	65.28	17.31	5.18	2.39	2.84	1.73	0.88	0.45	0.06	0.53	1.24
332	63.14	17.46	8.02	2.70	2.70	1.97	2.04	0.80	0.19	0.23	0.57
333	64.00	14.61	7.28	2.57	2.14	1.48	1.96	0.72	0.12	0.37	1.44
334	65.28	15.02	5.70	2.84	1.84	1.43	1.21	0.68	0.05	0.30	1.36
335	63.57	15.29	6.43	3.05	2.12	2.01	1.18	0.65	0.10	0.30	1.08
Avr	63.6	16.6	6.73	2.66	2.27	1.84	1.19	0.67	0.08	0.32	1.16
Stdev	2.75	0.98	0.96	0.79	0.31	0.32	0.39	0.11	0.04	0.15	0.34
Phase IV											
162	63.78	17.90	6.59	2.10	2.66	1.97	1.64	0.58	0.13	0.11	0.57
168	64.43	15.01	6.91	2.10	2.02	1.55	1.56	0.68	0.25	0.41	1.6
172	64.85	14.87	6.63	2.25	2.46	1.59	1.54	0.67	0.21	0.50	1.47
178	61.86	18.48	6.98	2.25	2.39	1.98	0.98	0.62	0.12	0.23	0.87
185	58.65	16.46	6.98	3.15	2.11	1.85	1.04	0.68	0.04	0.34	2
222	62.29	18.48	7.72	3.11	2.37	2.21	1.48	0.63	0.10	0.27	1.04
223	61.43	18.63	8.01	3.04	2.28	1.95	1.84	0.73	0.12	0.30	0.49
234	65.71	17.54	8.35	2.14	2.20	1.58	1.33	0.87	0.14	0.25	0.29
305	62.50	15.82	6.66	3.44	2.16	2.08	1.43	0.67	0.12	0.39	1.15
306	66.57	17.73	7.41	1.39	2.39	1.95	0.94	0.75	0.09	0.25	0.91
307	67.64	16.65	6.82	1.46	2.58	2.32	1.06	0.68	0.10	0.18	0.51

Table C.1 (continued)

308	68.92	16.05	6.82	1.50	2.55	2.30	1.08	0.70	0.10	0.16	0.53
309	66.35	16.27	6.42	3.06	2.32	2.22	1.33	0.67	0.13	0.41	0.86
310	62.29	13.42	6.51	5.60	1.48	1.58	1.43	0.67	0.04	0.39	1.54
311	62.50	16.50	6.03	2.59	2.40	1.85	1.24	0.52	0.10	0.27	1.18
312	59.50	18.26	9.82	4.16	2.24	2.39	1.64	1.08	0.22	0.27	0.49
313	59.29	18.18	10.12	4.16	2.40	2.41	1.71	1.13	0.19	0.25	0.49
314	61.43	16.63	7.23	2.07	2.24	2.10	0.81	0.67	0.06	0.16	1.02
315	65.07	14.25	6.56	2.13	1.94	1.51	1.49	0.63	0.27	0.46	1.3
317	60.79	16.76	6.91	3.76	2.40	2.51	1.43	0.60	0.12	0.53	1.05
318	65.92	18.18	6.51	1.90	2.67	1.94	1.76	0.57	0.13	0.11	0.26
Avr	63.4	16.8	7.2	2.7	2.3	2.0	1.4	0.7	0.1	0.3	0.93
Stdev	2.8	1.5	1.1	1.1	0.3	0.3	0.3	0.2	0.1	0.1	0.47
Phase III											
87	63.57	16.71	6.43	2.21	2.29	1.90	0.65	0.62	0.06	0.44	1.13
88	64.21	16.91	4.88	2.31	2.46	1.85	0.63	0.43	0.10	0.25	1.41
89	63.36	15.89	6.51	1.92	2.34	1.94	0.60	0.68	0.19	0.37	1.68
92	61.64	16.39	6.51	2.91	2.28	1.85	1.49	0.55	0.10	0.50	1.66
101	62.50	16.91	8.15	2.35	2.57	1.64	1.79	0.67	0.12	0.30	1.1
102	64.00	17.33	7.02	2.01	2.31	2.16	0.86	0.70	0.12	0.23	0.81
104	61.86	16.01	6.59	2.57	2.25	1.74	1.13	0.58	0.06	0.44	1.32
105	62.93	16.56	6.82	2.36	2.20	1.93	0.78	0.63	0.09	0.60	1.34
113	64.21	19.65	7.55	2.21	2.55	2.01	1.61	0.67	0.08	0.16	0.64
116	61.00	17.10	7.19	2.78	2.35	2.43	0.71	0.67	0.10	0.11	0.92
128	58.65	16.90	6.68	3.81	2.06	1.90	1.18	0.62	0.05	0.66	1.5
138	61.22	17.86	6.66	2.03	2.12	2.04	0.65	0.63	0.08	0.25	1.35
139	60.36	17.03	6.51	3.34	2.34	1.97	0.73	0.58	0.08	0.53	1.44
140	64.00	17.82	6.85	1.86	2.57	1.95	0.80	0.62	0.08	0.30	0.91
299	61.86	17.12	6.72	3.71	2.36	2.24	1.01	0.65	0.12	0.37	1.22
300	64.43	16.56	6.08	1.92	2.59	1.81	1.01	0.53	0.12	0.14	1.12
301	66.78	16.74	6.73	2.28	2.40	2.30	0.63	0.68	0.06	0.16	1.16
302	63.78	17.20	6.85	2.83	2.79	1.81	1.39	0.60	0.14	0.30	0.85
303	60.79	17.44	7.52	3.16	2.23	2.06	1.34	0.63	0.09	0.34	1.13
304	63.57	18.86	7.98	3.23	2.28	2.06	1.89	0.70	0.13	0.30	0.74
Avr	62.7	17.15	6.81	2.59	2.37	1.98	1.04	0.62	0.10	0.34	1.17
Stdev	1.8	0.9	0.7	0.6	0.2	0.2	0.4	0.1	0.0	0.2	0.3
11b	28.2	6.0	18.4	15.4	1.1	0.8	0.7	0.4	0.01	0.04	-
13a	59.1	10.9	6.9	8.5	1.4	1.5	1.2	0.7	0.08	0.1	-
14d	47.4	8.2	6.6	19.6	1.1	0.6	0.7	0.6	0.07	0.1	-

