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DIPLOMA THESIS:

PETROGRAPHIC AND CHEMICAL ANALYSIS OF POTTERY: THE CASE OF PREHISTORIC POTTERY FROM PASSAVAS, LACONIA

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Abstract

Archaeometric approaches in archaeology are becoming increasingly popular. Pottery studies are enhanced by archaeometric interpretations offering more integrated approaches. In the present study 14 pottery samples from southern Laconia dated macroscopically and archaeologically to the transitional phase of Middle to Late Helladic period are petrographically and chemically investigated.

Cultural dynamics during the emergence of the Mycenaean civilization and their impact in pottery traditions are widely discussed. The pottery from Passavas in southern Laconia, is distinguished by the influence of Minoan traditions, posing exciting questions about the origin, manufacture and traditions of its ceramic techniques and styles. The analytical methods of optical petrography and scanning electron microscopy are used to investigate issues of provenance and technology. The results of the petrographic analysis indicate a high correlation with the geology of the area and practices of pottery manufacture applied in the wider area of southern Laconia, including Kythera. Pastes of clay established for Kythera are also encountered in Passavas. The results of the chemical analysis are indicative of the metamorphic geological character of the area of Passavas or Kythera, in contrast to the sedimentary geological character of Ayios Stephanos, a well-known site in proximity, despite the high correlation of the latter with Passavas, regarding pottery traditions and styles.

1. Introduction

Natural sciences are gaining more and more ground, addressing archaeological issues. The interdisciplinary approach of archaeometry has found increasing appreciation from the archaeologists and the scientists of natural sciences. Artefacts are studied with respect to their cultural load, and usually on the basis of their nature. In this thesis, the study and archaeometric approach of prehistoric pottery from Laconia is presented, through petrographic and chemical analysis.

The Minoan expansion during the Middle to Late Helladic period is reflected to the pottery traditions during the emergence of the Mycenaean period. The pottery from Passavas does not differ from that tradition. The aim of this study is to detect how Minoan and local traditions intertwine from an archaeometric perspective, the results of this study are petrographically and chemically consistent with the local geology; in some cases, however, manufacture, surface treatment and shape point to Minoan traditions while in others mainland shapes are combined with tempering techniques of Minoan inspiration.

The pottery under investigation is dated in the transition from the Middle to the Late Helladic period, according to the archaeological interpretation, and the dawn of Mycenaean era. Sherds are studied on the basis of their chemical composition and geological character. Two analytical methods were applied, petrography and scanning electron microscopy with energy dispersive spectroscopy, aiming to provide information about the manufacture of the pottery in correlation with their stylistic characteristics.

After a brief presentation of the archaeological context, the samples and the cultural dynamics in prehistoric Laconia in Chapter 2, basic information about the pottery manufacture, chemistry and petrography are presented in Chapter 3. In chapter 4 after the presentation of the samples, the analytical methods applied for their study are presented, as well as information and settings about the analytical equipment. A catalogue of the samples is also presented in Appendix I. The results of the chemical and petrographical analysis are presented and discussed in Chapter 5, presented thoroughly, as well, in Appendix II and III. Last, conclusions drawn by the analytical study and archaeological context are presented in Chapter 6.

The archaeometrical approach of the present study sets specific questions and comes to verify the archaeological interpretation for the transitional stage of the Middle to Late Helladic Bronze Age.

2. Archaeological Context: The site of Passavas

Passavas is a modern town located to the south-eastern Laconia, on the Mani peninsula (fig. 1). Southern of the modern town, the hill of Passavas rises at a height of 154 meters. Ruins of medieval fortification are preserved here, till today. On the eastern part of the wall, underlying the medieval fortification, for about 55 meters long a polygonal masonry is visible, incorporated to the medieval wall (Banou et al. 2019).

Pausanias, after his visit in Laconia, located the ancient city of Las on the hill of Passavas. According to him, Las, also mentioned by Homer, is located 30 stadia from Gythium and 5 stadia from the river of Smenos, identified as the modern Tourkovrysi stream. Passavas is a well defended hill, with water supply close by, overlooking a small but fertile plain and commanding the passage to the Mani peninsula and southern Messenia (Forster 1907,232-234). However, and despite many visits by scholars, no prehistoric finds are made from the hill itself. A single obsidian chip does not consist sufficient evidence, as Waterhouse and Hope Simpson admit, who note, however, that the hill *''would have made a magnificent Mycenaean fortress, worthy of the name Λάας''* (Waterhouse and Simpson 1961, 118).

Recent construction works on the road Gytheio to Gerolimenas in 2013-2016 and 2017 have brought to light twelve new sites in the area of Passavas dated mainly from the Archaic to the Roman Period. On the eastern side of the hill between two parallel late classical walls and under a 20cm layer of yellow sandy soil, a 15cm thick layer was revealed containing prehistoric pottery dated to the Middle Helladic III-Late Helladic IIA period. These new finds provide more information about the transitional phase of Middle to Late Bronze Age around the Laconian gulf, known so far mainly by the excavation of the site of Ayios Stephanos, 16 km to the northeast on a straight line (Banou et al, 2019).

The transitional stage of Middle Helladic to Late Helladic period, also known as the Shaft Grave era, is a period of an increasing change, characterized by the introduction of ideas and crafts from the Aegean, especially from Minoan Crete (Basiliku 1995, 23-102). Passavas is located on the Laconian gulf and close to the well excavated and studied site of Ayios Stephanos on the Helos Plain. The Helos

Plain was probably the main entry of the Mainland by sea, from Kythera and further away. Ayios Stephanos' findings during this period are indicative of the transitional and experimental phase of the shaft grave era. Pottery can be reminiscent of Minoan stone vessels (Rutter, 1979). Contrary to Ayios Stephanos, Passavas is located on a hill and southeastern of the site, providing a different inspection of the sea. In southern Laconia the Minoan influence is highly reflected on pottery and probably is transmitted through Kythera, while in Messinia in funerary architecture and in Argolid in smithery (Rutter, 1979).

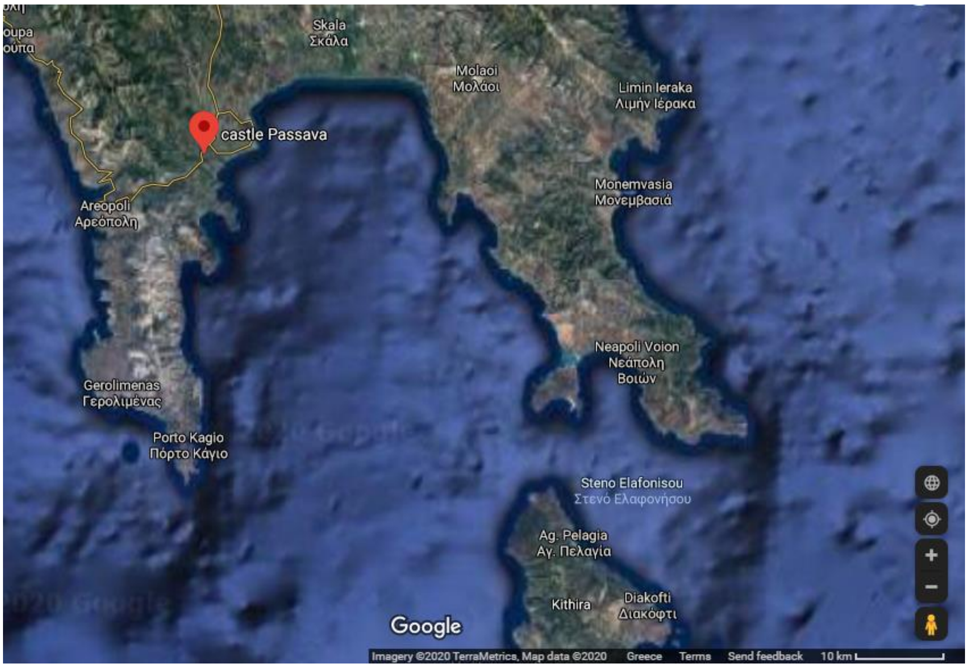

Fig. 1 Map of southern Laconia and Kythera. With a pin, the castle of Passavas

3. Pottery Analysis in Archaeology

Ceramics are the most common find in archaeological excavations. Are inorganic, manmade materials composed of earth and water, fired in high temperatures. Pottery manufacture is known for thousands of years and the properties and enduringness make pottery sherds a material that can withstand time and soil. For these reasons, archaeological sites are abundant in sherds of pottery. Due to the large number of sherds, pottery is a tool to define and characterize civilizations of all periods. It comprises a sensitive chronological factor that sets and defines periods of generations and styles. Pottery was used in everyday life activities, such as cooking, storage, culinary utilities but also for special uses regarding ceremonies and special practices. Thus, it is usual to find in one assembly fine vases with elaborate decoration together with coarse pots with no signs of decoration or special treatment. Styles and forms of pottery evolve through time defining generations and periods. For this reason, pottery is studied from many different aspects, including technology, function, and decoration. Today, archaeometry plays a significant role in studying ceramics as it can provide information about the origin and manufacture, the absolute dating, and even the content of a pot.

3.1. Pottery Manufacture

Pottery manufacture comprises a series of operations that transform raw materials into a finished product. The methods and techniques adopted, have been investigated via anthropology and ethnoarchaeology parallels (Rice 1987, 115-120). Ancient ceramists chose their raw materials through trial and error; once they become familiar and experienced, they chose raw materials by the touch of clay, distinguishing "fat" or fine-textured clay from a 'lean" or silty one. Properties that define good quality clay are particle size, plasticity, drying shrinkage, and thermal behaviour during and after firing. Localization and exploitation of suitable raw materials is the primary step to pottery manufacture. The selection and preparation of raw materials is an important aspect of pottery making, and liable for the final product. Raw materials can be obtained in different ways. Potters may use clay from a single source or employ different sources interchangeably. It was not uncommon for potters to travel up to 50 kilometres away to find suitable raw materials (Rice 1987, 116). Clay is usually found by river banks, stream beds, road cuts, and in depths. After mining, clay is purified of inclusions and coarser fractions by hands, grounding soil agglomerates, sifting, or soaking. Soaking, also known as levigation, sufficiently thins consistency of the clay and permits coarser particles to settle and leaves the fine mineral in a suspension. Then the potter determines the properties of the clay depending on the type of ceramics they want to create. If the clay is very fine and has high plasticity that it is hard to form into the desired shape, a non-plastic temper is added to make the clay matrix more suitable for the design in mind.[1]. A commonly added temper is grog, made up of smashed unfired pottery, or organic materials such as shells and straw. When the clay mixture is ready, it is homogenized by thoroughly mixing the paste even by foot, to eliminate trapped air and non-mixed clay presence (fig. 2) (Shepard 1956, 50-54)

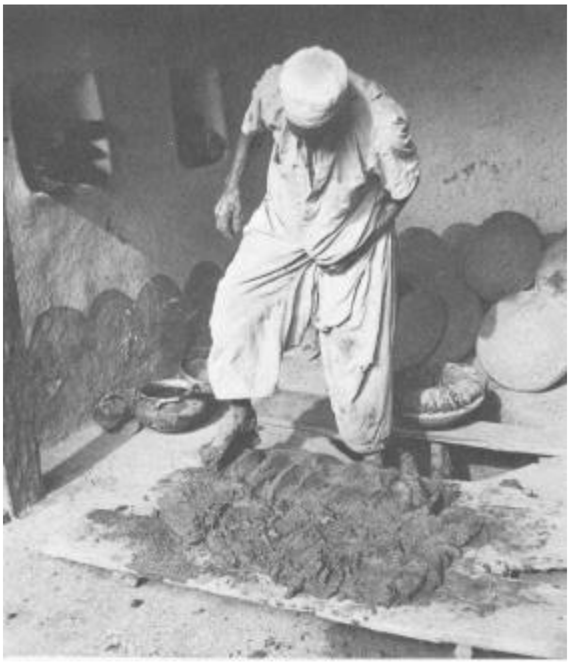

Fig. 2 Mixing and homogenization of clay paste (Velde & Druc 1999, 19)

When forming a vessel, it is necessary to appreciate the consistency of the clay and its water content that makes it workable (Rye 1981, 20-21). The forming stage includes a series of operations that transform the clay paste into a ceramic product. Different techniques and methods are determined by both cultural and functional factors, as ethnographic parallels demonstrate (Rice 1987, 124-125). Each method of forming a pot involves different techniques or physical modalities[2]. The size of a

[1] Temper is the material added by the potter to modify the plasticity of his clay base, to give it workability, or some specific properties. However, it is difficult to define naturals from added substances. Added temper is also called non-plastic, additive, aggregate, grog, filler. The term "inclusion" is more common, as it includes all types of temper, either added intentionally or not.

[2] Those techniques are classified by the source of energy (muscular or rotative kinetic energy), the clay mass onto which the pressures are exerted (homogenous or heterogeneous), the type of force (pressure or percussion), the type of pressure (discontinuous or continuous) and the degree of hygrometry of the clay paste (humid or leather hard clay) (Roux 2017, 103-105).

vessel influences the way it is built and frequently several techniques are implied (Roux 2017, 103-105).

The methods for creating ceramics are divided into two main categories: building by hand and throwing on a wheel (fig. 3). The simplest techniques are *pinching* and *drawing*, also known as lump modeling. By pinching, a lump of clay comes to shape by squeezing between fingers or opposite hands. The walls are thinned and increased in height gradually. Pinching is a technique for small vessels with round bases and no identifying traces of it are usually visible. Drawing, on the other hand, is used for larger vessels. The main concept is the same as pinching, but the movement here is vertical and this method can be identified by the orientation of the inclusions. *Slab building* is an assemblage handmade technique. Flat slabs are formed first and then joined to create the desired shape.

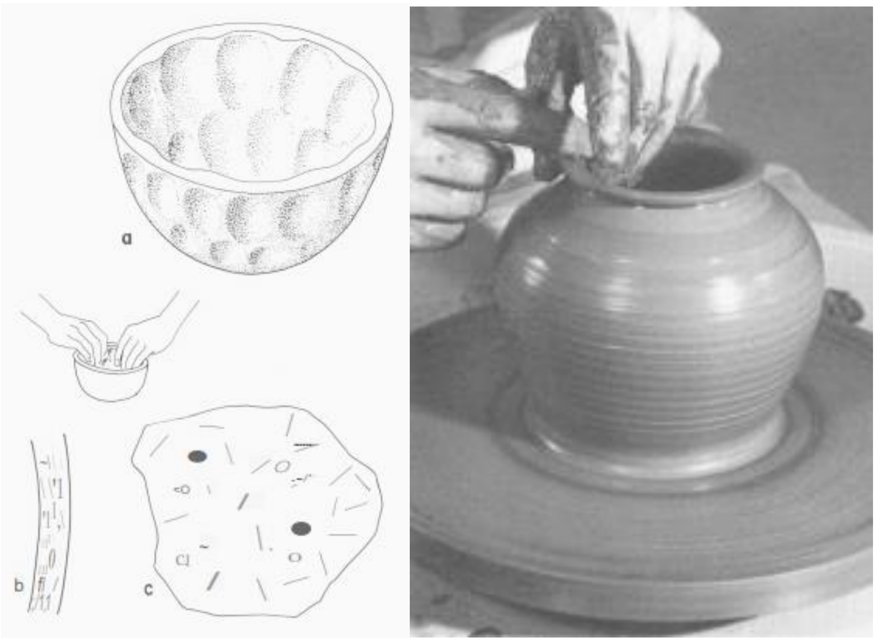

Fig. 3 Forming by Hand and Throwing on a Wheel (Velde & Druc 1999, 37,70)

On whole vessels, cracks of poor joining can be identified. *Molding* is another handmade technique that requires a mold, concave or convex. Flat slabs are pressed to molds and worked with tools to even out the edges. This technique is typical of large pots productions.

Another primary handmade vessels' technique is *coiling*. Rolls of clay are formed and then built up to create a vessel. Generally, the coils' diameter is about double the thickness of the desired thickness of the vessel. The coils are placed on a flat surface and gradually the vessel is built by increasing the height. There are three variants of coils and techniques: ring building, segmental coiling, and spiral coiling. In contrast to coiling ring building involves laying a series of circular coils on top of the other. Segmental is a variant of ring building in which each annular course is composed of several segments and spiral coiling refers to building a vessel from a spiraling rope of clay. The potter then evens out the lines by hand or with a flat surface tool. Generally, large vessels are built that way. The differentiation between those variations can be easily identified by the preferred orientation of inclusions. If the clay has dried before another coil can be superimposed on the vessel binding between these coils is poor then the joint is weak and the stress of drying and firing will create cracks implying the parallel coils and identifying coil building (Rye 1981, 66-73; Rice 1987, 125-128).

Throwing is a huge innovation in pottery manufacture. On a flat wheel, a potter works a slab of clay with his hands by actions of drawing and pinching. Usually, the clay for wheel throwing is wetter and finer because lifting actions require a wet clay, as well as because the water evaporation is rapid to rotation. The potter often immerses his hands in water, and a slab of clay is placed at the center of the wheel. Opening and lifting motions are applied to shape the desirable shape. Finishing and decorating are usually done on the wheel and afterwards, the vessel is cut and removed from the wheel. A wheel-thrown vessel has distinctive marks of parallel lines and usually marks on the base of the vessel from cutting. The inclusions here have a preferred orientation (Rye 1981, 74-81).

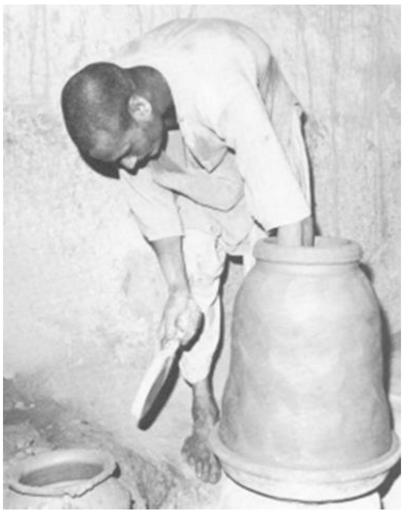

Fig. 4 Beating with a Paddle and anvil (Velde & Druc 1999, 84)

Since the roughout[3] has formed, secondary forming techniques are applied. Among these, the most common are trimming, scraping, and beating. The clay, still wet, can be remodeled by *beating* (fig. 4). Beating can alter the form of a vessel. This technique is employed with a paddle on the exterior and anvil in the interior to remodel specific parts of a vessel and it is common for coil-built vessels. With scraping excess clay can be removed from thicker parts, and trimming is applied mostly on mold-built vessels to remove protruding parts (Rice 1897, 136-137).

After the vessel has attained its final shape and is still wet or dried partially, finishing treatments are applied on its surface to remove irregularities and improve surface quality. *Smoothing* is the simplest method to obtain a surface effect. With a soft tool, cloth, leather or the potter's hand the clay particles and temper align themselves perpendicular to the pressure and parallel to the pot giving a matte finish to the surface. *Burnishing* is obtained with a hard object that has a smooth surface, like pebbles, bones, and horns. As the object is rubbed against the surface of the pot, it causes compaction and reorientation of the particles creating a luster surface. A *polished* surface differs from a burnished one in terms of care of execution. A burnished surface ordinarily bears parallel marks, facets, or strokes, which are distinctive. A polished surface is treated usually when the clay is hard and dry giving a uniform luster. Furthermore, incomplete burnishing or part burnishing occurs as a pattern on a luster and matte surface (Rye 1981, 84-88).

Decorative techniques are distinguished in displacement techniques or penetrative and additional decorations (Rice 1987, 144). Techniques that displace and penetrate clay are usually applied on hard leather clay. Through *incising* a part of the clay is displaced to create a pattern of decoration. The tools employed are used differently depending on the result the potter wanted. The tip of the tool provides a different result on each occasion. Incising is also characterized when it is applied as pre-slip, post-slip, or post-fire. On each occasion, the result is different; the Greek black and red-figured vases are an example of this method. Variants of the incision are combing, performed with a comb-like tool, to create parallel lines and sgraffito,

[3] According to Roux, the clay body is divided into two stages; roughout is a hollow form that has not any final characteristics of the vessel and preform is the vessel that has not been under any surface treatment techniques. The preform is obtained by shaping a roughout. (Roux 2017, 104)

where the glaze is cut out from the surface of the pot to create a contrast pattern between the clean surface and glaze. The penetration of clay occurs when techniques apply pressure to decorate the surface. The technique of *stamping* is achieved by the use of a stamp that is pressed on the surface to leave a negative; impressing, on the other hand, is when a tool shell or even the potter's thumb is pressed against the surface. Additional decorations are characterized by the addition of material to the surface. *Relief decoration* or plastic requires the addition of clay to create a three-dimensional decoration. When this technique is employed the clay, underneath is also displaced to create better adhesion. *Painted decoration* is achieved by the addition of colorants when the surface is dry and most commonly before firing. *Slip* is described as a fluid suspension of clay into water. Usually, it covers the entire surface to provide uniform color smoothness and seal any discontinuities. Also, it provides a clean surface for subsequent painting. It is applied either by dipping a vessel into the suspension, giving uniform coverage, or by pouring. *Pouring* is more useful for large vessels or when slip is only intended to cover the interior. Slip is typically a different color from the base and presents variations in luster, quality, and thickness. In comparison, *glaze* has the same purpose but is a thicker, glassy suspension of glass with colorants, giving the surface a different result. Also, it requires better expertise and higher firing temperatures. Colorants for creating decorative forms are applied usually with a brush. Most of them are heat resistant, inorganic, and formed by metal oxides. Firing conditions play a significant role in the final color. Pots that present decoration of two different colors are called bichrome and three, or more colors, are called polychrome (Rye 1981, 89-95).