Table C.1 (continued)

Sample	ppm									
	Li	Ba	Sr	V	Zn	Cr	Sc	Cu	Ni	Pb
245	0.0066	1179	459	126	116	90.6	13.8	40.7	99.7	41.4
250	0.005	1266	474	151	68.9	47.6	15.1	30.5	51.6	40.5
264	0.01	436	244	144	96.1	120	18	29.8	94.9	25.3
319	0.006	1349	647	155	71.9	102	22.2	48.5	70	27.6
320	0.007	1282	672	154	68.4	106	21	49.6	76.9	29.1
321	0.01	542	223	124	84.6	111	16.9	28	95.4	24.7
322	0.005	1053	555	125	80	77.7	14.5	44.7	77.7	28.1
323	0.003	1571	437	89.4	55	49.6	10.5	36.4	45.8	27.6
324	0.16	1468	525	137	81	55	13.6	40.4	57.9	45
325	0.003	1367	422	65.2	57.1	41.1	5.6	25.4	50.2	30.6
326	0.004	1465	667	154	80	106	15.7	47	81.6	31.2
327	0.004	1093	459	131	79.9	161	15.4	63.8	122	28.5
328	0.006	1274	432	141	99.6	57.5	12.4	58.4	99.9	51.2
329	0.006	955	461	138	85.3	120	16.3	29.7	92.2	38.9
330	0.004	1708	516	168	93.8	60.8	13.4	28.5	59.4	47.2
331	0.004	1905	451	81.4	79.3	38	9.5	36.9	48.3	30.5
332	0.006	1005	438	179	114	102	18	42.2	119	64.2
333	0.006	1007	318	144	132	161	15.1	32.9	174	44.1
334	0.004	1094	286	108	74.9	92.1	11.6	34	103	28.1
335	0.004	1175	547	139	72.3	78	13.7	37.6	73.9	31.6
Avr	0.005	1209.72	461.65	132.70	84.51	88.8	14.62	393	84.67	35.77
Stdev	0.002	347.7	126.38	28.5	19.46	36.3	3.80	10.4	31.24	10.43
Phase IV										
162	0.006	902	459	139	88.6	42.6	14.1	34.4	47.2	38.4
168	0.006	941	349	122	91.6	146	13.8	26.8	145	27.3
172	0.005	966	360	123	92.9	144	13.5	25.3	133	25.2
178	0.004	1117	480	139	81	44.2	13.7	29.8	49.3	41.2
185	0.003	1034	522	167	60.3	83.8	18.4	44.8	51.9	18.2
222	0.003	1100	631	170	79.4	85.2	20.2	41.8	61.3	30.1
223	0.005	861	559	173	81.4	106	21.1	48.4	71	31.2
234	0.005	736	537	194	112	152	20.8	34.5	112	33.5
305	0.004	1010	583	141	93.8	87.4	15.8	45.6	77.7	29.1
306	0.004	894	358	160	101	78.8	14.2	29.4	64	51
307	0.004	791	394	138	93.2	67	12.2	24.3	56.5	33.5
308	0.004	798	378	134	86.4	80.4	11.8	24.6	61.8	31
309	0.003	1085	563	139	66.5	98	14.6	35.2	61.2	34.9
310	0.003	731	426	142	82.3	218	16.5	31.3	120	22.1
311	0.004	1250	511	131	84	47.6	13.5	43.1	65.8	36.3

Table C.1 (continued)

312	0.002	1000	622	223	105	136	19.1	36	75.4	28.9
313	0.002	913	583	218	103	127	19.3	25.9	58	28.3
314	0.004	1157	475	158	79.4	32.3	12.1	34.9	44.8	36.6
315	0.005	986	340	128	98.7	142	13.3	32.9	149	27.7
317	0.003	1193	714	164	74.9	63	17.9	39.1	56.2	28.5
318	0.005	894	424	141	89	44.6	14.7	27.1	49.5	40.4
Avr	0.004	969.5	489.0	154.5	87.8	96.5	15.7	34.1	76.7	32.1
Stdev	0.001	146.1	106.5	28.6	12.6	47.4	3.0	7.4	33.4	7.2
Phase III										
87	0.007	1254	391	129	78	45.6	11.6	28.3	44.3	43.5
88	0.004	1588	363	76.9	52.4	45.3	7.3	18.8	47.7	30.6
89	0.007	1260	407	132	97	48.6	10.9	28.3	58.5	58.9
92	0.005	1101	490	142	107	65.6	13	51.9	85	37.3
101	0.005	1110	348	153	109	144	16.6	32.4	115	45.5
102	0.005	1044	440	142	98.8	51.4	13.1	29.1	56.3	32.9
104	0.004	1200	418	137	116	79.8	13.1	26	78.1	57.3
105	0.004	1230	476	157	98.1	35	12.4	28.1	48.8	48.1
113	0.005	1010	523	174	73.3	44.2	18.2	33	47.4	27.5
116	0.004	1043	527	136	73.3	122	15.1	32.8	87.8	20.4
128	0.003	1441	561	171	63.2	73.7	19	37.2	49.2	26.9
138	0.006	1296	386	132	88.3	39.1	13.9	25.3	49.8	36.4
139	0.006	1525	433	140	81.1	42.1	11.9	24.8	55.5	34.6
140	0.007	1255	342	124	85.8	116	13.7	27	114	24.8
299	0.003	1424	749	142	103	71.6	15	29.1	63.8	34.3
300	0.007	1156	418	124	111	68	12.5	30.5	63.6	69.4
301	0.005	980	470	135	77	41.9	11.7	22.3	49.2	24
302	0.006	1140	454	134	116	76.9	14.2	33.2	94.7	71.1
303	0.003	1198	630	164	75.4	96.8	20.1	52.6	79.7	28.6
304	0.004	850	584	172	80.9	105	21.7	47.6	76.6	31.3
Avr	0.005	1205.11	470.50	140.87	89.23	70.63	14.25	31.92	68.25	39.17
Stdev	0.001	186.7	102.4	21.8	18.1	31.5	3.4	9.1	22.1	14.9
11b	0.002	332.8	872.6	95.1	40.57	104.04	6.45	14.8	140.7	35.5
13a	0.006	283.9	332.2	113.5	68.4	144.5	14.88	27.3	117.9	15.2
14d	0.006	149.5	425.4	103.7	64.96	114.18	16.61	26.8	112.0	11.58
Sample	ppm									
	Ta	Zr	Nb	Mo	W	Co	Ga	Rb	Cs	U
245	0.41	69.8	8.78	0.87	1.1	16.4	18.5	100	7.26	2.93
250	0.39	81.7	8.83	1.05	0.99	13.4	19.8	82.4	7.01	2.77
264	0.53	59.2	10.5	0.97	1.39	21.3	22.2	95.8	7.08	2.32
319	0.26	66.2	6.08	0.57	0.99	18.7	18.7	75.9	4.35	3.03