After the vessel has attained its final shape and pre-firing decoration a very important stage of pottery manufacture begins, *drying*. Drying is a significant stage and very time-consuming. The pot must be completely dry before firing, since firing is a very intense process that can cause cracks and flaws to the pot. Sudden changes in temperature can ultimately destroy the pot. Drying time depends on weather conditions and if those are not favorable drying indoors is common. Also, preheating is common to ensure that the vessel is completely dry before firing (Rice 1987, 152).

Firing is a demanding process that requires expertise and natural resources. The temperature rate and atmosphere of the firing process must be under control throughout the process to ensure good quality as well as nice decoration. As pottery manufacture involved, the firing practices advanced as well. The simplest firing method is the open firing; no building is required here and the pots are placed directly on top of the fuel (usually of fast-burning) and are cover of fuel as well. The temperature in open firing spans between 600℃ and 850℃, but is common to have spots where the temperature exceeds 900℃. Open firing is an economic and time-saving solution; however, the pots are not protected from the fuel, there are rapid temperature changes, and it is impossible to control the temperature. Wind plays a significant role in open firing that can either promote firing or delay-destroy it. Pit firing is a variable of open firing where the pottery and the lower bed of fuels are placed in pits in the ground. It is an intermediate type of firing between open firing and kilns. Only blackened pottery can be produced here by covering the pile of pots with powdered manure or sawdust to cut the supply of oxygen; carbon is then deposited on the surface and in the pores of the vessel. Firing in a kiln requires a durable structure made of clay or stone and usually of cylindrical shape (for bricks square and rectangular kilns are used). There are two types of kilns consisting of two chambers, one for fuel and one for the vessels. In kiln firing the air can be controlled by reducing or promoting the oxygen in the pot chamber and producing vases of elaborate decoration. The rate is also under control and a higher temperature can be reached, around 1000℃ to 1300℃. An updraft kiln is a simple structure where the chamber is more or less on top of the fuel. This type of structure does not have an even distribution of heat efficiency in contrast with the downdraft kiln. A downdraft kiln has a horizontal firebox and chamber(s) of pottery separated by barriers. The heat and gases ventilate from chamber to chamber, to escape from a chimney. This way temperature is evenly distributed and there is less heat loss (fig. 5) (Rye 1981, 96-104).

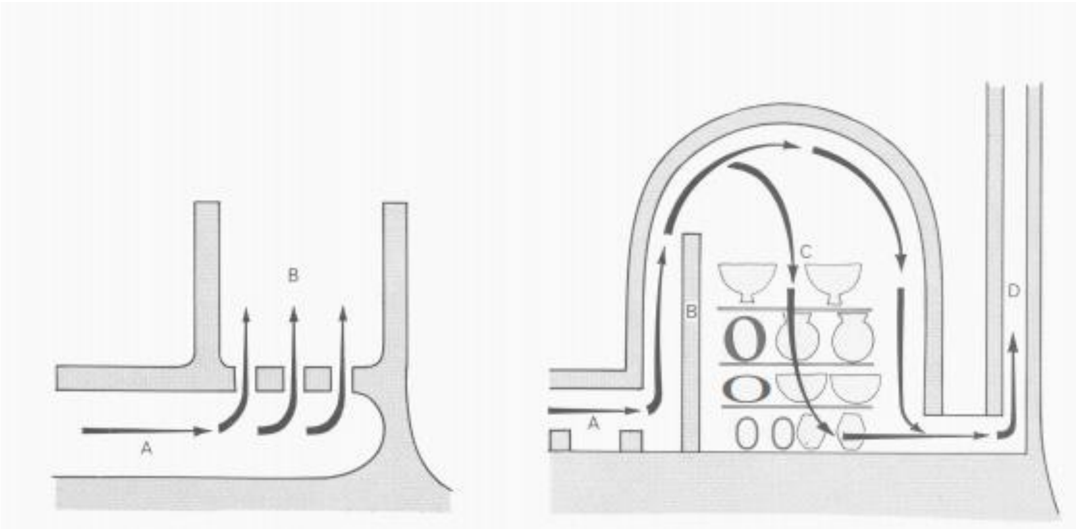

Fig. 5 Updraft (left) ad Downdraft (right) kilns (Velde 1999, 104)

3.2. Mineralogical and chemical characterization of pottery

Chemical and mineralogical[4] characterization of pottery is used in conjunction with technological and provenance issues such as temper investigation, firing, and temperature determinations. or the fabric from which pottery is created consists of clayey materials and inclusions. In archaeology it is common to use the term clay to describe the raw material from which the ceramist creates a pot (potter's clay). In geology, clay is a natural material composed of about 80 % clay minerals and other fine-grained material of different mineral species. This material has a natural grain size of less than 2 pm (micrometers) in diameter (Rice 1987, 31-50). Geological and chemical issues regarding pottery are going to be presented onwards.

3.2.1 Rocks and Minerals

Minerals are earth materials formed by elements and oxides combined in various ways. They are homogenous, inorganic, with definite chemical composition and atomic ordering. They have a systematic structural arrangement that exhibits one of many orderings and is called crystalline. Apart from their chemical characterization, their crystalline structure, gravity, luster, hardness, fracture and color of minerals are indicative of their identification. Several minerals compose rocks (fig. 6, 8). The minerals of each rock can be described as essential or accessory according to the amount of their presence. Minerals and rocks are classified in large families based upon their chemistry and structure (minerals) and upon the way they are formed (rocks) (Lyritzēs 2007, 90-97).

Rocks are classified as igneous, metamorphic, and sedimentary depending on their origin. Igneous rocks are formed from magma under high pressure and temperature under the earth's surface. According to where they are formed, they are classified as volcanic or plutonic. Volcanic rocks are formed when magma erupts to the earth's surface and cools rapidly, while plutonic are formed deep in the earth and

[4] Mineralogy is a subject of geology that deals with all aspects of minerals including their physical properties, internal crystal structure, and chemical composition, as well as their occurrence and distribution in nature.

cooled slowly. Thus, their difference in the crystal structure is characteristic and identifying. Metamorphic rocks are formed in-depth or under specific circumstances of heat and pressure by other rocks. They are named metamorphic since their original structure has been altered. Sedimentary rocks derive from sediments and are the result of transportation and redeposition of weathering products. In the lithosphere, sedimentary rocks account for 66% of rocks. Almost all rocks derive from igneous rocks which are formed mostly by silica (Velde & Druc , 1999, 16-18).

Most minerals are basically formed by silicon (Si) since the composition of earth's crust in Quartz (SiO_2) is 60.1% (Rice 2005, 32). The largest group of minerals, Silicates, includes minerals like Quartz, Feldspars, Pyroxenes and Amphiboles, Olivine, Micas, and Chlorite (Fig. 7). Those minerals (feldspars, mica, quartz) are also abundant in rocks since they are the most resistant to weathering (Fig. 6). All silicates have silica tetrahedra (four oxygens surrounding a single silicon atom) arranged in different structures. Accordingly, they are classified into seven major groups[5]. *Quartz* is the most silica-rich mineral and the most common on earth's crust. It is a very resistant mineral to weathering along with *chert*, which is also a crystalline form of silica but poorly formed. Rocks that contain large quantities of quartz are named sandstones (for sedimentary rocks) or quartzite (for metamorphic rocks) (Velde & Druc 1999, 21). Feldspars are alumina silicates that consist of SiO_2 and Al_2O_3. The presence of potassium (K), sodium (Na) and calcium (Ca) is responsible for the subdivision of feldspars into alkali feldspars (orthoclase), soda-lime feldspars (albite, oligoclase, andesine, anorthite, and plagioclase) (Rice 2005, 35). Most potassium feldspars found in ceramics come from

Table 2.3 Rock-Forming Minerals in Order of Resistance to Alteration

1. Quartz (most resistant)	10. Albite feldspar (Na/Ca)
2. Zircon	11. Oligoclase feldspar (Na/Ca)
3. Tourmaline	12. Andesine feldspar (Ca/Na)
4. Magnetite	13. Anorthite feldspar (Ca)
5. Ilmenite	14. Apatite
6. Rutile	15. Biotite mica
7. Muscovite mica	16. Hornblende (amphibole)
8. Orthoclase feldspar (K)	17. Augite (pyroxene)
9. Garnet	18. Olivine (least resistant)

Fig. 6 Rock-Forming Minerals in Order of Resistance to Alteration (Rice 2005, 34)

[5] Nesosilicates, Sorosilicates, Cyclosilicates, Inosilicates, Phyllosilicates, Tectosilicates. Feldspars and quartz are examples of tectosilicates with a 3D framework, micas and clays are phyllosilicates, with a sheet-like structure.

intrusive, slowly cooled rocks, while plagioclase feldspars are found in a variety of igneous rocks, and in metamorphic rocks. Other silicates, with special reference to pottery, are pyroxenes and amphiboles, which contain calcium (Ca), iron (Fe) silicon (Si) aluminum (AI), and magnesium (Mg). Amphiboles are often found in metamorphic rocks. Pyroxenes are found in magmatic rocks and more rarely in metamorphic rocks. They are rare in sedimentary rocks. Olivine is a mineral high in magnesium (Mg) and commonly found in igneous rocks. Micas are very common in ceramics, they composed of potassium (K) and the two groups are dominated by aluminum (Al) –Muscovite- and by iron (Fe) –biotite-. They are commonly found in metamorphic rocks and are frequent in igneous rocks.

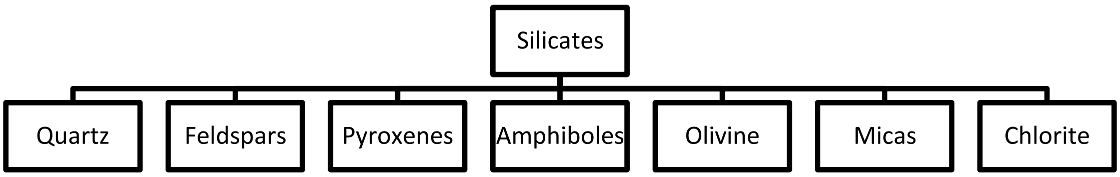

Fig. 7 The Silicate Minerals Common in Ceramics

Calcium minerals occur also in pottery as well as oxides. Calcium minerals consist of calcite ($CaCo_3$) and dolomite (CaMg(C03)2); they present differences in their crystallography. In clays, calcium minerals act as fluxes (they create a low melting point, reduce vitrification). Oxides are a mineral group mostly consisted of iron and manganese oxides, predominately. Those oxides are mostly responsible for the color of the pottery as well as for their decoration (Grimshaw 1971, 280-282).

Minerals	Original Rocks
Quartz (high abundance)	Sandstone or metamorphic sandstone (quartzite)
Micas + quartz	Metamorphic and clay-rich sedimentary rocks (pelites)
Quartz + potassium Feldspar + mica	Granite and high-temperature metamorphic rocks formed from clay-rich sediments or metamorphic clay-rich sediments
Amphiboles + plagioclase	Metamorphosed basic magmatic rocks, now amphibolites
Pyroxene + olivine	Basalts (lavas) and basic magmatic rocks
Calcite + dolomite	Carbonate rocks, either sedimentary or metamorphic

Fig. 8 Major Minerals Found in Different Rocks (Velde & Druc 1999, 32)

3.2.2 Clay Minerals

Clay minerals are hydrous (contains water) aluminum phyllosilicates. Phyllosilicates are a large family of silicates with characteristic sheet-like structure and a regular ordering of layers of silica and alumina. Those sheets are placed one on top of the other and alternately up and down. The two layers facing each other are held by cations and hydroxyl groups. Clay minerals are the plastic part of ceramics that are liable for the plasticity, necessary for pottery making. Phyllosilicates form different mineral groups, based upon their structure. Thus, we have the kaolin group, the smectite group, the vermiculite group, the illite group, and the chlorite group (Velde & Druc 1999, 20).

The Kaolin group is composed mainly of the clay mineral kaolinite. It is a two-layer group of silica and alumina. It is composed of 46,6% silica, 39,4% alumina and 13,9% water (Rice ,45). Chemically it can be identified by the presence of potassium and traces of iron (Velde & Druc 1999, 46). Its color is white and not altered by firing conditions. The smectite group has a three-layer structure, with two layers of silica separated by an intermediate layer of alumina. It is composed of 66,7% silica, 28,3% alumina, and 5% water (Rice 2005, 48). The illite group has also three-layer clays but is characterized as a non-expanding group in contrast to the smectite group. That means that the smectite group clays exhibit big variation in volume when worked, in contrast to the illite group clays. The chlorite group is a mixed layer mineral group that has a distinctive color of green due to the presence of ferrous iron (Fe^2). Also, it contains an amount of magnesium indicative of this group (Velde & Druc 1999, 45).

Clays are also categorized on the basis of their depositional situation. Thus, we have primary or residual clays and transported or secondary. Primary clays are found more or less in the area of the rock they may derive. They are coarse and have low plasticity and organic content, usually less than 1% (Rice 2005, 37). Secondary clays are found in deposits or clay beds distant from the rock they derived due to weathering actions (water streams, winds erosion, etc.). They are finer than primary ones, more homogenous, and contain more organic components (5-10%).

Granulometry of clays is also an important factor for clay studies. The small size of the clay particles enables it to be soluble in water and easy to handle. Clays have a specific particle size range, smaller than 2μm. Moreover, the presence of other minerals and materials can change the characterization of the soil as clay or not (fig. 5).

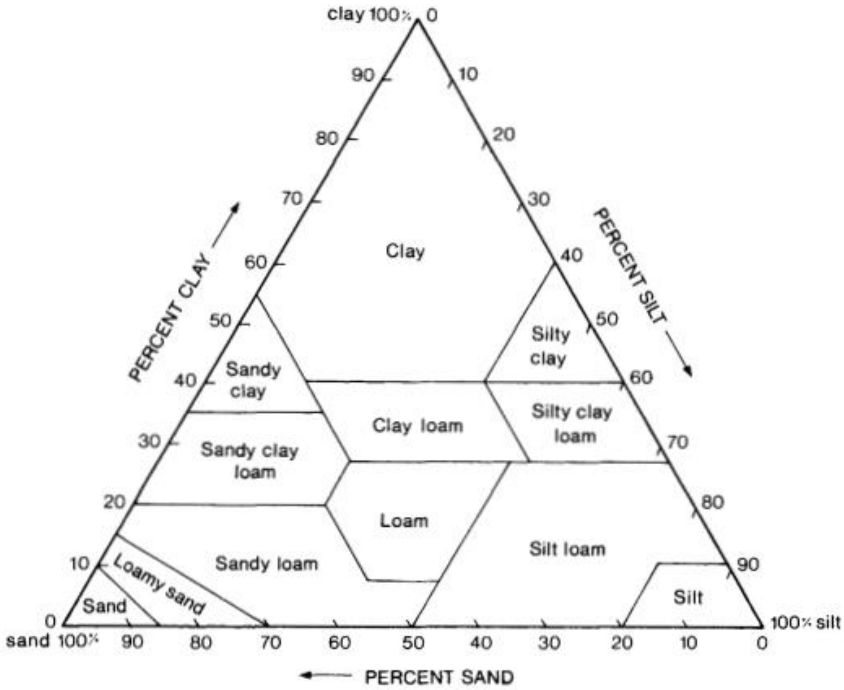

Fig. 9 Characterization of name class of soil according to its particle size distribution (Rice 2005 ,108)

3.2.3 The Impact of Fire on Clay Minerals

During pottery firing an irreversible chemical change takes place (fig. 10). The plastic clay-rich paste is transformed into a solid material. The clay is brought to a high enough temperature for a sufficient time to transform the mineral. Based on the firing time and the temperature, as well as on the chemical composition, the alterations differ. Thus, we categorize fired pottery to earthenware, stoneware, and porcelain.

First, a formed vessel has to lose all the excess water by air drying. This process is long, and the pot might shrink up to 15%. Then at the first stages of firing, at temperatures above 100℃ more water is evaporated. While the temperature rises, minerals lose their crystalline water, an irreversible process. Then at higher temperatures, the non-clay particles melt. At the most advanced stage, clay and temper form a glass structure.

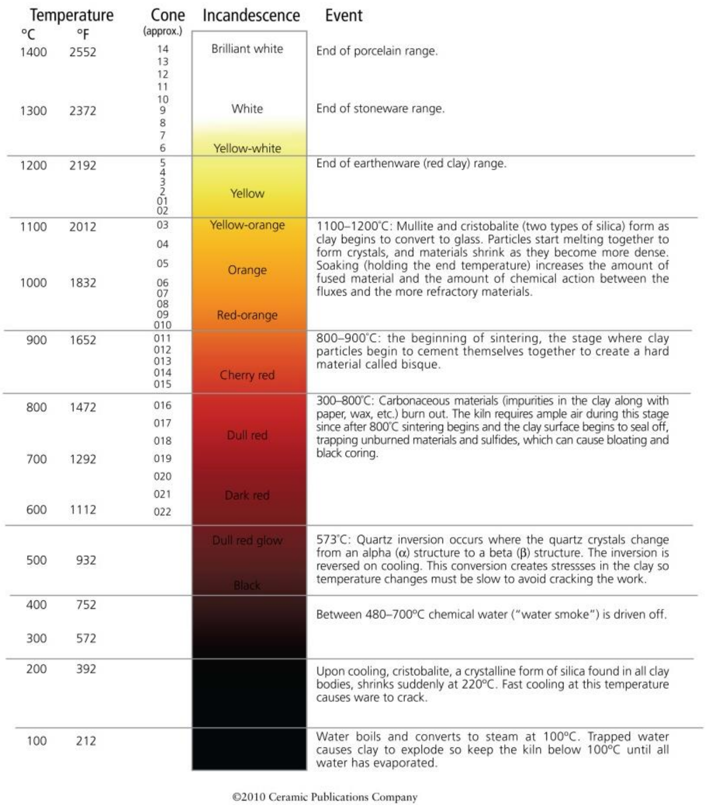

Fig. 10 Changes in Clay During Firing, Kiln Firing Chart of Modern Kilns (ceramicartsnetwork.org)

Earthenware, stoneware, and porcelain are the products of three firing stages and phases of minerals' physical alteration (fig. 11). Earthenware pottery has minerals in a crystalline phase with many interconnected pores. Stoneware has both crystalline and vitreous phase minerals and some closed pores, due to vitrification. Porcelain pots have predominately vitreous phase minerals and very rare pores.

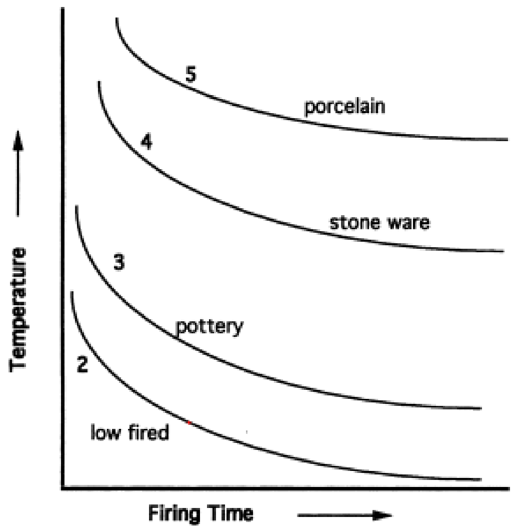

Fig. 11 The relation between Time and Firing Temperature for each type of Fired Pottery (Velde & Druc 1999, 102)

In sum, when we deal with the properties of ceramics, we should take into consideration the clay as well as the inclusions that affect the properties of the pot and its behavior during firing. The inclusions, natural or additive, usually act as fluxes or improve the mechanical properties of the pot (Velde & Druc 1999, 103-105).

4. The Pottery from Passavas: Material and Methods

In this chapter, the samples under investigation and the methods applied are presented. After the presentation of the pottery sample, some basic features of each method applied for their study are presented as well as the instruments used.

4.1. The Samples[6]

Fourteen prehistoric sherds have been selected for petrographic and chemical analysis. They are a part of a large assemblage of pottery (399 prehistoric sherds and two vessel fragments) excavated on the eastern foothill of the Passavas' hill and selected as representative of the main categories of pottery found. They all come from a layer of a single episode of deposition. In particular, the samples derive from a large group of 355 sherds, classified and dated macroscopically in the transition from the Middle Helladic to the Late Helladic period (Banou et al. 2019).

The prehistoric pottery is classified according to the Ayios Stephanos classification, due to the proximity and synchronization of the two sites. The pottery group finds breeding ground for Zerner's (Zerner 2008) and Rutter's (Jeremy & Rutter 1976) work on the classification of the prehistoric pottery, following the work of Rutter and Zerner. The samples fall into the following categories, established macroscopically: Dark Burnished, Mainland Polychrome, Oatmeal Minoanising and Fine Minoanising/Lustrous Decorated, Micaceous Minoanising ware, Coarse and Early Mycenaean ware (Banou et al. 2019).

The variety and experimentation which the aforementioned wares reveal is to be expected in Laconia in the transition from Middle Helladic to Late Helladic. Minoanising and mainland pottery traditions coexist and seem to be tested, throughout the coastal and inland Laconia (Banou 2000). The proximity of Laconia to the Minoan colony of Kythera, during a period of expansion of the Minoan civilization, seemed to have played a crucial role reflected in the pottery.

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[6] I would like to express my thankfulness here, to the archaeologists Tsouli and Preva, for allowing studying pottery sherds that they excavated. The sherds are also interpreted archaeologically by Banou & Tsiagouris (Banou et al. 2019)

For the catalog of samples, see APPENDIX I

The term “Minoanisation” is used to describe the cultural dynamics in places beyond Crete that show a strong Minoan influence within a timespan from the middle of the Early Bronze Age to the early Late Bronze Age. Cases of Minoan influence are evident in the Cyclades, the Eastern Peloponnese, and Attica till Samothrace. The term “Minoanisation” is well described by C. Broodbank (Broodbank 2004). However, the Cretan lifestyle was not accepted in all cases; in Kythera it was accepted while in Kolonna, Aegina, it was rejected, and in Lerna, Argolid, it was mediated (Kiriatzi 2010). As far as Laconia is concerned, Minoanising and mainland pottery traditions are both evident in Laconia (Cavanagh & Crowel 1996, 20) (Zerner 2008) (Jeremy & Rutter 1976, 10-12).