Table C.1 (continued)

320	0.28	67.6	6.25	0.79	1.02	20.1	18.6	75.5	4.19	2.97
321	0.47	46.2	9.81	1.53	1.11	19.4	19.3	87	5.85	1.83
322	0.32	59	7.6	1.03	1.13	17.9	17.8	93	4.75	3.11
323	0.44	74.7	10	0.81	1.14	9.83	18	84.2	6.58	3.04
324	0.88	212	17.5	1.92	3.58	16.3	20	125	6.89	5.22
325	0.53	84.3	11.9	1.53	1.17	8.28	18.1	98.6	4.39	3.06
326	0.38	67.4	8.35	1.35	1.16	20	18.4	80.8	4.53	3.29
327	0.46	76.3	9.47	0.85	1.25	20.5	17.9	90.8	5.03	3.06
328	0.41	92.6	8.62	1.37	0.98	15	19.2	91.7	5.95	2.47
329	0.66	80.6	12.2	0.88	1.51	17	21.3	122	30.3	3.36
330	0.36	80.4	8.38	1.12	0.89	13.4	22.1	91.5	6.33	2.68
331	0.47	108	10.3	0.79	0.99	11.3	19.5	101	6.94	3.48
332	0.55	82.2	10.6	0.68	1.42	27.9	22.1	123	6.42	3.28
333	0.53	79	10.7	0.7	1.38	25.2	18.5	108	5.58	2.45
334	0.53	95.3	10.4	0.61	1.36	13.9	16.4	76.7	4.25	2.24
335	0.39	65.8	8.35	0.55	1.16	17.9	18.5	88.8	4.86	3.21
Avr	0.46	82.42	9.73	1.00	1.29	17.19	19.25	94.59	6.93	2.99
Stdev	0.14	33.54	2.44	0.37	0.57	4.84	1.59	15.14	5.61	0.68
Phase IV										
162	0.36	68.7	7.42	0.72	1.03	15.5	21.9	103	7.22	3.97
168	0.58	96.9	11.4	1.77	1.22	23.2	20	92.9	6.05	2.55
172	0.55	98.1	10.5	1.4	1.13	21.2	18.7	88.5	5.93	2.66
178	0.35	71.6	7.64	1.29	1.01	16.1	21.9	88	5.85	2.93
185	0.29	72.6	6.6	0.79	1.08	10.9	19.9	91.6	9.32	3.16
222	0.37	66	7.81	1.01	1.33	18	22.5	88.9	4.26	3.5
223	0.46	75.1	9.47	0.81	1.03	20.2	23	89.6	5.15	3.68
234	0.56	67.8	10.5	1.64	1.31	27.2	22.8	93.7	9.19	3.23
305	0.48	79.7	9.18	0.8	1.13	19	18.5	90.1	5.21	2.56
306	0.5	88.4	10.6	1.56	1.15	16.2	22.8	99.7	6.29	2.52
307	0.48	59.6	10.2	1.91	1.13	16.8	21.2	97.8	6.22	2.7
308	0.52	69.8	10.6	2.19	1.14	17.2	21.1	97.7	5.88	2.67
309	0.59	84.6	10.8	0.66	1.23	17.1	20.1	94	5	3.11
310	0.4	44	8.32	0.99	1.2	15.4	16.3	66.3	4.54	1.68
311	0.31	71.4	6.53	0.92	1.02	14.6	19.5	92	6.35	3.63
312	0.53	137	9.61	2.4	1.48	26.6	22.4	85.7	4.25	3.81
313	0.51	128	9.76	1.71	1.49	26.4	22.5	82.6	4.21	3.87
314	0.38	89.9	8.08	1.29	0.89	13.6	21.1	93.8	5.65	2.56
315	0.55	92.1	10.3	2.34	1.25	25.4	18.7	91.7	6.31	2.64
317	0.3	63.5	6.72	0.87	1.2	17	19.5	90.2	4.07	3.91
318	0.34	68.9	7.17	0.86	1.14	15.6	22.3	107	8.57	4.28

Table C.1 (continued)