Dark Burnished/ Imitation Grey Minyan ware is represented by a single sample (no. 2). In total 10 sherds are identified, with a fracture color ranging from light grey to dark grey close to the surface, with few limestone and mica grits. All sherds are handmade. This group corresponds to Dark Minyan of Rutter (Rutter & Rutter 1976, 6) due to the large range of fracture color, with all vases being wheel made with a burnished surface. Zerner’s Dark Burnished ware is considered of local origin and mostly handmade (Zerner 2008, 189). Cavanagh (Cavanagh & Crowel 1996,18) notes that Zerner’s Dark Burnished ware is associated with Argive Minyan and Rutter’s Dark Minyan.

Mainland Polychrome is represented by one sample (no. 14). It is a transitional type of pottery of the early Late Helladic, with distinctive polychrome decoration on burnished surfaces, mostly wheel made. Mainland polychrome ware is highly correlated, stylistically, to Yellow Minyan and the category of the Dark on Light decoration but not technologically (Mathioudaki 2010 622-623). Totally three sherds have been included in this category and satisfy the requirements for the Mainland Polychrome (Mathioudaki 2010, 624-625), with reddish-brown clay, burnished surface, and dark on light decoration. Neither Zerner's nor Rutter's work refers to this type of decoration as a distinctive style.

Oatmeal Minoanising/ Lustrous Decorated is represented by 109 household ware sherds in Passavas. Four samples have been selected for further examination (no. 3, 5, 6, 10). Lustrous Decorated is considered Minoan in technology, but of local production (Zerner 2008, 206) Zerner’s, with Oatmeal Minoanizing, Fine

Minoanizing, and Lustrous Decorated (Jeremy & Rutter 1976, 10-12) representing a single group (group III) in Zerner's study. The paste is coarse to semi-coarse with limestone and dark-colored particles, occasionally mica. The mudstone-chert fabric appears in Lustrous Decorated and Polychrome styles (Kiriatzi 2010). In Kythera sand-tempered and mudstone-tempered fabrics occur already from the Early Bronze Age II to the Middle Bronze Age and from the Middle Minoan II to LMIAI respectively. Both wares are characterized by calcareous, mudstone and chert inclusions (Kiriatzi 2003, 125)[7]. This paste is considered to show strong Minoan influence and comprises 9-18% of Ayios Stephanos pottery (Kiriatzi 2010).

Micaceous Minoanising ware comprises household vessels with a distinctive fracture of orange to dark grey and huge amounts of silver mica (muscovite) inclusions. Out of 51 sherds identified at Passavas, three are petrographically and chemically investigated (no. 7, 8, 9). While Rutter describes this ware as Micaceous Minoanizing (Rutter & Rutter 1976, 11), Zerner describes it as Red Silver Micaceous since it shows a high correlation with Kythera's Red Silver Micaceous (Zerner 2008, 206-208). Zerner's term relies on the fact that she cannot be certain about the minoanising character of the pots on the base of shapes and decoration (in Kythera Micaceous Minoanising is confined to cooking pots and bears no decoration). At Ayios Stefanos this ware is also common in drinking vessels with painted decoration. In the sherds from Passavas incised or painted decoration occasionally occurs.

The fourth group of samples is composed of coarse pottery (no. 1,4,11,12). Two sherds of bowls with high, everted rim and angular profile, one sherd from a jar with everted rim and a rounded part from a cup or kantharos compose this group. Their fracture color is close to their surface color. Despite their coarse fabric they imitate the shapes and surface treatment of the Minyan ware[8]. Coarse pottery from Passavas combines "True minyan" shapes with an "oatmeal" paste, characterized as coarse fabrics and they all are handmade. The surface is smoothed and there is also an

[7] Sandstone tempered ware is distinguished from the mudstone tempered through the sandstone inclusions it has and is usually low fired.

[8] As Minyan ware is mainly characterized by the shapes of the pottery (Sarri 2010, 608).

attempt to imitate Grey or Argive Minyan by firing. In Ayios Stephanos Grey Minyan is almost absent and considered an import[9].

The last category of Early Mycenaean pottery is represented by 1 sample (no. 13). It is a rim of a goblet with monochrome decoration and a fine paste. The Early Mycenaean category is subdivided by Rutter into four subcategories (Monochrome, Linear Patterned, and Unpainted). As far as the paste and fracture are concerned, there is a great variation, but mostly are fine. All vessels of this category are wheel-made (Rutter & Rutter 1976, 13-14).

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[9] Yellow Minyan is more common (Zerner 2008, 195-199, 211), as noted also by Rutter (Rutter & Rutter 1976, 6).

4.2. Methods

Polarizing Microscope-Thin Section Petrography

The petrographic analysis is a microscopic analysis used for the investigation of geological materials, such as rocks, minerals, ores. It is applied to coal, concrete, wood, and earthy materials. Thin section-petrography is a useful mineralogical technique for the study of clay fabrics in archaeology, as it reflects the raw materials and the techniques applied for the manufacture of pottery (Quinn, 2009). In archaeology, the petrographic analysis provides information about the temper used, the fired clay, and the surface decoration. Hence, information about provenance, technology, usage can be gained. Ceramic petrography in the field of archaeology is a well-established research technique since the late '90s, with the first publication being on the volcanic rock fragments in Theran pottery, in 1879 (Braekmans & Degryse 2017,233-234).

The sample under investigation had to be prepared into a thin section. Ceramic thin sections require a small representative sample of the pot, about $1cm^3$ (Braekmans & Degryse 2017,237). When sampling a pot, we have to keep in mind that not all parts of it have the same composition or are of the same clay. For example, handles usually are of different composition. The sample is cut out from the pot using a non-deformational diamond saw. If necessary, resin is used to ensure that the pot will not be destroyed. The cut surface is grounded and attached to a glass slide. After that, the sample is cut parallel to the glass slide to 1-2mm and then grounded with fine abrasives until it is 25-30μm thick (Peterson & Betancourt 2009, 8). Usually, when quartz grains have a characteristic pale yellow and feldspars look gray or white under the microscope with crossed Nicols, the thin section is ready (Raith et al. 2011, 27-29). The thin section is either sealed with a top glass slide or not, and can be used for another type of analysis as well (usually SEM-EDS analysis) (Quinn 2009,29).

Thin section slides are studied under the polarizing microscope. A polarizing microscope is a compound light microscope fitted with a polarizer and an analyzer (fig. 12). It has the basic component of two system lenses. The objective turret is composed of the objective lenses of different magnification while the eyepiece lenses provide further magnification and increase the visual angle. So, the final image is produced to our retina through the binocular. These two system lenses are interrelated with a system of lenses. As soon as the light is emitted from the lower part of the microscope, it passes through the polarizer. The light source emits waves that vibrate randomly in all possible planes. The polarizer reduces these waves to a single vibration, creating a polarized plane. The polarizer is a film of stretched polyvinyl, also named Nicol prism[10]. The thin section is placed above the polarizer on a rotational stage and as the light passes through the section, it undergoes alterations that are characteristic for the specimen's identification. Above the thin section are the objective lenses and between them and the binocular is the analyzer. The analyzer is used to analyze the modifications the polarized light has undergone through the thin section. The light is natural when passes through the polarizer (parallel Nicols, PPL) and is polarized when passing through the analyzer (crossed Nicols, XPL). The analyzer can be modified by pushing and pulling it. Rocks and minerals show distinct different optical properties under each type of light. The magnification capabilities range from x20 to x200 times (Raith et al. 2011, 1-22).

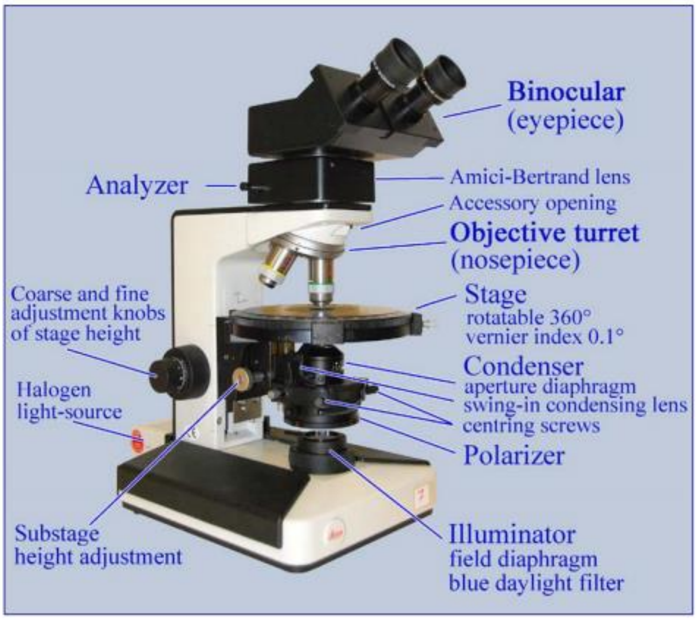

Fig. 12 The Polarizing Microscope (Raith et al. 2011, 12)

[10] It is named after the inventor William Nicol in 1828 (Peterson & Betancourt 2009, 12).

The basic optical properties of minerals observed in PPL are:

- Color; white or colorless minerals allow all wavelengths to pass through, black minerals (commonly Fe-rich) minerals absorb all wavelengths, and thus they can only be analyzed with a metallographic microscope. Different minerals exhibit different colors as they absorb certain wavelengths.
- Pleochroism; as the stage is rotated, the density or the color of the minerals is altered.
- Form; the shape of some minerals is identified.
- Relief; the correlation of the minerals with the groundmass and other minerals in the thin section.
- Cleavage; weakness lines in the minerals that correlate with their structure. The orientation and the number of them are diagnostic.

As the analyzer mounts each mineral exhibit different color properties than before. Minerals that go extinct in XPL are called isotropic minerals. The light passes through them unaltered in PPL and they appear completely black in XPL (no birefringence). Anisotropic minerals in XPL have different color and intensity. This also depends on the orientation of the thin section. In XPL the properties of the minerals that can be observed are:

- Interference Colors; the colors exhibited in XPL are also characteristic of the mineral.
- Extinction Angle; it is correlated to the crystal faces of the minerals. As we rotate the stage, some minerals might go extinct. The angle of extinction is taken into consideration for the identification of the mineral.
- Twining; it is correlated to the crystal structure of the mineral. Minerals have extinction angle internally, intertwined by areas with no extinction, they exhibit twining.

These properties are characteristic for each mineral, rock, and the processes through which they are formed.

Ceramic petrographic analysis with a polarized microscope is an affordable and accessible method for the study of the structure and composition of ceramics. Although thin section preparation might be time-consuming, the equipment is low cost and the interpretation of the thin section can take place anywhere. Thus, a large number of samples can be analyzed at a low cost (Shepard 1976, 139).

When studying a ceramic thin section, we observe the inclusions and the groundmass (clay) (Freestone 1995, 111-115). Usually, coarse ware fabrics are more suitable for petrographic analysis. The inclusions are demonstrative of the geological environment they originated and their shape for the circumstances under which they had been found in the clay matrix. The color of the argillaceous groundmass is indicative of its consistency in calcium (Riederer, 2004). This technique can provide both quantitative and qualitative (under circumstances, depending on the equipment) analysis for the inclusions but the type of the clay minerals cannot be identified (Shepard 1976, 147-168).

Scanning Electron Microscope with Energy Dispersive Spectroscopy (SEM/EDS)

A scanning electron microscope is a type of electron microscope that allows the observation and characterization of heterogeneous materials, organic or inorganic, on a high scale, from nanometer to millimeter. The method can provide high-resolution images of the specimen and chemical characterization. Chemical characterization derives from the image produced by relating structure to composition, as well as the Energy Dispersive Spectroscopy. Thus, it provides information about the topography and the chemical composition of the specimen almost simultaneously. It's a high-end method of analysis applied to any type of archaeological material.

Sample preparation is not required. However, when topography issues are about to study, the specimen should be ideally grounded and polished for better resolution. When preparing samples to be analyzed it is important to carbon coat the specimen, or use a carbon tape to avoid electron charge on the specimen while conducting the analysis. The electron charge is caused by continuous bombarding with electrons, affecting the image produced.

The Scanning Electron Microscope uses a highly focused electron beam that stimulates the specimen. The beam might be static, for chemical analysis, or swept in a raster to form images and conduct mapping analysis. The opposite also occurs; the beam is steady and the specimen's position swifts. The setup of a scanning electron microscope consists of the electron column and the control system. The electron column consists of the electron gun that generates the electron beam and a system of lenses and magnets that thins and focuses the electron beam onto the specimen. The specimen chamber is at the lowest part of the electron column and under vacuum during the analysis of about 10^{-4} Pa (22). Vacuum ensures that the electron beam will reach the surface of the specimen intact and protects the filament from corrosion.

The Tungsten Hairpin electron gun consists of three components. The filament, the grid cap, and the anode. The filament serves as the cathode, emitting electrons into a broad cone that is focused and controlled by the grid cap. The anode accelerates the high negative potential of the filament to ground potential. For the necessary accelerating voltage, the filament is placed at -20,000 V to produce 20kV. The electron beam produced is accelerated in a range of 0, 1 -20keV. Typical electron gun characteristics are the lifetime of the filament, the emission current, the stability, and the brightness, on which a high-resolution image depends (Goldstein et al. 2003, 29-35).

Electromagnetic and objective lenses then demagnify (0-50 nm) and focus the electron beam that interacts with the sample. The electron beam interaction with the sample is of very low penetration (depending on the currency) that makes the analytical method noninvasive (Goldstein et al. 2003, 66-67). As the sample is bombarded with the electrons, the atoms of it are stimulated producing energy that is characteristic of its atomic number and it (Pollard & Heron 1996, 36-41). Three types of emissions are detected; secondary electrons, backscatter electrons, and characteristic x-rays.

Secondary electrons are the result of inelastic scattering of the electron beam interaction with the loosely bound electrons of the outer orbits of the specimen's atoms. Specimen's electrons receive kinetic energy, are ejected and set into motion. They are very low energy electrons (less than 50 eV) scattered from the atoms of the outer surface of the specimen, thus reflecting the topography of it (Goldstein et al. 2003 87-97). Backscatter electrons are produced by the interaction between the electron beam and the nucleus of the specimen's atoms. They are higher energy electrons but less than secondary electrons. Their intensity is proportional to the atomic number of the nucleus they interact with. They provide useful chemical information but not topography features of the specimen, as they penetrate deeper into the atoms (Goldstein et al. 2003, 75-87). Characteristic x-rays are produced. As the specimen is excited by the electron beam, a vacancy or hole is created to the electronic structure of the atoms, making it unstable. The rearrangement of the electrons of the atoms in between their orbits produces characteristic x-rays not only of the atoms but also of the orbital structure of them (Pollard 2007, 94, 95).

Those emissions are detected by the secondary and backscatter electrons detectors and the energy dispersive x-ray detector respectively. Chemical analysis has a limit of detection between 00,5-0,12wt% concentration and characteristic x-rays from major elements (>10 wt%) (Goldstein et al. 2013, 12). Thus, these chemical analyses are considered semi-quantitative. However, the combination of SEM with EDS provides the opportunity of much-targeted chemical analysis, up to 1μm, or spatial chemical composition with elemental mapping (Pollard 2007, 111-112).

SEM/EDS analysis provides a focused chemical composition of the clay matrix, allowing the exclusion of any inclusions. Also, information about the texture, the firing, and the mechanical properties of ceramics can be investigated. However, the sample is required to be flat and polished and small enough to fit the sample chamber.

4.3. Devices and Settings

Petrographic Microscope

Thin sections of the pottery sherds were created by Eleni Nodarou, open on the one side (fig. 14). The section surface was damped with a drop of water for better visibility. The thin sections were studied at the Laboratory of Archaeometry, the University of the Peloponnese in Kalamata. The polarized microscope is a Leica DM EP model that features a 35 W halogen bulb, a rotating stage, and a swing in-out polarizer. The light microscope is connected and software controlled with a 2.5 Megapixel HD Microscope Camera Leica MC120 HD (fig. 13). Thin sections were also studied at the Wiener Laboratory at the American School of Classical Studies at Athens under a Leitz LaborLux 11 POL Polarizing Light Microscope and the photos of the slides presented here were taken with a Digital FireWire Camera Leica DFC290 HD[11]. For the interpretation of the thin section atlases of rocks and minerals

[11] I am indebted to Dr. E. Nodarou for her insightful comments on the petropgrphic analysis and to Dr. P. Karkanas, director of the Wiener Lab, at the American School of Classical Studies at Athens, for allowing me to access the lab.

were consulted[12]. Results of the interpretation of the thin sections are presented in APPENDIX II according to the Whitbread's description for ceramic thin sections. Frequencies are semi-quantitative estimations of the author based on comparator charts (Whitbread, 2017; Whitbread, 1995, 379-388). Thus, the results are easier comparable with other petrography publications of the area of Laconia. Finally, it should be noted that the results and the interpretations drawn are based on a small area sample, usually less than 1cm2.

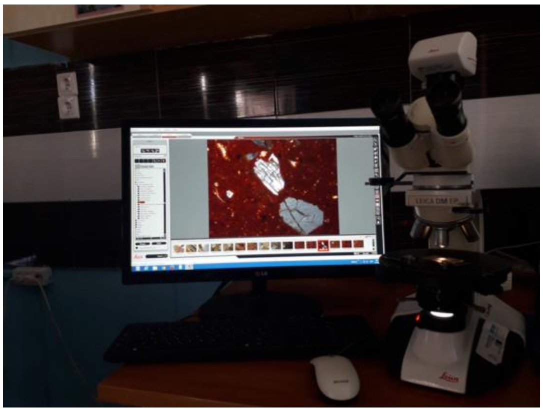

Fig. 13 The Polarized Microscope Set up at the Laboratory of Archaeometry, University of the Peloponnese

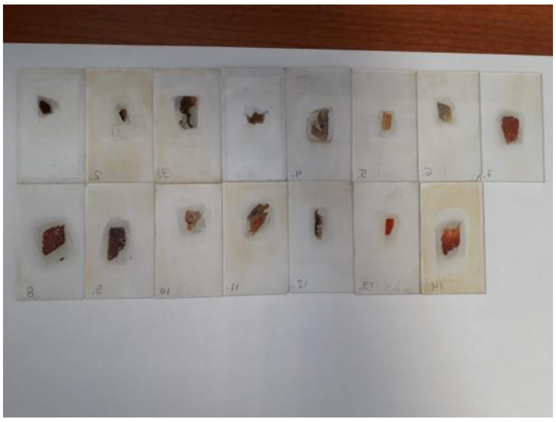

Fig. 14 The Thin Sections Studied

[12] Mackenzie 2015; Adams et al. 2007; Yardley et al. 1990; Mackenzie et al. 1982

Scanning Electron Microscope with Energy Dispersive Spectroscopy (SEM/EDS)

The chemical composition of the clay was determined by a Scanning Electron Microscope (SEM) by JEOL (JSM-6510LV) coupled with EDS by Oxford Systems. The analytical data were obtained by INCA software (fig. 15). The analyses were conducted under a high vacuum (if not, is noted) at 20 kV accelerating voltage, at a working distance of 15cm, under a magnification of ×100, and with a count time of 120 s. Samples (fig. 17) were mounted onto a specimen holder and were carbon taped to avoid electron charge[13] (fig. 16). At least 3 measurements were taken for each sample on different areas of fresh cuts. The results of the chemical analysis presented are normalized to 100% and expressed in weight percentage (wt.%); the concentrations of C and O have been excluded. The SEM/EDS composition of all ceramic bodies and their photographs are presented in APPENDIX III.

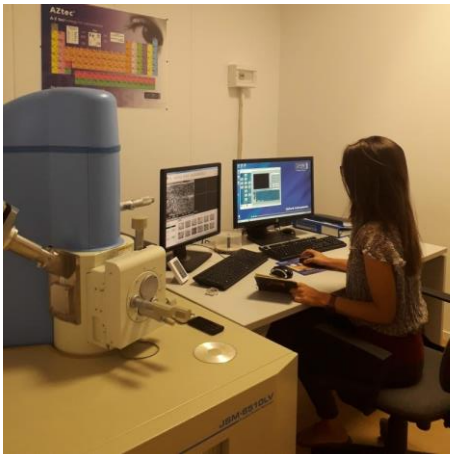

Fig. 17 SEM/EDS at the Laboratory of Archaeometry, University of the Peloponnese

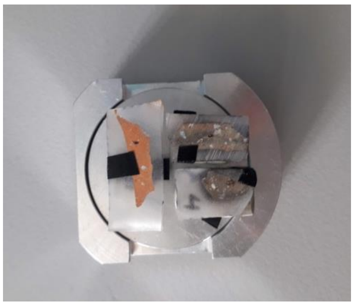

Fig. 15 Samples Carbon Taped and Mounted on the Specimen Holder

Fig. 16 Samples Studied with SEM/EDS

[13] Tthe chemical analysis is conducted not ov the thin sections, but on different samples of the same sherd.

5. Results and Discussion

The results of the petrographic and the chemical analysis of the samples are presented below. APPENDIX II and APPENDIX III present the results of the petrographic analysis and the chemical analysis by SEM/EDS, respectively, in more detail.