Avr	0.4	80.7	9.0	1.3	1.2	18.7	20.8	91.7	6.0	3.1
Stdev	0.1	21.7	1.6	0.6	0.1	4.6	1.8	8.1	1.5	0.7
Phase III										
87	1.03	55.3	8.42	1.11	1.74	11.6	18.5	95.8	5.98	1.98
88	0.96	77.1	11	1.46	1.01	9.7	19.3	88.5	3.76	2.61
89	0.84	55.8	10.7	1.31	1.17	16.1	19.4	98.5	4.75	2.14
92	0.64	76.8	7.76	1.04	1.05	18	19.6	98.3	6.85	3.38
101	0.74	88	9.97	0.89	1.26	22.4	21.4	108	5.81	2.43
102	0.69	69.3	10.6	0.9	1.14	16.4	22.3	99.9	5.85	2.06
104	0.53	66.6	8.42	0.95	0.97	14.9	20.2	100	5.34	2.09
105	0.48	92.3	8.27	1.65	0.93	15.2	21	93.4	5.37	2.44
113	0.5	86	9.79	1.07	1.13	17.2	24	93.2	16.4	3.72
116	0.48	61.3	8.2	1.26	0.85	18.2	20.5	88.7	5.3	1.79
128	0.36	66.5	7.23	0.88	1.14	14.3	20.4	73.5	3.53	3.58
138	0.47	63.5	9.1	1.52	1.05	14.3	22.3	79.6	5.32	2.14
139	0.46	58.7	8.64	1.17	0.86	12.8	20.4	93.7	5.38	2.27
140	0.54	65.5	10.3	1.06	1.05	17.2	22.3	98.9	4.16	2.25
299	0.45	83	10.1	1.25	1.04	15.5	20.6	80.5	7.56	2.94
300	0.37	77.2	7.06	0.81	1.08	15.4	20.3	105	6.3	4
301	0.46	50.9	9.08	1.59	0.94	15	20.7	84.2	5.54	1.94
302	0.43	73.3	8.48	1.41	1.21	18.6	21.8	103	6.79	3.94
303	0.4	66.5	8.25	1.18	1.3	17.5	22	87.4	4.16	3.69
304	0.44	73.9	9.04	1.13	1.06	21.4	23.6	88.9	4.8	3.72
Avr	0.56	70.38	9.02	1.18	1.10	16.09	21.03	92.95	5.95	2.76
Stdev	0.2	11.5	1.2	0.2	0.2	3.0	1.4	9.0	2.7	0.8
11b	0.6	31.36	4.49	7.08	0.71	15.17	8.73	51.84	3.18	1.42
13a	0.81	62.26	8.158	1.075	1.045	20.17	12.57	66.239	4.595	1.66
14d	0.54	43.77	5.92	1.55	0.89	18.6	9.35	50.88	3.74	1.65
Sample	ppm									
	Pr	Nd	Sm	Eu	Gd	Tb	Ho	Dy	Er	Tm
245	7.24	28.6	5.5	1.33	4.54	0.62	0.62	3.36	1.74	0.25
250	8.62	34.7	6.62	1.59	5.39	0.73	0.73	4.09	2.1	0.3
264	5.63	22.7	4.72	1.14	4.3	0.64	0.75	3.86	2.24	0.34
319	6.09	23.6	4.81	1.24	3.94	0.54	0.56	3.15	1.62	0.25
320	5.56	21.9	4.51	1.2	3.63	0.51	0.52	2.87	1.5	0.23
321	4.86	19.5	3.99	0.97	3.63	0.53	0.61	3.17	1.79	0.26
322	6.53	25.8	5	1.27	4.07	0.56	0.55	3.03	1.56	0.22
323	7.43	28.3	5.41	1.33	4.13	0.57	0.56	3.06	1.61	0.25
324	9.84	36.8	6.58	1.48	4.94	0.66	0.63	3.5	1.76	0.25
325	3.6	13.4	2.6	0.9	1.9	0.31	0.35	1.68	1.01	0.18

Table C.1 (continued)