5.1. Petrographic Analysis

The presentation of the petrographic analysis (essentially described in APPENDIX II) is based on Whitbread's suggestion for the description of petrographic results, as noted in Chapter 4.3. Here, a description and further discussion of the results are presented. The fabrics of the samples are grouped into 2 main sets, while 3 fabrics stand out as loners (fig. 18, 19). Group 1 is described as the Metamorphic Inclusions Set and is subdivided into three classes showing either a high quantity of metamorphic inclusions or predominance of distinct inclusions. Group 2 is described as the Silt Size Inclusions Set with two particular classes. It contains predominately quartz sand size inclusions. The three loners are presented and discussed separately. All fabrics are described and discussed in comparison with petrographic analyses of material from Ayios Stephanos and Kythera.

Set 1 Metamorphic Inclusions

Class 1	Well-sorted Quartz Sand and Mica Phyllite	Samples 1, 4, 12 (Coarse Fabric)
Class 2	Quartz-Schist and Phyllite Poorly Sorted	Samples 10(Oatmeal Minoanizing),11 (Coarse Fabric)
Class 3	White Mica of Coarse Sand Size	Samples 7,8,9 (Red Micaceous ware)

Set 2 Silt size inclusions

Class 1	Quartz and Feldspar Silt Moderately Sorted	Sample 6 (Lustrous Decorated?)
Class 2	Quartz and Chert Silt Moderately Sorted	Sample 13 (Early Mycenaean)
Class 3	Quartz and Mica Silt Moderately Sorted	Sample 14 (Mainland Polychrome)

Loner 1 Textural Concentration Features (henceforth Tcfs) Quartz and Mica in Fine-grained Matrix	Sample 2 (Dark Burnished/ Imitation Grey Minyan)
Loner 2 Mudstone and Chert Poorly Sorted	Sample 3 (Lustrous Decorated/ Fine Minoanizing)
Loner 3 Tcfs in Silty Matrix	Sample 5 (Lustrous Decorated)

Fig. 18 Summary of the Petrographic Classification

Sample	Catalogue Number	Ware/Type	Petrographic Characterization
1	Σ.Γ. 1368-5	Coarse	Sorted Quartz Sand and Mica Phyllite
2	-	Dark Burnished/Imitation Grey Minyan	Tcfs Quartz and Mica in Fine-grained Matrix
3	Σ.Γ. 1387-17	Lustrous Decorated/ Fine Minoanizing	Mudstone and Chert Poorly Sorted
4	Σ.Γ. 1387-18	Coarse	Well-sorted Quartz Sand and Mica Phyllite
5	Σ.Γ. 1338/2	Lustrous Decorated	Tcfs in Silty Matrix
6	-	Lustrous Decorated	Quartz and Feldspar Silt Moderately Sorted
7	Σ.Γ.1388-11	Micaceous Minoanizing- Red Micaceous	White Mica of Coarse Sand Size
8	Σ.Γ. 1386/14	Micaceous Minoanizing- Red Micaceous	White Mica of Coarse Sand Size
9	-	Micaceous Minoanizing- Red Micaceous	White Mica of Coarse Sand Size
10	Σ.Γ. 1386-7	Oatmeal Minoanizing	Quartz-Schist and Phyllite Poorly Sorted
11	Σ.Γ. 1386-8	Coarse	Quartz-Schist and Phyllite Poorly Sorted
12	Σ.Γ. 1386-9	Coarse	Well-sorted Quartz Sand and Mica Phyllite
13	Σ.Γ. 1385-4	Early Mycenaean (LH II A)	Quartz and Chert Silt Moderately Sorted
14	-	Mainland Polychrome	Quartz and Mica Silt Moderately Sorted

Fig. 19 Analytical Board of each Sample, Catalogue Number, Ware and Petrographic Characterization

Set 1 Metamorphic Inclusions (fig. 20, 21, 22)

The first set is comprised of 3 distinct subgroups all having a metamorphic type of inclusions. The 1st and 2nd classes are highly correlated and characterized by the phyllite inclusions. The difference between them lies in the sortation of the inclusions. The 3rd class is distinctive among all classes and fabrics because of the mica inclusions.

The 1st class is represented by a homogenous group of samples 1, 4, 12, all of Coarse fabric. This fabric has a dark grey /brown micro mass optically active, with well-sorted fine to medium-sized grains of quartz disrupted by larger inclusions of phyllite and chert. The composition of the inclusions indicates a metamorphic origin. The unimodal grain size distribution and the rounded shape of the inclusions suggest that none of the inclusions were added as temper, or that mixing of clays/ raw materials was attempted (Velde & Druc 1999, 197). The well-sorted and coarse nature of quartz, however, may indicate that the clay was processed by the potter before use. The optical active groundmass is indicative of low fired fabrics, probably below 830°C (Vaughan 1995, 117). This class shows a high correlation with Set 2 Class 3 from Ayios Stephanos' petrographic analysis (Whitbread & Jones 2008, CD 98- CD 100), which is comprised of Dark Burnished ware fabrics.

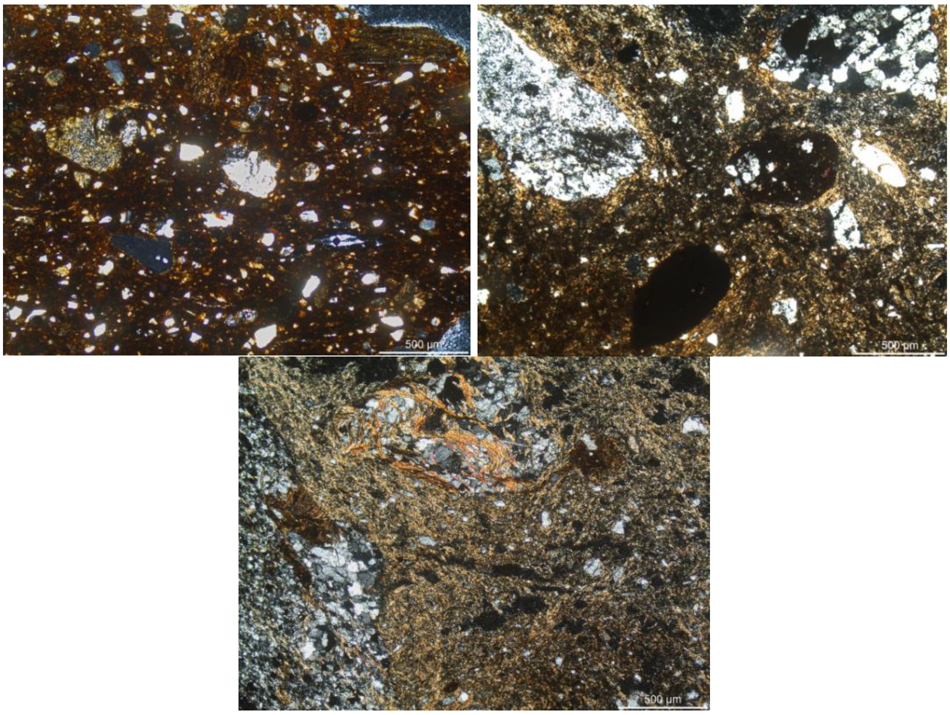

Fig. 20 Representative Microphotographs of thin sections samples, Set 1 Class 1 with Crossed Polars x50. Top left: Sample 1, Top Right: Sample 4, Down: Sample 12

The 2nd class is comprised of two samples; 10 (Oatmeal Minoanizing) and 11 (Coarse Fabric). It is highly correlated with Set 5 Class 4 from Ayios Stephanos (Whitbread & Jones 2008, CD 108- CD 110), which is characterized by Zerner as Minoan Schist Group and includes Fine Lustrous Decorated ware, Micaceous Minoan and two coarse wares. The groundmass is light grey to orange-brown and is optically active. The poorly sorted inclusions of closely packed quartz and larger inclusions of phyllite and chert are characteristic of this group. This class has rounded and elongate inclusions of phyllite, but the closely packed quartz differentiates the two classes. Also, the metamorphic character of inclusions is common for both classes and phyllite is the predominant inclusion. Probably there is no temper added by the potter as the rounded shape of the inclusions suggests. The ceramic is low fired as in the previous class.

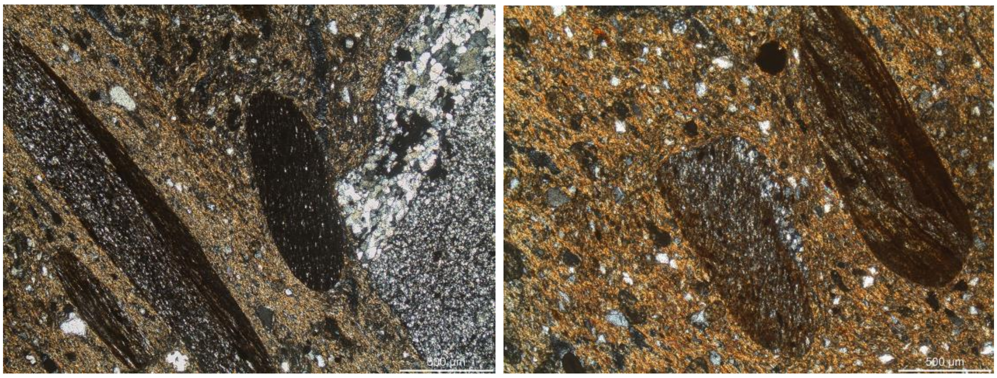

Fig. 21 Representative Microphotographs of thin sections samples, Set 1 Class 2 with Crossed Polars x50. Left: Sample 10, Right: Sample 11

The 3rd class of the Metamorphic Inclusions Set 1 consists of the most characteristic ware, Red Micaceous. Samples 7, 8, 9 are distinctive for the sand size mica inclusions. The reddish-brown matrix is optically inactive; hence it was fired at temperatures above 830℃. Particularly, sample 7 appears isotropic as well with crossed polars. The elongate white mica is dominant with preferred orientation developed (Thér, 2016). All samples display bimodal grain size distribution, which might be indicative of the presence of temper. This Set is characterized by Zerner as Micaceous Minoan Coarse (Zerner 2008, 207-208; Whitbread & Jones 2008, CD-107- CD-108). It is highly correlated with the Red Micaceous Ware from the Minoan colony of Kastri, Kythera, as well as from Antikythera (Antikythera Survey Project, n.d.; *KIP: Research Areas, Pottery, Fabric-Based Approaches & Ceramic Petrography*, n.d.). In Antikythera this type of ware is usually optically active (Pentedeka et al. 2010, 34).

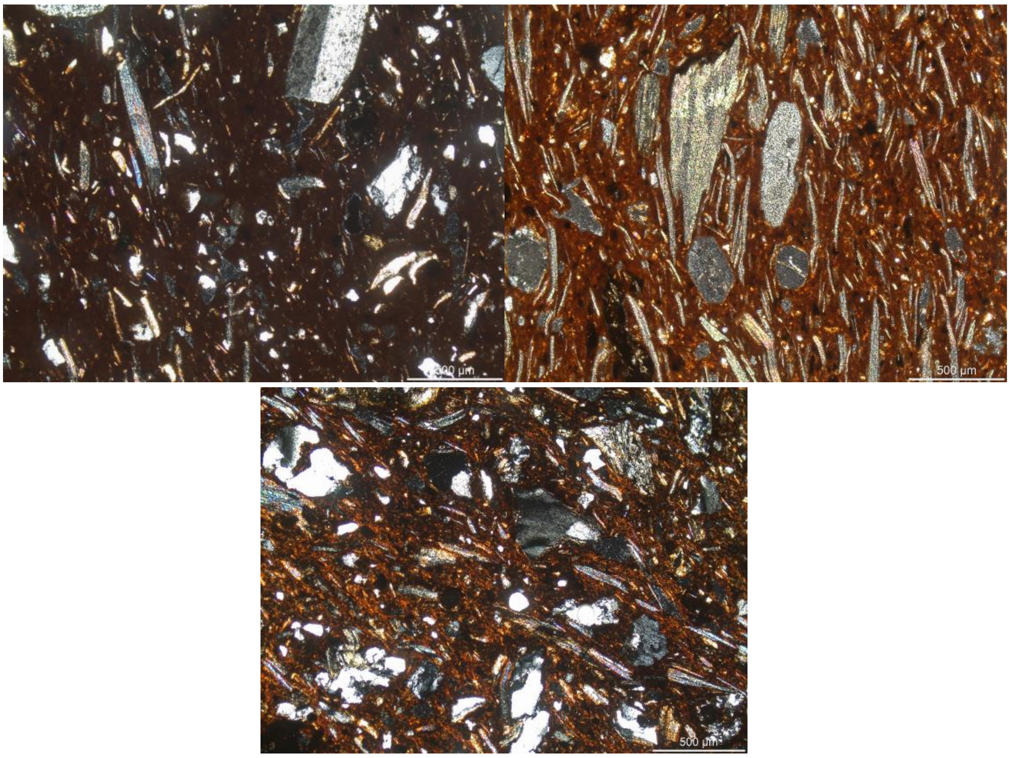

Fig. 22 Representative Microphotographs of thin sections samples, Set 1 Class 3 with Crossed Polars x50. Top left: Sample 7, Top Right: Sample 8, Down: Sample 9

Set 2 Silt size inclusions (fig. 23)

Set 2 includes fabrics with well-sorted silt size inclusions. The three different classes are represented with one sample each. Sample 6 (Lustrous Decorated), 13 (Early Mycenaean), and 14 (Mainland Polychrome) are characterized by silt size inclusions moderately sorted. However, each sample shows different types of inclusions, but in general basis quartz.

Class 1 is represented by sample 6. The matrix is very pale brown and isotropic/ optically inactive with crossed polars. The silt size inclusions are well-sorted quartz, mica (muscovite and biotite), and feldspar. Tcfs present crackings probably due to high firing. High firing is also indicated by the isotropic character of the fabric. Tcfs[14] are identified as argillaceous rock fragments with sharp and angular boundaries of sedimentary origin (Whitbread, 1986). The fine grain of this fabric does not suggest that any of these inclusions were added as temper. Probably, the clay was processed –refined- before use.

Class 2 is represented by sample 13. The matrix is red and optically inactive with crossed polars. Quartz and chert in silt size are well-sorted. Tcfs are present also here in bigger quantities, of sedimentary origin. The moderate sorted fine inclusions were not added as temper as their shape and occurrence suggest.

Class 3 is represented by sample 14. The groundmass is reddish-brown and optically inactive with crossed polars. Fine grain sized quartz, muscovite biotite and micrite limestone are dense in the matrix. Tcfs, probably clay pellets, are observed. The unimodal size distribution of the inclusions suggests that no temper was added and the silt size of them indicates that the clay was processed before use.

Set 2 is composed of semi fine fabrics that present the same type of distribution and size of inclusions. However, the type of inclusions is different for each fabric. Class 1 (sample 6, lustrous decorated?) is similar to Class 3 (sample 14, Early Mycenaean). Both have mica inclusions in large quantities, but Class 1 has elongate ones, is highly fired and there are fewer clay pellets. Class 2 has no mica and larger quantities of clay pellets. This Set shows a correlation with Set 1 Class 1 of Whitbread's classification of petrographic analysis from Ayios Stephanos (Whitbread & Jones 2008, CD-93 - CD-95) that includes Fine Lustrous Decorated, Dull Painted Fine Matt Painted and Mycenaean pottery. Accordingly, the fine grains of the samples cannot be indicative of provenance and probably these classes represent material from different regions.

[14] Textural Concentration Feature, usually clay pellets (Whitbread, 1986)

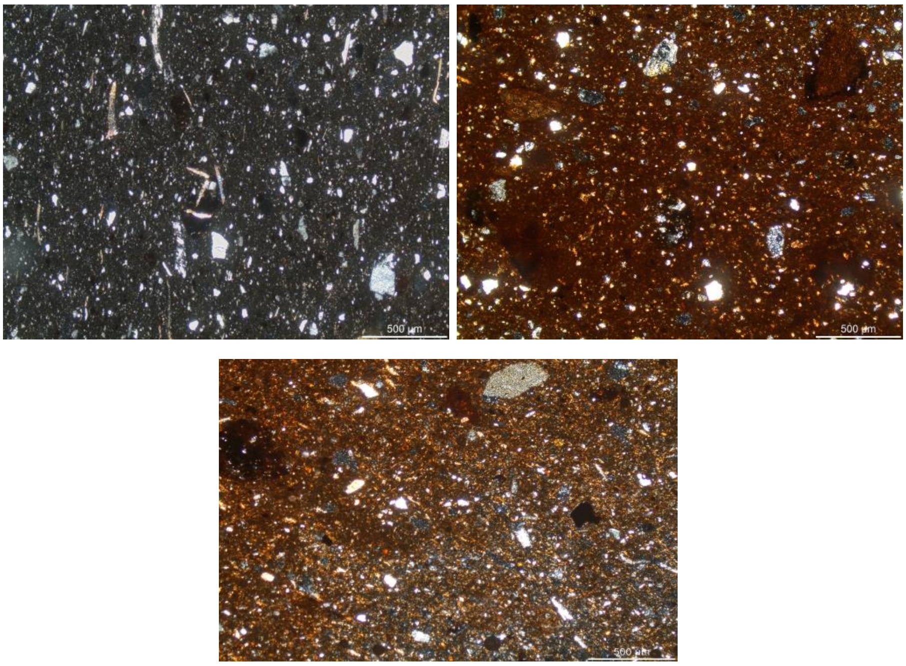

Fig. 23 Representative Microphotographs of thin sections samples, Set 2 with Crossed Polars x50. Top left: Sample 6, Top Right: Sample 13, Down: Sample 14

Loner; Tcfs Quartz and Mica in Fine Grained Matrix (fig. 24)

Sample 2 (Dark Burnished/Imitation Grey Minyan) presents few inclusions in a fine-grained matrix. Only a few quartz and mica inclusions are observed. The calcareous matrix is light brown in color and optically active with crossed polars. Tcfs are also observed. This loner can be correlated with Set 5 Class 2 from Ayios Stephanos with coarse wares (Whitbread and Jones 2008, CD-104 – CD-105).

Fig. 24 Representative Microphotograph of thin section sample 2 with Crossed Polars x50.

Loner; Mudstone and Chert Poorly Sorted (fig. 25)

Sample 3 (Lustrous Decorated/ Fine Minoanizing) is a grayish and reddish-brown fabric optically active with crossed polars. It is a distinctive and recognizable fabric by the mudstone temper it includes. Its composition is metamorphic concerning the inclusions of chert and schist. The grain size distribution is bimodal and mudstone appears as temper with variations in size, distribution, and angular shape. Sample 3 is a calcareous fabric with few microfossils (Quinn, 2008). In Whitbread's classification microfossils and mudstone are distinctive characteristics for two different groups, Set 3, Class 1, and Set 4 Class 1 respectively . Zerner identifies those groups as White Slipped Matt Painted (Set 3, Class 1) and as Lustrous Decorated medium/coarse and as Minoan medium/coarse (Set 4, Class 1) (Whitbread and Jones 2008). Mudstone tempered fabrics are common in Kythera and associated with the First Palace Period (Kiriatzi, 2003). Also, they are common in Antikythera (Pentedeka *et al.* 2010, 21).

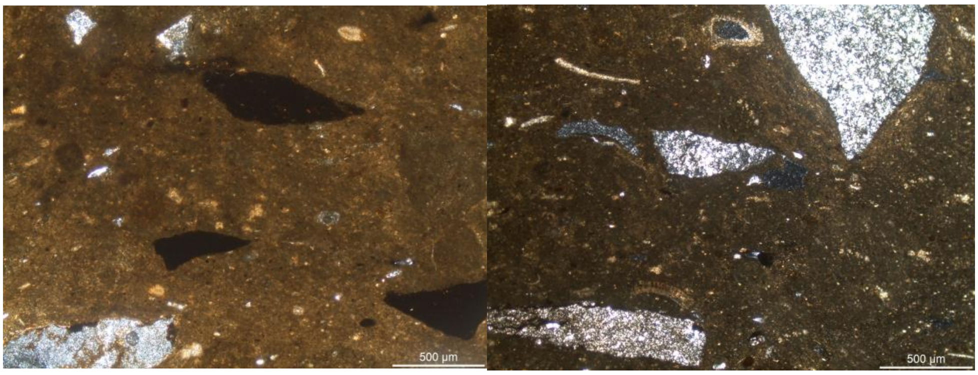

Fig. 25 Representative Microphotograph of thin section of sample 4 with Crossed Polars x50. Left: Mudstone temper, Right: Microfossils

Loner; Tcfs in Silty Matrix (fig. 26)

Sample 5 (Lustrous Decorated) is a fabric of fine light yellowish-brown groundmass. It is calcareous and optically inactive, high fired. Silt sized inclusions are few to rare and only rounded Tcfs are observed, probably clay pellets (Whitbread, 1986).

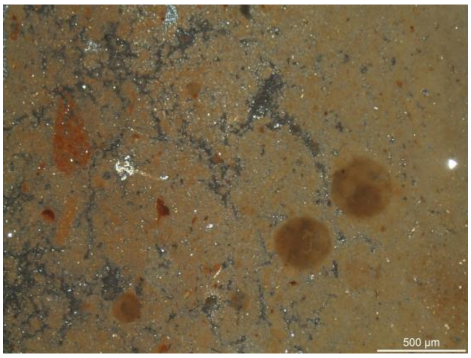

Fig. 26 Representative Microphotograph of thin section of sample 5 with Crossed Polars x50.

Any observations about provenance cannot be made without investigations of the local geology. The types of minerals and rocks identified are common both in the vicinity of Passavas and south- eastern Peloponnese. The mountains are composed of crystalline metamorphic schist with a lot of limestone at the base and crystalline limestone at the top (Bintliff, 2008). As it is shown in fig. 27 in the vicinity of Passavas are mapped the Tyros beds with formations of schist-porphyry, conglomerates, and sand dunes. This regional geology is reflected to the results of the petrographic analysis, with the metamorphic character of the fabrics being evident.

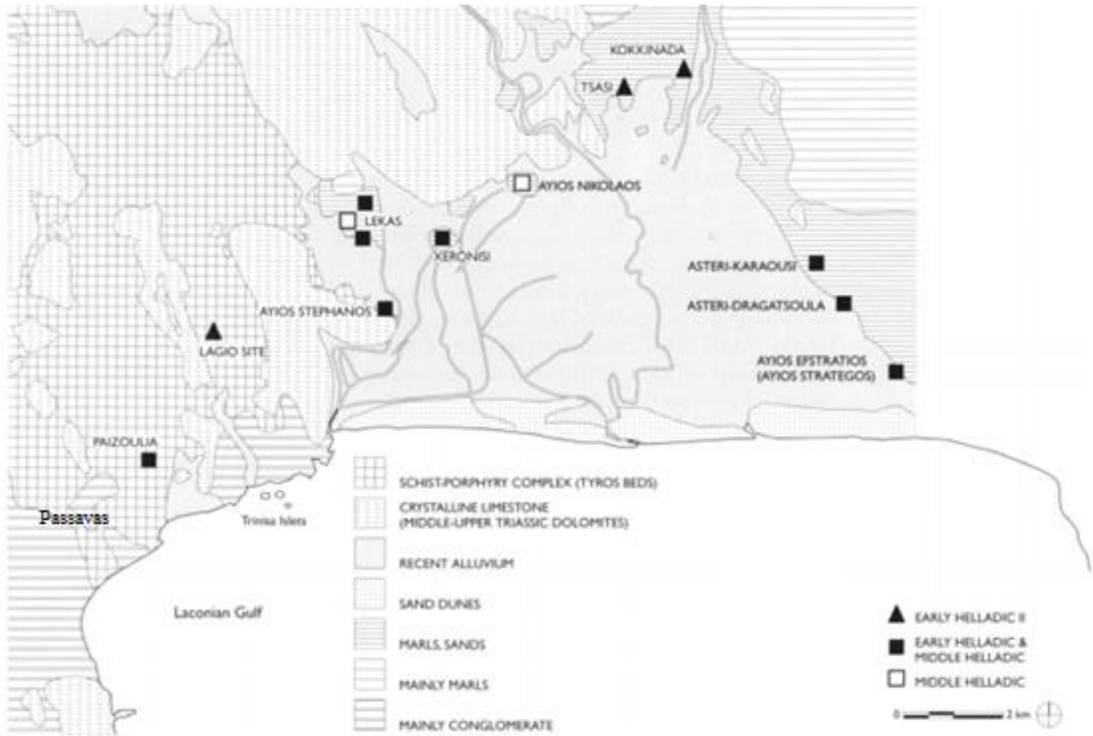

Fig. 27 Surface Geology of south Laconia and Helos Plain, including prehistoric sites. (Bintliff 2008, 532)

5.2. Scanning Electron Microscopy with Energy-dispersive X-ray spectroscopy Analysis (SEM/EDS)

Pottery sherds were also analyzed to investigate the concentration of the major elements and the fabric groups chemically. Oxide concertation (in wt. %) for the ceramic samples of major elements are presented in APPENDIX III along with the SEM photos with backscatter electrons. The chemical compositions are obtained by the SEM/EDS analysis. The settings and methodology of the analytical study are presented in Chapter 4.

The majority of the samples have similar composition characteristics, as it is shown in APPENDIX III and fig. 28. Based on the Silica versus Alumina concentrations, the fabrics appear relatively homogenous (Palamara *et al.* 2016). Any variation appears in Calcium and Magnesium concentrations. According to previous studies from Ayios Stephanos (samples analyzed by Atomic Absorption Spectrometry or Optical Emission Spectroscopy) the “canonical local” type of ware is characterized by the high concentrations in Ca, which is easily correlated with the depositional geological character of the Helos plain. Low concentrations in Calcium represent either an alternate clay source or production techniques that could have altered the composition of the clay (Jones and Rutter 2007). However, low concentrations in Calcium are also related to the metamorphic character of the inclusions of the samples (Whitbread and Jones 2008 § 3). Micaceous Minoanizing fabric from Ayios Stephanos is also low in Calcium and non-conforming to the “local calcareous” fabrics (Jones and Rutter 2007) since it contains large amounts of mica schist, while it contains higher amounts of Manganese and Magnesium. However, Kythera as a place of provenance, cannot be excluded. (Whitbread and Jones 2008 § 3).

The samples from Passavas have a low calcareous concentration in Calcium, below 6% (Maniatis and Tite 1981)-and only two samples appear high in Calcium, 3 (Calcium 13,80%) and 5 (Calcium 12,23 %). Sample 3 is archaeologically characterized as Fine Minoanizing and it contains mudstone inclusions and fossils. The presence of fossils is a probable reason for the high calcium content. Sample 5 is archaeologically characterized as Lustrous Decorated and is a fine fabric not related to any other fabric according to the petrographic analysis. In general, the samples from Passavas are characterized as metamorphic, as well as the environment of the site

(Bintliff, 2008), thus their low calcareous concentrations are expected. The Micaceous fabrics from Passavas are non-calcareous (Ca < 6%) and samples 7 and 8 show the highest concentrations among all samples in Magnesium (5,15 and 9,66 wt.% respectively). Also, the Micaceous fabrics have the highest concentrations in Fe (Sample 7: 10,34; Sample 8: 7,07; Sample 9: 9,23). This is reflected in the color of the fabric (reddish brown to dark red). Finally, it is worth noting that sample 8 which has the highest concentration in Mg has also the lowest concentration in Fe among the three micaceous samples.

In sum, the pottery from Passavas shows a different chemical composition than the one from Ayios Stephanos and the canonical local type, as it does not comply with the high Calcium concentrations that characterizes the local type of the latter. It seems to represent pottery that was produced in the vicinity of the site. Large-scale studies in chemical composition of Mycenaean and Minoan pottery have been made, focusing on their relation and provenance (Catling, Richards and Blin-Stoyle 1963). Pottery from Ayios Stephanos falls into the Peloponnesian group that is characteristic for all the Peloponnese and sites of the mainland (Catling, Richards and Blin-Stoyle 1963). However, we acknowledge that there are considerable variations among the geological variability of the raw materials and it is necessary to investigate the local geology in order to test whether the pottery is consistent with the local geology or not.

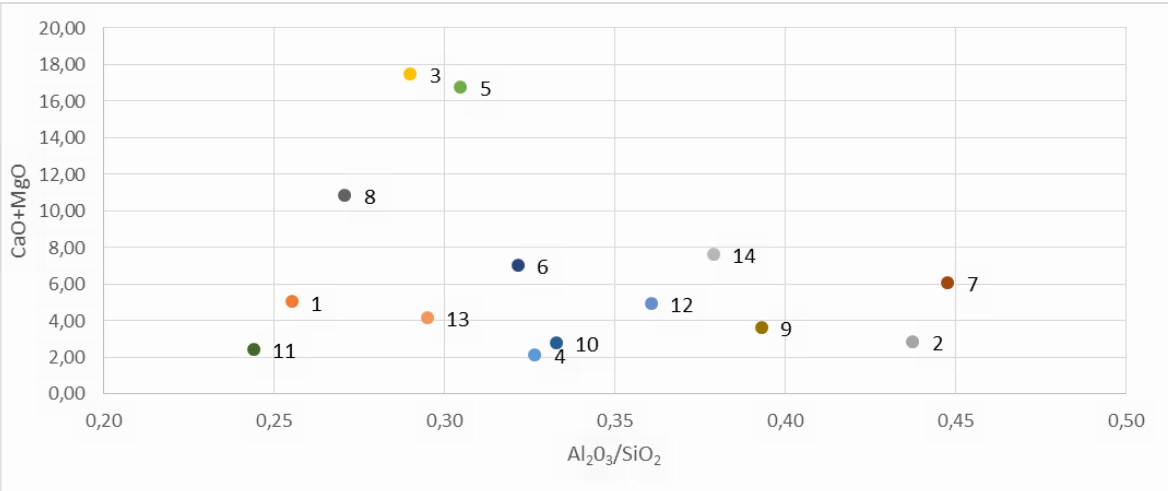

Fig. 28 Concentrations of Al_2O_3/ SiO_2 versus CaO+ MgO
Samples 1 Coarse fabric 2 Dark Burnished 3 Lustrous Decorated/ Fine Minoanizing 4 Coarse fabric 5 Lustrous Decorated 6 Lustrous Decorated 7 Micaceous Minoanizing- Red Micaceous 8 Micaceous Minoanizing- Red Micaceous 9 Micaceous Minoanizing- Red Micaceous 10 Oatmeal Minoanizing 11 Coarse fabric 12 Coarse fabric 13 Early Mycenaean 14 Mainland Polychrome

By the SEM analysis high magnification images of the fabric have been also obtained. In Appendix III images of each sample x30, x100 and x1000 are presented. Images are characteristic for the microstructure of the paste and provide information about the firing technology of the samples (Tite 1992). High magnification images (> 1000) of polished samples also represent the vitrification state of the paste, indicative of the firing temperature, and also the atmosphere of the kiln can be determined by the color of the fabric; red pottery indicates an oxidizing atmosphere, black or grey indicates reducing atmosphere. Backscattered electron images of the samples, presented in Appendix III, indicate coarse grain samples with grains loosely bound. The firing conditions seem poor, and no evidence of vitrification is shown. The estimation of the vitrification state is limited here due to unpolished samples; however, the loosely bound grains indicate low firing conditions. From Ayios Stephanos no parallel studies, concerning the vitrification and firing conditions are conducted.

6. Conclusions

In the present study fourteen pottery sherds from Passavas near Gytheio have been chemically and petrographically analyzed. They represent wares dated in the transitional Middle Helladic III/Late Helladic period, derived from a single deposition at the foothills of Passavas,. The proximity of this site to the well excavated and documented site of Ayios Stephanos is reflected in the similarity of the wares as established by this study.

Petrographical and chemical analysis were applied for the study of the samples. The chemical composition was attained by the SEM-EDS. Any limitations in analysis concern the different parts analyzed by each method, as well as the small area analyzed by the petrographic microscope. Overall, the samples were studied as thoroughly as possible and the results are presented analytically as well. The areas targeted for the SEM/EDS analysis were as much as possible free of inclusions, aiming for the chemical composition of the clay minerals.

The samples under investigation belong to the categories Coarse, Dark Burnished /Imitation Grey Minyan, Lustrous Decorated, Red Micaceous, Oatmeal Minoanising, Early Mycenaean, and Mainland Polychrome defined through the archeological study of the sherds from which they derive. They correspond to categories from Ayios Stephanos (Banou et al, 2019) established by studies of the pottery from that site Jeremy and Rutter (1976) and Zerner (2008). Petrographic and chemical analysis were also conducted on the pottery from Ayios Stephanos by Whitbread and Jones (2008) and Jones and Rutter (2007). The term "lustrous decorated" used by Zerner especially includes oatmeal minoanizing wares.

The results of the petrographic analysis are homogenous and 2 sets of 3 classes are identified, as well as 3 loners. The Metamorphic Inclusions Set is homogenous and. Coarse ware, Oatmeal Minoanizing and Red Micaceous ware fall into this group. Red micaceous ware is characterized so by Zerner since it is identical to the red micaceous ware found in Kythera (Pentedeka et al. 2010; Kiriatzi, 2003), but she hesitates to ascribe it to Minoan influence on local potters or to actual imports. It is actually impossible to be certain about the origin of these wares, since outcrops of these types of rocks are found on Crete, Kythera and the Southern Peloponnese (Rutter, 1979). The second Set includes the Lustrous decorated, Early Mycenaean and Mainland Polychrome samples, all having well-sorted and fine-grained inclusions that reflect the local metamorphic geology. The Mainland Polychrome sample is however differentiated from the other two since it contains large amounts of mica schist. The Dark burnished/ Imitation Grey Minyan sample is characterized as a loner with a differentiated matrix but with the same type of metamorphic inclusions. Sample 3 has mudstone inclusions and fossils and contrary to the petrographic analysis from Ayios Stephanos the mudstone appears more as temper and less as inclusion, with a sharp and angular profile. This type of temper seems more relevant to the type of mudstone tempered pottery from Kythera, rather than the same group from Ayios Stephanos (KIP: Research Areas, Pottery, Fabric-Based Approaches & Ceramic Petrography, no date). The last loner identified petrographically is a lustrous decorated sample that exhibits no inclusions and a silty matrix with argillaceous inclusions.

Generally, the petrographic results are consistent and similar with the results from Ayios Stephanos. The samples also reflect the local character of the area with metamorphic inclusions. Samples form Ayios Stephanos with metamorphic inclusions are characterized as local and produced probably in the vicinity of the site.

The chemical composition obtained by the SEM/EDS analysis indicates a group of similar compositional characteristics. Two outliers having higher concentrations in Calcium Carbonate are observed. Sample 3 (Fine Minoanizing/ Mudstone Tempered) has many inclusions of fossils, probably responsible for the high concentrations in Calcium Carbonate. Sample 5, on the contrary, in the only one with a fine matrix, and its clayey material reflects a high concentration in Calcium Carbonate. In chemical analysis of samples from Ayios Stephanos the canonical local type reflects the depositional character of the area. Thus, samples with a high concentration in calcium are considered local in Ayios Stephanos, while samples with low concentration are considered to be made somewhere in the wider area of a different technological character.

Broadly translated, our findings reflect the trends of the transitional stage to the Mycenaean era. The transition of the Middle to the Late Helladic period is a period of intense experimentation under the influence of Minoan Crete. The Minoans seafarers preponderate the Aegean and beyond looking for metals and trading luxury goods. Laconia constitutes a “stepping stone” for exchanges with the mainland;

trading as well semi-precious stones, Lapis Lacedemonious and Rosso Antico, abundant in Laconia (Rutter, 1979). The Minoan influence in pottery is evident in coastal Laconia, Ayios Stephanos and Passavas. Whereas in other sites Minoan traditions were rejected (Kiriatzi 2010), in southern Laconia Minoanizing wares predominate (Janko 2008) and are found as far as in the heartland of Laconia (Banou 2000). The locals are receptive to the Minoan trends; this does not mean, however, that are heavily minoanized, since in Passavas, mainland wares (Coarse, Lustrous Decorated-Sample 5, Early Mycenaean) coexist with minoanizing pottery traditions (red micaceous, oatmeal). An attempt to combine both traditions is maybe to be seen in the category of Coarse pottery (samples 1, 4 and 11 consistent with Dark Burnished wares also in shape while sample 11 is consistent with oatmeal wares albeit following a mainland shape. Kythera played a crucial pole to the transmission of Minoan pottery traditions. In fact, lustrous decorated, seen as a precursor of Mycenaean pottery, occurs in oatmeal fabrics. But experimentations with mainland and Minoan pottery also took place in Laconia as the pottery both from Ayios Stephanos and Passavas shows.

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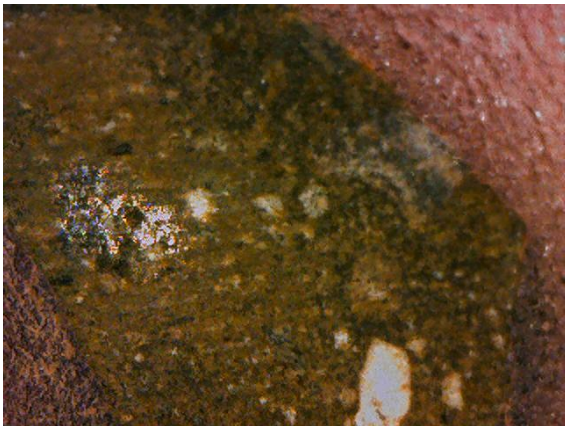
APPENDIX I[15]

<table>
<tr><td>Sample: 1</td><td colspan="2">Catalogue Number: Σ.Γ. 1368-5</td></tr>
<tr><td colspan="2">Ware / Type: Coarse</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="4"><u>Description</u>

Rim and shoulder from a kantharos. Traces of lower horizontal handle. Convex profile. Fracture greyish with black calcareous and a few white inclusions. Black core as well as surface. Surface smoothed, with sedimentations.

Height: 5,2cm

Width: 4,1cm

Thickness: 0,8cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

[15] Photos of the sherds were taken by Giorgos Tsiaggouris.

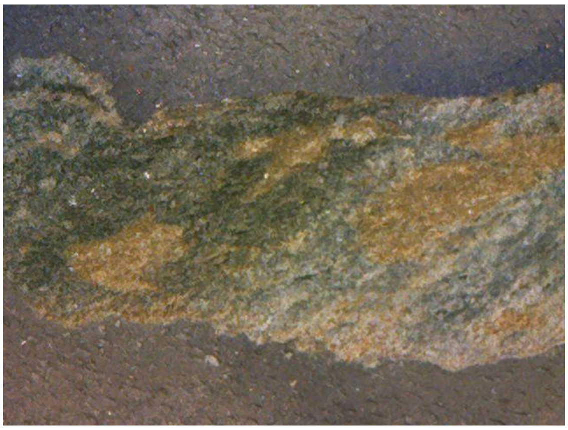
LED images were taken at the Laboratory of Archaeometry, University of the Peloponnese with a portable LED Moritex optical microscope.

<table>
<tr><td>Sample: 2</td><td colspan="2">Catalogue Number: -</td></tr>
<tr><td colspan="2">Ware / Type: Dark Burnished/ Imitation Grey Minyan</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="4"><u>Description</u>

Lower part and root of a kantharos stripe handle. Fine gray fracture. Sandwich-like effect with grayish core. Surface dark grey, moderately burnished.

Height: 3,9cm

Width: 1,9cm

Thickness: 1,7cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

<table>
<tr><td>Sample: 3</td><td colspan="2">Catalogue Number: Σ.Γ. 1387-17</td></tr>
<tr><td colspan="2">Ware / Type: Lustrous Decorated/ Fine Minoanizing</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Sherd from a vessel of closed shape. Brown clay with plenty of black calcareous inclusions. Core grey. Light brown surface with a whitish slip. Inner surface reddish-grey. Reddish-brown spiral decoration.</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

Sample: 4	Catalogue Number: Σ.Γ. 1387-18
Ware / Type: Coarse	Photo
<u>Description</u> High flaring rim and shoulder of a bowl. Whitish clay, few inclusions. Surface slipped whitish. Inner surface slipped reddish. Rim painted on the outer surface.	
	LED photo x50
	

<table>
<tr><td>Sample: 5</td><td colspan="2">Catalogue Number: Σ.Γ. 1338/2</td></tr>
<tr><td colspan="2">Ware / Type: Lustrous Decorated</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Fine ware sherd from a closed vessel. Profile slightly curved. Brown-reddish, fine clay, evenly fired. Surface whitish slipped with traces of dark brown painted decoration (spiral?). Wheel made.

Height: 2,8cm

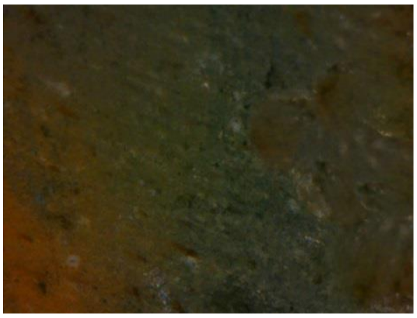
Width: 2,5cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

<table>
<tr><td>Sample: 6</td><td colspan="2">Catalogue Number:</td></tr>
<tr><td colspan="2">Ware / Type: Lustrous Decorated?</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Body sherd from a closed vessel. Profile slightly curved. Wheel made. Brown clay, grey core, with muscovite. Surface brown slipped. Decoration of two black curved bands connected through thin oblique lines. Inner surface greyish brown with whitish slip.