326	6.82	26.8	5.49	1.37	4.38	0.63	0.63	3.35	1.86	0.26
327	6.86	27.2	5.31	1.24	4.4	0.62	0.65	3.42	1.9	0.28
328	6.94	27.8	5.41	1.36	4.32	0.62	0.67	3.44	1.9	0.27
329	8.37	32.9	6.22	1.46	5.28	0.72	0.75	4	2.14	0.31
330	5.53	22.2	4.86	1.23	3.91	0.57	0.62	3.23	1.83	0.27
331	6.44	24	4.63	1.17	3.58	0.5	0.52	2.72	1.49	0.25
332	7.99	31.2	6.16	1.52	5.18	0.74	0.77	4.12	2.19	0.33
333	6.15	24.1	4.79	1.17	4.01	0.58	0.64	3.33	1.83	0.28
334	4.87	19.1	3.96	1.04	3.41	0.51	0.59	3.04	1.75	0.26
335	6.66	26.3	5	1.23	4.04	0.56	0.57	3.08	1.61	0.24
Avr	6.60	25.85	5.08	1.26	4.15	0.59	0.61	3.28	1.77	0.26
Stdev	1.44	5.56	0.95	0.18	0.78	0.10	0.10	0.54	0.28	0.04
Phase IV										
162	7.21	27.9	5.34	1.34	4.43	0.6	0.61	3.34	1.76	0.26
168	6.24	24.5	4.96	1.16	4.36	0.62	0.71	3.7	2.14	0.3
172	6.24	24.8	4.98	1.16	4.3	0.63	0.73	3.68	2.1	0.3
178	7.18	28.2	5.6	1.39	4.53	0.64	0.67	3.6	1.94	0.27
185	4.38	17.8	3.7	0.97	3.07	0.43	0.48	2.54	1.45	0.21
222	7.07	27.9	5.41	1.28	4.48	0.62	0.64	3.5	1.82	0.27
223	7.62	30.6	5.99	1.43	5.18	0.7	0.73	3.95	2.11	0.3
234	7.65	30.5	6.16	1.48	5.27	0.74	0.78	4.02	2.16	0.32
305	7.14	26.3	4.86	1.15	3.89	0.55	0.57	3.04	1.62	0.24
306	6.93	27.5	5.54	1.4	4.68	0.67	0.76	3.96	2.23	0.31
307	8	30.9	5.86	1.43	4.93	0.71	0.76	4	2.17	0.31
308	7.43	29	5.52	1.34	4.76	0.68	0.73	3.92	2.14	0.3
309	7.6	29	5.32	1.3	4.46	0.61	0.63	3.49	1.84	0.26
310	5.45	22	4.46	1.03	3.69	0.53	0.55	2.92	1.57	0.22
311	6.75	25.8	5.21	1.29	4.17	0.56	0.58	3.07	1.7	0.23
312	8.31	33.4	6.72	1.73	5.91	0.85	0.94	4.91	2.76	0.41
313	7.94	31.8	6.45	1.68	5.67	0.82	0.9	4.63	2.66	0.38
314	7.17	28	5.81	1.15	4.92	0.71	0.76	3.96	2.07	0.31
315	6.42	25.1	5.01	1.18	4.37	0.64	0.71	3.63	2.08	0.32
317	6.83	26.7	5.23	1.31	4.23	0.58	0.59	3.2	1.68	0.24
318	8.31	31.5	5.81	1.39	4.69	0.64	0.68	3.59	1.92	0.28
Avr	7.0	27.6	5.4	1.3	4.6	0.6	0.7	3.7	2.0	0.3
Stdev	0.9	3.6	0.7	0.2	0.6	0.1	0.1	0.5	0.33	0.05
Phase III										
87	6.2	24	4.81	1.21	3.82	0.56	0.57	3.1	1.64	0.25
88	5.52	21.1	4.11	1.05	2.96	0.44	0.44	2.43	1.34	0.2
89	6.85	26.3	5.07	1.26	4.1	0.58	0.62	3.29	1.76	0.27

Table C.1 (continued)