Height: 5,4cm

Width: 4,5cm

Thickness: 0,7cm</td><td></td></tr>
<tr><td>LED phot x50</td></tr>
<tr><td></td></tr>
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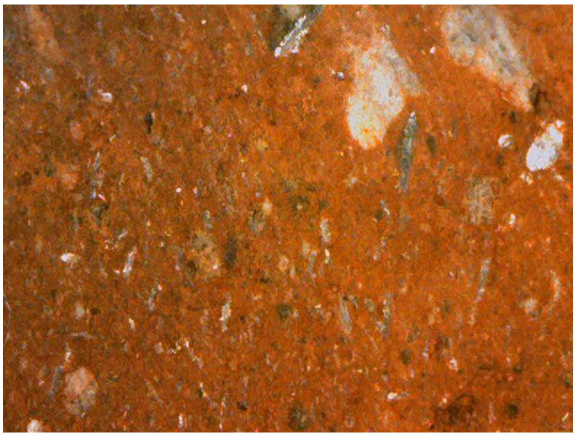
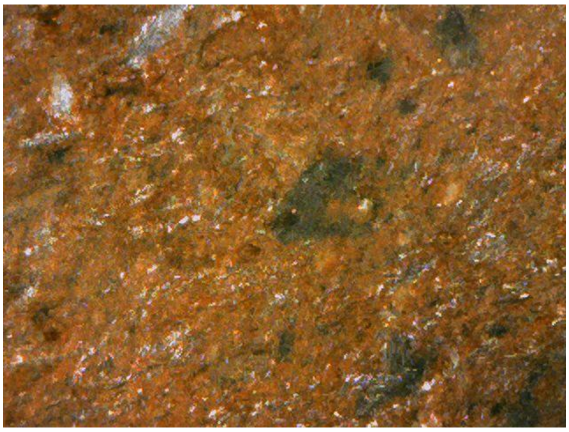
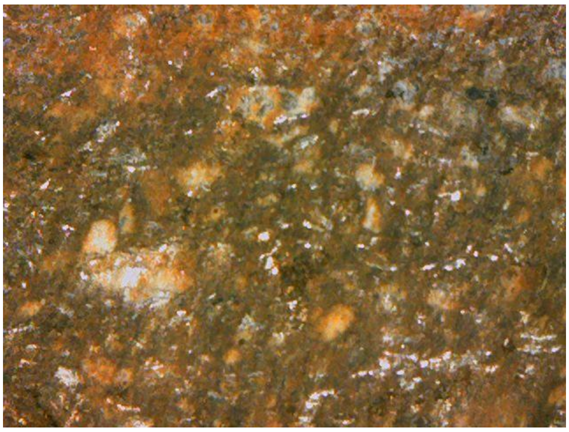
Sample: 7	Catalogue Number: Σ.Γ.1388-11
Ware / Type: Micaceous Minoanizing- Red Micaceous	Photo
<u>Description</u> Body sherd with straight sided profile. Red clay with large quantities of muscovite. Dark red surface with sediments. Probably handmade. Height: 3,5cm Width: 3,2cm Thickness: 0,8cm	 LED photo x50 

Sample: 8	Catalogue Number: Σ.Γ. 1386/14
Ware / Type: Micaceous Minoanizing- Red Micaceous	Photo
<u>Description</u> Upper body sherd and part of wide horizontal basin rim. Wheel-made. Red fracture with large quantities of muscovite and a few calcareous inclusions. Incised decoration of parallel lines on the top of the rim. Height: 2,7cm Width: 2,3cm Length: 4,6cm	 LED photo x50 

Sample: 9	Catalogue Number:
Ware / Type: Micaceous Minoanizing- Red Micaceous	Photo
<u>Description</u> Body sherd. Dark red fracture with a great amount of muscovite. The inside surface is reddish-brown. Height: 2,4cm Width: 6,6cm Thickness: 0,8cm	 LED photo x50 

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<tr><td>Sample: 10</td><td colspan="2">Catalogue Number: Σ.Γ. 1386-7</td></tr>
<tr><td colspan="2">Ware / Type: Oatmeal Minoanizing</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Rim and shoulder of a storage vessel with a curved profile. Fracture brownish red with plenty black calcareous inclusions and fewer white. Grey core. The surface is brownish red and the inner surface brownish red to grey. The outer part of the rim is smoothed.

Height: 5,9cm

Width: 6,7cm

Thickness: 0,9cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

<table>
<tr><td>Sample: 11</td><td colspan="2">Catalogue Number: Σ.Γ. 1386-8</td></tr>
<tr><td colspan="2">Ware / Type: Coarse</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Sherd of a high flaring rim and shoulder of a bowl. Clay brownish, coarse, with plenty like calcareous inclusions. Brown core. Surface brown. Rim with traces of burning, smoothed.

Height: 3,7cm

Width: 6,8cm

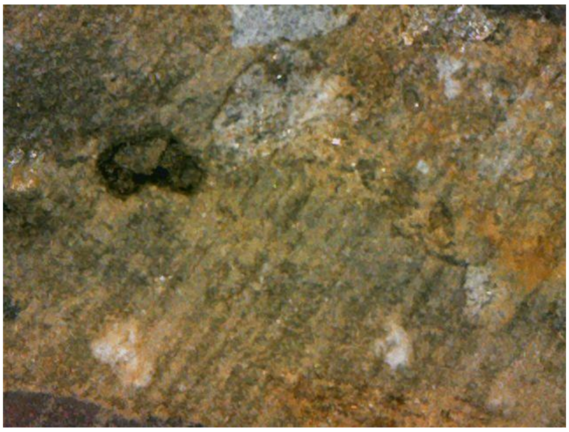
Thickness: 0,7cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

<table>
<tr><td>Sample: 12</td><td colspan="2">Catalogue Number: Σ.Γ. 1386-9</td></tr>
<tr><td colspan="2">Ware / Type: Coarse</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

High flaring rim and shoulder from a bowl. The rim is defined by two edging stripes. Curved sides. The fraction is coarse with black calcareous and a few white inclusions. The core is dark gray and the surface brownish. Traces of burning visible on the shoulder, both inside and outside.

Height: 8,5cm

Width: 7,1cm

Thickness: 0,8cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
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Sample: 13	Catalogue Number: Σ.Γ. 1385-4
Ware / Type: Early Mycenaean (LH II A)	Photo
<u>Description</u> Part of a high everted rim and shoulder from a goblet. The clay paste is fine, reddish. Brownish red pain on the exterior. Wheel made. Height: 2,7cm Width: 6,9cm Thickness: 0,5cm	 LED photo x50 

<table>
<tr><td>Sample: 14</td><td colspan="2">Catalogue Number:</td></tr>
<tr><td colspan="2">Ware / Type: Mainland Polychrome</td><td>Photo</td></tr>
<tr><td colspan="2" rowspan="3"><u>Description</u>

Rim and upper body from and open vessel. Horizontally protruding rim. Slightly curved. The fracture is light brown with muscovite. The core is brown reddish. Slipped surface, decoration of a wavy large stripe towards the rim. Wholly painted inside as well as the rim with a red brownish paint.

Height: 4,1cm

Width: 6,1cm

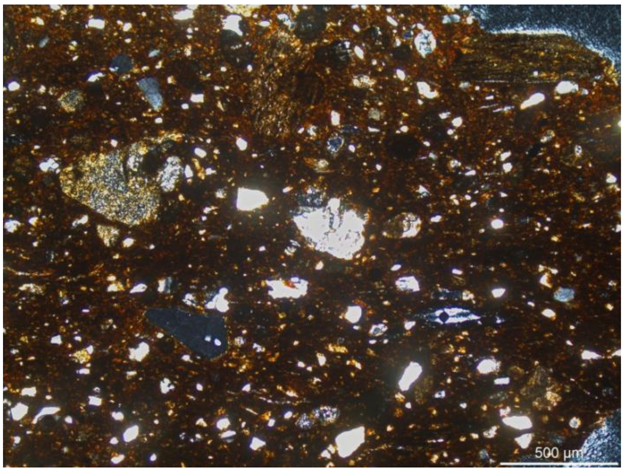
Thickness: 0,7cm</td><td></td></tr>
<tr><td>LED photo x50</td></tr>
<tr><td></td></tr>
</table>

APPENDIX II

G1.

Well-sorted Quartz Sand and Mica Phyllite

(Coarse ware)



I. *Matrix (groundmass)*

A. Optical Properties and Color

1. Plane polarized light (x5): brown to reddish brown
2. Crossed polarized light (x5): strong brown to reddish yellow, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 20% of the field. The grain size frequency distribution is bi-modal. Overall, the size distribution is moderately sorted. Voids occupy 5-10% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. Preferred orientation and poorly sorted large inclusions.

D. Silt sized inclusions

1. Monocrystalline quartz, equant and angular
2. Muscovite, equant and angular
3. Biotite, angular laths

II. *Inclusions above silt size*

A. Monocrystalline quartz, equant sub-angular with sharp boundaries, common
B. Polycrystalline quartz, equant sub-angular with sharp boundaries, common
C. Orthoclase Feldspar, equant sub-angular, very few
D. Phyllite, equant sub-angular with boundaries sharp to margin, very few
E. Micrite limestone, equant angular, poorly sorted, common

G2.

Tcfs Quartz and Mica in Fine-grained Matrix

(Dark Burnished/ Imitation Grey Minyan ware)

I. Matrix (groundmass)

A. Optical Properties and Color

1. Plane polarized light (x5): light brown
2. Crossed polarized light (x5): light brown and grayish yellow, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 1% of the field. The grain size frequency distribution is bi-modal. Voids occupy less than 5% of the field and they are shaped in vesicles. Ground mass with a coarse texture.

C. Overall preferred orientation of inclusions and voids. No preferred orientation.

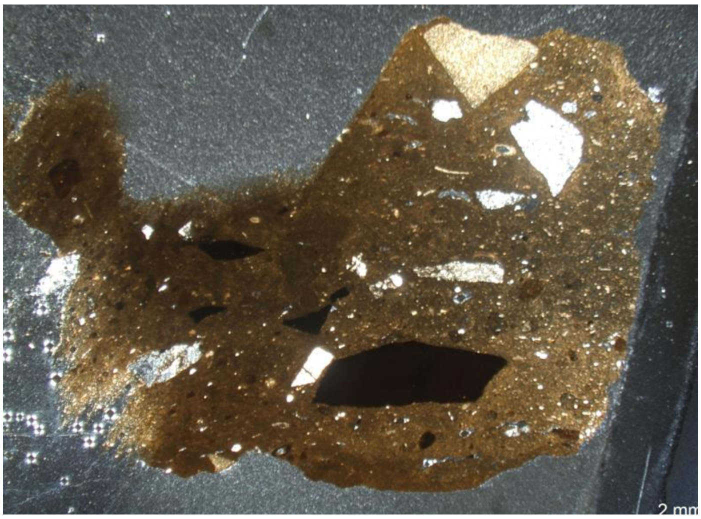
D. Silt sized inclusions

1. Monocrystalline quartz, equant and sub-angular, few

II. Inclusions above silt size

A. Quartz, equant and sub-angular, weathered few
B. Biotite, equant and sub-angular, few
C. Brown opaques, rounded, few

G3
Mudstone and Chert Poorly Sorted
(Lustrous Decorated)



I. Matrix (groundmass)

A. Optical Properties and Color

1. Plane polarized light (x5): yellowish brown
2. Crossed polarized light (x5): gray- yellowish brown, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 10% of the field. The grain size frequency distribution is bi-modal. Overall, the size distribution is very poorly sorted. Voids occupy 10% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. There is no preferred orientation.

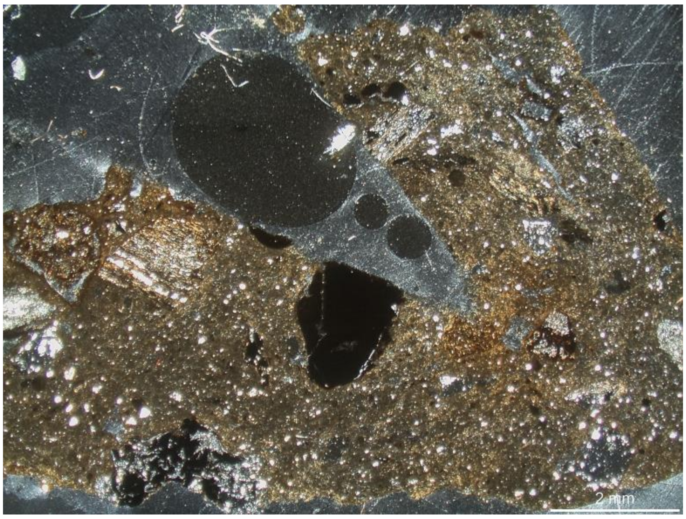
D. Silt sized inclusions

1. Monocrystalline quartz, equant and angular

2. Red opaques, rounded

III. Inclusions above silt size

- **A. Chert,** equant rectangular, common
- **B. Monocrystalline quartz,** equant sub-angular, few
- **C. Polycrystalline quartz,** equant sub-angular, few
- **D. Biotite –quartz Schist,** equant, angular, few
- **E. Mudstone,** equant, angular, few
- **F. Microfossil,** few to rare (1)



G4.
Well-sorted Quartz Sand and Mica Phyllite *(Coarse ware)*

I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): grayish and reddish brown

2. Crossed polarized light (x5): reddish-gray and reddish brown, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 30-40% of the field. The grain size frequency distribution is bi-modal. Overall, the size distribution is poorly sorted. Voids occupy 10% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. There is no preferred orientation.

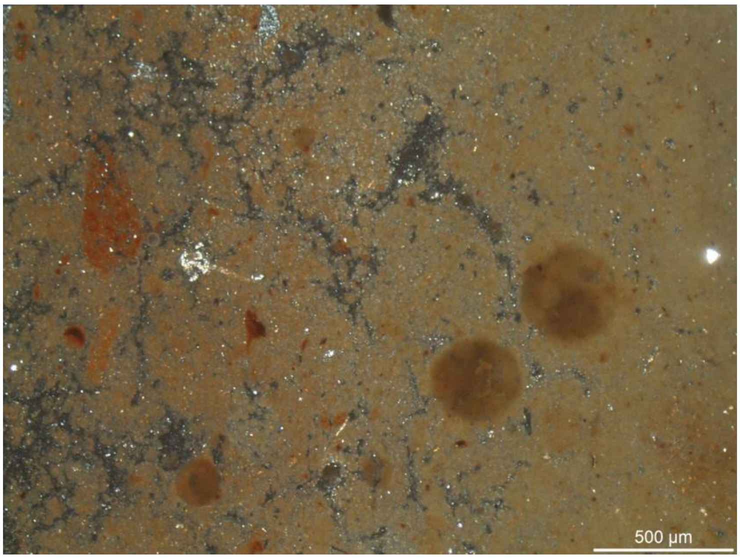
D. Silt sized inclusions

1. Monocrystalline quartz, equant and angular dominant
2. Black opaques, rounded
3. Muscovite, elongate sub-angular
4. Biotite, equant sub-angular
5. Clinopyroxene, equant, angular

II. Inclusions above silt size

A. **Chert,** equant angular, common
B. **Monocrystalline quartz,** equant sub-angular square shaped, common
C. **Polycrystalline quartz,** equant sub-angular square shaped, common
D. **Quartz-biotite-mica Schist,** equant, angular, few
E. **Chert,** equant angular, few

G5.
Tcfs in Silty Matrix
(Lustrous Decorated)



I. Matrix

A. Optical Properties and Color

1.Plane polarized light (x5): light yellowish brown

2.Crossed polarized light (x5): reddish brown, optically inactive

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 1% of the field. Overall, the size distribution is poorly sorted. Voids occupy 1% of the field and they are shaped in vesicles.

C. Overall preferred orientation of inclusions and voids. There is no preferred orientation.

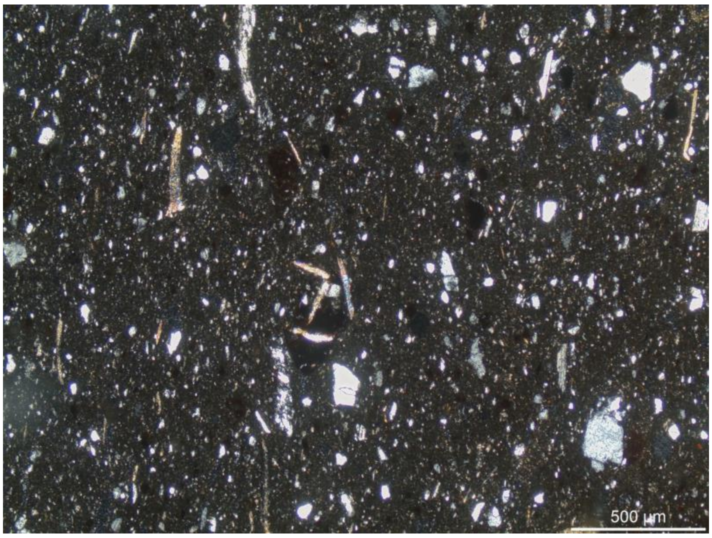
D. Silt sized inclusions

1. Quartz, equant, angular

II. Inclusions above silt size

- **A. Carbonate oids**
- **B. Tcfs**

G6.
Quartz and Feldspar Silt Moderately Sorted *(Lustrous Decorated)*



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): very pale brown

2. Crossed polarized light (x5): gray and light brown, optically inactive, appears isotropic

B. Overall grain size and modality of inclusions and voids. Grains occupy c.20% of the field. Overall, the size distribution is unimodal. Voids occupy 5-10% of the field and they are shaped in vesicles.

C. Overall preferred orientation of inclusions and voids. There is preferred orientation.

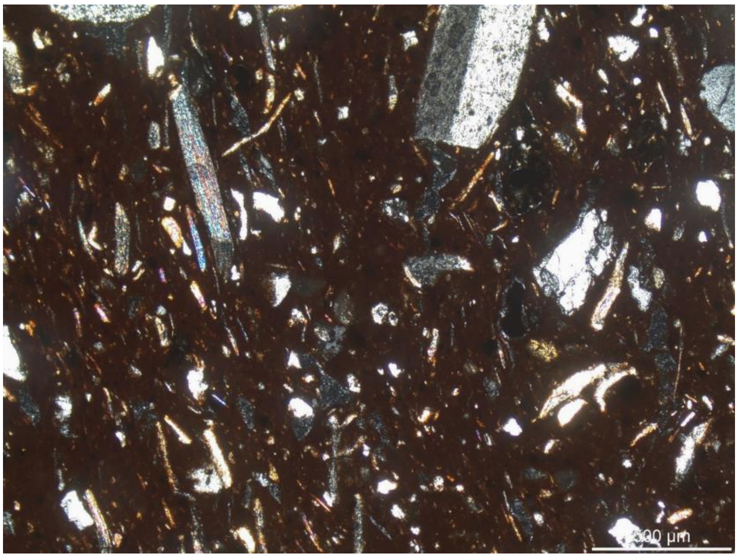
D. Silt sized inclusions

1. Quartz, equant, sub-angular, dominant
2. Amphibole, equant, angular, rare to absent

II. Inclusions above silt size

- **A. Orthoclase Feldspar,** equant very angular to rectangular, few
- **B. Muscovite,** elongate angular common
- **C. Biotite,** elongate angular, common
- **D. Quartz,** elongate and angular, frequent
- **E. Tcfs,** cracked, few

G7.
White Mica of Coarse Sand Size
(*Red Micaceous Ware)*



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): reddish brown

2. Crossed polarized light (x5): dark reddish brown, optically inactive, appears isotropic

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 30-40% of the field. The grain size frequency distribution is bi-modal. Overall, the size distribution is moderately sorted. Voids occupy 5% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. Orientation is developed

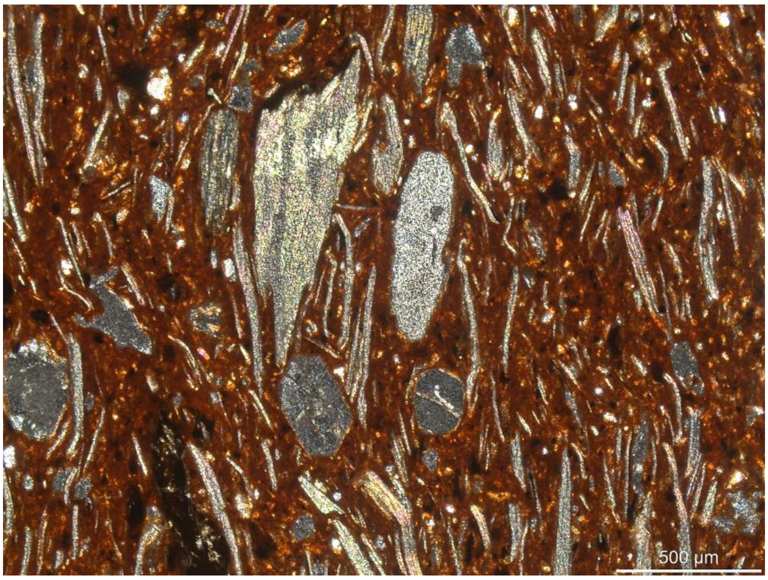
D. Silt sized inclusions

1. Monocrystalline quartz, angular to sub-angular
2. Muscovite, rounded platy like

II. Inclusions above silt size

A. **Muscovite,** long thin laths, angular and elongate dominant
B. **Orthoclase feldspar,** rectangular equant, few to rare
C. **Monocrystalline quartz,** equant, sub-angular, common
D. **Weathered quartz,** equant, sub-angular, few
E. **Phyllite with quartz, muscovite, mica**, elongate, sub-angular, few

G8.
White Mica of Coarse Sand Size
(Red Micaceous Ware)



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): reddish brown

2. Crossed polarized light (x5): dark reddish brown, optically inactive, appears isotropic

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 30-40% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is moderately sorted. Voids occupy 5% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. Orientation is developed but is discordant between large and smaller inclusions (quartz-muscovite)

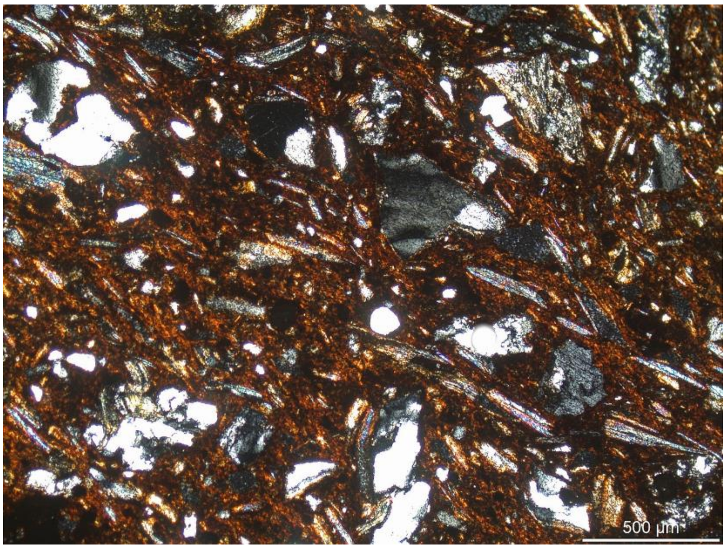
D. Silt sized inclusions

1. Monocrystalline quartz, angular to sub-angular
2. Fe-rich minerals, low sphericity rounded platy-like
3. Muscovite, rounded platy like

II.Inclusions above silt size

A. **Polycrystalline quartz,** sub-angular, equant common
B. **Quartz,** equant, elongate, sub-rounded, common
C. **Muscovite,** elongate angular, dominant
D. **Carbonates,** very few to rare
E. **Weathered quartz,** sub-rounded, few
F. **Pelloids,** very few to rare
G. **Phyllite,** equant, sub-angular, few to rare

G9.
White Mica of Coarse Sand Size
(Red Micaceous Ware)



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): yellowish to reddish brown

2. Crossed polarized light (x5): dark to reddish brown, optically inactive

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 40-50% of the field. The grain size frequency distribution is bi-modal. Overall, the size distribution is poorly sorted. Voids occupy 5% of the field and they are shaped in vughs channels and vesicles.