92	6.57	25.8	4.98	1.2	4.07	0.55	0.59	3.1	1.67	0.25
101	6.28	25.1	5.05	1.21	4.4	0.63	0.73	3.68	2.08	0.31
102	7.49	30.2	6	1.4	4.93	0.71	0.77	4.1	2.18	0.32
104	5.17	20.4	4.07	1.02	3.33	0.48	0.56	2.81	1.58	0.24
105	6.59	25.9	5.12	1.29	4.29	0.61	0.68	3.52	1.93	0.3
113	8.41	33.2	6.39	1.55	5.03	0.67	0.67	3.64	1.92	0.28
116	5.32	20.8	4.27	1.13	3.5	0.5	0.52	2.78	1.52	0.23
128	6	22.5	4.22	1.03	3.27	0.46	0.48	2.47	1.41	0.2
138	7.23	28.9	5.89	1.4	4.85	0.71	0.74	3.96	2.16	0.32
139	5.57	21.8	4.57	1.16	3.54	0.54	0.57	3.06	1.67	0.25
140	5.99	22.9	4.76	1.17	4	0.6	0.67	3.42	1.91	0.29
299	7.58	29.5	5.72	1.41	4.59	0.63	0.62	3.37	1.75	0.25
300	6.41	24.2	4.84	1.18	3.75	0.55	0.56	2.94	1.6	0.25
301	5.93	23.4	4.59	1.19	3.79	0.55	0.58	3.08	1.7	0.26
302	7.36	29	5.56	1.38	4.69	0.65	0.68	3.48	1.88	0.28
303	8.24	30.8	5.88	1.35	4.73	0.67	0.68	3.64	1.93	0.29
304	7.29	29.2	5.89	1.43	5.07	0.7	0.75	3.86	2.08	0.3
Avr	6.60	25.75	5.09	1.25	4.14	0.59	0.62	3.29	1.79	0.27
Stdev	0.9	3.8	0.7	0.1	0.6	0.1	0.1	0.5	0.2	0.0
11b	1.98	7.45	1.43	0.32	1.11	0.17	0.19	1.04	0.56	0.09
13a	4.92	19.81	4.15	1.00	4.05	0.63	0.74	3.95	2.06	0.30
14d	3.62	15	3.32	0.82	3.42	0.57	0.7	3.61	1.91	0.29
Sample	ppm									
	Yb	Lu	Y	La	Th	Ce	Hf	Sn	As	
245	1.7	0.25	17.1	31.3	13.6	62.5	2.66	1.67	17.8	
250	1.98	0.29	20.1	33.7	13	65.3	3.06	1.47	24.4	
264	2.16	0.31	19.9	22.5	9.19	56.8	2.24	1.87	23.7	
319	1.6	0.24	15.1	26.4	16.1	56.9	2.76	1.3	17.2	
320	1.52	0.22	13.7	23	16.1	55	2.72	1.39	16.2	
321	1.68	0.24	16.2	19.2	8.37	47.2	1.77	1.95	22.8	
322	1.47	0.21	15.1	27.2	14.3	56.3	2.38	1.88	8.04	
323	1.55	0.23	15	31	16	66.6	2.88	1.41	10.4	
324	1.69	0.26	17.9	44.9	25.1	88.8	7.36	2.6	16.1	
325	1.09	0.19	8.79	18.3	15	59.8	3.26	1.52	9.37	
326	1.8	0.27	17.3	28.3	15.4	62.1	2.55	1.4	18	
327	1.84	0.27	17.2	30.4	14.3	63.5	2.86	1.71	14.7	
328	1.87	0.27	17.3	27.6	12.4	66.1	3.33	1.94	27.8	
329	2.01	0.29	20.9	35.9	14.4	74.6	2.92	2.04	8.68	
330	1.72	0.26	16.4	21.5	12.2	53.8	2.95	1.85	42.9	
331	1.48	0.25	14.2	29.4	16.5	72.3	3.87	1.43	16	

Table C.1 (continued)