C. Overall preferred orientation of inclusions and voids. Orientation is not developed and only at the light-colored part of the section is developed

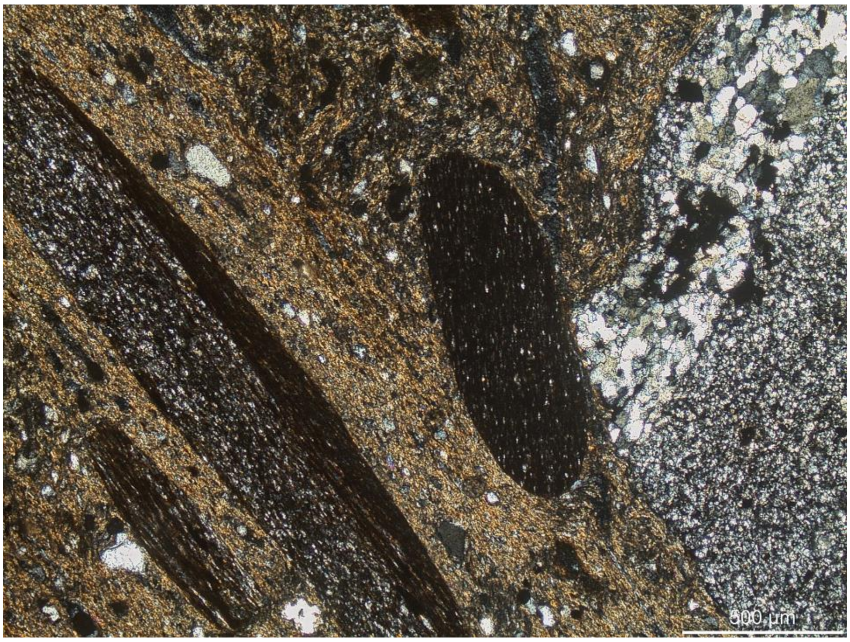
D. Silt sized inclusions

1. Tcfs, few
2. Quartz, equant, sub-rounded, common
3. Muscovite, elongate, sub-angular, common

II. Inclusions above silt size

A. **Polycrystalline quartz,** equant square shaped and elongate angular dominant
B. **Quartz-biotite-schist,** equant rectangular, few
C. **Muscovite,** angular and elongate, dominant
D. **Phyllite quartz and muscovite,** equant, rectangular, few
E. **Biotite,** elongate, sub-angular, few
F. **Fe-rich minerals,** equant, few to absent
G. **Quartz, equant**, sub-rounded, common
H. **Tcfs,** common

G10. ***Quartz-Schist and Phyllite Poorly Sorted*** *(Minoaniznig Ware)*



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): light gray, light red

2. Crossed polarized light (x5): grayish brown, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 20% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is poorly sorted. Voids occupy 10% of the field and they are shaped in vughs.

C. Overall preferred orientation of inclusions and voids. Orientation is developed

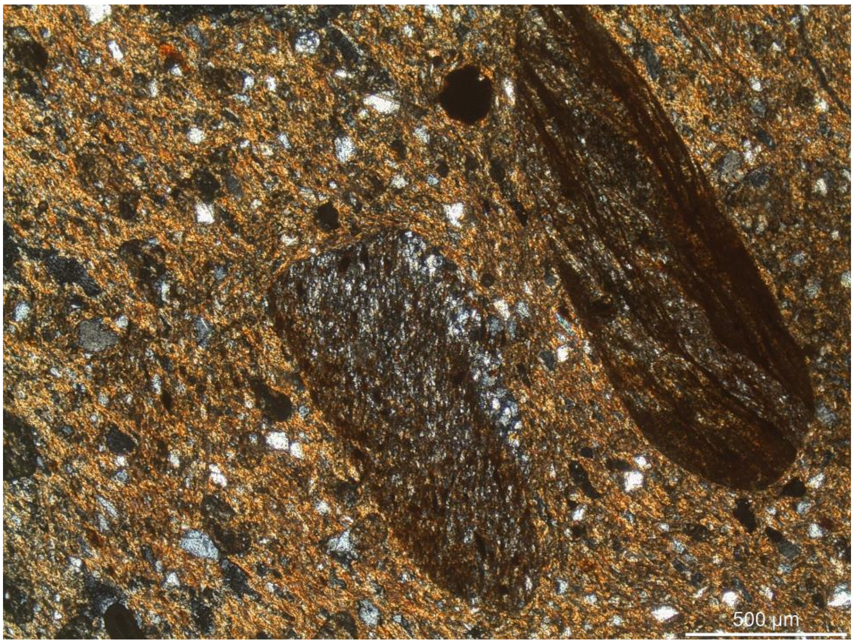
D. Silt sized inclusions

1. Monocrystalline quartz, angular to sub-angular square shaped, common
2. Dark rounded opaques, few
3. White mica, dominate

II. Inclusions above silt size

A. **Chert,** equant very angular, common
B. **Biotite schist,** elongate and angular, very few
C. **Polycrystalline quartz,** equant angular square shaped, common
D. **Monocrystalline quartz,** equant, angular, square shaped, common
E. **Phyllite white mica,** elongate rounded, few
F. **Quartzite schist,** elongate, sub-rounded, very few
G. **Micrite limestone,** equant, angular, very few
H. **Mudstone,** equant, sub-angular, very rare to absent (1 inclusion)

G11. ***Quartz-Schist and Phyllite Poorly Sorted*** *(Coarse ware)*



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): brown to orange brown

2. Crossed polarized light (x5): yellowish to grayish brown, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 40% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is poorly sorted. Voids occupy 10% of the field and they are shaped in vesicles.

C. Overall preferred orientation of inclusions and voids. Orientation is developed

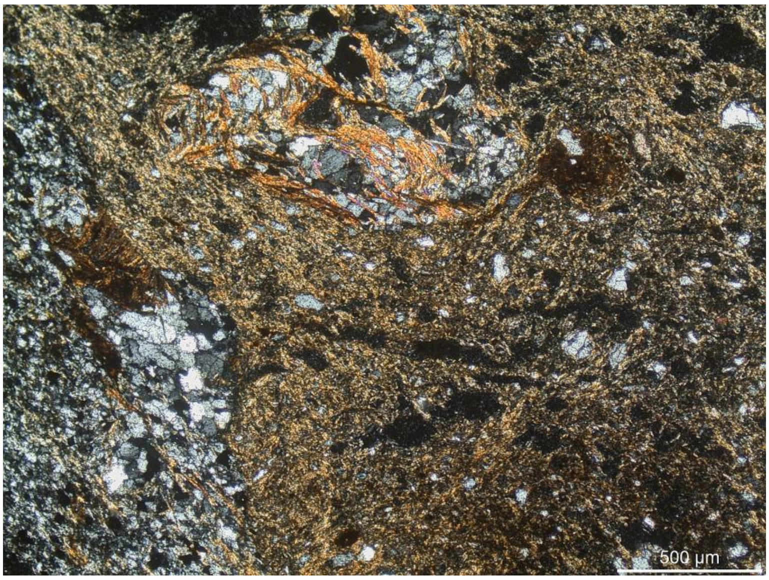
D. Silt sized inclusions

1. Monocrystalline quartz, equant, sub-angular, common

II. Inclusions above silt size

A. **Weathered quartz,** equant, subrounded, sub angular. Very few to rare
B. **Phyllite,** elongate rounded, few
C. **Chert-biotite,** elongate sub-angular, few to rare
D. **Micrite limestone, equant**, sub-angular, few
E. **Mudstone,** elongate, sub-rounded, very rare to absent

G12.
Well-sorted Quartz Sand and Mica Phyllite
(Coarse Ware)



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): pale yellowish brown and yellowish brown

2. Crossed polarized light (x5): yellowish to dark brown, optically active

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 20-30% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is very poorly sorted. Voids occupy 20% of the field and they are shaped in vesicles and channels.

C. Overall preferred orientation of inclusions and voids. Voids develop orientation

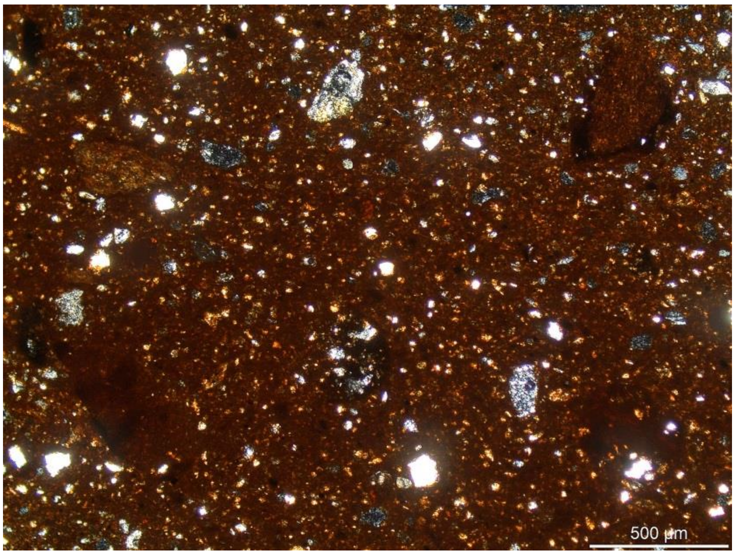
D. Silt sized inclusions

1. Monocrystalline quartz, equant angular to sub-angular, common
2. Polycrystalline quartz, equant angular to sub-angular, common
3. Black opaques, well rounded, very few
4. White mica, equant angular, few

II. Inclusions above silt size

- **A. Schist White mica - Biotite- Chert,** equant, sub-angular, few
- **B. Schist Quartzite- Biotite,** equant and angular, few
- **C. Polycrystalline quartz,** equant square shaped, few
- **D. Fe-rich minerals**, angular, few to rare

G13.
Quartz and Chert Silt Moderately Sorted
(Early Mycenaean)



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): red

2. Crossed polarized light (x5): dark yellowish red, optically inactive

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 20% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is moderately sorted. Voids occupy 10% of the field and they are shaped in vesicles.

C. Overall preferred orientation of inclusions and voids. No preferred orientation

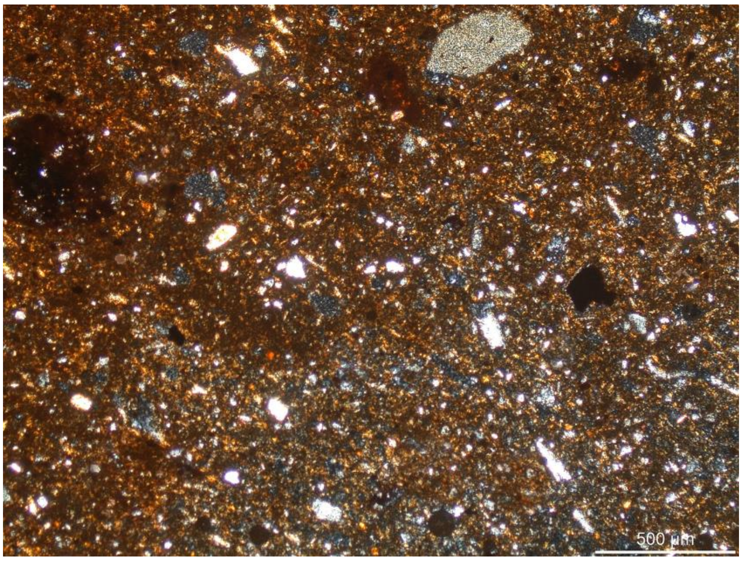
D. Silt sized inclusions

1. Monocrystalline quartz, equant angular to sub-angular, dominant
2. Plagioclase, equant, angular, few to rare

II. Inclusions above silt size

A. **Chert,** equant, sub-angular, few
B. **Monocrystalline/polycrystalline quartz,** equant, sub-angular, few
C. **Tcfs,** few

G14.
Quartz and Mica Silt Moderately Sorted
(Mainland Polychrome ware)



I. Matrix

A. Optical Properties and Color

1. Plane polarized light (x5): reddish brown

2. Crossed polarized light (x5): dark reddish brown, optically inactive

B. Overall grain size and modality of inclusions and voids. Grains occupy c. 10% of the field. The grain size frequency distribution is unimodal. Overall, the size distribution is poorly sorted. Voids occupy 10% of the field and they are shaped in vesicles.

C. Overall preferred orientation of inclusions and voids. No preferred orientation

D. Silt sized inclusions

1. Monocrystalline quartz, equant angular to sub-angular, common
2. Black opaques, well rounded, few
3. White mica, equant angular, common

II. Inclusions above silt size

A. White mica, equant sub angular, common
B. Muscovite, elongate sub-angular, common
C. Tcfs, few
D. Micrite Limestone, equant sub angular, few to rare

APPENDIX III

Sample	Na_2O	St. Dev	MgO	St. Dev	Al_2O_3	St. Dev	SiO_2	St. Dev	K_2O	St. Dev	CaO	St. Dev	TiO_2	St. Dev	MnO	St. Dev	FeO	St. Dev
1	0,26	0,03	1,47	0,23	16,84	1,26	65,96	2,56	3,61	0,22	3,52	0,59	0,91	0,06	0,34	0,08	7,20	1,07
2	0,87	0,08	1,32	0,13	26,34	0,68	60,20	1,18	4,56	0,27	1,51	0,16	1,54	0,23	n.d	n.d	3,66	0,25
3	0,48	0,10	3,67	0,10	16,04	0,33	55,30	0,74	3,22	0,17	13,80	0,86	0,57	0,06	0,36	0,00	6,81	0,29
4	1,01	0,12	1,23	0,29	21,60	2,24	66,14	2,88	2,05	0,11	0,88	0,32	1,48	0,13	n.d	n.d	5,62	0,18
5	0,61	0,09	4,51	0,07	16,75	0,43	54,95	0,45	2,92	0,14	12,23	0,16	0,97	0,17	0,26	0,03	6,89	0,24
6	0,74	0,11	2,75	0,12	19,42	0,39	60,38	0,43	3,37	0,06	4,26	0,17	0,83	0,08	0,22	0,01	8,15	0,37
7	0,95	0,05	5,15	0,09	23,49	0,53	52,46	0,98	5,59	0,19	0,87	0,16	0,81	0,23	0,33	0,08	10,34	1,17
8	0,55	0,13	9,66	1,47	16,48	0,76	60,82	1,45	3,13	0,31	1,17	0,17	0,54	0,13	0,59	0,21	7,07	0,39
9	0,90	0,08	1,70	0,08	23,03	0,40	58,58	0,42	3,69	0,16	1,90	0,10	0,95	0,19	n.d	n.d	9,23	0,09
10	0,97	0,17	1,13	0,07	21,95	0,95	65,92	1,36	3,88	0,30	1,65	0,44	1,15	0,07	n.d	n.d	3,35	0,27
11	1,15	0,19	1,32	0,25	17,24	1,70	70,60	1,78	3,01	0,32	1,07	0,26	1,07	0,09	n.d	n.d	4,55	0,34
12	0,46	0,15	2,20	0,10	21,83	0,23	60,49	0,49	3,52	0,14	2,70	0,15	1,19	0,16	0,26	0,00	7,55	0,27
13	0,48	0,09	2,78	0,14	19,57	0,23	66,32	0,83	2,31	0,19	1,36	0,41	0,87	0,16	0,34	0,01	6,08	0,24
14	0,61	0,04	3,18	0,51	21,59	0,45	56,95	0,61	3,75	0,12	4,43	0,71	0,99	0,08	0,36	0,05	8,27	0,18

Fig. 29 Concentration of the measured values of the elements obtained by SEM-EDS, normalized and expressed in % wt. (St. Dev.: Standard Deviation, n.d.: Not Detected)

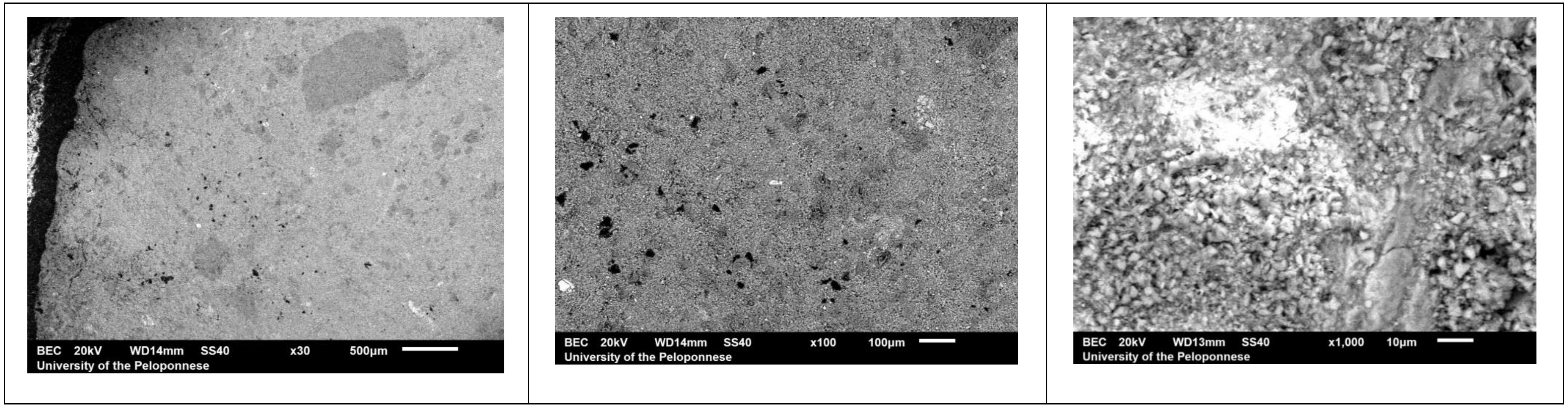


Fig. 30 Backscattered Electron Images by SEM of Sample 1; Magnification x30, x100, x1000

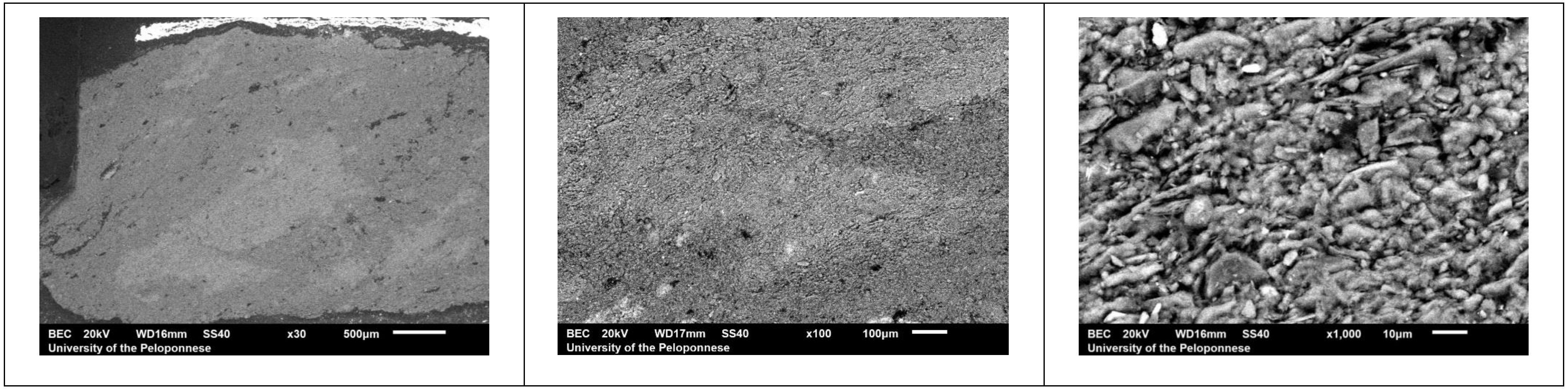


Fig. 31 Backscattered Electron Images by SEM of Sample 2; Magnification x30, x100, x1000

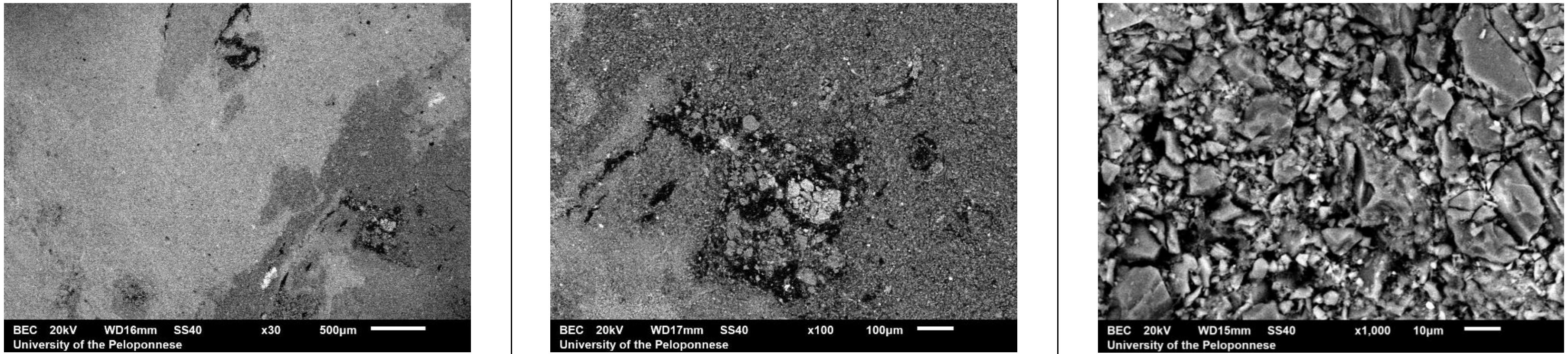


Fig. 32 Backscattered Electron Images by SEM of Sample 3; Magnification x30, x100, x1000

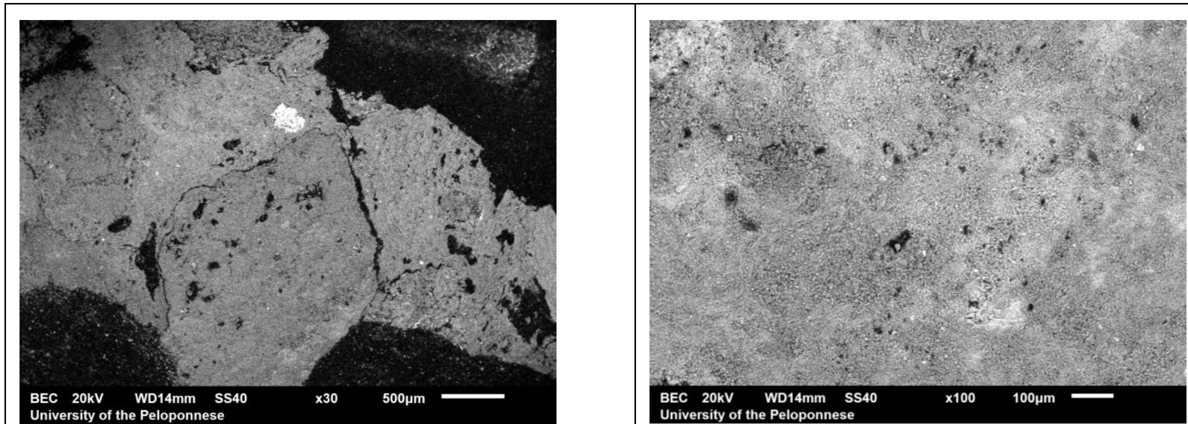


Fig. 33 Backscattered Electron Images by SEM of Sample 4; Magnification x30, x100.

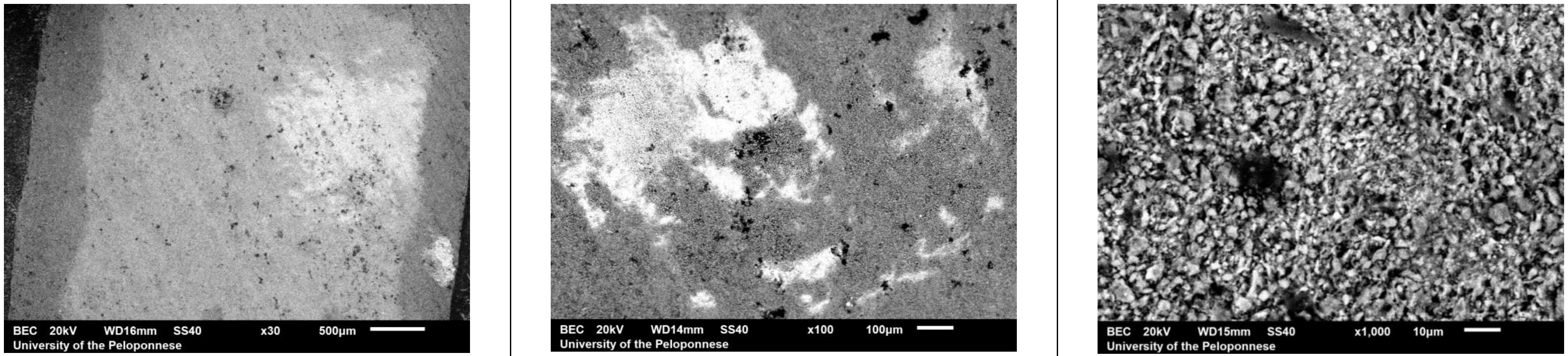


Fig. 34 Backscattered Electron Images by SEM of Sample 5; Magnification x30, x100, x1000

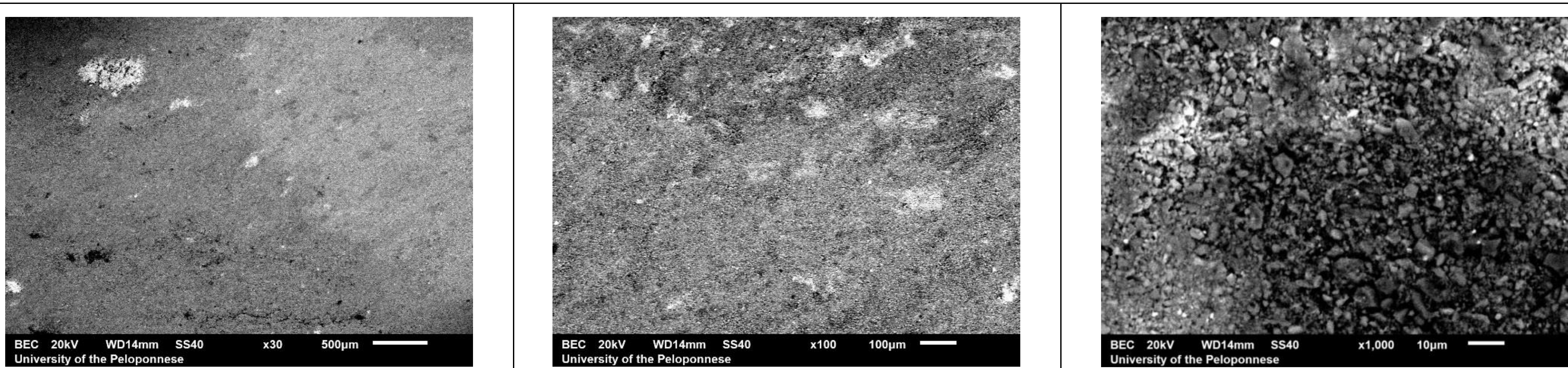


Fig. 35 Backscattered Electron Images by SEM of Sample 6; Magnification x30, x100, x1000

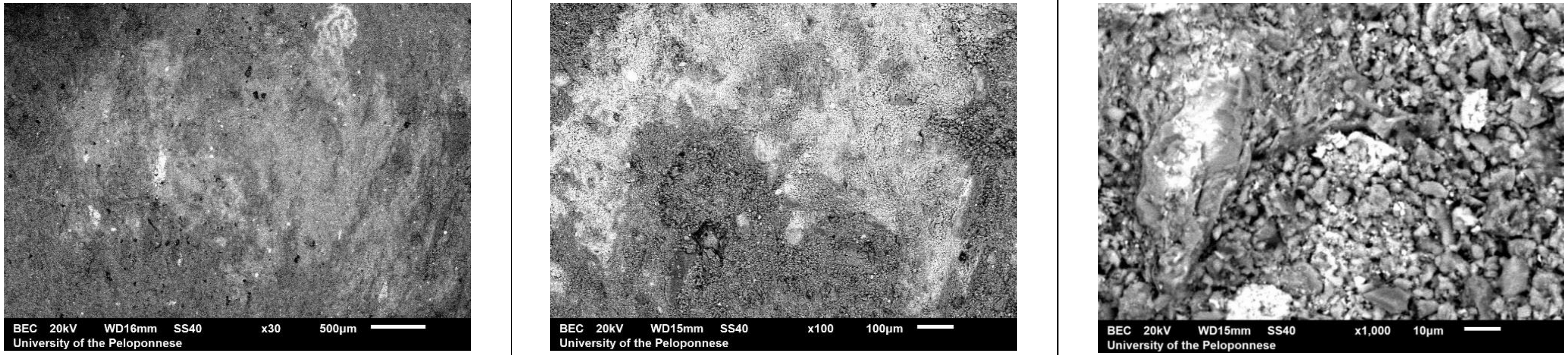


Fig. 36 Backscattered Electron Images by SEM of Sample 7; Magnification x30, x100, x1000

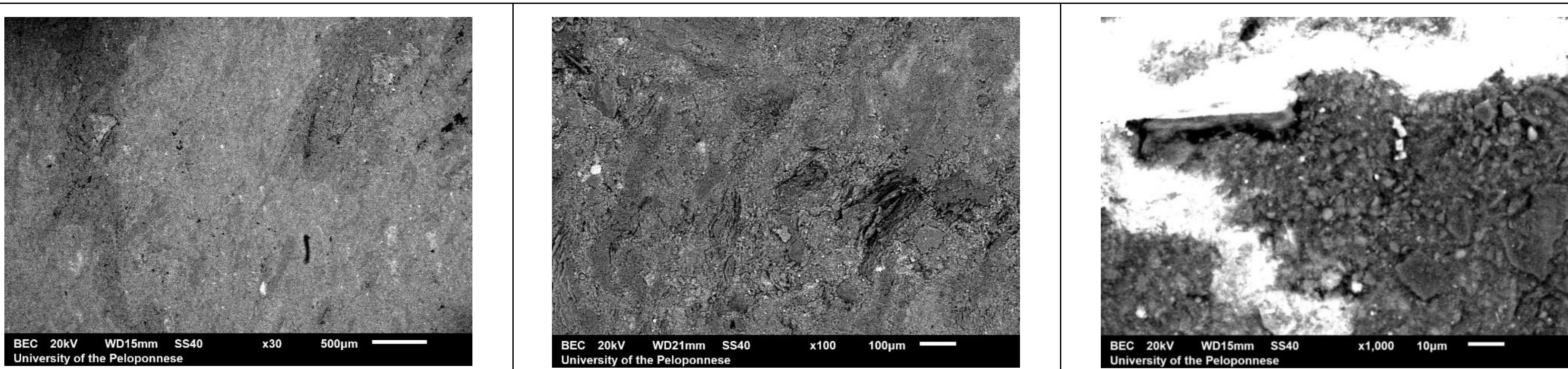


Fig. 37 Backscattered Electron Images by SEM of Sample 8; Magnification x30, x100, x1000

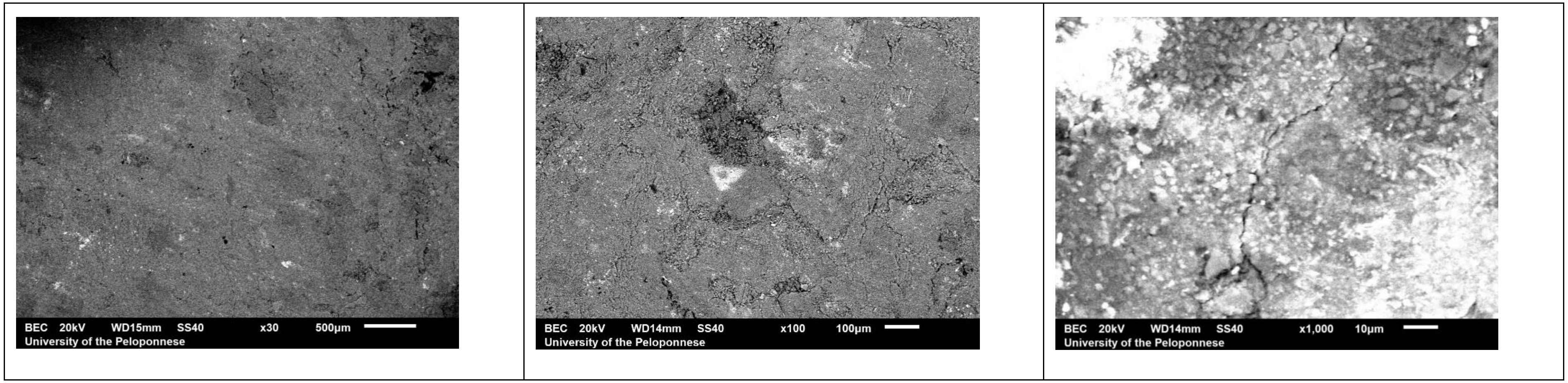


Fig. 38 Backscattered Electron Images by SEM of Sample 9; Magnification x30, x100, x1000

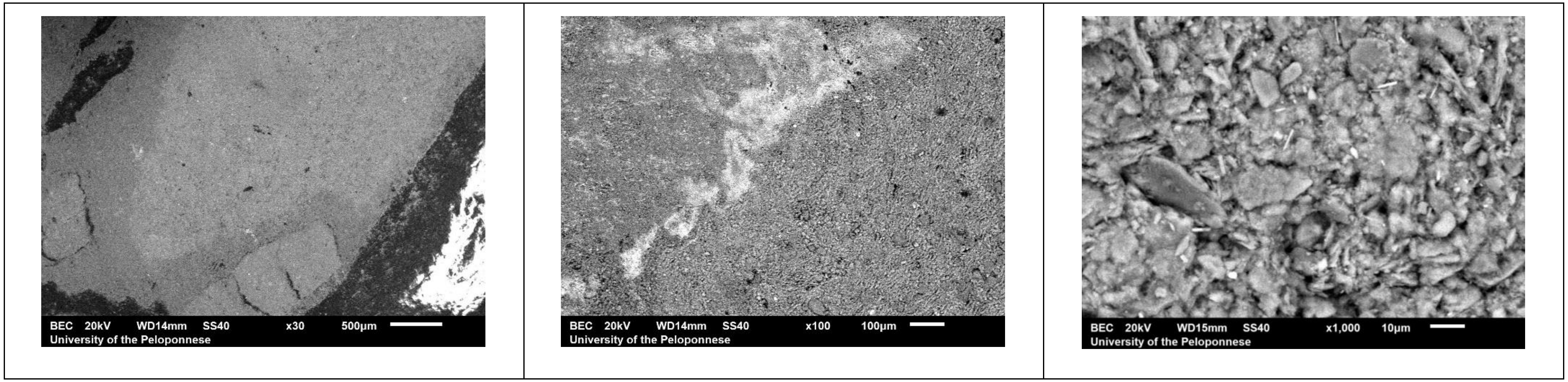


Fig. 39 Backscattered Electron Images by SEM of Sample 10; Magnification x30, x100, x1000

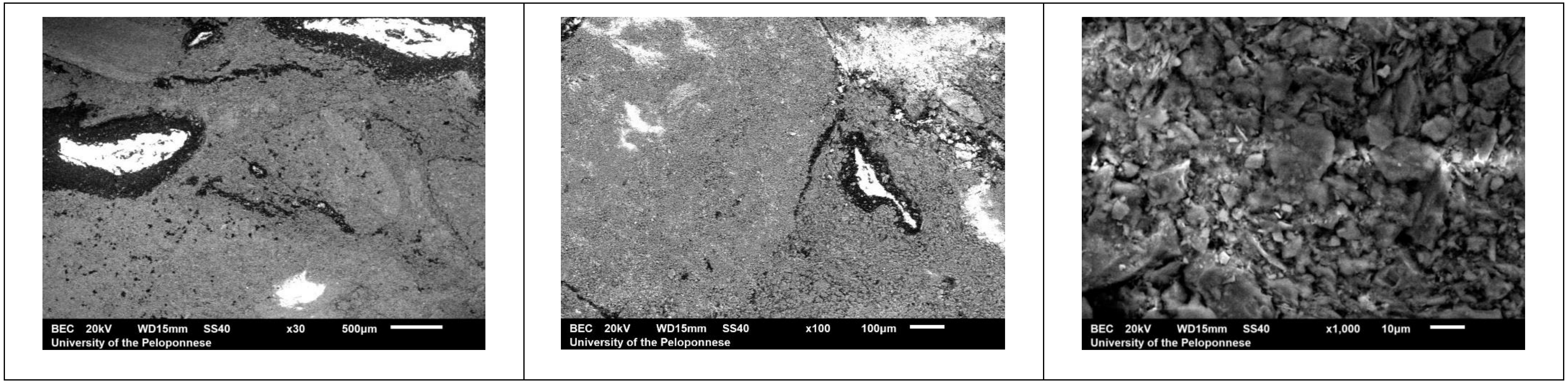


Fig. 40 Backscattered Electron Images by SEM of Sample 11; Magnification x30, x100, x1000

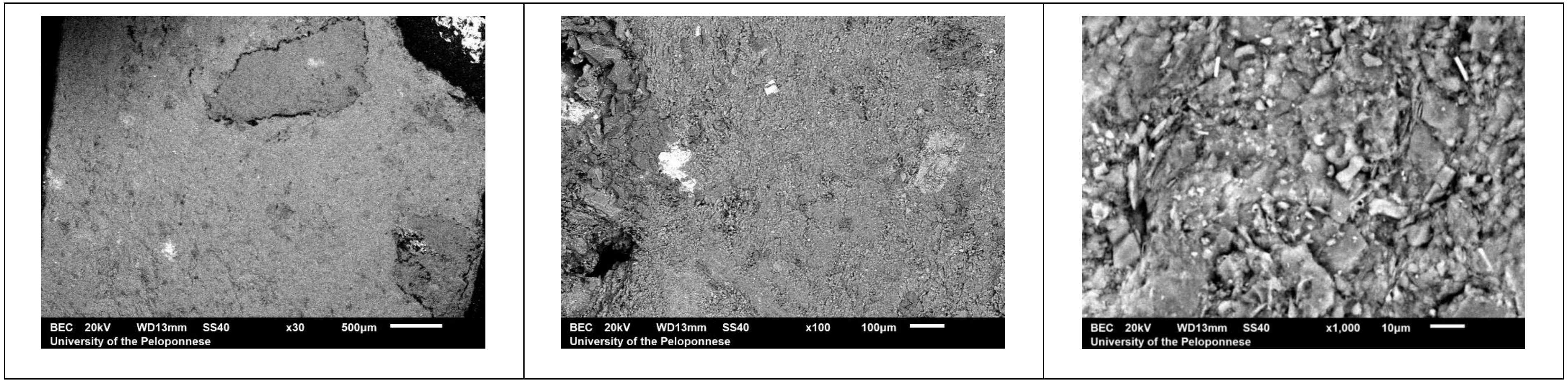


Fig. 41 Backscattered Electron Images by SEM of Sample 12; Magnification x30, x100, x1000

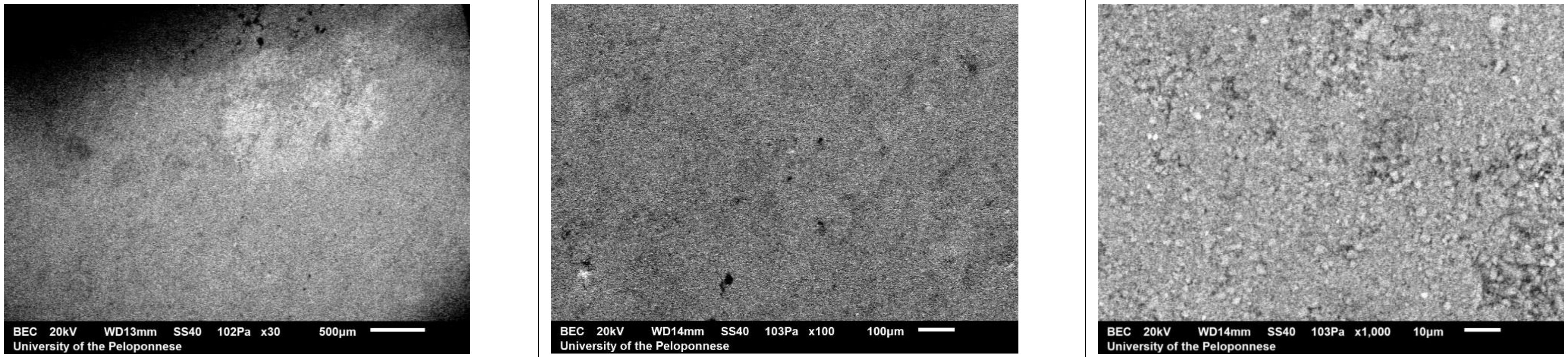


Fig. 42 Backscattered Electron Images by SEM of Sample 13; Magnification x30, x100, x1000

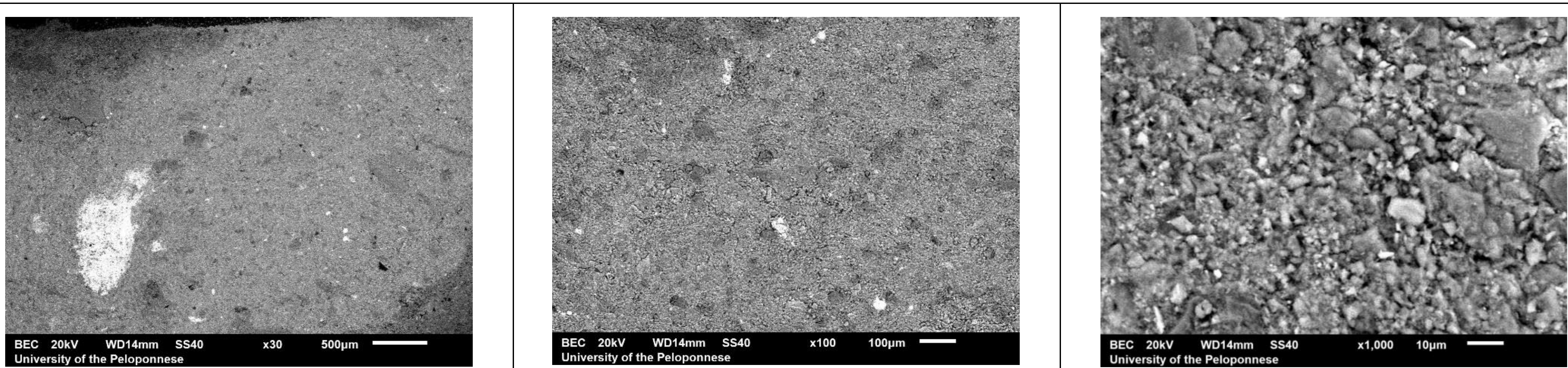


Fig. 43 Backscattered Electron Images by SEM of Sample 14; Magnification x30, x100, x1000