332	2.05	0.32	21.2	34.5	15.9	80.1	3.01	2.2	14.9	
333	1.77	0.26	16.5	25.9	11.8	57.8	2.78	1.98	24.6	
334	1.78	0.27	16.1	20.8	10.4	43.6	3.18	1.66	19.3	
335	1.61	0.24	15.3	29.8	16	64.5	2.5	1.57	14.7	
Avr	1.72	0.26	16.56	28.08	14.30	62.68	3.05	1.74	18.38	
Stdev	0.24	0.03	2.81	6.42	3.49	10.62	1.10	0.33	8.00	
Phase IV										
162	1.69	0.26	18.4	32.2	19	68.4	2.81	2.42	13.4	
168	2.06	0.3	20.8	26.4	12.6	56.1	3.45	2.07	29.5	
172	2.02	0.3	21.6	26.4	12.3	55	3.54	1.96	33.8	
178	1.85	0.27	19.2	29	14.1	64.9	2.9	1.66	24.9	
185	1.41	0.22	13.8	18.9	15	35.7	2.9	1.39	15.4	
222	1.81	0.27	18.6	30.9	18.1	62.6	2.84	1.64	19.9	
223	2.02	0.29	22.3	31.1	15.9	65.2	2.93	2.47	21.4	
234	2.03	0.31	20.3	30.2	15.6	70.9	2.6	2.33	39.4	
305	1.51	0.23	16.5	36.1	17.3	72.3	2.99	1.8	18.1	
306	2.13	0.31	21.5	27.7	12.1	60.8	3.17	1.65	34	
307	2.06	0.28	22.3	33.8	12.5	69.5	2.35	2.04	26.5	
308	1.97	0.28	21.7	31.8	12.6	65	2.75	1.99	27.2	
309	1.73	0.26	18.4	37.2	17.7	73.2	3.24	1.76	20.6	
310	1.44	0.21	15.1	22.1	10.2	43.1	1.74	1.53	26.5	
311	1.66	0.24	16.4	28.9	17.7	64.8	2.82	1.26	14.5	
312	2.67	0.4	26.3	35.4	17.3	89.7	4.92	2.06	11.8	
313	2.64	0.38	25.5	34.2	16.9	72.7	4.79	2.12	4.84	
314	2.07	0.3	20.1	28.7	12.3	64.1	3.32	1.63	24.6	
315	1.94	0.31	18.9	28.1	12.4	60.9	3.27	2.25	30.6	
317	1.66	0.24	16.1	29.4	17.8	62.8	2.6	1.39	21.9	
318	1.78	0.27	19	41	21.3	80.8	2.79	1.72	11.8	
Avr	1.9	0.3	19.7	30.5	15.3	64.7	3.1	1.9	22.4	
Stdev	0.33	0.05	3.16	5.01	2.94	11.55	0.71	0.35	8.64	
Phase III										
87	1.58	0.24	14.6	24.5	11.3	61.4	2.81	2.16	56.8	
88	1.39	0.2	12.4	23.84	14.8	70.5	3.36	1.94	17.8	
89	1.62	0.25	17.4	29.8	12.2	68.8	2.54	2.11	54.3	
92	1.66	0.24	17.2	28.8	16.6	61.6	3.13	1.76	27.2	
101	2.02	0.3	21	27.1	12.6	53.8	3.39	2.04	23.2	
102	2.02	0.3	22.5	30.3	12	66.3	2.91	2.13	19	
104	1.53	0.23	15.7	22.2	11.5	48.6	2.71	1.68	39.1	
105	1.91	0.3	18.7	26.8	11.5	62.4	3.53	1.66	42.4	
113	1.89	0.27	19.5	34.8	15.3	71.5	3.53	3.46	12.4	

Table C.1 (continued)

116	1.45	0.22	14.3	22.2	11.4	56.2	2.56	3.15	26.4	
128	1.39	0.21	13.9	33	19.9	56.3	2.94	1.59	36.4	
138	2.09	0.3	21.4	28.8	13	65.9	2.88	2	32.8	
139	1.6	0.23	16.5	22.6	11.4	53.1	2.53	1.53	41.4	
140	1.87	0.28	18.9	25.3	12.6	52.9	2.59	1.96	21.5	
299	1.65	0.24	17.8	31.7	14.1	64.6	3.27	3.96	36.8	
300	1.69	0.26	16.2	27.3	18.2	63.4	3.02	2.01	33.3	
301	1.56	0.25	16.5	25	11.2	58	2.28	1.62	14.6	
302	1.7	0.28	19.5	32.2	16.3	65.4	2.81	3.19	39	
303	1.89	0.28	19.7	42.6	20.8	77.5	2.87	1.76	16.9	
304	1.93	0.29	22.1	30.4	15.6	63.6	2.85	2.89	22.1	
Avr	1.72	0.26	17.79	28.46	14.12	62.09	2.93	2.23	30.67	
Stdev	0.2	0.0	2.8	5.0	3.0	7.2	0.4	0.7	12.7	
11b	0.61	0.09	5.47	9.05	2.85	17.29	1.11	1.1	15.98	
13a	1.95	0.31	18.96	19.90	6.74	40.38	2.27	1.76	15.23	
14d	1.82	0.29	18.43	14.1	5.05	28.94	1.66	1.33	14.23	



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EDUCATION

Degree	Institution	Year of Graduation
PHD	Archaeometry, METU	2025
MS	Analytical Chemistry, Hacettepe Univ.	2005
MS	Biotechnology, METU	2000
BS	Chemistry, Hacettepe Univ.	1997
High School	Ayşe abla Koleji, Ankara	1992

WORK EXPERIENCE

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2022 March-	METU Central Laboratory, R&D Training and Measurement Center.
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July 1996	Novartis (Sandoz) Products, Drug Department, Quality Control and Security Probation, Büyükdere Cad. No: 215 4. Levent, İstanbul
July 1995	Novartis (Sandoz) Products, Drug Department, Operation Probation, Büyükdere Cad. No: 215 4. Levent, İstanbul.

FOREIGN LANGUAGES

Advanced English, French

PUBLICATIONS

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